SUPERCONDUCTING RFQ'S READY FOR ION BEAM OPERATION AT INFN-LNL

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Abstract

The high current injector PIAVE [1], for the superconducting (sc) linac ALPI of INFN-LNL, is getting close to beam commissioning from the ECR ion source. In this paper, the tests carried out on the sc RFQ's on a test cryostat are reported.

1 INTRODUCTION

The transport line from the ECRIS platform (350 kV voltage) to the entrance point of the first of the two RFQ's (SRFQ1) has already undergone beam tests[2], demonstrating a phase space emittance in agreement with the project specifications. SRFQ1 and SRFQ2 resonate at 80 MHz and are about 0.8 m in diameter, the first being 1.34 m and the second 0.74 m long. The 8 new QW resonators, matching the ion velocities between the RFQ's and the linac, are ready to be installed in their cryostats. The cryogenic plant was recently installed and tested on a dummy load. The sc RFQ's are completing their test phase and, in the next few months, they will be also mounted in their common cryostat, which is being shipped to INFN-LNL from the Budker Institute (Novosibirsk, Russia), which built it.

Characterization of the sc RFQ's will be completed as soon as they will be mounted on the final cryostat in the linac vault and connected to the cryogenic plant in its working refrigeration cycle.

2 EVOLUTION IN THE PERFORMANCE OF SRFQ2

The construction of the 80 MHz sc RFQ's [3] is now complete. Over the last two years, SRFQ2 has undergone a series of sc tests, in parallel with the construction of SRFQ1 (fig.1), which is now being characterized, being anyhow less demanding in terms of inter-electrode voltage and stored energy.

The most significant steps in the evolution of the Q vs. $E_{s,p}$are summarized in fig. 2.

We believe it to be instructive to follow the main steps in the performance of SRFQ2 over the last two years. While the June-2000 curve [3] showed that the design specifications of 25.5 MV/m peak surface field, with a cavity power dissipation of 7 W, could be achieved; significant field emission (FE) appeared beyond ~80% of the specified field.

Figure 1: The newly built 1.34 m long SRFQ1 resnoator during HPWR, preceding the sc tests.

It took till March 2001 curve to discover and fix a cold leak in the liquid He reservoir which surrounds the cavity: the lower performance in the pertaining Q-curve can be easily attributed to repeated openings, not followed by a final high pressure water rinsing (HPWR).

In June, after proper HPWR, an even better Q-curve than in June 2000 could be obtained (curve 2001-June (a)). FE took a few hours only, when we switched to strongly over-coupled mode (Q~10^6) operation, in order to test phase and amplitude stability with respect to an external reference. In a short time, an anomalous power consumption, not correlated to any temperature increase on the resonator sensors, made the low-field Q_0 to drop to $2x10^8$, the curve (2001-June (b) in fig. 2) being rather flat then up to the design field, but with twice the specified power consumption.

The cause of the spoiled performance was then found to be a discharge in the high power coupler cable, probably due to a loose contact of the outer conductor: sputtering of a thin layer of Cu and stainless steel, originated in the

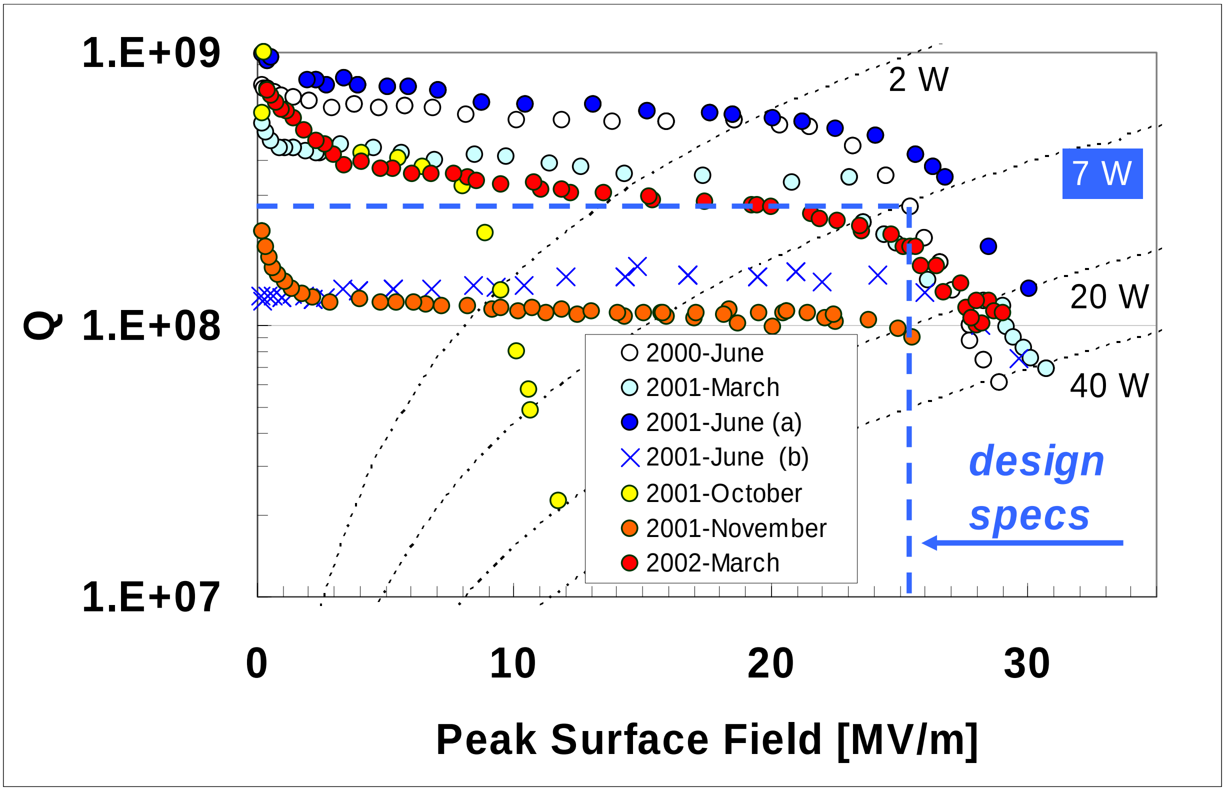

Figure 2: Evolution in the performance of SRFQ2, during the tests performed in the last two years.

cable region, spread over a high current density region of tens of cm^2.

Since chemical polishing (CP, which we perform in collaboration with CERN) would have taken months,: we attempted to simply remove the contaminated layer by means of 3M Scotch Brite lapping, followed by standard HPWR. The 2001-October curve of fig. 2 shows, that a substantial recovery of the previous condition was possible.

However, a new problem occurred while trying to condition the last RFE level [3]: during pulsed rf treatment of the resonator and after a few discharges associated with increasing temperatures on a couple of sensors inside the modulated vanes, the Q curve dropped to the low 10^7 scale. It was not possible to recover it during the same shift. After warm-up and opening of the resonator, distributed clear signs of discharge between the end-plate and one couple of electrodes were strikingly evident.
The damaged areas on the electrodes were treated by 3M Imperial lapping film, with Al_2O_3 abrasive and decreasing roughness. The sputtered end-plates were replaced by new ones, originally designed for SRFQ1: the 15 mm thick outer corona, pressed by the pushers onto the joint between cavity and end-plates, was 25% larger.
The following 2001-November curve partly recovered the performance (from the low 10^{-7} scale at which the previous test was finished). Although Q was limited to $1x10^8$, FE conditioning was unprecedently quick (1÷2 hours, with respect to a couple of days) and the X-ray dose remained within 10 µSv/h, up to the highest fields.
The design voltage could be reached at the price of higher power consumption (20 instead of 7 W), but ample experimental time was finally available for the cavity characterization tests, described in the following paragraph.
Still the doubt remained, whether the decrease in Q_0 was to be attributed to the mechanical lapping on the electrode areas facing the end-plates, or rather to the larger end-plate corona: the latter would diminish the pressure, exerted by the mechanical pushers on the end-plate-to-cavity joint. In the last shift on SRFQ2 the old repaired end-plates, meanwhile re-sputtered, were mounted. Curve 2002-March shows that this was in fact the case, and the cavity could be rather easily conditioned up to the specified field at a higher Q value, and at a power dissipation of 10 W, i.e. just above specification.
Ample time was again available for locking tests.
The conclusions of this rather troublesome iter are rather interesting and can be summarized as follows:
- mechanic repair of the front end of electrodes (region of high E field) by alumina abrasive can be performed, at no cost of Q degradation, without any CP;
- lapping of regions of high current density, not followed by CP, has no effect on the very low field Q_0 value; the field decreases, however, linearly in the logarithmic plot, up to 3 MV/m peak surface field, and then remains rather flat at an acceptable value; it can be guessed that some contaminants, or rather a mechanically rougher surface in

the scratched area, remain sc at low fields, but become nc at increasing field;

- the pressure onto the joint between the Nb sputtered end-plates and the resonator is a crucial issue: if that pressure is sufficiently high, the sc joint, on which the field ranges between 3 and 6 mT at the design value of 25.5 MV/m peak surface field, allows to reach a Q value comprised between $5x10^8$ and $2x10^9$.

The decision was taken, to stop the experiments on SRFQ2 with the March 2002 shift, being the Q curve more than acceptable for typical beam operation, for which it is expected that the large majority of requests will not exceed 80% of the resonator design specifications. We are anyhow fully confident, that a 20 μm CP would bring SRFQ2 up to its best performance, whenever we would judge it to be useful.

3 RESONATOR BEHAVIOR, STABILITY AND LOCKING TEST AT 4 K

A very important step towards the reliable use of sc RFQ's on a linear accelerator is the characterization of the resonator frequency (f) changes with respect to: changes in the He bath pressure, microphonics and Lorenz detuning.

A pressure increase in the He bath decreases the intervane distance, which makes f to decrease. The measured sensitivity (39 Hz/mbar, fig.8) is rather high. However, it should be compatible with the specifications set for the cryogenic system, which will work at 1.2 ± 0.05 bar, with pressure drifts smaller than 2 mbar/min, that can be followed up by the SRFQs slow tuners.

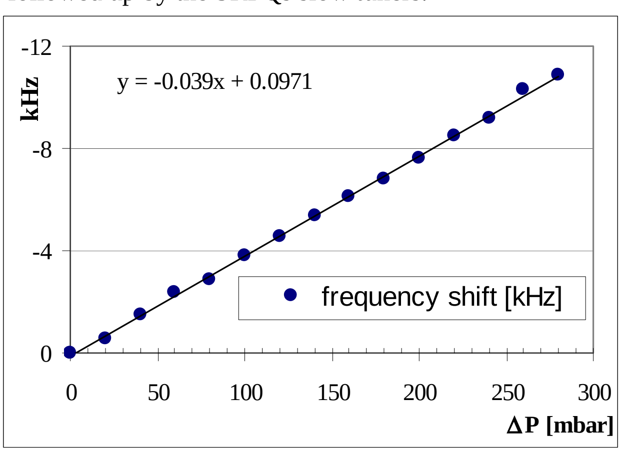

Figure 3: Frequency shift induced by He bath pressurization.

As for the slow tuner themselves, they have been characterized in their total tuning range (~300 kHz), sensitivity (0.5 Hz/step) and mechanical backlash (~500 steps). It was proven possible to use only one end-plate in the push-pull mode [4], so as to follow the slow variations of the resonator frequency during periods of several hours. Nevertheless, the total f-drift seems to amount to about a few hundreds Hz/day at most, as far as repeated recordings in the test cryostat showed. It was hence possible to conceive a double end-plate tuning, where one end plate is always used in the pushing and the other in the pulling mode. The total f-shift is probably so small with respect to the overall tuning range, that it will not be necessary to revert their direction of motion during a beam time of a few days. In so doing, we believe that the resonator operation on the accelerator is made significantly easier. The double end-plate slow tuner will be tested on SRFQ1 in one of the latest tests before mounting both resonators in their final position.

Lorenz detuning makes the resonator f to decrease quadratically as a function of the inter-electrode voltage, as shown in fig. 4: detuning amounts to ~ 10 [mHz/kV^2].

In the test cryostat, it was possible to lock SRFQ2 in both amplitude and phase for periods of 1÷1.5 hours [5]: microphonics do not seem to be a very crucial issue, at least in the test cryostat working conditions. We are confident to further enhance the duration of uninterrupted locking, as soon as the backlash-free double end-plate slow tuner will be available.

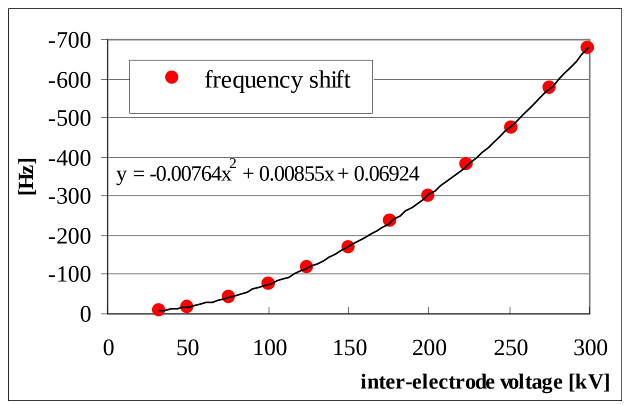

Figure 4: SRFQ2 resonance frequency shift is shown as a function of the inter-electrode voltage.

4 CONCLUSION

The latest test with SRFQ2 provided a Q value and an accelerating field, which are definitely compatible with on-line operation (par 2). Investigations on the frequency stability were also nearly completed. Tests on the fast tuner device (built in collaboration with ANL), which should help resonator locking in operation, will be possible only in the on-line cryostat, which will house both SRFQ's on the beam line in Fall this year.

5 REFERENCES

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