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SRF 2005

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Abstracts

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THALES

Sunday, July 10, 2005

Sunday Tutorials

SuA01: Basic Principles of SRF
K. Saito (KEK)
(abstract not submitted)

SuA02: High-β Cavity Design*
S. Belomestnykh, V. Shemelin (Cornell University)
In this tutorial we will present design principles for high-β superconducting accelerating cavities. Both RF and mechanical aspects of the cavity design will be discussed. We will discuss approaches to cavity shape optimization and illustrate this with computer simulations.
$*$ Work is supported by the National Science Foundation.

SuA03: Input Couplers for Superconducting Cavities - Design and Test
W.-D. Moeller (DESY)
The operating conditions of high power input couplers for superconducting cavities are different from those for normal conducting cavities. In this tutorial the design principles, diagnostic issues, and fabrication is discussed. Test results and operational experience is presented.

SuA04: Low Beta Cavity Design
A. Facco (INFN-LNL)
Low beta superconducting cavities are gaining more and more interest in the particle accelerators community. Their use, once limited to low current, low energy heavy ion beams, was recently extended to high current proton and deuteron linacs for energy production, spallation neutron sources, radioactive beam production, nuclear waste transmutation and other applications. A large number of different resonator geometries is now available, with peculiar characteristics suitable for different applications. In spite of their complex structures and construction difficulties, their performance, in terms of surface resistance and maximum achievable electric and magnetic fields, is comparable to the one of high gradient elliptical cavities. An introduction on low-beta resonators types, characteristics and design techniques, including accessories which are typical of this class of cavities, will be given.

SuA05: The Nb-oxide System - Implications for SRF Cavities
J. Halbritter (Karlsruhe)
Corrosion, i.e. oxidation in air, of metals is well known and cost billlions of dollars per year, despite modern corrosion protection. What happens to Nb, where corrosion protection has not been applied to SRF cavities, yet? Based on elaborate surface studies at Karlsruhe the following scenario has to be dealt with: The strong, directional Nb-O bonding via d-electrons together with the open lattice of Nb-metal causes a sequence of reactions:
- Nb sucks up O, which precipitates to metallic NbO_x ($x \leq 1$), especially, to the NbO_x surface layer.
- A dielectric Nb_2O_{5-y} coating forms by Cabrera-Mott oxidation where nanocrystalline Nb_2O_{5-y} grows consisting of crystalline blocks (CB) of size 1 nm and barrier height $\Phi_B \approx 1$ eV separated by crystallographic shear planes (CS) with $\Phi_S \approx 0.1$ eV housing localized states $n_L(z) \approx 10^{19}/cm^3$ easing the charge transfer across Nb_2O_{5-y}.
- In oxidation the factor three volume increase by CB strains the Nb surface being released by nucleated injection of NbO_x into Nb up to depth between 0.1-50 μm. Nb_2O_{5-y} does not dissolve in most acids.
- Nb_2O_{5-y} hydroxilize and chemisorbes water and hydrocarbons.
Consequences of the O dissolution and of the crack corrosion on Nb RF cavity performance reach from the reduced energy gap $\delta\Delta \approx 10 \text{x} \Delta$ by O_x in the BCS surface resistance R_{BCS}(T,f), to RF residual losses $R_{res}(T \leq T_c/2, \omega) \propto \omega^2$, to the R_{BCS}(T,≤15mT) minimum, to hysteresis losses $R_{hys} \propto \omega B$, to heating $\delta R(T,B) \propto (B/B_c)^2$, and to dielectric interface losses $R_E \propto \exp(-c/E)$, which do depend not only on Nb quality but also on the oxidation process, e.g., speed or chemical environment, as will be elucidated. Further improvements by corrosion protection will be mentioned.

SuP01: Ponderomotive Instabilities and Microphonics*
J.R. Delayen (TJNAF)
Phase and amplitude stabilization of the fields in superconducting cavities in the presence of ponderomotive effects and microphonics was one of the major challenges that had to be surmounted in order to make superconducting rf accelerators practical. This was of particular concern in low-velocity proton and ion accelerators since the beam loading was often negligible, but was usually not relevant in electron accelerators since the beam loading was often high and the gradients low. More recent or future applications of electron linacs (for example JLab upgrade, ERLs) will operate at increasingly higher gradients with little beam loading, and the issues associated with microphonics and ponderomotive instabilities will again become relevant areas of research. This paper will describe the ponderomotive instabilities and the conditions under which they can occur, and review the methods by which they, and microphonics, can be overcome.
* Work supported by the U.S. DOE under contracts DE-AC05-84-ER40150.

SuP02: Theory and Practice of Cavity Test Systems*

T. Powers (TJNAF)

Over the years Jefferson Lab staff members have processed and tested in excess of 500 superconducting cavities. Most of these cavities were later installed in 73 different cryomodules, which were used in three different accelerators. All of the cavities were tested in our vertical test area. About 25% of the cryomodules were tested in our cryomodule test facility and later commissioned in an accelerator. The remainder of the cryomodules were tested and commissioned after they were installed in their respective accelerator. In this tutorial I will provide a practical background in the RF systems used to test the cavities as well as provide the mathematics necessary to convert the raw pulsed or continuous wave RF signals into useful information such as gradient, quality factor, RF-heat loads and loaded Q's. Additionally, I will provide the equations necessary for determining the measurement error associated with these values.

∗ Supported by US DOE Contract No. DE-AC05-84ER40150.

SuP03: Cleanliness Techniques

D. Reschke (DESY)

Cleanliness techniques play the key role in the preparation of field emission free, high gradient, low loss superconducting cavities. Contaminations like particles and chemical residues as well as surface irregularities have been identified as major sources of field emission. To avoid these contaminations cleanroom environments and chemical pure, particle filtered media are used.

This talk will focus on the conditions for a clean cavity preparation as well as the discussion of the final processing, cleaning and assembly techniques.

SuP04: Cryomodule Design, Assembly, Alignment

C. Pagani (DESY / INFN-Milano)

(abstract not submitted)

Monday, July 11, 2005

Monday Morning: Oral Session

MoA01: Introduction - SRF: Two Hectic Years
H. Padamsee (Cornell University)
(abstract not submitted)

MoA02: Status of SNS
I. Campisi (ORNL/SNS)
(abstract not submitted)

MoA03: Status of TTF
L. Lilje (DESY)
The TESLA Test Facility in its second phase (TTF) serves two main purposes: It is a testbed for the superconducting RF technology for the International Linear Collider as well as a user facility providing a VUV-FEL beam for experiments using synchrotron light.
The presentation will review the progress on the superconducting RF technology at TTF. This includes tests on individual cavities as well as full accelerating modules.

MoA04: A 100 MV Cryomodule for CW Operation*
C. Reece (TJNAF)
A cryomodule designed for high-gradient CW operation has been built at Jefferson Lab. The Renascence cryomodule is the final prototype of a design for use in the 12 GeV CEBAF upgrade. The module uses eight 7-cell 1497 MHz cavities to be individually powered by 13 kW klystrons. Specifications call for providing >109 MV CW with <250 W of dynamic heat at 2.07 K. The module incorporates a new generation of tuners and higher power input waveguides. A mixture of the new HG and LL cavity shapes are used. A new high thermal conductivity RF feedthrough has been developed and used on the 32 HOM coupler probes of Renascence. The cryomodule assembly is complete. Testing is to begin late June. Design features and initial test data will be presented.
* Funded under Contract No. DE-AC05-84ER-40150 with the U.S. Department of Energy.

MoA05: SRF in Storage Rings
M. Pekeler (ACCEL)
Superconducting cavities are used in storage rings worldwide as they allow to transfer almost all available RF power to the beam and to operate at high accelerating voltage thus minimizing the number of installed cavities. Further these cavities can be designed “HOM-free” allowing stable operation of high currents and providing better beam quality. Pioneering work was done by CERN for the LEP storage ring (352 MHz), by DESY for the HERA electron ring (500 MHz),

by KEK for Tristan and the high energy ring of the KEK-B factory (508 MHz) and by Cornell for their B-factory proposal and later for the CESR upgrade program (500 MHz). Today such SRF technology can be delivered by industry and operation of SRF systems is done at institutions without an extended background in SRF technology. LEP technology will be used at the LHC (400 MHz) and at the Synchrotron Soleil (350 MHz) and KEK technology at the BEPC-II collider in Beijing. Cornell technology is used already at the Taiwan Light Source, the Canadian Light Source and will be used at the Diamond Light Source. In addition the Shanghai Light Source has decided to use SRF technology for their storage ring. Beside the main accelerating structures, higher harmonic superconducting cavities can be used to increase the bunch length and the beam lifetime. A collaboration of CEA, SLS, ELLETRA and CERN designed, installed and operated a 1.5 GHz system at the SLS and ELLETRA. A second approach with a Cornell CESR II cavity scaled to 1.5 GHz was delivered from ACCEL to BESSY and the cryogenic test is scheduled to be done in this summer.

Monday Afternoon: Oral Session

MoP01: Structures for RIA and FNAL Booster
M.P. Kelly (ANL)
Superconducting (SC) cavities for two new large ion linacs, the Rare Isotope Accelerator driver and a proposed 8-GeV proton driver at Fermilab, continue to be developed at many institutions. Cavity structures range from co-axial quarter- and half-waves to elliptical-cell geometries with an option for multiple-spoke loaded cavities in the mid- and high-beta linacs. Both new and adapted designs have been incorporated to fulfill diverse requirements. The CW RIA linac requires 400 SC cavities for accelerating ions over the full mass range with beta up to ∼0.8, and the pulsed proton driver linac requires 1000 cavities spanning the full range of velocities. Gradients required for RIA and the proton driver ($E_{peak} \sim 30$ MV/m) have already been demonstrated in prototype cavities in large part through the incorporation of modern clean handling and processing techniques. Critical issues in the choice of final RIA cavities will be beam dynamics, microphonics and RF phase control. Proton driver cavity design will be driven largely by the requirements for high-power pulsed operation. The present status of various structures developed for RIA and the FNAL Booster is presented here.

MoP02: SPIRAL 2 Resonators
G. Devanz (CEA-Saclay)
The SPIRAL 2 project to be built in GANIL is a high intensity ion linear accelerator for radioactive beam production. Most of the acceleration is provided by 24 88 MHz quarter wave resonators breaking into two beta families. The first ($\beta = 0.07$) was developped at CEA-Saclay, while the second ($\beta = 0.12$) was studied at IPN-Orsay. Each team has carried out the integration study of the QWRs in their respective cryomodule taking into account tight longitudinal space requirements. Prototypes of each cavity type have been built, prepared and tested in vertical cryostats. We present the RF and mechanical design of the resonators, cryostats, the preparation and test equipment specifically developped for QWRs, as well as the RF test results.

MoP03: The HW Resonators in Juelich
R. Stassen (FZ-Juelich)
Within the design of a new injector for the Cooler Synchrotron COSY, a linac option based on pulsed operated superconducting halfwave resonators (HWR) was investigated. Two prototypes of the HWRs at 160MHz have been built from different manufactures. We will present measurements in CW as well as pulsed operation to characterize RF performance and mechanical behaviours of the two cavities. Whereas the slightly differences in fabrication did not affect the electromagnetic results, the mechanical properties (mechanical eigenreso-

nances, LFD) differed significant. To operate the cavities, ancillary systems (coupler, tuner, RF-control) were designed and tested, the results of which will be summarized.

MoP04: Niobium Sputtered QWRs
A. Porcellato, S. Stark, et al. (INFN-LNL)
Nb sputtered QWRs are a valid alternative to bulk Nb resonators. The reduced cost of the cavity is only one of the possible benefits. In ALPI, the superconducting linac for heavy ions operating at Legnaro where 52 cavities of this type are operating, we can also appreciate the insensitivity of their resonant frequency to pressure fluctuations over the liquid He bath. This leads to a very stable resonant frequency making unnecessary both the continuous cavity tuning by fast or "soft" tuner devices and the big enlargement of resonant bandwidth by strong over-coupling.
The first cavities are in ALPI since 1998. They are very reliable and easy to be put into operation and do not show any deterioration in performance with time. We have resonators that can operate (locked in phase and amplitude) at fields exceeding 7 MV/m, even though the operational average field is limited to 4.4 MV/m, since most of the resonators have been obtained by the refurbishing of the previously installed Pb/Cu QWRs, whose characteristics did not allow to take full advantage of the Nb sputtering process.

MoP05: Superconducting RFQs
G. Bisoffi (INFN-LNL)
At INFN-Legnaro the heavy ion injector PIAVE, based on superconducting RFQ resonators, is at an advanced stage of beam commissioning. The RFQs (SRFQ1 and SRFQ2), built in full Nb within a stiffening Ti jacket, are 0.8 m in diameter and 1.4 and 0.8 m long, respectively (the resonant frequency is 80 MHz). Beam bunching is separate. They are specified to work at a peak surface field of 25.5 MV/m, a value which was exceeded in the test phase and has been recently confirmed in on-line tests. Phase and amplitude locking, versus both microphonics and pressure variations of the liquid helium bath in which they are immersed, is an issue.
The two SRFQs have been used quite extensively since November 2004, for beam acceleration tests in PIAVE, with a high degree of reliability. A pilot beam of $^{16}O^{3+}$ was used in the tests, with a typical ion beam current of a few hundreds nA, received from an ECR ion source on a high voltage platform. The ion beam current could be raised up to a few electrical uA without any inconveniences. Beam tests with $^{132}Xe^{18+}$ were made too. The most recent results will be reported.

MoP06: Recent Progress in the Superconducting RF Program at TRIUMF/ISAC

R.E. Laxdal, K. Fong, M. Laverty, A. Mitra, R. Poirier, V. Zvyagintsev (TRIUMF)

A heavy ion superconducting linac is being installed at TRIUMF to increase the final energy of radioactive beams from ISAC. A first stage of 20MV consisting of five medium beta cryomodules each with four quarter wave bulk niobium cavities and a superconducting solenoid is being installed with commissioning scheduled for Dec. 2005. The cavities ($\beta_0 = 0.057$, 0.071) operate CW at 106MHz with design peak fields of $E_p = 30$ MV/m, $B_p = 60$ mT while delivering an accelerating voltage of 1.08MV at ~ 4 W power consumption. The cavities have been fully characterized for RF performance and are presently being mounted in cryomodules for an initial beam test in Dec. 2005. Two cryomodules have been tested at cold temperatures. A high beta cavity ($\beta_0 = 0.104$) for the next phase is presently in design. A weak phase lock loop technique is used to monitor the control loop phase noise to characterize system microphonics. The report will summarize all aspects of the program.

MoP07: Performance of Medium-beta and High-beta Elliptical Cavities

J. Ozelis (TJNAF)

(abstract not submitted)

MoP08: Physical and Mechanical Properties of Single and Large Crystal High-RRR Niobium*

G.R. Myneni (TJNAF)

High RRR bulk niobium SRF cavities are the building blocks of the latest and future particle accelerators, free electron lasers (FELs) and energy recovery linacs (ERLs). These cavities are fabricated from high purity (RRR) polycrystalline niobium sheets via deep drawing, e-beam welding and surface treatment to obtain high accelerating gradients and quality factors. However, the starting bulk RRR niobium properties are not yet optimized with respect to both cost reduction and achievement of ultimate performance. A major limitation in achieving the highest performance can possibly be attributed to imperfections at or near the grain boundaries. Recently, at Jefferson Lab single/large grain RRR niobium cavities are developed using customized RRR ingots with optimized amounts of impurities such as Tantalum and minimizing the interstitial contents (O, C, N and H). The new cavities are directly made from the sliced discs of the special ingots with large grains and significantly reduced grain boundaries rather than from rolled sheets. This new cavity fabrication process is expected to reduce not only the production cost of the cavities due to less complex processes but also will improve the ultimate cavities' performance due to reduced grain boundaries. In this paper physical and mechanical properties of the single/large grain high RRR niobium will be presented.

* This work was supported by the U.S. Department of Energy Contract No. DE-AC05-84ER40150.

MoP09: Performance of Large Grain and Single Crystal Niobium Cavities*

P. Kneisel, G.R. Myneni, G. Ciovati (TJNAF), J. Sekutowicz (DESY), T. Carneiro (Reference Metals Co.)

We have fabricated and tested several single and one multi-cell cavity made from large grain niobium of four different ingots.

Two cavities at a frequency of ∼2.2 GHz were made from single crystal sheets. For four single cell cavities of the HG and OC shapes, a 7-cell cavity of the HG shape - all resonating at 1500 MHz - and an ILC_LL single cell cavity at 1300 MHz large grain material was used.

We explored also different chemical polishing baths such as a 1:1:1 and a 1:1:2 buffered solution and explored the change of cavity performance as a function of material removal.

The results from these preliminary investigations will be reported.

∗ Work supported by the U.S. DOE Contract No DE-AC05-84ER40150.

MoP10: Seamless/bonded Niobium Cavities

W. Singer (DESY)

Technological aspects and performance of seamless cavities produced by hydroforming or spinning are analyzed and compared to cavities manufactured by standard procedure (deep drawing and EB welding). 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. The highest achieved accelerating gradient E_{acc} is up to now the same for both versions (ca. 40 MV/m.) Nevertheless further development of seamless cavities is desirable in order to avoid the careful preparation of parts for welding and get reliable statistics.

Technological problems of the fabrication of seamless cavities from bulk niobium are mainly solved thanks to the progress of last years. Fabrication of NbCu clad cavities from bimetallic tubes is an interesting option that gives to the seamless technique new opportunity. On the one hand it allows reducing the niobium costs contribution; on the other hand it increases the thermal stability of the cavity. The highest accelerating gradient achieved on seamless NbCu clad single cell cavities is the same as on bulk Nb cavities. Fabrication of multi cell NbCu cavities by hydroforming was recently proven.

MoP11: Progress in Nb-Cu Coating Techniques

S. Calatroni for the CERN Superconducting RF Community (CERN)

The first niobium-coated copper cavities were produced at CERN in the early eighties. The sputter technology was chosen, first in the pure diode configuration and subsequently in the magnetron configuration, which was adopted for the successful series production of the LEP and LHC cavities. In parallel, a lot of R&D effort was undertaken at CERN and other labs in order to understand the advantages and limitations of this technique. Some highlights of the present understanding will be given. Several new developments in the coating technique are being pursued around the world, which will be discussed together with their motivations.

MoP12: Hi-Tc: New Developments & Progress on Understanding the Mechanisms & Hope for the Future

T. Tajima (LANL)

Mechanisms of superconductivity, and RF and other properties of Hi-Tc materials such as YBCO and MgB_2 will be briefly reviewed. In addition, some new developments for the application of those materials to RF cavities and other fields will be shown with some emphasis on MgB_2 work.

Tuesday, July 12, 2005

Tuesday Morning: Oral Session

TuA01: Theoretical Advances in SRF*
A. Gurevich (University of Wisconsin)
An overview of mechanisms, which may determine the ultimate SRF performance not limited by extrinsic factors due to vortex penetration along grain boundaries, is given. First, generation of hyper sound waves by RF field, sound attenuation and geometrical acoustic resonances to the non-BCS residual resistance and the low-field Q slope are discussed. Then mechanisms of the high-field Q slope due to the nonlinear BCS surface resistance R_s in the clean limit are considered. For the AC amplitude H much smaller than the thermodynamic critical field H_c, the surface resistance $R_s(H)$ acquires a pairbreaking correction quadratic in H, while at higher H of the order of H_cT/T_c, the surface resistance $R_s(H)$ depends exponentially on H. Implications of these mechanisms for both uniform and non uniform thermal RF breakdown of high performance cavities are considered. In particular, the important effect of surface hotspots revealed by local temperature maps is addressed. Such hotspots initiated by local surface defects or/and magnetic field and hyper sound focusing expand as H increases, causing a strong high-field Q slope and triggering a global thermal breakdown at lower RF fields.
* Supported by DOE-HEP under grant DE-FG02-91ER40643.

TuA02: Advancement in Comprehension of the Q-slope for Superconducting Cavities
V. Palmieri (INFN-LNL)
Gap depression due to the depairing effect of a supercurrent is a basic and important mechanism that has been unjustifiably neglected in the theoretical treatment of surface resistance. The energy gap in the current-carrying state decreases of Fermi momentum, p_f, times the supervelocity, v_s, that is related to the magnetic field at the surface of superconductor. This effect crucially depends on mean free path and for such a reason strongly affects Nb coated Copper cavities. On the basis of fundamental concepts hence a simple explanation is also given for the effect of Q-rise versus field at low RF power.

TuA03: Review of Frontier Workshop and Q-Slope Results
G. Ciovati (TJNAF)
Over the last few years, a lot of progress has been made to produce field emission free niobium surfaces. Nowadays, the major limitation towards achieving the superconducting critical field in radio-frequency (RF) superconducting cavities made of bulk niobium of high purity is represented by the so-called "high field Q-slope" or "Q-drop". This phenomenon is characterized by a sharp decrease of the cavity quality factor, in absence of field emission, starting at peak surface magnetic field of the order of 100 mT. It has been observed that these losses are

usually reduced by a low-temperature "in-situ" baking, typically at 100-120°C for 24-48 h.
Several models have been proposed to explain the high field Q-slope and many experiments have been conducted in different laboratories to validate such models.
A three-day workshop was held in Argonne in September 2004 to present and discuss experimental and theoretical results on the present limitations of superconducting RF cavities. In this paper, we will focus on the high field Q-slope by reviewing the results presented at the workshop along with some new experimental data. In order to explain the Q-drop and the baking effect we will present an improved version of the oxygen diffusion model.

TuA04: Review of New Shapes for Higher Gradient
R.L. Geng (Cornell University)
The accelerating gradient (E_{acc}) achieved by superconducting RF cavities has increased steadily over the past decade. The surface magnetic field in high-gradient niobium cavities is approaching to the critical magnetic field $H_{c,RF}$, of niobium. $H_{c,RF}$ imposes a physical limit to the achievable gradient because superconductivity breakdowns into normal conductivity at $H_{c,RF}$. Reducing the ratio of the peak magnetic field to the accelerating gradient (H_{pk}/E_{acc}) of niobium RF cavities has been proposed as a principle for pushing the gradient envelope. Recent experiments have confirmed the validity of this principle. A lower H_{pk}/E_{acc} is possible by optimizing the cell shape of RF cavities. Two new shapes for higher gradient are being actively explored: the re-entrant shape at Cornell University and the low-loss shape by a DESY, JLab, KEK collaborative effort. Today's record accelerating gradient is 46 MV/m achieved by a re-entrant cavity. In this report, we will review the concepts and experimental developments of new shapes for higher gradients. The impact of new shapes on other important cavity parameters will also be examined.

Tuesday Morning: Student/Young Researchers Session

TuA05: High Current SRF Cavity Design

D. Meidlinger, T.L. Grimm, W. Hartung (MSU)

For high current applications, it is desirable for the cavity shape to have a low longitudinal loss factor and to have a high beam-breakup threshold current. This presentation briefly describes three different cavities designed for this purpose: a six-cell elliptical cavity for particles traveling at the speed of light, a two-cell elliptical cavity for subluminal particle speeds, and a single cell cavity which uses the TM012 mode for acceleration. SUPERFISH simulations predict the peak fields in both of the elliptical cavities will not exceed the TESLA values by more than 10% but both will have 28.7% larger apertures. The elliptical designs assume the bunch frequency equals the accelerating mode frequency. The beam pipe radius is chosen so that the cutoff frequency is less than twice that of the accelerating mode. Hence all of the monopole and dipole higher-order modes (HOMs) that can be driven by a Fourier component of the beam have low loaded Q values. This simplifies the problem of HOM damping. The TM012 cavity is predicted to have much higher peak fields than a pi-mode elliptical cavity, but offers potential advantages from its simplified shape; it is essentially a circular waveguide with curved end plates. This basic shape results in easier fabrication and simplified tuning.

TuA06: Pulsed Operation of SC Spoke Cavities

Z. Conway (University of Illinois Urbana-Champaign)

(abstract not submitted)

TuA07: ERL 5-cell cavity design for high currents

R. Calaga (BNL)

(abstract not submitted)

TuA08: New Results on High Field Q-slope

G. Eremeev (Cornell University)

(abstract not submitted)

TuA09: SC Cavities at 3.9 GHz

T. Koeth (FNAL)

(abstract not submitted)

TuA10: Surface Studies of Niobium Chemically Polished under Conditions for SRF Cavity Production*

H. Tian, M. Kelley (College of William & Mary / Jefferson Lab), C. Reece (TJNAF), L. Plucinski, S. Wang, K. Smith (Boston University)

The surface of polycrystalline Nb etched at different flow rates by 1:1:2 BCP chemical solution was studied morphologically and chemically by profilometry, AFM, laboratory XPS and variable photon energy XPS on the soft x-ray undulator beamline X1B at National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory (BNL). The results show that the different flow rate causes the different surface chemistry. Compared with static solution, the surface Nb_2O_5 layer is thicker for the flowing sample but the surface roughness shows no significant change. The variation of the Nb 3d peaks, which were measured by using variable photon energy XPS, illustrates the power of that approach, and motivates future study.

* The Boston University program is supported in part by the Department of Energy under DE-FG02-98ER45680. The X1B endstation is funded by the U.S. Army Research Office under Grant No. DAAD19-01-1-0364. The NSLS is supported by the U.S. Department of Energy, Division of Materials and Chemical Sciences. The Jefferson Lab work is supported by the U.S. Department of Energy under DE-AC05-84ER40150.

TuA11: General Automation of LLRF Control for Superconducting Accelerators

A. Brandt, V. Ayvazyan, S. Simrock (DESY), W. Cichalewski, B. Koseda (TUL-DMCS)

Future and present superconducting linear accelerator projects based on superconducting resonators have tight requirements on field stabiliy that vary with their application. The Vacuum Ultra Violet Free Electron Laser (VUV-FEL) that is currently commissioined at DESY, Hamburg, requires 10^{-3} in amplitude and 0.1 degree in phase. The upcoming x-ray Free Electron Laser (XFEL) is even more demanding by one order of magnitude. Additionally, these machines need to provide a high reliability and availability, since light sources serve as user facilities. Facing the large number of RF stations as for the case of an international linear collider, this is even more challenging. Therefore, a high degree of automation is mandatory for the Low Level RF (LLRF) control in order to accomplish for these demands. At the VUV-FEL, an automation framework based on the techniques of finite state machines has been developed and tested. It provides already a number of automated procedures that improve the operation of the VUV-FEL. It is a design goal to develop a framework that is general enough to be applied to future accelerator projects.

TuA12: New Magnetron Configuration for Nb onto Cu

G. Lanza, A. Frigo (INFN-LNL / University of Padua), H. Padamsee (Cornell University), V. Palmieri (INFN-LNL / University of Padua), D. Tonini (University of Padua)

Niobium sputtered film microstructure and morphology, and consequently its superconducting properties, strongly depend on target-substrate deposition angle. This dependence is confirmed by X-ray diffractometry, AFM analysis, magneto-optical images and electrochemical impedance spectroscopy.

In order to improve the Nb film quality, we pursue two main ideas: making niobium atoms impinging perpendicularly the substrate surface and promoting the effect of plasma bombardment of the growing film.

Therefore, three different magnetron configurations are under development. The effect of Nb atoms arriving perpendicular to the substrate is explored either by using a cathode that follows the cavity shape or by increasing the plasma confinement efficiency with a target parallel to the magnetic field lines. An unbalanced magnetron configuration has been tested in order to induce a plasma washing effect on the growing film. This is done by using two external coils placed all around the beam tubes, above and below the cell.

The removal of adsorbed impurities from the film surface and the increase of the film density is investigated by a bias third electrode that promotes the positive ions bombardment of the growing film. A mixed bias-magnetron has been built using a positively charged metal grid positioned all around the cathode.

TuA13: A-15 Superconductors - Alternative to Niobium for RF Cavities

S. Deambrosis, G. Keppel, V. Palmieri, V. Rampazzo, C. Roncolato (INFN-LNL), R.G. Sharma (Nuclear Science Centre, New Delhi)

High values of T_c and large mean free path are mandatory requirements for any superconductor to be an alternative materials to niobium for RF applications. In our study on A15 intermetallic compounds, we investigated three systems maybe suitable for application: Nb_3Sn, V_3Si and Mo_3Re.

For the Mo-Re system, under varying conditions of depositions and anneals, we studied the three compositions $Mo_{75}Re_{25}$, $Mo_{60}Re_{40}$ and $Mo_{38}Re_{62}$. Micron scale thick films were deposited by DC magnetron sputtering technique. We obtained T_c values of 12 K for the 60:40 composition which indicates a bcc structure with a lattice parameter of 3.1207 Angstrom. Attempts are made to deposit films at elevated temperature around 1000 C and try to synthesize films of A15 phase which is expected to have a T_c of 15 K.

Work on the ubiquitous Nb_3Sn has been developed by following a molten tin diffusion method for converting the Nb cavity surface to Nb_3Sn. We were able to control the growth of Nb_3Sn layer from 10 μm to 25 μm without a trace of pure tin on the cavity surface. The stoichiometry across the 25 μm Nb_3Sn layer is found to be uniform within 4%. The grain growth is achieved by prolonging heating and at elevated temperature. Preliminary results show T_c values of 17.5 K and detailed studies are in progress.

Work on V_3Si coating, based on the reactive thermal diffusion technique in Silane atmosphere, provided T_c values up to 17 K.

TuA14: Flux Gate Magnetometry Applied to Cavities

C. Bonavolonta (INFN-LNL, CRS Coherentia), M. Valentino (CRS Coherentia), V. Palmieri (INFN)

In this work an electromagnetic non invasive and contact-less technique using flux gate gradiometer is proposed. Static and dynamic measurement of the magnetic field distribution during the electro polishing of the copper surface has been performed.
To evaluate the capability of the flux gate magnetometry applied on the electropolishing of metals surface, rectangular electrolytic cells of different dimensions, with copper electrodes have been fabricated. This simple shape of the cells are chosen to modelling them by a short dipole, a necessary approximation to calculate the current density distribution via electromagnetic inversion of the measured magnetic field signals.
Static and dynamic measurements of the in plane magnetic field components and successively an electromagnetic inversion of the magnetic field distribution along the cells have been carried out. Changing the voltage across the cells and setting the gradiometer on the electrodes, the magnetic characteristic curve H-V of the electrolytic cells was detected.
The advantage due to the application of the magnetic field monitoring respect to the current-voltage technique concerns the possibility to obtain a local information, in a non invasive way, of the polishing process over the Copper and Niobium surface even when its shape could be very complicated. In conclusion flux-gate magnetometry could be considered as a promising diagnostic technique to assert the quality control of the copper surface during the fabrication of the rf cavities.

TuA15: Input Coupler Development for Superconducting Cavity 500 kW CW Power Feed

M.A. Gusarova, A.A. Krasnov, M.W. Lalayan, N.P. Sobenin (MEPHI), A.A. Zavadtsev, A.D. Zavadtsev (Introscan, Ltd.)

The coaxial-type input coupler for Energy Recovery Linac injector cavity simulation results are presented. This device is to feed the superconducting cavity with 150 kW RF power in continuous wave regime at 1.3 GHz operating frequency. The thermal simulation was done for the modified coupler able to transmit the RF power up to 500 kW. The basic coupler design was changed thus lowering the heat load to injector cryogenic system. Coaxial type design with external Q_{ext} factor adjustment with variable capacitive antenna was considered.

TuA16: Piezoelectric Stack Based System for Lorentz Force Compensation

P. Sekalski (Technical University of Lodz - DMCS / DESY), S. Simrock (DESY)

The superconducting cavities based on TESLA technology will operate at high gradients up to 37 MV/m. However, during pulsed operation, its resonant frequency is changing due to the Lorentz force. A fast tuning system, which contains smart materials such as a piezoelectric stack and a magnetostrictive rod, is needed. Simultaneously, this tuner must be fully integrated with stepper motor and its gearbox, used for pretuning stage (commonly named slow tuner). The paper presents the current status of development of a tuner system based on piezoelectric elements. In particular, the estimation of the mechanical preload force applied to the piezostack at LHe temperature is presented. Furthermore, the control loop investigations are described.

Tuesday Aternoon: Poster Session

TuP01: A Comparison of Q-Slope Models and Data in Bulk Nb SRF Cavities

P. Bauer, N. Solyak (FNAL), G. Ciovati (TJNAF), A. Gurevich (University of Wisconsin), L. Lilje (DESY), H. Padamsee (Cornell University), B. Visentin (CEA-Saclay)

Very powerful RF cavities are now being developed for future large-scale particle accelerators using niobium superconductor. Todays prototype cavities operate in RF surface magnetic fields of up to 180 mT. This remarkable achievement is the result of a successful worldwide technology development effort over the last decades. The basic model for Q-slope in SRF cavities, i.e. the reduction of the cavity quality factor with increasing operating electric and magnetic fields, is the so-called thermal feedback model. The exponential dependence of the BCS surface resistance on temperature, in feedback with the dependence of the RF power dissipation on the surface resistance ultimately leads to thermal runaway (thermal quench) of the RF exposed surface. Before investigating further the high field surface resistance it is important to understand better the basic Q slope (or surface resistance increase with applied RF field amplitude) due to thermal feedback. This paper compares calculations of Q-slope on the basis of the BCS resistance and the thermal feedback model with experimental data from cavities. The discussion encompasses a wide variety of cavities operating at different frequencies and temepratures and produced by at DESY, CEA-Saclay, J-Lab, Cornell and Fermilab. Contrary to similar, previous publications, we also included the non-linear correction to the BCS resistance such as recently discussed by A. Gurevich in our model.

TuP02: Analysis of the Medium Field Q-Slope in Superconducting Cavities made of Bulk Niobium

G. Ciovati (TJNAF), J. Halbritter (FZK Karlsruhe)

The quality factor of superconducting radio-frequency cavities made of high purity niobium is observed to decrease for increasing RF field in the medium field range (peak surface magnetic field between 20 and 80 mT). The causes for this effect are not clear yet. The dependence of the surface resistance from the peak surface magnetic field is often observed to be linear and quadratic. This paper will present an analysis of the medium field Q-slope data measured on cavities treated with buffered chemical polishing (BCP) at Jefferson Lab, as function of different treatments such as post-purification and low temperature baking. The data have been compared with a model involving a combination of the thermal feedback effect and of hysteresis losses due to "strong-links" formed on the niobium surface during oxidation.

TuP03: Change In High Field Q-Slope By Anodizing Of The Baked Cavities

G. Eremeev, H. Padamsee (Cornell University)

The high field Q-slope is a known effect of degradation of the Q at high fields without X-rays. The low temperature baking reduces the Q-slope by modifying the RF Nb layer. The goal of the experiments was to determine the depth of "baking modified niobium" responsible for the improvement in the high field Q-slope. We tried to approach this goal by anodizing (electrolytic "oxidizing") baked Nb cavities. By growing thicker oxide we push effective RF layer deeper into the bulk. Reported here are the results on these experiments supported by temperature maps.

TuP04: In-situ Investigation of the Nb/oxygen Interfaces - Correlation with the Properties of the Nb RF Superconducting Cavities

M. Delheusy (Max-Planck-Institut fuer Metallforschung/CEA), C. Antoine (CEA), A. Stierle, H. Dosch (Max-Planck-Institut fuer Metallforschung)

The effect of mild thermal treatments (120°C-300°C, UHV conditions) on the depth-distribution of interstitial oxygen impurities as well as on the atomic structure at the Nb(110)/oxide and Nb(100)/oxide interfaces have been investigated by x-ray surface sensitive techniques. In-situ diffuse scattering, crystal truncation rods and x-ray reflectivity measurements have been performed under grazing incidence geometry. In particular, we have shown the occurrence of a specific diffuse scattering as the signature of isolated interstitial oxygen atoms randomly distributed in the vicinity of the niobium surface (3-500 nm, nanometer resolution). Their behaviour has been monitored upon the various heat treatments, along with the evolution of the oxide layer.

TuP05: First Experimental Results on Fast Air-Baking. A First Step towards the Baking Process Optimization for Cavity Mass Production

B. Visentin, Y. Gasser, J.P. Charrier (CEA-Saclay)

High gradient performances of bulk niobium cavities go through a low-temperature baking (110°C/60h) following the surface chemical treatment by electropolishing. Baking suppresses the high field Q-slope while electropolishing allows to push away to higher values the quench limitation. These both cavity treatments are not still physically understood in spite of a lot of theories push forward to explain the experimental observations [1].

Baking under ultra high vacuum conditions (UHV-Baking) has been first applied [2]; later baking under air at the atmospheric pressure (Air-Baking) has also demonstrated its efficiency [3]. In this paper we will report on the Fast Air-Baking (145°C/3h). These first experimental results have two major consequences:

$*$ The oxygen diffusion appears as the main reason to explain the high field Q-slope suppression and that opens a new way towards the Q-slope understanding [4].

∗ This method brings a solution for the large-scale cavity preparation (ILC Project) with the temporal shortening of the baking linked to the procedure simplification through the process integration in the clean room preparation.

[1] Proceedings of SRF2003 Workshop Travemuende (September 2003) TuO 01
[2] Proceedings of EPAC98 Stockholm (June 1998) TUP 07B
[3] Proceedings of SRF2003 Workshop Travemuende (September 2003) MoP 19
[4] Proceedings of the Argonne Workshop on Pushing the Limits of RF Superconductivity (September 2004)

TuP06: Atom-Probe Tomography Analyses of Niobium Superconducting RF Cavity Materials

J. Sebastian, D.N. Seidman, K. Yoon (Northwestern University), P. Bauer, T. Reid, C. Boffo (FNAL), J. Norem (ANL)

We present the first atom-probe tomographic (APT) measurements of niobium superconducting RF (SCRF) cavity materials. APT involves the atom-by-atom dissection of sharp niobium tips, along with their niobium oxide coatings, via the application of a high pulsed electric field and the measurement of each ion's mass-to-charge state ratio with time-of-flight mass spectrometry. The resulting atomic reconstructions, typically containing at least 10^5 atoms and with typical dimensions of 10^5 nm^3 (or less), show the detailed, nano-scale chemistry of the niobium oxide coatings, and of the underlying high-purity niobium metal. Our initial results show a nano-chemically smooth transition through the oxide layer from near-Nb_2O_5 at the surface to near-Nb_2O as the underlying metal is approached (after ∼10 nm of surface oxide). The underlying metal, in the near-oxide region, contain a significant amount of interstitially dissolved oxygen (∼5-10 at.%), as well as a considerable amount of dissolved hydrogen. The experimental results are interpreted in light of current models of oxide and sub-oxide formation in the Nb-O system.

TuP07: Study of Gas Cluster Ion Beam Surface Treatments for Mitigating RF Breakdown

D. Swenson, E. Degenkolb (Epion Corporation), Z. Insepov (ANL)

Reaching higher gradients in SRF cavities has required ever more stringent surface preparation, and yet the field emission of electrodes remains orders of magnitude greater than the prediction of the Fowler-Nordheim theory. We are investigating surface processing with high-energy Gas Cluster Ion Beams (GCIB), a new technology that achieves an atomic level of smoothness on planar and non-planar surfaces, to increase the RF breakdown strength of RF cavities and electrodes. GCIB smoothing of Nb, Cu, stainless steel and Ti electrode materials have been tested using beams of Ar, Ar+H_2, O_2, N_2, Ar+CH_4, or O_2+NF_3 clusters with accelerating potentials up to 35 kV. Smoothing effects were evaluated using SEM and AFM imaging, hardening was measured using a nano indenter, and oxide thickness was determined with XPS. Fourier analysis of the AFM images shows that smoothing effects extend from atomic levels up to 2 μm. High energy Ar GCIB removed an isolated asperity on Cu that was

35 nm high and 350 nm across, and greatly attenuated 200 nm wide polishing scratch marks on Stainless Steel and Ti. Etching using chemically active clusters like NF_3, reduces the grain structure of Nb used for SRF cavities. The field emission of a GCIB processed photocathode was a factor of 10^6 less than an untreated photocathode.

TuP08: Investigation of Oxide Layer Structure on Nb Surfaces Using a Secondary Ion Mass Spectrometer*

A. Wu (TJNAF)

Oxide layer structure on the surfaces of niobium (Nb) can be studied in details by continuously monitoring peaks of the secondary ions of Nb and its relevant oxides as a function of time during depth profiling measurements employing a secondary ion mass spectrometer (SIMS). This is based on the fact that different oxides have different cracking patterns. This new approach is much simpler and easier for studying oxide layer structure on Nb surfaces than the conventional approach through deconvolution of oxide peaks obtained from an x-ray photoemission spectrometer. Eventually it can be developed into an in-situ tool for monitoring the oxide layer structure on Nb surfaces prepared by various procedures. Preliminary results of SIMS measurements on the surfaces of Nb samples treated by buffered electropolishing and buffered chemical polishing will be reported.

* This manuscript has been authorized by SURA, Inc. under Contract No. DE-AC05-84ER-40150 with the U.S. Department of Energy.

TuP09: SIMS Analysis of NbO on Nb Samples of Different Oxygen Content

J. Kaufman, H. Padamsee (Cornell University)

Using a newly installed SIMS instrument at Cornell LEPP, we have carried out depth profile measurements on NbO/Nb content for various Nb samples: low and high RRR, inside an e-beam weld and in the heat affected zone, 100 C baked and unbaked samples prepared by EP and by BCP. High intensity and low intensity argon beams were used.

TuP10: Surface Roughness vs. Grain Size Analysis on Nb Samples

J. Kaufman, H. Padamsee (Cornell University)

Using a profilometer we have measured the surface roughness produced by BCP for polycrystalline Nb samples of various grain sizes. We find that the roughness increases with grain size.

TuP11: DC Field Emission Scanning Measurements of Electropolished Nb Samples

A. Dangwal, G. Mueller (University of Wuppertal)

Enhanced field emission (EFE) from metal surfaces is one major obstacle which has to be overcome for the high gradient operation of superconducting niobium cavities. Accelerating gradients up to 40 MV/m corresponding to peak electric surface fields of about 80 MV/m at the cavity irises are envisaged for future accelerators like the XFEL at DESY and the ILC. In order to avoid EFE in these cavities reliably, typical field emitters on Nb surfaces resulting from actually used surface preparation techniques must be identified. Since electropolished Nb surfaces are considered to improve the achievable cavity fields, we have started to investigate Nb samples of 28 mm in diameter which have been electropolished at Saclay by means of the DC field emission scanning microscope (FESM). This apparatus has recently been modernized with new hardware components (Keithley picoamperemeter with 1 kHz rate, FUG power supply with PID regulation) and software programs (LabVIEW based), resulting in fast voltage scans of large samples thus improving the statistics of the FESM measurements. First results of voltage scans up to 120 MV/m and local measurements are presented here. Five different anodes of tip diameters ranging from 300 μm to 2 μm are used for the complete series of measurements. A statistical overview of the density of emitters for applied electric fields, varying from 40 MV/m to 120 MV/m, has been made. In one particular scanned area of (5×5) mm^2, not a single emitter is observed up to the field level of 120 MV/m. On the other hand, in a scan of an adjacent area of (7.5×7.5) mm^2 at the same electric field level, a high emitter density of 29/cm^2 is observed. Reproducibility of the emitters in the successive scans is observed clearly. The zoomed in scans of some emitters, with the anodes of diameters 10 μm and 2 μm, show some interesting images, which might give an idea of the physical appearance of the emitters. Local measurements for voltage calibration and FN curves have been done on three particularly chosen emitters. The β values for the investigated emitters lie in the range of 32 to 386, while the calculated S-parameters are of the order of 10^{-18} to 10^{-23} cm^2, which are too low to be interpreted as the size of the emitters. High resolution SEM pictures of some emitters will be presented.

TuP12: Use of Precision X-Ray Diffraction, Interstitial Gas Fusion Analysis and Squid Measurements to Investigate CVD- and Bulk-Niobium Samples

L.N. Hand, J.P. Sinnott, M.S. Weathers (Cornell University), W.R. Frisken (York University)

Niobium produced by chemical vapor deposition (CVD) is compared to two bulk niobium samples. We report our measurements of impurity concentrations, lattice constant, and values of T_c and H_{c2}.

X-ray measurements of moderate precision, taken before and after vacuum furnace annealing, indicated a greater reduction in the lattice constant of the CVD sample than in the lattice constant of the bulk sample. Qualitative Secondary Ion Mass Spectroscopy (SIMS) revealed the CVD sample was relatively rich in hydrogen before annealing. The annealing did not eliminate the hydrogen from either sample, but greatly reduced it in the CVD sample.

Impurity concentrations of H, O, C, N were calibrated by commercial interstitial gas fusion analysis (IGF) of the two bulk samples. Using a precision comparison of nearby Bragg reflections with known single crystals of silicon and

sapphire, the relationship between interstitial impurities and lattice constants is examined, with emphasis on the hydrogen content and its effect on the lattice. Estimates of the RRR for the bulk samples are calculated from the IGF results. Magnetic measurements in the superconducting state were made with a SQUID magnetometer. T_c and H_{c2} results for the CVD sample, before and after annealing, are reported and compared to pure bulk niobium.
As a by-product of this work, we propose a non-destructive method for determining hydrogen content which should ultimately be able to detect hydrogen concentrations of >0.2 at.% in accelerator-grade niobium.

TuP13: Vertical and Horizontal Test Results of TESLA Cavities for BESSY

S. Bauer, M. Pekeler (ACCEL), W. Anders, J. Knobloch (BESSY), W.-D. Moeller (DESY)

In order to demonstrate CW operation of TESLA cavities for a possible FEL at BESSY, two TESLA cavities were produced and prepared for vertical test. During the vertical test accelerating gradients above 20 MV/m with Q above 10^{10} were achieved. One cavity was furnished with helium vessel, high power coupler, HOM couplers and tuner and tested in the horizontal cryostat HoBiCaT at BESSY.

TuP14: Recent Results of Testing 3-cell 3.9 GHz Accelerating Cavity at Fermilab

L. Bellantoni, M. Foley, H. Edwards, T. Khabiboulline, D. Mitchell, A. Rowe, N. Solyak (FNAL)

A superconducting, 3.9 GHz, third harmonic, accelerating cavity was proposed to improve the beam quality in the TTF photoinjector. Fermilab developed, built, and tested several prototypes, including two copper 9-cell cavities and one niobium 3-cell cavity. In the 3-cell cavity, $E_{acc} = 19$ MV/m, $B_{peak} = 103$ mT, and $R_{res} = 6$ nOhm were achieved at 1.8K without field emission. The accelerating gradient was likely limited by thermal breakdown. The quench limit was almost independent of temperature, and can be explained by the field dependence of the residual resistance, which was observed in the experiment. In this paper, we discuss the status of the cavity development and our future plans.

TuP015: Design of Half-Reentrant SRF Cavities

M. Meidlinger, T.L. Grimm, W. Hartung (MSU)

As superconducting niobium cavities achieve higher gradients, there is a foreseeable limit as the peak surface magnetic field approaches the critical magnetic field, causing the cavity to quench. Several superconducting niobium cavity designs will be presented that reduce B_{pk}/E_{acc} at least 10% below that of a TESLA mid-cell. The cavity designs are “half-reentrant”, meaning one side of the cavity is reentrant, while the other side is a conventional elliptical shape. The advantage of this design is that one gains some of the performance im-

provement associated with a reentrant cavity while still making it possible for chemicals to drain from the cavity when it is turned on end. One such preliminary design has the following improvements over TESLA: B_{pk}/E_{acc} drops 15% and (R/Q)*G increases 22% while k_{cc} is maintained at 1.87%. This lower B_{pk}/E_{acc} comes at the expense of a 32% higher E_{pk}/E_{acc} which is however not a theoretical limit.

TuP16: RF Design of a Single Cell Superconducting Elliptical Cavity with Input Coupler

A. Roy, A.S. Dhavle, J. Mondal, K.C. Mittal (Bhabha Atomic Research Centre)

A prototype single cell elliptical cavity for accelerating 100 MeV high intensity proton beam has been designed. The cavity shape is optimized for cavity $\beta = 0.42$ at a frequency of 700 MHz. using SUPERFISH code. Calculated Q value of the cavity is 0.61×10^9 at 4.2 K. A rigorous analysis of trapped modes via eigenmode and time domain simulation has been done in the frequency range 2-5 GHz using CST MICROWAVE STUDIO. The result shows a Q value of the order of 10^3 for trapped modes. This analysis also removes the ambiguity of some candidates which are treated as trapped modes in closed cavity model. An input power coupler is also designed on the basis of operating frequency and source power. It has been designed taking into account the advantages of both the waveguide type and coaxial type coupler. The optimized coupler parameters are calculated that provide perfect matching ($Q_0 \approx Q_{ext}$) under different operating conditions. For superconducting coupler with 20 mA beam load the optimized coupler position w.r.t. cavity centre is 13 cm, penetration depth is 0.2 cm and the evaluated $Q_{ext} = 1.39 \times 10^6$. The calculated resonance frequency under beam loading condition due to the presence of coupler is 699.807 MHz.

TuP17: Structural Analysis of Single Cell Superconducting Elliptical Cavity with Static Lorentz Force

A. Roy, J. Mondal, K.C. Mittal (Bhabha Atomic Research Centre)

A single cell $\beta = 0.42$, 700 MHz superconducting elliptical cavity has been designed for a high current proton accelerator. The structural behavior of a single cell superconducting elliptical cavity has been studied by finite element structural analysis. The static Lorentz force detuning of the cavity has been studied numerically with SUPERFISH code at accelerating gradients of 5 MV/m and 10 MV/m. The calculated maximum Lorentz forces for 5 MV/m gradient are 302 Pa acting outward near the cell equator and 742 Pa acting inward at the cell bore. Cavity shape deformations are calculated both for copper and niobium with different material thicknesses. For 3 mm copper at 5 MV/m gradient the calculated frequency shift was -243 Hz while for 5 mm copper it reduced to -86 Hz. When niobium is concerned 3 mm thickness gives -212 Hz frequency shift and 5 mm thickness has a frequency shift of -75 Hz. For 5 mm niobium at 10 MV/m gradient the frequency shift was -344 Hz. Three dimensional finite element models were used to determine the cavities' mechanical resonance frequencies. The lowest frequency observed for 5 mm copper was 81 Hz when one end of the beam tube was held rigidly fixed in all coordinates and other beam tube free. The lowest frequency increased to 281 Hz when both end of the beam tube were kept fixed. The cavity shape was found to meet all design requirements without an annular stiffener if fabricated from 5 mm thick material operated at 5 MV/m accelerating gradient. A stiffener will be required if operated at more than 5 MV/m accelerating gradient.

TuP18: Optimization of Wall Thickness of Superconducting 700 MHz Bulk Niobium and Niobium Coated OFHC Copper Cavities by Thermal/Structural Analysis

J. Mondal, A. Roy, K.C. Mittal (Bhabha Atomic Research Centre)

A prototype single cell superconducting elliptical cavity of $\beta = 0.42$, 700 MHz has been designed for high current proton accelerator. A detailed thermal and structural analysis is carried out on bulk niobium and niobium-coated copper cavities using the code COSMOS. The cavities are cooled down from 300K to 4.2K with a convective boundary condition at the outer surface and a radiation boundary condition at the inner metal-vacuum interface. The corresponding thermal load is then coupled with the inward liquid He pressure saturated at 1 atm. at the outer surface of the cavity. With these loads the final structural analysis of the cavity with different wall thickness has been carried out. Finally the shift in the resonance frequency due to the structure deformation is calculated using SUPERFISH code. The results of the niobium and niobium-coated copper cavities are compared with respect to resonance frequency shift, transit time factor, E_{pk}/E_{acc} on surface, H_{pk}/E_{acc} on surface and effective maximum stress value on the surface. The optimized cavity wall thickness is 5 mm. It provides adequate structural stiffness and the final frequency shift is within the band of 650-750 kHz. In order to bring down the frequency shift within the bandwidth (BW) of the superconducting cavity and to provide additional structure stiffness, a conical stiffener has been incorporated and analyzed with respect to the different positions at the cavity wall to see its effect on the frequency shift and on the effective stress value. The lowest frequency shift of 64 KHz was obtained when the stiffener is fixed at the middle of the cavity wall. In order to reduce the frequency shift further and bring it at acceptable level (below 504 MHz i.e. the BW of a loaded cavity with 20 mA beam current) a frequency tuner is necessary.

TuP19: Design and Analysis of 45 MV/m Superconducting Structures

Y. Morozumi, T. Higo, K. Saito, F. Furuta, Y. Higashi, T. Saeki, H. Yamaoka (KEK), J. Sekutowicz (DESY), K. Ko (SLAC)

We have been developing high gradient superconducting structures to be operated at 45 MV/m. We chose a cavity shape with a minimum available ratio of surface magnetic field to accelerating gradient and designed 9-cell structures aiming at a maximum gradient toward 50 MV/m, a theoretical limit set by the critical surface magnetic field around 1800 Oe. We simulated the structures electromagnetically and mechanically to obtain detailed analysis data for fabrication and tuning. The first four 9-cell Nb structures will soon be completed and tested.

TuP20: Fabrication of Four 9-cell IHCIRO High-Gradient Cavities for the R&D of ILC Accelerator in KEK

T. Saeki, F. Furuta, K. Saito, H. Inoue, Y. Morozumi, Y. Higashi, T. Higo, T. Yamaoka, K. Ueno, Y. Sohn, K. Ko, J. Sekutowicz (KEK, PAL, DESY, SLAC)

After the first ILC Workshop in KEK in November 2004, the Working-Group 5 (WG5) Asia made a plan to fabricate four 9-cell high-gradient cavities in LL-shape for Super-conductivity Test Facility (STF) in KEK, where these cavities will be installed in a cryostat and operated at 45 MV/m to accelerate real electron beams. These four cavities are designed as having the low H_p/E_{acc} ratio of 36 Oe/(MV/m), and thus the high gradient of Eacc $\sim$51 MV/m is expected in the best case. We named the cavity as ICHIRO after the famous baseball player: ICHIRO's back number 51.
This paper describes the status of the fabrication of these four 9-cell ICHIRO cavities as well as discusses about the dimensional deviations of fabricated cavities from the design values.

TuP21: Mechanical Structure Analysis for ICHIRO 9-Cell Cavity

H. Yamaoka, Y. Higashi, Y. Morozumi, T. Higo, K. Saito (KEK)

A high gradient superconducting cavity so called ICHIRO 9-cell cavity is being developed in KEK. In the mechanical design, several kinds of calculation are required: cavity deformation due to Lorentz stress, the resonant frequency shift, spring constant of cavity in the axial direction, stiffness of He base plates and so on. Another important issue is thermal stress in the cooling down to 2K. In this paper, analysis results of mechanical structure with ICHIRO 9-cell cavity are described.

TuP22: Field Profile Measurement of the $3\frac{1}{2}$ Cell SRF Gun

A. Arnold (Dresden University of Technology), H. Buettig, D. Janssen, P. Murcek, J. Teichert (Research Center Rossendorf)

The paper describes the development of a fully PC-controlled bead-pull measurement device based on LabView software. The device is part of a cavity tuning test stand and has been used successfully to measure the field profile and the shunt impedance of the prototype Nb-cavities for the $3\frac{1}{2}$ cell SRF-Gun project at FZ-Rossendorf.

TuP23: Status of the $3\frac{1}{2}$ Cell SRF Gun Project in Rossendorf

F. Staufenbiel, H. Buettig, P. Evtushenko, D. Janssen, U. Lehnert, P. Michel, K. Moeller, C. Schneider, R. Schurig, J. Teichert, R. Xiang (Forschungszentrum Rossendorf), J. Stephan (IKS), W.-D. Lehmann (IFE), T. Kamps, D. Lipka (BESSY), I. Will (Max-Born-Institut), V. Volkov (Budker Institute of Nuclear Physics)

This paper describes the current status of the $3\frac{1}{2}$ cell SRF gun. The SRF photo injector will produce short pulses with high bunch charges and low transverse emittance like the traditional photo injector. The requirement for the ELBE superconducting electron linear accelerator is to provide low emittance electron beam with 1 mA current and 9.5 MeV energy. Additionally, it will easily operate in the CW-mode caused by the low RF power losses in the superconducting material. This is an exceptional property of the mid infrared ELBE-FEL to work in such a regime. Therefore, the normal conducting copper cathode must be cooled by liquid N_2 in order to preserve the temperature of the cavity at 2 K. The estimated power input from the RF field into the cathode amounts 10 W. First results of temperature distributions on the cathode respectively the cooling system by a heat load of 10 W are presented.

TuP24: Exponential Decayed Pulse Incident Power Measurement Formulae for a Superconducting RF Cavity without Beam Load

S. An (SNS), H. Wang (TJNAF)

Superconducting RF (SRF) is an increasingly important branch of accelerator physics and technology because it heightens accelerating performances and lowers operating expenses. The normal method for evaluating a SRF cavity performance is through the low power and the high power measurements without a beam load. At present, the equations for square incident power pulse are the most popular formulae for the SRF cavity pulsed mode measurements. In practice, incident power may not be exactly square pulse. To understand cavity behavior and performance more accurately, in this paper, the SRF cavity's measurement equations for an exponential decayed pulse incident power are developed from a series equivalent circuit. The calculated result can be directly compared with the experimental data of SNS cavities obtained from the Cryomodule Test Facility (CMTF) at Jefferson Lab.

TuP25: Preliminary Study of Bulk Niobium Superconductive Photonic Bandgap Accelerating

A. Andreone, M. Masullo, C. Roncolato, S. Stark, D. Tonini, V. Palmieri, V.G. Vaccaro, D. Zafiropoulos (INFN-LNL)

Photonic Band Gap (PBG) structures can be designed and realized to build quasi monomodal accelerating cavities operating in the microwave region. In a 2D PBG a periodic pattern of metallic rods arranged in a hexagonal lattice reproduces for the electric field the conditions existing for the electrons in a real crystal. PBG structures are characterized by a bandgap, i.e. a frequency region in which field propagation is forbidden. Introducing a defect in the structure,

i.e. a missing rod, there is a propagation mode localized inside the bandgap, this "defect mode" determines an allowed state inside the bandgap surrounded by a region in which no propagating modes can exist and can be excited in order to create an accelerating field inside the cavity. In this paper we present the preliminary results for prototypes with a defect mode localized at 6 GHz. Cavities present a sharp resonant peak localized at the defect and no high order modes in the frequency range covered by the power supply.

TuP26: High Electric Fields in RF Cavities

J. Norem, Z. Insepov (ANL), P. Bauer (FNAL), D.N. Seidman, J. Sebastian, K. Yoon (Northwestern University)

Field emission in cavities requires electric fields that can be high enough to damage materials. We outline a model of breakdown and field emission from local asperities, and show how electric field effects, (field emission of electrons, field evaporation of ions, ultimately fracture), can limit accelerating fields. Although based on data from copper cavities and preliminary results from atom probe tomography experiments, the model seems to be generally valid for DC to 30 GHz, 10^{-11} to 10^5 Torr, different materials and temperatures, secondary emitters, strong magnetic fields, atom probe data, and the variety of surfaces encountered during copper cavity conditioning. We believe studies of normal materials can help to understand mechanisms operating in SCRF, such as fracture, field emission and evaporation effects, control of the surface, and surface metallurgy.

TuP27: X-Ray Imaging of Superconducting Radio Frequency Cavities

S.E. Musser, J. Bierwagen, T.L. Grimm, W. Hartung (MSU)

The goal of this research is to develop an improved diagnostic technique to locate field emission sources in superconducting radio frequency cavities. The present technique can be used after the cavities are installed in an accelerator, unlike existing techniques such as temperature mapping. Field emitted electrons are accelerated by the RF field and strike the cavity walls, producing Bremsstrahlung x-rays. The locations of the x-ray sources can be determined using a collimated sodium iodide detector moving along the cavity outside the cryostat. The sodium iodide detector measures the energy spectrum of the x-rays, with the maximum x-ray energy being equal to the kinetic energy of the impacting electrons. A particle tracking code is used to infer the locations of the electron emitters and the emitter parameters. X-ray imaging measurements were done on a prototype cryomodule containing two 6-cell 805 MHz β =0.47 cavities. The results and analysis will be presented. Measurements were done on several modes in the TM_{010} pass-band, in addition to the accelerating mode (TM_{010} π). The electron trajectories and electron impact locations are different for different pass-band modes, providing a method to check the consistency of the emitter locations and parameters inferred from the simulations.

TuP28: Multipacting analysis for JLAB ampere class cavities*

G. Wu, M. Stirbet, H. Wang, R. Rimmer (TJNAF)

JLAB's ampere class 5-cell cavities require a moderate accelerating gradient (16.7∼20 MV/m). Electron multipacting activity in the machine operating range can degrade the expected performance. A survey was conducted in the area of multipacting analysis for $\beta = 1$ electron cavity shapes, including options for the new high current cavity shape. The results obtained provided useful guidance to the final cavity shape adopted and to its expected performance.

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TuP29: The Fast Piezo-Blade Tuner for SCRF Resonators

C. Pagani, A. Bosotti, P. Michelato, N. Panzeri, R. Paparella, P. Pierini (INFN Milano LASA)

The blade tuner concept has been extended to provide the fast tuning capabilities needed for Lorentz Force Detuning (LFD) compensation and microphonics stabilization of superconducting RF cavities. This functionality is achieved in addition to the slow tuning capabilities, extensively proven with the successful experimental program on the superstructures at TTF. Two complete fast/slow tuning systems are being developed in the context of CARE subprograms, one for the high-field ILC case, currently under fabrication, and one for reduced beta elliptical cavities for high intensity pulsed proton injectors.

TuP30: Niobium-Copper Cavity Development for Muon Collider

R.L. Geng, P. Barnes, D. Hartill, J. Haufman, H. Padamsee, J. Sears (Cornell University), M. Pekeler (ACCEL), R. Losito (CERN), G. Wu (TJNAF)

We will describe Cornell activities of niobium-copper cavity development for the future neutrino factory and muon collider.

TuP31: Electromagnetic and Mechanical Mode Interactions of Spoke-Loaded Cavities

Z. Conway, K.W. Shepard, M.P. Kelly, J. Fuerst, M. Kedzie (University of Illinois Urbana-Champaign)

This paper reports the investigation of the electromagnetic and mechanical properties of spoke-loaded intermediate-β superconducting cavities being developed for both CW and pulsed operation. These structures are of interest in large new ion linacs such as the proposed RIA driver linac and the 8-GeV FNAL proton driver. Results characterizing the interaction between electromagnetic and mechanical structure will be presented focusing on Lorentz and mechanical tuner transfer functions.

TuP32: The Summarized Findings from the Juelich Halfwave Resonators

R. Stassen, R. Eichhorn, G. Schugg, H. Singer, F. Esser, B. Laatsch (Forschungszentrum Juelich)

Within the design of superconducting linac, two prototype halfwave resonators were built. This contribution will report the results from the RF measurements of the cavity and the mechanical analysis of the data. To operate the cavity, an adjustable power coupler based on a cold ceramic window and a tuner system were built, the design and operational findings of which will be shown. Finally, result of the pulsed operation of the cavity within an RF-control loop are given.

TuP33: Triple-Spoke Cavity Design Improvement for HIPPI Collaboration

H. Gassot, S. Blivet, G. Olry, T. Junquera (IPN Orsay), E. Zaplatine (FZ Juelich)

Within the framework of the HIPPI (High Intensity Pulsed Proton Injector) programme, supported by the 6th PCRD of the European Union, the German research centre Forschungszentrum Juelich has proposed a new type of superconducting cavity: the multi-spoke cavity for the intermediate energy section ($\beta = 0.5$) of high power proton linear accelerators. The Nuclear Physics Institute of Orsay is associated with FZ Juelich for the prototype design, and before that, all preminary mechanical studies.
In terms of structure design, a triple-spoke superconducting cavity has a more complicated geometry, as compared to the same beta elliptical cavity. As a consequence the design requires some sophicated tools, like the CAD (Computer Aided Design) code CATIA. In addition, in order to solve the specific mechanics problems, imposed by external constraints, a sophicated mechanics simulation tool is necessary.
To perform these tasks, the mechanics simulation code CAST3M (Calcul et Analyse de Structure et Thermique par la methode des Elements Finis) has been linked to the CATIA via a dedicated program, which has been developed for this purpose. It translates directly the finite elements meshing made by Catia in the specific Cast3m meshing. This new program allows the immediate passage from a CATIA design to mechanical calculations under Cast3m, it reduces considerably the delay of the mechanical studies.
The mechanical of behaviours of the triple spoke cavity in static and dynamic regime have been studied with these codes. The obtained results are presented and discussed in this report.

TuP34: DESIGN OF 325 MHz SINGLE SPOKE RESONATOR AT FNAL

G. Apollinari, I. Gonin, T. Khabiboulline, G. Lanfranco, G. Romanov (FNAL)

The proposed 8-GeV driver at FNAL is based on about 400 independently phased SC resonators. In this paper the design of 325 MHz (β=0.22) Single Spoke Resonator (SSR) for the Proton Driver front end is presented. We describe the optimization of the SSR geometry, the goal being to minimize the $E_{\text{peak}}/E_{\text{acc}}$ and $B_{\text{peak}}/E_{\text{acc}}$ ratios. The aforementioned optimization has been achieved by use of the software package Microwave Studio (MWS) and has lead to very encouraging results. We also report on the coupled ANSYS-MWS analysis on the SSR mechanical properties. Finally the preliminary power coupler RF design for the SSR is presented.

TuP35: Development of the SCRF β=0.81 cavity for Proton Driver

I. Gonin, T. Khabiboulline, N. Solyak (FNAL)

Proton Driver Linac needs different types of superconducting accelerating cavities to accelerate protons from 15 MeV to 8 GeV. In this paper we discuss two possible designs of the 1.3 GHz elliptical β=0.81 cavities for the beam acceleration in range 400-1200 MeV: SNS β=0.81 cavity, scaled to 1.3 GHz, and Low Losses (LL) cavity. The shape of LL cavity was optimized to improve H_{peak}/E_{acc} ratio. The analysis of the electromagnetic properties, HOM, Lorentz forces detuning with and without stiffening rings was done for LL design. Better cell-to cell coupling in LL cavity allows use of the 8-cell design. The disadvantage of LL design is ∼10% higher surface electric field with compare to SNS design. The final choice of design will be done after more studies in frame of MSU/FNAL collaboration by the end of 2005.

TuP36: ISAC-II QWR Cavity Characterizations and Investigations

R.E. Laxdal, B. Boussier, K. Fong, M. Laverty, A. Mitra, V. Zvyagintsev (TRIUMF)

A heavy ion superconducting linac is being installed at ISAC/TRIUMF. A first stage of the ISAC-II upgrade at TRIUMF will see the installation of 20 quarter wave bulk niobium cavities (β_0 = 0.057,0.071). The cavities operate CW at 106MHz with design peak fields of E_p = 30 MV/m, B_p = 60 mT while delivering an accelerating voltage of 1.08MV at ∼4W power consumption. All of the cavities have received BCP processing with two of the cavities receiving an additional electro-polishing treatment. The cavities have been fully characterized for RF performance and are presently being mounted in cryomodules for an initial beam test in Dec. 2005. The report will summarize the cavity treatment procedures and present the cavity test results. In particular we compare the EP vs. BCP treatment and present data confirming the presence of Q-disease in the BCP cavities.

TuP37: Development of Beta 0.12, 88 MHz, Quater-Wave Resonator and its Cryomodule for the SPIRAL2 Project

G. Olry, J-L. Biarrotte, S. Blivet, S. Bousson, C. Commeaux, C. Joly, T. Junquera, J. Lesrel, E. Roy, H. Saugnac, P. Szott (CNRS/IN2P3/IPNO, Orsay)

SPIRAL2 is a radioactive beams facility, composed of a superconducting linac driver, delivering deuterons with an energy up to 40 MeV (5 mA) and heavy ions with an energy of 14.5 MeV/u (1 mA). This facility is now fully approved by the French government.
The first prototype of $\beta = 0.12$ quarter-wave resonator has been recently fabricated by Zanon company and tested at IPN Orsay. The details on its fabrication and the results of the RF and mechanical tests at 4K will be presented. Then, we will show the design of the cryomodule-B, dedicated to the high energy section of the linac, which is now ready to be ordered. Finally, the last studies of the R&D program, such as the last optimizations of the geometry, the new developments of the tuning system or the design of the helium vessel, are described.

TuP38: Development of Spoke Cavities for the EURISOL and EUROTRANS Projects

G. Olry, J-L. Biarrotte, S. Blivet, S. Bousson, F. Chatelet, C. Joly, T. Junquera, J. Lesrel, L. Lukovac, C. Mielot, A.C. Mueller, D. Ruffier, H. Saugnac, P. Szott (CNRS/IN2P3/IPNO, Orsay)

IPN Orsay is strongly involved within the EURISOL and EUROTRANS projects, especially collaborating to the overall design of the linac. Since a few years, main part of the work is dedicated to the development of superconducting spoke cavities and their associated components (RF coupler, tuning system...).
The results of the recent tests of both $\beta = 0.15$ and $\beta = 0.35$, 352 MHz, spoke cavities are presented. We will also describe the study realized on the future horizontal cryomodule for spoke cavities tests and, also the first design of the power coupler. Then, an overview of the latest beam dynamics calculations performed in order to design a linac using spoke cavities will be presented.

TuP39: Performance of a Prototype 176 MHz $\beta = 0.09$ Half-Wave Resonator for the SARAF Linac

S. Bauer, M. Pekeler, P. vom Stein, C. Piel, K. Dunkel (ACCEL), V. Zvyagintsev (TRIUMF)

A prototype 176 MHz $\beta = 0.09$ half-wave resonator was designed, built and tested at 4 K in a vertical test cryostat at ACCEL. Peak electric fields of 44 MV/m corresponding to peak magnetic fields of 95 mT were achieved after some RF processing. The quality factor at the design gradient of $E_{peak} = 25$ MV/m allows operation with cryogenic losses well below 10 W RF losses. Multipacting was observed at very low field ($E_{peak} = 0.1$ MV/m) and intermediate fields ($E_{peak} = 7-10$ MV/m). Three dimensional multipacting calculations predicted these multipacting levels. Calculations show, that the low field multipacting should be strongly reduced with a new slightly changed geometry. Additional

six cavities for a prototype superconducting module will be produced with this new shape.

TuP40: Development of Spoke Cavities for RIA

K.W. Shepard, M.P. Kelly, J. Fuerst, M. Kedzie, Z. Conway (ANL)

This paper reports the development status of 345 MHz, 4 cm beam aperture, three-spoke-loaded TEM-class superconducting cavities for particle velocities $0.4 < v/c < 0.8$. Two prototype cavities have been operated cw at 4.2 K at accelerating gradients above 10 MV/m. Results of cold tests, including mechanical properties and microphonic behavior, are presented.

TuP41: Multi-Spoke Cavity End Region Analysis

E. Zaplatine (FZ-Juelich)

The end region design of the multi-spoke cavities defines the homogeneity of the accelerating electrical field distribution along cavity axes. Using electrostatic representation of the cavity the last (end) cavity gap should be made half long of the others. Such conclusion is not absolutely valid. An electrostatic approach that is used for this decision is true only for the loading electrodes (spokes) since their dimension along the beam line is much smaller than a wavelength. On the other hand, the end region that compiles the last spoke, end gap and the end electrode (or the shape of the cavity end cup) should be designed based on electrodynamics problem. Here we present the results of numerical simulations of end region electrodynamics problem and experimental data of the four-spoke 500 MHz, $\beta = 0.5$ cavity measurements. The main result of this work is that the end gap of the multi-spoke cavity might be of the same length like others with the certain end region design. The comparison of the usual (half length end gap) and full length end gap cavities has been made based on the simulation results for the triple-spoke 352 MHz, $\beta = 0.48$ cavity. An option of end region with RFQ electrodes is discussed.

TuP42: FZJ SC Cavity Coupled Analyses

E. Zaplatine (FZ-Juelich)

A sequential coupled field analysis thermal/structural/RF is used to predict the frequency drift of three types of superconducting cavities (500 MHz, $\beta = 0.75$ - elliptic cavity, 160 MHz, $\beta = 0.11$ - half-wave resonator, 760 MHz, $\beta = 0.2$ - triple-spoke cavity), which are under investigations at Forschungszentrum Juelich. The resonant cavity frequency is affected by the deformations of its shape due to the atmospheric pressure, cavity cool-down, Lorenz forces and tuning force.

The factors that define the accuracy of these analyses are discussed. The results of simulations are compared with experimental data.

TuP43: High-Gradient Activities at Cornell: Reentrant Cavities

R.L. Geng, H. Padamsee, A. Seaman, V. Shemelin (Cornell University)

An accelerating gradient of 46 MV/m was achieved (CW) in a superconducting niobium cavity with an unloaded quality factor (Q_0) over 10^{10} at a temperature of 1.9 K. This represents a world record gradient in a niobium RF resonator. At a reduced temperature of 1.5-1.6 K, an enhanced Q_0 was measured, ranging from 7×10^{10} at 5 MV/m to 2×10^{10} at 45 MV/m. The 1.3 GHz single-cell cavity has a reduced ratio of H_{pk}/E_{acc}, ensured by a reentrant geometry. The maximum peak surface electric and magnetic field exceeded 100 MV/m and 1750 Oe respectively. A soft multipacting barrier (predicted by calculations) was observed near 25 MV/m gradient and was easily processed through. Field emission in the cavity was negligibly small, and the highest field was limited by thermal breakdown. The cavity was built, processed, and tested with LEPP facilities at Cornell University. The second generation reentrant cavity design has a 60 mm beam tube diameter. It has potential to reach 50 MV/m accelerating gradient due to a further reduced H_{pk}/E_{acc}. New 60 mm beam tube reentrant cavities are being fabricated and will be tested in the near future.

TuP44: R&D Activities for ILC High Gradient Cavity in KEK

K. Saito, T. Saeki, F. Furuta, Y. Morozumi, Y. Higashi, T. Higo, H. Yamaoka, H. Matsumoto, S. Kazakov, K. Enami, K. Ueno, N. Toge, Y. Sohn, J. Sekutowicz, K. Ko (KEK, PAL, DESY, SLAC)

After the ILC 1st workshop, KEK organized a high gradient SRF cavity R&D group. As a result of many considerations, KEK decided to push both R&D of 35MV/m baseline cavity and 45MV/m higher gradient cavity, of which purpose is to realize the colliding energy 1-TeV in 40km tunnel. The 35MV/m cavity development will be done by industrial fabrication base. On the other hand the 45MV/m cavity R&D is done by in-house base. Such a high gradient operation needs 500kW input coupler and new tuner system. These all related issues are developed in our group. In this paper we concentrate to report about the status of the 45MV/m cavity, 500kW input coupler and mechanical tuner system.

TuP45: Feasibility Study of ~50MV/m by Single Cell Cavities

Y. Sohn, K. Saito, T. Saeki, F. Furuta, H. Inoue, T. Higo, Y. Higashi, H. Matsumoto, U. Morozumi, H. Yamaoka, K. Ueno, N. Toge, K.Umemori, S. Kazakov, J. Sekutowicz, H. Padamsee (KEK,PAL, DESY, Cornell University)

To provide the design goal of ILC Technical Design Report with SC RF cavities, the low loss type ICHRO 9-cell cavity is under development in KEK. As known the performance of high gradient SC RF cavity is deeply dependent on the surface conditions and qualities of post-fabrication processes. The single-cell cavities, of which E_{acc} is expected as high as ~50MV/m, were prepared to study the performances of cavity geometry and conditions of post-processes such as centrifugal barrel polishing (CBP), chemical polishing (CP), electropolishing (EP), high pressure water rinsing (HPR), baking and so on. This report shows the feasibility of new shape cavity with Eacc as ~50MV/m and high Q_0.

TuP46: A Sapphire Loaded TE_{011} Cavity for Surface Impedance Measurements - Design, Construction, and Commissioning Status*

J.P. Ozelis, L. Phillips, G. Davis, J.R. Delayen, H. Wang (TJNAF)

In order to measure the superconducting surface properties of niobium that are of interest to SRF applications, a facility which utilizes a Nb cavity operating in the TE_{011} mode at 7.65 GHz which provides a well-defined RF field on a disk shaped sample has been designed and fabricated. The RF losses due to the sample's surface impedance are determined by using a calorimetric technique. The system has the capability to measure such properties as R_s, H_{c1}, H_{c2}, and penetration depth, which can then be correlated with surface properties and preparation processes. The design, fabrication, and results from initial commissioning operations will be discussed, along with the near term sample evaluation program.

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TuP47: Recent RRR measurements on Niobium at Fermilab

P. Bauer, C. Boffo, M. Foley (FNAL)

In the frame of SRF cavity development Fermilab is measuring the RRR of the niobium used for the cavity fabrication. These measurements are not only performed on the as received material, but also after a complete surface treatment, such as that applied to the SRF cavities. These measurements verify if the various etchings and heat treaments applied to the cavity do not result in RRR degradation. These studies also include tests of the e-beam welding step. Finally we will also report on our recent efforts to expand the RRR measurement infrastructure at Fermilab.

TuP48: Eddy Current Scanning at Fermilab

C. Boffo, P. Bauer, A. Brinkmann, J.P. Ozelis (FNAL)

In the framework of SRF cavity development, Fermilab is creating the infrastructure needed for the characterization of the material used in the cavity fabrication. An important step in the characterization of "as received" niobium sheets is the eddy current scanning. Eddy current scanning is a non destructive technique originally adopted by DESY with the purpose of checking the cavity material for sub-surface defects and inclusions. Fermilab has received and further upgraded a commercial eddy current scanner previously used for the SNS project. The upgrading process included the development a new filtering software. This scanner is now used on daily basis to scan the niobium sheets for the Fermilab third harmonic and transverse deflecting cavities. This paper gives a status report on the scanning results obtained so far, including a discussion of the typology of signals being detected. We also report on the efforts to calibrate this scanner, a work conducted in collaboration with DESY.

TuP49: SQUID-Based Scanning System for Detecting Defects in NB Sheets for RF Cavities

W. Singer, A. Brinkmann (DESY), F. Schölz, A. Farr, E. Wappler (WSK), M. Mück (ez-Squid)

The conventional eddy current system for detecting material defects in Nb sheets for superconducting cavities has limited sensitivity. WSK Mess- und Datentechnik in Hanau has developed a system for scanning Nb sheets for 1.3 GHz cavities. The system uses SQUID detectors for measuring the eddy current's secondary magnetic field with an extremely high sensitivity and excellent signal/noise ratio.

The scanner is based on a xyz table with ca. 300 mm x 300 mm travel area. The low TC SQUID is situated within a 1.5 l fibre glass He cryostat fixed at the z axis. The eddy current is generated by a selectable coil of diameter 1-3 mm. In order to maximize the resolution of the sensor the magnetic field of the excitation coil can be minimized at the sensor location by a fine adjustable compensation current. The SQUID is used with a flux compensating amplifier; the amplifiers output is then processed by a lock-in amplifier to gain the magnetic field in phase and with 90° phase shift at the location of the squid sensor. Different filters are implemented into the lock in amplifier to improve the signal/noise ratio. The lift-off effect has been minimized by the geometry of the coil. The system works in a non-shielded environment.

TuP50: Laser Annealing Experiments with Niobium

W.R. Frisken (York University), L.N. Hand, J.A. Hunt (Cornell University CCMR), G.H. Chapman, J. Wong, C.-H. Choo, Y. Tu (Simon Fraser University)

We describe our recent pulsed laser annealing studies on small samples of bulk niobium. We compare the effects of annealing over a wide range of single pulse energy density, and in three gas environments: air, nitrogen, and argon. Our Nd:YAG laser allows annealing studies with 266 nm UV light, and with 533 nm green light. We examine the sample surfaces for changes in roughness by SEM (Scanning Electron Microscope), and for changes in near surface oxygen concentrations by WDS (Wavelength Dispersive Spectroscopy). We used SIMS (Secondary Ion mass Spectroscopy) to look for changes in depth profiles of impurity levels.

An earlier study at CERN used a XeCl Excimer laser at 308 nm to study annealing of niobium films on copper substrates. Eruptive events confined them to a very narrow operating range in single pulse energy density. See E. Radicioni et al., NIM A 365 (1995) pp 28-35. The energy density range in our experiment covered a wider range, bracketing that used by the CERN experiment.

TuP51: Computer Simulation of Surface Modification with Ion Beams

Z. Insepov, A. Hassanein, D. Swenson (ANL)

The RF-vacuum breakdown occurs in either copper ("warm") or niobium superconducting ("cold") cavities and one of the most possible mechanisms at electric field gradients as high as 10 GV/m is due to electrode surface irregularities including scratches, whiskers, crater rims, cracks, grain boundaries, oxidized areas, organic absorbed species, and dust particles. The cavity surface periodically have negative or positive electric potentials. During the negative half-period of the electric field, the breakdown occurs when the local field-emitted current (dark-current) density from a given site reaches 10^{11} A/m^2 and causes enough heat dissipation to melt and vaporize surface material. Field emitted electrons could easily ionize such atomic clouds at the near-surface region and form plasma that may erode the cavity surface. Niobium surface modification dynamics treated by cluster ion irradiation was studied based on a Kuramoto-Sivashinsky surface dynamics equation that was further modified by adding a random crater formation mechanism. Based on the analysis of the available experimental data and existing theoretical models, a new concept of plasma formation and surface breakdown model was developed. A Molecular Dynamics simulation model of the vacuum high-voltage breakdown has been developed and applied to study a picosecond-scale dynamics of the nanometer scale tip on the top of the cavity surface under applied high-voltage gradient. Our work showed that a new physical effect exists that consists of tearing out a small chunk (cluster of atoms) of the surface material in a high surface electric gradient and such metal clusters would fill out the near-the-surface region of the cavity. They could easily be ionized by the dark-current and hence hit back the cavity surface thus leading to the vacuum breakdown. Based on this study, a surface smoothening method is proposed consisting of the treatment of cavity surfaces by accelerated gas (argon) cluster ion beams that is capable to reducing the surface roughness up to a theoretical limit.

TuP52: Cold Rolling Texture Evolution in High Purity Niobium Using a Tapered Wedge Specimen

H. Jiang, T.R. Bieler, C. Compton, T.L. Grimm (MSU)

A tapered wedge niobium specimen was rolled at room temperature with multiple passes in the same direction without lubricant and then annealed at 750°C for 1 hour. The crystal orientation distribution of the 50%, 70%, 80%, 90% deformed samples was investigated using x-rays to obtain a quantitative texture analysis. The initial rotated cube (001) $< 110 >$ texture was largely retained up to about 70% reduction in the interior of the samples. After 80% rolling deformation the initial texture vanished and revealed a {111} fiber texture in the interior, which remained stable during annealing. With 90% reduction, the {111} fiber texture become somewhat stronger. In the surface layer, the {001} fiber orientation remained stable but after annealing, the surface texture sharpened to become $\{001\} < 110 >$.

TuP53: Creep and Dimensional Stability of High Purity Niobium Electron Beam Welds

H. Jiang, T.R. Bieler, C. Compton, T.L. Grimm (MSU)

A study was conducted to characterize the microstructure of electron beam welds in high purity niobium and its effect on creep behavior at room temperature. The parent material was 2 mm sheet with a 50 μm grain size. The weld fusion zone had $\sim$ 1mm grains, implying that these grains all intersected the free surface. Room temperature creep of the parent material showed no deformation below the yield stress, but room temperature creep of weld specimens caused up to 10% strain in the weld region at $\sim$75% of the yield strength, over 1-2 months. Creep deformation was not smooth or continuous; strain saturated at some value, and then increased after an incubation time, several times over 1-2 months. The magnitude of the strain for several specimens was similar but the creep deformation behavior was highly dependent on both the actual microstructure and loading history. An initial prestrain with a load release can shut down the creep deformation mechanism due to a dislocation locking effect. An elastic FEM simulation of a portion of the weld fusion zone microstructure indicated that local stresses arising from anisotropic elastic interactions due to different crystal orientations that exceeded the yield strength locally.

TuP54: Grain Boundary Flux Penetration and Resistivity in Large Grain Niobium Sheet*

P. Lee, A. Polyanskii, A. Gurevich, A. Squitieri (University of Wisconsin), D. Larbalestier, P. Bauer, L. Bellantoni, C. Boffo, H. Edwards (FNAL), P. Kneisel (TJNAF)

Jefferson Lab has recently fabricated two superconducting cavities from the center of a large grain Nb billet. Both cavities had excellent properties with one reaching 185 mT and the other attaining an accelerating gradient of 45 MV/m. An investigation is underway to use Magneto Optical (MO) imaging to observe the flux penetration behavior of a sheet sliced from this billet. The large grain size (some grain larger than 50 mm in diameter) allowed us to fabricate multiple samples from bi-crystal and tri-crystal regions. In the first stage of the present study we have taken the as-received sheet (RRR $\sim$280), which has been etched to reveal grain location. In this condition we observed flux penetration at the grain boundary for a bi-crystal where the grain boundary was almost perpendicular to the sample surface and there was < 1 μm surface step across the boundary. Bi-crystal and tri-crystal samples where the grain boundaries were not normal to the surface did not show localized flux penetration. The large grains also enable us to fabricate samples for inter- and intra-grain boundary resistance using an ion-etch and Au deposition technique in order to make good contact with the deeply etched Nb surface.

* The work at UW-Madison was funded by Fermilab contract #559390 and DOE-HEP under grant DE-FG02-91ER40643.

TuP55: A Magneto Optical Study of Grain Boundary Flux Penetration in Niobium Sheet Sampled Across Simulated Cavity Production Route*

A. Polyanskii, A. Gurevich, A. Squitieri, P. Lee (University of Wisconsin), D. Larbalestier, P. Bauer, L. Bellantoni, C. Boffo, H. Edwards (FNAL)

Our initial studies of Nb sheet coupons prepared by BCP have shown that magneto-optical (MO) imaging can be used to show, microscopically, local flux penetration. In the work reported here, we have prepared small samples (3.5 mm × 3.5 mm) suited for MO investigation at each stage of processing associated with cavity production. The samples were cut from 2.8 mm thick sheet (RRR ∼ 450) using machining in order to induce cold work on the surface of the samples. Sample welds were also made from the sheets and compared with the regular sheet samples. In addition to the MO imaging the surface topology was characterized and bulk magnetization measurements were made. It was found that the as-received sheet exhibited classical uniform ("roof-top") penetration as magnetic field increased, independent of microstructure and surface topology. However, after the 750°C heat treatment was applied, localized dendritic penetration was observed in the regular sheet and rapid penetration to the center was observed in the welded sheet. Our results suggest that chemical changes induced by the 750°C heat treatment have a much greater influence on vortex penetration than surface condition, topology and weld fabrication.

* The work at UW-Madison was funded by Fermilab contract #559390 and DOE-HEP under grant DE-FG02-91ER40643.

TuP56: Contaminant Analysis of Polycrystalline and Single Crystal Niobium used in Accelerator Cavities by SIMS*

G.R. Myneni, P. Kneisel (TJNAF), F.A. Stevie, F. Zhu, D.P. Griffis, (North Carolina State University)

The surface of the niobium in superconducting accelerating cavities used in particle accelerators is of significant interest since the range of the interaction of electromagnetic fields only encompasses the first 60 nm of the niobium. Cavity performance still is not as reproducible as desired and further characterization is warranted, especially in light of the introduction of single crystal niobium cavities. Analysis to at least 100 nm has been accomplished using Secondary Ion Mass Spectrometry (SIMS) on unannealed and annealed polycrystalline and single crystal niobium samples. Hydrogen, carbon, nitrogen, oxygen, and several metallic contaminants have been studied. Use of a low impact energy O_2^+ primary beam provided sufficient depth resolution to allow determination of Nb oxide to be in the 2-3 nm range depending on the sample. Most metallic impurities are found at the surface, but tantalum is distributed uniformly throughout the material. Hydrogen depth profiles show a depleted hydrogen concentration in the surface oxide as compared to the bulk, and a significantly lower hydrogen concentration in a polycrystalline sample from one of the supplier. Nitrogen, oxygen, and carbon are lower in the annealed single crystal sample compared with the polycrystalline samples. The concentrations of these three elements

vary for the different polycrystalline samples. SIMS analytical techniques are being used for accurate quantitative analysis of these important impurities in this ongoing study.
∗ This work was supported by the U.S. Department of Energy Contract No. DE-AC05-84ER40150

TuP57: Comparison of Deformation in High-Purity Singe/Large Grain and Polycrystalline Niobium Superconducting Cavities∗

R.E. Ricker, T.H. Gnaeupel-Herold, M.R. Stoudt (NIST), G.R. Myneni, P. Kneisel, (TJNAF)

The current approach for the fabrication of superconducting radio frequency (SRF) cavities is to roll and deep draw sheets of polycrystalline high-purity niobium. Recently, a new technique was developed at Jefferson Laboratory that enables the fabrication of single-crystal high-purity Nb SRF cavities. To better understand the differences between SRF cavities fabricated out of fine-grained polycrystalline sheet in the standard manner and single crystal cavities fabricated by the new technique, two half-cells were produced according to the two different procedures and compared using a variety of analytical techniques including optical microscopy, scanning laser confocal microscopy, profilometry, and X-ray diffraction. Crystallographic orientations, texture, and residual stresses were determined in the samples before and after forming and this poster presents the results of this ongoing study.
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TuP58: Investigation of Ingot Material with Large Grain for Cavities

X. Singer, A. Brinkmann, H.-G. Brokmeier, J. Iversen, P. Kneisel, G.R. Myneni, E. Schulz, W. Singer (DESY)

Metallurgical properties of high purity niobium discs cut from ingot of three companies are investigated. Measurement of the crystal lattice orientation in neighboring grains is done in order to understand high elongation at break and specific behaviour of grain boundaries. The cube orientation is represented in the stereographic projection or as pole figures. The eddy current scanning shows pronounced signal in grain boundary areas. The microstructure of two large crystals connected by EB welding as well as microstructure of chemically treated crystals and grain boundaries is investigated by light microscope and AFM. The deep drawing behaviour and the accuracy of the half cell shape are tested.

TuP59: Development of Nb/Cu Clad Seamless Cavity
K. Enami, K. Ueno, H. Inoue, Y. Higashi, Y. Funahashi, K. Saito, F. Furuta, T. Saeki, W. Singer (KEK and DESY)
KEK is developing Nb/Cu clad 9-cells Seamless Cavities to reduce cost and make higher reliability for ILC. Seamless cavities are made by mainly two processes. The first process is to neck tube at the iris area. The last one is hydroforming the necked tube to manufacture a final shape. We perform basic experiment using Cu tubes and analysis for optimum necking shape and hydroforming mechanism. From these results, we design a necking machine and a hydrofoming machine to develop Nb/Cu clad seamless cavities in house. In addition to these basic studies, we are collaborating with DESY. Recently DESY formed 2-cells seamless clad cavities from Nb/Cu clad tubes. The cavity performance also will be reported.

TuP60: Different Materials Bonding by HIP Technology and the Reliability
F. Furuta, K. Saito, H. Yamaoka (KEK)
HIP method is one of the key technologies for different materials bonding. We applied stainless steel tube bonded to niobium tube by HIP method to the beam pipe flange and the base plate of our high gradient ICHIRO 9-cell superconducting RF cavities. By using a leak test stand in KEK, we made leak test of those HIP parts. Those parts gave leak tightness in the super fluid liquid helium. The leak rate calculated from integration measurement were below 10^{-15} Atm cm^3 / sec after the thermal cycle from 750°C to 2 K. In this workshop, the results of leak test of aluminum sealing will be also reported.

TuP61: Studies of Niobium thin Films Deposited by Coaxial Energetic Deposition*
A. Gerhan, G. Wu, A. Wu, A-M. Valente, J. Wright, B. Bures, M. Krishnan (Alameda Applied Sciences Corp)
A Coaxial Energetic Deposition process based on a cathodic arc has been developed at Alameda Applied Sciences Corporation. A feasibility study of coating Niobium on small, flat samples and on the inside of an RF cavity half cell was conducted recently. The transition temperature and RRR of these films have been measured. One drawback of cathodic arcs is the generation of droplets and macro-particles in the source plasma. We have installed a novel macro-particle filter to block these particles and transmit only the highly ionized plasma to the substrate surface. Surface inspection by SEM showed significant reduction of Niobium droplets and macro-particles, with the macro particle filter installed. SIMS analysis showed surface oxides were moderate compared to solid niobium and films made by other processes.
$*$ This manuscript has been authorized by SURA, Inc. under Contract No. DE-AC05-84ER-40150 with the U.S. Department of Energy.

TuP62: Cathodic Arc Grown Niobium Films for RF Superconducting Cavity Applications

R. Russo, L. Catani, A. Cianchi, J. Lorkiewicz, S. Tazzari,, A. Andreone, G. Cifariello, E. Di Gennaro, G. Lamura (INFN Sezione di Napoli), J. Langer (The Andrzej Soltan Institute for Nuclear Studies)

Niobium thin film coated copper RF cavities are an interesting alternative to niobium bulk cavities mainly because copper is cheaper, has higher thermal conductivity and better mechanical workability and stability than niobium. Coated cavities are also less sensitive to external magnetic fields. Unfortunately the observed degradation of the sputter-coated cavities quality factor with increasing accelerating voltage prevents their use in future accelerators specified to work at field values higher than 15 MV/m.

To try and overcome this limitation we are developing an alternative coating technique based on a cathodic arc system working under UHV conditions. Main advantages of this technique compared to standard sputtering are the ionized state of the evaporated material, absence of gases to sustain the discharge, high energy of atoms reaching the substrate surface and possibility to have high deposition rates. For arc ignition one must produce a small plasma burst of sufficient density to form a high-conductivity path between cathode and anode, which in our case is generated by a 50 mJ Nd-YAG pulsed laser focused onto the cathode surface. Such a triggering system provides ultra-clean and reliable ignition. Recent results on the characterization of niobium film samples produced by UHV cathodic arc are presented, showing that the technique can produce bulk-like films suitable for RF superconducting applications. Measurements of the microwave properties of such samples, carried out by using dielectric resonant test cavities operating between 7 and 20 GHz, are also shown. Results on the linear and nonlinear electrodynamic response, including surface impedance Zs as a function of temperature and surface magnetic field, and intermodulation products at different temperatures, are reported.

TuP63: RF Properties at 6 GHz of Cathodic Arc Films up to 300 Oe

A. Romanenko, H. Padamsee (Cornell University)

We received several Nb films deposited on electropolished copper plates via the Cathodic Arc deposition method under development by R. Russo et al. We attached these end-plates to a 6 GHz cavity operating in the TE_{011} mode. At low field, the Q values obtained were $1 - 2 \times 10^8$ corresponding to a surface resistance of $3-6$ $\mu\Omega$ as compared to the BCS R_s of 0.22 $\mu\Omega$ at 2.2 K and small mean free path. The Q remained constant up to a field of 300 Oe. A baseline Q of 3.5×10^8 ($R_s = 2.2$ $\mu\Omega$) was determined for the host cavity by attaching a bulk Nb end-plate. We expect the BCS resistance to be 0.5 $\mu\Omega$ for the higher mean free path end plate and cavity material. Therefore the host cavity has 1.5 $\mu\Omega$ of residual loss. The film resistance appears to be higher than the residual resistance of the host cavity. Future efforts will focus on reducing the residual resistance of the host cavity.

TuP64: A prototype of 500 MHz Cavity Coating System by ECR Plasma*

G. Wu, L. Phillips, R. Rimmer, A-M. Valente, H. Wang, A. Wu (TJNAF), H. Padamsee (Cornell University)

A coating prototype for 500MHz copper cavity is currently being commissioned under the collaboration between Jefferson Lab and Cornell University. This report discusses the many important aspect of the system including plasma efficiency, magnetic field optimization, and electron energy distribution. Current progress will also be reported.

* This manuscript has been authorized by SURA, Inc. under Contract No. DE-AC05-84ER-40150 with the U.S. Department of Energy.

TuP65: RRR of Copper Coating and Low Temperature Electrical Resistivity of Materials for TTF Couplers

M. Fouaidy, N. Hammoudi (IPN Orsay), T. Garvey (LAL)

In the frame of the R&D program on the TTF III main RF coupler, IPN Orsay developed in close collaboration with LAL institute, a dedicated facility for the electrical characterization at low temperature of different materials. This apparatus was used for measuring the electrical resistivity versus temperature (4.2 K- 300 K) of various samples produced in the industry. These tests were performed in order to compare the RRR of various samples, to qualify and find the optimum parameters for the coating process. Seven flat samples were tested: bare 316L samples, nickel coated 316L samples, copper coated 316L samples with a nickel under layer. We investigated, in particular, the effect of vacuum annealing at 400°C on the RRR of the copper coating. Our experimental data are compared to previous results reported by other groups, theoretical values and empirical correlation leading to a good agreement.

TuP66: Modeling RF Cavities and Multipacting with the VORPAL Code

C. Nieter, G.R. Werner, P.H. Stoltz (Tech-X-Corporation)

Considerable resources are required to run three dimensional simulations of multipacting in superconducting rf cavities. Three dimensional simulations are needed to understand the possible roles of non-axisymmetric features such as the power couplers. The ability to run in parallel is important if self-consistent simulations of the accelerating structures are to be done. The plasma simulation code VORPAL [1] can run in parallel and has the needed models to simulate multipacting in superconductive cavities. VORPAL's general domain decomposition will allow complex geometries to be simulated in parallel. VORPAL incorporates the CMEE (Computational Modules of Electron Effects) library [2] to model secondary electron emission. Results from a simulation showing the the excitation of multiple modes of a cylindrical cavity will be shown. Simulations of electron trajectories in the relevant cavity modes will also be presented.

[1] C. Nieter and J.R. Cary, J. Comp. Phys. 196 (2004), p. 448.
[2] P.H. Stoltz, ICFA electron cloud work shop, Napa, CA (2004)

TuP67: Studies of Electron Activities in SNS Cavities Using FishPact*
G. Wu, J. Mammosser, R. Rimmer, H. Wang, L. Phillips
During vertical testing of SNS superconducting RF cavities, a lot of electron activity was observed. This could be in-cell multipacting, multi-cell electron migration or near-axis dark current. A multi-purpose electron tracking code (FishPact) was developed based on the poisson/superfish field solvers. We report the findings on SNS cavities' electron activity based on FishPact numerical simulation results.
* This manuscript has been authorized by SURA, Inc. under Contract No. DE-AC05-84ER-40150 with the U.S. Department of Energy.

TuP68: PROGRESS ON SPUN SEAMLESS CAVITIES*
V. Palmieri (INFN-LNL)
Not only the progressive achievement of higher accelerating fields, but also the drastic reduction in resonator production time and costs (K$ per MV/m) is compulsorily for the feasibility of more and more powerful accelerators, as for instance the ILC. This is the motivation under the research toward simpler and cheaper fabrication techniques as for instance seamless cavities. Plastic deformation of metals by spinning is a technique as ancient as powerful and it has already shown that seamless resonators can be cold formed starting either from circular flat blanks or from tubes without need of any intermediate annealing. In the optics of a low cost resonator mass production, a strong effort on fabrication times reduction (around 4 hours per resonator) has been spent in last two years. Much shorter fabrication times are however possible and are under study at the moment.
⋆ Work performed in the framework of WP3.1 in JRA1 of CARE Project

Tuesday Evening: Industrialization Symposium

Organized by D. Proch (DESY)

Part 1: Presentation of past, ongoing or planned laboratory activities for industrialization
a) CERN (LHC), *TBD*
b) DESY (XFEL)
- cavity fabrication & treatment, *D. Proch (DESY)*
- input coupler, *T. Garvey (IN2P3)*
- module assembly, *B. Petersen (DESY)*
c) KEK, *TBD*
d) FNAL activities towards industrialization, *N. Lockyer (FNAL)*
e) Comments by Industry, *all*

Part 2: Presentation/ information about existing "Industry Forum"
a) Linear collider forum of Japan, *N. Nishi (LCF of Japan)*
b) Linear collider forum of Europe, *M. Peiniger (ACCEL)*
c) Formation of an US Industrial Consortium for ILC, *T. Favale (AES)*

Part 3: Open discussion about best coordinated way to industrialization of SRF technology
Contributions by industry and laboratory partners

Part 4: Conclusions and outlook

Wednesday, July 13, 2005

Wednesday Morning: Moderated Discussions

WeA01: Topic 1: High-field Q-slope

Moderator: P. Kneisel (TJNAF)

On the previous day several talks have been presented both of theoretical aspects (A. Gurevich, E. Palmieri) of the Q-slope and of experimental observations (G. Ciovati, G. Eremeev).
To remind everybody of the contents of these presentations Peter Kneisel will start with a short summary of the essential observations. P. Bauer of FNAL will present his collaborative work on a Q-slope model and representatives of DESY and Saclay will briefly summarize their findings in these labs.
The discussion should focus on answering or finding consensus on the following questions:

1. Is the high field Q-drop a magnetic or electric field effect?
2. What is the impact of grain boundaries on Q-drop?
3. Is there a frequency dependence of the onset value of the Q-drop?
4. Are there other remedies besides "in-situ" baking to eliminate the Q-drop?
5. Does surface smoothness (EP vs BCP) play an important role in a successful "in-situ" baking?
6. Is there an optimum baking temperature and baking time, which does not only improve the high field Q-value, but also maintains (does not increase) the residual resistance?
7. Out of all the suggested models for the Q-drop, is there a favorite model, which explains all/most of the experimental observations?
8. What additional crucial experiments are necessary to fully understand the Q-drop?

WeA02: Topic 2: Surface Analysis

Moderator: C. Antoine (CEA-Saclay)

In this group, we will discuss how surface studies can help us to find out the physical origin of limitations inside cavities (field emission, Q-slope, quench). For each phenomena or each proposed model we should try to know what can be observable/measured, and what technique manage to approach that, keeping in mind the interpretation limitations of each technioques.

We can separate those techniques into several topics:

1. Classic basic tools: e.g. SIMS, XPS, AUGER, X-Ray techniques.... Other profiling techniques
2. Extension of these techniques to high level precision: e.g. use of synchrotron sources, time of flight analysis etc...
3. Surface topography: at atomic resolution STM, AFM... 3DAP and at larger scale: profilometry, replicas...
4. Dedicated techniques for RF superconductivity : magnetic measurements, RRR, mean free path l, field emission.
5. Emerging techniques : 3DAP, D measurement by photoemission

Possible 10 minute talks:

- D. Seidman (North Western University) : 3DAP (3D-atomic probe Tomography) (topic 3 or topic 5)
- G.M. Rao (JLab) : Dynamic SIMS (topic 2) and XPS (topic 1)
- S. Berry (Saclay) : Replicas and quench modelling (topic 3)

And possibly:

- M. Delheussy (MPI-Stuttgart/Saclay) : X-Ray technics : diffusion, reflectivity, CTR (topic 1 or topic 2)
- C. Antoine (Saclay, collaboration with Tokyo University) : D measurement by photoemission (topic 5)
- J. Kauffman (Cornell)
- Someone from Desy (topic 4)

WeA03: Topic 3: Spoke vs Elliptical Cavities for $\beta = 0.5$

Moderator: F. Krawczyk (LANL)

Elliptical and spoke resonators originally have been developed for particle acceleration at different ends of the beam velocity spectrum. While elliptical resonators have been developed for the acceleration of electrons at the speed of light, spoke resonators are a variant of a half-wave resonator that have their origin in the acceleration of protons or ions at low to moderate energies and velocities ($0.15 < \beta < 0.4$).
In the last 10 years we saw an extension of the proposed use of elliptical resonators towards the acceleration of higher energy protons ($0.5 < \beta < 1.0$) (e.g. APT, ADS, RIA and SNS). This was achieved by longitudinally compressing the dimensions of standard elliptical resonator geometries. Due to the mechanical problems resulting from this compression, there is a certain limit on the velocity of particles that the elliptical cavities can accelerate. The SRF community agrees that the lower limit is around a beta of 0.4 - 0.5.
Spoke resonators, in comparison, do not have any geometric limitation to the range of velocities they could be designed for. The limits for their range of application are on historic grounds. This created the idea of extending their application to beam velocities beyond their standard range of application. This can be seen in the proposals for new proton linacs that often use spoke resonators in the range of β >0.2 and in some cases up to betas around 0.6 (e.g. ADS, ESS, RIA, ...).
Goal of this discussion is to find out which of the two technologies is more advantageous than the other in the transition region around $\beta = 0.5$. As there is no operational experience of any of those structures the evaluation of the properties of each technology will have to be based on simulations and low power tests that have been done in the past.
Criteria will include RF-performance, fabrication, surface treatment/cleaning, mechanical properties, choice of frequency, choice of operation temperature, beam-cavity interaction and cost. It might also turn out that there is no distinct advantage for one of the technologies and that the best choice is related to the specific application.

Thursday, July 14, 2005

Thursday Morning: Oral Session

ThA01: Superconducting RF Test Facility (STF) in KEK
H. Hayano (KEK)
After the technology choice for the main linac of the International Linear Collider (ILC), construction of a SC-RF test facility in KEK was discussed and decided to promote Asian SC-technology for ILC production share. Since KEK does not have experience of a 9-cell cavity production and an ILC like cryomodule assembly, the test facility plan is divided two stages. The first stage (STF Phase 1) is aiming quick start up of 9-cell cavity production and having experience of assembly engineering of half-size cryomodule. The second stage (STF Phase 2) is to build one RF unit of ILC main linac. Higher gradient greater than 35 MV/m is essential for KEK to host ILC in Japan, because of limited length of site candidates. The demonstration of high gradient by changing cavity shape is thought to be high priority. Four of LL-type 9 cell cavity aiming 45 MV/m have being fabricated for phase 1 half-sized cryomodule. Another half-sized cryomodule has been fabricated in parallel to accommodate four of TESLA-type cavities aiming 35 MV/m. STF will be constructed in the building of proton linac facility for J-PARC in KEK. The most of J-PARC linac components in there will be moved to Tokai site till September 2005. The installation of He plant and RF power source will start after moving. The installation of two half-sized cryomodule will begin June 2006. Once the ILC baseline configuration is determined at Snowmass workshop or by the time of BCD, STF phase 2 configuration will follow it. The phase 2 cryomodule construction will be done using the new EP facility, the new assembly clean room and the new cryomodule installation stand. The infrastructure of STF will be one of ILC module assembly facility in the beginning of phase 2 stages. The role and plan of the superconducting RF test facility (STF) is reported in this paper together with the current status.

ThA02: Results from the New Linear Collider Test Facility at FermiLab
H. Edwards (DESY/FNAL)
(abstract not submitted)

ThA03: Review of Various Approaches to Address High Currents in SRF Electron Linacs
I. Ben-Zvi (BNL)
The combination of high-brightness electron sources and high-current SRF Energy Recovery Linacs (ERL) leads to a new emerging technology: high-power, high-brightness electron beams. This technology enables extremely high average power Free-Electron Lasers, a new generation of extreme brightness light sources, electron coolers of high-energy hadron storage rings, polarized electron-

hadron colliders of very high luminosity, compact Thomson scattering X-ray sources, terahertz radiation generators and much more. What is typical for many of these applications is the need for very high current, defined here as over 100 mA average current, and high brightness, which is charge dependant, but needs to be in the range of between sub micron up to perhaps 50 microns, usually the lower - the better. Suffice it to say that while there are a number of projects aiming at this level of performance, none is anywhere near it. This work will review the problems associated with the achievement of such performance and the various approaches taken in a number of laboratories around the world to address the issues.

ThA04: A Review of the Design and Performance of CW and Pulsed High Power Couplers

T. Gravey (LAL)

The design of input power couplers represents one of the most important challenges of accelerators that use super-conducting RF technology. These devices must fulfill several functions while being subject to mechanical, electromagnetic, vacuum and cryogenic constraints. The rapidly increasing number of projects, planned or under construction, which propose to use super-conducting cavities has prompted developments in power couplers for both CW and pulsed applications. Amongst the projects for which couplers have, or are being, developed one finds VUV and X-ray free electron lasers (based on self-amplified spontaneous emission), spallation neutron sources (SNS), energy recovery linacs, and high energy colliders. We will review the design requirements and performances obtained for several of these couplers. Particular attention will be paid to the couplers which have been used on the TESLA Test Facility at DESY, the variations of this coupler which are under consideration for future synchrotron light sources and the coupler chosen for use on the SNS.

ThA05: Advances in Electromagnetic Modeling through High Performance Computing

K. Ko (SLAC)

Under the DOE SciDAC project on Accelerator Simulation, a suite of electromagnetic codes has been under development at SLAC that are based on unstructured grids for higher accuracy, and on parallel computing to enable large-scale simulation. The new modeling capability is further enhanced by SciDAC collaborations in computational science which include meshing, partitioning, solvers, refinement, visualization, and optimization. These advances together with simulation results from applying these tools to existing accelerators and planned facilities will be presented.

ThA06: Review of Superconducting RF Guns

D. Janssen, H. Bueetig, U. Lehnert, P. Michel, P. Murcek, C. Schneider, R. Schurig, F. Staufenbiel, J. Teichert, R. Xiang (FZR, Dresden), J. Stephan (IKS Dresden), V. Volkov (BINP SB RAS)

In the first topic the superconducting RF (SRF) photo-injector projects are reviewed. The DC SC photo-injector at the Peking University Accelerator Facility, the all-niobium SRF gun of Brookhaven and the high current SRF photo-injector project of AES and Brookhaven are discussed. Special attention is paid to the project of the FZ Rossendorf. The experimental set-up with a 1.3 GHz half-cell cavity has demonstrated the stable operation of a SRF photoelectron gun for the first time. The manufacture and the warm tuning of two $3\frac{1}{2}$ cell niobium cavities for the new photo-injector project are finished. A new cryostat with a special tuning and cathode transfer system has been designed. The status of manufacture for different components is shown. In future it is planed to operate this SRF gun with an energy of 9.5 MeV as a low-emittance photo-injector for the ELBE accelerator.

In the second topic of the review some special points are discussed, which are specific for superconducting RF guns. The advantages and disadvantages of different shapes for the first cavity cell (gun cell) are discussed. Different kinds of photo-cathodes (normal conducting, superconducting, all niobium) and their integration into a superconducting cavity are explained. Different possibilities (RF focussing, magnetic RF field (TE - mode), static magnetic field outside the cavity) are discussed for beam focussing and emittance compensation inside the superconducting cavity.

ThA07: Review of Slow and Fast Tuners

S. Simrock (DESY)

Frequency tuners are an essential and critical component of acceleration systems based on superconducting cavities. Slow tuners must cover a wide tuning range (of up to several hundred kHz), while providing a resolution of the order of 1 Hz. Fast tuners which are used to compensate Lorentz force detuning and to control microphonics provide only a tuning range of several cavity bandwidths but can support a control bandwidth of several kHz. Furthermore the frequency tuners should be free of hysteresis, and guarantee a long lifetime of more than 10 years. Various types of slow and fast tuners which are presently in operation or under development will be presented.

ThA08: Review on Progress in RF Control Systems

M. Liepe (Cornell University)

In the past two decades accelerator controls and feedback systems have changed dramatically. While in the past relatively simple analog systems were used, present systems are highly complex, and all accelerators in planning or under construction heavily rely on advanced feedback and feedforward control schemes. The Low-Level-Radio-Frequency (LLRF) system not only stabilizes the field in the RF cavities, but also has to provide among other things frequency control, exception handling, extensive diagnostic, and performance and machine availability maximization. As manifold as the tasks are for the LLRF system, so are the challenges. Linac driven light sources require highest field stability, while pulsed machines or low beta linacs bring their own challenges for the LLRF system. This presentation reviews the challenges and demands on present and future LLRF systems, gives an overview of state-of-the-art solutions, and an introduction into a very active and exciting field of accelerator physics.

ThA09: Crab Cavity Development
K. Hosoyama (KEK)
(abstract not submitted)

ThA10: Summary of Industrialization Symposium
D. Proch (DESY)
(abstract not submitted)

Thursday Afternoon: Poster Session

ThP01: EP on Small Samples Studies at FermiLab

C. Boffo, P. Bauer, C. Cooper, R.L. Geng, T. Reid (FNAL)

Electropolishing (EP) is considered an essential step in the processing of high gradient SRF cavities. Studies on EP of small samples have been started at Fermilab as part of the SRF materials R&D program. A simple bench top setup was developed to study the variables affecting the EP process. Surface roughness measurements and chemical analysis are used to assess the quality of the polishing process. In addition setups for vertical EP of half cells, based on the Cornell design, as well as for dumbbells were built and tested. Results and findings are reported in this article.

ThP02: Efficiency of Electropolishing versus Bath Composition and Aging: First Results*

F. Eozenou, C. Antoine, A. Aspart, S. Berry (CEA-Saclay)

Electropolishing experiments on niobium samples are carried out in Saclay within the CARE/SRF framework:

- to study the bath aging, its origins and the consequences on the polishing performances
- to highlight the influence of parameters such as temperature and acids concentrations (hydrofluoric and sulphuric)

Some mixtures with different concentrations have already been investigated. Intensity as a function of time, surface states and polishing speed were considered at different potentials. These experiments should be considered as an introduction to a more complete program involving design of experiments to find an optimal mixture.

* We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395).

ThP03: Aluminum and Sulphur Impurities in ElectroPolishing Baths*

F. Eozenou, A. Aspart, C. Antoine (CEA-Saclay)

This study highlights the impurities formation in electropolishing bath (mixture of sulphuric and hydrofluoric acids) when aluminium is chosen as cathode material. Such impurities could partially explain the performance disparities observed on electropolished cavities. These products might be aluminium derivatives, sulphur, S, and hydrogen sulphide, H_2S. It is fundamental to distinguish two cases: with or without applied voltage. Furthermore, parameters such as temperature, acid concentrations are also taken into account.

* We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395).

ThP04: Vertical Electropolishing Niobium Cavities
R.L. Geng, A. Crawford, H. Padamsee, A. Seaman (Cornell University)
We will describe vertical electropolishing process developed at Cornell for niobium cavity preparation.

ThP05: Update on the Experiences of Electropolishing of Multi-Cell Resonators at DESY
N. Steinhau-Kuehl, A. Matheisen, L. Lilje, B. Petersen, M. Schmokel, H. Weitkamper (DESY)
At DESY electropolishing is applied on superconducting cavities for about 2 years now. Acceleration gradients of up to 39 MV/m have been achieved on nine-cell resonators. The electro polishing infrastructure is running continuously since 2004 and serves as major surface preparation tool now. Data, basing on the statistic gained so far, are available for parameters like current density, removal rate, live time of components and process temperature. We report on the latest data as well as on ongoing studies on material stability and sulphur segregation that was found recently during maintenance of the EP infrastructure.

ThP06: Electropolishing of Niobium Mono-Cell Cavities at HENKEL Electropolishing Technology Ltd.
L. Lilje, D. Reschke, A. Matheisen, A. Brinkmann, N. Steinhau-Kuehl (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 up to three-cell cavities. Final cleaning procedures take place in a classified clean room. Test results of single-cell cavities will be presented.

ThP07: Status of the Electropolishing Program at Jefferson Lab
J. Mammosser, G. Ciovati, L. Phillips, C. Reece, A. Wu (TJNAF)
Jefferson Lab has established an electropolishing program devoted to process understanding and improvement. This program consists of bench style measurements, production process development and improved process instrumentation. Process improvements to date and single cell performance will be reported in this paper.

ThP08: Preparation Sequences for Electro-Polished High Gradient Multi-Cell Cavities at DESY
A. Matheisen, B.v.d Horst, B. Petersen, S. Sagebarth, P. Schilling (DESY)
During the last years encouraging results on improvements of acceleration gradients on TESLA TTF cavities are gained. Within the Collaboration of DESY and KEK in 2001 as well as treatments in the DESY electro-polishing facility acceleration gradients are pushed towards 40 MV/m by electro polishing. Beside the new surface preparation technique the subsequent handling and preparation steps had to be adjusted to the need of the electropolished high gradient resonators. We report on the major differences in the treatment sequence of BCP

and EP cavity handling. Changes on the infrastructure and tooling as well as processing sequences, adapted to the need of electropolished resonators, will be described in detail.

ThP09: Further Improvements with Dry-Ice Cleaning on SRF-Cavities
A. Brinkmann, J. Iversen, D. Reschke, J. Ziegler (DESY)
Looking for advanced potentials to clean surfaces of superconducting accelerator cavities, a dry-ice cleaning method promises to be a useful additional application to the standard high pressure rinsing with ultra-pure water.
Dry-ice cleaning using the sublimation-impulse method removes particles and film contaminations, especially carbon-hydrates, without residues. First cleaning tests on single-cell cavities showed Q-values at low fields up to 4×10^{10} at 1.8 K. Gradients up to 32 MV/m were achieved, but field emission still is the limiting effect. Further tests are planned to optimize the dry-ice cleaning technique.

ThP10: High Pressure Rinsing Parameters Measurement and Process Optimization
Paolo Michelato (INFN)
High pressure rinsing with ultra-pure water jet is an essential step in the high field superconducting cavity production process. In this paper we illustrate the experimental characterization of an HPR system, in terms of specific power and energy deposition on the cavity surfaces and on the damage threshold for niobium. These measurements are used to tentatively derive general rules for the optimization of the free process parameters (nozzle geometry, speeds and water pressure).

ThP11: A Joint ANL/FNAL Cavity Surface Processing Facility
M.P. Kelly, M. Kedzie, K.W. Shepard (ANL)
Common interest at Argonne and Fermi National Accelerator Laboratories in developing superconducting cavities for projects such as RIA, the ILC and the 8 GeV FNAL Proton Driver has led to a new joint cavity processing facility with initial operations to start this fall and full operations in early 2006. This 200 m^2 single cavity processing and assembly area located at Argonne will complement the planned superconducting module and test facility (SMTF) at Fermilab. New infrastructure includes two separate chemical processing rooms each connected to a common use class 1000 anteroom and two separate class 100 clean rooms. Other common facilities include a large exhaust-fume scrubber and an ultra-pure water system servicing all chemical and clean rooms. The facility is sized to process a range of elliptical and TEM class cavities at a rate of several per week using modern processing techniques including chemical and electropolishing, ultra-pure high-pressure water rinsing, ultrasonic cleaning and clean room assembly.

ThP12: Developments in Electron Beam Welding of Niobium Cavities

J. Sears, B. Clasby (Cornell University)

In order to produce niobium cavities with better control over their final tolerances work is being done at Cornell to develop better electron beam welds. Cavities for machines such as an ERL will require tight tolerances be maintained and will need welds that are repeatable with predicable shrinkage and distortion. Full penetration outside beam welds with no under bead in .078 to .110 inch thick niobium have been developed for this purpose.

ThP13: Update on Quality Control of the Clean-Room for Superconducting Multi-Cell Cavities at DESY

N. Krupka, K. Escherich, M. Habermann, K. Harries, A. Matheisen, B. Petersen (DESY)

Superconducting accelerator resonators improve their acceleration gradients continuously. The surface electric- and magnetic fields are driven close to the theoretical limit. Nevertheless, field emission loading still limits the application of these resonators for accelerator application.

For the preparation of the XFEL Project a quality control system for the clean-room is set up. Three air particle counters are installed in the class 10 and 100 area. Two liquid particle counters and an automatic scanning microscope for optical analysis of filter discs are installed to control the ultra-pure water system and the high pressure rinsing process. An N_2-fog generator is installed to visualize the airflow inside a class 10 / 100 clean room.

We report on air particle measurements to qualify the infrastructure and assembly steps, liquid particle measurements and scanning microscope analysis of the high pressure rinsing cycles. In addition results visualizing the influence on the laminar airflow by the cavity geometry as well as of the personnal during the assembly sequence will be presented.

ThP14: Clean-Room Facilities for High Gradient Resonator Preparation

K. Escherich, A. Matheisen, N. Krupka, B. Petersen, M. Schmokel (DESY)

In 1991 a clean room facility to serve for high gradient super conducting cavity treatment- and preparation technique was set up at DESY. Since then several improvements on the infrastructure were made. A total of 88 multi cell TTF / TESLA design resonators with acceleration gradients of up to 39 MV/m have undergone treatments in this facility. We report on reliability experiences of the individual infrastructure components and the flow scheme of cavity preparation. Experiences on infrastructure maintenance procedures and improved quality control of the infrastructure will be presented. Basing on these experiences and the state of art of clean-room technology in 2005, a baseline layout for an advanced cavity preparation and assembly infrastructure will be discussed.

ThP15: Towards Industrialization: Supporting the Manufacturing Processes of Superconducting Cavities at DESY

J.A. Dammann, J. Burger, L. Hagge, J. Iversen, A. Matheisen, W. Singer (DESY)

Manufacturing high gradient superconducting cavities for future accelerators implies a very detailed knowledge of the entire production process regarding fabrications steps and quality control. This knowledge has to be transferred from laboratories to industry in order to achieve reproducible results in industrial production.

For the proposed European XFEL laser about 1000 cavities have to be manufactured by industry. Presently at DESY a series of 30 cavities is under production in collaboration with industry. One aim is to study the requirements on tools for process control and documentation. To enable optimal realization and to prepare easy transfer to industry an engineering data management system (EDMS) has been installed to support the production processes including the integration of external manufacturers.

For the mechanical manufacturing process work instructions and quality management documents are used to control parameters like mechanical tolerances or surface preparation for electron beam welding. The information is structured according to the breakdown structure of produced parts which is represented in the system parallel to the design structure. The built-in workflow engine is used to control the subsequent preparation process by creating and issuing work instructions for individual steps like surface or weld preparation. Thereby the EDMS collects and stores all important information including the necessary documentation for quality assurance.

One of the important benefits is that a complete and coherent documentation can be ensured for the entire life cycle of the cavities. The poster presents the DESY approach to use a commercially available EDMS tool to support the current cavity fabrication process.

ThP16: Prototyping Activities at AES for ANL-RIA and ATLAS Cavities

J. Rathke, M. Cole, E. Peterson, T. Schultheiss (Advanced Energy Systems Inc.), K.W. Shepard, J. Fuerst, M. Kedzie, M.P. Kelly (ANL)

Since mid-2001 Advanced Energy Systems (AES) has worked with Argonne National Laboratory (ANL) to produce five prototype cavities for their RIA and ATLAS projects. With ANL leading the effort, AES worked in collaboration in developing design details, performing engineering analysis, and developing manufacturing plans and tooling designs for niobium forming and machining. In manufacturing the cavities AES was responsible for the bulk of the niobium forming and machining while Sciaky Inc. in Chicago performed the electron beam welding under the direction of ANL. Tuning operations prior to the final welds were done at AES while all processing, tuning and testing of the finished cavities was done by ANL. This paper will discuss highlights of the design, analysis and fabrication of these cavities and the concurrent engineering environment that was applied very successfully in this program. We will also discuss the application of modern design and analysis tools to facilitate efficient prototype production.

ThP17: Development of the Superconducting Cavity at Mitsubishi Heavy Industries, LTD.

K. Sennyu, H. Hara, T. Yanagisawa, H. Hattori, K. Okubo, M. Matsuoka (Mitsubishi Heavy Industries Ltd.)

MHI has developed various types of the superconducting cavity since the construction of TRISTAN at KEK. We introduce some superconducting cavity in these days.

ThP18: Status of the Superconducting Accelerating Cavity for KEKB

T. Furuya, K. Akai, S. Mitsunobu, Y. Yamamoto (KEK), Z. Li, W. Pan, S. Yi, G. Wang (IHEP)

The peak luminosity of KEKB is still growing up and has reached 1.5×10^{34} $cm^{-2}s^{-1}$ that is 150% of the design value. One of the most important contribution to this improvement is the beam intensity of HER, in which an electron beam of 1.3 A is stored in 1389 bunches. The RF system of eight superconducting damped cavities provides the voltage of 11 MV and the power of 2.4 MW to the beam. The status of this operation will be given as well as a recent development for a future upgrading plan.

ThP19: Status of the CESR Superconducting RF System*

S. Belomestnykh, R. Kaplan, H. Padamsee, P. Quigley, J. Reilly, J. Sears, V. Veshcherevich (Cornell University)

Electron-positron storage ring CESR operates with four superconducting single-cell cavity cryomodules. CESR runs in two distinct regimes: as CESR-c collider at 1.55 to 2.5 GeV and as CESR-CHESS synchrotron light source at 5.3 GeV. RF system is configured with one klystron per two cavities for both regimes of operation. In CESR-CHESS mode SRF cryomodules have to support maximum beam current of 500 mA by delivering up to 160 kW of RF power per cryomodule. CESR-c operation is radically different for RF system as the emphasis is not on delivering very high RF power to beams, but on providing very high RF voltage to produce short bunches and high synchrotron tune. Superconducting cavities perform well in both regimes.

* Work is supported by the National Science Foundation

ThP20: High Current Superconducting Cavities at RHIC

R. Calaga, I. Ben-Zvi, X. Chang, D. Kayran, V. Litvinenko (BNL)

A half-cell superconducting electron gun has been proposed as an injector to the 20 MeV energy recovery linac (ERL) prototype at Brookhaven National Lab (BNL). The design and optimization of the half-cell gun based on RF parameters, HOM wakefields as well as preservation of very low emittance beam in the high current regime are discussed.

Comparison of several different shapes based on the above criteria and issues relating to multipacting will be presented.

ThP21: A Database for Superconducting Cavities for the TESLA Test Facility

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

We look back on 10 years experience using a database for superconducting cavities for the TESLA Test Facility TTF. The database was developed to collect data of every cavity preparation step and measurement in order to optimize cavity production and preparation techniques to meet the ambitious goal of high accelerating gradients at high quality factors.
Data from 110 superconducting 9-cell cavities, 50 single cell cavities, several 2- to 7-cell cavities and about 60 RF couplers were collected in the database. In addition, the company measurements on sub-assemblies and parts forming the next 30 9-cell cavities are stored, thus establishing the database as an effective part for a Quality Management System.
This database is dynamically accessible via an extensive graphical WEB interface based on ORACLE products, which enables the users to select and analyze the collected data easily from anywhere.

ThP22: Two-Cell Niobium Injector Cavity for Cornell's ERL Prototype

R.L. Geng, P. Barnes, M. Liepe, V. Medjidzade, H. Padamsee, J. Sears, N. Sherwood, V. Shemelin (Cornell University)

Five 1300 MHz two-cell niobium cavities are used in the injector of Cornell's ERL prototype. Copper model cavities are built and measured. The first niobium cavity is under fabrication. We describe the status of the 2-cell injector cavity development.

ThP23: Recent Results and Developments from the S-DALINAC

M. Gopych, A. Aras, M. Brunken, H.-D. Graf, J. Hasper, M. Hertling, M. Platz, A. Richter, S. Watzlawik, A. Zilges (Istitut fuer Kernphysik), W. Bayer, U. Laier (Geselschaft fuer Schwerionenforschung), H. Kunze, W. Muller, S. Setzer, T. Weiland (Institut fuer Theorie Elktromagnetischer Felder)

Field emission accompanied by the emission of light has already been studied in a 20-cell superconducting niobium 3 GHz cavity of the S-DALINAC. The investigations were extended to cavities of the S-DALINAC injector, where the location and intensity of light emitters as well as the spectral distribution of the emitted light were investigated. We conclude that the light emitters are dust particles heated by the RF field inside the cavity. Measured bremsstrahlung spectra of dark current electrons can be reproduced using GEANT4 simulations. The maximum electron energies determined from these spectra are compared with the results obtained by numerical simulations of electron trajectories. The emission of characteristic X-rays from niobium could be measured with a special semiconductor detector installed inside the beam vacuum tube downstream of

the injector. The intensity of the X-rays as a function of the accelerating field is well described by Fowler-Nordheim relation with a field enhancement factor of $\beta = 340 \pm 40$.
Furthermore the first results of high temperature treatment (850°C) applied to the 5-cell capture cavity of the S-DALINAC in the high vacuum furnace at Darmstadt are presented. The intention of the procedure was to remove residual hydrogen from the cavity niobium. Residual gas analysis during the heat treatment showed that the cavity was rather strongly contaminated.
For the injector linac new RF input couplers have been designed aiming at a minimal transverse kick. The couplers presently under construction will be able to handle several kW of power.
The most significant improvement of the infrastructure concerned the 2K helium refrigerator. There the original piston compressor was replaced by an air cooled screw compressor and four pumping modules operating in parallel were installed for the 2K operation, superceding the former five stage roots pump.

ThP24: Recent Progresses on DC-SC photoinjector at Peking University

J. Hao, K. Zhao, S. Quan, X. Lu, Y. Ding, S. Huang, B. Zhang, L. Wang, D. Xie, L. Lin, F. Jiao, G. Wang, F. Zhu, J. Chen (Peking University)

Progress has been made on the DC-SC photoinjector at Peking University. A test facility of the DC-SC photoinjector has been completely installed. The performance of 1+1/2 superconducting cavity is improved after special treatment. Electron beam loading tests at 4.4 K have been finished. Upon the present experiments, the gradient of 6 MV/m is achieved. The energy gain of 1.1 MeV is obtained at 4.4 K. The measured rms emittance is about 5 mm-mrad with the beam current of 270 μA. 2 K experiments are in preparation.

ThP25: Possibility of Adopting Solenoid in DC-SC Photoinjector

J. Hao, R. Xiang, K. Zhao, S. Quan, X. Lu, Y. Ding, S. Huang, B. Zhang, L. Wang (Peking University)

Solenoid is an efficient beam line element to control the transverse rms emittance in normal conducting injectors. However, for the case of superconducting photoinjector, the extra magnetic field can not exist in the area of SC cavity. By calculation and simulation, this paper presents the limitation and possibility of applying solenoid emittance compensation in the DC-SC photoinjector, a new type of superconducting gun developed at Peking University.

ThP26: Design and Fabrication of the RHIC Electron Cooling Experiment High Beta Cavity and Cryomodule

D. Holmes, A. Ambrosio, M. Cole, M. Falletta, E. Peterson, J. Rathke, T. Schultheiss, R. Wong (Advanced Energy Systems Inc.), I. Ben-Zvi, A. Burrill, R. Calaga, P. Cameron, X. Chang, H. Hahn, H. Hseuth, D. Kayran, V. Litvinenko, G. McIntyre, A. Nicoletti, J. Rank, J. Scaduto, T. Rao, K. Wu, Y. Zhao (BNL)

Advanced Energy Systems is currently under contract to BNL to design and fabricate a five cell superconducting 703.75 MHz cavity and cryomodule for the RHIC e-Cooler SRF Energy Recovery Linac (ERL) program. The superconducting cavity fabrication is complete while fabrication of cryomodule components has begun. The cryomodule component design facilitates a build-in-place integration approach of the cavity string with the other major components of the cryomodule, helping to minimize assembly tooling requirements. This paper will review the design, analysis and fabrication of the e-Cooler cavity and cryomodule.

ThP27: Single Cell Cavity Program for the XFEL

J. Iversen, P.D. Gall, D. Reschke, W. Singer, J. Tiessen (DESY)

The future European X-ray Free Electron Laser (XFEL) is based on 1.3 GHz 9-cell Nb cavities mainly identical to the proven TTF cavity design. In order to establish the fabrication process of approx. 1000 cavities for the XFEL a test cavity program was initiated at DESY. The program consists of fabrication, preparation and RF testing of approx. 30 single-cell cavities. Main objectives are the qualification of new niobium vendors, the evaluation of manufacturing of cavities from large grain ingot discs as well as the specification of precise material and process requirements for the large scale production. Design, documentation and qualification of the whole DESY internal fabrication are established. The first single-cell cavities are produced and successfully tested.

ThP28: Report on Superconducting RF Activities at ANU

N. Lobanov, D. Weisser (ANU)

Superconducting RF activity in the last two years has been targeted on improving the performance of the ANU LINAC by upgrading with new RF Control System supplied by BARC, India. The commissioning of RF Control System is described. Efforts are now mostly devoted to the development of the low velocity two-stub resonator (DVOIKA). A prototype two-stub resonator has been submitted to the workshop. A number of projects for the design, production and test of DVOIKA has been established. A summary of this work will be given. The extension of these concepts to a three-stub resonator (TROIKA) is addressed.

ThP29: Fermilab's Mechanical Design and Engineering of the 3.9 GHz 3rd Harmonic SRF System

D. Mitchell, N. Solyak, M. Foley, T. Khabiboulline, D. Olis, J. Fast, A. Stefanik, C.M. Lie (FNAL)

Fermilab has refined the mechanical design of the Superconducting, 3.9 GHz, 3rd Harmonic System over the past two years. This 2 meter long, 4 cavity cryomodule will be installed at DESY's TTF in the summer of 2006. Our design is summarized in this paper to include: the development of the 9-cell niobium cavity; the design of the helium vessel, blade tuner, and cryostat; and the HOM and main input coupler designs. The cryogenic interface with DESY's existing components will be addressed. The manufacturing processes for forming, coining, brazing, and e-beam welding of the HOM coupler, main coupler, cavity cells, and end tubes are also described as well as the general assembly process.

ThP30: STF Baseline Cavities and RF Components

S. Noguchi, E. Kako, K. Watanbe (KEK), K. Sennyu (MHI)

A cryomodule containing eight 9-cell 1.3 GHz superconducting cavities is under construction for STF phase-I, (STF: Superconducting cryomodule Test Facility). Four baseline cavities are TESLA type and others are aiming at high gradient of 45 MV/m. We will report the design performance of the TESLA type cavities and their RF components like input couplers, HOM couplers and frequency tuners.

ThP31: The AES/BNL SRF Photocathode Electron Gun

T. Schultheiss, M. Cole, A. Ambrosio, M. Falletta, D. Holmes, E. Peterson, J. Rathke, R. Wong, J. Lewellan, L. Preble, L. Phillips, V. Nguyen-Tuong (Advanced Energy Systems), I. Ben-Zvi, A. Burrill, R. Calaga, P. Cameron, X. Chang, H. Hahn, D. Kayran, V. Litvinenko, G. McIntyre, A. Nicoletti, J. Rank, J. Scaduto, T. Rao, K. Wu, Y. Zhao (BNL)

Advanced Energy Systems and Brookhaven National Lab are collaborating to design and build a superconducting photocathode electron gun to ultimately be tested at BNL's ERL test facility. VTA testing and cavity string integration will be performed at JLAB. The gun will operate at 703.75 MHz and will produce a 2 MeV CW current of 0.5 Amps. The beam will have 1.33 nC bunch charge. Transverse emittance is projected at 5.5 mm-mrad (rms), longitudinal emittance at 42 keV-psec (rms), energy spread at 3.1%, and bunch length at 7.2 psec rms. We are currently finalizing the physics design of the gun cavity. In parallel we are working on the mechanical design of the cavity, cavity string, and cryomodule. A significant thermal and structural analysis effort is also underway. Fabrication is expected to begin in November of this year. Cleaning and VTA testing of the cavity should begin in August of 2006 followed by cavity string cleanroom assembly at JLAB. Integration of the coldmass will take place at BNL in November of 2006, with testing to commence at BNL in March of 2007.

ThP32: Canadian Light Source Storage Ring RF System

R. Tanner, J. Stampe, M. Silzer, E. Matias, G. Wright, M. Jong (University of Saskatchewan)

The Canadian Light Source (CLS) selected a superconducting RF cavity based on the Cornell design for the CLS storage ring. The RF cavity, amplifier and cryogenics plant were purchased commercially while overall system integration was performed by CLS. CLS also took on the design and construction of the low-level RF (LLRF). This paper discusses the CLS experience including: the design of the RF cavity control system, obstacles encountered during integration and solutions implemented or proposed to address them.

ThP33: Status and Development of the Superconductivity RF at NSRRC

C. Wang, L.H. Chang, M.C. Lin, G.H. Luo, T.T. Yang, M.S. Yeh, C.T. Chen (NSRRC)

A project to replace two existing room-temperature radio-frequency (RF) cavities by one CESR-III 500 MHz superconducting radio-frequency (SRF) module was initiated for the Taiwan Light Source (TLS) synchrotron ring at the National Synchrotron Radiation Research Centre in 1999. The goals are to double the photon flux of the synchrotron light by doubling the electron beam current and to increase the stability of the electron beam by taking advantage of the ultra-weak high-order modes (HOM) of the SRF cavity. The SRF module has been routinely operated since February 2005. The NSRRC users have benefited from a very high photon flux stability ($\Delta I_0/I_0 \sim 0.05\%$) that had never been achieved previously. Here, we report the operational experience of the SRF system, focusing on its impact on the machine operation. Review of the project achievement is given.

ThP34: The Progress Report at Peking University

B. Zhang, S. Huang, S. Quan, Y. Ding, J. Hao, X. Lu, L. Wang, L. Lin, J. Chen (Peking University)

The Peking University Superconductivitng Accelerator Facility (PKU-SCAF) is under construction at Peking University. It will include a DC-SC photo-injector with $1\frac{1}{2}$, 1.3GHz Nb cavity, the main accelerator which is a superconducting 1.3GHz linac module with two TESLA-type 1.3 GHz Nb cavities. As the most important subsystem, the 2 K cryogenic plant was approved by Peking University and 2 K cryogenic system will be started to design in this year. The foundational research on RF superconductivity is being carried on at Peking University. A $3\frac{1}{2}$ Nb cavity for DC-SC photo-injector is designed and a two-cell Nb cavity was fabricated simultaneously.

ThP35: A European Advanced Technology Programme for ADS Accelerator Development

J.-L. Biarrotte, A. Mueller (IPN Orsay)

Consecutive to the work of the European Technical Working Group (ETWG) on ADS, the Preliminary Design Study of an Experimental ADS (PDS-XADS) was launched in 2001 as a 5^{th} Framework Program EC project[1] A special working package (WP3) was dedicated to the accelerator design, and in particular taking into account that the issue of "beam-trips" could be a potential "show-stopper" for ADS technology in general. A reference solution, based on a linear superconducting accelerator with its associated doubly achromatic beam line has been worked out up to some detail. For very high reliability, the proposed design is intrinsically fault tolerant, relying especially on highly modular "de-rated" components associated to a fast digital feedback system. A programme for the remaining R&D, focused on experimental reliability demonstration of prototypical components has been elaborated. This R&D will be performed in the 6^{th} Framework Program EC project "EUROTRANS"[2], which presently is just started.

[1] EC Contract N° FIKW-CT-2001-00179, "PDS-XADS"
[2] EC Contract N° FI6W 516520, "EUROTRANS"

ThP36: High Power (35 kW and 190 kW) Solid State Amplifiers for the SOLEIL Synchrotron

C. Thomas-Madec, P. Marchand, M. Diop, R. Lopes, J. Polian, F. Ribeiro, T. Ruan (Synchrotron SOLEIL)

In the SOLEIL Storage Ring, two cryomodules, each containing a pair of superconducting cavities, will provide the maximum power of 600 kW, required at the nominal energy of 2.75 GeV with the full beam current of 500 mA and all the insertion devices. Each of the four cavities will be powered with a 190 kW solid state amplifier consisting in a combination of 315 W elementary modules (about 730 modules per amplifier). The amplifier modules, based on a technology developed in house, with MOSFET transistor, integrated circulator and individual power supply, are fabricated in the industry. In the booster, a 35 kW solid state amplifier (147 modules) will power a 5-cell copper cavity of the LEP type.

The first operational results and the status of the RF power plants are reported in this paper. Although quite innovative for the required power range, the solid state technology proved to be very attractive with significant advantages as compared to vacuum tubes.

ThP37: Cryomodule Development at Michigan State University for the Rare Isotope Accelerator

W. Hartung, J. Bierwagen, S. Bricker, C. Compton, P. Glennon, T.L. Grimm, D. Harvell, M. Johnson, F. Marti, A. Moblo, J. Popielarski, L. Saxton, R.C. York, A. Zeller (NSCL/MSU)

The Rare Isotope Accelerator (RIA) is to provide an intense supply of exotic isotopes for nuclear physics research. A superconducting linac is 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 (base frequency = 80.5 MHz) are in progress at Michigan State University. Quarter-wave and half-wave resonators, interspersed with superconducting magnets, are to be used for the first two segments of the linac; elliptical cavities are envisaged for the third segment. The basic cryomodule design is flexible enough so that it can be adapted to all of the cavity sizes and shapes needed for RIA. A titanium rail system is used for support and alignment of the cavities and magnets. The cavities have coaxial couplers and externally-actuated tuners. The number of cavities per cryomodule ranges from 4 to 10. A prototype elliptical cavity cryomodule has been fabricated for two 6-cell cavities of geometric $\beta = 0.47$. RF testing and microphonics studies were done in 2004. A prototype low-beta cryomodule is under construction, with RF testing to be done in 2005. The low-beta cryomodule accommodates one quarter-wave cavity, one half-wave cavity, and 2 superconducting magnets. Passive and active magnetic shields are used to ensure that the stray fields from the magnets do not degrade the cavities' performance.

ThP38: Status of the ATLAS Upgrade Cryomodule

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

A new cryomodule for TEM-class superconducting (SC) cavities is under construction both as part of an accelerator improvement project to upgrade the existing ATLAS heavy ion linac at ANL and also to prototype a cryostat design for RIA. A novel design feature is the provision of separate cavity and insulating vacuum systems, which has not previously been attempted with TEM-class SC cavities. The separated vacuum systems will facilitate clean assembly of the cavity string. We present an update on the status of this effort, including progress on mechanical assembly as well as thermal and magnetic shield performance data. Subsystem design details will be discussed including thermal and magnetic shielding, support and alignment, tuners, and RF couplers.

ThP39: Pulsed Operation of the 972 MHz Prototype Cryomodule for ADS Superconducting Linac

E. Kako, S. Noguchi, N. Ohuchi, T. Shishido, K. Tsuchiya (KEK), N. Akaoka, E. Chishiro, T. Hori, H. Kobayashi, M. Nakato, N. Ouchi, M. Yamazaki (JAERI)

A prototype cryomodule containing two 9-cell superconducting cavities of $\beta = 0.725$ and $f_0 = 972$ MHz had been constructed under the collaboration of Japan Atomic Energy Research Institute (JAERI) and High Energy Accelerator Research Organization (KEK) on the development of superconducting LINAC for Accelerator Driven System (ADS). Cool-down tests to 2 K of the cryomodule and high power RF tests with a 972 MHz pulsed klystron have been carried out. RF power of 350 kW in pulsed operation of 3 msec and 25 Hz was transferred to a nine-cell cavity through an input coupler. Accelerating gradients of 14 MV/m higher than the specification of 10 MV/m have been achieved in both cavities. Compensation of Lorentz-force detuning by a piezo tuner was successfully demonstrated.

ThP40: Magnetic Field Studies in the ISAC-II Cryomodule

R.E. Laxdal, B. Boussier, R. Eichhorn, K. Fong, I. Sekachev, G. Clark, V. Zvyagintsev, (TRIUMF)

The medium β section of the ISAC-II Heavy Ion Accelerator consists of five cryomodules each containing four quarter wave bulk niobium resonators and one superconducting solenoid. The 9 T solenoid is not shielded but is equipped with bucking coils to reduce the magnetic field in the neighbouring RF cavities. A prototype cryomodule has been designed and assembled at TRIUMF. The cryomodule vacuum space shares the cavity vacuum and contains a mu-metal shield, an LN cooled copper thermal shield, plus the cold mass and support system. Several cold tests have been done to characterize the cryomodule. Early operating experience with a high field solenoid inside a cryomodule containing SRF cavities will be given. Of note are measurements of the passive magnetic field in the cryomodule and estimations of changes in the magnetic field during the test due to trapped flux in the solenoid and magnetization of the environment. Residual field reduction due to hysteresis cycling of the solenoid has been demonstrated.

ThP41: The CW Cornell ERL Injector Cryomodule

M. Liepe, V. Medjidzade, S. Belomestnykh, R.L. Geng, H. Padamsee, V. Shemelin, V. Veshcherevich (Cornell University)

The Cornell ERL Prototype injector RF system will accelerate bunches of a 100 mA beam to an energy of several MeV, while preserving the ultra-low emittance of the beam. The injector linac will be based on superconducting RF technology with five 2-cell RF cavities operated in CW mode. Beside the five RF cavities, the injector cryomodule houses six broadband RF ring-absorbers located at 80 K for HOM damping, ten input couplers, LHe vessels with cavity frequency tuner, a cavity support structure and the cryogenic piping. The axial symmetry of the HOM absorbers, together with a twin-coupler design, avoids transverse on-axis fields, which would cause emittance growth. The design of the cryomodule is nearly finished, and prototyping of subcomponents has started. We expect first beam through the injector RF system late 2008. In this paper we give an update on the ERL injector cryomodule work.

ThP42: Design of the Liquid Helium Supply Unit of the SOLEIL Superconducting RF System

M. Louvet-Monsanglant, P. Marchand, K. Tavakoli, C. Thomas-Madec, (Synchrotron SOLEIL)

In the Storage Ring of the Synchrotron SOLEIL light source, two cryomodules will provide the maximum power of 600 kW required at the nominal energy of 2.75 GeV with the full beam current of 500 mA and all the insertion devices. Each cryomodule contains a pair of 352 MHz superconducting cavities (Nb/Cu), cooled in a bath of liquid helium at 4.5 K. A single cryogenic plant will supply the liquid helium for the two cryomodules.
The process that led us to the final cryogenic plant specification and design is explained. The first experimental results and the status of the system are also reported.

ThP43: The Wire Position Monitor (WPM) as a Sensor for Mechanical Vibration for TTF Cryomodules

P. Pierini, A. Bosotti, C. Pagani, R. Paparella, D. Sertore (INFN/LASA), R. Lange (DESY), R. De Monte, M. Ferianis (Elettra, Basovizza, Trieste)

The WPM installed on the last two TTF cryomodules can be used as microphonic and sub-microphonic vibration detectors. The spectra taken during a first test using the normal readout electronics, performed using the last four stripline monitors of the 5th cryomodule has shown that the system has the necessary sensitivity needed to detect small mechanical vibrations (up to resolving 100 nm) in the 0.01-100 Hz range. The low frequency mechanical noise can be recovered de-modulating the WPM RF signals, amplitude modulated by the TTF cold mass mechanical vibrations. In this paper we show the potentialities of our system to achieve resolutions in the nanometer range, together with the analysis of the complete spectra of cryomodules 4 and 5 of the TTF.

ThP44: Commissioning and Operational Experience With an Intermediate Upgrade Cyromodule for CEBAF 12 GeV Upgrade

T. Powers, K. Davis, M. Drury, C. Grenoble, C. Hovater, L. King, T. Plawski, J. Preble (TJNAF)

Three cryomodules have been designed and built as intermediate prototypes for the CEBAF 12 GeV upgrade. This paper will discuss the commissioning and operational experience with the second of these cryomodules, which was installed and commissioned in the Jefferson Lab 10 kW Free Electron Laser Facility. Within the cryomodule are eight 7-cell, 1497 MHz cavities. It was designed to accelerate 1 mA of beam in excess of 70 MV and to have the same footprint as a standard CEBAF cryomodule. The cryomodule was installed in parallel with the FEL beam line in the spring of 2004 and characterized simultaneous with beam delivery. It was installed in the beam line in the early summer of 2004 and has since been operated as part of an energy recovered linac with 5 mA of beam current and 75 MV accelerating gradient for extended periods of time. Additionally, it was operated at 1 mA of beam current and 80 MV of accelerating gradient for several hours without a trip. In the latter operating mode the beam current was limited by the injector setup.

ThP45: Successful RF and Cryogenic Tests of the SOLEIL Cryomodule

P. Bosland, P. Bredy, S. Chel, G. Devanz, (CEA Saclay), M. Louvet, P. Marchand, K. Tavakoli, C. Thomas-Madec (Synchrotron SOLEIL)

In the Storage Ring (SR) of the Synchrotron SOLEIL light source, two cryomodules will provide the maximum power of 600 kW required at the nominal energy of 2.75 GeV with the full beam current of 500 mA and all the insertion devices.

A cryomodule prototype, housing two 352 MHz superconducting single-cell cavities with strong damping of the Higher Order Modes has been built and successfully tested in the ESRF. Even though the achieved performance (3 MV and 380 kW) does meet the SOLEIL requirement for the first year of operation, it was decided to upgrade the cryomodule prototype before its implementation in the SR. Modifications of the internal cryogenic system as well as the input power and dipolar HOM couplers required complete disassembling, reassembling and testing of the cryomodule, which were carried out at CERN. The refurbishment program, the RF and cryogenic tests of the cryomodule are reported in this paper.

A second cryomodule, similar to the modified prototype, is under manufacturing and will be implemented in the SR by the end of 2006.

ThP46: The JLab Ampere-Class cryomodule*

R. Rimmer, E.F. Daly, W.R. Hicks, J. Henry, J. Preble, M. Stirbet, H. Wang, K.M. Wilson, G. Wu (TJNAF)

We report on the design of a new cryomodule capable of accelerating high-current beams for future ERL based high power compact FEL's. We discuss the factors influencing the design choices, including BBU threshold, frequency, HOM power, real-estate gradient, peak surface fields, and operating efficiency. We present a conceptual design that meets the requirements of compact MW-class FEL, however this module design could be useful for a wide range of applications such as electron cooling, electron-ion colliders, industrial processing etc. The concepts developed for this design could also be useful for larger ERL-based light sources, XFELs and even linear colliders.

* This manuscript has been authorized by SURA, Inc. under Contract No. DE-AC05-84ER-40150 with the U.S. Department of Energy.

ThP47: Development and Testing of RF Window Input Power Couplers for TESLA

W.D. Moeller, D. Proch, D. Kostin (DESY), Q.S. Shu, J.T. Susta, G. Cheng (AMAC International Inc.), S. Einarson, T.A. Treado (Communications & Power Industries), T. Garvey (LAL)

More and more accelerators are built with superconducting cavities operating at cryogenic temperatures. A possible window failure might result in contamination of the cavity surface and degrade the accelerating performance. As a result of the experiences obtained during the development of high RF power input couplers for the SNS and RIA projects, a cost effective design and fabrication method for a new coupler has been developed in the framework of a DOE STTR grant. This new design is an alternative to the present TESLA cylindrical ceramic windows layout. The new design includes two planar disc windows separated by a vacuum space. An alternative design option proposes filling dry nitrogen gas in between the two ceramic windows. Furthermore the new design is optimized for RF input power, taking into consideration the possible requirements of the TESLA superstructure layout. There is hope, that this novel coupler will reduce the costs of fabrication and improve the RF performance. Two prototype couplers with this design have been fabricated. The couplers are being tested on the high power test stand at DESY, Germany. In this paper we will describe the new coupler design and discuss the first measured results.

ThP48: Preparation and Conditioning of the TTF VUV-FEL Power Couplers

H. Jenhani (LAL Orsay)

Recent advances in accelerator technology have permitted the manufacture of superconducting cavities with high gradients ($>$ 30 MV/m). One ambitious aim now consists of making them operational in accelerator facilities (correctly matched to the RF source, having a minimum of RF reflection and preserving the vacuum, cleanliness and operating temperature conditions). The input power couplers have a crucial role in achieving all of these functions. Therefore, the input power couplers for these cavities are designed and prepared under very strict conditions.

RF conditioning of input power couplers at room temperature is an important step in their preparation before mounting them on cavities. It allows one to test the robustness of the coupler, condition away residual absorbed gases and "burn-off" microscopic surface imperfections.

The conditioning of the TTF-III couplers (for the TTF VUV-FEL accelerator at DESY) is an ideal occasion to learn about their properties and behavior and to asses their suitability for the ILC, which will use cold RF technology. We will present the status of processing the TTF-III couplers at LAL (Orsay), an activity performed in close collaboration with DESY.

ThP49: RF Processing of Couplers for the SNS Superconducting Cavities*

Y. Kang, I. Campisi, D. Stout, A. Vassioutchenko (ORNL), M. Stirbet (TJNAF)

All eighty-one fundamental power couplers for the 805 MHz superconducting cavities of the SNS linac have been RF conditioned and installed in the cryomodules successfully. The couplers were RF processed at JLAB and then at the SNS in ORNL: more than forty couplers have been RF conditioned in the SNS RF Test Facility (RFTF) after the first forty couplers were conditioned at JLAB. The couplers were conditioned up to 650 kW forward power at 8% duty cycle in traveling and standing waves. They were installed on the cavities in the cryomodules and then assembled with the airside waveguide transitions. The couplers have been tested with high power RF in the cooled cavities reliably with satisfactory accelerating field gradients. At SNS, the coupler conditioning was performed in the RFTF that has been completed to support test and conditioning of various RF subsystems and components with two high power pulsed klystrons: 2.5 MW at 402.5 MHz and 5 MW at 805 MHz.

* SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos and Oak Ridge.

ThP50: Power Couplers Design for Third Harmonic and Spoke Cavities at Fermilab

D. Arnold, T. Khabiboulline, J. Li, D. Mitchell, T. Nicol, D. Olis, N. Solyak (FNAL)

A superconducting, 3.9 GHz, third harmonic accelerating cavity, developed at Fermilab, required a completely new main power coupler design to meet performance requirements, cost, and manufacturability. The RF design and optimization, multipactor problem analysis, and solid modeling were completed for the adjustable and non-adjustable versions of the coupler. We have also begun a new power coupler design for the 325 MHz single, double and triple spoke cavities. The analysis of the couplers included magnetic and electrical coupling versions. In this paper, we discuss the status of the coupler development for 3.9 GHz and 325 MHz cavities and our future plans.

ThP51: A New Design for the ILC-45MV/m Cavity Input Coupler

H. Matsumoto, S. Kazakov, K. Saito (KEK)

An attractive structure using capacitive coupling has been found for the input coupler for the 45 MV/m versions of the International Linear Collider (ILC) project. The coupler supports an electrical field gradient of ~1 kV/m around the RF window ceramic with 500 kW through power, a VSWR of 1.1 and a frequency bandwidth of 460 MHz. No unwanted resonances were found in the

RF window near the first and second harmonics of the operation frequency. In this paper, we report the detailed design of a new cold side input coupler using a capacitive coupling coaxial line.

ThP52: High Power Test of Input Couplers and HOM Dampers for KEKB Superconducting Cavity

S. Mitsunobu, K. Ebihar, T. Furuya, Y. Yamamoto (KEK)

KEKB is continuously increasing the currents and so the superconducting cavities demand higher power input couplers and HOM dampers. Now input coupler powers are 350 to 400 kW, the powers will be increased to 500 and 600 kW soon. The coupling strength increased for 3 cavities by replacing the gasket with thinner one successfully at last summer's shutdown time. The spare couplers and doorknob transformers already tested up to 500 kW and 800 kW in a short time. The HOM dampers operating at 15 kW will be operate with 40 kW. The spare HOM dampers have been tested at 18 kW for SBP damper and 25 kW for LBP damper, and at this power level some super sonic acoustic sensors start to indicate some signals. So more higher power HOM dampers for future super B factory need thinner ferrite dampers.

ThP53: Study of Thermal Interaction Between a CW 150 kW Power Coupler and a Superconducting 700 MHz Elliptical Cavity

M. Souli, S. Bousson, M. Fouaidy, N. Gandolfo, H. Saugnac, P. Szott (CNRS /IN2P3) D. Braud, J.P. Charrier, D. Roudier, P. Sahuquet, B. Visentin (CEA Saclay)

Superconducting Radio-Frequency (SRF) elliptical niobium cavities (f=704 MHz) will be used as accelerating structures in the high energy section (185 MeV-600 MeV) of the proton LINAC driver in Accelerator Driven System. The power coupler needed for these resonators should transmit a 150 kW CW RF power to a maximum 20 mA protons beam. The estimated average values of the RF losses in the coupler are 260 W (respectively 90 W) in the inner (respectively outer) conductor in SW mode. Due to such high values of RF losses, it is necessary to very carefully design and optimise the cooling circuits in order to efficiently remove the generated heat and to reduce the thermal load to the cavity operating at T=2 K.

An experiment simulating the thermal interactions between the power coupler and a 704 MHz SRF five cells cavity was performed in the CRYHOLAB test facility in order to determine the critical heat load that can be sustained by the cavity without RF performance degradation. Experimental data are compared to numerical simulation results obtained with the finite element code COSMOS. These data also allow us to perform in-situ measurement of thermal parameters used in the model (thermal conductivity, thermal contact resistance,) and they were used to validate the numerical simulation model.

ThP54: Design of High Power Input Coupler for Cornell ERL Injector Cavities

V. Veshcherevich, S. Belomestnykh, M. Liepe, V. Medjidzade, H. Padamsee, V. Shemelin (Cornell University), N. Sobenin (MEPhI), A. Zavadtsev (Introscan)

A 75 kW CW coupler for superconducting injector cavities of Cornell ERL project has been designed. The coupler has a variable coupling. Q_{ext} varies from $9.2 * 10^4$ to $8.2 * 10^5$. The prototype TTF-III TESLA coupler design has been revised to a great extent. Cooling of critical parts has been radically improved. The new design is close to be multipacting-free. The coupler design is presented as well as results of its thermal analysis. Possible schemes of high power tests are discussed.

ThP55: A Beam Line HOM Absorber for the European XFEL LINAC

N. Mildner, M. Dohlus, J. Sekutowicz, K. Zapfe (DESY)

High frequency Higher Order Modes propagating in beam line of a superconducting linac carry big fraction of the energy deposited by an accelerated beam. In this contribution we describe the design of beam line absorbers which we plan to install between cryomodules to dissipate the propagating energy in 70 K environment. Experiments with absorbing material and mechanical and thermal modeling of the absorber are presented in the paper.

ThP56: R-square Impedance of ERL Ferrite HOM absorber

H. Hahn (BNL)

An R&D facility for an Energy Recovery Linac (ERL) intended as part of an electron-cooling project is being constructed at this laboratory. The center piece of the facility is a 5-cell 703.75 MHz super-conducting RF linac. Successful operation will depend on effective HOM damping. It is planned to achieve HOM damping exclusively with ferrite absorbers. The performance of a prototype absorber was measured by transforming it into a resonant cavity and alternatively by a conventional wire method. The results expressed as a surface or R-square impedance are presented in this paper.

ThP57: Broadband HOM Absorber for the Cornell ERL

M. Liepe, V. S. Belomestnykh, Medjidzade, V. Shemelin (Cornell University)

The damping of higher-order-modes (HOMs) in the Cornell ERL injector cryomodule is demanding: The high current beam (100 mA) with short bunch length will deposit significant HOM power at high RF frequencies up to tens of GHz. In addition emittance preservation is of outmost importance, and requires axial symmetry of the HOM absorber. Based on the successful HOM ring absorber in the CESR RF system, we have designed an RF absorber, which will be placed in the beam pipe between adjacent cavities in the ERL injector cryomodule. This absorber will be operated at 80 K to simplify thermal transitions to the cavities at 2 K. Several potential absorber materials have been studied in detail, and a combination of three materials has been chosen to guarantee efficient RF absorption over a wide frequency range. Prototyping of the ab-

sorber has been started. In this paper we present the design of the broadband absorber, show results of RF studies on the absorbing materials, and give an update on the prototyping work.

ThP58: Electromagnetic Simulations of Coaxial Type HOM Coupler*

G. Wu, H. Wang, R. Rimmer, C. Reece (TJNAF)

DESY-type coaxial HOM coupler was used in many superconducting cavities. The electric probe tip is located at the maximum B-field inside the coupler can. For CW high current application, the heating of this tip can be severe to degrade the cavity performance. EM simulation was done to estimate the tip heating term. The geometric remedies and detuning effect were discussed. The effect to HOM Q_{ext} was also estimated due to these remedies. The HOM probe tip heating power was provided for CEBAF 12-GeV cavities and AES injector cavities.

∗ This manuscript has been authorized by SURA, Inc. under Contract No. DE-AC05-84ER-40150 with the U.S. Department of Energy.

ThP59: FNAL 3.9 GHz HOM Coupler & Coaxial Cable Thermal FEA

S. Tariq, T. Khabiboulline (FNAL)

A thermal analysis has been performed on the FNAL proposed 3.9GHz HOM coupler design using finite element analysis (FEA). Complete cable and connector details have been included in the model. Nominal heat loads for both static (no RF power) and dynamic (average RF power) cases are reported at the 2K, 4.5K, 80K, and 300K junctions together with corresponding temperature profiles in the coupler and coaxial cable. A combination of different boundary condition scenarios have been analyzed and effects of cable size (x-section) and cable length on heat loads and temperatures is discussed.

ThP60: Electromechanical, Thermal Properties, and Radiation Hardness Tests of Piezoelectric Actuators at Low Temperature

M. Fouaidy, G. Martinet, N. Hammoudi, F. Chatelet, S. Blivet, A. Olivier, H. Saugnac (IPN Orsay)

IPN Orsay participates, in the frame of the CARE project activities supported by EU, to the development of a fast cold tuning system for SRF cavities. The main task of IPN is the full characterization of piezoelectric actuators at low temperature T, and the study of their behavior when subjected to fast neutrons radiation at T=4.2 K. In order to compare the performance of piezoelectric actuators, a new apparatus was developed and successfully used for measuring the electromechanical and thermal properties of various industrial piezostacks for T in the range 1.8 K-300 K. Different parameters were investigated as function of T: piezoelectric constant, dielectric (capacitance, dielectric constant, impedance, loss tangent), thermal properties (thermal resistance, heat capacity and time constant) and finally heating δT due to dielectric losses vs. modulating voltage V_{mod} and frequency f. We observed a decrease of the Full Range Displacement (FRD or δX) of the tested actuators from $\sim 40\mu$m at 300K to 1.8μm to 3μm at 1.8K, depending on both material and fabrication process of these devices. Besides, both material and fabrication process have a strong influence on the shape of the characteristics δX vs. T dependence. Moreover, we studied the stiffness, dynamic properties, and piezostacks behavior as sensors when subjected to a preloading force at 1.8K-300K and the corresponding preliminary results are reported. Finally a dedicated facility located at CERI institute (Orleans, France) for radiation hardness tests of actuators with fast neutrons at T=4.2 K was developed and the first beam tests results are summarized.

ThP61: Coaxial Ball Screw Tuner for ICHRO 9-Cell Cavity

Y. Higashi, H. Yamamoko, F. Furuta, T. Higo, S. Morozumi, T. Saeki, K. Saito, K. Ueno (KEK)

The ICHIRO 9-cell cavity design such a high gradient (45 MV/m) pointed out hard requirement on the tuner system. To achieve the required high speed, stiffening and tunability range, we designed a tuning system based on a coaxial screw system. The slow mechanical tuning is performed by coaxial screw, which is driven by pulse motor located near inside of the vacuum vessel. The pulse motor drives a warm and warm wheel mounted on the coaxial ball screw. The advantage to use the warm and warm wheel is to reduce driving power of the screw rotating force and the higher tunability. Another tuner is required to tune the effects of so called Lorentz de-tuning. As a first mechanical tuner, PIEZO actuator gives directly rotating force to the ball screw. PIEZO is placed on room temperature environment in the vacuum vessel. In this mechanical design, thermal flow rate to 100K from 2K was strongly considered.

ThP62: Characterization of an Elliptical Low Beta Multicell Structure for Pulsed Operation

P. Pierini, A. Bosotti, C. Pagani, N. Panzeri (INFN), G. Ciovati (TJNAF)

The five cell TRASCO cavities, with a geometrical β of 0.47, have been equipped with a stiffening system in a position close to the nominal optimal for Lorentz force detuning minimization, even if they have been designed for CW operation. Due to this feature, in the context of the CARE Hippi EC program, the cavities are being equipped with a piezo assisted tuner of the "blade" type, in order to test them under pulsed operation in the future high power test facility that will be available at CRYHOLAB in Saclay. In this paper we report the design work for the tuning system, and the ongoing experimental characterization of the cavities at low power levels in vertical cryostats.

ThP63: Digital Cavity Resonance Monitor-Alternative Way to Measure Cavity Microphonics

T. Plawski, K. Davis, H. Dong, C. Hovater, J. Musson, T. Powers (TJNAF)

As is well known, mechanical vibrations or microphonics in a cryomodule causes the cavity resonance frequency to change at the vibration frequency. A way to measure the cavity microphonics is to drive the cavity with a Phase Lock Loop

(PLL). Measurement of the instantaneous frequency or PLL error signal provides information about the cavity microphonic frequencies. Although the PLL error signal is available directly, precision frequency measurements require additional instrumentation, a Cavity Resonance Monitor - CRM. The analog version of such a device has been successfully used for several cavity tests [1]. In this paper we present a prototype of a Digital Cavity Resonance Monitor designed and built in the last year. The hardware of this instrument consists of an RF downconverter, digital quadrature demodulator and digital processor motherboard (Altera FPGA). The motherboard processes received data and computes frequency changes with a resolution of 0.2 Hz, with a 3 kHz output bandwidth. The results are available in both analog and digital format. These paper discuses the hardware and reports on the test results of the new system.
∗ This work was supported by DOE contract No. DE-AC05-84ER40150.
[1] MICROPHONICS TESTING OF THE CEBAF UPGRADE 7-CELL CAVITY, K. Davis, J. Delayen, M. Drury, T. Hiatt, C. Hovater, T. Powers, J. Preble, TJNAF, Newport News, VA 23606, USA , PAC2001.

ThP64: Transient Microphonic Effects in Superconducting Cavities∗
T. Powers, K. Davis, L. King (TJNAF)
A number of experiments were performed on an installed and operational 5-cell CEBAF cavity to determine the minimum time required to reestablish stable gradient after a cavity window arc trip. Once it was determined that gradient could be reestablished within 10 ms by applying constant power RF signal in and a voltage controlled Oscillator-phase locked loop based system (VCO-PLL), a second experiment was performed to determine if stable gradient could be reestablished using a fixed frequency RF system with a simple gradient based closed loop control system. During this test, instabilities were observed in the cavity forward power signal, which were determined to be microphonic in nature. These microphonic effects were quantified using a cavity resonance monitor and a VCO-PLL RF system. Two types of microphonic effects were observed depending on the type of arc event. If the arc occurred in the vacuum space between the warm and cold windows, the transient frequency shift was about 75 Hz peak-to-peak. If the arc occurred on the cavity side of the cold window the transient frequency shift was about 400 Hz peak-to-peak. The background microphonics level for the tested cavity was approximately 30 Hz peak-to-peak. Experimental results, analysis of the resultant klystron power transients, the decay time of the transients, and the implications with respect to fast reset algorithms will be presented.
∗ Supported by US DOE Contract No. DE-AC05-84ER40150

ThP65: Cold Tuning System for 700 MHz Elliptical Superconducting Cavity for Protons

H. Saugnac, M. Fouaidy, N. Hammoudi, N. Gandolfo, S. Rousselot, M. Nicolas, P. Szott, S. Blivet, S. Bousson (IPN Orsay)

A first prototype of a slow cold tuning system dedicated to the 700 MHz proton cavity, as been tested in cryogenic conditions in the "CRYHOLAB" test facility. These first results show a good mechanical behaviour and have to be completed with long term tests. In parallel, a piezo tuner is under study. This tuner will be designed from the slow system, based on the CEA "Soleil" type tuner, and will be equipped with piezoelectric stacks for fast tuning requirements (Lorentz forces, microphonics). Characterizations of piezoelectric actuators from various firms have been done in cryogenic conditions in order to fix the mechanical parameters (stroke, pre stress) required for the mechanical design of the fast tuner.

ThP66: Pushing the Limits: RF Field Control at High Loaded Q

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

The superconducting cavities in an Energy-Recovery-Linac will be operated with a high loaded Q of several 10^7, possible up to 10^8. Not only has no prior control system ever stabilized the RF field in a linac cavity with such high loaded Q, but also highest field stability in amplitude and phase is required at this high loaded Q. Because of a resulting bandwidth of the cavity of only a few Hz, this presents a significant challenge: the field in the cavity extremely sensitive to any perturbation of the cavity resonance frequency due to microphonics and Lorentz force detuning. To prove that the RF field in a high loaded Q cavity can be stabilized, and that Cornell's newly developed digital control system is able to achieve this, the system was connected to a high loaded Q cavity at the JLab IR-FEL. Excellent cw field stability - about 2×10^{-4} rms in relative amplitude and 0.03 deg rms in phase - was achieved at a loaded Q of 2.1×10^7 and 1.4×10^8, setting a new record in high loaded Q operation of a linac cavity. Piezo tuner based cavity frequency control proved to be very effective in keeping the cavity on resonance and allowed reliable to ramp up to high gradients in less than 1 second.

ThP67: Experience with the New Digital RF Control System at the CESR Storage Ring

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

A new digital control system has been developed, providing great flexibility, high computational power and low latency for a wide range of control and data acquisition applications. This system is now installed in the CESR storage ring and stabilizes the vector sum field of two of the superconducting CESR 500 MHz cavities and the output power from the driving klystron. The installed control system includes in-house developed digital and RF hardware, very fast feedback and feedforward control, a state machine for automatic start-up and trip recovery, cw and pulsed mode operation, fast quench detection, and cavity frequency control. Several months of continuous operation have proven high reliability of the system. The achieved field stability surpasses requirements.

Friday, July 15, 2005

Friday Morning: Oral Session

FrA01: The Rare Isotope Accelerator (RIA)
R.C. York (MSU)
The Rare Isotope Accelerator (RIA) is the highest priority for major new construction in the Nuclear Science Advisory Committee's Long Range Plan (April 2002). In addition, RIA is tied for third position among near term priorities in the Department of Energy's twenty-year facility plan (November 2003). RIA's high priority derives from its unique ability to help answer fundamental questions such as the origin of the heavier elements and to probe the fundamental laws of physics. RIA will produce rare isotopes at the very limits of stability that are not now available any place on earth. RIA begins with a high-power superconducting heavy-ion linac called the Driver Linac. The Driver Linac will accelerate any stable isotope from protons through uranium to energies of 400 MeV/u or more with a beam power of 100 kW to 400 kW. After acceleration of a stable isotope in the Driver Linac, the best known methods will be used to produce rare isotopes from the 100% duty factor beam. A general facility overview will be given, presenting key facility elements and isotope production mechanisms. Specific Accelerator issues will be presented including possible design solutions.

FrA02: Proton Driver
G.W. Foster (FNAL)
(abstract not submitted)

FrA03: Status of the SPIRAL 2 Project at GANIL
M. di Giacomo (CEA-GANIL-SPIRAL2)
The SPIRAL 2 facility , the GANIL extension for radioactive beam production through the fission of uranium carbide (UC_x) target , was founded in May 2005. A superconducting linac with low-temperature injector, is used to accelerate a 5 mA deuteron beam up to 20 MeV/nucleon. The deuteron beam produces neutrons on a carbon converter, which are used for the fission process of the UC_x target. The fission products are then accelerated by the existing CIME cyclotron. The paper presents the status of the project at the end of the 2.5 year period of the detailed design study.

FrA04: ERL workshop review
M. Dykes (ASTeC Daresbury)
(abstract not submitted)

FrA05: Future FELs
J. Corlett (LBNL)
Free electron lasers offer exciting new capabilities in EUV and x-ray science, with possibilities for producing intense x-ray pulses with temporal and spatial coherence, tunable wavelength and polarization, and with pulse duration from hundreds of femtoseconds to sub-femtosecond.
Superconducting linacs offer significant benefits in providing high quality electron beams required for free-electron lasers, maintaining a high gradient with reduced wakefield effects. CW applications offer potential for higher pulse repetition rates, with the advantages of stable phase and amplitude of steady-state operations. A number of new SC RF FEL facilities are proposed, and outlined in this talk. Requirements of major systems are described and proposals and concepts for future FEL's presented.

FrA06: European X-FEL Project
K. Floettmann (DESY)
(abstract not submitted)

FrA07: Accelerator Physics Challenges of the ILC
G. Dugan (Cornell University)
(abstract not submitted)

FrA08: Challenges of International Collaboration
M. Tigner (Cornell University)
(abstract not submitted)

FrA09: GDE Expectations from SRF Community
B. Barish (Caltech)
(abstract not submitted)

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