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ERL17 WORKSHOP, WG4 SUMMARY: SUPERCONDUCTING RF

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Abstract

Working Group 4 consisted of 10 talks (see References), which were split into three sessions around four main themes. These themes will be listed and summarized in the following along with a summary of the discussion session.

HIGHER ORDER MODE DAMPING AND FUNDAMENTAL POWER COUPLERS

ERL power couplers need to be able to provide 10's of kWs in Continuous Wave (CW) operation. While CW power transmission has been demonstrated up to levels of 500 kW (standing wave) or even 750 kW in travelling wave, e.g. at CERN [1], it became clear that a successful coupler development is a multi-year effort, which is only mastered by a few experts worldwide. For lower frequencies, which are often favoured by ERLs, coaxial couplers are typically preferred [2] with a new development of TE11 coaxial couplers showing particular promise to handle high average CW power. High-pass filters in Higher Order Mode Suppressors (HOMS) are relatively new and require further development.

ADVANCES IN SRF SURFACE PERFORMANCE

In CW ERLs, RF surface losses often determine the maximum gradients at which the SRF cavities can be used. Lowering surface losses therefore has a significant impact on the facility footprint, initial cost, and running costs of the RF stations and cryogenic installations. Recent advances in the field of nitrogen doping flattened out the Q-slopes (in 1.3 GHz cavities) up to gradients of around 25 MV/m. Nitrogen infusion, which is still being optimized shows high Q values even at high gradients up to 40/45 MV/m. The nitrogen infusion method offers the possibility to tailor cavities to specific applications [3]. The effort of Niobium on Copper coatings has re-started and first samples show that it is possible to flatten the Q-slope, which was typically observed on coated cavities up until today [4]. Further effort is needed to unblock the full potential of this technique, which is used at CERN for LEP, LHC, and recently the HIE-ISOLDE cavities.

MICROPHONICS AND RESONANCE CONTROL

Issues of microphonics and cavity resonance stability continue to challenge new SRF installations, especially in view of the recent advances with nitrogen doping/infusion, which substantially increases the cavity Q but which equally decreases the cavity bandwidth. In case of the LCLS-II cryo module this translates into a cavity half-bandwidth of 16 Hz and a peak detuning requirement of 10 Hz, which means that active resonance control is becoming mandatory for operation [5]. First beam has just been seen in the Main Linac Cryomodule (MLC) at the CBETA facility (Cornell), which also faces the challenge of operating with a very small bandwidth (10 Hz) [6].

As part of the Low-Level Control System (LLRF) [7] active resonance control typically consists of Lorentz Force detuning compensation via fast piezo tuners and adaptive feedforward algorithms. In order to achieve the small detuning levels, which are necessary for the active resonance control to work, the cavities [8], the cryo module design and the cryogenic supply system all have to be optimised for very low vibrations/microphonics [9].

CAVITY DESIGNS AND CRYOMODULE PERFORMANCE

Dual axis cavities [10] can offer significant advantages as they: i) allow to have a straight trajectory for the injection of low-energy beams, ii) allow dumping of beams with large energy spread (no dispersion in the dumped beam as there is no bend between the decelerating cavity and the dump), iii) have the potential of improved BBU suppression. Despite these advantages, there are very few proposals today to actually use this type of cavities in a machine (see discussion session).

DISCUSSION SESSION

Coated versus bulk Niobium cavities

The question of which fabrication technique to choose depends on the desired beam characteristics. For high-current applications lower frequency cavities are often chosen because of the lower excitation and easier extraction of HOM power. Due to their larger size, low-frequency cavities are mechanically more stable if made out of copper, as it was done for instance for the 350 MHz LEP cavities or the 400 MHz LHC cavities. For lower-current applications, higher frequency (> 650 MHz) multi-cell cavities out of bulk Nb are typically chosen, as they are easier to fabricate and require small cryostats. Recent progress in nitrogen doping/infusion have dramatically reduced the surface resistance of bulk Nb cavities and this technique is already being applied to the series production of LCLS-II cavities [3]. One can argue that nitrogen doping is in fact a thin film/coating technique as the ensuing physics takes place only in the top surface layer.

Nb/Cu has lower residual resistance at low fields than bulk Nb but has traditionally suffered from a strong Q-slope at higher fields. Recent work has related the Q-slope to small defects at the Nb/Cu interface. Moving

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from sputtering to energetic condensation techniques first samples have shown a significantly reduced Q-slope, which indicates that further R&D may be able to yield substantial performance increases [4].

Further R&D in both techniques is strongly encouraged.

Dual-axis cavities – the way forward?

Questioned whether anyone would dare to use dual-axis cavities, the following points were raised: i) During a test of a dual-axis cavity at Los Alamos RF instabilities were observed. However, these were not related to the cavity itself but rather to a complicated bridge system used to put power into the cavities. Despite these issues successful lasing could be demonstrated; ii) the larger RF surface will increase the likelihood of having surface defects. However, considering that ERLs typically run at lower gradients and furthermore considering the successful recent commissioning of very long SC linacs (e.g. XFEL) it is assumed that the issue of the larger surface area can be mastered with modern Quality Assurance; iii) Using dual axis cavities may be especially interesting in cases where the beam quality in the injection is important, or where the returning beam has a large energy spread (such as in FELs). However, due to the added cost of doubling the number of cavities, this approach may be better suited to small ERLs with demanding beam conditions than for large ERLs, such as colliders.

RECOMMENDATIONS FOR FUTURE R&D

Coaxial couplers need further development for high average power capability. Especially TE11 power couplers should be investigated. Also high-pass, high-power HOMSs should be studied further. Nitrogen infusion and thin films hold great promise for SRF cavity performance and both techniques need dedicated R&D programs to unlock their full potential. On cavity shapes we highly recommend a vigorous R&D program on dual-axis energy recovery cavities and for cryomodules we encourage the development of designs that minimise microphonics.

REFERENCES FROM ERL 2017

[1] E. Montesinos, “Power Couplers & HOM Dampers at CERN”

[2] Q. Wu, “Coaxial Couplers”

[3] M. Checchin, “High-Q R&D at FNAL”

[4] S. Aull, “The Potential of Nb/Cu Technology for High Beam Current Applications”

[5] W. Schappert, “Resonance Control of the PIP-II SC Cavities”

[6] F. Furuta, “Cornell ERL CM Performance”

[7] S. Orth, “Development of an ERL RF Control System”

[8] T. Miura, “Resonant Frequency Control at the Compact ERL in KEK”

[9] F. Furuta, “Microphonics Analysis of ERL Cryomodule”

[10] F. Marhauser, “Twin-Axis Elliptical Cavity”