# 11th WORKSHOP ON RF-SUPERCONDUCTIVITY
## SRF 2003
## 8. – 12. September 2003
## LÜBECK/TRAVEMÜNDE MARITIM - STRANDHOTEL

## Introduction

The International Workshop on Superconducting Radio Frequency (SRF) devices was founded in 1983 as a platform of communication for the application of superconductivity for particle acceleration. The workshop is held every two years at various laboratories around the world.
Superconducting radio frequency accelerating systems have grown into a mature technology, more than 1000 meters of SRF cavities have been installed worldwide. Superconducting cavities are under operation in electron storage rings as well as in linear accelerators for electrons, protons and heavy ions.
The most recent project under construction is the neutron spallation source in Oak Ridge, USA. There is vigorous interest in using superconducting accelerating systems in the upgrade of existing installations or in new powerful accelerators for fundamental physics research (such as heavy ions, high intensity electron beams in storage rings, neutrino factories) or applied physics (spallation neutron sources, ultraviolet and X-ray free electron lasers).
The most challenging future project is a 30 km long superconducting linear accelerator, proposed by the TESLA (TeV Energy Superconducting Linear Accelerator) collaboration for the next linear electron-positron collider. In the past decade the accelerating fields in SRF cavities have been raised from 5 MV/m to more than 25MV/m at quality factors above 10^10.

The SRF Workshop is intended to communicate the latest findings in the field of RF superconductivity, present new developments, stimulate controversial discussions, establish contacts to near-by research areas and, last but not least, to serve as an educational guide for newcomers.

Dieter Proch (DESY), Chairman of the Workshop

**Program Committee**

C. Antoine - SACLAY
E. Chiaveri - CERN
P. Kneisel - Jefferson Lab
G. Mueller - Wuppertal University
S. Noguchi - KEK
H. Padamsee - Cornell University
V. Palmieri - INFN di Legnaro
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J. Sekutowicz - DESY
S. Simrock - DESY
W. Singer - DESY
K. Zapfe - DESY

# Workshop Contents

The workshop is organized in form of review talks, invited talks, poster contributions and working groups. It will cover the following topics:

**Review of RF superconductivity and superconducting materials**

- Basics of RF superconductivity
- Material properties of niobium
- Alternative superconductors for RF application
- Fundamental limits of RF superconductivity

**Progress in performance of SRF cavities**

- Limitations by field emission, multipacting or thermal instabilities
- Improved preparation methods
- Comparison between theoretical and experimental limitations
- Diagnostic methods for SRF cavities

**Technical issues**

- RF power input couplers
- Higher order mode damping
- Lorentz force detuning
- Microphonics
- Frequency tuning
- Fabrication techniques for niobium and niobium-coated copper resonators

**Operational aspects**

- Energy recovery linacs
- RF control and cryogenic system for continuous-wave and pulsed operation
- Analysis of failure modes

**Posters on laboratory activities**

**Future developments**

- Proposals for new superconducting accelerators

# General Information

## Conference Venue

The address and telephone numbers of the workshop hotel are:

MARITIM Strandhotel Travemünde
Trelleborgallee 2
23570 Lübeck-Travemünde
Germany

Telephone: +49-4502-890
Fax: +49-4502-89 20 20

## Registration Desk

The registration desk is located on the ground floor of the MARITIM hotel where you will find all the workshop facilities.
Here you will be provided with your name badge and other registration material. Please see the official floor plan of the hotel in this abstract book. The area is called "**Garderobe**".

Opening hours are:

| | | |
|---|---|---|
| Sunday, September 7 | 4:00 pm to 6:00 pm | |
| Monday, September 8 | 8:30 am to 12:30 pm | and 2:00 pm to 6:30 pm |

## Information Desk and Secretary's Office (Room "Salon Braunlage")

The information desk in combination with the secretary's office is located in the room "Salon Braunlage".
The opening hours are:

| | | |
|---|---|---|
| Sunday, September 7 | 4:00 pm to 6:00 pm | |
| Monday-Thursday, September 8-11 | 8:30 am to 12:30 pm | and 2:00 pm to 6:30 pm |
| Friday, September 12 | 8:30 am to noon | |

You will find a message board just in the neighbourhood of the entrance to "Salon Braunlage".

## Welcome Reception

All workshop participants and companions are cordially invited to the Welcome Reception,
Sunday, September 7, starting at 6 pm on the Terrace of the Maritim Hotel, located at the seaside between the hotel and the beach promenade.
In case of bad weather the Welcome Reception would take place at room "Saal Schleswig-Holstein".

## Dinner/Banquet

On Wednesday, September 10, we will have a dinner from 7 pm to 11 pm on the sailing ship *Passat*, now a museum ship. There will be a transfer from the hotel to the sailing ship by a ferry boat which takes approximately 5 Minutes. No evening dress is needed, casual wear is adequate. Warm clothing may be necessary, because we will sit outside on the upper deck of the sailing ship.

## Internet Café/E-Mail Room (Room “Bad Pyrmont”)

For checking emails, submitting papers or correcting problems with papers an e-mail room is available. It contains PCs and laptop ports. This so called Internet Café is located on the ground floor of the hotel. The room is called “**Bad Pyrmont**”. The hours are from:

| | |
|---|---|
| Monday - Thursday, September 8-11 | 8:30 am to 8:00 pm |
| Friday, September 12 | 8:30 am to 12:00 (noon) |

## Paper Submission Office/Proceedings Office (Room “Salon Braunlage”)

The workshop proceedings will be published on the web as soon as possible. Authors are required to submit their papers via web upload. The final deadline for contributions is October 15th, 2003.
Authors who arrive at the workshop with a disk will be asked to go to the Internet Café to submit their files via the web. If assistance is needed please contact the paper submission office.
Authors are still required to submit a hard copy of the paper, with the session ID listed at the top, and the corresponding copyright form to the Paper Submission Office. The Paper Submission Office is located at the ground floor of the Maritim Hotel. The room is called “**Salon Braunlage**”. The hours are:

| | | | |
|---|---|---|---|
| Sunday | 4:00 pm to 6:00 pm | | |
| Monday | 8:30 am to 12:30 pm | and | 2:00 pm to 6:30 pm |
| Tuesday | 8:30 am to 12:30 pm | and | 2:00 pm to 6:30 pm |
| Wednesday | 8:30 am to 12:30 pm | and | 2:00 pm to 6:30 pm |
| Thursday | 8:30 am to 12:30 pm | and | 2:00 pm to 6:30 pm |
| Friday | 8:30 am to 12:00 (noon) | | |

The editorial staff will process papers before, during and after the conference. Files will be processed quickly, and authors will be informed of their acceptance or any problems via a paper status board located at the entrance to the Paper Submission Office.

## Poster Sessions (Room “Salon Timmendorf”)

The poster sessions will be held on **Monday**, **Tuesday** and **Thursday** from 2:30 pm 5:30 pm.
Posters should be mounted half an hour before the poster sessions will start.
Drawing pins will be provided.
At the end of each poster session the posters have to be dismounted (except posters with laboratory reports).
The space that can be used for displaying information is **1.32 m high and 0.93 m wide**.

## Oral Presentations

To avoid loss of time the speakers are requested to deliver their electronic manuscript one day before the lecture takes place at the secretary's office. We do accept general media like CDs, USB-Sticks or diskettes. Allowed formats are Power Point and PDF (portable data format).
Speakers who would like to give a lecture without a PC do not need to submit their transparencies in advance.
After the presentation all media can be picked up again at the secretary's office.

## Sponsors/Industrial Exhibits (Room "Bad Salzuflen")

The industrial exhibits will open from Monday, September 8 to Thursday, September 11.
The exhibitors registered at the time this book went to press are:

**ACCEL Instruments GmbH,** Bergisch Gladbach, Germany
**AMAC International Inc.**, Newport News,Virginia, USA
**CERCA**, Romans, Drome, France
**DeMaCo Holland bv**, Noord-Scharwoude, Holland
**W. C. Heraeus GmbH & Co. KG,** Hanau, Germany
**Ningxia Orient Non-Ferrous Metals Group Company**, Shizuishan , Ningxia, China
**Niobium Products Company**, Duesseldorf, Germany
**Tokyo Denkai Co., Ltd.**, Tokyo, Japan
**Toshiba Corporation**, Otawara-shi, Tochigi, Japan

More exhibitors may have been scheduled after this book went to the printer. A complete listing will be available on the workshop website, http://srf2003.desy.de .

## Ground Transportation

**By plane**: Travemünde is accessible from Airport Hamburg-Fuhlsbüttel, Germany within approx. 2 hours by public transportation. We will organize a shuttle on Sunday, September 7 from Hamburg Airport to the workshop hotel in Travemünde. The other days you should take the Airport Express Bus (Jasper Bus) to Hamburg Hauptbahnhof (main station) and change there to a train to Lübeck. From Lübeck take a train to Travemünde, see below.

**By train**: You can reach Travemünde from all directions. The station is in a walking distance (only 800 m) from the hotel. There is a train service between Lübeck and Travemünde every 30 minutes. For detailed information see the web page of the Deutsche Bahn:

URL http://www.bahn.de/pv/uebersicht/die_bahn_international_guests.shtml

**By car**: Travemünde is only 15 km from Lübeck. From Hamburg and Hamburg Airport you take the A1 (freeway) Hamburg - Lübeck or Puttgarden - Lübeck. From Hamburg it takes approximately 50 minutes to reach Travemünde. On the Lübeck tourism Web page under URL http://www.luebeck-tourism.de , click Lübeck - Directions on the blue bar. You will receive a map of Germany showing the freeways leading to Travemünde/Lübeck.

## Shuttle on Sunday, September 7 (From Hamburg Airport to the Workshop Hotel)

We will provide a shuttle bus service from Hamburg Airport to Travemünde Maritim Hotel at

**11:00** am, **2:00** pm, **5:00** pm, **8:00** pm and **10:30** pm.

Please come to the Meeting Point at the arrival zone at Terminal 4. Look for a person carrying a SRF2003 sign. The transfer nearly takes 1.5 hours.

## Afternoon Schedule for Friday, Sept. 12 | TTF-Tour at DESY | Shuttle Service

On Friday, September 12 a tour to DESY is offered. We will leave Travemünde after lunch.
There will be a shuttle service organized in the following way:

1:00 pm Bus from Maritim Hotel Travemünde to DESY, Hamburg

The tour starts at 3:00 pm.

If, after the TTF tour at DESY, you want to get to Hamburg Airport, there is a bus leaving at 5:00 pm from DESY to Hamburg Airport.
If you need to go to Hamburg Airport directly from Travemünde, the same schedule applies:
1:00 pm From Maritim Hotel Travemünde to Hamburg Airport.

## Companions' Program

We do offer some proposals for Companion Tours. Many interesting sightseeing tours are arranged by local services, too. The workshop secretaries will be glad to help you if you need further assistance.

## Security and Insurance

Participants are asked not to leave their belongings unattended and to wear their conference badges at all times. The conference organizers cannot accept liability for personal injuries sustained, or loss of, or damage to, property belonging to conference participants (or accompanying persons), either during or as a result of the conference. Please check the validity of your own insurance.

# Program SRF Workshop

## Overview

| Time | Sunday | Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|---|---|
| 8:30 – 9:00 | | Registration | Plenary | Plenary | Working Groups | New Projects |
| 9:00 – 10:30 | | Welcome/ Review | | | | |
| 10:30 – 11:00 | | Coffee | Coffee | Coffee | Coffee | Coffee |
| 11:00 – 12:00 | | Review | Invited Talks I | Invited Talks II | Working Groups | New Projects |
| 12:00 – 12:30 | | | | | | Closing/ Sandwich |
| 12:30 – 13:00 | | Lunch | | | | |
| 13:00 – 13:30 | | | Lunch | Lunch | Lunch | To DESY/Airport |
| 13:30 – 14:30 | | | | | | |
| 14:30 – 16:00 | | Poster I | Poster II | Invited Talks III | Poster III | 15:00 TTF-Tour |
| 16:00 – 16:30 | Registration | Coffee | Coffee | Coffee | Coffee | |
| 16:30 – 17:30 | | Poster I | Poster II | Tutorial III | Poster III | |
| 17:30 – 18:30 | Reception | Tutorial I | Tutorial II | | Report Working Groups | |
| 19:00 - END | | | | Dinner | | |

## Sunday, September 7, 2003

| | |
|---|---|
| 16:00 | Registration starts |
| 16:00 | Paper submission office opens |
| 18:00 | Welcome Reception<br>Maritim, Basement, room to be announced |

## Monday September 8, 2003

| | | |
|---|---|---|
| 8:30 – 18:30 | **Salon Braunlage**: Registration | |
| | **Saal Maritim – Reviews** **[Chairman: D. Schrage]** | |
| 9:00 – 9:15 | Opening**,** Welcome | |
| 9:15 - 9:45 | Introductory remarks: Status of SRF accelerator technology, what do we expect from this workshop | H. Padamsee |
| 9:45-10:30 | Theoretical critical field for RF application | K. Saito |
| 10:30 - 11:00 | Coffee | |
| | **Reviews (cont)** **[Chairman: G. Mueller]** | |
| 11:00 - 11:45 | Thin film SRF Applications beyond accelerators | N. Klein |
| 11:45 - 12:30 | Application of low and high Tc superconductors in magnets and power applications | R. Fluekiger |
| 12:30 – 14:30 | Lunch | |
| | **Salon Timmendorf:** | |
| 14:30 - 16:00 | Poster Session I | |
| 16:00 – 16:30 | Coffee | |
| 16:30 – 17:30 | Poster Session I (cont) | |
| | **Saal Maritim – Tutorial I** | |
| 17:30 – 18:30 | Basic principles of RF superconductivity and SC cavities, limitations in SRF cavities | P. Schmueser |

## Tuesday, September 9, 2003

| | | |
|---|---|---|
| 8:30 – 18:30 | **Salon Braunlage**: Registration | |
| | **Saal Maritim – Plenary Talks [Chairman: C. Antoine]** | |
| 8:30 - 9:00 | Q-slope at high gradients: Review about experiments and explanations | B. Visentin |
| 9:00 - 9:30 | Surface characterization: What has been done, what has been learned | P. Kneisel |
| 9:30 - 10:00 | High gradient in multi-cell cavities | L. Lilje |
| 10:00 - 10:30 | Operating experience with beta 1 high current accelerators | S. Belomestnykh |
| 10:30 – 11:00 | Coffee | |
| | **Invited Talks:**<br>**Accelerator oriented studies [Chairman: E. Chiaveri]** | |
| 11:00 - 11:20 | Superstructures: First cold test and future applications | J. Sekutowicz |
| 11:20 - 11:40 | Third harmonic superconducting passive cavities in ELETTRA and SLS | P. Bosland |
| 11:40 - 12:00 | Review of the status of SRF photo-injectors | J. Teichert |
| 12:00 - 12:20 | CEBAF-ER: Extending the Frontier of Energy Recovery at Jefferson Lab | C. Tennant |
| | **Cavity, coupler, tuner [Chairman: E. Chiaveri]** | |
| 12:20 - 12:40 | Control of microphonics and Lorentz force detuning with a fast mechanical tuner | S. Simrock |
| 12:40 - 13:00 | SCRF detectors for gravitational waves | G. Gemme |
| 13:00 – 14:30 | Lunch | |
| | **Salon Timmendorf:** | |
| 14:30 – 16:00 | Poster Session II | |
| 16:00 – 16:30 | Coffee | |
| 16:30 – 17:30 | Poster Session II (cont) | |
| | **Saal Maritim – Tutorial II:** | |
| 17:30 – 18:00 | Low and intermediate beta cavity design | J. Delayen |
| 18:00 - 18:30 | Power Coupler tutorial, HOM coupler tutorial | B. Rusnak |

## Wednesday, September 10, 2003

| | | |
|---|---|---|
| 8:30 – 18:30 | **Salon Braunlage**: Registration | |
| | **Saal Maritim – Plenary Talks [Chairman: P. Kneisel]** | |
| 8:30 – 8:55 | Status of the SNS SC cavity and cryostat production | J. Mammosser |
| 8:55 - 9:20 | Operating experience with low beta accelerators | G. Zinkann |
| 9:20 - 9:45 | Status of the TTF FEL | S. Schreiber |
| 9:45 - 10:10 | Report from input coupler workshop | I. Campisi |
| 10:10 - 10:35 | Report from spoke cavity workshop | F. Krawczyk |
| 10:35 – 11:00 | Coffee | |
| | **Invited Talks: Cavity, coupler, tuner [Chairman: V. Palmieri]** | |
| 11:00 - 11:20 | 200 MHz Nb-Cu cavities for muon acceleration | R.L. Geng |
| 11:20 - 11:40 | Results on LNL Nb RFQs | G. Bisoffi |
| 11:40 - 12:00 | SC Structures for RIA | K. Shepard |
| | **Fabrication techniques [Chairman: V. Palmieri]** | |
| 12:00 - 12:20 | Progress of Nb/Cu technology with 1.5 GHz cavities | S. Calatroni |
| 12:20 - 12:40 | Performance of seamless cavities, experience with different fabrication methods | W. Singer |
| 12:40 - 13:00 | Mechanical properties of high purity niobium - novel measurement | G. Myneni |
| 13:00 - 14:30 | Lunch | |
| | **Presentations from new researchers (Diploma work, PhD work, activities by newcomers) [Chairman: P. Schmueser]** | |
| 14:30 - 14:50 | Voltage Breakdown and the Processing Mechanism | G. Werner |
| 14:50 - 15:10 | Magnetic susceptibility measurements as a tool to characterize niobium for RF cavities | S. Casalbuoni |
| 15:10 - 15:30 | Study of material parameters on SC cavities | G. Ciovati |
| 15:30 - 15:50 | Hydrogen free EP/ Hydrogen absorption phenomena | T. Higuchi |
| 15:50 - 16:30 | Coffee | |
| | **Saal Maritim – Tutorial III** | |
| 16:30 - 17:00 | Design principles of NC and SC cavities: Example for high current storage rings | J. Knobloch |
| 17:00 - 17:30 | Fundamentals of EP; application to Nb and Cu | V. Palmieri |
| | Free time | |
| 19:00 – end | Dinner on the Passat | |

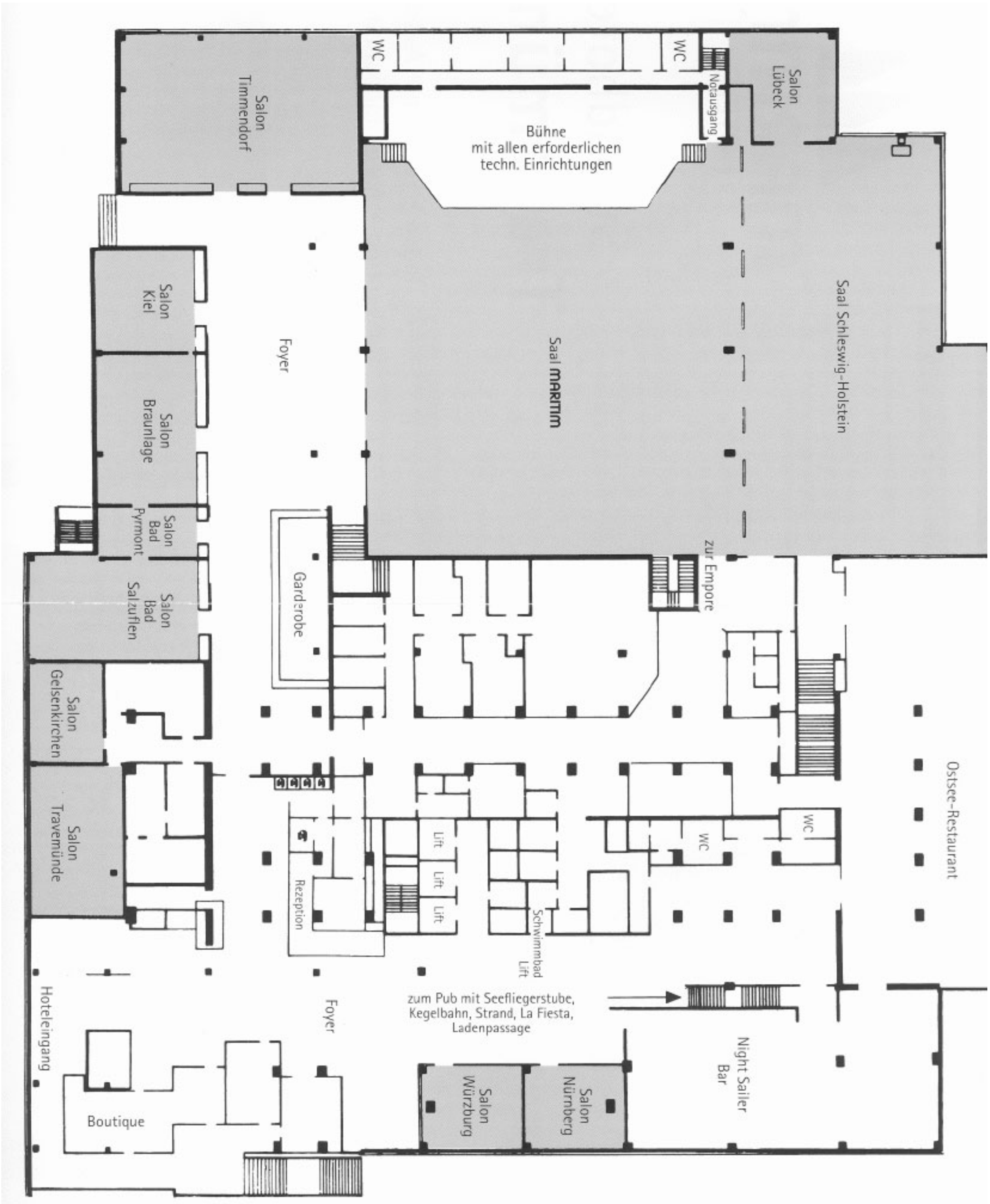
## Thursday, September 11, 2003

| | |
|---|---|
| 8:30 – 18:30 | **Salon Braunlage:** Registration |
| 8:30 – 10:30 | **Working Groups**<br>WG 1: Q drop at high gradient, Prospects of higher Q for CW, critical RF SC field<br>WG 2: Ion accelerating structures/intermediate velocity cavities<br>WG 3: Couplers, tuners, pieco compensation<br>WG 4: High gradient cw modules for FEL/ standard modules |
| 10:30 – 11:00 | Coffee |
| 11:00 – 13:00 | **Working Groups continued** |
| 13:00 – 14:30 | Lunch |
| | **Salon Timmendorf:** |
| 14:30 – 16:00 | Poster Session III |
| 16:00 – 16:30 | Coffee |
| 16:30 – 17:30 | Poster Session III (cont.) |
| | **Saal Maritim – Working Group Summaries [Chairman: S. Noguchi]** |
| 17:30 – 17:45 | WG 1 |
| 17:45 – 18:00 | WG 2 |
| 18:00 – 18:15 | WG 3 |
| 18:15 – 18:30 | WG 4 |

## Friday, September 12, 2003

| | | |
|---|---|---|
| 8:30 – 12:00 | **Salon Braunlage:** Registration | |
| | **Saal Maritim – New Projects [Chairman: K. Shepard]** | |
| 8:30 - 9:00 | Challenges for Future Light Sources (ERL and FEL) | M. Liepe |
| 9:00 - 9:30 | X-Ray FEL at DESY | H. Weise |
| 9:30 - 10:00 | High intensity proton sources | A. Facco |
| 10:00 - 10:30 | Rare isotope (heavy ion) accelerators | S. Schriber |
| 10:30 – 11:00 | Coffee | |
| | **New Projects (cont) [Chairman: H. Padamsee]** | |
| 11:00 - 11:30 | Future stable-beam Accelerators for Nuclear Physics | L. Harwood |
| 11:30 - 12:00 | Status of warm/cold linear collider competition | N. Walker |
| 12:00 - 12:30 | Closing | |
| 12:30 – 13:00 | Sandwich | |
| 13:00 | Busses leaving either to Hamburg Airport<br>or to DESY for the TTF Tour | |
| 14:30 - 17:00 | TTF Tour | |
| 17:00 | Bus leaving for Airport Hamburg | |

## Floor plan showing all workshop facilities on the ground floor:



# List of all the abstracts for the
# 11th Workshop on RF Superconductivity
# SRF2003
# 8 - 12th September, 2003
# Lübeck/Travemünde

September 4, 2003

# Monday, 8th September 2003

## Oral Presentations

### MoO02: Theoretical Critical Field in RF Application

*K. Saito (KEK)*

For these ten years, the high gradient of niobium sc RF cavities seems to saturate around 40 MV/m. The question is in the further technical issue or in the fundamental critical field of niobium material. In this paper the author will try to explain the saturation from the theoretical point of view. Superheating field is reviewed as the fundamental critical field in RF application. In next the author will analyse the temperature variation of the superheating field especially on niobium material. The result is compared with the experimental RF critical field of niobium bulk cavity, which was measured in Cornell University and a good agreement with the prospect ion of vortex nucleation is obtained. The same analysis is extended Nb3Sn or lead cavities, and the consistent result is obtained with the vortex nucleation as the theoretical critical field in RF application.

### MoO03: Thin Film SRF Applications Beyond Accelerators

*N. Klein (Juelich)*

High-temperature superconducting thin films offer unique properties which can be utilised for a variety of high-frequency device applications in many areas related to the strongly progressing market of information technology. One important property is a low level of microwave absorption at temperatures attainable with low power cryocoolers. This unique property has initiated the development of various novel type of microwave devices and commercialised subsystems with special emphasis on application in advanced microwave communication systems. The second important achievement related to efforts in oxide thin and multilayer technology was the reproducible fabrication of low-noise Josephson junctions in high-temperature superconducting thin films. As a consequence of this achievement, several novel non-linear high-frequency devices, most of them exploiting the unique features of the AC-Josephson effect, have been developed and found to exhibit challenging properties to be utilised in basic metrology and Terahertz technology.

### MoO04: Application of Low and High Tc Superconductors in Magnets and Power Applications

*R. Fluekiger (University of Geneva)*

The present state of the Low Tc materials Nb3Sn and MgB2 as well as of the High Tc superconductors is discussed in view of magnet and/or power applications. In Nb3Sn wires, the control of grain boundaries and the homogeneity of the Sn content is essential for optimizing flux pinning properties. The fabrication of the more recent superconductor Fe/MgB2 encounters new obstacles, e.g. low thermal stability of the sheath material and difficult deformability. The present state of Powder-in-Tube processed Bi,Pb(2223) tapes is summarized and possible future developments are discussed. High expectations are concentrated on Coated Conductors, based on Y(123), which show a promising development and will briefly discussed. Actual technological applications require different superconducting materials. Low Tc materials, e.g. Nb3Sn, are used for high field magnets (B <= 21 T at T = 2 K) as well as for fusion magnets and have actually the highest market penetration. MgB2 conductors are foreseen for cryocooled systems in the range between 20 and 25 K. High Tc materials are highly promising for a series of future applications: power transmission cables at T = 65 - 77K, fault current limiters at 77K and synchronous motors at about 30 K. A larger future market for High Tc materials can be envisaged, but requires a serious reduction of production costs.

## Tutorials

### MoT01: Basic Principles of RF Superconductivity and SC Cavities, Limitations in SRF Cavities

*P. Schmueser (University of Hamburg)*

The analytic field computation in a pill box cavity is outlined and the relevant cavity parameters (stored energy, dissipated power, quality factor) are calculated. The properties of superconductors in microwave fields are discussed with special emphasis on the physical limitations given by the critical magnetic field. Finally, the performance of practical multi-cell cavities and the quest for highest accelerating fields is shortly addressed.

## Poster Presentations

**Categories:**
**Lab Reports**
**SRF Basics**
**High Gradient**
**Operating Experience**
**New Projects**

### MoP00: Activities at DESY with High Gradient Superconducting RF Cavities for e+/e- Linear Accelerators

*K. Zapfe for the TESLA Collaboration (DESY)*
Activities with high gradient superconducting rf cavities at DESY focus on applications for e+/e-linear accelerators. Since several years the TESLA-Test-Facility (TTF) at DESY/Hamburg is operated by an international collaboration. It comprises the complete infrastructure for treatment, assembly and test of superconducting cavities as well as a 250 m long superconducting linear accelerator for development and test of machine components. In addition to the fabrication, preparation and test of TESLA nine cell cavities an intensive research program on single cell cavities is performed. Recently a facility for electropolishing of nine cell cavities as well as an electron beam welding machine have been set up and are in operation now. Further developments and improvement on components like couplers, tuners, klystron etc. are ongoing. During phase 1 of the TTF superconducting linac, which has been completed successfully end of 2002, four modules, each containing eight resonators, as well as a module with two superstructures have been tested and operated with beam. Presently the linac is substantially modified to become a VUV-FEL user facility with tunable wavelengths in the nm range within 2004. Beginning of 2003 the XFEL project, a 1.4 km long superconducting linac with X-ray free-electron laser radiation laboratory, has been approved. The preparations to start building this machine have been initiated. In addition the high gradient program of superconducting cavities for a future e+e- linear collider are continued.

### MoP01: CEA-Saclay Laboratory Report

*C. Z. Antoine (CEA-Saclay)*
The CEA Saclay in France is involved in many different superconducting radiofrequency related activities ranging from basic R and D to support for present or future accelerator projects. A brief overview of the present going on work will be presented. - surface morphology (cf. poster), - resistivity measurements (cf. poster), - hydrogen contamination (cf. poster), - baking (cf. invited paper: Q-slope at high gradients), - super3HC (cf invited paper: Third harmonic superconducting passive cavities in ELETTRA and SLS), - CryHoLab, 700 MHz cavities, - SOLEIL, SPIRAL 2, - RF components: cold tuning system, coupler, BPM.

### MoP02: The TESLA High Power Coupler Program at Orsay.

*T. Garvey, H. Borie, L. Grandsire, P. Lepercq, M. Omeich, R. Panvier (LAL-Orsay)*
Within the general TESLA collaboration the Laboratoire de lAccelerateur Lineaire has the responsibility for the development of high power input couplers for the superconducting cavities. To this end we have put together the required infra-structure necessary for the preparation, conditioning and tests of proto-type couplers. This infra-structure will be described along with brief results of the first proto-type tests.

### MoP03: Superconducting RF Activities at Michigan State University

*T. Grimm, V. Andreev, J. Bierwagen, S. Bricker, C. Compton, D. Gorelov, W. Hartung, M. Johnson, F. Marti, S. Schriber, X. Wu, R. York, Q. Zhao (Michigan State University)*
In the year 2000, the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) initiated a program in superconducting radio frequency (SRF) research and development. All of the infrastructure needed for SRF research is now available at or near MSU. Presses (>800 tons) are available locally for deep drawing of niobium. Niobium parts are machined at NSCL. Electron beam welding is done in Chicago. Chemical etching, high pressure rinsing, clean room assembly, and cryogenic RF testing are done at NSCL. One SRF application of interest at NSCL is the proposed Rare Isotope Accelerator (RIA). The RIA driver linac is to accelerate stable isotopes (protons through uranium) to energies >400 MeV per nucleon (beta = v/c > 0.72) with beam powers up to 400 kW. To obtain these intensities, partially stripped ions are accelerated through 1400 MV in the SRF linac. A 10th-harmonic linac (80.5 MHz base frequency) requires six cavity types. The first and last cav-

ity types were developed for other linacs (INFN Legnaro and SNS, respectively), and the other four are variants of these two. A half-wave resonator (optimum beta = 0.285) and a six-cell elliptical cavity (optimum beta = 0.49) were successfully prototyped in 2002. Recent work on quarter-wave resonators (optimum beta = 0.085 and 0.16) is reported separately. A cryomodule for the RIA cavities and focussing elements has been designed. A first systems test with two elliptical cavities will be done in 2004. A second cryomodule with drift-tube cavities and superconducting solenoids will be tested later in 2004.

**MoP04: Superconducting RF Activities at the IPN Orsay (France)**

*T. Junquera (IPN Orsay)*

IPN Orsay is presently involved in several R and D programs for the future accelerators in Europe. High intensity linear proton accelerators are proposed for Nuclear Physics (EURISOL) and for Nuclear Waste Transmutation (XADS). Both projects propose to use Superconducting RF cavities for the whole energy range (5 MeV - 1 GeV). Two types of cavities are developed: spoke type for the low/intermediate energy and elliptical multi-cell type for the high energy range. Power couplers, cold tuning systems and ancillary equipments are also under development. A horizontal cryostat (CRYHOLAB), constructed in collaboration with the CEA Saclay, is now entered into a routine operation phase. An associated helium liqufier and RF power sources allow to test cavities with couplers and auxiliary equipments under conditions which are very close to those encounterd in a real accelerator. More recently IPN Orsay has started a new SRF development for the Spiral-2 Radioactive Beams Facility project. A 176 MHz half wave resonator was designed and is under construction. Other important activities concern the new developments around the TESLA cavities, in particular the low temperature characterization of materials proposed for some components like the power couplers or the piezo tuning system.

**MoP05: Report on Superconducting RF Activities at CERN in 2001/2003**

*R. Losito, E. Chiaveri, J. Tuckmantel, S. Calatroni, D. Valuch (CERN)*

The main project on superconducting RF at CERN in the period from 2001 to 2003 has been the 400MHz SC system for the LHC. Five modules, each containing four single cell niobium sputtered cavities, have been assembled and low power tested at room temperature and at 4.5K. Production of the first four series power couplers has been delayed but high power tests should start on the first module this fall. A small program of RD is maintained on the SPL. Both the beta=0.7 and beta=0.8 cavities have been high power tested up to nominal field without particular problems. A detailed characterization of the cavity mechanical resonances is ongoing and some preliminary results are presented. A computer code has been written to predict the effects of Lorentz detuning and microphonics on the stability of the RF feedback loops in SC linacs where several cavities are driven by a single high power source. Fast ferrite phase shifters are being developed to allow the decoupling of the feedback loops of individual cavities attached to the same klystron. Several collaborations e.g. SOLEIL, PACO and S3HC, have successfully achieved their objectives. The collaboration established with Cornell to develop a 200 MHz SC cavity has not yet led to the desired level of performance. The RD program on 1.5 GHz is continuing. Based on an optimised electropolishing process for surface preparation, the study is at present focused on the effect of hydrogen in the Nb films.

**MoP06: SCRF Activities for the ISAC-II Upgrade at TRIUMF**

*R.E. Laxdal, K. Fong, A.K. Mitra, R. Poirier, T. Ries, I. Sekachev, G. Stanford (TRIUMF)*

TRIUMF is proceeding with a major upgrade to the ISAC project, ISAC-II, that includes the addition of 43 MV of heavy ion superconducting linear accelerator. An initial installation of 18 MV of mid beta quarter-wave bulk niobium cavities (beta=5.8%, 7.1%) is due for commissioning in 2005. A SCRF laboratory consisting of clean assembly and rinse area plus an rf test area is operational with an active program for cavity preparation and coupling loop and tuner developments. The paper will describe the superconducting linac program at TRIUMF including the status of the production cavities, the design of the medium beta cryomodule and a summary of the activities of the SCRF laboratory.

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**MoP07: KEK Superconducting Cavities**

*S. Mitsunobu (KEK)*

These two years, KEK superconducting cavities have large progresses both for high power applications and high gradient applications. The one of milestone for high power application is KEKB superconducting cavities accelerating more than 1A beam current. And the current reached the KEKB HER design current of 1.1 A (T. Furuya et al.) and will be increased higher with high power coupler. (S. Mitsunobu et al.) To increase luminosity of KEKB, crab cavities for KEKB have been developed (H. Nakai et al.) and studied mutipactoring problems at iris part of the cavity. (Y. Morita et al.) Test crab cavities will be installed in LER and HER of KEKB at the near place of the SC accelerating cavities in next few years. Following, field of nein cell cavities reached more than 30 MV/m by electropolishing with collaboration with DESY presented last Workshop, many basic studies related to electropolishing performed. (K. Saito et al., I. Ito et al. and T. Higuchi et al.) The highest field of SC cavities seems to saturate around 40 MV/m. (K. Saito) J-PARC activities continued for upgrade program for J-PARC proton SC linac. (S. Noguchi et al., E. Kako et al. and K. Saito et al.) Recently KEK is seriously studying to make a design of ERL project using SC linac for future light source.

**MoP08: An Overview of SRF Activities at Cornells Laboratory of Elementary Particle Physics**

*H. Padamsee, P. Barnes, B. Barstow, I. Bazarov, S. Belomestnykh, C. Crawford, G. Eremeev, D. Hartill, R. Kaplan, J. Knobloch, M. Liepe, R.L. Geng, P. Quigley, J. Reilly, O. Romanenko, J. Sears, V. Shemelin, J. Shipman, C. Sinclair, E. Smith, K. Smolenski, M. Tigner, V. Veserevich, G. Werner (Cornell University)*

Cornell continues activities in many areas in collaboration with other labs: systems development and operation for CESR, supporting technology transfer of CESR SRF systems to storage ring light sources around the world, collaboration with the world-wide TESLA project, collaboration with Muon Collider/Neutrino Factory projects, developing an Energy Recovery Linac (ERL) based light source in collaboration with other labs, and basic R and D in the areas of high field Q-slope, field emission, voltage breakdown and waveguide multipacting.

**MoP09: SRF Activities at INFN-Genoa.**

*R.F. Parodi, R. Ballantini, A. Chincarini, G. Gemme, A. Podesta (INFN-Genoa)*

The activities of INFN Genoa in the field of the RF Superconductivity are shifting toward the application of Superconducting Cavities to a Gravitational Wave detector operating in the 4-10 KHz frequency range of the Gravitational Wave spectrum. The first prototype of the detector cavity, built at CERN under an INFN-CERN collaboration agreement, is under test in Genoa. The group is planning for the next three years the construction of a Demonstrator Detector based on the already existing INFN-CERN cavity. As a side activity the Genoa Group is developing a small RD project to check the achievable limits (field and Quality Factor) for Pipe Cooled cavities. If proven successful, pipe cooling will greatly reduce the acoustic coupling in the GW detector. Pipe cooling can also be useful in reducing the helium inventory, (and cryo-system complexity) in standard Superconducting Cavity applications. The Genoa group is still refining and updating the Twtraj Code for the simulation of electronic discharges (resonant or not) in accelerating cavities.

**MoP10: Superconducting RF Activities at FZ-Juelich**

*R. Stassen, R. Eichhorn, F.M. Esser, B. Laatsch, G. Schug, R. Toelle, E. Zaplatin (FZJ)*

Two types of superconductive cavities are currently under investigation at the research center FZJ in Juelich. The Niob prototype of a four gap spoke cavity is already in fabrication at the central workshop after analysing and tests of copper models. As a second activity, a new pulsed linac for the cooler synchrotron COSY has been designed based on superconductive half-wave resonators HWRs. These resonators are well suitable to accelerate polarized protons and deuterons ending up with a similar energy of about 50MeV. Two prototypes of a 160MHz HWR were ordered at different manufactures. We will present the mechanical analyses of the HWR as well as a study for an optimized high pressure cleaning system. The results of different mechanical fabrication options will be shown.

### MoP11: Status of the LANL Activities in the Field of RF Superconductivity

*T. Tajima, K. C. D. Chan, R. L. Edwards, R. C. Gentzlinger, W. B. Haynes, J. P. Kelley, F. L. Krawczyk, J. E. Ledford, J. Liu, M. A. Madrid, D. I. Montoya (LANL), P. L. Roybal, R. J. Roybal, E. N. Schmierer, D. L. Schrage, A. H. Shapiro (LANL)*

The activities at LANL in the past two years since the last workshop are described. The main theme of our activity was the development of spoke cavities for low-energy sections of high-power proton accelerators. We designed and procured two 350 MHz, beta=0.175, 2-gap spoke cavities from industry and tested them. Both cavities have shown excellent performance, i.e., accelerating gradients of 13-13.5 MV/m with low-field unloaded Q of >1E9 as compared to required 7.5 MV/m and 5E8, respectively. Some results on RF surface resistance measurements of magnesium diboride (MgB2), a relatively new high Tc material with transition temperature of 39 K, will also be shown.

### MoP12: Surface Superconductivity of Niobium: Onset of Long-range Coherence

*L. von Sawilski, S. Casalbuoni, J. Koetzler (Inst. of Appl. Phys., Univ. Hamburg)*

Superconductivity above the upper critical field of Niobium cylinders with as-grown (i.e. rough), chemically, and electrolytically polished surfaces is investigated. Using the popular criterion for the surface critical field, i.e. the onset of a screening in the low-frequency (10 Hz) susceptibility chi, we find the ratio R between the surface critical field and the upper critical field to be larger than the classical Ginzburg-Landau based value of 1.69 and to increase from 1.8 to 2.0 by electropolishing the surface. This increase is tentatively related to a reduction of the correlation length near the surface due to impurities released from a dirty layer to the Nb due the polishing processes. We have also determined from the ac susceptibility the ac-conductivity, and find that the surface critical field marks only the appearance of a strongly increasing Ohmic conductance, accompanied by a rather small screening component. At a lower field, where the Ohmic conductivity tends to diverge, we observe a sharp increase of the screening component, i.e. of a long-range coherent surface superconductivity. The appearance of phase coherence at this coherent surface critical field is corroborated by the onset of a (inductively measured) finite critical surface current. The field and temperature variation of this current can be well explained in terms of the critical state model by J. Fink (Phys. Rev. Lett. 14, 853 (1965)). For the smoothest surface, also the magnitude of the surface critical current is close to the prediction of this GL-based model. Upon surface roughening, the current density is reduced, and along with the decrease of the ratio R this indicates a larger instability of surface superconductivity. Our analyses of the frequency variation of both conductivity components reveal the validity of dynamical scaling near the surface coherent field. The critical exponents suggest that the coherence is achieved by a percolation between superconducting patches nucleated at the surface critical field.

### MoP13: Microwave Nonlinear Resonance Incorporating the Helium Liquid-vapour Phase Transition in Superconducting Microstrip Resonators

*A.L. Karuzskii, A.N. Lykov, A.V. Perestoronin, A.I. Golovashkin (LPI)*

New nonlinear microwave resonances in superconducting niobium-teflon microstrip resonators cooled by liquid helium are studied. Helium heating caused by the losses of microwave power in superconductor changes the resonant frequency because of the temperature dependence of helium permittivity. Manifestations of this thermal instability discover a new type of nonlinear phenomena including the generation of the monochromatic microwave pulses, generation of acoustic signals. The found nonlinear resonances are explained by thermally induced variations of the helium dielectric permittivity caused by the microwave power dissipated in superconductor, which enable incorporating the jump nonlinearity of a liquid-vapour phase transition in helium.

**MoP14: A Review of High-Field Q-Slope Studies at Cornell**

*H. Padamsee, P. Barnes, I. Bazarov, C. Crawford, G. Eremeev, R.L. Geng, J. Knobloch, M. Liepe, O. Romanenko, J. Sears (Cornell University)*

The TESLA collaboration has been making steady progress in developing cavity treatment procedures to regularly reach accelerating fields above 25 MV/m. At higher gradients the Q begins to drop precipitously without field emission. New treatments such as electropolishing and 100 C baking have been developed to delay the onset of the Q-drop to 30 - 40 MV/m. Missing is a good understanding of the cause of the Q-decline, the reason for the effectiveness of the empirical cures, and whether the cures work on all cavities. Advances in these areas will open the door to higher gradients. This paper will summarize Q-slope studies at Cornell over the last few years. These include tests on cavities prepared by various treatments: standard chemical etching, electro-polishing, and anodizing. DESY has provided some of the cavities, especially those with electro-polished surfaces. Each cavity is tested before and after baking over a range of temperatures, as well as after baking at 800 C. Tests at Cornell include a powerful thermometry diagnostic system which helps identify regions of high RF losses. Models for the Q-slope and baking effects will also be discussed in the context of the Cornell experiments.

**MoP15: Near-Surface Composition of Electropolished Niobium by Variable Photon Energy XPS**

*A.M. Valente (JLab), H. Tian, M. Kelley (College of William and Mary), C. McGuiness, P.A. Glans, K. Smith (Boston University)*

The mechanical and other damage to the interior surfaces of niobium cavities for superconducting radio frequency accelerators can be removed by either buffered chemical polishing or by electropolishing. The effect of each on SRF performance has been extensively reported, with much attention given to the near-surface composition. In particular, angle-resolved XPS has been used to elucidate the sequence of oxides. We report first results of an alternative approach, varying the x-ray photon energy at normal incidence to accordingly obtain information from different depths. The experiments were performed on Beamline X1B at the National Synchrotron Light Source, Brookhaven Laboratory.

**MoP16: Low Temperature Heat Treatment Effect on High-field EP Cavities**

*J. Hao (DESY/Peking University), D. Reschke, A. Brinkmann, L. Lilje (DESY)*

It is well known that low temperature (100-150)C heat treatment (bake) has positive effects on the performance of high field EP cavities. More than 40 test results are analyzed based on single-cell cavity experiments of the CERN-Saclay-DESY collaboration and nine-cell cavities at DESY. The average gradient Eacc,max increased from 31.9 MV/m to 35.4 MV/m after baking. No dependency of Eacc,max and the gain of Eacc,max on the baking temperature is observed. The Q-value at maximum gradient Q0(Eacc,max) depends significantly on the bake temperature. The average Q0(Eacc,max)s are 5.3E9, 9.2E9 and 7.7E9 at bake temperate (100-110)C, (120-130)C and (130-140)C, respectively. Comparison of BCP and EP cavities shows that at least 60-80 um EP on a BCP surface is necessary. More than 10-15 um removal of the surface by BCP will reduce the performance of an EP cavity.

**MoP17: First Cryogenic Tests with JLabs new Upgrade Cavities**

*P. Kneisel, G. Ciovati, G.R. Myneni, J. Sekutowicz, G. Wu (JLAB), J. Halbritter (FZK,IMF I)*

For the upgrade of CEBAF to 12 GeV two types of 7-cell cavities have been developed: the High Gradient type (HG) has been optimized with respect to the ratio of Epeak / Eacc and for the Low Loss (LL) type the shunt impedance has been maximized. Both cavity styles feature two DESY type coaxial HOM couplers on the beam pipes on both ends of the cavity, a waveguide input coupler, a transmission probe, NbTi end dishes as part of an integrated He-vessel and stiffening rings between the cells and the end dishes. Design goals for these cavities have been set to Eacc = 20 MV/m with a Q-value at 2.05K of Q0 = 8*1E9. A niobium prototype of each cavity has been fabricated at JLab and in a first test the HG cavity has been evaluated at cryogenic temperatures after appropriate buffered chemical polishing. Data for Q(E) were taken at several temperatures after R(T) was measured during initial pump down. In addition the pressure sensitivity as well as the

Lorentz force detuning were evaluated. The damping of approximately 20 High Order Modes was measured to verify the room temperature data. In addition we have built and tested several single cell cavities of both cell shapes. In the LL cavity of the end cell geometry a peak surface electric field Epeak of about 87 MV/m corresponding to a magnetic peak field Hpeak of about 173 mT was achieved after a heat treatment at 1250 C and in-situ baking. This cavity showed characteristic Q vs. E dependences, which we investigated at different temperatures with particular interest in the low field ($<$ 20 mT) Q - variation with field. There are strong indications that diffusion of oxygen into the penetration depth is responsible for this feature. A second LL cavity of the inner cell geometry with a small beam aperture of 53 mm was tested several times, the main objectives being to answer questions of cleaning and multipacting. For the same purpose a HG single cell cavity of the inner cell geometry was manufactured, however in a different sequence: at first the half cells were post purified at 1250 C with Ti, then they were electropolished, machined and electron beam welded. We present in this contribution a summary of measured results of all tests we performed on the new proposed shapes of the upgrade cavities.

**MoP18: A Pleasant Surprise: Mild Baking Gives Large Improvement for the Q-Slope of a BCP Cavity**

*G. Eremeev, M. Liepe, H. Padamsee, R. Roy (Cornell University)*

Previous measurements have shown that mild baking has a significant effect on the high field Q-drop of electropolished cavities. But for BCP (112) cavities, the improvement is not so substantial. Recently we tested a RRR = 500 cavity without high temperature (1350 C) titanium purification, nor 800 C baking. To our surprise a mild baking (110 C, 48 hours) increased the onset field of the Q-slope by 50%. At 1E10 Q the field increased from Eacc = 18 to Eacc 27 MV/m. At a Q = 2E9 the field improved from Eacc = 24 to 32 MV/m. A light BCP re-established the stronger Q-slope. A second baking at 140 C had little effect on the Q-slope. Results from other cavities show Q-slope degradation for higher temperature bakes. All tests are accompanied by temperature mapping which show interesting features.

**MoP19: High Gradient Q-Slope : Comparison between BCP and EP Cavities - Modification by Plasma Disharge**

*B. Visentin, J.P. Charrier, D. Roudier, A. Aspart, Y. Gasser, J.P. Poupeau, B. Coadou (CEA Saclay)*

BCP (buffered chemical polishing) and EP (electropolishing) superconducting niobium cavities show similar behaviours, before and after baking (at low temperature) and particularly towards the Q-slope removal. Furthermore, the surface treatment of a BCP cavity by oxygen plasma show similar results such baking. These results prove that the surface roughness is not involved in the Q-slope origin and that the oxygen has a leading part to remove the Q-slope.

**MoP20: Statistics of Beam Abort due to SC-RF in KEKB-HER**

*T. Furuya, K. Akai, H. Ikeda, G. Katano, M. Yamaga (KEK)*

Because of strong coupling and reaction between RF cavities and a stored beam, it is difficult to identify the source of beam loss and RF-trip phenomena among a lot of interlock indications of a machine protection system. In KEKB, every beam dump has been monitored together with the RF signals of the superconducting (SC) cavities using a multi channel recorder. Analysis of this signal is useful not only to know the real source of the beam loss but also to polish up a machine protection system against a high intensity beam of 1 A. Typical results will be given as well as the statistics of the SC trips.

**MoP21: Achievements of the Superconducting Damped Cavities in KEKB Accelerator**

*T. Furuya, K. Akai, K. Hara, K. Hosoyama, A. Kabe, G. Katano, Y. Kojima, S. Mitsunobu, Y. Morita, H. Nakai, M. Yamaga (KEK)*

After the last workshop in 2001, drastic progress has been achieved in KEKB. The beam intensity of High Energy Ring (HER) reached the design value of 1.1 A, and the operation in reduced number of bunches achieved a peak luminosity to 1.06E+34 cm-2s-1. Eight superconducting (SC) damped cavities installed in HER have provided an accelerating voltage of 10 MV and delivered the RF power of 2.2 MW to the electron beam. The bunch charge of 8 nC which was four times higher than the designed one induced a HOM power of more than 10 kW in each SC cavity module. Ferrite dampers absorbed this HOM power sufficiently and no beam instability has been observed. Update of the operation performance will be given.

### MoP22: Test of the SOLEIL Cryomodule Prototype with Beam at ESRF

*J. Jacob, D. Boilot (ESRF), S. Chel, P. Bosland, P. Bredy (CEA), E. Chiaveri, R. Losito (CERN), J.-M. Filhol, P. Marchand, C. Thomas-Madec (SOLEIL)*

A cryomodule housing two strongly HOM-damped 352 MHz superconducting (SC) Nb/Cu single-cell-cavities has been developed within the framework of the SOLEIL project design phase. In 2002, the prototype was installed in the ESRF storage ring and tested with beam in the accelerating regime, the cavities being cooled down to 4.5 K by means of liquid helium from Dewars. Four series of tests have been carried out at the end of scheduled shutdowns. In order not to disturb the ESRF machine performance during the user mode of operation, the cavities were maintained detuned at room temperature. In this passive regime, they remained transparent to the beam with less than 100 W of deposited power, evacuated by a warm helium gas flow. Up to 170 mA of beam could be accelerated with a peak RF voltage of 3 MV and a power of 360 kW from the SC module. This corresponds to the performance required for the first SOLEIL operation phase. The concept of effective HOM damping was validated up to the maximum ESRF intensity of 200 mA. A few week points already identified at previous CERN tests were confirmed: high static cryogenic losses, poor cooling of one HOM coupler and too high fundamental power through the dipolar HOM couplers.

### MoP23: Field Emission Related Phenomena in a 3 GHz 20 Cell Cavity of the S-DALINAC

*M. Gopych, H.-D. Graef, U. Laier, M. Platz, A. Richter, A. Staschek, S. Watzlawik (TUD), S. Setzter, T. Weiland (TEMF)*

Investigations of field emission accompanied by emission of light in a superconducting niobium rf cavity of the S-DALINAC have been carried out by analysis of bremsstrahlung and optical spectra. The spectral power density of the observed light spots could be interpreted as black body radiation emitted at a temperature of some 1500 K. From bremsstrahlung spectra measured at accelerating gradients from 6 to 7 MV/m the maximum energies gained by dark current electrons that were accelerated and able to leave the cavity were determined. In order to localize a possible position of an emission site, trajectories of dark current electrons in the cavity were numerically simulated by a simulation code based on the Leap-Frog method. The simulations have shown that the observed electron energies cannot be gained in a cavity with an ideal field flatness. Best agreement has resulted for a strongly deteriorated field profile with an end cell detuned by 5.4 MHz. Experimental evidence for this hypothesis is deduced from a comparison of the present eigenfrequencies of this particular cavity with both, the present eigenfrequencies of other S-DALINAC cavities and the eigenfrequencies of the respective cavities after their initial tuning for field flatness in the pi-mode.

### MoP24: Higher Order Beam Multipactoring and Single Side Beam Multipactoring

*S. Misunobu (KEK)*

High current application of superconducting cavity, some electron energy depositions affect to not only cavity performance but also cryogenic load of refrigerators. The threshold current formula for two side beam multipactoring derived by O. Grobner is easily extended to higher order beam multipactoring and single side beam multipactoring. Order estimation of the threshold current of positive or negative charge beam at the field free beam tube can be performed easily for high current application or small bore beam tube application such as KEKB or TESLA respectively.

### MoP25: SLS Operational Performance with Third Harmonic Superconducting System

*M. Pedrozzi, J.-Y. Raguin, W. Gloor (PSI), A. Anghel (EPFL-CRPP), P. Marchand (SOLEIL), P. Bosland, P. Bredy, S. Chel, C. Devanz (CEA-SACLAY), M. Svandrlik, G. Penco, P. Craievich, A. Fabris, C. Pasotti (ELETTRA), E. Chiaveri, R. Losito, O. Aberle (CERN)*

Within the framework of the S3HC project, two identical cryomodules, one for SLS and one for ELETTRA, were developed at CEA Saclay. Each cryomodule contains a third harmonic superconducting RF system consisting of two passive 1500 MHz Nb/Cu single-cell cavities. At the SLS the commissioning of the cavity in the bunch lengthening mode took successfully place end of August 2002, becoming the nominal mode of operation of the storage ring. The measurement made at SLS shows bunch lengthening up to a factor of 3 and a lifetime increase greater than a factor 2. The additional Landau damping, generated at high harmonic voltage by the increased non-linearity of the global RF voltage, allows stable top-up operation at the maximum design current of 400 mA. The commissioning and the operational results obtained with this system are reported here.

### MoP26: Upgrade to Cryomodule Test Facility at Jefferson Lab

*T. Powers, T. Allison, G. K. Davis, M. Drury, C. Grenoble, L. King, T. Plawski, J. Preble (JLAB)*

The cryomodule test facility was originally implemented in the late eighties for testing of a small fraction of the cryomodules during the production run for the Continuous Electron Beam Accelerator Facility. The original system was built using a dedicated wiring scheme and a pair of 2 kW, 1497 MHz RF sources. This dedicated system made it difficult to test cryomodules and other RF structures of non-standard configuration. Additionally, due to a previously installed cyclotron, there were static magnetic fields in excess of 4 Gauss within the test cave, which limited the capability of the facility when measuring the quality factor of superconducting cavities. Testing of the Spallation Neutron Source cryomodules as well as future upgrades to the CEBAF accelerator necessitated that the facility be reconfigured to be flexible both with respect to RF source power and cryomodule wiring configuration. This paper will describe the implementation of a generalized wiring scheme that is easily adapted to different cryomodule configurations. It will also describe the capabilities of the LabView based low level RF controls and the related data acquisition systems currently being used to test cryomodules and related hardware. The high power RF source capabilities will be described well as the magnetic shielding put in place in order to reduce the ambient magnetic file to levels below 50 mGauss will also be described. Supported by US DOE Contract Number DE-AC05-84ER40150.

### MoP27: Performance of the 3rd Harmonic Superconducting Cavity at ELETTRA

*M. Svandrlik, G. Penco, P. Craievich, A. Fabris, C. Pasotti (Sincrotrone Trieste), M. Pedrozzi (PSI), A. Anghel (EPFL-CRPP), P. Marchand (SOLEIL), P. Bosland, P. Bredy, S. Chel, G. Devanz (CEA-SACLAY), E. Chiaveri, R. Losito (CERN)*

A superconducting cavity designed to operate at ELETTRA at the third harmonic of the main RF frequency, 1.5 GHz, has been constructed in the frame of the SUPER-3HC collaboration with CEA, SLS and CERN. The 2-cells Nb-Cu cavity, derived from the SOLEIL design, was installed on the ELETTRA storage ring during the summer 2002 shutdown. After a commissioning period it was operated for the first time during user shifts in February 2003. Activation of the 3rd harmonic cavity allows to stabilize longitudinally the beam at 2.0 GeV, 300 mA, due to the Landau damping induced by the cavity. At the same time the beam lifetime is increased by about a factor 2. The cavity is now routinely operated during user shifts at 2.0 GeV. We will discuss the performance of the cavity and of the cryogenic plant along with the first results of the beam-cavity interaction studies.

### MoP28: ERLP Cryogenics

*R. Bate (ASTeC CCLRC), R. Goulden, R. Jones (SRD CCLRC), C. Monroe (Monroe LTD)*

An ERLP, (energy recovery linac prototype) is to be built over the next three years at the CCLRC site at Daresbury UK. The purpose of this machine is to increase the UKs skill base in photo injector electron guns and superconducting linac technology. This paper will discuss the options before us for the installation of a 2K Cryogenic plant for such a machine.

### MoP29: The Diamond Light Source RF System

*R. Bate (ASTeC), M. Jensen (DLS), D.M. Dykes (ASTeC)*

The Diamond Light Source (DLS) storage ring RF system will use single cell superconducting accelerating cavities, which are being manufactured as a turn-key contract. An overview of the whole storage ring RF system is presented, with emphasis on the choice of cavity type and the required 4.5 K cryogenic plant.

### MoP30: Drift Tube Cavity Cryomodule Design for RIA

*J. Fuerst, K. Shepard, M. Kelly, M. Kedzie (ANL)*

We present the current status of our Rare Isotope Accelerator (RIA) cryomodule development effort. The RIA

driver and post accelerator linac drift tube sections require about forty reliable, low heat leak cryomodules, each containing from seven to nine drift-tube-loaded cavities. A proposed triple spoke option for RIA would increase this count to about seventy. We have developed a cryomodule featuring separated cavity and insulating vacuum spaces suitable for all classes of drift-tube-loaded cavities used in RIA. Issues include ease of assembly, cavity cleanliness, heat leak, and subsystem interface (cryogenics, couplers, tuners, shields). We employ an innovative warm-to-cold beam line transition to reduce module-to-module dead space while preserving a top loading box design that minimizes the size of the cleanroom assembly. An AIP-funded upgrade to the existing ATLAS heavy ion linac will allow us to gain valuable operating experience by qualifying the prototype cryomodule in a real machine.

### MoP31: Experimental Results on SCRF Cavity Prototypes for Gravitational Wave Detection

*G. Gemme (INFN Genova), O. Aberle (CERN), R. Ballantini (INFN Genova), Ph. Bernard, S. Calatroni, E. Chiaveri (CERN), A. Chincarini (INFN Genova), R. Losito (CERN), R. Parodi (INFN Genova), E. Picasso (SNS Pisa)*

The results of the measurements on the prototypes for a novel gravitational wave detector based on coupled superconducting cavities are presented. The detector, based on the parametric converter scheme, is a tunable device suitable for gravitational wave detection in the frequency range above few kHz. The tests on a double pill-box, operating at 3 GHz, allowed to check the operation of the detector, the sensitivity of the system, and to develop the electronics. Mechanical measurements allowed also to gather informations about the frequency and quality factor of the mechanical modes of the cavity. The characteristics of these modes are relevant to reduce the thermo-mechanical noise (Brownian noise) which sets the ultimate limit of the detection sensitivity. Starting from the results on the pill-box prototype, a cavity, based on two coupled spheres, suitable for gravitational wave detection was built and tested. The results of the first measurements are reported and discussed.

### MoP32: Prototype Cryomodule for the ADS LINAC

*S. Noguchi (KEK)*

For the future application of SC LINAC to ADS, a prototype cryomodule is being constructed under the collaboration of JAERI and KEK. The module contains two nine-cell structures of beta=0.725 and f=972 MHz. The module will be ready for the high-power test by the next March.

### MoP33: Conceptual Layout of the Cavity String of the Cornell ERL Main Linac Cryomodule

*M. Liepe (Cornell University)*

Cornell University, in collaboration with Jefferson Laboratory, has proposed the construction of a prototype energy-recovery linac (ERL) to study the energy recovery concept with high current, low emittance beams [Study for a proposed Phase I ERL Synchrotron Light Source at Cornell University, ed. by S. Gruner and M. Tigner, CHESS Tech. Memo 01-003, JLAB-ACT-01-04 (July 2001)]. In the main linac of this machine two beams, with a beam current of up to 100 mA each, will excite significant higher-order-mode (HOM) power in the superconducting RF cavities. Cost efficiency requires the use of multicell cavities, which is challenging along with the storage-ring like beam current. In this paper we present a promising layout of the cavity string in the main linac module and discuss the HOM damping concept.

### MoP34: Research and Development Program on Superconducting Crab Cavities for KEKB

*H. Nakai, K. Hara, T. Honma, K. Hosoyama, A. Kabe, Y. Kojima, Y. Morita (KEK), K. Nakanishi, M. Rahman (GUAS), K. Okubo (MHI)*

Recent stable operation of the KEKB accelerator brings the highest integrated luminosity in the world and opens the new world of the particle physics. Then KEK has determined to install superconducting crab cavities into KEKB to obtain much more luminosity. Since no crab cavities have been operated in any accelerators so far, we had to started our research and development program on crab cavities for KEKB from the beginning literally. With 1/3-scale crab cavities made of pure niobium we had learned and experienced the fundamental characteristics of the crab cavities. As the second phase, we have fabricated two full-scale crab cavities and measured their performance. Beside these activities, various special parts to the crab cavities, such as coaxial couplers, notch filters, stub supports are under development. Also we have started to design the cryostats which accommodate crab cavities in KEKB.

**MoP35: Development of Superconducting Proton Linac for ADS**

*N. Ouchi, N. Akaoka, H. Asano, E. Chishiro, Y. Namekawa, H. Suzuki, T. Ueno (JAERI), Sh. Noguchi, E. Kako, N. Ohuchi, K. Saito, T. Shishido, K. Tsuchiya (KEK), K. Okubo, M. Matsuoka, K. Sennyu (MHI), T. Murai, T. Ohtani, Ch. Tsukishima (MELCO)*

ADS (accelerator driven nuclear transmutation system) require a high intensity proton accelerator of which energy and beam power are about 1 GeV and 20-30 MW, respectively. JAERI, KEK, MHI and MELCO have conducted a program for the development of superconducting proton linac for the ADS since 2002. This program, which is based on the achievement of the J-PARC design work, consists of two parts, development of a 972 MHz cryomodule and system design of a superconducting proton linac in the energy range between 0.1 and 1 GeV. In the development work of the 972 MHz cryomodule, a prototype cryomodule will be developed and the horizontal test will be performed. The cryomodule includes two 972 MHz 9-cell cavities of beta=0.725. The goal of this work is stable operation in the horizontal tests at the surface peak field at 30 MV/m, which corresponds to the accelerating gradient of 10 MV/m. The cavity development, which includes the vertical tests, is mainly being performed at KEK. The horizontal tests will be performed at JAERI where a 972 MHz Klystron is in operation, which is also utilized for the high power tests of the power couplers. The details of the cavity development, the cryomodule design and the power coupler development are presented by K. Saito, S. Noguchi and E. Kako, respectively. In the system design work, the beam dynamics design and the configuration design in a tunnel will be performed.

**MoP36: Design of a Superconducting Half Wave Resonator Module for Proton/Deuteron Acceleration**

*M. Pekeler (ACCEL), K. Dunkel, R. Henneborn, C. Piel, M. Poier, P. vom Stein, H. Vogel*

Within the contract of the supply of a turn key proton/deuteron Linac for SOREQ, a superconducting half wave resonator RF module was designed for the acceleration of protons/deuterons from about 2 MeV to about 7 MeV. The module consists out of 6 superconducting half wave resonators designed for optimum acceleration of beta = 0.09 protons/deuterons, 3 superconducting solenoids for focusing, cavity tuners and couplers, thermal shield, magnetic shielding, vacuum vessel, helium vessels, helium supply/return and all instrumentation. Main design considerations of the cavities, solenoids, tuners and couplers as well as for the module especially in view of assembly and alignment will be explained. A major design challenge was the need from beam dynamics to minimize the longitudinal distance between the cavities. Prototype tests of cavity, helium vessel, tuner and coupler all at cryogenic temperatures are foreseen before the main production is launched. A cavity preparation and cold RF test facility for cavities and completed modules is under construction at ACCEL to allow first cold RF tests at the beginning of next year.

**MoP37: Installation, Commissioning and Test Results of Superconducting RF Modules for Light Sources and Electron Storage Rings**

*M. Pekeler, S. Bauer, M. Peiniger, P. vom Stein, H. Vogel (ACCEL), S. Belomestnykh, H. Padamsee, P. Quigley, J. Sears (Cornell)*

The production of superconducting 500 MHz modules for Taiwan Light Source, Canadian Light Source and Cornell University is almost finished. We report on installation and commissioning work and discuss test results of completed modules, valve boxes and SRF electronics. The module test results will be compared to the test results of the subcomponents like windows and cavities. Operational experience with modules installed in the accelerator is also given. One module test resulted in a failure of the RF window. A detailed analysis of that test is included. ACCEL was recently contracted from Diamond Light Source on the production of two additional SRF modules. We shortly report on the intended design improvements.

**MoP38: Design and Construction of the Prototype Cryomodule for the CEBAF 12 GeV Upgrade - Renascence**

*C. E. Reece (JLab), G Ciovati, I. E. Campisi, E. F. Daly, J. Henry, W. R. Hicks, J. Hogan, P. Kneisel, D. Machie, J. Preble, T. Rothgeb, J. Sekutowicz, K. Smith, T. Whitlatch, K. M. Wilson, M. Wiseman, G. Wu*

In the past two years, the design of the cryomodules for the anticipated CEBAF 12 GeV upgrade has evolved considerably. While maintaining compatibility with existing infrastructure, several modifications have been made which are expected to improve both gradient and 2 K heat load performance and to simplify assembly.

Two versions of improved cavity design have been prototyped, a new tuner design has been developed, new flange sealing hardware has been developed, and refinements to the cryogenic design promise to extend the usable net cw voltage from the eight-cavity cryomodule to about 110 MV with 250 W load to 2 K. The final prototype cryomodule, Renascence, is under construction and scheduled for completion in summer of 2004. System improvements, problems encountered along the way, and present solutions will be presented.

**MoP39: Design of 1.2-GeV SCL as new Injector for BNL AGS***

*A. G. Ruggiero, J. Alessi, M. Harrison, M. Iarocci, T. Nehring, D. Raparia, T. Roser, J. Tuozzolo, W. Weng (BNL)*

It has been proposed to upgrade the Alternating Gradient Synchrotron (AGS) accelerator complex at the Brookhaven National Laboratory (BNL) to provide an average proton beam power of 1 MW at the energy of 28 GeV. The facility is to be primarily used as a proton driver for the production of intense neutrino beams. This communication reports on the conceptual study of a proton Super-Conducting Linac (SCL) as the new injector to the AGS. The Linac beam energy is 1.2 GeV. The beam intensity is adjusted to provide the required average beam power of 1 MW at 28 GeV. The repetition rate of the SCL-AGS facility is 2.5 beam pulses per second, with a duty cycle of 0.2%. The SCL is injected from the present 200-MeV room-temperature Linac, and is made of three sections: Low-Energy from 200 to 400 MeV operating at 805 MHz, Medium-Energy from 400 to 800 MeV at 1.61 GHz, and High-Energy to the final 1.2 GeV also operating at 1.61 GHz. The preliminary design of the SCL has already received positive consent, as it was found indeed feasible. We are now approaching a second phase where we are more explicitly investigating engineering considerations in the design, namely: cryogenic, cryostat design, RF cavity design, RF power couplers and power sources, civil engineering, and insertions for transverse focusing and other beam utilities. The approach used to address some of these technical issues and preliminary results will be discussed in the present paper. * Work performed under the auspices of the U.S. Department of Energy

**MoP40: Development of Superstructures for High Current Application**

*J. Sekutowicz, P. Kneisel, G. Wu (JLab)*

Devices for acceleration of electron currents beyond 100 mA are becoming increasingly interesting for high power FEL's or for ERL's. To achieve photon beams of several hundreds of kW's, low emittance electron beams of up to 1 A have to be delivered to undulators from a driving linear accelerator. High quality beams and stable operation of the accelerating sections are only possible if the Higher Order Modes (HOM) generated by the beams can be sufficiently damped. The positive experience with the HERA cavities [1], in which the dominant monopole modes are damped to Qext about 700 and all dipole modes to Qext $<$ 6000 makes it highly likely that a superstructure (SST) consisting out of two weakly coupled subunits and employing coaxial HOM dampers of the DESY design can be successfully adapted to a properly designed cavity for acceleration of a 1 A beam. This contribution describes a 750 MHz SST design for a 1 A electron beam. The calculated R/Q - values of the HOM's of this SST are quite favorable. The total impedance of the first 16 monopole modes is approx. 140 Ohm, app. a factor of 3 smaller than the impedance for the fundamental mode. It seems very likely that the HOM's can be suppressed to the appropriate levels for stable beam operation. In order to explore the achievable damping, a 1500 MHz Cu 1:2 model of the SST was built and the Qext - value of the dominant HOM's were measured with various HOM coupler configurations. As a result it can be concluded with some confidence that the necessary damping for a 1A machine can be achieved with the proposed superstructure configuration. However, in a next step it is essential to repeat these measurements on a 1:1 model. [1] B. Dwersteg et al.; "Superconducting Cavities for HERA", Proc. of the 3. Workshop on RF Superconductivity, Report ANL-PHY-88-1, p. 81ff , ANL, 1987

**MoP41: CW Energy Recovery Operation of XFELs**

*J. Sekutowicz (JLAB/DESY), A. Bogacz (JLAB), M. Ferrario (INFN), I. Ben-Zvi (BNL), P. Colestock (LANL), D. Douglas, P. Kneisel (JLAB), W.-D. Moeller, D. Proch (DESY), J. Rose (BNL), J. Rosenzweig (UCLA), L. Serafini (INFN), S. Simrock (DESY), T. Srinivasan-Rao (BNL)*

The commissioning of two big coherent light facilities

at SLAC and DESY should begin in 2008 and in 2011 respectively. In this paper we look further into the future, hoping to answer, in a very preliminary way, two questions. First: what will the next generation of the XFEL facilities look like? Believing that superconducting technology offers several advantages like high quality beams with highly populated bunches (higher peak brilliance), the possibility of energy recovery or higher overall efficiency than warm technology, we focus this preliminary short study on the superconducting option. From this assumption the second question arises: what modifications in superconducting technology and in design are needed, as compared to the present DESY XFEL, and what kind of Research and Development program should be proposed to arrive in next few years at a technically feasible solution with even higher brilliance and increased overall conversion of AC power to photon beam power. In this paper we will very often refer to and profit from the DESY XFEL design, acknowledging its many technically innovative

### MoP42: Conceptual Design of A Multi-turn Energy Recovery Linac for the Advanced Photon Source (APS) Storage Ring

*Y. Cho, M. White (ANL)*

The Advanced Photon Source (APS) is a fully developed 3rd-generation x-ray source with some 40 beam-lines for materials, condensed matter, and biomolecular structure studies. The concept put forth in this paper improves source brilliance of the APS by two orders of magnitude and shortens the x-ray beam pulse length from about 30 picoseconds to the order of 1 femtosecond by combining the existing APS ring with a multi-turn energy-recovery linac. The paper discusses one difficulty, the cryogenic heat load, associated with operation of a multi-GeV CW linac. We propose a possible solution to the heat-load problem by re-circulating the beam as is done in CEBAF, while using the additional energy recovery system to shorten the linac. We discuss implementation of this idea in the APS storage ring or at other 3rd generation light sources in order to best preserve the excellent linac beam emittance.

### MoP43: The Daresbury ERLP Project

*M. Dykes (ASTeC)*

Daresbury laboratory is designing and building an Energy Recovery Linac(ERL). This is to gain the necessary skill base, particularly in photo-injector electron guns and superconducting RF linac technology, to design, construct, commission and operate the 4GLS Light Source.

### MoP44: Degradation of Superconducting RF Cavity Performance by Extrinsic Properties

*J. D. Halbritter (FZK, IMF 1)*

The intrinsic surface resistance of superconductors R_BCS(T,f,B) is degraded by extrinsic effects which actually limit applications, e.g., by rf breakdown or severe heat load. Examples for extrinsic effects are, rf residual losses Rres increasing with rf electric field Ep or rf magnetic field Bp or heating Delta_T of the cavity surface relative to the He-bath. With the now available material qualities and surface preparations gross local defects became rare and global degradations show up. Aside of the rf residual losses Rres related to the Nb-Nb2O5 interface, extrinsic field dependencies are encountered reaching form Q-slope, i.e. delta_R prop. R_BCS(T,f)*(1 + gamma*(Brf/Bc)**2 + eta*(Brf/Bc)**4 + ...) with gamma > eta as the begin of a Taylor series and Bc(0)=0.2 T, from Q-drop, i.e. delta_R prop. exp(-c/Ep) without field emission, and for Nb films or heavily corroded Nb, to Rhys prop. omega*Brf/jcJ (T) with jcJ the critical current density of weak links. For carefully prepared and oxidized Nb Rres(T,f) prop. f**2/jcJ**3/2(T) > 2*(f/GHz)**2 nano-Ohm have been attained. With rf field in bulk Nb cavities immersed in He a Q-slope with gamma(T<2.17K = T_lambda) < 1 - 3 has been reached turning above T_lambda to gamma > 10 - 20 confirming Delta_T heating as main cause. By interface resistances, e.g., in sputtered cavities, gamma(T) = 20 - 50 have been found simulating an exponential R(B)-increase via the exponential R_BCS(T+Delta_T,f,B) increase. The Q-drop by interfacial tunnel exchange with Nb2O5 at the outside surface grows with defects and nanoroughnesses in Nb2O5. Internal surfaces, i.e., weak links, as they occur by oxidation along grain boundaries or at other defects, e.g., in cold worked Nb, yield hysteresis losses at rather low fields. Because of jcJ(T < Tc/2)= const, Rres(T<=Tc/2) and Rhys(T <= Tc/2) are T-independent for Nb, like the interface losses delta_R prop. exp(-c/Ep), whereas the Q-slope replicates via gamma(T) the BCS surface resistance in its T-dependence. All observations, up to date, can be explained in this frame work, pointing to the key interface material properties for further improvements of peak fields and for the reduction of rf losses.

**MoP45: Optimized Shape Sliding Phase Structure for TESLA**

*V. Shemelin, R.L. Geng, M. Liepe, H. Padamsee (Cornell Univ.)*

Optimization of the cavity shape gives a possibility to increase the accelerating rate with the same peak surface magnetic field as in the TESLA structures now. Some increase of the peak surface electric field is acceptable because the electric field is not a severe limit in the SC cavities. Usage of a sliding phase in the 7 - 9 cells cavity gives additional possibilities to increase the accelerating rate and even to reduce the number of cells in the cavity keeping the same energy gain per cavity. The shorter cavity has smaller wakefields and allows smaller cell-to-cell coupling, so it can have smaller iris aperture that gives further possibility to increase the accelerating rate. Description of the proposed geometry, some results of the optimization and fabrication are presented. A considerable gain can be obtained by using this approach for the TESLA structure, about 10 - 20 % in accelerating rate with the corresponding increase of the final energy, or reduction in the length.

**MoP46: CRYHOLAB, A Horizontal Cavity Test Facility : New Results and Development**

*H SAUGNAC, S BOUSSON (IPNO), B VISENTIN (CEA-Saclay) H. Saugnac, S. Bousson (IPNO), B. Visentin (CEA-Saclay)*

In the framework of super conducting RF cavity RD for high intensity proton LINAC (XADS, EURISOL) the IPN Orsay CEA Saclay collaboration is developing five-cell (700 MHz, beta = 0.65) cavity for the high energy section of the LINAC. A first prototype, previously tested in vertical cryostat, has been equipped with a stainless steel 316L helium vessel and tested in the horizontal facility CRYHOLAB at 2K. The cryogenic installation of CRYHOLAB is now fully integrated and the cryostat is directly feed from a 120 l/h helium liquefier. After a short overview of the cavity horizontal tests results the cryogenic installation developments and performances will be presented.

**MoP47: The Process of PKU-SCAF Project**

*R. Xiang, Sh. Quan, K. Zhao, B. Zhang, Y. Ding, S. Huang, X. Lu, L. Lin, L. Wang, J. Chen (PKU)*

At Peking University, there has been significant progress in the development and testing of components and subsystems of Peking Univ. SC Accelerator Facility (PKU-SCAF) for FEL project based on the SRF technology. PKU-SCAF is composed of the SC photo injector and a SC main accelerator. The injector is the first photocathode electron gun to connect Pierce DC gun with 1.3 GHz SC cavity, which has been completely installed in our lab, including 1+1/2 cell Nb cavity, cryostat, RF subsystem, photocathode preparation chamber, drive laser, timing stabilizer and beam diagnostic tools. Testing of the DC-SC photo injector is nearing completion. Fresh effort has been initiated to design a main SC accelerator for PKU-SCAF. Two 9-cell cavities of TESLA type and Rossendorf cryostat will be adopted. To support this effort, the collaboration with DESY and ROSSENDORF is underway, where focuses are 9-cell cavity, cryostat and main coupler etc.

**MoP48: HOBICAT - A Horizontal Test Facility for Superconducting RF Cavities**

*J. Knobloch, W. Anders, D. Plückhahn, M. Schuster (BESSY GmbH)*

Superconducting TESLA cavities are planned for the booster and linac sections of the CW BESSY FEL. A number of challenges and unknowns must be investigated prior to finalizing the design and parameter list. These include the demonstration of long-term, high-gradient CW cavity and RF-coupler operation, the optimization of the input coupling, the measurement and reduction of microphonics, the precise RF regulation of very-narrow-bandwidth cavities, and the investigation of the cryogenic parameters such as optimal bath temperature and achievable pressure stability. To enable systematic tests with rapid turn-around, BESSY is constructing a horizontal cavity test facility called HOBICAT. This setup will permit the off-line testing of 9-cell TESLA cavity pairs with all the ancillary devices needed for the final linac, including the helium tank, tuner, input coupler, HOM couplers, and monitor probe. Piezo stacks will be integrated in the tuner system to both study and cancel out microphonics to minimize the required RF power. First cavity tests are planned for early 2004.

**MoP49: AC Susceptibility Measurements on Surface Treated Niobium Samples - Influence of Electropolishing and Baking Parameters on the Surface Crititical Field**

*B. Steffen, E.-A. Knabbe, L. Lilje, P. Schmueser (DESY), S. Casalbuoni, L. von Sawilski, J. Koetzler (Uni Hamburg)*

The effects of low temperature heat treatment (baking) and electropolishing (EP) on the high-gradient performance of superconducting niobium cavities are of high interest for future electron-positron colliders and X ray free electron lasers. Niobium samples are investigated at 4.2 K using ac susceptibility measurements. The surface critical field and the shielding currents are investigated with respect to the duration (12 hours to 28 days) and the temperature (100 C, 123 C and 144 C) of the UHV heat treatment. Secondly, the difference between chemically etched and electropolished samples has been studied. The surface superconductivity in a thin surface layer is utilized to study the influence of various surface treatments on the superconducting properties. Electropolishing raises the surface critical field by about 8%. A further increase by up to 20% is caused by the baking procedure.

# Tuesday, 9th September 2003

## Oral Presentations

### TuO01: Q-slope at High Gradients: Review About Experiments and Explanations

*B. Visentin (CEA Saclay)*

The quality factor of niobium superconducting cavities shows a strong degradation (Q-slope) for accelerating fields above 20 MV/m. These non quadratic losses are not linked to a field emission because no electrons or X-rays are detected. A simple in-situ bake-out around 120 C induces modifications of the surface superconducting parameters and the Q-slope removal. The Q-slope improvement seems more easy to achieve if the cavity is electro-polished (EP) rather than etched by using a standard buffered chemical polishing (BCP). On the basis of these experimental observations, different models have been developed and many experiments carried out to explain the Q-slope origin. We will try to make a overall analysis of theories and experiments to make allowances and to reduce the field of research.

### TuO02: Surface Characterization: What Has Been Done, What Has Been Learnt?

*P. Kneisel (JLAB)*

Electromagnetic fields penetrate only a distance of about 60 nm into the surface of a superconductor such as niobium. Therefore it is obvious that the surface condition of a cavity surface will effect in a major way the performance of this cavity. For at least the last 30 years niobium surfaces as used in superconducting accelerating cavities have been investigated by surface characterization techniques such as scanning electron microscopy (SEM), Auger spectroscopy (AES), X-ray photon spectroscopy (XPS), energy dispersive X-ray spectroscopy (EDX), electron spectroscopy for chemical analysis (ESCA) and secondary ion mass spectrometry (SIMS). The objective of all these investigations was to establish correlations between surface conditions and cavity performances such as surface resistance and accelerating gradients. Much emphasis was placed on investigating surface topography and the oxidation states of niobium under varying conditions such as buffered chemical polishing, electropolishing, oxipolishing, high temperature heat treatment, post-purification heat treatment and in-situ baking. Additional measurements were conducted to characterize the behavior of a niobium surface more relevant to rf cavities such as resonant (multipacting) and non-resonant (field emission) electron loading. A large amount of knowledge has been extracted by all these investigations; nevertheless, there is still a lack of reproducibility in cavity performance when applying the best process to a cavity surface and no clear correlation has been established between niobium surface features and cavity performance. This contribution gives a review of the attempts to characterize niobium surfaces over the last three decades and tries to extract the white spots in our knowledge.

### TuO03: High gradient Experiments in Electropolished TESLA Multi-cell Cavities

*L. Lilje (DESY), E. Kako, K. Saito (KEK), T. Suzuki (Nomura Plating), D. Kostin, W.-D. Moeller, R. Lange, J. Eschke, D. Reschke, S. Simrock, P. Schmueser, D. Proch, A. Matheisen (DESY), P. Sekalski (University of Lodz), A. Bosotti, R. Paparella (INFN)*

Several nine-cell cavities of the TESLA type have been electropolished at Nomura Plating in collaboration with KEK and DESY. Four cavities have achieved gradients of 35 MV/m and quality factors exceeding the TESLA specification of a Qo=5x10E9 in the continuous wave vertical test. Up to now, one cavity was equipped with a helium tank and a high power coupler. In the horizontal high power pulsed test stand (CHECHIA) the excellent performance was maintained. The use of piezo actuators for Lorentz-force compensation was successfully demonstrated. Multipacting was observed around 20 MV/m, but could be processed easily. The cavity was operated for more than 600 hours at 35 MV/m and has shown no sign of degradation. Further high gradient tests are under preparation.

### TuO04: Operating Experience with Beta=1 High Current Accelerators

*S. Belomestnykh (Cornell)*

Using superconducting cavities proved to be a reliable and efficient way to provide RF power to high-current, high-energy beams. Significant operating experience was accumulated in recent years in running superconducting cavities in electron-positron colliders CESR and KEKB. Recent results are reviewed. Successful operation of these machines as well as of accelerators of an older generation like LEP, TRISTAN and HERA made superconducting RF the technology of choice for many other high-current colliders (BEPCII, LHC) and light sources (CLS, DIAMOND, SOLEIL, TLS). A full set of superconducting cavities for LHC has been already manufactured and tested. The first cryomodule for SOLEIL was fabricated, tested on a test stand at CERN and recently was subjected to a beam test at ESRF. The first CLS cryomodule has been commissioned without beam. Results of those tests are discussed. Another trend in recent years is to use beam-driven (passive) superconducting cavities for bunch length manipulation. Harmonic cavities are commonly used for this purpose. In the collider mode of operation bunch shortening enhances luminosity. Recent experimental results with fundamental RF harmonic cavities at CESR-c are presented. In the light source mode of operation bunch lengthening improves beam lifetime and raises coupled-bunch instability thresholds as it is shown by experience with third-harmonic cavities at SLS and ELETTRA. BESSY-II plans to use a third-harmonic passive superconducting cavity for bunch lengthening as well.

### TuO05: Superstructures: First Cold Test and Future Applications

*J. Sekutowicz (JLAB/DESY), C. Albrecht, V. Ayvazyan, R. Bandelmann, T. Buettner, P. Castro, S. Choroba, J. Eschke, B. Faatz, A. Goessel, K. Honkavaara, B. Horst, J. Iversen, K. Jensch, H. Kaiser, R. Kammering, G. Kreps, D. Kostin, R. Lange, J. Lorkiewicz, A. Matheisen, W.-D. Moeller, H.-B. Peters, D. Proch, K. Rehlich, D. Reschke, H. Schlarb, S. Schreiber, S. Simrock, W. Singer, X. Singer, K. Twarowski, G. Weichert, M. Wendt, G. Wojtkiewicz, K. Zapfe (DESY), M. Liepe (Cornell), M. Huening (FNAL), M. Ferrario (INFN), E. Plawski (INS), C. Pagani (INFN), P. Kneisel, G. Wu (JLAB), N. Baboi (SLAC), C. Thomas (Synchrotron Soleil), H. Chen, W. Huang, C. Tang, S. Zhen (Tsinghua University)*

Superstructures, chains of superconducting multi-cell cavities (subunits) connected by half-wavelength long tube(s) have been proposed as an alternative layout for the TESLA main accelerator. After three years of preparation, two superstructures, each made of two superconducting 7-cell weakly coupled subunits, have been installed in the Tesla Test Facility linac for the cold- and beam test. Energy stability, HOM damping, frequency and field adjustment methods were tested. The measured results confirmed expectations on the superstructure performance and proved that an alternative layout for the 800 GeV upgrade of the TESLA collider is feasible. We report on the test and give here an overview of its results. The cold test confirmed very good damping of HOMs in superstructures and thus has opened a new possible application of this concept to high current energy recovery machines. We have built two 1.5 GHz copper models of two superstructures: 2x5-cells and 2x2-cells to prove further improvement of HOM damping. This contribution presents also measured results on these models.

### TuO06: Third Harmonic Superconducting Passive Cavities in ELETTRA and SLS

*P. Bosland, P. Bredy, S. Chel, G. Devanz (CEA Saclay France), P. Craievich, G. Penco, M. Svandrlick (Sincrotrone Trieste Italy), M. Pedrozzi, W. Gloor (PSI Switzerland), A. Anghels (EPFL-CRPP Switzerland), E. Chiaveri, R. Losito, O. Aberle (CERN Switzerland), P. Marchand (Synchrotron SOLEIL France)*

Two identical Super-3HC cryomodules have been implemented in ELETTRA and SLS since mid of year 2002. For both machines this third harmonic superconducting system, operating in bunch lengthening mode, improves performances in terms of stability and lifetime. The general design of the cryomodule was demonstrated to reach very tight specifications for HOMs damping, tuning resolution and maximum tuning range. Goals for accelerating fields, cryogenic losses, and vacuum were also reached with more margins. Some technological problems at ELETTRA delayed the complete system operation for some months, whereas SLS cryomodule system caused no direct interlock since the commissioning done at the end of August 2002.

### TuO07: Review of the Status of SRF Photo-Injectors

*J. Teichert, H. Buettig, P. Evtushenko, D. Janssen, U. Lehnert, P. Michel, Ch. Schneider (FZR)*

Superconducting radio frequency photoelectron injectors open the way to low-emittance electron beams in continuous-wave operation mode. Their progress is essential for future projects of high-power free electron lasers, energy recovery linacs and next generation light sources. In this presentation, the technical issues associated with the design, construction and operation of SRF photo-injectors will be reviewed together with the progress in several laboratories during the past few years. Results of the operation of the Rossendorf SRF photo-injector with an 1.3 GHz niobium half cell and the future projects are discussed in detail.

### TuO08: CEBAF-ER: Extending the Frontier of Energy Recovery at Jefferson Lab

*C. Tennant, K. Beard, A. Bogacz, Y. Chao, S. Chattopadhyay, D. Douglas, A. Freyberger, A. Hutton, L. Merminga, M. Tiefenback, H. Toyokawa (JLab)*

A successful GeV scale energy recovery demonstration with a high ratio of accelerated-to-recovered energies (50:1) was recently carried out on the CEBAF (Continuous Electron Beam Accelerator Facility) recirculating superconducting linear accelerator in an effort to address issues related to beam quality preservation in a large scale energy recovery system. To gain a quantitative understanding of the beam behavior through the machine, an intense effort was made to characterize the 6D phase space during the CEBAF-ER experimental run. A scheme was implemented to measure the transverse emittance of the energy recovered beam prior to being sent to the dump, as well as in the injector and in each arc. The emittance provides a figure of merit in this context inasmuch as it characterizes the extent to which beam quality is preserved during energy recovery. In addition to describing the transverse phase space, the momentum spread was measured in the injector and arcs to characterize the longitudinal phase space. Measurements also included the RF systems response to the energy recovery process. By using a novel technique employing wire scans in conjunction with PMTs (Photomultiplier Tubes) to accurately measure the beam profile at the dump, we can quantify beam losses in the recirculator. One of the salient conclusions from the experiment is that the energy recovery process does not contribute significantly to the emittance degradation since the emittance degradation of the recirculating pass is consistent with that of the accelerating pass.

### TuO09: Control of Microphonics and Lorentz Force Detuning with a Fast Mechanical Tuner

*S.N. Simrock (DESY)*

Microphonics and Lorentz force detuning have a significant impact on the achievable field stability and rf power requirements in superconducting accelerators. The pulsed operation of high gradient cavities results in dynamic Lorentz force detuning approaching or exceeding the bandwidth of the cavity of the order of a few hundred Hz. In energy recovery linacs the highest possible loaded Q is desired to reduce rf power requirements. In this case a typical microphonic noise level of a few Hz is limiting the permitted loaded Q. In both cases detuning control with a fast mechanical tuner using piezoelectric or magnetostrictive actuators appears very attractive. The issues to be addressed are the achievable stroke at low temperatures, mechanical preload to maximize lifetime and associated in situ force measurement, design of the fast tuner fixture including the actuator/sensor configuration, feedforward algorithm for the compensation of repetitive Lorentz force detuning, and feedback algorithm for the control of microphonics.

### TuO10: SCRF Detectors for Gravitational Waves

*G. Gemme (INFN Genova), O. Aberle (CERN), R. Ballantini (INFN Genova), Ph. Bernard, E. Chiaveri (CERN), A. Chincarini (INFN Genova), R. Losito (CERN), R. Parodi (INFN Genova), E. Picasso (SNS Pisa)*

The basic ideas underlying the use of SCRF cavities for the detection of high frequency gravitational waves are discussed. Experimental results on prototypes are presented. The outline of a possible detector design and its expected sensitivity are also shown.

## Tutorials

### TuT01: Low and Intermediate Beta Cavity Design

*J.R. Delayen (JLab)*

The purpose of this tutorial is to address the design issues specific to low and medium beta superconducting cavities. Simple but useful electrostatic and electrodynamic models based on transmission lines will be presented, and scaling laws will be derived.

### TuT02: RF Coupler Tutorial

*B. Rusnak (LLNL)*

RF couplers are used on superconducting cavities to deliver fundamental RF power for creating accelerating fields and to remove unwanted higher-order mode power for reducing emittance growth and cryogenic load. RF couplers in superconducting applications present a number of interdisciplinary design challenges that need to be addressed, since poor performance in these devices can profoundly impact accelerator operations and the overall success of a major facility. This talk will focus on critical design issues for fundamental and HOM power couplers, highlight a sampling of reliability-related problems observed in couplers, and discuss some design strategies for improving performance.

## Poster Presentations

**Category:**
**Cavity Design / Fabrication / Treatment**

### TuP01: Field Flatness Tuning of TM110 Mode Cavities With Closely Spaced Modes

*L. Bellantoni, H. Edwards, T. Khabibouline (FNAL), A. Rowe*

Superconducting cavities for the CKM RF separated kaon beamline at Fermilab have modes which are closely spaced compared to the resonance bandwidths when warm, and this complicates the field flatness tuning process. Additionally, it is necessary to maintain the azimuthal orientation of the mode during the tuning deformations. We present two analytic techniques to warm-tune cavities with overlapping modes, a finite-element analysis of the tuning process, the design of a warm tuner which maintains mode polarization, and the results of tuning a cavity in which initial manufacturing variations caused the desired pi and nearby pi-1 modes to be indistinguishable before field flatness tuning.

### TuP02: Design Study of a 176 MHz SRF Half-wave Resonator for the SPIRAL-2 Project

*J.-L. Biarrotte, S. Blivet, S. Bousson, T. Junquera, G. Olry, H. Saugnac (IPNO)*

In November 2002, the decision was taken to prepare an RnD program to study and develop the superconducting resonators (QWR and HWR) proposed for the Spiral-2 project. In this context, IPN Orsay started the design study of a 176 MHz beta 0.14 half-wave SRF cavity and its integration in a cryomodule, in close connection with the requirements coming from the beam dynamics along the Spiral-2 superconducting linac. The final aim is to build and test a first HWR prototype before summer 2004. The main results of this on-going study are presented here.

### TuP03: Results From the Room Temperature Model of the Ladder Resonator, a Very Low Beta Cavity for High Current Proton Linacs

*G. Bisoffi (INFN-LNL), V. Andreev (MSU), D. Micheletti, A. Palmieri, S. Stark, A.M. Porcellato (INFN-LNL)*

The 4-gap full Nb Ladder resonator is designed for the 0.1 - 0.2 range of high current linacs. The rf design and beam dynamics studies were presented in [1]. A thourogh mechanical analysis has been completed. An Al model has been built to check rough tuning sensitivity, mechanical precison tolerances with respect to mode mixing and field flatness along the 4 gaps, reliability of the mechanical vibration studies. Results are given in the paper. [1] PRST-AB 6, 040101 (2003)

### TuP04: Control System for BCP Processing Facility at FNAL

*C. Boffo, D. Connolly, L. Elementi, Y. Tereshkin (FNAL)*

Since the surface processing is one of the key elements of superconducting RF cavity fabrication, safety and reliability are the main requirements for the chemical surface treatment facility being developed at FNAL. Accepting the BCP as a baseline process, a gravity feed and open tank approach has been chosen at this stage. This choice forced the introduction of strong automation due to the number of elements to be controlled at different steps of the process. In order to allow for maximum flexibility, two operational modes were defined within the control system: semiautomatic, which requires operator s decision to move from one stage to another, and manual. This paper describes the main features of the control system under development at FNAL to be used in the new BCP facility.

### TuP05: Study of Higher Order Modes in 5-Cell SRF Cavity for E-Cooling at RHIC

*R. Calaga (Stony Brook/BNL), I. Ben-Zvi, Y. Zhao, D. Wang (BNL)*

The electron cooling project for RHIC luminosity upgrade and future projects such as eRHIC demand cavities operating at high average current and high charge in CW energy recovery mode. This paper will describe the ongoing effort in developing a 5-cell superconducting cavity for such high current and high charge linac. The operation frequency of the cavity is 703.75 MHz with an iris of 17cm and two ferrite absorbers for HOM damping. The main focus of this paper is to identify and investigate possible trapped HOM modes that might result in multibunch instabilites. Detailed Mafia calculations were perfomed using e-module for different end cell geometries and results from these calculations including beam breakup thresholds from TDBBU will be presented.

### TuP06: Quarter-wave Cavities for the SPIRAL 2 Project

*G. Devanz, P.E. Bernaudin, P. Bosland, S. Chel, J.M. Baze, F. Nunio, Y. Morin (CEA/Saclay)*

Spiral 2 is the next accelerator to be built at GANIL. It consists of a superconducting linac accelerating deuterons up to 40 MeV/u, and target/source for production of rare isotopes. The superconducting accelerating part of the linac is a combination of two beta families of quarter-wave and/or half-wave resonators. The RF base frequency is 88 MHz for the lower energy part and 176 MHz for the high energy section. An design with a high energy part at 88 MHz is also evaluated. We review the RF optimisation and properties of the quarter-wave resonators for the different beta and frequency families. The mechanical aspects dealing with the frequency stability of the cavities, namely helium pressure effects and tunability have been studied using coupled RF and structural 3D codes.

### TuP07: Processing of TTF-Cavities at DESY

*T. Ebeling, R. Bandelmann, K. Escherich, N. Krupka, A. Matheisen, B. Petersen, N. Steinhau-Kuehl, F. Zhu (DESY)*

The superconducting (s.c.) 9 cell-cavities of TESLA /TTF design are produced by industry. The preparation by surface treatments like chemical etching (buffered chemical polishing /BCP), Electro-polishing (E.P.), high pressure rinsing (HPR) and the assembly take place inside the TTF cleanroom. At first the cavities are treated without their individual Helium vessel (He-vessel) for the acceptance test. This test is done vertically in cw. mode operation at 2 K. After meeting the specification (Eacc $>$ 25MV/m; Qo $>$ 5 *10 9), the cavities are welded into their He-vessel. Also this is a complex procedure with several steps and up to now standardized for BCP-cavities only. After this welding process the BCP treated cavities get a final chemical etch. This final preparation step can not be applied to electro-polished (E.P.) resonators. Here a HPR rinse is done for preparation of module assembly. Finally eight cavities, each equipped with pick up antennas for higher order mode (HOM) absorption, field probe and the power coupler, are connected. A beam position monitor (BPM) and one s.c. quadrupole complete the TTF module string assembly. The actual cavity preparation process at DESY will be represented in flow diagrams. The difference between the He-vessel-welding-procedure of etched cavities and the first attempt for E.P. cavity tank-welding will be shown. We will summarize cavity preparations and cavity test results of the last year. In several cases correlations between preparation expiration and the cavity performance will be discussed.

### TuP08: Mechanical Design of a 161 MHz, Beta=0.16 Superconducting Quarter Wave Resonator with Steering Correction for RIA

*A. Facco, V. Zviagintsev (INFN-LNL), C.C. Compton, T.L. Grimm, W. Hartung, F. Marti, R.C. York (MSU-NSCL)*

The RIA driver designed at MSU includes 161 MHz, b=0.16 superconducting Quarter Wave Resonators with steering correction. The rf design of the cavity was previously performed at MSU and used in beam dynamics simulations for RIA. The cavity mechanical design and final rf simulations have been performed at LNL, resulting in a double-wall structure with short length along the beam line, compatible with both separate vacuum between beam line and cryostats or unified one. This design can be easily extended to different frequencies, e.g. to obtain the 80 MHz b=0.085 cavity required in RIA, and it could be used also in the high intensity deuteron injector of the SPES project at LNL. The construction of the first prototype has recently started. The cavity mechanical design characteristics and their influence on rf behavior will be presented and discussed.

### TuP09: Design and Construction of a 352 MHz, Beta=0.31 Superconducting Half Wave Resonator for High Intensity Beams

*A. Facco, V. Zviagintsev (INFN-LNL)*

A 352 MHz, b=0.31 superconducting Half Wave resonator was designed at LNL and the prototype is presently under construction. The cavity is aimed for the intermediate energy section of the SPES driver, a wide-b linac for high intensity protons and deuterons;

it could also fit the requirements of superconducting linacs for radioactive beams, like the EURISOL post-accelerator. The resonator is designed with a double wall structure similar to the LNL 80 MHz low-b quarter-wave resonators. Compared to Spoke-type resonators with similar optimum velocity, the SPES HWR aims to be more compact in order to obtain a higher real-estate gradient and a better mechanical stability, at the expenses of a slightly lower shunt impedance. This could make it particularly suitable to pulsed operation. The cavity rf and mechanical design will be presented and discussed, as well as the status of the prototype construction.

**TuP10: Fabrication of Superconducting Cavities for the RF Separated Kaon Beam**

*M. Foley, L. Bellantoni, H. Edwards (FNAL)*

Superconducting cavities for the RF Separated Kaon Beam Project are formed by joining multiple, deep-drawn, niobium half cells via electron beam welding. In the deflection mode the fields are a maximum in the iris, and hence this area is critical. Strict mechanical and electrical tolerances are imposed, especially in the iris region. We present a fabrication process that has been developed to minimize deviations from the nominal design shape and thereby maximize the ease of achieving design frequency and field flatness in the final cavities.

**TuP11: Niobium to Stainless Steel Braze Transition Development**

*J. Fuerst, W. Toter, K. Shepard (ANL)*

We present results of a program to develop and test a reliable cryogenic leak-tight, copper-brazed transition between niobium and stainless steel for use in superconducting niobium cavities. We have chosen to make the integral helium container that houses a niobium cavity of stainless steel rather than titanium both for ease of fabrication and also for low cost. Other techniques for joining niobium to stainless steel such as electron beam welding (EBW) and explosive bonding have not in our experience provided the quality and reliability needed for the intended service. The braze technique described is a further development and simplification of a technique developed several years ago at CERN. Our technique has improved on the CERN method in requiring less machining and a simpler set-up, while producing a very robust, void-free, and leak tight joint. The braze joint withstands mechanical load, repeated LHe cooling cycles, and can tolerate subsequent EBW of niobium within a few cm of the braze joint.

**TuP12: A Database for Superconducting Cavities for the TESLA Test Facility**

*P.D. Gall, A. Goessel, V. Gubarev (DESY)*

The most important data about the superconducting cavities and RF couplers for the TESLA Test Facility TTF are stored in a relational database. The data are mainly due to the visual, mechanical and electrical entrance checks of the cavities, their chemical treatments and the results of their RF measurements at 2 K. Further data concern the testing and conditioning of the RF couplers with and without cavity. Up to now data from more than 100 superconducting 9-cell cavities, about 40 single cell, some 2-, 3-, 5- and 7-cell cavities and about 50 RF couplers have been collected in the database. 30 more 9-cell cavities are expected in the near future. The database is dynamically accessible for everybody via an extensive graphical WEB interface, based on ORACLE products, which enables the users to select and analyse the stored data easily from everywhere.

**TuP13: Continuous Current Oscillation Electropolishing and its Application to Half-cells**

*R.L. Geng, G. Eremeev, A. Crawford, H. Padamsee (Cornell)*

We will describe the process of continuous current oscillation electropolishing and its application to niobium half-cells. First test results on a 1.5 GHz cavity made from two half-cells polished with this method will be reported.

**TuP14: Niobium Quarter-Wave Resonator Development for the Rare Isotope Accelerator**

*W. Hartung, J. Bierwagen, S. Bricker, J. Colthorp, C. Compton, T. Grimm, S. Hitchcock, F. Marti, L. Saxton, R. York (NSCL/MSU), A. Facco, V. Zviagintsev (INFN-LNL)*

The Rare Isotope Accelerator (RIA) is being designed to provide an intense supply of exotic isotopes for nuclear physics research. Superconducting cavities (continuous wave operation) are to be used for the driver linac to accelerate heavy ions to an energy of 400 MeV per nucleon, with a beam power of up to 400 kW. Design studies for a 10th-harmonic driver linac are in progress at NSCL. Three different types of superconducting quarter-wave resonators (QWRs) are envisaged for the first segment of the driver linac. The first QWR type (optimum beta = 0.041, 80.5 MHz) is very similar to existing QWRs in use at LNL. The second (optimum beta = 0.085, 80.5 MHz) and third (optimum beta = 0.16, 161 MHz) types are being designed and prototyped as a collaborative effort between LNL and NSCL. A simplified version of the beta = 0.085 QWR is under construction; a simplified beta = 0.16 QWR has been completed, and is presently being tested. The QWR development effort and first RF testing results will be discussed in this paper. The design and prototyping of a more advanced beta = 0.16 QWR with an integrated helium vessel is also underway, as will be reported in a separate paper for this workshop.

### TuP15: Analysis of SCRF 350 MHz Bulk Nb Cavity for 100 MeV Proton LINAC

*V. Jain, S. Pande, M. Karmarkar (Centre for Advanced Technology)*

Different accelerating schemes are under consideration after RFQ stage for 100 MeV cw Proton Linac Project. 350 MHz reentrant type SCRF cavity is one of the promising options. Structural analysis for same has been conducted. Geometry of 350 MHz cavity has been worked out at operating temperature 4.2 K using SUPERFISH code. From this cold geometry the room temperature dimensions are worked out using ANSYS. The inside shell material is selected as bulk Nb and analysis of various materials for outer shell is discussed here. Nb sheet thickness for inner shell and outer shell is estimated from mechanical stresses and deflection necessary for tuning purpose. The effect of the vacuum load at room temperature and at 4.2 K with and without helium pressure is studied for finalizing stiffener design and for the both the radial and circumferential option. The effect of change in the pressure inside the vessel is also studied for frequency response. Selection of Nb4-3 structure (thickness of inner shell and outer shell is 4 and 3 mm respectively) is done on the basis of this combined analysis.

### TuP16: Multi-Beam Accelerating Structures

*S. Noguchi, E. Kako (KEK)*

Motivated by an application to Energy Recovery LINAC (ERL), some two-beam structures are designed and discussed.

### TuP17: Approach Towards Establishing Cryogenic Test Facility for SCRF Cavities of 100MeV Proton LINAC

*P. Khare, P. Kush, M. Karmarkar (C.A.T.)*

This paper describes our approach for establishing a facility for testing of SCRF cavities (350 MHz) at 4.2K. These cavities, made from bulk Niobium, are proposed for 100 MeV CW Proton Linac project which is being pursued at Centre for Advanced Technology (CAT). This test facility will be used for validating fabrication and processing schemes adopted in manufacturing the cavities. The tests to be performed will include (i) testing the main cavity vessel for leak at 4.2 K and after warm up (ii) Thermal mapping of the cavity inner vessel to investigate cause of quench or any other anomalous signal (iii) effect of helium pressure fluctuation on tuning of the cavity and (iv) full power rf test at 4.2K for Q Vs Ea , Multipacting, Field Emission etc. The test facility will comprise of two vertical cryostats, one for the testing of inner vessel that needs to be immersed in a liquid helium bath. The other cryostat will be used for testing of assembled cavity with its own helium capacity. This cryostat will have a container of helium positioned on top of the cavity. Suitable system for rf powering and pick up antenna will be provided. The cryostat will have appropriate instruments for monitoring helium pressure, vessel vibration, thermal mapping, FE etc. The work on the facility has been launched.

### TuP18: Quality Control at the TTF- Cleanroom Infrastructure for Cavity- processing

*N. Krupka, Th. Ebeling, K. Escherich, A. Matheisen, H. Morales, B. Petersen, D. Reschke, N. Steinhau-Kuehl (DESY), F. Zhu (Phd Student from Peking University)*

At DESY Hamburg the Tesla Test Facility (TTF) was set up in the year 1992. One major component of the TTF infrastructure is the cleanroom (Ref.: 1) where the preparation of about 70 superconducting (s.c.) TESLA/TTF-cavities took place. A strong variation of results in the cavity performances in respect to field emission onset level was observed. To minimize the spread and to dedicate the origin of field emitters a quality control system is set up. The TTF-cleanroom is divided in 3 classes of air quality (class 10, class 100 and class 10 000) specified by Federal Standard 209E, ISO 14 644 and VDI 2083. The preparation of cavities by ultrasound cleaning, chemical surface treatment, pure water rinse is done in class 10 000 environment while the high pressure rinsing station and assembly areas are placed in the class 10 and 100 laminar air flow region. For pumping and drying of cavities three oil free vacuum-pump stations are connected to the class 10 assembly areas. Three air particle counters are located in class 10 and 100 area. A liquid particle counter, located in the gray room, and a automatic scanning microscope for optical filter analysis in the class 10 000 area, are installed for quality control. This is a report about the quality control established in the preparation sequences. Results of routine check of cleanroom air and ultra pure water as well as qualification of components after system break down will be presented. In addition the analysis of datasets of contamination control measurements and cavity performance will be shown. [Ref.: 1 Proceedings of the fourth international conference and exhibition: World Congress on superconductivity NASA Conference Publication 3290 Page 84 ff]

### TuP19: Electropolishing of Niobium Mono-cell Cavities at Henkel Electropolishing Technology Ltd. (Germany)

*L. Lilje (DESY), B. Henkel (Henkel Electropolishing Technology Ltd.), D. Reschke, J. Hao, K. Twarowski, A. Matheisen (DESY)*

A system for electropolishing niobium 1.3 GHz cavities has been built by Henkel Electropolishing Technology Ltd. (Germany). The system allows electropolishing of mono-cell cavities. The process includes rinsing with hot ultrapure water and diluted nitric acid after the electropolishing process to reduce the risk of a surface contamination by salt residues from the acid mixture. Final cleaning procedures take place in a classified clean room. Two mono-cell cavities have been electropolished showing gradients exceeding 30 MV/m. A modification to electropolish multi-cell cavities is underway.

### TuP20: Accomplishment of Re-plating ANU LINAC

*N.R. Lobanov, D.C. Weisser (RSPhSE ANU)*

The performance of the twelve split-loop resonators (SLRs) of the ANU LINAC has been substantially improved by re-plated with 96%Pb-4%Sn. The re-plating with Pb-Sn Schlotter MSA solution was initially plagued by the appearance of dendrites on the surface plated. Reverse-pulse-plating at modest currents eliminated the dendrites. In addition, a new technique has been demonstrated of mechanically polishing the unsatisfactory PbSn surface and then re-plating, rather than laboriously chemically stripping the old PbSn and hand polishing the Cu substrate. It is enormously easier, faster and does not put at risk the thin cosmetic electron-beam-welds or the solder-repaired welds. An average acceleration field of 3.5 MV/m has been achieved in off-line tests. Twelve SLRs are currently installed and operated in the ANU LINAC.

### TuP21: Development Superconducting RF Resonators for ANU Heavy Ion Accelerator

*N.R. Lobanov, D.C. Weisser (RSPhSE ANU), E.N. Zaplatin (FZJ Juelich)*

An upgrade of the LINAC at the ANU will rely upon the proven success of PbSn plating split-loop-resonators (SLRs), which perform at accelerating fields of 3.5 MV/m. These resonators will be combined with 21, two and three-stub resonators, of novel and efficient design. The multi-stub resonators have demonstrated adequate frequency splitting between the accelerating from other modes and feature a demountable stub assembly joint with acceptably low currents. Superconducting RF activity in the last two years has been targeted on: 1. improving the performance of the 12 SLRs by re-plating with PbSn and 2. the optimization of the two-stub resonator (DVOIKA) using Mafia/MWS software in collaboration with FZJ, Juelich. A pre-prototype two-stub resonator was manufactured and is ready for cold test. The development work and current status for DVOIKA cavities is discussed.

### TuP22: HFSS Computation of Frequency Sensitivity of ISAC-II Medium Beta Superconducting Cavities

*A.K Mitra, R.E Laxdal, R Poirier, K. Fong (TRIUMF)*

Medium beta superconducting cavities are part of the ISAC-II project to upgrade the final energy of the ISAC facility at TRIUMF. Prior to the fabrication of these bulk Niobium cavities, HFSS simulations are used to estimate the physical dimensions of the 106.08 MHz cavities and to obtain the sensitivity of the frequency variation to various physical dimensions. The same software is also used to calculate the rf parameters of the cavities. The sensitivity of the tuner plates is also computed and verified with measurements. Rf measurements of the production cavities and the simulation results are reported.

**TuP23: Multipacting in the Crab Cavity**

*Y. Morita, K. Hara, K. Hosoyama, A. Kabe, Y. Kojima, H. Nakai (KEK), K. Nakanishi, M. Rahman (GUAS)*

For the Research and Development of the crab cavity for KEKB, we have fabricated two prototype cavities. The crab cavity is a beam-deflecting cavity excited with the 508 MHz, TM110-like mode. To extract unwanted parasitic modes, the cavity has a squashed cell shape and a coaxial coupler along the beam pipe. The prototype cavities were tested in a vertical cryostat with/without the coaxial coupler. We observed multipacting at the first RF excitation. To study this event in detail, we measured temperatures of the coupler and cavity during RF tests. Temperature measurement showed that multipacting occurred at the tip of coaxial coupler at low RF fields, and then along the coaxial line. These events were processed in an hour. We observed another type of temperature rise around the iris. Temperature rise began at low fields, continued to rise up to a surface peak field of 18 MV/m, and then, disappeared above 20 MV/m. The excitation mode of the crab cavity has a maximum magnetic field and zero electric field on the same iris position. Temperature rise near this region suggests the multipacting events. A model simulation shows a stable two-point multipacting can exist at this position. We will present temperature measurement results and discuss multipacting near the iris.

**TuP24: Overview of the Cornell ERL Injector Cryomodule**

*H. Padamsee, B. Barstow, I. Bazarov, S. Belomestnykh, R.L. Geng, M. Liepe, V. Shemelin, C. Sinclair, E. Smith, K. Smolenski, M. Tigner, V. Veserevich (Cornell University)*

The ERL injector will accelerate bunches from the electron source from 0.5 MeV to 5 MeV with minimal emittance dilution. There will be one cryomodule with five 1300 MHz 2-cell cavities, each providing one MV of acceleration, corresponding to an accelerating field of about 4.3 MV/m in CW operation. Besides standard features, each cavity has two input couplers, symmetrically placed on the beam pipe to cancel kicks due to coupler fields. For a 100 mA maximum injected beam current, each coupler must deliver 50 kW of beam power leading to a Qext of 4.6 x10**4 for matched beam loading conditions. Antenna- and loop-based HOM couplers can also disturb beam emittance through kicks. We plan to avoid the use of such couplers. Following the strategy for B-factory SRF cavities, the beam pipe aperture has been enlarged on one side to propagate all higher order modes out to symmetric ferrite beam pipe loads. These are positioned outside the helium vessel and cooled to liquid nitrogen temperature. Ferrite properties at 77 K have been measured and the corresponding damping evaluated. To explore the full capabilities of the injector, energy gains up to 3 MV per cavity will be considered at lower beam currents. For this flexibility, the input coupling needs to be adjustable by a factor of 9.

**TuP25: Application of Flux Gate Magnetometry to Electropolishing**

*C. Bonavolonta (Naples University), F. Laviano (Torin Politechnical), V. Palmieri (INFN-LNL), M. Valentino (INFM-Na)*

Flux gate magnetometry is a well-established technology for non destructive diagnostics applied to the monitoring of magnetic fields up to nanotesla. Up to now its application to chemical and electrochemical processes remain still unexplored. The authors have applied such diagnostics to the electropolishing, evidencing a plethora of experimental evidences that can be useful both for a better understanding and for better designing electropolishing cathodic configurations.

**TuP26: Advancements on Spinning of Seamless Multicell Cavities**

*V. Palmieri (INFN-LNL)*

Spinning is forming technique as simple as powerful. Seamless multicell cavities with uniform thickness can be obtained starting from seamless tubes cold-formed from Niobium or Copper blanks. In this paper we will report technical considerations in perspective of a eventual mass production.

**TuP27: Pipe Cooling of Superconducting Cavities**

*R.F. Parodi, R. Ballantini, A. Chinacarini, G. Gemme (INFN-Genoa)*

Cryostat and Cryogenic system account for a relevant amount of the total SRF accelerator Budget. The standard bath cooling, already in use singe the beginning of the use of SRF cavities have some drawbacks mainly due to the large inventory of Liquid helium to be handled and stored. Pipe cooling, if proven successful, will greatly reduce the Cryogenic design of an SRF accelerator, and possibly, substantially reduce the construction and operation costs. We will present a specially developed post processor for our OSCAR code allowing for the evaluation of the maximum achievable fields in Pipe Cooled SRF Cavities. Pipe cooling will be invaluable for all the application, as Gravitational Wave detectors, needing a minimum interaction between the cavity mechanical modes and the A typical application for pipe-cooled cavities will be shown, and the limits of the cooling method will be discussed. Based on the results of the numerical optimization, an experimental program is started to check the validity and the limits of the Pipe cooling system for a 3 GHz cavity.

**TuP28: Superconducting Cavity Production and Preparation at ACCEL Instruments GmbH**

*M. Pekeler, S. Bauer, M. Tradt, J. Schwellenbach, P. vom Stein, H. Vogel (ACCEL)*

The series production of 35 medium beta and 74 high beta cavities for the Spallation Neutron Source Linac allowed us to improve our cavity manufacturing and processing facilities. We are now able to produce one SNS cavity per week including chemical treatment and field flatness tuning. The SNS project occupies our two electron beam welding machines to only about 70 % in a one shift operation ensuring completion of the cavity production within the contractual foreseen three years period (140 weeks). In addition two TESLA type cavities for BESSY were produced within 6 months after provision of niobium. The preparation including tuning to field flatness, closed loop chemistry, high pressure rinsing and clean room assembly for vertical and horizontal tests is within our scope and is foreseen for the end of this year. A new high pressure rinsing system was developed and is currently built with the goal to achieve gradients in the 20 MV/m regime. A superconducting CH-mode cavity for acceleration of ions for Universitaet Frankfurt and two prototype half wave resonators (one for Forschungszentrum Juelich, one for SOREQ) for proton/deuteron acceleration are under production. Also those three cavities will receive chemical treatment, high pressure rinsing and clean room assembly with vertical test equipment at our facilities.

**TuP29: Status of the Development of a Superconducting 352 MHz CH-Prototype Cavity**

*H. Podlech, H. Liebermann, U. Ratzinger, H. Deitinghoff, H. Klein, A. Sauer (IAP)*

Normalconducting H-mode cavities have been developed and operated sucessfully during the last decades for a large variety of applications in the field of ion acceleration. The superconducting CH-structure which is currently under development at the IAP/Frankfurt is a new multi-gap drift tube structure operated in the TE21 mode. The use of the KONUS beam dynamics allows long lens free sections and in consequence multi gap structures at low beta values. A 352 MHz CH-prototype cavity optimized for a beta of 0.1 is under fabrication. We present the design concept of this 19-cell cavity as well as the status of the production and possible applications.

**TuP30: Completion of ALPI Medium Beta Section Upgrading**

*A.M. Porcellato, S.Y. Stark, V. Palmieri, L. Bertazzo, A. Capuzzo, F. Stivanello, A. Beltramin, T. Contran, M. De Lazzari (INFN LNL)*

The upgrading of ALPI has just been completed. All the 44 accelerating medium beta cavities had their Pb coating replaced by sputtered Nb. The refurbishing of the resonators allowed to increase their average accelerating field from 2.6 to more than 4.3 MV/m, at 7W dissipated power, in spite of geometry and copper quality problems in the existing substrates. Some resonators can reach and operate at more than 6 MV/m. The renewed cavities are driven by the same amplifiers and control systems of the previous Pb/Cu resonators and maintain the same reliability even when set at much higher accelerating field. The low sensitivity of their resonant frequency to He bath pressure fluctuations (up to more than 300 mbar) allows their operation without necessity of any continuous tuning system. The upgrading upgrading of resonators, that was realized at a negligible cost and was combined to a necessary programme of cryostat maintenance, did not interfere with ALPI beam time schedule.

**TuP31: SNS Medium Beta Cryomodule Performance**

*M. Drury, I. Campisi, E. Daly, K. Davis, J. Delayen, Ch. Grenoble, J. Hogan, L. King, T. Powers, J. Preble, M. Stirbet, H. Wang, M. Wiseman (JLAB)*

Thomas Jefferson National Accelerating Facility (Jefferson Lab) is producing 24 Superconducting Radio Frequency (SRF) cryomodules for the Spallation Neutron Source (SNS) cold linac. This includes one medium-beta (0.61) prototype, 11 medium-beta production, and 12 high-beta (0.81) production cryomodules. Each of the medium-beta cryomodules is scheduled to undergo complete operational performance testing at Jefferson Laboratory before shipment to ORNL. To date, the prototype and three production models of the medium beta cryomodule have been tested. The performance results of the tested cryomodules will be discussed.

**TuP32: Process Control and Documentation for SNS Cryomodule Production**

*J. Preble, V. Bookwalter, M. Drury, J. Hogan, B. Madre, J. Ozelis (JLab)*

Jefferson Lab has completed production of 6 of the planned 12 SNS medium Beta cryomodules. A web-based system that integrates commercial database, data analysis, document archiving and retrieval, and user interface software into a coherent knowledge management product, called Pansophy, has been developed in part to provide control and documentation of production processes. SNS cryomodule production has provided the first opportunity for large-scale implementation of this system, as an integral part of the projects QA program. The experience of users, development, and support staff of Pansophy during SNS production to date will be discussed, along with examples of the systems utility in controlling and analyzing production processes and data. Finally, further optimization strategies will be presented.

**TuP33: SNS Cryomodule Production Progress and Key Lessons Learned**

*J. Hogan, E. Daly, J. Fischer, J. Preble, T. Whitlatch, M. Wiseman (JLab)*

Jefferson Lab has been commissioned to design and manufacture one prototype, eleven-.61 Beta and twelve-.81 Beta cryomodules for the Spallation Neutron Source project. The production process is up and running with half of the .61 Beta cryomodules complete to date. This paper will present an overview of the beginning of production, with an emphasis on key lessons learned, that have been used to refine cryomodule production.

**TuP34: Approach Towards Development of 350 MHz Bulk Nb SCRF Cavities for 100MeV LINAC.**

*A. Puntambekar, M. Karmarkar (CAT, Indore)*

In this paper we present the approach for the development of bulk niobium reentrant type 350 MHz SC RF cavity. The work is a part of development of a 100 MeV CW Proton LINAC being pursued by Centre for Advanced Technology as part of Indian ADS programme. 350 MHz Cavity for beta 0.1 has been designed using SUPERFISH and structural analysis has been done by FE analysis. It is proposed to adopt the bulk niobium approach for double wall cavity. The cavity inner and outer vessels will be produced by deep drawing techniques and finally electron beam welded in stages. The inner vessel will be made from high RRR Nb (more than 200) while the outer vessel will be made using low RRR Nb (approx.30, reactor grade). The pipe ports reaching cavity may need pullouts to have smooth surface and joints. The transition metal joints required for the demountable flanges, which are to be welded to Nb ports will be a made using explosion bonded Nb to SS sheets. Fabrication of cavity is an interactive process between press shop, machine shop, EB welding, chemical cleaning and high pressure rinsing station. Various stages worked out for the complete cycle are, Deep drawing, precision machining at weld joint, EB welding with intermediate (BCP) cleaning, high pressure rinsing, high temperature vacuum annealing and leak check and final assembly in a clean room followed by assembly in cryostat and RF testing. The special infrastructure development for various application like electrochemical cleaning (BCP), high temperature vacuum annealing, electron beam welding, and high pressure rinsing has also been initiated.

**TuP35: Production and Performance of the First CEBAF Upgrade Cryomodule Prototype**

*A.M. Valente, J. Delayen, M. Drury, C. Hovater, J. Mammmosser, L. Phillips, T. Powers, J. Preble, C. Reece, R. Rimmer, C. Thomas-Madec, H. Wang (JLab)*

The first CEBAF Upgrade cryomodule intermediate prototype has been produced and installed in the CEBAF accelerator. It contains eight 7-cell cavities with the original CEBAF cell shape and was designed to deliver 70 MV. Several significant design modifications are demonstrated in this cryomodule. This paper describes the production procedures, the performance characteristics of these cavities in vertical tests, results of tests in the new cryomodule test facility (CMTF) as well as the commissioning in the CEBAF tunnel. The cryomodule showed gradient capabilities well beyond the design specifications in the CMTF. After its installation in the CEBAF accelerator, its performance suffers from some cryogenic limitations, which are discussed in this paper along with improvements proposed for future cryomodules.

### TuP36: Strongly HOM-Damped Multi-cell RF Cavities for High-current Applications

*R. Rimmer, H. Wang, G. Wu (JLab)*

Strongly HOM-damped single-cell cavities have been used for some time in storage rings where modest voltage and high beam current are required. Future high-current applications such as electron cooling or high-powered free electron lasers based on energy-recovered linacs would benefit from similarly damped multi-cell structures. We explore the possibilities for applying strong HOM damping techniques to multi-cell structures. We use modern simulation techniques to compare several commonly used methods such as beam-pipe damping, coaxial and waveguide dampers, and the influence of number of cells and cell shape on the resulting impedance. (Superstructures consisting of more than one multi-cell cavity are not covered here but are discussed elsewhere at this meeting). We also consider the possibilities for even stronger damping, if required, and discuss the implications for cavity construction and performance that might result from these changes.

### TuP37: UHV Arc Deposition for RF Superconducting Cavity

*R. Russo, L. Catani, A. Cianchi, S. Tazzari (INFN-Roma2), F. Tazzioli (LNF), J. Langner, M. Sadowski (IPJ)*

Copper RF cavities coated with thin niobium films are an interesting alternative to bulk-Nb ones, since Cu is much cheaper than Nb, has higher thermal conductivity and superior mechanical stability. Coating by the magnetron sputtering method was very successfully implemented at CERN to produce 350 Mhz, 7 MV/m accelerating cavities for LEP. Unfortunately, the degradation of the sputtered cavities quality factor with increasing cavity voltage limits their maximum useful gradient to approximately 15 MV/m. The reason for the degradation being still not clear there are reasons to suspect that it may be connected to features of the sputtering process. An alternative powerful and versatile technique is vacuum arc coating. Its main advantages over standard sputtering are the ionized state of the evaporated material, the fact that no gas to sustain the discharge is required, a much higher energy of atoms reaching the substrate surface and the capability to achieve very high deposition rates. We describe here the apparata to arc deposit Nb films in UHV and in different ( planar, filtered and cylindrical) geometries. Because for igniting the arc a small plasma burst of a sufficient density to form a high-conductivity path between cathode and anode has to be produced, a Nd-YAG pulsed laser focused on the cathode surface is used that provides very reliable, totally clean triggering. The different systems are presented and discussed in particular in view of the possibility of the RF cavity coating application.

### TuP38: UHV Arc for Superconducting Niobium Film Deposition

*R. Russo, L. Catani, A. Cianchi (INFN-Roma2), R. Polini (Uniroma2), S. Tazzari (INFN-Roma2), F. Tazzioli (LNF), J. Langner, M. Sadowski (IPJ)*

Copper RF cavities coated with thin niobium films are an interesting alternative to bulk-Nb ones, since Cu is much cheaper than Nb, has higher thermal conductivity and superior mechanical stability. Coating by the magnetron sputtering method was very successfully implemented at CERN to produce 350 MHz, 7 MV/m accelerating cavities for LEP. Unfortunately, the degradation of the sputtered cavities quality factor with increasing cavity voltage limits their maximum useful gradient to approximately 15 MV/m. The reason for the degradation being still not clear there are reasons to suspect that it may be connected to features of the sputtering process. An alternative powerful and versatile technique is vacuum arc coating. Its main advantages over standard sputtering are the ionized state of the evaporated material, the fact that no gas to sustain the discharge is required, a much higher energy of atoms reaching the substrate surface, the capability to achieve very high deposition rates and, when the arc is triggered with a laser, total cleanliness. We have shown that the technique produces bulk-like films suitable for superconducting applications. The main disadvantage is the production of macroparticles (or microdroplets) that could increase the film roughness and induce field emission. We present our recent results on the characterization of niobium film produced by UHV cathodic arc in different conditions and on the microdroplet problem.

**TuP39: Simple Aluminum Sealing Against Superfluid Helium**

*K. Saito (KEK), H. Tatsumoto (JAERI), H. Inoue (KEK)*
Indium sealing is well established for superfluid helium in superconducting application but the sticky material brings an indium contamination during cavity disassembly. DESY has already successfully changed indium to other aluminium alloy material. We are also looking for other simple, cheap and reliable sealing method instead of indium. We are investing fine pure aluminium ring sealing, which is a square cross-section 1 mm x 1 mm. We tested it for several material combinations between flange and bolt and get good results. In this paper the results will be reported.

**TuP40: Hot Roll Bonding Method for Nb/Cu Clad Seamless SC Cavity**

*I. Ito (NSC), K Saito (KEK), W Singer (DESY)*
We have successfully developed Cu/Nb/Cu sandwiched seamless pipes for superconducting RF L-band single cell cavities using deep-drawing and spinning of a Cu/Nb/Cu clad sheet, which was fabricated by hot rolling technique. DESY formed single-cells with TESLA shape from the sandwiched pipes using their hydro-forming technology. KEK electron-beam welded niobium bulk beam tubes on the cells and made surface treatments included barrel polishing, annealing and electropolishing. As a result of vertical cold test, an excellent performance: Eacc, max =39.0 MV/m, Q0, max= 1.67E10 at 1.5 K was then achieved in the first test. In this paper, the hot rolling bonded clad tube fabrication method and the cold test results will be presented.

**TuP41: Half-cell Die Design for Right Cavity Geometry in High Intensity SC Proton Linac**

*K. Saito, S. Noguchi (KEK), T. Ohota (MHI)*
Today, application of sc RF cavities to proton LINAC is conducted very intensively like SNS project in USA. KEK is also making a collaborative work for the future ADS at 972 MHz. In proton sc LINAC, phase control is much severe due to the heavy proton mass. As a result, cavity fabrication tolerance becomes severe comparing with electron sc RF applications. To date, deep drawing forms half cups of sc cavity. This severe fabrication tolerance affects the design of dies. Generally cell cups deform due to the spring-back after detaching it from the die. We designed a die considering about the spring-back effect by mechanical structure analysis and formed half cups using the die. As a result, we made a die successfully with a forming error less than 0.3 mm with half cups. In this paper, the results are presented.

**TuP42: Development of Pre-tuning System for 972 MHz 9-Cell Superconducting Cavities**

*T. Shishido, E. Kako, S. Noguchi (KEK)*
The pre-tuning system for 972 MHz 9-cell SC cavities in the high intensity proton linac was developed. The initial pre-tuning was carried out with the Nb and Cu 9-cell cavities. The details of this system and the performance will be reported.

**TuP43: Development of the 3.9 GHz, 3rd Harmonic Cavity at FNAL**

*N. Solyak, E. Borissov, H. Edwards, M. Foley, T. Khabiboulline, D. Mitchell (FNAL)*
Peak current and emittance of the high brightness photoinjector are limited by non-linear energy distribution in the bunch. Adding a weighted amount of third harmonic accelerating voltage allows compensate this nonlinearity. For FNAL-NICADD photoinjector it can result in significant improvement of its performance reducing emittance and increasing peak current. These benefits have triggered designing and prototyping of a superconducting 3.9 GHz (3rd harmonic to 1.3 GHz used as a main accelerating frequency) cavity at FNAL. At first stage it was built two models: 9-cell copper cavity and 3-cell niobium cavity. In this paper the status of the cavity design and results of RF measurements of the two models are presented.

**TuP44: Mechanical Design and Engineering of the 3.9 GHz, 3rd Harmonic SRF System at Fermilab**

*D. Mitchell, M. Foley, T. Khabiboulline, N. Solyak (FNAL)*
The mechanical development of the 3.9 GHz, 3rd Harmonic SRF System is summarized in this poster presentation to include: the development of a full scale copper prototype cavity structure; the design of the niobium 3 cell and niobium 9 cell structures; the design of the helium vessel and cryostat; the HOM coupler design; and a preliminary look at the main coupler design. The manufacturing processes for forming, rolling, and e-beam welding the HOM coupler, cavity cells, and end

tubes are also described. Due to the exotic materials and manufacturing processes used in this type of device, a cost estimate for the material and fabrication is provided. As outlined in this presentation, the third harmonic design is being managed via a web-based data management approach. Throughout the entire design and engineering process, our data is being organized to keep us on track and to share our ideas with our collaborators.

### TuP45: COSY SC HWR Investigations

*E. Zaplatin, R. Eichhorn, F.M. Esser, B. Laatsch, G. Schug, R. Stassen, R. Toelle (FZJ)*

This paper contents the results of COSY SC Linac cavity prototype (160 MHz, beta=0.11) simulations. The main purpose of the work was to get as much as possible information about this particular cavity and in some extend to investigate this type cavity general parameters for broader application. The main effort of investigations has been devoted to provide structure coupled analysis with ANSYS. This allows using the same cavity numerical model with the same mesh for electrodynamics and structural analysis. The cavity frequency shift caused by structure cool-down, LHe pressure and tuning deformations using this method are evaluated. The specific questions of cavity manufacturing are discussed.

### TuP46: Electro Polishing at DESY

*N. Steinhau-Kuehl, Th. Ebeling, K. Escherich, L. Lilje, A. Matheisen, H. Morales, B. Petersen (DESY)*

At DESY a facility for electro polishing (E.P.) of the superconducting (s.c.) TESLA/TTF cavities is build. The E.P. infrastructure is capable to handle single cell structures, the standard TTF 9 cell cavities as well as the proposed double 9 cell superstructure cavities. The goal of this facility is to exceed the acceleration voltage of s.c. cavities reproducible to the region of up to 40 MV/m. The EP process is computerized and there are 25 sensors monitored to control the parameter set. The electro polishing facility is now operational since April 2003. We report on measurements and experiences gained during the first electro polishing of single- and nine cell cavities. We present specific data like heat production during the process, variation of current density and acid temperature as well as current oscillations correlated to process temperature. The results of the RF measurements of the first cavities treated in the new EP facility and the process parameters of that treatments will be shown. Another important point for reproducible result is the quality control of the electro polishing process. We will present a proposal of quality control steps to be implanted in the E.P. procedure.

### TuP47: BCP Processing Facility

*Y. Tereshkin, C. Boffo, G. Davis, H. Edwards, A. Rowe (FNAL)*

FNAL is engaged in fabrication of two types of superconducting cavities: 3.9 GHz deflection mode cavities for RF separator of the CKM experiment and 3.9 GHz accelerating mode cavities for FNAL-NICADD photoinjector upgrade. To reach acceptable cavity performance, thorough surface treatment is required for both of the cavities at several stages of fabrication. Buffered chemical polishing has been chosen as a baseline treatment process. During processing, cavity is contained in a process tank that is filled with acid mix using gravity feed. Several stages of the etching process include the system check-up, filling, etching, and rinsing. This paper describes details of the BCP process implementation at ANL-FNAL Surface Treatment Facility, which is to be built at ANL.

### TuP48: Synchrotron Soleil Superconducting RF Status

*C. Thomas-Madec (SOLEIL), P. Bosland (CEA/DSM/DAPNIA/SACM), J. Jacob (ESRF), R. Losito, E. Chiaveri (CERN), S. Chel, Ph. Bredy, G. Devanz, V. Hennion (CEA/DSM/DAPNIA/SACM), D. Boilot (ESRF), J.-M. Filhol, M.-P. Level, P. Marchand, J. Polian, T. Ruan, F. Ribeiro (SOLEIL), R. Lopes (LURE - France), K. Tavakoli (SOLEIL)*

The RF system of the Synchrotron SOLEIL light source involves superconducting cavities and solid state amplifiers. Two cryomodules are needed to provide the maximum power of 650 kW, required with the full beam current of 500 mA, at the nominal energy of 2.75 GeV and all the insertion devices. A prototype cryomodule, housing two 352 MHz superconducting single-cell cavity with strong damping of the HOM, has been built and successfully tested in the ESRF storage ring. Even though the achieved performance does meet the SOLEIL requirement for the 1st year of operation, the cryomodule prototype will be refurbished (insertion of a thermal copper shield cooled with liquid nitrogen, improvement of the HOM dipolar couplers, modification and lengthening of the fundamental power coupler antenna to achieve a Qext of 1105). A second cryomodule will be built and installed about one year later. Each of the four cavities will be powered with a 200 kW solid state amplifier consisting in a combination of 320 W elementary modules. The amplifier modules, based on a technology developed in house (with integrated circulator and individual power supply), will be fabricated in the industry. A 40 kW solid state amplifier (146 modules) for the booster is being assembled and should be tested on a dummy load, before the end of 2003.

### TuP49: The Fabrication and Experimental Investigations of Superconducting Photoinjector at Peking University

*Sh. Quan, Y. Ding, R. Xiang, L. Lin, B. Zhang, X. Lu, L. Wang, S. Huang, K. Zhao (PKU)*

An important application of superconduting RF technology at Peking University is the development of the SC photoinjector, which is built to provide electron source for future free electron laser. This is the first photocathode electron gun to connect Pierce DC gun with 1.3 GHz superconducting cavity, which has been installed in Peking University. The injector consists of a Pierce gun and 1+1/2 superconducting cavitiy. In this paper the fabrication of the Nb cavity is introduced, and the testing results of the injector are summarized.

### TuP50: A Cleaning Facility to Prepare Particle Free UHV-components

*K. Zapfe, U. Hahn, M. Hesse, H. Remde (DESY)*

A new cleaning facility has been installed at DESY/Hamburg to prepare UHV components both hydrocarbon and particle free. Both requirements are important for accelerators using superconducting accelerating structures of high gradients as well as for synchrotron radiation beamlines connected to an accelerator using optical components like mirrors for the photon beam transport. The cleaning facility is located in a clean room which fulfills class 10.000 and partly class 100 specification. Following standard UHV-cleaning the final cleaning process consists of a fine degreasing of the components in an ultrasonic bath and rinsing with ultra pure water. Finally the components are dried using up to 110 C hot filtered air or nitrogen (according to clean room class 100 requirements). Vacuum chambers of up to 4.5 m length can be handled. Small components are cleaned using a dishwasher, which is loaded from outside the clean room. A small assembly area equipped with an oil free pump station with leak detector and residual gas analyzer completes the facility.

### TuP51: High Field Multipacting of 1.3 GHz Tesla Cavity

*F. Zhu (DESY/PKU,China), D. Proch (DESY), J.K. Hao (DESY/PKU), D. Reschke (DESY)*

Recently multipacting (MP) recalculation of Tesla cavity was done at DESY. In addition to the normal multipacting which occurs at an accelerating gradient of around 20 MV/m for the single-cell Tesla cavity, another type of multipacting (called high field multipacting) whose electron trajectory is far from the equator is also seen and it occurs at a gradient around 30 MV/m to 35 MV/m which is accord with the experiment. This type of multipacting usually occurs in low-beta cavities, but the latest calculation shows it could also occur in Tesla cavities.

### TuP52: Measurements on Particle Contamination During Cavity Assemblies

*F. Zhu (DESY/PKU), R. Bandelmann, Th. Ebeling, N. Krupka, A. Matheisen, B. Petersen, D. Reschke (DESY)*

At the DESY infrastructure a total of eight cryomodules have been assembled up to now, In each module a degradation of some cavities was observed in respect to their previous test results in vertical and horizontal test. Most of the degradations are caused by field emission. As we know, particle contamination on the surface of a superconductor can induce field emission and limit the accelerating gradient. Therefore, a clean method to assemble cavities is very important for a module. To understand the origin of particulates and to improve the assembly method a test set up is built. Two air particle counters are installed, one inside the cavity and one outside to monitor the total amount of particulates. We report on measurements of different orientations of the resonator during assembly as well as on various sequences of assembly. In addition measurements with clean gas overlay inside the cavities will also be reported.

### TuP53: Cold Tests of the RIA Two-Cell Spoke Cavity

*M.P. Kelly, K.W. Shepard, J.D. Fuerst, M. Kedzie (ANL)*

This paper reports recent cold tests of a two-cell 345 MHz spoke-loaded superconducting cavity built and tested for the U.S. RIA project driver linac. This cavity establishes a new performance record for lambda/2 structures. Rf surfaces were prepared using electropolish, high-pressure water rinsing and clean assembly techniques. At a realistic operating field of EACC=7 MV/m (EPEAK=24 MV/m) the cavity has a residual surface resistance of RRES=12 nOhms with minimal Q-slope even in 4 K operation. In addition the cavity operates field emission free up to EACC=12 MV/m (EPEAK=41 MV/m). With a 3 cm aperture the cavity provides 3 MV of accelerating potential with 15 Watts of input power and useful acceleration over the velocity range 0.3c $<$ v $<$ 0.6c while operating at 4 K. A fully integrated stainless-steel housing with niobium-to-stainless steel braze transitions has been demonstrated and is suitable for production cavities.

**TuP54: Process Control and Web based Software Set-up for the DESY Electro Polishing Infrastructure**

*H. Morales, K. Escherich, L. Lilje, A. Matheisen, B. Petersen, N. Steinhau-Kuehl (DESY)*

At DESY an Electro Polishing (EP) infrastructure for single- cell, nine-cell and the proposed double 9-cell superstructure of TESLA/TTF design was set up in 2002. Baseline for the lay out of the EP facility is a computerized system to control process parameters, process steering and safety options. Twenty five sensors are installed to maintain high reproducibility of the EP process as well as a high safety level for operation. The supervision and the Human Machine Interface (HMI) of the process are done by a Simatic PLC (Programmable Logic Controller) system using a customized version of the standard WinCC software. More than 100 process data and events are archived in the form of process values, alarms and user archives. Process messages and local events can be due to an alarm message frame directly from the automation system or to analog alarms in the case of out-limit conditions. An implemented web server supports monitoring and optionally full operation across the internet. We will present the network implementation solution applied to the EP process control, the alarm level handling and system reaction chart as well as the extended monitoring and operation options realized in the EP operation and control.

**TuP55: Development of SRF Spoke Cavities for Low and Intermediate Energy Ion Linacs**

*G. Olry, S. Blivet, S. Bousson, F. Chatelet, T. Junquera, J. Lesrel, C. Mielot, A.C. Mueller, H. Saugnac, P. Szott (IPNO)*

Spoke cavities have been studied for 3 years at IPN Orsay. Beam dynamics studies dedicated to the EURISOL and XADS European projects have pointed out that this kind of cavity is particularly suited to be used from typically 20 MeV up to 100 or 150 MeV (for proton linacs). The fabrication of the first European spoke cavity prototype (beta 0.35, 352 MHz, 2 gaps) was made by the French company Cerca and has been achieved in July 2002. A series of mechanical and RF tests at warm and cold temperature was performed this year. These tests have demonstrated, on the one hand, the good feasibility, stiffness and tunability of the spoke cavity and, on the other hand, its excellent RF performances with a maximum accelerating field of 12.5 MV/m reached at 4K.

**TuP56: Development of Centrifugal Barrel Polishing and Single - Point Burnishing Methods for Treatment of Superconducting Nb - Cavities**

*G. Issarovitch, D. Proch, X. Singer, D. Reschke, W. Singer (DESY)*

The technological process and a machine for centrifugal barrel polishing (CBP) of the RF surface of single cell, two- and three cell cavities was developed. Influence of technological parameters on the removal rate and surface quality is investigated. Maximal removal rate of Nb layer is $>$ 25 mum/h. The highest accelerating gradient achieved on single cell cavities after CBP, electropolishing and baking was Eacc = 36 - 38 MV/m with a quality factor up to Q = 2.1*1E10. The single - point burnishing process of the niobium surface by freely rotating ball is investigated. Influence of the rotating speed, radial displacement of the ball, pressing force and lubrication medium on the quality of burnished surface and possibility to get a work hardened surface layer is explored on a flat niobium samples. Burnishing experiments on the cavity cell curvature were done. The roughness of the burnished surface is = 0.05...0.08 um, Rz = 0.2...0.3 um, Rmax = 0.2...0.3 um. The depth of the work hardened layer is 2...10 um.

# Wednesday, 10th September 2003

## Oral Presentations

### WeO02: Operating Experience with Low-beta Accelerators

*G. Zinkann (ANL)*
Currently there are nine superconducting heavy-ion linacs in the world, some in operation and some under construction. Although the programs at each facility differ, they all have a common concern in operating superconducting low-beta cavities. This paper discusses the operational experiences and the construction status of these facilities.

### WeO03: Status of the TTF FEL

*S. Schreiber (DESY)*
The free electron laser at the TESLA Test Facility at DESY (TTF-FEL) is now being extended to lase with shorter wavelengths from the VUV to the soft X-ray regime, serving a broad spectrum of users. Compared to the first phase of the TTF-FEL, additional superconducting accelerating modules of the TESLA type have been installed recently. In their final stage, they will boost the electron beam energy up to 1 GeV, permitting lasing at a wavelength of 6 nm. For this, the undulator system is being extended to a length of almost 30 m. Further upgrades for instance in the injector will enhance the beam quality required for short wavelengths. A description and the status of the project is given.

### WeO05: Report from the LANL Spoke Cavity Workshop in October 2002

*F. Krawczyk (LANL)*
In the last few years spoke resonators became serious candidates as accelerating structures for low velocity proton and ion beams. Starting from the early work by Jean Delayen and Ken Shepard and their colleagues various designs at different frequencies and betas have been demonstrated in low power tests. With the consideration of these resonators in recent linac designs (ATW, ESS, EURISOL, RIA, XADS) the next steps have to be taken to demonstrate their usefulness on real accelerators. At a workshop held in Los Alamos in October of 2002 the community working in the field gathered to review their approaches and develop ideas to advance the field. The presentation will give a summary of the discussions and report on first successes to implement findings from the workshop.

### WeO06: 200 MHz Cu-Nb Cavities for Muon Acceleration

*R.L. Geng, H. Padamsee, D. Hartill, P. Barnes, J. Sears (Cornell), R. Losito, E. Chiaveri, H. Preis, S. Calatroni (CERN)*
We will report on the fabrication and test results of the first 200 Cu-Nb cavity developed for muon acceleration.

### WeO07: Results on LNL Nb RFQs

*G. Bisoffi, A.M. Porcellato, S. Stark, F. Chiurlotto, G. Bassato, S. Canella (INFN-LNL), V. Andreev (MSU), A. Lombardi, G.P. Bezzon (INFN-LNL), R. Losito (CERN), W. Singer (DESY), V. Palmieri (INFN-LNL)*
Two superconducting RFQs, following an ECR source and preceding superconducting quarter wave resonators, are now installed in their common cryostat at INFN-Legnaro. The cavities have been thoroughly and successfully characterized on a test cryostat with respect to: Q versus accelerating field, frequency tuning, Lorenz force detuning, locking in phase and amplitude, sensitivity to liquid He bath pressure. The new ion injector will expand the mass range of accelerated projectiles in the laboratory up to the heaviest ones.

### WeO08: Development of SC Intermediate-velocity Structures for the U.S. RIA Project

*K.W. Shepard (ANL)*
Several types of SC cavity are being developed for use in the RIA driver linac, which must produce 400 kW cw ion beams at output velocities as high as v/c = 0.8. This talk will focus on intermediate velocity cavities for $v/c > 0.2$ which includes half-wave, spoke-loaded, and elliptical cell cavities. The parameters of the various cavities being prototyped as well as recent test results will be discussed.

### WeO09: Progress Of Nb/Cu Technology with 1.5 GHz Cavities

*S. Calatroni, E. Barbero-Soto, C. Benvenuti, L. Ferreira, H. Neupert (CERN)*
The residual resistance of Nb/Cu cavities increases exponentially at high RF field. Two main possible causes

have been investigated in detail: the hydrogen incorporated in the film during the sputtering process and the roughness induced by the substrate. The latter has been reduced with an optimised electropolishing technique, which couples laboratory analyses of the electrical characteristics of the bath with numerical simulations of the actual process. The hydrogen content of the film can be reduced by increasing the pumping speed during deposition, either in the form of a suitable getter underlayer or of an appendage getter pump. The main results from these studies will be presented, together with other minor developments.

## WeO10: Performance of Seamless Cavities and Fabrication Experience

*W. Singer (DESY)*

Performance of seamless cavities produced by hydroforming or spinning is analyzed and compared with conventionally manufactured EB welded cavities. RRR degradation and grain growth in welding areas of conventional cavities can be critical for the performance. Good progress of last years in the welded technology allows overcoming most problems on the way towards high gradient. RRR degradation in welding area can be avoided by combination of careful preparation for welding, improved vacuum conditions and cavity post purification; magnetic field enhancement on the grain boundaries of the welding area can be avoided by electropolishing. The highest achieved accelerating gradient is up to now the same for both versions (ca. 40 MV/m.) Nevertheless seamless cavity fabrication is desirable in order to overcome the welding risk and get reliable statistics. Moreover comparison of available data for both types of cavities after sufficient BCP treatment shows better performance of seamless cavities. Technological problems of the fabrication of seam less cavities are mainly solved thanks to the progress in fabrication of seam less tubes and parameter optimization. There is an indication that the material properties potentially can be improved by pressurization during hydroforming. Fabrication of seamless cavities from bimetallic NbCu tubes deserves more attention. On the one hand it allows reducing the niobium costs; on the other hand it increases the thermal stability of the cavity. The highest accelerating gradient achieved on seamless bimetallic single cell cavity is Eacc = 40 MV/m. This is far better result in comparison with performances known for NbCu sputtered cavities.

## WeO11: Mechanical Properties of High Purity Niobium - Novel Measurements

*G.R. Myneni (JLAB), S. Agnew (Uni Virginia), G. Ciovati, P. Kneisel (JLAB), W.A. Lanford (SUNY), R.L. Paul, R.E. Ricker (NIST)*

One of the procedures to improve the performance of superconducting niobium cavities is a heat treatment for several hours in an ultrahigh vacuum at temperatures between 800 C and 1400 C for hydrogen degassing or post-purification, respectively. However, it was recently observed with Spallation Neutron Source Project (SNS) prototype cavities, that a heat treatment at 800 C for even 1 hour degraded the mechanical properties of RRR niobium, in particular the yield strength. This lower strength resulted in cavity deformations during handling thus affecting both their resonant frequency and field profile. In addition to lowering the yield strength, it was observed in some lots of material that the Youngs modulus was also apparently reduced by a factor of 2 as a result of the hydrogen outgassing at 800 C. Surprisingly, material received at other national laboratories exhibited similar anomalous behavior even without any heat treatments in vacuum. Based on these observations a multi-institutional collaborative basic research activity on high RRR niobium (determination of Nb yield strength as a function of grain size, work hardening, chemical composition, and heat treatment temperature) has been initiated by JLAB to gain a better understanding of the material properties affecting the mechanical behavior. In this contribution, a brief review of the measurements at JLAB, at the Materials Science and Engineering Department of the University of Virginia, at the Analytical Chemistry and Metallurgy Divisions of the National Institute of Standard and Technology, Gaithersburg and in the Department of Physics, SUNY, Albany are presented. The measurements include yield strength, hardness, ultrasonic velocity, crystallographic texture, microstructure, determination of interstitial contents using internal friction; particular emphasis is placed on determining the hydrogen concentration in the niobium via Cold Neutron Prompt Gamma-Ray Activation Analysis and Neutron Incoherent Scattering and to measure hydrogen depth profiles near surface regions by Nuclear Reactions Analysis.

**WeO12: Voltage Breakdown and the Processing Mechanism**

*G.R. Werner, H. Padamsee, D.P. Lundberg, A.S. Romanenko, J.E. Shipman, L.T. Ying (Cornell University)*

Although field emission and voltage breakdown are not current major limitations of superconducting RF cavities, field emission continues to degrade accelerator cavity performance, sometimes causing breakdown; ironically, voltage breakdown often obliterates field emitters,improving cavity performance. With the eventual goal of finding surface treatments that will reduce electric-field-related problems and processing methods that will promote <<therapeutic>> breakdown with less power input, we have been studying the nature of the breakdown event itself in DC experiments and computer simulations, both of which lend themselves more easily to diagnostics than SRF experiments.

**WeO13: Superconductivity Above the Upper Critical Field as a Probe for Niobium RF-cavity Surfaces**

*S. Casalbuoni, L. von Sawiliski, J. Koetzler (Inst. of Appl. Phys., Univ. Hamburg)*

Since surface superconductivity (SSC) resides in the same sheath, where also microwave currents are flowing, SCC may be employed as an alternative probe to explore the effects of surface treatments, by which currently the performance of superconducting accelerator cavities were improved. We demonstrate this idea by investigating the linear complex conductivity between 10 Hz and 1 MHz and also the critical current density along the circumference of Nb-cylinders in magnetic fields beyond the upper critical field, applied parallel to the cylinder axes. The cylinders have been cut from Nb-sheets (RRR=300), being used for the cavity production for the TESLA project at DESY. They have been subjected to the same chemical (CP) and electrolytical (EP) surface polishing and subsequent low temperature baking (LTB) processes as the RF cavities. Using the conventional definition of the surface critical field, i.e. the onset of an excess Ohmic conductivity, we find for all temperatures between 2 K and 7 K the ratio R between the surface critical field and the upper critical field to increase from 1.87 for CP to 2.07 by EP. After LTB R rises to even larger values, 2.13 and 2.51, respectively. The screening part of the conductivity reveals that long-range coherence of SSC appears at a field, which turns out to be about 25 percent lower than the surface critical field. There also a critical surface current starts to circulate around the cylinder. While EP enhances this current by a factor of eight, LTB has no effect. We relate our results to two features of the surface: (i) polishing and LTB induce chemical impurities in a layer in the order of the magnetic penetration depth, which enhance the nucleation fields, and (ii) the roughness reduces the stability of the SSC. Both results demonstrate the close relation between the characteristics of SSC and RF cavity performance. As a rather surprising feature, we detected rather large concentrations of localized paramagnetic moments of unknown origin, which even increase upon LTB.

**WeO14: Effect of Low Temperature Baking on Niobium Cavities**

*G. Ciovati, P. Kneisel, G.R. Myneni (TJNAF)*

A low temperature (100 C to 150 C) in situ baking under ultra high vacuum has been successfully applied as final preparation of niobium RF cavities by several laboratories over the last few years. The benefits reported consist mainly of an improvement of the cavity quality factor and a recovery from the so-called Q drop without field emission at high field. A series of experiments with a CEBAF single cell cavity have been carried out at Jefferson Lab to carefully investigate the effect of baking at progressively higher temperatures for a fixed time on all the relevant material parameters. Measurements of the cavity quality factor in the temperature range 1.37 K to 300 K and resonant frequency shift between 7 K and 9.3 K provide information about surface resistance, energy gap, penetration depth and mean free path. The experimental data have been analyzed with the complete BCS theory of superconductivity using a modified version of the computer code originally written by J. Halbritter. Small niobium samples inserted in the cavity during its surface preparation were analyzed with respect to their hydrogen content with a nuclear reaction analysis (NRA). The single cell cavity have been tested at three different temperatures before and after baking to gain some insight on thermal conductivity and Kapitza resistance and the data are compared with different models. This paper will describe the results from these experiments and will comment on the existing models to explain the effect of baking on the performance of niobium RF cavities. Future work will include measurements on single cell cavities prepared with electropolishing. Work supported by the U.S. Department of Energy, contract DE-AC05-84ER40150

**WeO15: Development of Hydrogen-free EP and Hydrogen Absorption Phenomena**

*T. Higuchi (Grad. Univ. Advanced Studies), K. Saito (KEK, Accelerator Laboratory)*

We developed a hydrogen-free electropolishing (EP) method for superconducting niobium RF cavities in KEK. By this method one can eliminate necessity for any kind of annealing. Since TRISTAN project we applied the combination of mechanical grinding and EP to have high gradient performance reliably. In such process, annealing process was inevitable to eliminate the hydrogen Q-disease problem. This annealing is time-consuming and pushes the preparation cost up. For a large scale production like TESLA, this process should be omitted if possible for the cost-effective production. We searched for such possibility and finally innovated a hydrogen-free preparation method without annealing. We found hydrogen absorption occurs because of the water during the wet mechanical grinding like barrel polishing. We succeeded to prevent hydrogen absorption in barrel polishing replacing the water by a liquid without hydrogen component. Later we found that such hydrogen-free barrel polishing was not sufficient, because hydrogen is picked up during the successive EP. We found a stationary oxidation process like in chemical polishing prevents this hydrogen problem to occur. Thus we finally invented the hydrogen-free electropolishing by putting one drop of nitric acid into the EP acid.

## Tutorials

**WeT02: Fundamentals of EP: Application to Nb and Cu**

*V. Palmieri (LNL-INFN)*

Among several possible cleaning techniques for cavity resonators, electropolishing allows the removal of large material quantities together with a mirror like surface. The fundamentals of electrochemical chemical kinetics will be briefly reviewed, in order to get deeper in process understanding and better controlling. Powerful techniques as electrolytic impedance spectroscopy will also be exposed.

# Thursday, 11th September 2003

## Poster Presentations

**Categories:**
**Materials / Surface Effects**
**Coupler / Tuner / Controls**

### ThP01: RRR Measurements on Niobium for Superconducting RF Cavities at Fermilab

*P. Bauer, C. Boffo, M. Foley, M. Kuchnir, Y. Terechkine (Fermilab)*

Fermilab is involved in the prototyping of superconducting RF cavities of the bulk Niobium type for the CKM separated kaon beam experiment and the A0 photo-injector project. As part of the quality control of the Niobium sheets ordered from industry for the cavity manufacturing process, Fermilab is measuring the RRR of small samples cut from the delivered sheets. The following reports on RRR measurements on samples cut from Niobium sheets for the CKM prototype cavities. The RRR was measured upon receipt and after the 800 C heat treatment that is used to outgas the cavity half-cells before assembly. Then samples were cut from a plate, which was produced by joining two smaller plates by e-beam welding. In this way the effect of welding on the material RRR could be assessed. These measurements allowed not only to qualify the material received but also to predict the RRR of the Niobium material within the completed cavity.

### ThP02: Why Does the Q-slope of a Nb Cavity Change Upon Baking at 100 C?

*I.V. Bazarov, H.S. Padamsee (Cornell), G.R. Werner*

One model is that the region below the natural oxide is rich in oxygen, which lowers the rf critical field at which grain boundary steps go normal. Baking dilutes the oxygen so that the critical field goes up. We are doing O profile measurements with Auger to quantify this model. O depth measurements anticipated: BCP, BCP + bake 100 C, EP, EP+ bake 100 C.

### ThP03: Grain Boundary Specific Resistance and RRR Measurements in Large Grain Pure Niobium

*S. Berry, C.Z. Antoine, S. Regnaud, Y. Boudigou, L. Margueritte (CEA-Saclay)*

Preliminary results have showed some variation of grain boundary specific resistance and RRR measurements with surface treatment. A continuous degradation of the RRR appears upon further chemical or electrochemical treatment. This paper shows further investigation to try to determine where those variations originate from. The question to know if it arises from surface effect or enhanced diffusion at grain boundary is discussed.

### ThP04: Topologic Analysis of Samples and Cavities: A New Tool for Morphologic Inspection of Quench Site

*S. Berry, C.Z. Antoine, J.P. Charrier, M. Desmon, L. Margueritte (CEA-Saclay)*

It has been demonstrated recently that local magnetic field enhancement can originate from roughness (e.g. steps at grain boundaries).We want to investigate the quench observed in superconducting niobium cavities can be related to such morphological defects. Thus, we need to develop two kinds of tools. 1) A replica technique that allows reproducing the internal surface of cavities (non destructive testing). 2) A morphological analysis tool. Indeed, classical roughness measurements are not relevant to determinate local curvature radius. This paper describes a new topological approach dedicated to better characterization of the surface morphology in regard with field enhancement. This technique has been applied to Niobium samples treated with different kind of surface treatments. We also present the first results of this approach applied to replica taken from cavities near the quench site.

### ThP05: Hydrogen Surface Analysis of Niobium in Function of Various Electrochemical Conditions

*C.Z. Antoine, S. Berry, H. Shou (CEA-Saclay)*

Electropolishing is presently accepted like most efficient surface treatment obtaining high gradients in niobium RF cavities. This treatment seems to introduce more hydrogen in niobium than chemical etching [1]. We shall investigate hydrogen contamination changes in various electrochemical conditions (like anodic protection) during chemical etching and electropolishing, and other conditions like hot water rinsing, hydrofluoric acid rinsing, etc... Hydrogen contamination near the surface is analyzed with HFS (hydrogen forward scattering). This technique allows exploring 200 to 300 nm of the surface (i.e. little bit more than the field penetration depth) and it is used to monitor the hydrogen up-take inside niobium in various electrochemical conditions. [1] Higuchi, T., K. Saito, et al. (2001). 10th Workshop on RF Superconductivity.

### ThP06: Wet Oxidation of an Epitaxial Niobium Film

*W.R. Frisken (York U.), L.N. Hand (Cornell U.)*

Freshly ion-milled surfaces of epitaxial niobium film were exposed to humid environments and then depth profiled for contaminants by Secondary Ion Mass Specroscopy (SIMS). The first series of measurements used an exposure to 30% humid laboratory air, and the second series used heavy water vapour in an argon atmosphere. The usual oxygen profiles are seen in the first 30 nanometers in both series. Hydrogen (deuterium in the second series) is seen to diffuse throughout the film, but not uniformly. A thin subsurface hydrogen (deuterium) layer is seen to form within the oxygen rich layer. In the absence of heat treatment the hydrogen layer appears to be stable for many days.

### ThP07: Characterization of Niobium Films and Bulk Sample by RRR,SIMS and a SQUID Magnetometer

*L.N. Hand (Physics Dept.,Cornell University), J.P. Craig (Physics Dept., Cornell University), J.A. Thompson (Physics Dept.,Cornell University, Ithaca, N.Y. USA), W.R. Frisken (York Univ.)*

We have studied: 1) a Niobium bulk sample from DESY with RRR=282, 2) a Nb film on oxidized copper produced at CERN, and 3) several different epitaxial Nb films on sapphire produced at Cornell by DC magnetron sputtering. We compare the values of RRR, the element vs. depth profiles from SIMS and the critical fields from magnetization curves vs applied magnetic field. We look for clues as to how these different samples would perform in an SRF accelerator cavity. In addition, we have two first surface niobium films deposited on graphite or hafnium-coated graphite. In the future, we will compare these films to the others and comment on the suitability of first surface films for SRF applications.

### ThP08: Development of a Niobium Bellow for Beamline Connections

*L. Turlington, J. Brawley, B. Manus, S. Manning, S. Morgan, G. Slack, P. Kneisel (JLAB)*

Superconducting cavities in an accelerator assembly are usually connected at thebeampipes with stainless steel bellows at an intermediate temperature, which compensate for alignment tolerances on the cavity beamlines and for thermal contraction during cooldown to cryogenic temperatures. This transition from one cavity to the next in a cavity string is typically of the order of 3/2 lambda long with approximately 1/2 lambda taken up by the bellow. If one would incorporate a niobium bellow in the beam pipe, this distance could be reduced by half a wave length. In the case of an accelerator such as TESLA the overall cavity length for the accelerator could be reduced by roughly 10 % or 2000 m. In terms of cost savings this would amount to 20 - 30 Million Dollars. Based on this estimate we have started to develop a niobium bellow to be used on a 2.75 inch diameter beamline. It is made from 0.3 mm thick niobium sheet, which has been rolled into a tube and completed by a longitudinal full penetration electron beam weld; the weld is made with a narrow, focused beam to reduce the heat affected zone and therefore limit the grain growth, which could affect the formability. Subsequently, two convolutions have been pressed into this tube in a 2-stage process, using an external die and a polyurethane internal expander. Niobium cuffs and flanges were electron beam welded to the formed bellow, which then makes leak testing possible and allows some measurements of compression/expansion and bending. In this contribution the fabrication process and the subsequent mechanical and vacuum tests with the bellows will be described.

### ThP09: In Situ XPS Investigation of the Baking Effect on the Surface Oxide Structure Formed on Niobium Sheets Used in Superconducting RF Cavity Production

*K. Kowalski, A. Bernasik (AGH University of Science and Technology, Krakow, Poland), W. Singer, X. Singer (DESY, Hamburg, Germany), J. Camra (Jagellonian University, Krakow, Poland)*

Investigations were performed for two types of Nb samples prepared by the standard treatments used for the niobium RF cavity production, electro-polishing (EP) and buffered chemical polishing (BCP). The chemical structure of thin oxide films naturally formed on the Nb surface changed on baking. It was observed in situ by means of the X-ray Photoelectron Spectroscopy (XPS). The experiments were carried out in the temperature range from 100 to 180 degrees Celsius for 120-hour periods of time. It was found out that the film thickness for the EP samples was greater than that for the BCP ones. The Angle-Resolved XPS (AR-XPS) analyses indicated that the oxide films consisted of the thicker external Nb2O5 layer and the much thinner NbO2 and NbO phases placed below it. The Nb2O5 phase progressively dissociated and the NbO2 and NbO oxides developed on baking. This effect was hardly noticeable at 100 C but considerably revealed at higher temperatures. At the temperature of 180 C the NbC phase was formed at a certain stage of the oxide layer evolution and then it developed on further baking. While the tendency of the process was the same for the both EP and BCP samples, the kinetics of the surface oxide layer evolution was much faster for the BCP samples than for the EP ones.

### ThP10: Influence of Metal Particle Contaminations on the DC Field Emission of Niobium

*G. Mueller, B. Guenther, F. Kaldasch (Univ. of Wuppertal), D. Proch, D. Reschke (DESY Hamburg)*

Field emission (FE) from particulates often limit the performance of superconducting accelerator structures. Therefore we have studied the dc FE properties of Nb samples which were intentionally contaminated with metal particles (Fe,Cu,Al) typical for cavity environments. At first such particulates were randomly deposited on the whole Nb surface. Three samples were investigated with a field emission scanning microscope (FESM) before and after dry ice cleaning (DIC). (** See footnote). Comparative voltage maps show a drastic reduction of the number of emitters by DIC up to surface fields of 120 MV/m. In order to learn more about the nature and current stability of particulate emitters, a new support system was constructed. It allows the local contamination of samples within six areas (diameter about 0.5 mm) in a 2 x 3 raster with a given sort of particles. This facilitates the relocalisation of emitters found with the FESM and the correlation of their strength and morphology by means of in-situ and high resolution ex-situ SEM investigations. Voltage maps reveal that 35% of the 5-20 mikron Al particles and 45% of the 1-5 mikrom Fe-particles emit at onset fields E(1nA) up to 75 and 140 MV/m, respectively. During the scans about 50% of the particles were removed from the sample surface by electrostatic forces. Most of the non-emitting particles show charging effects during the SEM investigations, thus suggesting that an insulating oxide layer suppress FE. Three types of current processing effects were observed. Up to currents of 1000 nA approximately 50% of the emitters show strong irreversible emission reduction. Moreover, 26% of emitting particles show stable reversible emission and 24% irreversible emission activation. (**) Performed at Fraunhofer IPA, Stuttgart

### ThP11: Morphology of Niobium Films Sputtered at Different Sputtering Target-substrate Angle

*D. Tonini, C. Greggio, G. Keppel (INFN-LNL), F. Laviano (Torin Politechnical), R. Losito (CERN), M. Musiani (CNR-IENI), G. Torzo (CNR), V Palmieri (CNR-LNL)*

The Q-degradation versus accelerating field represents a great limitation for Niobium sputtered electron cavities. Moreover it is well-known that passing to middle beta cavities, by increasing the sputtering target-substrate angle, the Q-slope becomes more and more severe. The authors have investigated the role that such angle has onto film morphology.

### ThP12: Correlation Studies Between Material and Surface Characteristics and Superconducting Properties of Nb for RF Cavities

*C.E. Reece, J. Mammosser, L. Phillips, A.-M. Valente, T. Wang, A.T. Wu (JLab)*

In an attempt to improve our understanding of microscopic surface characteristics of practical superconducting rf structures, the Jefferson Lab Institute for Superconducting RF Science and Technology has initiated characterization studies of the niobium surfaces produced by our current preparation techniques and is measuring possible correlations between residual contaminations, surface oxide structure, surface morphology, microstructure of samples, and high-field surface impedance. Samples from the same material are co-processed in a mock cavity together with a single cell cavity and subjected to surface profilometry, SIMS, metallographic optical microscopy, SIMS, SAM, SFEM, and SEM analysis. Variations in the produced surfaces are described with respect to sample orientation in the mock cavity during processing, chemical processing bath temperature, BCP vs. electropolish preparation, and subsequent thermal treatments. Though the study has just begun, results and analysis to date will be presented.

**ThP13: Surface Science Laboratory for studying the Surfaces of Superconducting Radio Frequency Cavities**

*A. T. Wu (JLab)*
A Surface Science Laboratory (SSL) has been established at JLab to study surfaces relevant to superconducting radio frequency (SRF) cavities. Current operational facilities include a scanning electron microscope equipped with energy dispersive x-ray analysis, a secondary ion mass spectrometry, a metallographic optical microscope, a transmission electron microscope, a high precision and large scan area 3-D profilometer, a scanning field emission microscope, and a fully equipped sample preparation room. A scanning Auger microscope is being commissioned, and will be available for routine usage soon. Results from typical examples of the projects on SRF cavities that were supported in the past through the use of the facilities in the SSL will be briefly reported.

**ThP14: Investigations to Improve Field Emission Performance of Production SRF Cavities at Jlab**

*T. Wang, J. Mammosser, L. Phillips, R. Rimmer (JLab)*
Field emission remains the dominant setback in cavity production at Jlab. We will present our results in investigating field emission performance from witness samples incorporated in various cavity production processes. Drying experiments which show distinct patterns of particulate residence on cavity surface will be presented along with corresponding results from production cavities. A new apparatus to facilitate FE measurement and QC in production is well under way in design and will be described.

**ThP15: Surface Smoothness for High Gradient Niobium SC RF Cavities**

*K. Saito (KEK)*
The author analysed the Q-slope in the Qo-Eacc excitation cures of niobium RF cavities in other paper using two models: global heating and magnetic gap smearing model. The latter can derive the effective thermodynamical magnetic critical field (Hc) of the niobium material used for the cavity. The effective magnetic field looks to be smaller than the ideal that in chemically polished cavities. It might be due to the field enhancement effect. In this paper, supposing this consideration, the relationship between the high gradient and the field enhancement factor will be obtained experimentally. The needed surface roughness will be less than 2 micron in Rz for the high gradient Eacc $>$ 30MV/m.

**ThP16: RRR Effect on the Flux Trapping of Niobium SC CAVITIES**

*K. Saito (KEK)*
We sometimes observe the flux trapping phenomena during cold testing niobium superconduction RF cavities. Especially, it is a serious problem with Nb/Cu clad cavities. In this paper RRR effect on this problem will be considered from the theoretical point of view and be compared with experimental results.

**ThP17: Q-Slope Analysis of Niobium SC RF Cavities**

*K. Saito (KEK)*
Q-slope, which often appears at medium field or high field in Qo-Eacc excitation curves of superconducting RF cavities, is analysed by two models: global heating model and magnetic gap smearing model. The latter is newly proposed in this paper. Qo-Eacc excitation curves are nicely fitted overall by combination of these models. Only the global heating on the RF surface due to the poor thermal conductivity in superconducting state cannot explain fully the Q-slope in the high gradient. The band gap smearing due to the RF magnetic field brings exponential degradation behaviour when the Hc is degraded seriously. The Q-slope seen in chemical polished cavity seems to be caused by the lower Hc due to the magnetic field enhancement. The rough surface might enhance field and the resultant Hc looks to be lower.

**ThP18: Properties and Structure of Electrodeposited Copper Layers in Parts of the TTF Power Coupler**

*X. Singer, H.M. Wen, W. Singer, W.-D. Moeller (DESY)*
The TESLA input coupler has to transmit pulses up to 1 MW RF peak power and at an average up to 300 kW for an 800 us long beam pulse. The transmission line parts should combine low heat conductivity and high electrical surface conductivity. Therefore stainless steel pipes or bellows are plated by a thin copper layer (10-20 um) at the RF surface. Such parts are exposed to high temperatures in a UHV furnace during fabrication and treatment. Influence of copper thickness, coating

technique and annealing parameters on the microstructure, RRR, electrical and thermal conductivity is investigated. Two processes take place during heat treatment. On one hand occurs the recrystallization of copper that positively influenced the required parameters, on the other hand the diffusion of elements from stainless steel at high temperatures can significantly pollute the copper and reduce the electrical properties of the layer. Reasonable parameters of the heat treatment for electrodeposited copper layers are defined.

### ThP19: Q Disease: Insights from 350 MHz Spoke Cavities Tests and ERD Analyses of Hydrogen Profile in Nb

*T. Tajima, R.L. Edwards, F.L. Krawczyk, J. Liu, D.L. Schrage, A.H. Shapiro (LANL)*

While degassing hydrogen at an elevated temperature (>600 C) can reduce the chance of Q degradation (Q disease), eliminating this process would significantly reduce the production cost and time of cavities. Past published data elsewhere have shown significant Q disease at relatively low frequencies such as the 130 MHz quarter-wave resonator at JAERI despite general observation of insignificant effect on low-frequency cavities. We have tested our 350 MHz spoke cavities and found that these cavities do not show any Q disease after up to 24 hours of holding at 100 K, but show the disease with longer holding time, although the extent of the degradation was different between the two cavities. Elastic Recoil Detection Analyses (ERDA) data on the hydrogen content and the depth profile in niobium used for the fabrication of our spoke cavities will also be shown with various surface treatments. Finally, insights from these studies into what is the best way to treat cavity to avoid high-temperature degassing will be drawn.

### ThP20: Engineering a Light Source for the Future: Studies of a Higher Order Mode Absorber for Cornells Energy Recovery Linac

*B. Barstow, M. Liepe, H. Padamsee (Cornell)*

An X-Ray source for the future will need to produce brilliant, ultra-short and coherent pulses of light to allow exploration of new biology and material science. Engineering this light source will push the envelope of accelerator engineering. Cornell proposes the construction of an energy recovery linac based light source. One crucial challenge in the design is the control of the higher order mode spectrum in the main linac and injector cavities spanning from 1.3 to over 40 GHz. Presented here are results of continuing investigation into the electromagnetic properties of various microwave absorbing materials from 1 to 18 GHz at room and liquid nitrogen temperatures.

### ThP21: Microphonics and Lorentz Transfer Function Measurements on the SNS Cryomodules

*J.R. Delayen, G.K. Davis (JLab)*

As part of the acceptance tests we have performed a number of measurements of microphonics levels and frequency spectra on the SNS cryomodules. These measurements are particularly important since those cryomodules may be used in the high-energy section of the RIA driver, a low-current cw accelerator. Measurements of the complete transfer functions between rf field modulation and cavity resonant frequency have also been performed.

### ThP22: Piezoelectric Tuner Compensation of Lorentz Detuning in Superconducting Cavities

*J.R. Delayen, G.K. Davis (JLab)*

Pulsed operation of superconducting cavities can induce large variations of the resonant frequency through excitation of the mechanical modes by the radiation pressure. The phase and amplitude control system must be able to accommodate this frequency variation; this can be accomplished by increasing the capability of the rf power source. Alternatively, a piezo electric tuner can be activated at the same repetition rate as the rf to counteract the effect of the radiation pressure. We have demonstrated such a system on the prototype medium beta SNS cryomodule with a reduction of the dynamic Lorentz detuning during the rf pulse by a factor of 3. Piezo electric tuners can also be used to reduce the level of microphonics in low-current cw accelerators, and we have measured the amplitude and phase of the transfer function of the piezo control system (from input voltage to cavity frequency) up to several KHz.

### ThP23: Characterization of Piezoelectric Actuators Used for SRF Cavities Active Tuning at Low Temperature

*M. FOUAIDY (IPN Orsay), N. HAMMOUDI*

Superconducting RF (SRF) cavities are very sensitive to small mechanical perturbations due to their narrow

bandwidth. High electromagnetic fields induce mechanical deformation in the micron range leading to a frequency detuning of the same order of magnitude of the bandwidth of these accelerating structures. In order to reduce this effect, which results other ways in a substantial additional RF power so as to control the electromagnetic fields, the SRF cavities are stiffened. However, the detuning factor reached with stiffened SRF cavities is still much higher than needed. An alternative strategy or dynamic compensation of Lorenz Force detuning based on commercial piezoelectric actuators was proposed recently and the principle was demonstrated on TESLA cavities. A piezo-tuning system is actually developed at IPN Orsay for high intensity proton linacs SRF cavities. A dedicated facility was designed and successfully used for the characterization of piezoelectric capacitive actuators at low temperature (i.e 1.8 K-300K). This device is described and the first experimental results (i.e piezoelectric actuator calibration or displacement DX vs. applied voltage V, capacitance C vs. T dielectric properties vs. T and frequency) are analyzed and discussed. The experimental data show that the full range displacement DX of the actuator decreases strongly with T. For the actuators studied, the variations of dielectric losses with T for a sine displacement of given amplitude (1 micrometer) show a maximum around 10 K-20 K leading to a thermal load lower than 1 mW at 1.8 K for a sinusoidal displacement of 1 micrometer at a frequency of 100 Hz.

### ThP24: Multipacting Experiments With Rectangular Coupler Waveguides

*R.L. Geng, S. Belomestnykh, H. Padamsee (Cornell), P. Goudket, D.M. Dykes (ASTeC), R.G. Carter (Lancaster U.)*

We will report results on multipacting experiemnts with CESR type rectangular coupler waveguides.

### ThP25: Multipactor Studies in Rectangular Waveguides

*P. Goudket (ASTeC)*

A test section of rectangular waveguide similar to the input coupler of the CESR-type SRF cavities will be used to conduct further investigations of multipactor behaviour. This new section will allow the study on a full scale waveguide of the effects on multipactor of cryogenic cooling (down to 77 K), as well as the effects of surface coatings and roughness, through the use of changeable sample plates. These experiments are due to take place later in the year.

### ThP26: RF Conditioning and Testing of Fundamental Power Couplers for the RIA Project

*M. Stirbet (Jefferson Laboratory), J. Popielarski, T.L. Grimm, M. Johnson (Michigan State Universitiy)*

The Rare Isotope Accelerator (RIA) is the highest priority of the nuclear physics community in the United States for a major new accelerator facility. A principal element of RIA will be a 1.4 GeV superconducting heavy-ion linac for accelerating isotopes from hydrogen to uranium onto production targets. The superconducting linac technology is closely related to that used at existing accelerators and the Spallation Neutron Source. Taking advantage of JLABS SRF Institute facilities and expertise for the SNS project, preparation of couplers, RF conditioning and high power tests have been performed on fundamental power couplers for the RIA project. The fundamental power couplers are 50-ohm coaxial lines with planar ceramic windows similar in design with the SNS fundamental power couplers. The JLABs pulsed 805 MHz 1 MW room temperature test stand was used for RF tests. After RF conditioning, the first two RIA fundamental power couplers have sustained in traveling wave mode power levels of 200 kW (pulsed RF, 1 ms 60 Hz) well above the specifications (intended CW operation up to 10 kW). An overview of the RIA fundamental power couplers, procedures applied and RF tests results will be given in this paper.

### ThP27: Input Couplers for 972 MHz Superconducting Cavities in the High Intensity Proton Linac

*E. Kako, S. Noguchi, T. Shishido (KEK)*

Prototype coaxial input couplers with a planar rf window and a high power test stand were designed and fabricated. The high power test with a 972 MHz pulsed klystron had been successfully carried out. Input rf power of 2.2 MW in a pulsed operation of 0.6 msec and 25 Hz (370 kW in 3.0 msec and 25 Hz) was transfered to the input couplers without any problem.

### ThP28: Selective Mode Damping and Improvement of the Quality Factor of a Microstrip Resonator

*A.L. Karuzskii, A.N. Lykov, V.N. Murzin, N.A. Volchkov (LPI)*

The highest achievable quality factor (Q) values of a microwave resonator may be restricted by radiation losses caused by intermode coupling. It may be difficult to improve Q by dumping the intermode coupling while a complete mode spectrum is unknown. This is a true for semi-open microstrip-like resonators. Previously it has been found that negligible geometry fluctuations of the microstrip resonators result in strong and unpredictable changes of Q from less than 10E3 to higher than 10E5. Here we have studied the influence of the dispersion properties on the loss characteristics of the superconducting microstrip-like resonator. Transmittance spectra of the half-wave resonator have been measured in 10 GHz frequencies range. The electromagnetic field was intentionally disturbed outside in the region of transmission lines to dump modes selectively. Series of Q measurements using short-circuited stubs on input and output microstrip lines were performed in order to find interaction of the main half-wave resonance mode with other modes. It is found that spectrum of resonances includes parasitic modes, the energy of which is concentrated mainly in the region of connecting microstrip lines. Interaction of the main mode with parasitic ones significantly reduces the highest Q value of the main operating mode. It is also demonstrated that dielectric resonance in the dielectric substrates of resonator can be excited.

### ThP29: Microphonics Measurements in RIA Cavities

*M.P. Kelly, K.W. Shepard, J.D. Fuerst, M. Kedzie (ANL)*

Phase stabilization of the RIA drift-tube cavities in the presence of microphonics will drive the rf power requirements for the RIA driver linac. Microphonics measurements on the ANL beta=0.4 two-cell spoke cavity have been performed many at high fields and using a new cavity resonance monitor devide developed in collaboration with JLAB. Cold tests on the fully jacketed two-cell spoke operated under realistic conditions are the first ever on a multi-cell spoke geometry and indicate exceptional performance in this regard with no low-lying mechanical modes which couple to the cavity rf eigenfrequency. Rather, at useful accelerating fields of Eacc=7-8 MV/m the modest frequency jitter (roughly 5 Hz RMS) is due to low frequency non-resonant vibrations from pool boiling in the helium bath. The issue of microphonics is being addressed at Argonne in three ways: (1) construction of piezoelectric and magnetostrictive tuners, (2) cavity design to reduce the pressure sensitivity and (3) reducing the source of helium pressure fluctuations.

### ThP30: A new Digital Control System for CESR-c and the Cornell ERL

*M. Liepe, S. Belomestnykh, J. Dobbins, R. Kaplan, C. Strohman (Cornell University)*

The present CESR RF control design is based on classic analog amplitude and phase feedback loops. In order to address the required flexibility of the RF control system in the CESR-c upgrade and to implement a true vector sum control we have designed, built and tested a new digital control system. The main features of the new controller are high sampling rates, high computation power and very low latency. The digital control hardware consists of a powerful VME processing board with a Xilinx FPGA, an Analog Devices digital signal processor (DSP) and memory. The Xilinx FPGA is used to compute the fast controller, while the floating-point DSP is used for higher level functions. A daughter board is equipped with four fast analog-to-digital converters (up to 65 MHz sampling rate) and two digital-to-analog converters (up to 50 MHz update rate). The first set of new electronics will be used in the CESR RF system. However, it can also be used for the proposed Cornell energy-recovery linac (ERL) as it was designed to meet the challenging ERL field stability requirements. In this paper we describe the layout of the new RF controller and present the results of initial performance tests.

### ThP31: Characteristics of TiN Anti-multipactor Layers Reached By Titanium Vapor Deposition on Alumina Coupler Windows

*J. Lorkiewicz (DESY), A. Bilinski (Inst.of Physical Chemistry, Warsaw, Poland), T. Fadina (DESY), J. Kula, S. Pszona (The A. Soltan Institute for Nuclear Studies, Swierk, Poland), J. Sobczak (Institute for Physical Chemistry, Warsaw, Poland), Z. Yu (Institute of High Energy Physics, Beijing)*

A procedure of thin TiN layers generation on RF coupler surfaces was developed at DESY in order to reduce multipactor effects. Within last three years roughly 200 various components of couplers for Tesla Test Facility (TTF) have been TiN-coated using titanium vapor deposition in ammonia. Surface layer properties which are essential for coupler performance, like secondary electron yield (SEY) and loss tangent, have been studied.

The loss tangent in RF field, measured for TiN-coated cylindrical alumina coupler windows showed a considerable growth with rising layer thickness for thickness values higher than 9 nm. The chemical composition of a typical TiN anti-multipactor layer was determined using XPS analysis. The received depth profiles revealed that titanium dioxide and titanium oxinitrides dominate TiN across the layer.

### ThP32: A Mechanical Tuner and RF Drive Line System for the ISAC II Quarter Wave Superconducting Cavities

*R.E. Laxdal, A.K. Mitra, K. Fong, R. Poirier, T. Ries, V. Zviagantsev (TRIUMF)*

The ISAC-II medium beta cavities have a design gradient of 6MV/m. This corresponds to a peak surface field of 30MV/m and a stored energy of U=3.2 J and is a significant increase over other operating heavy ion facilities. To achieve stable phase and amplitude control the natural bandwidth of +-0.1 Hz is broadened by overcoupling to accommodate detuning by microphonic noise and helium pressure fluctuation (1Hz/Torr). The chosen tuning bandwidth of +-20 Hz demands a cw forward power of 200 watts and peak power capability of 400 watts to be delivered to the coupling loop at the cavity. Two complimentary developments are ongoing at TRIUMF to achieve the design goal. In the first a new rf coupling loop is being developed with the goal to operate at 200 W forward power with less than 1 W of power being added to the helium load. The coupler has a thin stainless steel body for thermal isolation and a copper outer conductor cooled with LN2. Cooling of the inner conductor is achieved by adopting a thermally conducting Aluminum Nitride dielectric localized in the loop. Secondly TRIUMF is developing a mechanical tuner capable of both coarse (KHz) and fine (Hz) frequency adjustments of the cavity. A 1 mm thick Niobium plate at the high field end of the cavity is actuated by a vertically mounted permanent magnet linear servo motor, at the top of the cryostat, using a zero backlash lever and push rod configuration through a bellows feed-through. The demonstrated tuner resolution is better than 0.1 micro-m (0.6 Hz) with a dynamic range of 8 KHz and a manual coarse tuning range of 33 KHz. The response bandwidth is presently limited to 20 Hz by a mechanical resonance but is sufficient to accurately follow changes in cavity frequency due to variations in the helium pressure to a rate of several Hz/second. Mechanical details and cold test results of the ISAC-II coupling loop and mechanical tuner will be given.

### ThP33: High Power Input Coupler for KEKB SC Cavity and New 1 MW Test Bench

*S. Mitsunobu, K. Akai, K. Ebihara, T. Furuya, S. Isagawa, H. Nakanishi, M. Yamaga (KEK), S. Yi (IHEP), Y. Kijima (Mitsubishi), T. Tanaka (Furukawa)*

KEKB superconducting cavities have been driving the design current of 1.1 A from spring of 2003. To increase luminosity of KEKB, the current will be increased as high as possible. For higher current operation of superconducting cavity more than 1.1 A for KEKB, one of key component is a high power input coupler. To increase operation power of 300 kW to 500 kW, the 1 MW coupler test bench have been constructed. The new couplers already tested up to 500 kW with doorknob transitions enforced air cooling at the new 1 MW coupler test bench.

### ThP34: Design, Fabrication, and Testing of Novel High Power RF Input Couplers

*Q.-Sh. Shu, J. Susta, G. Cheng (AMAC), St. Einarson, T. Treado, W. Guss, M. Tracy (CPI), I. Campisi, M. Stirbet (JLAB)*

Two types of novel high power RF coupler were developed and designed by AMAC to reliably operate at an average power level over 200 kW and to exceed the present specification requirements for the SNS accelerator project. CPI performed the manufacturing optimization and the fabrication of prototypes.The RF couplers were conditioned and tested at the Jefferson Laboratory. An innovative feature consisting of a compression ring was incorporated to reduce the tensile forces on the ceramic by pre-stressing the ceramic and increase the reliability of the ceramic window. Watercooling is used to remove the dissipated power at the window and the antenna. Extensive calculations were performed to optimize window design using MAFIA, HFSS, ANSYS, multipacting program. Based on the above efforts, an innovative RF surfaces design (AMAC-2) was developed to remove the chocks used in AMAC-1 and provided the following advantages: better vacuum, easier cleaning, and less secondary electron-multipacting. The simulation, design consideration, engineering design and results of the RF high power qualification were briefly discussed in this paper.

**ThP35: Input RF Coupler Windows for RIA Cavities**

*Q.-Sh. Shu, J. Susta, G. Cheng (AMAC), T. Grimm, J. Popielarski (NSCL), St. Einarson, T. Treado (CPI)*

The RF coupler window was designed by AMAC and MSU to meet the specification requirements for the proposed RIA accelerator project. CPI performed the manufacturing optimization and fabrication. The preparation, testing, and conditioning were performed at the Jefferson Laboratory and the results are presented in another paper at this conference.The main specification parameters for RIA prototype coupler are: VSWR: 1.05 or lower at 805 MHz; Maximum CW power: 10 kW; External Q of coupler: 2 x 107; Maximum thermal load to 2 K circuit: 2 W; Operating pressure: $<$ 5 x 10-9 torr; Radiation resistance: 4 x 108 rads. Air-cooling removes the dissipated power at the window and the antenna and outer conductor are conduction cooled. The outer conductor is copper plated stainless with a 50 or 77 K thermal intercept. The RIA cryostat geometry requires a coaxial 805 MHz coupler design with a transition to standard 3-1/8 in. transmission line. This coupler design is similar to the AMAC SNS high power prototype couplers. The geometry incorporates chokes at the inner and outer conductor. CPI fabricated two coupler window assemblies. The coupler windows have been conditioned and successfully RF tested at the Jefferson Laboratory, and meet or exceeds the RIA specifications with small temperature increases in the ceramic and no arcing. Calculation results, details, drawings, and a summary of the RF tests results for this coupler window will be presented in this paper.

**ThP36: RF System Modeling for the JLAB 12 GeV Upgrade and RIA**

*S. Simrock (DESY), J. Delayen, C. Hovater, A. Hofler (TJNAF)*

Jefferson Lab is using the MATLAB Simulink library for RF systems developed for TTF as a tool to develop a model of its 12 GeV upgrade and the Rare Isotope Accelerator (RIA) to study the behavior and performance of the RF control system. The library includes elements describing a superconducting cavity with mechanical modes excited by Lorentz Force effects and a klystron including saturation characteristics. It can be applied to gradient and phase or in-phase and quadrature control for cavities operating in either a self-excited loop or generator driven mode. We will provide an overview of the theory behind the library components and present initial modeling results for Jefferson Labs 12 GeV Upgrade and the RIA systems.

**ThP37: Development of a Pulsed Light Ion Accelerator Module Based on Half-wave Resonators**

*R. Eichhorn, F.M. Esser, B. Laatsch, G. Schug, R. Stassen, R. Toelle, E. Zaplatin (FZJ)*

A new injector for the cooler Synchrotron COSY at FZ Juelich has been foreseen based on half-wave resonators. The first prototype of the inductive RF power coupler has recently been built and will be used to operate the prototype cavities in a vertical bathcryostat. The coupling is adjustable to get a loaded Q of 106 to 109. Concerning the cavity different mechanical tuning concepts have been analysed. One solution is now under fabrication including a piezo fine tuner to compensate the Lorentz-Force-Detuning. The cryomodul design, which houses four cavities, will be finished - taking into account the restricted place of the whole linac.

**ThP38: A High Power CW Input Coupler for Cornell ERL Injector Cavities**

*V. Veshcherevich, I. Bazarov, S. Belomestnykh, M. Liepe, H. Padamsee, V. Shemelin (Cornell University)*

A conceptual design of the input coupler for superconducting injector cavities of Cornell ERL project is presented. The injector cavities are two-cell structures operating at 1300 MHz in CW mode. The coupler has a symmetric design to accommodate requirements for small transverse kick, high RF power delivery to the cavity, and high coupling value. It consists of two identical antenna type couplers symmetrically attached to a beam pipe of the cavity. Each of these individual couplers has to deliver at least 50 kW of CW RF power to the beam. The coupler has a variable coupling. Qext varies from 4.6x10E4 to 4.1x10E5. The symmetric design of the coupler dramatically reduces the transverse kick, a critical requirement for the ERL project. Individual couplers design is based on the design of TTF-III TESLA couplers but it has been significantly modified for requirements of ERL injector cavities.

**ThP39: Microphonic Detuning Compensation in 3.9 GHz Superconducting RF Cavities**

*L. Bellantoni, T. Berenc, R. Carcagno, H. Edwards, A. Rowe (FNAL)*

Mechanical vibrations can detune superconducting radio frequency cavities unless a tuning mechanism counteracting the vibrations is present. Due to their narrow operating bandwidth and demanding mechanical structure, the 13-cell 3.9 GHz SCRF cavities for the Charged Kaons at the Main Injector (CKM) experiment at Fermilab are especially susceptible to this microphonic phenomena. We present early results correlating RF frequency detuning with cavity vibration measurements for CKM cavities; initial detuning compensation results with piezoelectric actuators are also presented.

**ThP40: Testing of Nb Sheets on a SQUID NDE System with Large Scale x/y Table for Use in Industrial Enviroment**

*A. Farr, F. Schoelz, J. Reuss (wsk Mess- und Datentechnik GmbH, Hanau), M. Mueck, C. Welzel (Inst. of Applied Physics University of Giessen)*

The reachable field strength in superconducting resonators used in particle accelerators is limited by surface defects or inclusions of unwanted elements. Inclusions of some 100 mum in diameter can significantly reduce the reachable field strength. Since the manufacturing of Nb resonators is very expensive, the Nb sheets must be checked prior to production of the resonator tubes on such defects. We have constructed a system for non-destructive inspection of niobium sheets, based on eddy current measurements. To receive the neccessary detection sensitivity, a SQUID sensor for measuring the local eddy current density is used. The system works in a non-shielded enviroment. Within test sheets supplied from DESY tantalum inclusions with diameters of approximately 100 mum could be confidentially detected. With a sheet size of about 300x300 mm**2 and a line width of 1 mm a scan of one sheet lasts about 15 min, because of the SQUIDs low noise the sheets can be scanned with up to 100 mm/s scanning speed. Because of the high sensitivity of the SQUID detector it is not only possible to detect very small defects within sheets but also to gather a detailed image of the found defects, so it is easier to categorize the results than with an inspection of lower resolution and sensitivity. The software written for the project allows it to group different measurements on the same sample and catalogizes the measured results. During the project, different measurement equipments were build up, some with stationary SQUID systems, other with stationary sample holder. In all cases it was possible to operate the SQUID, even if a setup with stationary SQUID are often easer to work with, since gradients in the local field in such a case are no problem for the dynamic range of the magnetic field sensor.

**ThP41: Multipacting in 9-cell Tesla Cavities**

*K. Twarowski, L. Lilje, D. Reschke (DESY)*

The recent multipacting observations for 9-cell Tesla cavities are presented. Investigated cavities were prepared by BCP or EP method, after 800 or 1350 C heat treatment. An influence of low temperature heat treatment (120 - 140 C) on multipacting process for EP cavities is analyzed. An attempt to correlate multipacting in 9-cell cavities with method of preparation, chemical and thermal treatments is done.

# Friday, 12th September 2003

## Oral Presentations

### FrO01: Challenges for Future Light Sources (ERL and FEL) Or: ERLs and FELs: A Bright Future for Superconducting Cavities

*M. Liepe (Cornell University)*

Before it even started the 21st century has been named the century of live science. Part of this fast growing field are light sources with their high brilliant light beams for biology, chemistry and material science. The high scientific potential of future ERL and FEL light sources has given superconducting cavity technology an enormous boost in interest. Never before have so many laboratories and universities worked in the field of s.c. cavities, and a variety of machines have been proposed for construction. The envisioned brilliants of the light beams require excellent electron beam properties beyond present state-of-the-art. The RF cavity linacs will be the driving engines, and cost efficiency and emittance preservation will be of great importance. The resulting challenges for the s.c. cavity technology are manifold and a focus of the ongoing research work in this field.

### FrO02: X-Ray FEL at DESY

*H. Weise (DESY)*

The overall layout of the X-Ray FEL to be built at DESY will be described. This includes the envisaged operation parameters for the linear accelerator. Main emphasis is put on the specifications of the superconducting accelerator modules. The work packages needed to finalize the linac design will be presented.

### FrO03: High Intensity Proton Sources

*A. Facco (INFN-LNL)*

Since the start of the Spallation Neutron Source project, the field of high intensity (in the mA range and above) proton linacs based on superconducting resonators is living a time of great interest. A large variety of possible applications (nuclear waste transmutation, spallation neutron production, energy amplifier, radioactive ion production, neutrino factories, etc.) prompted many studies and proposals of new machines with final energy typically from a few tens of MeV to about 1 GeV; high power requirements and reliability issues introduced new kinds of problems in linac and resonators design. A zoo of different superconducting cavity types, often evolved either from the electron or from the heavy ion SRF technology, is growing to cover the many different proposed applications, and triggering development in related high power couplers and fast tuners. During the last few years, high gradient resonators have been successfully prototyped in the full range of interesting beam energy, down to beta=0.1. The trend is to extend the SC sections of high current proton linacs to very low beta, taking advantage of the large acceptance of short cavities in order to increase linac reliability and, in some cases, to allow acceleration of deuteron beams. The construction of new, superconducting high intensity proton linacs is foreseen in the next future.

### FrO04: Rare Isotope (Heavy Ion) Accelerators

*S. Schriber (MSU)*

A review of projects worldwide for rare isotope accelerators will be presented with an emphasis on requirements for superconducting rf accelerating structures. Areas of SRF research and development that would have a big impact on performance, cost, maintainability and facility operation availability will be discussed in terms of user impact.

### FrO05: Future Stable-beam Accelerators for Nuclear Physics

*L. Harwood (TJNAF)*

Several projects are at various stages of development or construction for nuclear physics research. The fixed target projects include a hadron facility now under construction at JAERI and an upgrade of the 6 GeV CEBAF electron facility at Jefferson Lab to 12 GeV utilizing ten new 100+ MV cryomodules. eRHIC is the proposed electron-ion collider at Brookhaven National Laboratory. Jefferson Lab has proposed a project that combines a 25 GeV fixed target capability with an electron-ion collider, eLIC. The conceptual layouts for all the projects will be presented as will the utilization of srf technology. The research and development opportunities will be discussed.

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