Title: **STATUS OF RF SUPERCONDUCTIVITY AT LOS ALAMOS NATIONAL LABORATORY**

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Abstract

Work in RF Superconductivity at Los Alamos in the last 2 years has been in fabricating and testing a 4-cell 805-MHz cavity, and completing a preliminary design study comparing normal and superconducting versions of a high-intensity proton linac. The 4-cell cavity work was the completion of a prototype test on a proposed (but unfunded) project for pion acceleration that used a double-sided heat treated cavity with a stiffening scheme to reduce microphonics and allow operation at high external Q's. The high-intensity proton linac design study compared the feasibility, reliability, and capital and operating cost savings possible in replacing the 100-MeV to 1-GeV portion of a 100-mA CW proton accelerator with superconducting elliptical cavities at 700-MHz. An overview of the work shall be presented.

4-Cell Cavity Fabrication and Processing

The 4-cell 805-MHz cavity was designed to achieve accelerating gradients on the order of 10 MV/m and run with minimal beam loading. To achieve these objectives, the design approach utilized advanced techniques for obtaining high RRR, for cleaning, and for stiffening the cavity against microphonics. A table of the cavity parameters is shown in Table 1.

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frequency:	805 MHz
Ep/Ea:	2.10
Hp/Ea:	52.98 Oe/MV/m
cavity β:	0.90
aperture radius:	6.50 cm
vacuum seals:	Helicoflex Delta®, silver

Table 1. Parameters for the 4-cell 805-MHz cavity

To achieve a high gradient reliably, the cavity cells were double-side titanium heat treated after the equatorial weld was done. After the titanium was etched off, the iris and beam-tube welds completed the cavity assembly.

This approach yielded a niobium RRR of between 550 and 700, based on samples taken from different steps of the process.

Niobium-hafnium alloy flanges were used with Helicoflex® seals to avoid indium joints and improve cleanliness. Alloy flanges were chosen so the seal wouldn't deform the flange surface on compression, even after a high-temperature heat treatment.

To take advantage of the low beam loading, the cavity was externally stiffened to allow operation at an external Q of $2x10^7$. The stiffeners were 6 titanium tubes attached to tabs that were welded the cavity surface just off the equator. A drawing of the cavity and the stiffeners is shown in Figure 1.

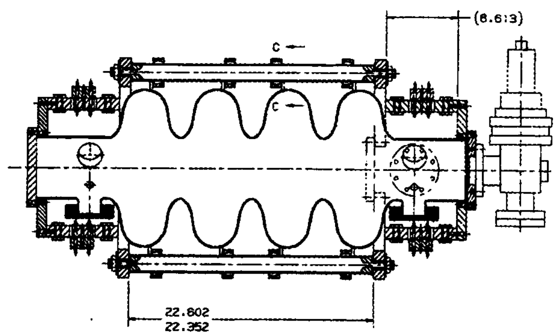

Figure 1. Drawing of the cavity and stiffening scheme.

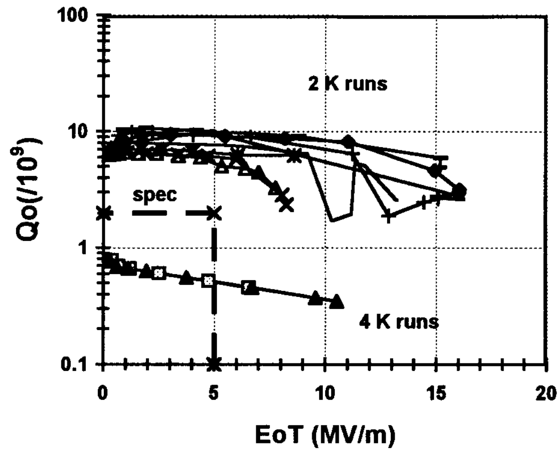

Figure 2. Q_0 vs E_0T plot at 2 and 4 K. Increasing field level was due to rf processing.

The final clean processing of the cavity at Siemens (Accel) consisted of a filtered, cooled recirculating chemical etch with 112 BCP (buffered chemical polish), followed by a long-term clean water rinsing of 90 hours, an HPLC (high-purity liquid-chromatography grade) methanol rinse, and assembly in a clean room.

Prior to testing at Los Alamos, the cavity was disassembled and cleaned with high-pressure ultra-pure water followed by an HPLC methanol rinse. The cavity was then resealed for testing.

4-Cell Cavity Testing

The cavity was tested at 2 and 4 K. The testing was done with an adjustable coaxial coupler capable of handling 1-kW CW, 100-kW pulsed power, to allow maximum flexibility in operation. During testing, standard RF processing was done. Conditioning with higher peak power was attempted to 100-kW, but as field levels in the cavity only reached the CW conditioning levels, higher fields from pulsed processing were not realized. A plot of the cavity performance is shown in Figure 2.

Overall, the cavity ran very well, and was limited exclusively by field emission at these field levels.

High Intensity Proton Linac Study

As a project to investigate applying RF superconductivity to intense proton accelerators for transmutation, a comprehensive design study was done. The approach was to replace the 100-MeV to 1-GeV portion of a 100-mA, CW room-temperature linac design with a superconducting linac design. Below 100-MeV, the linac was the same as the room-temperature design.

The purpose was to produce a superconducting point design to allow technical and cost comparisons to the baseline room-temperature design. As the existing room-temperature design was fairly detailed, a similar level of design detail was required for the superconducting case to make credible comparisons.

The approach for the design study was constrained by the requirements that the accelerator have high reliability, that it have a large aperture to beam size ratio to minimize activation, and that it would incorporate technology available today.

Even though using today's technology is recognized as being very conservative, the constraint on using existing technology was maintained as it provided a readily available upgrade path. Any advances in gradients, couplers, or windows directly translate to operational flexibility in increasing overall machine current and energy.

The linac would be composed of 4-cell 700-MHz cavities of 2 β types to cover the entire energy range. A schematic of the linac is shown in Figure 3.

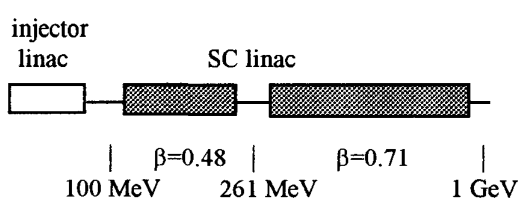

Figure 3. Schematic of the SC proton linac with two β types.

By using 4 cells per cavity, and 4 cavities per 1-MW klystron, sufficient operational flexibility is achieved by klystron rephasing, given that the phase advance between cavities is set in the RF delivery system. Focusing is done by a quadrupole doublet lattice with room-temperature magnetic quadrupoles between the cryostats.

As high power couplers and windows have been problematic on a number of superconducting accelerator projects, we chose to use two power couplers per cavity, to decrease the power requirements to 105 kW each. This gives us appreciable margin for beam current or gradient changes using the existing couplers. With the two-coupler-per-cavity configuration, RF power from the klystron is split 3 times before reaching the cavity.

In order to achieve a sufficient level of detail for comparisons to be made to the room-temperature design, preliminary engineering drawings were done on the overall layout, and on assembly details of the cryostat and coupler. Details of this work are presented in other publications at this Workshop [1,2].

Conclusions

Testing of the 4-cell cavity demonstrated that applying state-of-the-art fabrication and processing steps can lead to a high-gradient cavity, produced by industry.

A point design and costing study was completed that investigated the feasibility of applying RF superconductivity to a high-intensity, CW proton linac. The study showed that applying RF superconductivity to this class of machine is not only technically reasonable, but can result in operational cost savings.

References

[1] K. C. Chan, et al., "Superconducting High-Intensity RF Proton Accelerator for Transmutation Technologies", this workshop.

[2] D. Schrage, et al., "Static and Dynamic Analysis of the APT Superconducting Cavities", this workshop.