SUPERCONDUCTING RF ACTIVITIES AT INFN MILANO-LASA

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Abstract

The SC RF Group at INFN Milano-LASA is mainly involved in the TESLA/TTF Collaboration. In this Collaboration we have the responsibility of the design and manufacturing (through the Italian company Zanon) of the 12 m long TTF Cryostats. A total of three cryomodules have been sent to DESY and installed on the TTF linac. Three additional cryomodules, based on a third generation design that fulfill the TESLA requirements, are close to be delivered and installed. Among other contributions, we have been involved in the successful fabrication (through the Italian company Zanon) of part of the TTF nine-cell cavities. The group is also engaged in the joint ENEA-INFN Project TRASCO for the development of the design and of the prototype components for an Accelerator Driven System for Nuclear Waste Transmutation. In this context, jointly with CERN and INFN-Genova, we have designed a reduced beta 5-cell cavity that has been successfully sputtered and tested at CERN. With CEA/Saclay and IPN/Orsay we are now working for a common proton linac design and the construction of prototype structures at 704 MHz has been started and a test facility for cold RF measurements is close to be commissioned at LASA.

1 TTF ACTIVITIES

Our main involvement in the superconducting activities for the TESLA and TTF collaboration is the design, the commissioning (by the mean of the Italian company Zanon) and the installation at DESY of the cryostat containing eight superconducting cavities and a quadrupole package[1-2].

Currently, two cryomodule have been installed and are running in the linac tunnel. The first (prototype) cryomodule has been modified in order to reach the better performances of the other two second generation cryomodules installed. This will also allow for upgrading the cavity string. The modifications consist in changing the thermal shields to the newly designed ones, in which the cooling aluminum pipe is directly integrated in the shield panel by means of finger welding[3-4]. Some ancillaries have been modified and the system has been assembled at Zanon to check the mechanical compatibility. The modified cryostat has already been delivered to DESY.

The third generation cryostat engineering, that will fulfill the TESLA requirements, has been finished[5-7] and the complete set of drawings has been given for fabrication. A total of three modules are close to be ready.

The major improvements in the new cryomodule design are outlined in the following.

- The redistribution of the components in the cryostat cross-section allows to reduce by 15% the vacuum vessel diameter, that uses a standard 38'' pipe.
- The thermal shields has been adapted to fit the new vacuum vessel, while the finger-welding technique has become a standard solution.
- A higher stability of the quadrupole package position, in spite of the possible asymmetrical forces acting on the Helium Gas return Pipe (HeGRP) edges during pumping and cooldown, has been obtained modifying the three post positions.
- The bellows, connecting the HeGRP of two consecutive cryomodules has been directly welded during the cryostat fabrication, in order to reduce misalignments that could increase external forces.
- To ensure the possible use of rigid couplers and superstructures a sliding support scheme has been developed for cavities. In connection with a reference Invar bar this system allows the cavities to remain fixed and aligned while the HeGRP slides over them during the cooldown and warmup.

In order to assembly at DESY the new generation cryomodule the necessary tools have been modified, to be compatible both with the old and the new designs. The modified assembling tools are going to be installed, measured and tested soon with the modified cryostat, while the compatibility test will be done at the beginning of next year.

The third generation cryomodule design, proposed for the TESLA 500 Linear Collider Project[8], has been reviewed in October 1999 by members of the "Review Committee on TESLA500 Cryomodules", that expressed a very positive judgement on the design improvements and confirmed that the TESLA cryomodule performance goals and requirements have been reached.

In order to prepare the commissioning of the industrial production of the cryomodule the INFN is going to fund a study for the industrial production of the 2500 cryomodule that will be required by the TESLA500 Linear Collider.

Our Group at LASA is also involved in the successful fabrication (through the Zanon company) of some of the nine-cell cavities for the TTF linac. A total of 12 cavities has been delivered by Zanon, for installation on the TTF linac. As for to the cryomodules, an industrial feasibility study for the mass production of the 20,000 TESLA superconducting cavities is going to be funded by INFN.

2 TRASCO SC LINAC ACTIVITIES

The group is also involved in the design of the superconducting high energy section of the TRASCO Project linac for nuclear waste transmutation [9-14].

The 350 MHz option for the linac has been fully investigated and its performances has been assessed with an extensive numerical beam dynamic simulation activity[15-17].

In the framework of a collaboration with the French Institutions CEA and IN2P3, the group is working at a 700 MHz common design for the superconducting linac. Cavity prototypes decided by the Collaboration will be fabricated and tested at this frequency.

The convergence at the 700 MHz frequency has been mainly driven by the machine cost estimation. More performing cavities at this frequency, based on the TESLA experience, can be realized, and they can be treated and tested at the existing facilities both in Saclay and Milano.

The design guidelines that have been used so far to define the common design are outlined in the following:

- The linac is split in three sections, strarting from 85 MeV, and the transition energies have been set to 200 and 500 MeV.
- A doublet focusing lattice is employed, with a warm 1.5 m space for quadrupoles, vacuum ports and diagnostics.
- The cryomodules contain 2 cavities in the first two sections and 4 cavities in the last section. A small number of cavities per cryomodule in the lower end of the linac is preferred because of the expected higher reliability.
- Reliability considerations suggest to limit the number of cavities fed by a single klystron, in order to minimize the effect of a klystron failure.
- The accelerating fields have been chosen on the basis of very conservative cavity performances (50 mT maximum peak surface fields).
- Different beam currents (up to 50 mA) will be extensively computed and qualified, while an average current of 20 mA has been chosen as a reference.
- The highest beta section (0.86) is designed to be efficiently extendable up to 2 GeV, the final energy being just determined by the number of identical cryomodules installed.
- The cryomodule design is based on the extensive TESLA cryomodule experience.

A simplified scheme of the cavity energy gain along the linac (step curve) is shown in Figure 1 as a function of the beam energy. The second curve in the figure shows the energy gain at the maximum peak field of 50 mA and at the synchronous phase of –30 degrees. This figure has been used as a crude reference to determine the cavity and cryomodule number per linac section and gives an idea of the criteria used to chose the betas of the three linac sections. The main linac parameters are listed in Table 1.

On the basis of the performances routinely obtained on the 9-cell TESLA cavities and of the results on the first single cell developed at Saclay, the number of cavities in each section exceeds by more than 20% the minimum required. A coordinate computational activity is now under way to make use of this redundancy, that should be considered as the in line installation of spare components. The aim of this work is to demonstrate that the proton beam can stay on in case of a linac component failure.

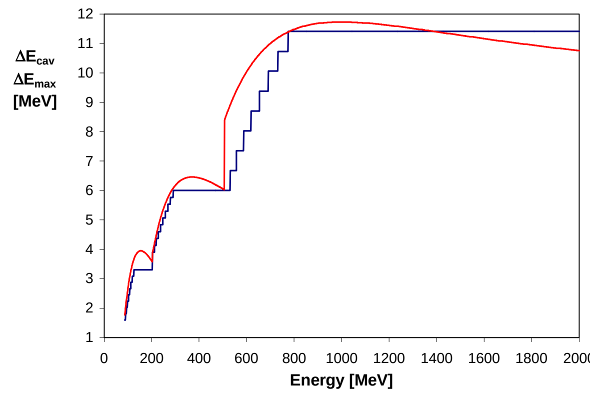

Figure 1: Energy gain per cavity (step curve), as a function of the beam energy. The smooth curve is the maximum energy gain at the peak surface field of 50 mT (and synchronous phase of –30 degrees).

Table 1: Linac parameters at 2 GeV, 20 mA.

	S 1	S 2	S 3
Section β_S	0.50	0.68	0.86
Section Length [m]	84	124.2	297.5
Input Energy [MeV]	85	200	500
Focusing Period [m]	4.2	4.6	8.5
# Focusing Periods	20	27	35
Max Gain/Cavity [MeV]	3.3	6.0	11.4
Max Eacc [MV/m]	8.5	10.2	12.3
# Cells/Cavity	5	5	6
# Cavities/Section	40	54	140
# Cavities/Cryomodule	2	2	4
# Cavities/Klystron	2	2	2
Max RF/Coupler [kW]	66	120	228

3 PRODUCTION AND TEST OF A 350 MHZ β=0.85 FIVE CELL CAVITY

An agreement with CERN has been established in order to fabricate and test a full β=0.85 five cell cavity and a single cell test structure, on the basis of our design.

The β=0.85 monocell was ready at the end of 1998 and has been successfully tested at CERN at the beginning of February 1999, while the five cell cavity was tested in May 1999, giving performances comparable to the best LEP cavities. The results of these tests together with the cavity details are shown in another paper at these Proceedings [18].

4 CAVITY POWER TEST FACILITY

For the necessities of the TRASCO program, a cavity test laboratory for cold superconducting cavity power tests is under commissioning. Power tests will be performed in a vertical cryostat.

A block diagram of the vertical test facility is shown in Figure 2.

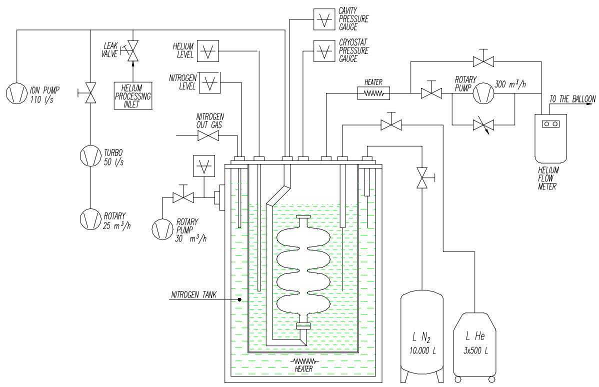

Figure 2: Block diagram of the vertical test facility in LASA.

In order to measure the cavity Q as a function of temperature and accelerating field, the cavity is fit in a stainless steel vertical bath cryostat. The cryostat was developed originally for 4 cell 500 MHz cavities (for another INFN project) and can be used for tests of cavities at higher frequencies. For the 704.4 MHz operation, a volume reduction vessel has been fabricated, in order to reduce the helium consumption.

The cryostat is placed below ground level and is completely surrounded by a structure made of thick concrete blocks to shield X-ray radiation.

A shield made from 2 mm thick sheet of high magnetic permeability metal (μ-metal shield) covers the cylindrical lateral surface and the bottom of the cryostat. The μ-metal shield reduces the ambient magnetic field in the niobium during the cooldown operation. Resistive temperature sensors placed on the insert are used to monitor the helium bath temperature during the cooldown. Power resistors are also placed on the cavity supports, and are used as a heating system to speed up the evacuation of the liquid helium from the cryostat after the cavity tests are done.

The cryostat is equipped with a superinsulation layer that is evacuated through a 25 m^3/h rotary pump. The pressure in the superinsulation layer is about 10^{-2} mbar. The cavity is evacuated through a 110 l/s ion pump before the cooldown. The cavity inner pressure is below 10^{-8} mbar.

The cooldown operation will take place in two phases. First, a pre-cooldown is made by filling with liquid nitrogen the space surrounding the inner vessel in which the insert is placed. In this stage the inner vessel is filled with pressurized He gas, which will cool the cavity by free convection[19]. This method has the advantage of avoiding N and He gas mixing, that takes place during a conventional precooling. Then the nitrogen is evacuated by heating with a power resistor, and the inner vessel is filled with liquid helium to nearly the first copper screen.

A proper Helium gas pump system is connected to the exhaust line of the cryostat in order to reduce the time needed to reach the chosen test temperature, down to 1.8 K. A 300 m^3/h rotary pump, together with a 5 kW heater and an automated valve control system, maintain the required equilibrium vapor pressure. A balloon at the end of the exhaust line is used to recover the Helium gas.

The 704.4 MHz insert is currently under fabrication. In the meanwhile the test facility will be tested with its original insert to test a spare 500 MHz cavity. The picture of an insertion of the 500 MHz cavity insert into the vertical cryostat is shown in Figure 3.

Figure 3: Insertion of a 500 MHz cavity insert into the vertical cryostat.

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