Status of the LANL Activities in the Field of RF Superconductivity*

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Abstract

Since the 8th workshop, LANL has significantly upgraded their existing superconducting laboratory. The improved cavity test area allows for vertical tests of 5-cell, elliptical cavities at 700 MHz in a 38-inch diameter magnetically shielded cryostat. The class 100 cleanroom has been enlarged to allow assembly of a two-cavity cryo-module with four high power RF couplers. The upgrade included construction of a re-circulating piped chemical polishing system that can accommodate multicell, 700 MHz, niobium cavities. One 5-cell, 700 MHz cavity was fabricated in house and five similar cavities have been ordered and received from industry. Structural and modal analyses of these cavities have been done. The first vertical test of a 5-cell cavity in the vertical cryostat is planned for the end of the year. Development work was also done in the area of high power RF couplers. Coaxial window-coupler prototypes were designed, fabricated and tested on a room-temperature test stand. The first pair of couplers has been tested up to 1 MW continuous wave (cw) transmitted power. This overview talk will present the highlights of our work done during the last two years.

1 FACILITY UPGRADE

Since the last workshop we did a significant upgrade of our facility. This upgrade included the modernization of test equipment, expansion and modernization of the clean room facilities, improvement of safety in the test building, expansion of the high-pressure rinse cleaning process equipment and the introduction of a re-circulating closed pipe BCP (buffered chemical polishing) system.

The cleanroom (see figure 1) has been extended from 800 ft^2 (74 m^2) to 2600 ft^2 (242 m^2). Half of this area is class 100 or better, the rest is class 1000 or better. This expansion provides sufficient space for the cleaning and assembly of the larger 700 MHz, 5-cell cavities as well as the assembly of multi-cavity cryo-modules including the power couplers that in the APT design have to be installed in the cleanroom [1]. For access of these modules, a 10 ft (3m) by 8ft (2.4m) access door has been installed.

Figure 1: The new class 100 cleanroom.

The cavity test area has been equipped with a mezzanine for easy insert assembly. Also, the original lab layout was intended for the testing of small 3 GHz or single cell 700-805 MHz cavities. The 5-cell 700 MHz cavities will show somewhat higher radiation levels. Thus, the control room has been moved into the adjacent room and a movable steel shield of up to 8 inches thick has been added to the test room. This shield can be moved on rails to cover the cryopit (see figure 2).

There are two high-pressure rinse stations in the cleanroom that provide up to 1500 psi (10.3 MPa) pressure. The de-ionized water system can provide 2-3 gallons of ultra-pure water per minute (7.6-11.4 L/min) at a resistivity better than 18.2 MΩ, filtration down to below 0.2 microns.

For structure tests a klystron system can provide up to 100 kW RF-power in the range from 700MHz to 860MHz.
Besides the upgrade of the test facility, our chemistry laboratory has also been improved. A closed pipe chemistry system has been installed to improve the control over the chemical polishing process. As a control measure, an IR camera has been added that monitors the

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cavity temperature during the polishing process. The direct observation of the temperature of the cavity material allows us to control the temperature and keep it below 15° C (288K) during the polish.

Figure 2: The movable radiation shield in the test area.

2 CAVITY WORK

After an extensive design study of the cavity design based on RF-properties [2], an optimization of the design under structural considerations has been done. This was an iterative process [3] that incorporated operational and safety considerations, mechanical analyses and the requirements for integration into the cryostat.

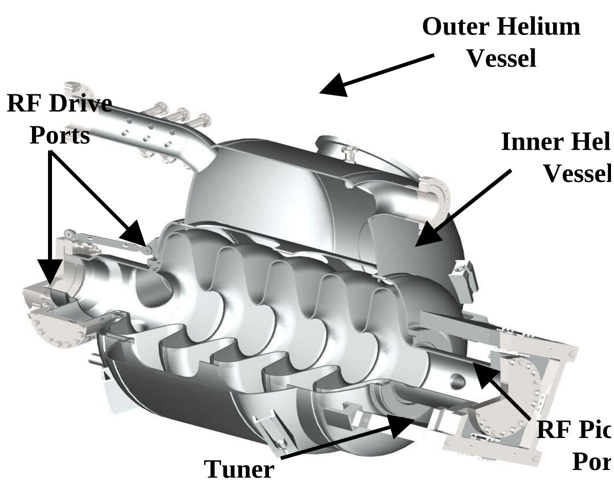

Figure 3: The β=0.64, 5-cell cavity with titanium helium vessels and some piping.

The design yielded material and fabrication specifications for the cavity, the inner and outer helium vessel, the tuner layout and the venting system for cryogenic operation.
Based on the resulting specifications, several cavities have been built, one by our own machine shop and several by industry: AES in the US built one cavity and CERCA in France is building 4 cavities. The LANL cavity, the AES cavity and one CERCA cavity are ready for testing. In recent months we have performed a number of mechanical and structural tests to gain a better understanding of the qualifiers for a good quality control. The quality control tests also included lifetime and cycling tests of movable components. The results of many of those tests have been reported during this workshop [4].
For a good understanding of the cavity operation, a mechanical modal analysis has been done and compared with the theoretical predictions for the cavities' modal spectrum [5]. These results will lead to an understanding of the required low level RF control, the cavities' response to ambient external noise sources and an understanding, whether the damping of intolerable mechanical frequencies might be required. The analyses under operational considerations also included a cool-down analysis of the cavity.
The results of the tuning sensitivity analysis have also been used to properly lay out a new bench-tuning system to tune multi-cell cavities and to adjust their field levels to a desired flatness. The tuning bench has removable tuning plates that allow using the bench for different cavity geometries as long as these fit into the bench-frame.

3 COUPLER WORK

The RF, mechanical and thermal design [6] of the APT power coupler has been completed and the first couplers and windows have been built. The coaxial coupler design has been done in-house, while the window design has been contracted out to industry. All parts of the coupler have been built in industry.

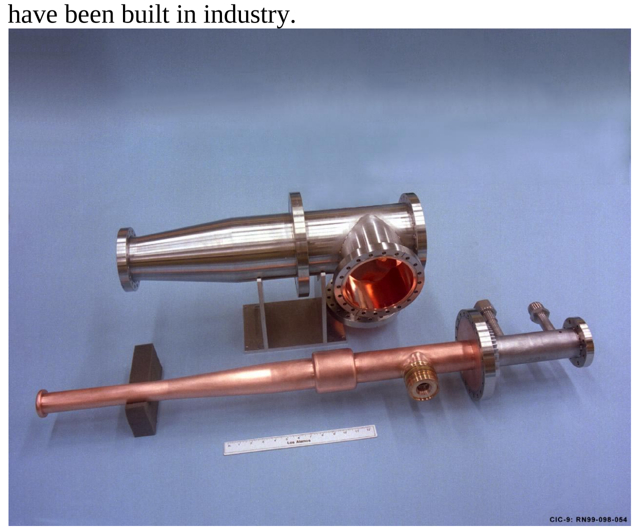

Figure 4: The inner and outer conductor of the APT power coupler.

To test the performance of these couplers, a test stand has been built. On the test stand two couplers are tested simultaneously. They are coupled by a pillbox-shaped copper cavity. One coupler acts as the cavity feed and the other as the power output. The couplers are adjusted for very high coupling to the cavity. The loaded Q is only 40.

This allows a very high power transmission with low fields and thus little x-ray production in the cavity.

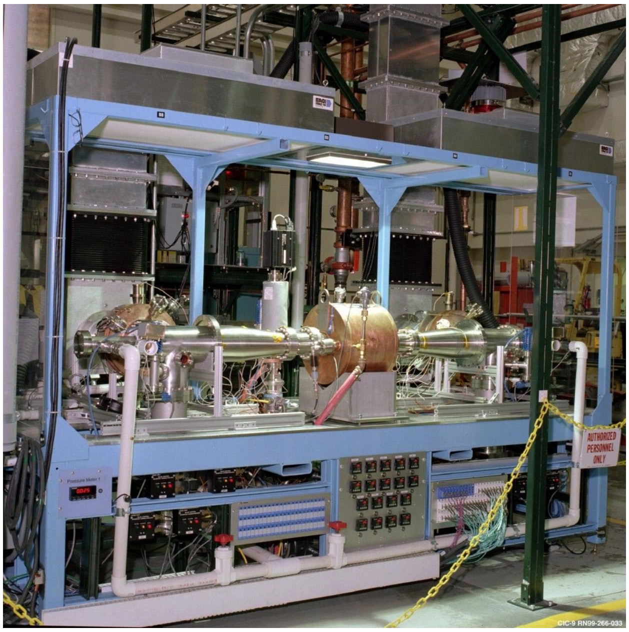

Figure 5: The Room Temperature Test Bed (RTTB) is a test stand for the high power test of the APT couplers.

The test stand is connected to a 1.1 MW klystron that provides the power for the performance tests. The first set of tests had the goal to investigate the power carrying limitations of the coupler, as well as a verification of the vacuum and cooling systems for the coupler.

The RF-tests were very successful. The first conditioning was done very carefully. Even with a vacuum leak in the coupler this took only 15 hours over 3 days to go from no power to 420 kW of transmitted RF power in cw operation. This is twice the nominal operation power for the APT accelerator. After the replacement of the faulty inner conductor it took 9 hours over 2 days to increase the transmitted power to 900 kW. The coupler operated at power levels above 900 kW for several periods of up to 3.5 hours. For a short time we reached more than 1 MW. The limitations for the operation at this level stem from klystron limitations. Once the couplers had been conditioned up to a certain level, the power can be turned back on to the maximum almost immediately.

The vacuum and cooling systems performed very well. Vacuum levels and temperatures compared well with the simulations. At 900 kW transmitted power, the vacuum level in the coupling cavity was about $2.5\ 10^{-7}$ Torr with the major constituent of the gas being hydrogen. The exit temperature of the center conductor cooling air was 180^{o}C. The thermocouple inside the inner conductor reads about 240^{o}C (513 K). The outer conductor and external temperature at the window, with external air-cooling, was below 70^{o}C (343 K).

The only unusual events to report so far are a weak multipacting event at about 280 kW (the only signature is a small, reproducible rise in the vacuum level from $2.2\ 10^{-8}$ to $2.3\ 10^{-8}$ Torr) and a glowing outer braze joint on the vacuum side window.

4 CRYO-MODULE MOCK-UP

Figure 6: The mocked-up cryo-module is a full size model of the APT cryo-module for the β=0.64 cavities.

A cryo-module, based in the CERN wrap-up design [7], has been designed for the APT β=0.64 cavities. Different from the CERN approach, the APT design includes 2 power couplers that penetrate the shell horizontally and that due to the warm double-window have to be almost completely assembled in the clean-room. To understand the related issues and added complexity, a full-scale mock-up of the 2-cavity cryostat has been built.

The assembly of the mock-up, among others, helped to understand the required assembly procedures and fixtures to deal with space constraints and blocked laminar flow[8] during assembly. Also the performance of the proposed magnetic shield was demonstrated. This and more lessons learned are described in more detail elsewhere during the workshop [8].

5 OUTLOOK

The test laboratory for superconducting cavities in Los Alamos has been improved over the last two years. It has been converted into a fairly general facility for assembly and testing of superconducting cavities. The lab will be operational again before the end of 1999. As a first test, a single cell cavity will be re-tested to verify the proper operation of the new facility.

Then for the following 10 months an extensive test program for the APT 5-cell cavities is planned. Since there are 6 cavities to be tested with limited resources, the test program will be a joint effort between LANL and Jefferson Lab. Each of the labs will test 3 of the cavities.

Also an extensive test program for the APT power couplers will continue. The fixed couplers, which tested up to 1 MW traveling wave power will be investigated for their behavior under standing wave operation. At the end of the year also the first variable coupler will be delivered from industry. This unit will go through the same testing program as the previously tested couplers.

Based on the mock-up, an APT cryo-module will be build. This includes two cavities and four power couplers. If funding is available, a cold-test of this cryo-module with RF will be performed within the next two years.

6 REFERENCES

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