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PROTOTYPE 350 MHZ NIOBIUM SPOKE-LOADED CAVITIES

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Abstract

This paper reports the development of 350 MHz superconducting cavities of a spoke-loaded geometry [1], intended for the velocity range 0.2 < v/c < 0.6. Two prototype single-cell cavities have been designed, one optimised for velocity v/c = 0.4, and the other for v/c = 0.29. Construction of the prototype niobium cavities is nearly complete. Details of the design and construction will be discussed, along with the results of cold tests

1 INTRODUCTION

The Argonne Physics Division several years ago put forward a concept for an ISOL-type exotic beam facility using a proton/light-ion linac to drive a spallation source for radioactive ions [1,2,3]. As initially proposed, the driver linac would be a normally-conducting, fixed velocity profile, 220 MV linac which could provide beams of protons or light ions at a output energy of 100 MeV per nucleon with a total beam power of 100 kW

A normal-conducting linac would have several limitations. The velocity profile would need to be fixed in order to maximise shunt impedance. Consequently, for the lighter ions, particularly protons, the linac would have to be operated at substantially less than maximum gradient. Also, operation would be pulsed, with a duty factor of at most a few percent which could cause transient heating problems in the spallation target and also make voltage stability of the ion source problematic.

These limitations would be overcome by making the driver linac superconducting [4]. Then, the linac could be formed of short independently-phased cavities. The resulting broadly variable velocity profile would greatly enhance performance, for example, nearly doubling the maximum proton energy.

The cw operation possible with a superconducting linac would be advantageous in several respects. The reduction in peak beam current would reduce space charge and enable increased beam current, allowing, for example, the driving of several targets simultaneously. Also, the injector ion sources would be simplified..

We must note, however, that little development work has been done on superconducting cavities for the required velocity range 0.2 < β < 0.6 [5].

Cavities currently under development for β > 0.6 are foreshortened versions of the β = 1, multi-cell elliptical cavities used for accelerating electrons [6]. The present application, however, deals with energies below 200 MeV/A, and appropriate cavities would require excessive foreshortening. To obtain a reasonable accelerating voltage, particularly in the single or double cell structures needed to obtain broad velocity acceptance, would require cavity diameters approaching a meter. Construction, handling, and cryostat design would all be rendered difficult. Also, the mechanical stability of such large, highly foreshortened cavities would be at best marginal.

A more promising geometry is the spoke resonator, which has been successfully prototyped in the form of an 855 MHz, single-cell niobium cavity [7,8]. For the linac contemplated here, a substantially lower frequency, say in the range 300-400 MHz, is desirable. Lower frequency would provide increased voltage, larger beam aperture, and higher operating temperature. Since this frequency range is more than an octave lower than tested to date, further prototyping is required.

In what follows, we discuss parameter choices and construction of two prototype cavities [9]. Preliminary test results are also discussed.

2 CAVITY DESIGN AND CONSTRUCTION

Principal parameters for the two prototype cavities are shown in Table 1. To minimise time and cost, the two prototype cavities were designed to require no sheet-metal forming dies. Also, cavities were formed for two different velocities by changing only the cavity length and spoke diameter. For use in a linac, the frequencies of

Figure 1: Prototype niobium spoke cavity for β = 0.4 prior to welding on the end bulkhead. The outer diameter of the 350 MHz cavity is 44 cm.

Table 1: Parameters for the prototype cavities

Parameter	β = 0.4	β = 0.3
Active length	22.2 cm	17.7
Frequency	349 MHz	338
Geometric Factor QR_s	72	75
*RF Energy	85 mjoule	51
*E peak surface	4.0 MV/m	4.2
*B peak surface	107	91

.*Referenced to an accelerating field of 1 MV/m

the two cavities would need to be matched. But for purposes of evaluating prototype resonator performance, the slightly lower frequency that results from using the same tooling for both cavities is of no consequence

The cavity housings are formed from 1/8 inch sheet, and the central spoke of 1/16 inch sheet niobium. The 17 inch diameter bulkheads at either end are dished inwards by 1.3 inches to reduce cavity deformation under external pressure. To further enhance mechanical stability, a series of support ribs are welded to the exterior of the end bulkheads. The two coupling ports provide access for vacuum and rf coupling, and also for chemical processing, rinsing, and cleaning.

3 EXPERIMENTAL RESULTS AND CONCLUSIONS

Construction of both prototype cavities has recently been completed. The critical niobium surfaces of both cavities were heavily electopolished, approximately 150 microns, just prior to the final closure weld being made. After the final weld, both cavities were chemically polished to remove 50 microns of material and then rinsed with a high-pressure water spray.

Very preliminary results from initial cold tests of the β = 0.4 cavity are shown in Fig. 2. The Q observed at 4.5 K is characteristic of a surface resistance R_s of 100 nΩ, within a factor of two of the BCS surface resistance for niobium at this frequency and temperature.

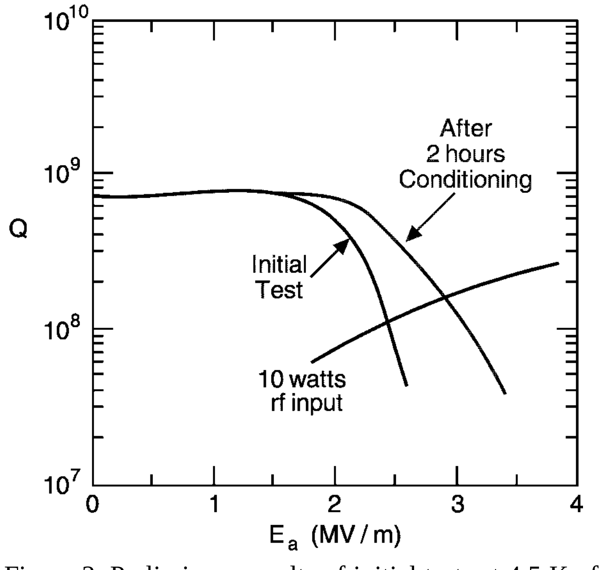

Figure 2: Preliminary results of initial tests at 4.5 K of the beta = 0.4 prototype 350 MHz niobium spoke

On initial cooldown, the cavity exhibited multipacting starting at low field levels, a few tenths of a MV/m, and extending continuously to the highest field levels so far reached, 3.5 MV/m. This level may be limited by the amount of rf power, 100 watts, currently available for pulse conditioning of the multipacting barriers.

Mechanical stability of the β = 0.4 cavity seems adequate. Ambient mechanical noise was observed to cause rf eigenfrequency jitter on the order of a few tens of Hz peak to peak. It should be noted that these observations were made while the test cryostat system was connected into the continuously circulating helium refrigeration loop cooling the ATLAS linac, so that the test conditions realistically simulate a linac environment.

Further tests are scheduled for both the β = 0.4 and the β = 0.3 cavities. Increased rf power will be available for conditioning of multipacting barriers.

4 ACKNOWLEDGEMENTS

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