SRF Activities at the IPN-LAL (CNRS-Orsay) Laboratories

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Abstract

In the last two years, both laboratories, in collaboration with the CEA-Saclay, have actively participated to the study and construction of the TESLA Test Facility at DESY (Hamburg). The main effort was concentrated on the completion and first tests of the injector: electron gun, s.c. capture cavity, beam lines and associated diagnostic systems. After succesful tests the injector is currently delivering 10 MeV electron beam to the first cryomodule. Different R&D activities on SRF cavities were also conducted during this period: studies on input couplers, development of new cavity fabrication techniques, and basic studies on electron emission and thermal behaviour of cavities.

Introduction

Two main activities have continued during the last two years: 1) TTF project, and 2) R&D on SRF cavities. In both activities a close collaboration with the CEA-Saclay Laboratory was reinforced in the frame of an agreement between the two french institutions (CEA and CNRS) for the study and development of superconducting particle accelerators. Concerning the TTF project, the activities were essentially oriented to promote and support the construction of a test facility (TTF at DESY), which will become a test bed for the next generation of high energy superconducting electron linear accelerators. The R&D effort on cavities was related to the search for higher gradients and good reliability, together with the necessary reduction of fabrication costs.

1. TTF Injector.

The three french laboratories took in charge the study and construction of the first TTF Injector **[1]**. This injector incorporates an electron gun with its High Voltage platform, a room temperature pre-buncher system, a superconducting capture cavity, beam focusing systems, and a large number of beam diagnostic devices. The capture cavity is a standard TESLA type cavity (1.3 GHz, 9 cells) with standard input coupler, HOM couplers and cold tuning system. It is installed in a special cryostat CRYOCAP **[2]**.

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The cavity fabricated by CERCA S.A. was preliminary tested in vertical and horizontal test cryostats, where very good performances were obtained: E_{acc}(max)=21 MV/m limited by quench. A small field emission at high gradient was detected: E_{onset}=18 MV/m. The final mounting procedure in the capture cryostat leads to a small degradation of these performances: field emission onset reduced to E_{onset}=14 MV/m.

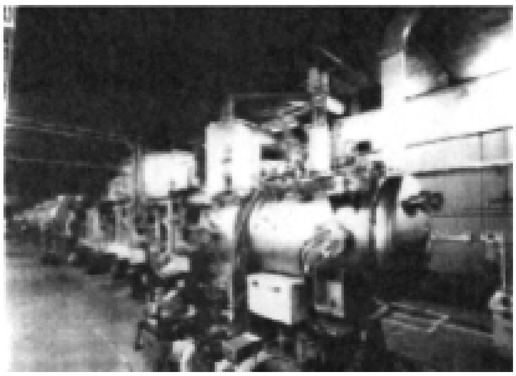

Fig.1. Capture Cryostat installed in the TTF tunnel at DESY Laboratory.

The static losses of the cryostat were measured during the last test: 2.5 W in the 1.8 K circuit, 1.3 W in the 4.5 K circuit, confirming the initial specifications. With the standard TTF pulsing conditions, the total losses, including the RF losses, were measured using calorimetric methods: 2.72 W at 12.5 MV/m in the 1.8 K circuit and 2 W in the 4.5 K circuit. These measurements allow to make a rough estimation of the RF losses in the cavity: $Q_0 \sim 8.2 \pm 1.5\ 10^9$.

The installation of the injector at DESY was completed in December 1996 (Fig.1). The first injector beam tests took place during the period January-April 1997 **[3]**, and a beam was injected in the first cryomodule in May 1997. The main specifications of the injector were easily achieved (Table 1), and a beam with energy ranging from 10 to 12 MV/m is currently delivered for the tests of the first cryomodule.

	Specified	**Achieved**
Energy	> 8 MeV	8 - 13.5 MeV
Current	8 mA	8 mA
Pulse width	800 μs	800 μs
RMS Energy Spread	< 100 keV	~ 70 keV
RMS Emittance	< 5 mm.mrad	< 4 mm.mrad

Table 1. TTF Injector Parameters

The beam energy spread was measured with a magnetic spectrometer and a SEM grid device (20 μm tungsten wires). At 11 MeV, corresponding to a gradient in the capture cavity E_{acc}=12.5 MV/m, and 6 mA beam current, the RMS energy spread is 68 keV. The transverse emittance has been measured with an optical transition radiation (OTR) device. Light from the OTR foil (aluminium foil of 20 μm thickness), is focused on a gated and intensified CCD camera. Image processing and statistical analysis allow on-line calculation of the emittance. At 10.6 MeV (beam pulsewidth of 30 μs) the 50% amplitude contours give normalised emittances of e_x=2.4 mm.mrad and e_y=2.8 mm.mrad for the horizontal and vertical planes respectively.

2. R & D on SRF Cavities

2. 1. Copper Plasma Sprayed Niobium Cavities

The main activity was the study of a new technique of cavity fabrication using a classical deposition method by plasma spray. A copper layer of 2 mm typical thickness, is deposited on a thin wall (0.5 mm) niobium cavity previously fabricated following the standard forming and welding methods**[4]**. The underlying goal was to develop a fabrication method which could respond to two major questions in large scale cavity production: reduction of cost and simpler stiffening techniques. **Fig. 2** shows two of the first 3 GHz prototypes (before and after copper deposition), which have been fabricated to validate this method and study the influence of the copper layer on the cavity performance.

Fig. 2. **Cavity prototypes (3 Ghz): before (left) and after (right) copper deposition by pla sma spray.**

Some of the first results are presented in the **Fig. 3**. The two cavities exhibit quench limitations before adding the copper layer. Small or no degradation was observed after the copper deposition. The quench location was detected at each test using surface thermometers and the copper layer do not modify the position.

In a separate experiment the overall thermal resistance of the compound Nb/Cu wall was compared to the Kapitza resistance of a naked niobium sample. A small increase of this resistance (+20 to +30 %) can explain the sligth reduction of the quench field.

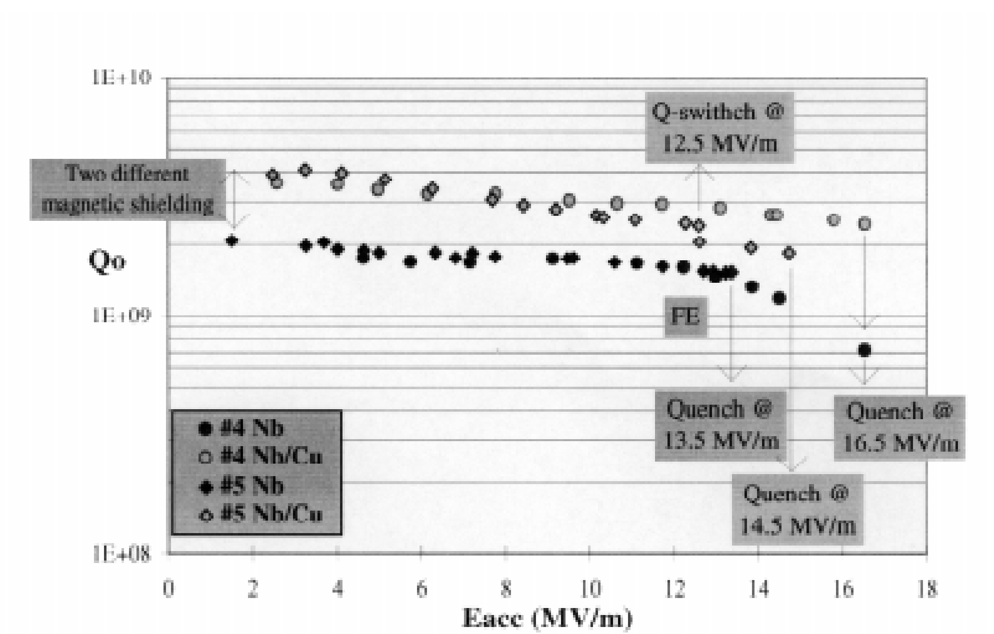

Fig. 3. RF tests at 1.8 K of two 3 GHz prototype cavities

2.2 Thermal effects in SRF cavities

Surface scanning thermometers have been currently used to detect anomalous losses in SRF cavities. This diagnostic technique is well adapted to localize the quench and the electron emission in mono and multi-cell cavities. Strong RF heating have been observed on some TESLA cavity temperature maps showing large signal hot spots (DT > 1 K). In order to analyze these data, an experimental study was performed for the investigation of the heat transfer from large surfaces to HeII at high flux densities **[5]**. Surface scanning thermometers were calibrated in a large heat flux range showing good reproducibility and efficiency (20-25% at high flux $q > 10^4$ W/m^2). The thermometers were able to detect phase change phenomena at the cold surface and the critical heat flux was measured.

Concerning the thermal stability of SRF cavities, analytical and numerical methods have been used to analyse the thermal effects taking place at the cavity surface. The main modelling methods have been presented in a recent paper **[6]**, covering the study of thermal quenchs originated by lack of cooling in large surface areas and those originated by the presence of defects on the cavity wall.The study of thermal transients has also been performed with the help of numerical models which allow to follow the time evolution of the temperature field in a cavity during a quench event. An experimental study using 3 GHz cavities with fixed surface thermometers and fast RF measurements has supplied interesting data on transient thermal effects **[7]**. A method based on RF signal analysis, is proposed to evaluate the normal zone propagation velocity during the cavity quench.

2.3 Electron Emission in High RF fields

One of the major causes of electron emission in SRF cavities is the presence of dust or metallic particles during the final assembly of cavity and couplers. A special 1.5 GHz copper cavity with a removable sample located in the high electric field region has been used these last years for contamination studies with metallic and dielectric particles.The electron emission was analysed with the help of several diagnostic devices: insulated electrode for current measurements, and special optical devices (intensified camera and spectral analysis system). The luminous phenomena associated with the electron emission were recorded, together with the emission current and the RF field in the cavity, for different types of particles. A good correlation between the luminous events, the electron current and the conditioning process of the cavity was observed **[8]**.

The contamination studies were carried on with a special SRF cavity operating at 3.6 GHz in the TM020 mode. Very high surface electric fields (90MV/m) can be reached with this cavity, and its bottle shape facilitates the installation of an optical system for observation of large surface areas **[9]**. After contamination with alumina particles of the high field region, luminous spots were observed and its evolution with the increasing RF electric field was studied.

2.4 High pulsed fields in SRF cavities

Very high RF fields can be reached in SRF cavities using short pulses delivered by high power klystrons. At the LAL Laboratory, the NEPAL facility can deliver pulses of 35 MW peak and widths ranging from 1 to 4.5 µs. An experiment at reduced power (5 MW for 4.5 µs and 15 MW for 1 µs pulses) is being prepared using 3 GHz Niobium cavitites mounted in a special cryostat with waveguides and variable input coupler **[10]**. This experiment will try to determine the critical magnetic field of niobium and investigate the non resonant electron loading due to the field emitted electrons from the high field regions.

2.5 Studies on Input Couplers

A dedicated test stand for input couplers is now in operation at the CEA Laboratory. It incorporates a 1 MW klystron (0.8 ms, 0.1 Hz), evacuated waveguides and different diagnostic systems. The study of different components has started **[11]**: waveguide to coaxial transition with D.C. bias, ceramic windows of different types (conical, cylindrical, disk),RF contacts,...The investigation of the multipactor in the vicinity of windows was performed using numerical simulations of electron trajectories and comparing the results to the experimental data. Two main activities are foreseen for the next year: installation of a LN_2 cryostat for input coupler tests and the fabrication and test of the first prototype coupler.

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