

LATEST RESULTS FROM THE PRODUCTION OF 500 MHZ SRF MODULES FOR LIGHT SOURCES AND CESR UPGRADE

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Abstract

In the year 2000 ACCEL Instruments agreed with Cornell University on a transfer of technology of their superconducting 500 MHz RF module and is now producing such modules turn key for use in Light Sources or other high current e⁺e⁻ storage rings. Currently 6 such modules are under production: two for the Taiwan Light Source, two for the Canadian Light Source and 2 for further CESR upgrade. The infrastructure at ACCEL has been upgraded to allow state of the art cavity preparation including closed loop BCP and high pressure water rinsing. The first test results of the cavities are encouraging. Accelerating gradients above 12 MV/m with quality factors of $Q_0=8 \cdot 10^8$ at a bath temperature of 4.2 K have been reached. The final assembly of the first modules is scheduled for autumn 2001.

1 INTRODUCTION

The big success of the superconducting modules under operation in CESR and in the KEK B-factory together with the enormous progress made by the TESLA collaboration in reliably achieving extremely high accelerating gradients (> 25 MV/m) in superconducting cavities led to a wide acceptance among the accelerator community, that the technology of superconducting RF can be used routinely now.

For high current machines such as Light Sources or high luminosity colliders, the advantage of a superconducting cavity system compared to a normal conducting one can be found in detail in [1] and is summarised as follows:

- A very effective damping of the higher-order modes, resulting in reduced requirements on the RF feedback system of the storage ring.
- The capability to operate at high accelerating voltage and transfer high power to the beam, thereby reducing the number of required cavities.
- Negligible power dissipation in the cavity wall, allowing the use of all installed RF power for particle acceleration, thus reducing the overall power consumption of the accelerator.

Due to an agreement with Cornell on the transfer of the technology of their SRF module, ACCEL Instruments is able to offer such modules now world-wide.

A first contract was concluded in 2000 with the Taiwan Light Source on the delivery of 2 SRF modules. Also in 2000 Cornell itself and the Canadian Light Source ordered 2 SRF modules each.

2 MODULE LAYOUT

The general design of the Cornell SRF module is described in detail in [2,3]. An overview drawing of the module is shown in figure 1 and the operating parameters are summarised in table 1.

Table 1: Typical operating parameters of the SRF module

frequency	500 MHz
operating temperature	4.5 K
U_{acc}, E_{acc}	2.4 MV, 8 MV/m
unloaded Q	$> 7 \cdot 10^8$
losses at 4.5 K and 2.5 MV/m including 30 W standby losses	< 120 W
$Q_{external}$ of input coupler	$2 \cdot 10^5$
maximum power transferable to the beam	250 kW

The key components of the SRF module are:

- Superconducting 500 MHz cavity with waveguide input coupler manufactured out of bulk RRR300 niobium.
- Cryostat consisting of:
 - helium vessel out of 316L stainless steel,
 - vacuum vessel,
 - liquid nitrogen shield,
 - double layer magnetic shielding, cryogenic supply and return lines for liquid helium, gaseous helium and liquid nitrogen
- Input coupler consisting of 6 parts:
 1. niobium waveguide (part of the cavity),
 2. HEX: A straight copper plated SS waveguide cooled by cold helium gas boiling off the helium vessel.
 3. Double elbow: A U-type copper plated SS waveguide cooled by liquid nitrogen,
 4. WG thermal transition: A short thin walled copper plated SS waveguide,
 5. Pump out box: A straight copper plated SS waveguide with ports for connecting ion pumps and pressure gauges,

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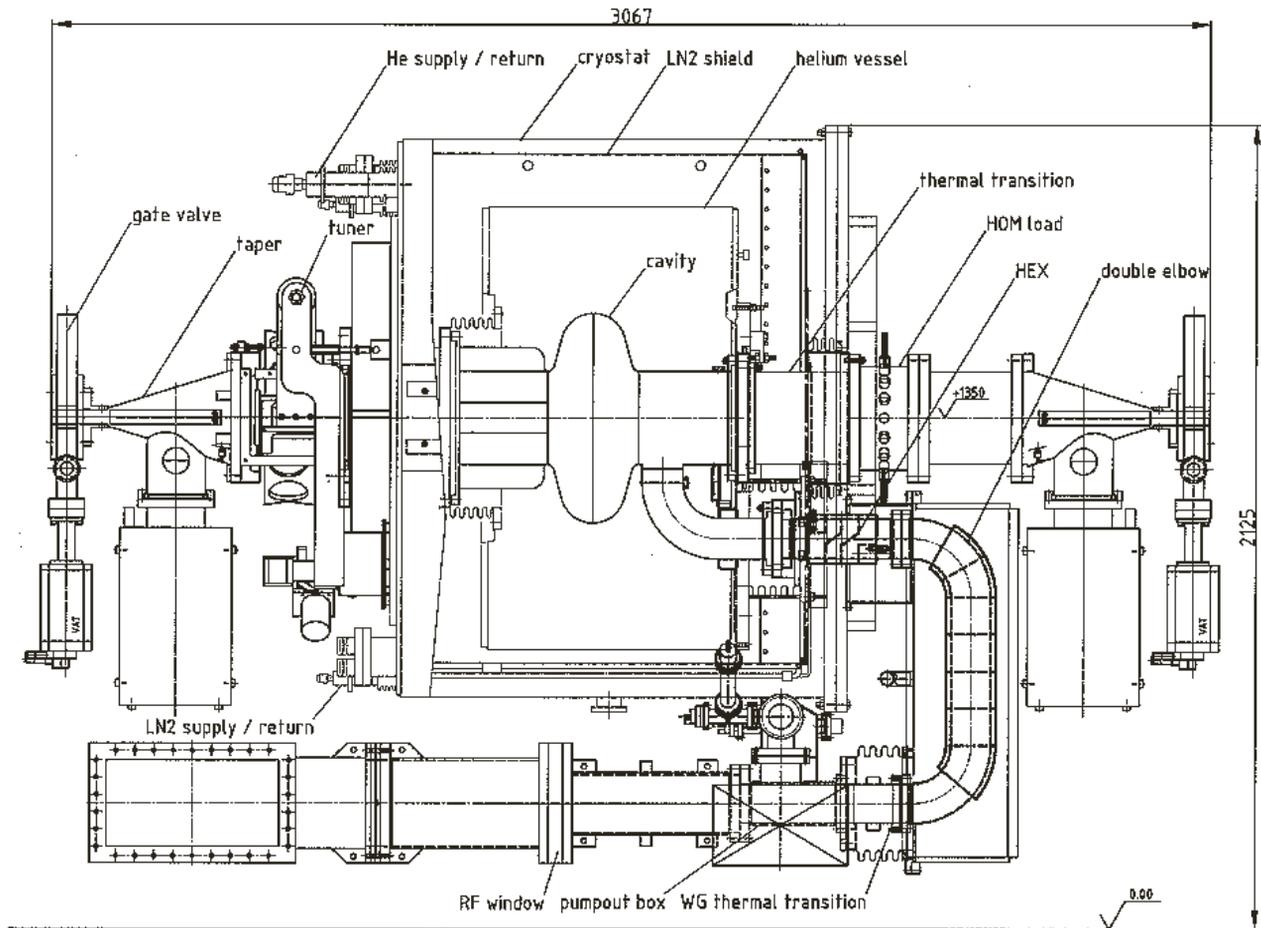


Figure 1: Schematic view of the SRF module

- 6. A 500 MHz RF window, designed for a maximum of 500 kW travelling wave power.
- thermal transitions on the round and “fluted” beam pipe out of thin walled SS, with heat intercept to 70 K.
- Two water cooled higher order mode loads, each capable to absorb up to 10 kW of HOM RF power. The HOM loads are located outside on both sides of the cryostat. They are realised by means of ferrite tiles which are placed inside a short piece of beam tube.
- Mechanical Tuner driven by a stepping motor.
- Taper from cavity beam tube to storage ring beam tube. Synchrotron light masks and pumping ports are integrated into the tapers.
- RF shielded gate valves

After the technology transfer, the module design was reviewed and minor modifications were incorporated on various components to simplify them in view of manufacturing. The number of adapter flanges in the system were greatly reduced by incorporating them into the individual components and the sealing technique was revised in order to have only 3 kinds of seals: Indium at

the cavity flanges, CF conflat at the beam pipe and waveguide flanges and O-rings at the insulation vacuum flanges.

For future projects we are open to redesign and further develop the system to fit it to individual applications.

The power dissipation P_{module} of the SRF module at the operating temperature of 4.5 K is the sum of the static or standby losses of the module (30 W) and the dynamic losses P_{dynamic} of the cavity during operation. The dynamic losses can be approximated according to the formula:

$$P_{\text{dynamic}} = (E_{\text{acc}}[\text{MV/m}])^2 / Q_0[10^9].$$

As an example, at an accelerating voltage of 2.4 MV corresponding to an accelerating gradient of 8 MV/m and a Q-value of $7 \cdot 10^8$, the dynamic losses of the module are about 90 W and the total losses of the module are 120 W.

3 PRODUCTION STATUS

All components of the modules are under production now. From the key component, the 500 MHz niobium cavity, the cavities for Cornell University and the Taiwan

Light Source are completed. Three of this four cavities are shown in figure 2. The cavities for the Canadian Light Source will be completed in October 2001.



Figure 2: Three 500 MHz single cell niobium cavities ready for preparation for vertical test.

Figure 3 shows two completed HOM panels. The ferrite tiles are sputtered from one side with 3 layers: First a +titanium layer, second a mixture out of titanium/copper and third a copper layer, all three together approximately 1 μm thick. The ferrite tiles are soldered then to a copper plated Elkonite (Copper-Tungsten sinter metal that fits the thermal expansion of the ferrites) plate. On the backside of the Elkonite plate the water cooling tubes are soldered. Each HOM panel is designed to absorb up to 600 W RF power. For the delicate soldering of the ferrites to the Elkonite plate we now use inductive brazing under Argon atmosphere instead of vacuum brazing. After successful test 18 panels are mounted into one HOM load around the beam pipe.



Figure 3: Two HOM panels capable to absorb 600 W RF power.

All other components of the SRF module are under construction at ACCEL or qualified subcontractors. We expect to start the assembly of the first module in autumn.

4 TEST OF SUBCOMPONENTS

Before module assembly key components have been individually tested, namely:

- cryogenic low power RF test of the cavity in a vertical bath cryostat.
- High power RF test of the waveguide windows on a separate test stand.
- Test of HOM loads on a separate test stand.

The assembled module will also be tested on a dedicated test stand and the guaranteed module performance will be demonstrated.

4.1 Cavity tests

The cavities are chemically treated, high pressure rinsed and assembled at ACCEL. They are then shipped to Cornell. At Cornell, they are only connected to the vertical test stand. The test itself is performed by ACCEL personnel.

In order to perform state of the art cavity preparation, the chemical plant at ACCEL was upgraded to allow closed loop chemistry (BCP 1:1:2). In addition a high pressure rinsing plant was built at ACCEL for rinsing this kind of cavity with ultra-pure demineralized water at 100 bar. The preparation of a cavity is shown in figure 4. The cavity mounted in the closed loop chemical plant and during the high pressure rinsing is shown there together with the cleanroom assembly which is done in a class 100 clean room.



Figure 4: Preparation at ACCEL of a 500 MHz cavity for a vertical test. up left: closed loop BCP, up right: high pressure rinsing, below: clean room assembly.

The best vertical test result achieved so far is shown in Figure 5. The cavity reached 12.5 MV/m with $Q_0 > 7 \cdot 10^8$. The cavity was limited by available RF power (200 W). At 11 MV/m the cavity Q is still above $1 \cdot 10^9$.

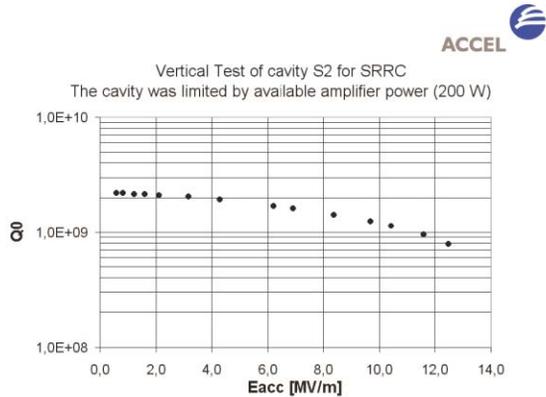


Figure 5: Vertical RF test at 4.5 K of cavity S2 suited for SRRC.

A second cavity was tested and reached 9 MV/m limited by field emission and available RF power. This cavity was tested additionally after slow cooldown to 4.5 K to check the cavity against the so called “Q-disease”. No Q-degradation was observed demonstrating the correct performance of the chemical plant. The cavity was then also heated at 150 °C for 48 hours under vacuum. The successive measurement showed an improvement in low field Q by a factor of 1.5. The test result of this cavity is shown in figure 6. A third cavity reached 7 MV/m limited by field emission. This not satisfactory result was probably caused by fixing a leak in the clean room without applying a new high pressure rinse. This cavity will be tested soon again after new chemical preparation and high pressure rinse.

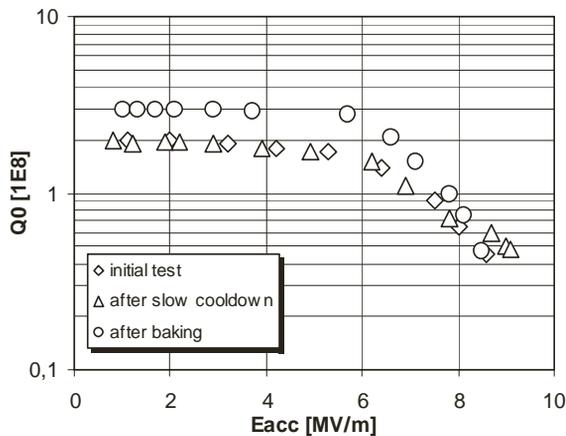


Figure 6: Vertical RF test at 4.5 K of cavity Co1 suited for Cornell

4.2 Test of the RF windows

After arrival from Thomson (window manufacturer), the windows are carefully inspected, cleaned and

assembled together back to back with an intermediate waveguide piece in a clean room (see figure 7). Ion pumps are connected to the intermediate waveguide to allow pumping of the desorbed gases caused from the RF processing.

After assembly, the whole assembly is baked to 190 °C in order to clean the surfaces. It is then shipped to Cornell for RF processing. The processing is performed by ACCEL personnel.



Figure 7: Two 500 MHz RF windows assembled and baked at ACCEL after final leak-check, ready for RF processing at Cornell.

The RF processing of the first window pair was completed in only 2 days. The following were reached:

- 220 kW cw travelling wave mode,
- 400 kW travelling wave mode with 30% duty cycle
- 64 kW cw standing wave mode
- 100 kW standing wave mode with 15 % duty cycle

During the standing wave mode processing, the ceramic was placed at voltage maximum first and afterwards at voltage minimum as well as at a phase of 45°. At the highest power levels, infrared pictures of the ceramics were taken. The maximum temperature rise of the ceramics were 40°C (compare figure 8 and 9).

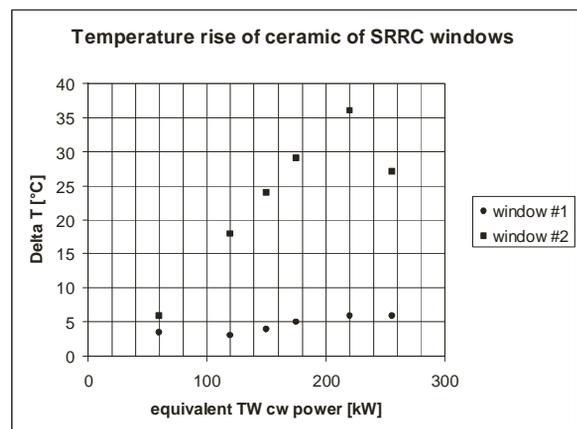


Figure 8: Maximum temperature rise at the ceramic of the two tested windows in dependence of the RF power.

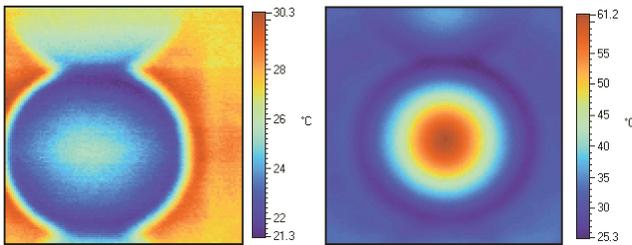


Figure 9: Infrared pictures of the ceramics of the windows taken at 220 kW cw travelling wave mode.

4.3 HOM panel tests

After some improvements, the HOM panels now routinely meet the specification. At 600 W RF absorption, the maximum temperature on the ferrite tile surface observed with an infrared camera is below 100 °C. The cooling of the ferrites to room temperature after shut off the RF is in the order of 10 s, all indicating a good contact of the ferrites with the Elkonite plate through the solder.

5 ADDITIONAL SUPPLIES

In order to deliver the modules turn key, ACCEL's scope of supply also contains:

- Distribution valve box for LHe and LN₂ supply of the modules and cryogenic transfer lines between valve box and SRF module. The valve box is the interface to the refrigeration system.
- Complete cryostat instrumentation and Control Electronics.

6 REFERENCES

- [1] J. Kirchgessner, "The Use of Superconducting RF for High Current Applications", CLNS-93-1247, Part. Accel. 46, 151-162, (1994).
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- [3] E. Chojnacki and J. Sears, "Superconducting RF Cavities and Cryogenics for the CESR III Upgrade", Proceedings of the 1999 Cryogenic Engineering and Intl. Cryogenic Materials Conf., Montreal, Quebec, Canada.