SUPERCONDUCTING RF ACTIVITIES AT LNL

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Abstract

Many superconducting rf activities are being pursued at LNL for present and future projects: the ALPI superconducting linac operation, maintenance and upgrading with Cu-Nb sputtered and bulk Nb cavities; the construction of the PIAVE injector with the new superconducting RFQ's and low-beta quarter wave resonators; the development of new construction techniques by spinning of Tesla-type bulk Nb and Nb-clad-Cu cavities, in collaboration with DESY, JLAB, KEK; sputtering of superconducting MgB_2 thin films on samples; linac design studies and intermediate beta cavities prototyping for high intensity proton accelerators (TRASCO) and for future radioactive beam facilities (SPES, EURISOL). Superconducting cavity prototyping is done also in collaboration with other laboratories (CERN, TRIUMF, MSU, KFA JUELICH) for present and future superconducting linac projects. The status of these activities, the recent results and the future goals will be presented.

1 INTRODUCTION

Rf superconductivity is since 1987 one of the leading subjects of research and development at Laboratori Nazionali di Legnaro. This activity started with the construction of the superconducting heavy ion booster ALPI [1] and evolved in different directions, covering a large part of the rf superconductivity research fields. The frameworks are INFN Projects (PIAVE [2], TRASCO[3]) and international collaborations in European (TESLA[4], EURISOL[5]) and extra-European projects (e.g. ISAC-II [6]).

Activities span from the design of superconducting cavities of different velocity range, including mechanical, rf and cryogenic aspects, to the development of new geometries, new construction techniques and new superconducting materials.

In the present paper an overview of these activities will be given, bearing in mind that an important part of them will be presented in detail in other articles of these proceedings.

2 ALPI UPGRADING

The ALPI heavy ion booster at LNL, active since 1994, is presently being upgraded by replacing the Pb plating of the medium-β, 160 MHz copper cavities with sputtered niobium (Figure 1). This operation allowed to increase the average cavities operating gradient by about 50%, reaching an average of 4.3 MV/m and allowing a significant reduction of the required number of units.

Fig. 1 : 160 MHz, medium β cryostat equipped with four Nb/Cu sputtered resonators

An extensive presentation of the ALPI upgrading, Nb sputtering state-of-the-art and operational experience can be found in ref. [7] of these proceedings.

The ALPI low-β line includes twelve 80 MHz, β=0.055 cavities which have shown rather high performance (an average of about 6.9 MV/m at 7 W in the off-line test, confirmed in the units tested insofar on line); the cavities could be operated up to 6 MV/m with the present rf system [8],[9]. These resonators, built, tested and installed in the past years, have been operated only for short periods due to insufficient cooling capability of the corresponding cryogenic line; this allowed only acceleration of ions with mass below 100. The future operation of the new PIAVE injector, providing ions of mass number above 100, will necessarily require the low beta cryostats. To this aim a refurbishing of the cryogenic system is foreseen during the next year.

Rf defocusing, proportional to the accelerating field and to the resonator rf frequency, in some cases could make it difficult to operate at the high gradients obtained by the ALPI cavities; the lattice, in fact, was designed for operation at 3 MV/m and contains 8 resonators between two successive focusing magnets. Optimisation of the accelerator tuning to allow high accelerating field will be an important issue in the future ALPI operation.

3 STATUS OF PIAVE

The superconducting heavy ion injector PIAVE, which will provide high charge state heavy ions of all masses to the ALPI booster, is presently in an advanced stage of construction [10]. The ECR source, the high voltage platform, the all Low Energy Beam Transport line and the triple harmonic buncher are in place; this section has been commissioned with a continuous beam [11].

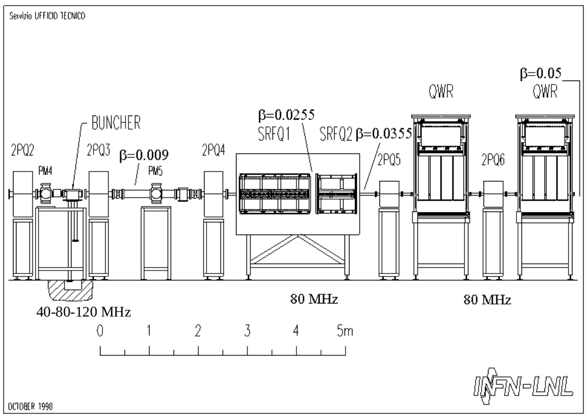

Figure 2: The PIAVE linac layout.

PIAVE comprises two superconducting RFQ's as the first accelerating elements. They are built in full Nb, with external stiffening cage and end-flanges in Ti (Fig. 3).

SRFQ2 has been completed and the curve showing its Q versus the peak surface electric field has been measured several times so far, showing that the cavity performance exceeds its design specifications (fig.4). Experiments aimed at checking the resonator phase stability at the field required by beam acceleration are going on.

Fig. 3: SRFQ1 during frequency rough tuning test, which precede the final EB welds.

The construction of SRFQ1, very similar in cross section to SRFQ2, twice longer but less demanding both in terms of required voltages and hence of mechanical stability, started only after the successful completion of the tests on SRFQ2 and it shall be completed by the end of 2001. The SRFQ cryostat is being constructed by the Budker Institute of Novosibirsk. It is foreseen to mount both RFQ's in their dedicated cryostat within March 2002. The SRFQ status is described in detail elsewhere in these proceedings [12].

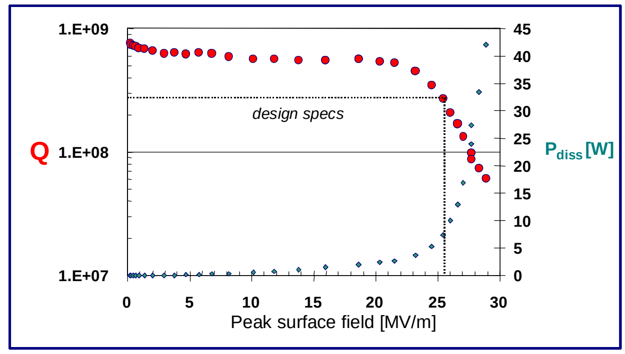

Fig. 4: SRFQ2 rf test results.

The β=0.047, 80 MHz bulk niobium quarter wave resonators (fig. 5), equipped with mechanical dampers, are ready for installation, as well as their cryostats.

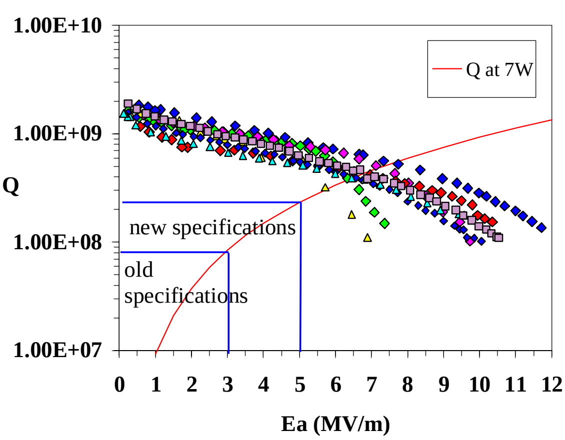

Figure 5: Rf test results of the PIAVE 80 MHz, quarter wave resonators equipped with mechanical dampers. Only cavity n. 8 (square marker) underwent high pressure rinse.

Figure 6: View of a PIAVE type bulk niobium cavity.

Their off line test results showed an average 7 W gradient of 6.7 MV/m, that largely exceeds the specified value of 5 MV/m (fig. 6) [13]. The 400 W cryogenic system has been acquired and its installation will start in autumn 2001. The completion of PIAVE is foreseen within 2002.

4 NEW SUPERCONDUCTING LINAC PROJECTS

4.1 TRASCO

The LNL activity in TRASCO, a project study of an Accelerator Driven System for nuclear waste transmutation, is mainly related to the low energy (normal-conducting 352 MHz RFQ), and to the intermediate energy part, which consists of a 5-100 MeV, 30 mA proton linac. The LNL design is based on a ISCL (Independently-phased Superconducting Cavity Linac) scheme [14], able to transport the full beam current even in the case of failure of one cavity. This characteristic is strictly related to a specific need of nuclear reactors, which can be seriously damaged by beam interruptions longer than about 1 second. This imposes particular requirements on the linac structure and to the design of the resonator, which cannot exceed 0.5 MeV acceleration in the initial part of the linac. The drawback of this design is the rather large number of resonators required (230) each one powered by a 15 kW rf amplifier. Development of low cost, high performance solid state rf amplifiers for this purpose is going on at LNL in collaboration with LURE at Orsay.

A prototype of the required 352 MHz reentrant cavity [15] has been built (fig. 7). This single gap resonator is very short and has a wide flat surface exposed to the helium pressure. The required mechanical stability has been obtained by means of reinforcing rings connecting the 3 mm thick, inner niobium disks to the helium vessel.

Advantages of this design are the field symmetry, the capability to work at a rather low beam velocity for this frequency (from β=0.1), a relatively large bore of 30 mm. The cavity is presently under chemical polishing, and rf testing at 4.2K will follow soon.

Fig. 7: The TRASCO 352 MHz reentrant cavity prototype.

Work is in progress to study the possibility of reducing the number of cavities in the ISCL. A solution is the use of 2-gap cavities (e.g. QWRs) in the second part of the linac, where the beam is less sensitive to cavity failure. A 352 MHz QWR with a design similar to the ALPI 80 MHz cavities has been built (fig.8) by using material recovered by an old prototype. The aim of this cavity is to study at 352 MHz the mechanical and the multipacting characteristics of this geometry, which are already known to be very good at lower frequency.

Fig. 8: The 352 MHz quarter wave cavity.

One of the still open questions on the possibility of using quarter wave resonators for proton linacs is their steering effect. We deeply studied this effect with our QWR geometries by means of numerical and analytical calculations [16]. The steering, dominated by the magnetic field, depends almost linearly on the beam position and a proper lattice design seems to be able to nearly cancel it.

4.2 EURISOL

EURISOL, the European project study for a 3rd generation radioactive beam facility [5], includes a 1 GeV, 5 mA superconducting proton linac driver, and a 100 MeV/u heavy ion reaccelerator. LNL is involved in both tasks and proposes a reaccelerator design based on QWRs of the PIAVE and ALPI type, and on 3 superconducting RFQ's at the beginning of the reaccelerator. For the Intermediate Energy part of the proton driver, LNL is studying a superconducting solution based on 1 and 2 gap cavities. The EURISOL design is presently in progress.

4.3 SPES

SPES is the project for an ISOL-type radioactive beam facility at Legnaro [17]. The facility will include a high intensity proton accelerator driver; the beam will be stopped in a high power target, and the secondary neutrons will be used for radioactive beam production in a ISOL type ion source (Fig. 9). The radioactive beam will be reaccelerated by a PIAVE-like injector and by ALPI. The project, still in the design and R&D stage, can be thought as a lower scale model for EURISOL.

The rf superconductivity activities in the RIB projects and TRASCO have a large number of common tasks, and all of these machines require intermediate-β superconducting rf structures of similar type.

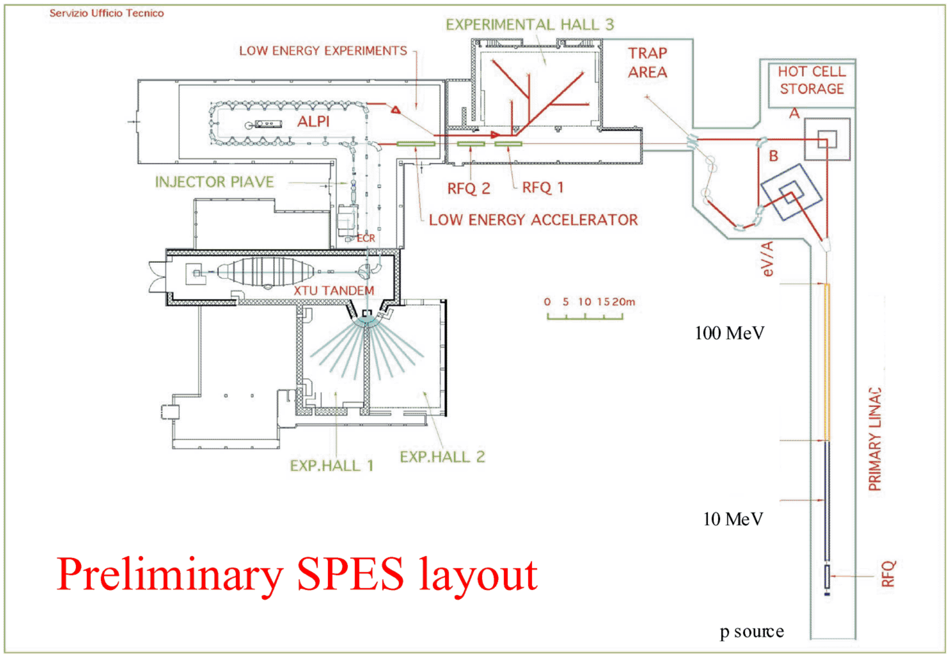

Fig. 9 Preliminary SPES layout

5 OTHER INTERNATIONAL COLLABORATIONS

5.1 TESLA

New techniques have been developed at LNL to reduce the TESLA cavity cost in the view of mass production. A very successful one is the spinning technique [18], which allowed the construction of top performing seamless cavities. Seamless resonators both in niobium and in copper can be spun from a simple disk in a short time (several tenth of minutes per cell) without intermediate annealings.

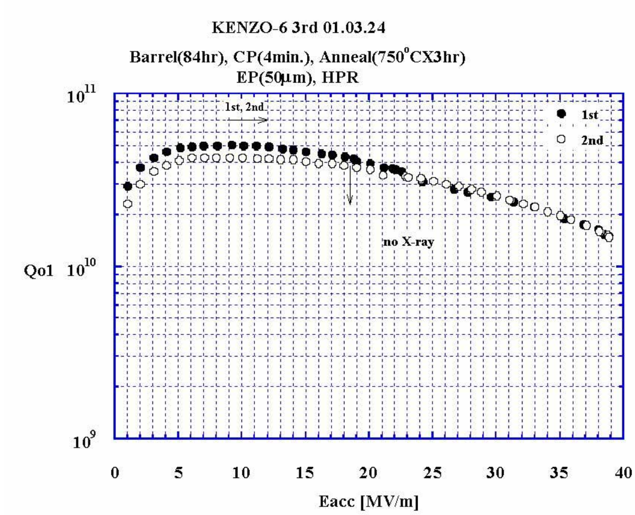

Fig. 10 - The cavity KENZO 6 is a bulk Niobium monocell spun at LNL, and electropolished at KEK.

The research activity is carried on at LNL in collaboration with DESY and KEK laboratories on 1.3 GHz cavities, and is widely described elsewhere in these proceedings. The technique has achieved the threshold of 40 MV/m on bulk Nb monocells and it is under progress for multicells.

In collaboration with K. Saito of KEK laboratories also Nb clad copper cavities have been fabricated by spinning a clad disk. The activity is however still under progress, the best accelerating field at the moment being only 30 MV/m.

5.2 ISAC-II at TRIUMF

LNL developed, in collaboration with TRIUMF and CERN, the medium-β cavity prototype for the radioactive beam facility ISAC-II at TRIUMF.

Fig. 11: The 106 MHz cavity for ISAC-II at TRIUMF

The resonator is an upgraded version of the ALPI bulk niobium low beta cavities, modified to match the 106.08 MHz required by the ISAC injector and with an improved mechanical stability. This resonator, after Chemical Polishing performed at CERN, have shown a rather good performance (6.7 MV/m at 7 W, and more than 11 MV/m maximum field). All design specifications have been more than fulfilled from the first test [19].

5.3 Other collaborations

LNL is collaborating with other laboratories in the development of superconducting cavities and in linac design. Collaboration agreements are active with CERN (high intensity proton cavities), NSCL at the Michigan State University (low and intermediate beta QWRs for heavy ions and superferric quadrupole magnets), KFA Juelich (low and intermediate beta proton and deuteron cavities for pulsed operation), the University of Kyoto (superconducting RFQ's), BARC and TIFR in Bombay, and others.

6 NEW SUPERCONDUCTING MATERIALS

The recent discovery of superconductivity at 39K in MgB_2 [22] has renewed the interest of research in intermetallic superconductivity. Due to its peculiar features (high critical temperature, high critical fields, metallic behaviour in the normal state, and the so-called "transparency" of grain boundaries), Magnesium Diboride films appear very promising for RF applications. At LNL, superconducting films with T_C lower than 30 K and only with a wide transition have been sputtered by high rate DC pulsed magnetron sputtering. The starting material was Magnesium-enriched MgB_2 powder pressed targets at a substrate temperature of 500C. The powder-pressed target gives the possibility to change the target composition without need to sinter new targets [20] .

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