SSR1 Pulsed Tests (some notes)

Bob Wagner

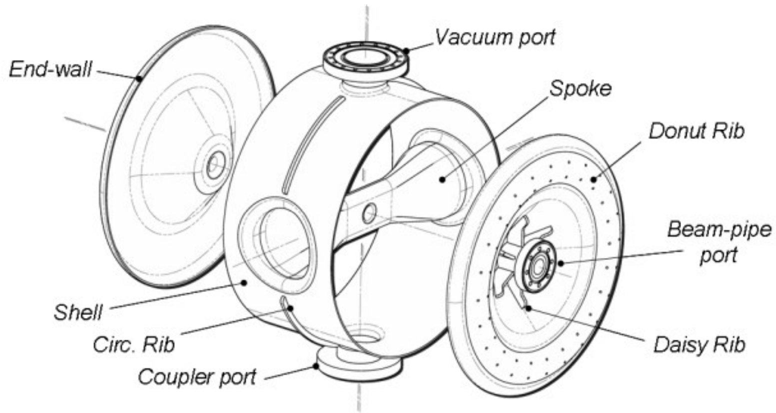
T. N. Khabiboulline, R. Madrak, Y. Pishchalnikov, L. Ristori, W. Shappert, W. Soyars,

I. Terechkine

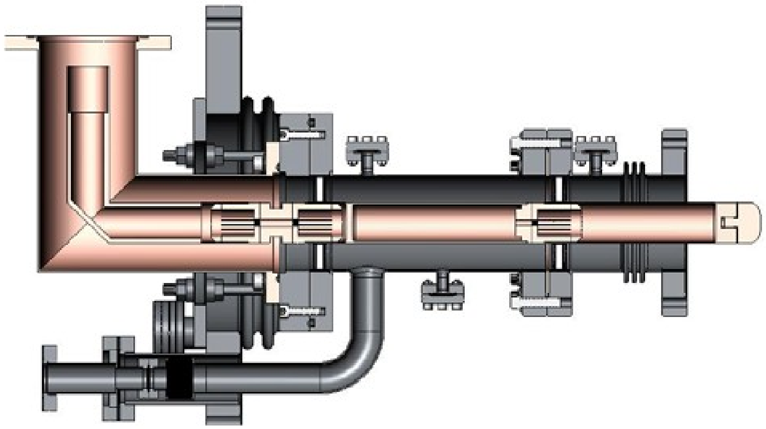
Design and operating parameters of 325 MHz SSR1

Quantity	Value
Beampipe, shell ID	30 mm, 492 mm
E_{peak}/E_{acc}	2.56
B_{peak}/E_{acc}	3.87 mT/(MV/m)
G, R/Q_0 , $ß_g$	84 Ω, 242 Ω, 0.21
RF structure	1 ms, 9 mA ⇒ CW, 1, 5 mA
Loaded BW	388 Hz ⇒ 43, 215 Hz
He temp, pressure	4.4 K, 900 torr ⇒ 2.0 K, 20 torr
He press variation	±12.9 torr ⇒ ± .25 torr
Accel. Grad., E_{acc}	10 MV/m ⇒ 15 MV/m ?
Q_0 at E_{acc}	> $0.5x10^9$ ⇒ ?
LFD co. (jacketed)	3.8 Hz/$(MV/m)^2$ ⇒ Non-issue
df/dp (jacketed)	-210 Hz/torr with present tuner

SSR1-02, the 2nd SSR1 prototype. Fabricated by Roark.



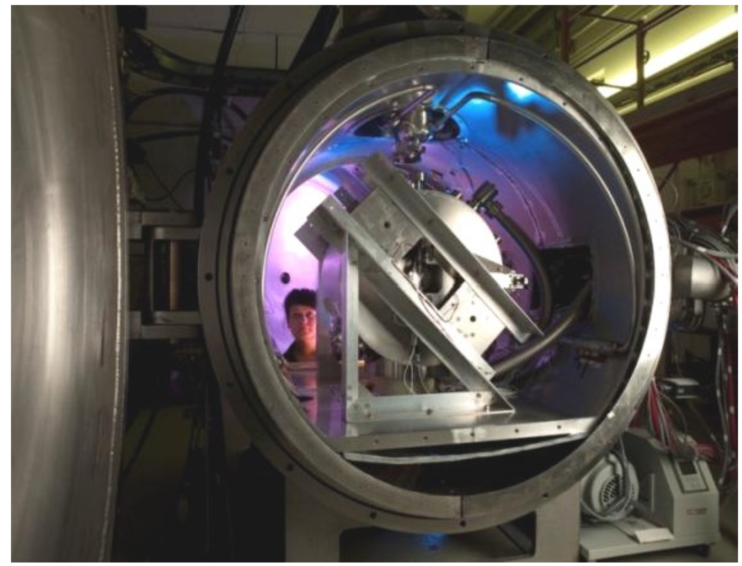
Helium vessel, tuner and Power Coupler



- SSR1-01 inside 316L stainless steel (SS) helium vessel with tuner.
- Tuner: two piezo actuators “in series” with slow tuner arms (pivot with 5:1 mech. advantage).
- Stepping motor with harmonic drive,1:100 ratio (0.9 Hz/step).
- Present tests with a tuner on each end.

- These are the first cold tests of the SSR1 with a Power Coupler suitable for accelerator operations.
- Cold section with antenna was installed onto cavity port at the MP9 clean room.
- Warm section attached through the cryomodule port at the SCTF cave.
- The warm section has its own vacuum pump.

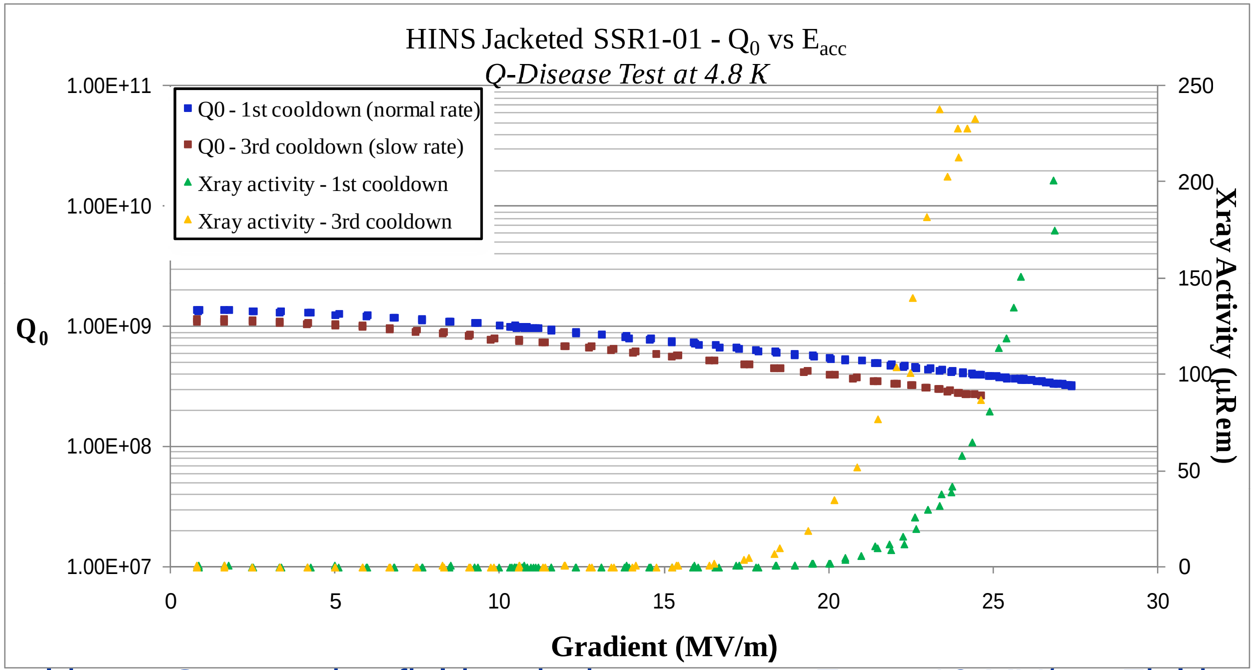
SSR1-01 pulsed tests at the 325 MHz Spoke Cavity Test Facility(SCTF)



- Cooling to 4.4 K, 4.5 psig.
- 250 kW Klystron line attenuated to 50 kW for pulsed tests. Pulses up to 3 ms long at 1 Hz or 2 Hz.
- Digital LLRF with GUI interface screens .
- E_{acc} calculated from P_t using Q_t measured in the CW tests (same field probe antenna).

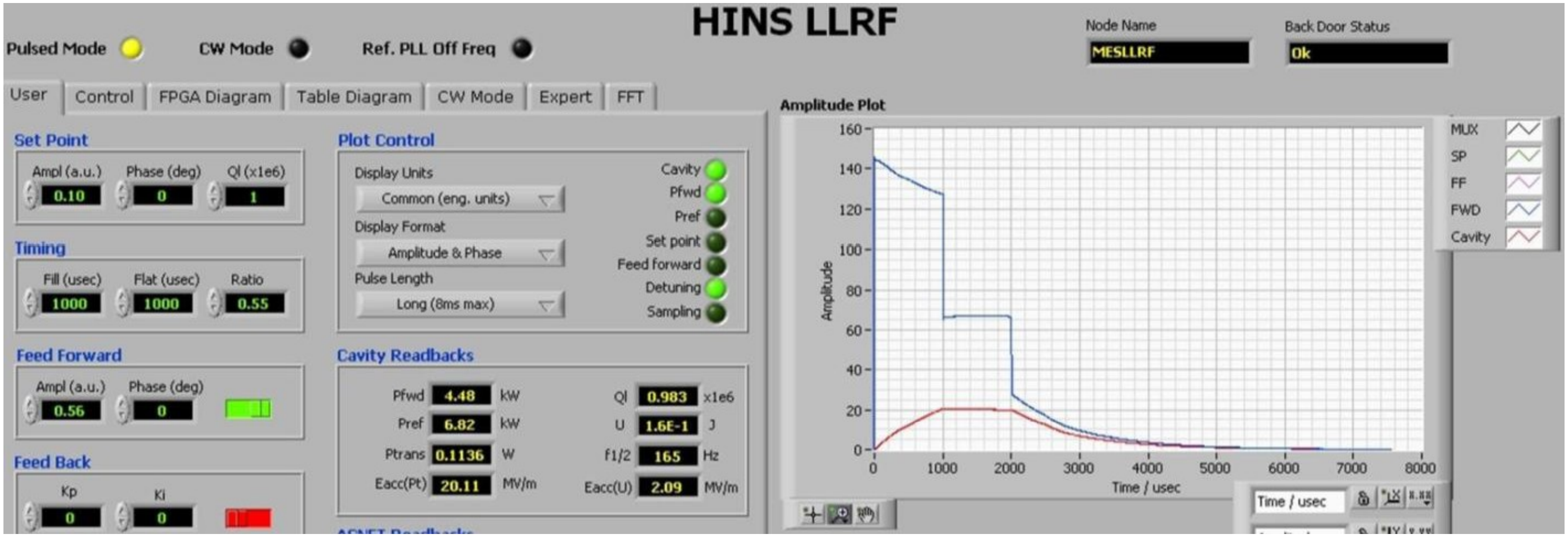
- Room temp B shield just inside cryostat wall.
- 80 K thermal shield. Robyn (runs the place).
- Jacketed cavity with tuner. Test magnets.
- X-ray detectors along beam line:
  - Foxes and Chipmunks ~50 cm outside cryostat.
- Power Coupler had $Q_{ext} = 0.95 \times 10^6$ (determined from the pulse decay time).

Expected behavior from CW tests



- First cooldown: Start seeing field emission x-rays at E_{acc} ~ 19 MV/m. Field emission induced quench at ~ 27 MV/m. Many hours of processing multipacting barriers.
- Within 5% measurement uncertainty, scan was unchanged after a second 3 hour cooldown.
- Third cooldown of 11 hours through sensitive region (150 K to 70 K): Mild case of Q disease.
- For this test, helium was fed through the bottom (not top) port, and the cool down time was faster (near 2 hours). Therefore we expect things to be similar to the curves for the first cool down.

Pulsed LLRF Controls



- Feed Forward: From the measured E_{acc} pulse shape, the program adjusts the phase, amplitude and length of P_F(fill) and P_F(flat) to match the E_{acc} template as best it can.
- It worked extremely well, even when encountering multipacting, field emission and quenching. By adjusting the phase (and therefore the frequency), Feed Forward was able to keep the cavity in resonance even at high field with large Lorentz Force Detuning (LFD).

Some notes from the initial E_{acc} scan

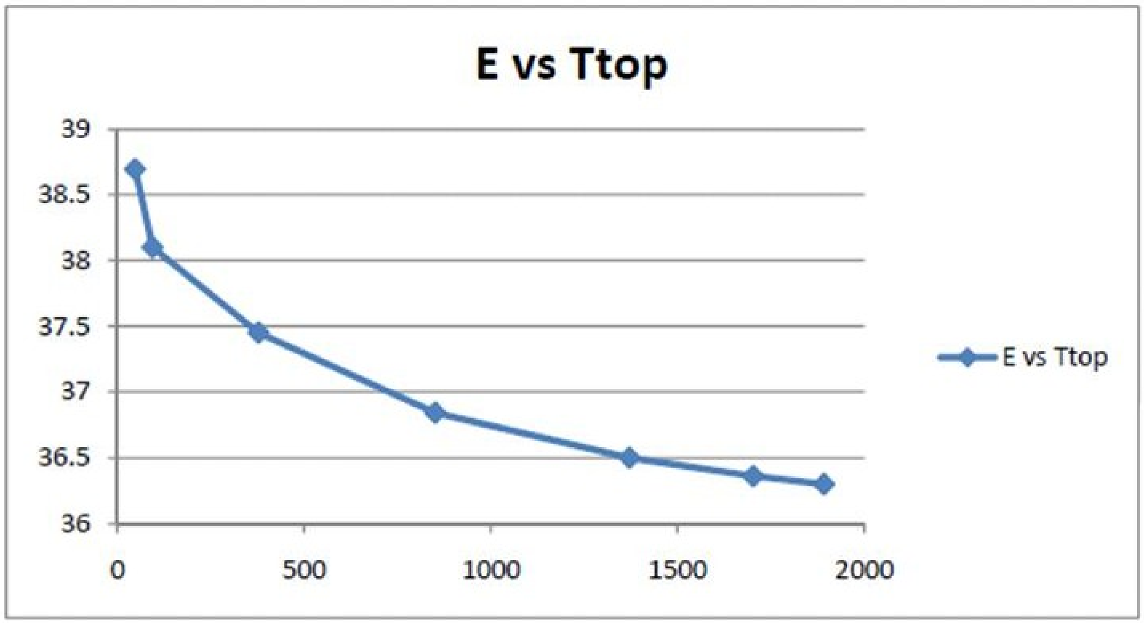
- The scan started using a 1 ms Klystron pulse at 1 Hz. The template was a 500 μs fill time with the rest flat top.
- Multipacting in both the cavity and the power coupler during the initial scan.
- Multipacting at the 11-13 MV/m barrier caused strange structures in P_F: peaks and valleys with 10 kW or more swings. However, Feed Forward kept the E_{acc} pulse true to the template. The P_F structures were virtually identical from pulse to pulse. This was also true of P_F and E_{acc} when quenching.
- Another interesting thing about multipacting in pulsed mode is that the Klystron had sufficient power to support a huge excess in P_F(flat) while maintaining the desired E_{acc} flat top in the template. That is, you did not have to wait to "process" multipacting barriers before proceeding to higher fields.
- Because of the unprocessed multipacting barriers, x-rays had an "offset" count due to the field passing through the barriers on the rise and fall.

Some notes from the initial E_{acc} scan

- As expected from the CW field emission, x-ray counts slowly started to rise at ~19 MV/m and continued to increase.
- At ~20 MV/m, the E_{acc} pulse rise time increased and the flat top length was reduced due to the 50 kW limit of P_F. At ~27 MV/m, one ran out of flat top altogether, so we either had to decrease the attenuation or increase the pulse length of the Klystron. Timergali decided that it was safer for the Power Coupler to increase the pulse length, and Robyn increased it to 1.5 ms.
- The first quench (field emission induced) occurred at ~30 MV/m, somewhat higher than the 27 MV/m in the CW test. This delay in the onset of quenching was likely due to the short time spent at flat top in pulsed mode (there was insufficient time to heat up to the point of quenching). One kept raising the field to ~34 MV/m, often experiencing quenches.
- At that point the Klystron pulse was widened to 2 ms and we proceeded up to about 35.9 MV/m, where large x-ray bursts occurred frequently. At some point the bursts just stopped and the quiescent x-ray level also went down. This strongly suggests that a field emitter experienced some major processing (High-powered pulsed processing or HPP). The cavity could then be run up to ~37 MV/m without quenching.

Some notes from the initial E_{acc} scan

- The flat top had again almost disappeared at 37 MV/m , so the Klystron pulse was increased to it's maximum of 3 ms. One could run at 36.5 MV/m with a 1.5 ms flat top without quenching. On a later E_{acc} scan (HINS ELOG 1-11-11), Timergali and Robyn measured how high one could run as a function of flat top length. It looks like it may level out at about 36 MV/m for CW operation, but this is obviously a large extrapolation. Anyway, the peak surface B field at E_{acc} = 36 MV/m is 139 mT (from Ivan's simulation).

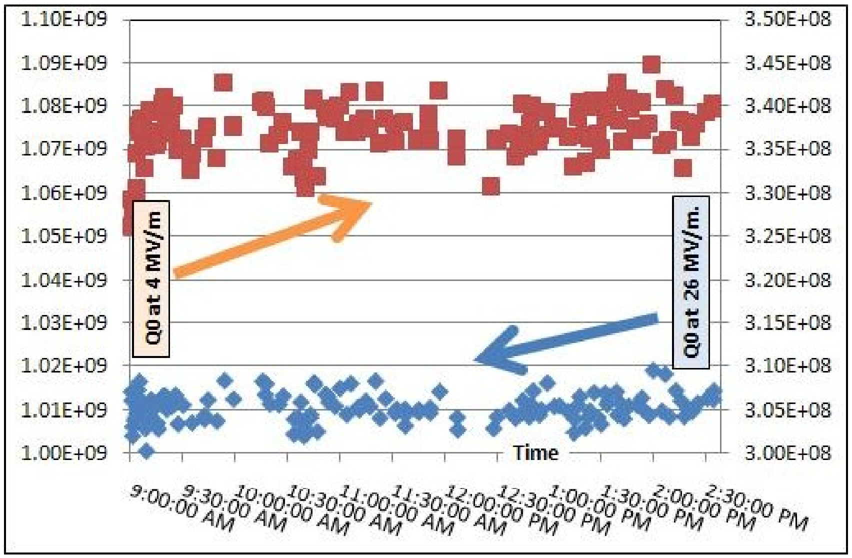


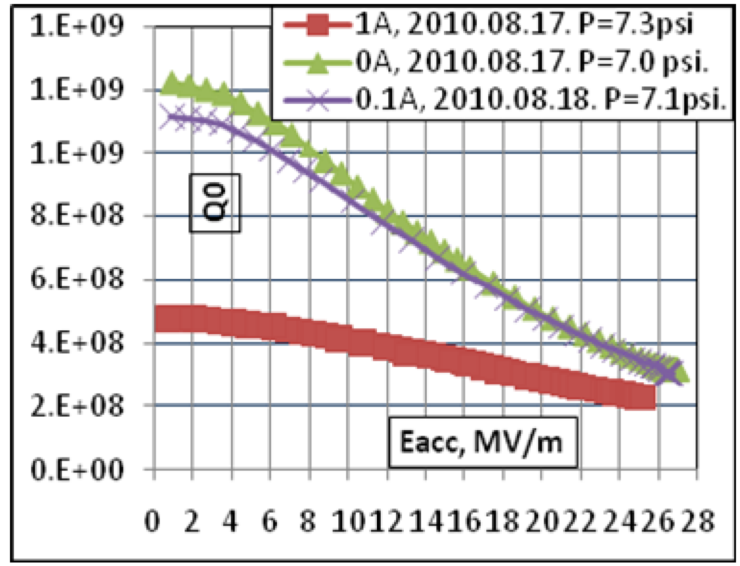
Brief mention of other results (need separate talks)

- Quench with B field:
  - On Monday, 1/10/11 we quenched the cavity at 1 Hz (37.5 MV/m) In the presence of a B field (pulsed to 8A in coils during RF pulse) for 7 hours. This is about 25K quenches. We saw no degradation (drop in quench field).
  - The previous test was 4-5A for 6 hours with 6000 quenches at 27 MV/m (CW) with no drop in quench field. Note that 0.05A produces the expected fringe field of ~0.1Gauss in the "nominal" solenoid design.
- LFD and pressure compensation with tuner:
  - Simultaneous compensation for pressure and LFD at 10 MV/m. At 37 MV/m, they compensated for LFD only, correcting an ~2.3 kHz detuning to +/-250 Hz.
  - On 1-14-11, Yuriy continued to optimize the LFD correction and achieved better than +/-100 Hz during the flat top at 34 MV/m.

Project X

Effect of fringe field of proposed solenoid focusing





- Expect maximum fringe field of 0.1 G (test solenoid current of 0.05 A).
- At E_{acc} ~ 27 MV/m, cavity quenches almost certainly at spoke.
- At 4-5 A current, quenched 5000 times in ~6 hours with no degradation of Q_0.
- Spoke is very well shielded.
- Also tested cooling through niobium transition point at various fields.
- See an ~10% drop in Q_0 at twice the expected field (likely close to a factor of two drop at 2 K). Should test at 2 K.
- As expected, a much larger drop is seen at twenty times the expected field.