STATUS OF RF SUPERCONDUCTIVITY AT L.N.L.

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Introduction

The activity in the field of RF superconductivity at Legnaro National Laboratory consists in two main branches: the commissioning, upgrading and operation of the S.C. linac for heavy ions ALPI [1] and the design and development of new superconducting resonators.

The medium β section of ALPI, including 44 accelerating Pb on Cu QWR's, was completed at the end of 1993 [2]. In May 1994 a ^{58}Ni beam, out-coming from the XTU Tandem and accelerated to 346 Mev, was led to the experimental hall. Beams of ^{32}S, ^{37}Cl, ^{58}Ni, ^{76}Ge, ^{81}Br were available during 1995 to check beam quality and stability. An array of 20 bulk Nb resonators (β=0.056) [3], following the already constructed ECR ion source located on a 350 kV platform [4] and a positive ion injector [5], will extend the energy upgrade to the heavier ions. The linac will be completed by sputtered Nb on Cu QWR's (β=0.14) [6] to deliver, in the final configuration, ion beams ranging from Si to U up to energies of 6 - 20 MeV/amu.

TESLA type resonators were manufactured in Nb, Cu and Al by spinning [7]. The sputtering of Nb on Cu was investigated and a post magnetron sputtering configuration developed [8].

ALPI

The superconducting linac for heavy ions ALPI, the construction of which started in 1989 at Legnaro National Laboratory, is now in operation in its first configuration stage. It includes 44 accelerating QWR's working at 160 MHZ and with an optimum β of 0.11 [9]. The absence of electron beam welds, substituted by vacuum brazed joints, and the straight inner conductor, ended by a hemisphere, are the resonator peculiarities. In this configuration the linac accelerates ions, out-coming from the 16 MV Tandem, to an energy up to 6-15 MV/amu in the mass range 28-100. Moreover the first cryostat of the high β-section, which contains four sputtered Nb on Cu resonators operating at 160 MHz, is operational. Two low-β units, a buncher and a cryostat housing four accelerating 80 MHz bulk Nb resonators are installed and under test.

ALPI is in its operational configuration stage: magnets, diagnostics, cryogenics, vacuum and control system are ready to operate with all the foreseen resonators. According to the users' greater interest towards heavier ions, two medium-β and four low-β cryostats are under construction and the construction of new high-β units will follow.

The linac reliability was much improved by the installation of an emergency heat exchanger that allows to maintain the thermal shield temperature at 60 K in case of a failure in the cryogenic system or related equipment [1].

The medium-β resonators work reliably at a mean accelerating field of 2.5 MV/m. The details of the conditioning and operational procedure [2] are summarised here.

Three complete conditioning processes, following two thermal cycles up to room temperature, were performed on the linac resonators since spring 1994. The time needed for the process was reduced after combining the RF power conditioning (two 1 kW amplifiers available) with low power He conditioning. We took advantage of the implemented possibility of setting automatically a He pressure of about $4x10^{-5}$ mbar in the cryostats while operating 12-16 resonators at the same time at 10-20 W forward power. Further advantage was obtained from a modification of the RF control program that allowed to pulse the power of the 100 W installed amplifier with a duty factor of 20% and a pulse length of about 400 msec. The procedure, associated with He conditioning, was used to complete the RF peak power treatment and to maintain, stabilise and sometimes improve, the accelerating field in between beam time shifts. The cavity performance increased with time and a slight improvement is still possible.

The resonators are usually set up for beam transport one day in advance. After setting the 7 W field, adjusting the suitable coupling and the frequency, the resonator amplifier can be turned off and switched on just when the cavity is used for acceleration. Readjustments are not required if the resonator is maintained at 4.5 K, thus making the resonator linac set-up very fast when the input beam is available. The cavities remain locked at fixed field and phase for days.

Progress in low-β resonator construction

a) Low β bulk Nb resonators

The linac low β section includes 20 accelerating cavities and a buncher, working at 80 MHz and with an optimum β of 0.056. The cavity is a coaxial line with a straight inner conductor. It is characterised by a double wall structure realised in bulk Nb. We have now 6 resonators ready. In the first installed resonator the 3 MV/m ALPI design field could be obtained at 0.35 W of dissipated power; 6.3 MV/m could be obtained at the available refrigeration power of 7 W. They were built by an Italian company while the chemical treatment was performed at CERN. The first cryostat housing the buncher units was installed on the beam line in May 1995. The standard resonator treatment was not possible before summer having to share time and liquid He with beam time operation. Anyway without power and He conditioning, an accelerating field higher than 4 MV/m could be easily obtained. Once overcoupled (50 W forward power) the resonator was locked reliably at 3 MV/m. The unlock events at higher field were correlated to fluctuations of the resonant frequency due to changes of the He bath pressure. Further measurements have shown that, depending on the state of the cryogenic system, a condition of safe lock very often can not be reached due to wider pressure fluctuations. A fast tuning system consisting in an inductive coupler connected through a resonant line to an external impedance is under construction [3].

b) Medium β Pb on Cu resonators

The plating procedure and the related cleaning process were re-examined [9] in a systematic way this year. Preliminary results show that Q of the order of $4x10^8$ and accelerating fields exceeding 3.5 MV/m could be obtained. Moreover a post plating treatment, that prevents lead oxidation, was fixed, thus reducing the risk of resonator exposition to air.

c) High β Nb sputtered resonators

The DC biased sputtering technology applied to QW resonators allowed to exceed several times accelerating field of 6.5 MV/m, at 7 W of dissipated power, in 160 MHz, β=0.14 cavities [6]. The field obtained on the beam line was limited at 3 MV/m being the resonators heavily affected by field emission [6]. A leak discovered just before transferring the cryostat to the beam hall forced us to cut and replace a bellow with the resonator mounted. The repair heavily affected the performance of the cavities, that usually are very fast to condition. A new cavity set will be ready soon.

d) RFQ's project

A new positive ion injector [5] consisting in an already existing ECR [4], two superconducting RFQ's and eight 80 MHz QWR's is being completed. The superconducting RFQ's , that are 80 MHz four-rod structures, are in prototype phase [10]. The prototype work foresees both the construction of a full scale bulk Nb cavity and studies of magnetron sputtering on a Cu substrate.

Resonators For Tesla

a) Seamless resonators

The L.N.L are involved in a CERN-INFN collaboration on superconducting cavities. The LNL contribution to the project is the production by cold forming of Tesla type seamless resonators. The method is based on spinning of a metal sheet pressed by a suitable tool against a mandrin mounted on a lathe headstock. In a preliminary stage the disk is spun into a preformed cone, in the final stage onto a cavity shaped demountable die. The advantages of the process are the simplicity, the reduced execution time and minimum swarf. Al, Cu and Nb monocell, and Al and Cu multicells with uniform thickness, have been obtained without the necessity of intermediate annealing. The stress of the material during the process is limited. The quality of the inner surface is not affected by the working procedure because the tool works the external cavity surface. Multicells resonators have been produced using the same method both starting from an aluminium disk and from a tube [7].

b) $\beta = 1$ resonator sputtering

Nb sputtering into 1.5 GHz copper monocell was investigated in a DC post magnetron configuration. Coils of adjustable position, external to the cavities, allow to obtain high deposition rate and a uniform and homogeneous film growth. Up to now $T_C > 9.25$ K everywhere in the cavity and RRR between 22 (equator) and 52 (iris) were obtained [8].

References

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