ACTIVITIES ON RF SUPERCONDUCTIVITY IN FRASCATI, GENOVA, MILANO LABORATORIES

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Introduction

Activities on RF Superconductivity at INFN laboratories in Frascati, Genova, Milano are mainly oriented towards the realization of high gradient cavities and construction of test accelerators for high energy physics (Φ factories).

The activities consist in the construction of a test 50 MeV accelerator (LISA) and in the development of SC RF cavity prototypes and low emittance RF guns. The interest is both in bulk Nb and in films sputtered on copper. Characterization of films of various materials is carried on.

SC RF for LISA

The construction of a 25 to 50 MeV linear SC accelerator (LISA)[1] is in progress in Frascati. The aims of the project are to study the problems of SC linacs with high quality, high peak current beams.

The LISA project was funded at the end of 1987. The design started almost simultaneously and the main orders were placed in 1988. All the main accelerator components will be delivered by the end of 1989 and commissioning of the machine is foreseen in 1990.

A layout of the accelerator is shown in Fig. 1 and the main parameters are given in Tab. I.

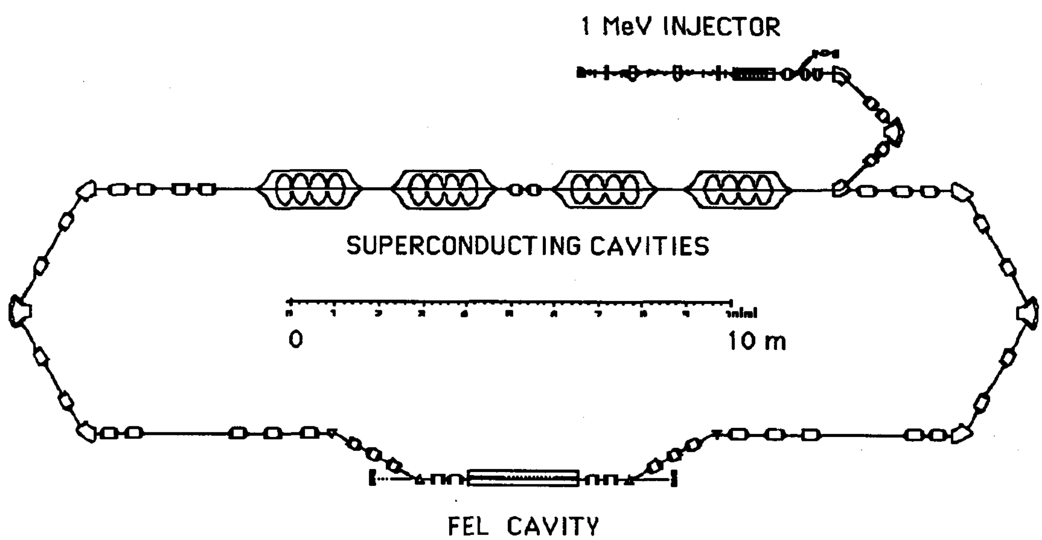

Fig. 1 - View of LISA layout.

Table I

Main parameters of LISA

Energy (MeV)	25 ÷ 49
Bunch length (mm)	2.5
Bunch charge (pC)	40
Electrons per bunch	$2.6\ 10^8$
Peak current (A)	5
Duty cycle	≤ 2%
Average macropulse current (mA)	2
Invariant emittance (πm rad)	10^{-5}
Energy spread (@25 MeV)	$2{\cdot}10^{-3}$

The parameters of the RF cavities are given in Tab. II

Table II

Parameters of the RF cavities

Frequency (MHz)	499.8
r/Q_0 (Ω/m)	380
Active length (m)	1.2
Overall length (m)	2.5
Number of cells	4
Accelerating field (MV/m)	5
Q_0 (@4.2 °K)	$2 \cdot 10^9$
Q_{ext}	$6.5 \cdot 10^6$

The choice of the frequency, 500 MHz, was dictated by a compromise between high peak current capability, size and availability of proven designs. In fact the design of the cavity is the same as that for DESY-HERA except for the cryostat, that in our case contains a single cavity, so as to simplify handling and give more flexibility in operation. For the same reason each cavity is fed by an independent 15 kW RF power generator. Fast phasing of the cavities is made at low power level. The cavities, complete with cryostats and RF couplers,will be supplied fully tested by INTERATOM. One of the Nb structures is shown in Fig. 2.

The SC cavities are designed to operate at 4.2 °K and the expected low temperature heat load of the whole accelerator is about 200 W. The refrigerator is a standard model Sulzer TCF50, equipped with automatic control system, also providing intermediate temperature (40-80 °K) cooling. It is designed to handle 300 W at 4.5 °K.

The high quality beam from LISA is well suited to realize a high power and high efficiency FEL covering the infrared wavelength region. A collaboration has been set up with the ENEA Frascati FEL group to implement a FEL whose main characteristics are given in Tab. III. The undulator (50 poles, hybrid NdFeB), will be supplied by ENEA; it is expected to be delivered by the end of 1990, following closely the end of the commissioning of the accelerator.

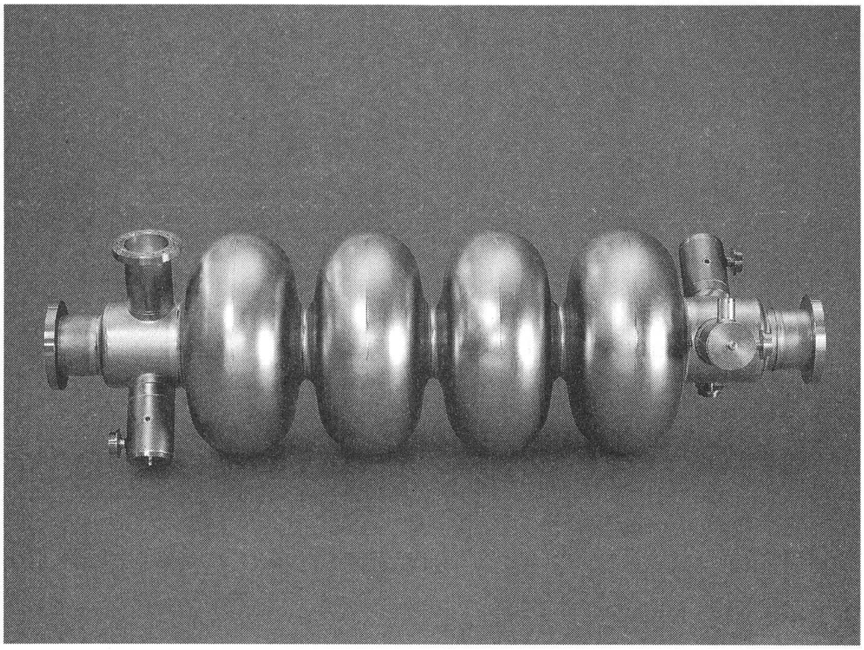

Fig. 2 - One of the Nb cavities after welding.

Table III

FEL: Main Parameters

Beam energy (MeV)	25
Number of undulator periods	≤ 50
Undulator wavelength (cm)	5
Radiation wavelength (μm)	12 ÷ 22
Optical cavity length (m)	6
Cavity passive losses (%)	2
Cavity output coupling (%)	3

Characterization of SC cavities and studies on sputtered thin films

Facilities have been set up for testing complete SC resonator cells with RF power. They consist in a vertical cryostat 2.7 meter deep, a 1 kW 500 MHz amplifier, electronic instrumentation and a data acquisition system for the temperature mapping. Moreover basic handling tools such as a laminar flow panel wall (class 100) arranged in a dedicated room, and an ultra-pure water (resistivity ≥ 18 MΩ cm) system are now available.

Recently $Q_0(E_a)$ measurements have been performed on a single 500 MHz cavity made of Nb sheet, kindly lent to us by CERN EF/RF group, to test our measuring apparatus. Results from this cavity are shown in Fig. 3. They have been obtained without compensation of the earth's magnetic field. In order to achieve these results the cavity has been opened several times and also cleaned with alcohol and rinsed with pure water for 1 h 20 m. It has therefore been a good test of all our facilities.

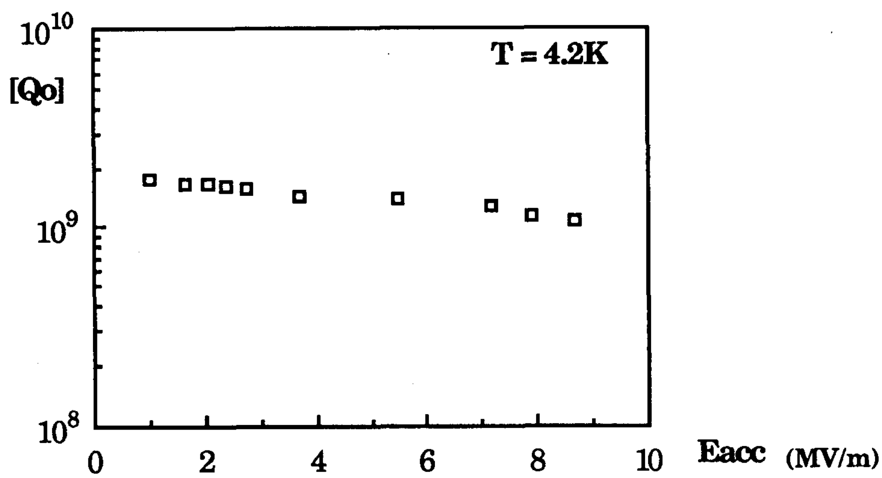

Fig. 3 - Quality factor vs. accelerating field for single cell 500 MHz cavity.

Worthy of mention are also some tests that have been made on a 6 GHz bulk Nb cavity for a possible application to a microwave undulator as an insertion device for particle storage rings.

The cavity is simply a cylinder with elliptical cross section, working in the TE_{11n} transverse deflecting mode, where n is the number of periods along the axis. Although the synchrotron radiation photon flux obtainable is limited by the peak surface field (~1 KG), such a device has some properties that could make it attractive for synchrotron radiation users.

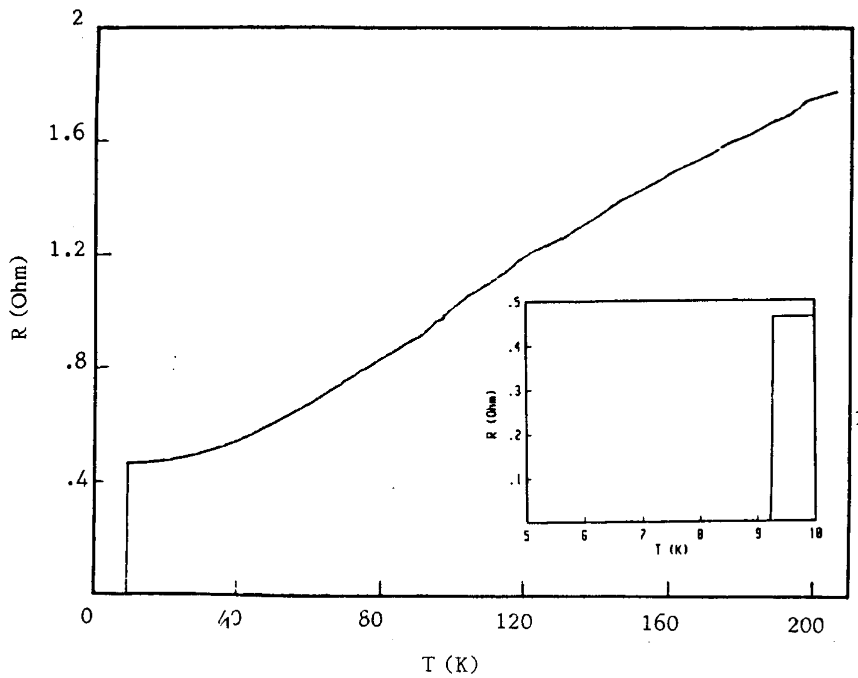

Fig. 4 - Resistance vs. temperature for Nb thin film.

A cooperation with the INFN-LNL laboratory, CERN and the Universities of Napoli and Salerno has been set up with the aim to study thin films of superconducting materials useful for the accelerating cavities.

The goal is to develop SC cavities with $Q_0 \approx 3 \times 10^9$ at accelerating fields of 10 MV/m by using the sputtered coated technique. In this framework we acquired both a DC magnetron thin film deposition system for realizing small samples of sputtered thin films, and a cryostat with the necessary electronic instrumentations to characterize the film in static magnetic fields up to 5 Tesla.

Several small Nb thin film samples have been fabricated on a planar glass substrate at ambient temperature.

To achieve good understanding of the superconducting properties we sputtered through a metal mask in order to get a linear strip. The following measurements on our samples indicated we were able to get rather good quality niobium films.

In Fig. 4 typical behavior of the resistance as a function of the temperature is reported, while in the inset the transition region is magnified ($T_c \approx 9.24 \pm 0.05$ °K). Another feature of these samples is the rate of decrease of the T_c in a parallel magnetic field, which is ≈ 2 °K/Tesla, as summarized in Fig. 5.

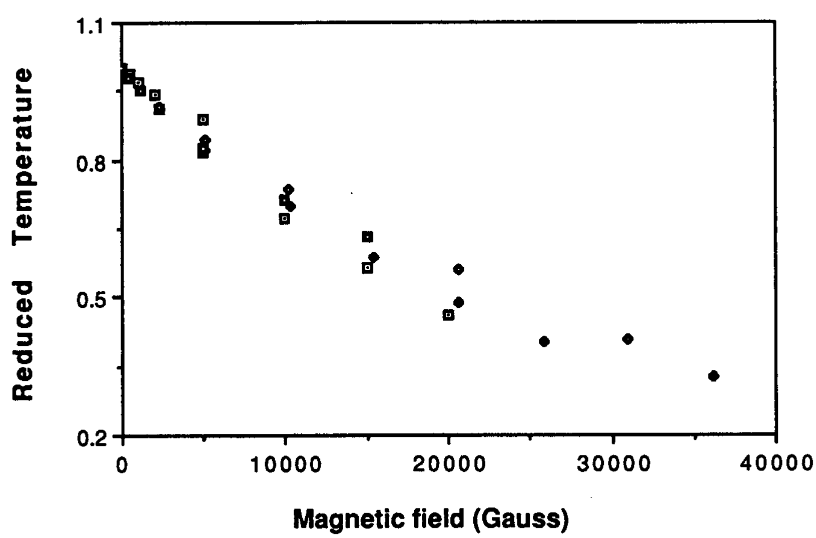

Fig. 5 - Critical temperature vs. magnetic field for Nb thin film.

Further investigation on the superconducting properties of materials are in progress by using slow ac magnetic field and phase sensitive detection, to get indication on the dissipative behavior of a superconductor.

In Fig. 6 the superconducting transition detected with inductive method is reported for a Nb sample having RRR ≈ 40: X' is the "in-phase" signal due to the Meissner state, while X" is the "out of phase" signal due to the magnetic induced losses.

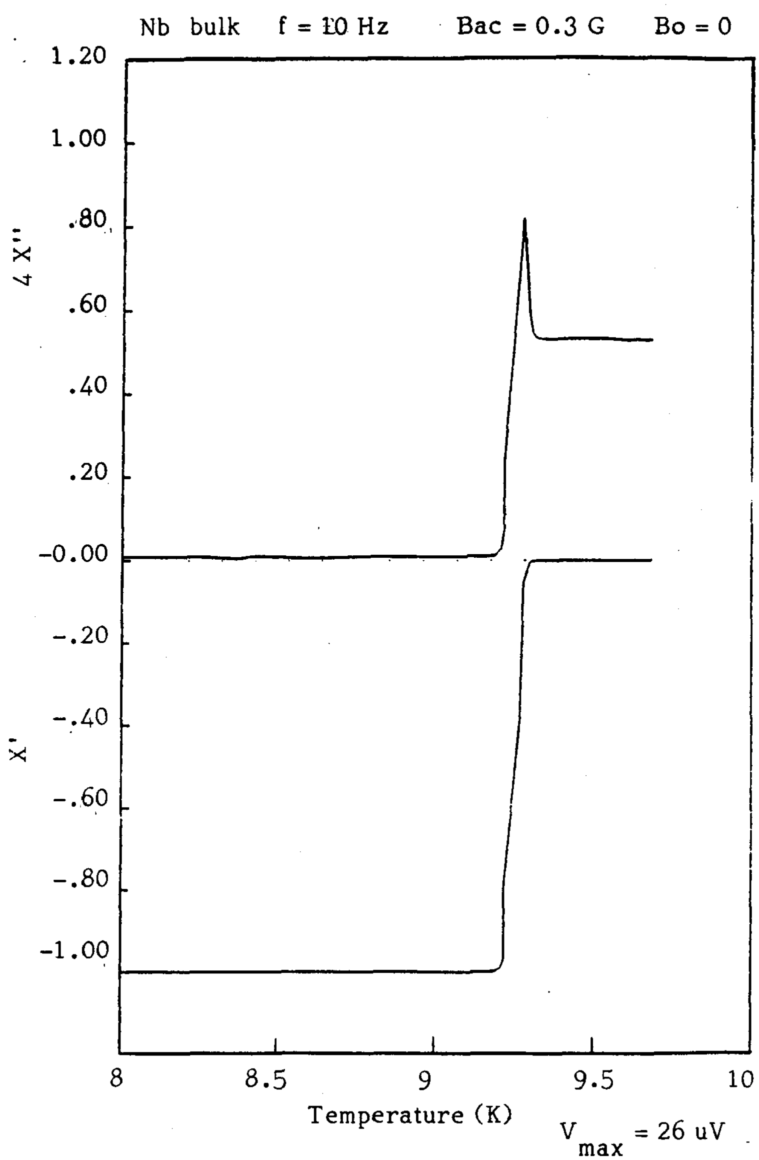

Fig. 6 - Real and imaginary parts of susceptivity vs. temperature.

The ARES project

As a synthesis of the R&D work on RF superconductivity, the feasibility study of an advanced 500 MeV SC linac[2] is in progress and we expect to present the proposal to INFN by the end of this year. This machine is intended to be a test bench for the development of future colliders components (high gradient sputtered cavities, RF SC Gun for high repetition rate low emittance beams, etc.), while producing beams directly usable for UV and soft X-ray FEL and Nuclear Physics experiments.

A major application of the Linac will be the injection of e^- and e^+ beams in a Φ factory of new conception, whose design is in progress too.

A preliminary set of the Linac Parameters, which can be thought as the goals of a 3 years R&D program, is given in Tab. IV.

Table IV

Goals for the ARES Linac

Energy (MeV)	≈ 500
Number of cavities	48
Accelerating field (MeV/m)	~ 9 (@ 4.2 °K)
Q_0 (10^9)	3
Radiofrequency (MHz)	500
Refrigeration power (kW)	5 (@ 4.2 °K)
RF power (kW)	120
Mains power (MW)	< 4.

References

[1] F. Tazzioli et al.: "The Linear superconducting accelerator project LISA", Proceedings of EPAC '88, Rome June 7-11,1988, World Scientific, Vol. 1, p. 52.

[2] S. Tazzari, F. Tazzioli, C. Pagani, R. Parodi: "Lineamenti di programma per ARES", LNF Internal Report November 1988.