PROTOTYPE MODELS FOR THE SNS RFQ*

A. Ratti, J. Ayers, R. Gough, J. Greer, M. Hoff, R. Keller, R. MacGill,
J. Remais, J. Staples, R. Yourd
Lawrence Berkeley National Laboratory, Berkeley, CA, USA

Abstract

Prototype models that simulate components of the RFQ which is part of the Spallation Neutron Source front end injector [1] are described. The RFQ operates at 402.5 MHz, a maximum current of 70 mA H^- and 6% duty factor. The first model, made of copper plated aluminum is a full size version of one of the four sections of the RFQ and is used to perform low level r.f. measurements of frequency, r.f. tuning, field structure and power coupling port studies. It serves to benchmark the 3D computer simulation studies and to test assembly and field measurement procedures. The second model is a quarter-wave coaxial resonator is used to perform full-power tests of high current seals and joints. This model is also used to test the prototype of the RFQ tuners. The design and construction of both models are presented, as well as test results.

1 INTRODUCTION

The detailed design of the RFQ [2] requires intensive computer simulations to define the cavity shape as well as the optimal configuration of many of the components like the π-mode stabilizers (PISL) [3], tuners and power ports. While some of the work can be done with a 2D code like Superfish, whose accuracy is quite satisfactory, the lack of radial symmetry mandates the use of 3D codes like MAFIA, which are not accurate enough to determine final dimensions. A test model has been built to perform low level measurements to validate and refine the computer simulations results. A quarter wave cavity has also been built to study tuners and seals under vacuum and rf power.

2 COMPUTER MODELING

The main cavity body geometry for the SNS RFQ has been developed with Superfish. With the adoption of the PISL stabilizer scheme, the structure has also been analyzed for mode separation and stabilization. The insertion of the stabilizer bars has the twofold effect of lowering the resonance frequency of the quadrupole mode and of raising the frequency of the degenerate dipole mode. A family of MAFIA simulations, summarized in Fig. 1, shows the effect of the stabilizer rods on both the quadrupole and the dipole modes as a function of the rods' spacing.

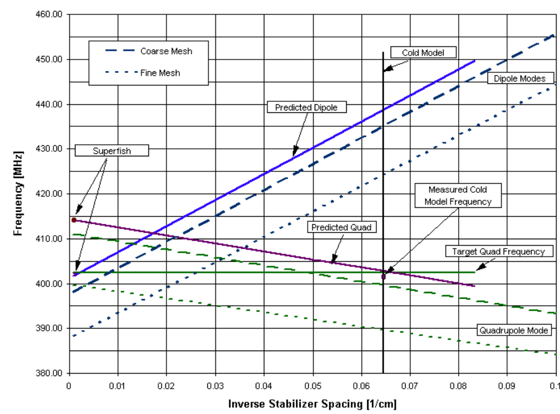

Figure 1 – Computer analyses of the quadrupole and dipole modes as a function of stabilizer spacing.

As a result of these analyses, the spacing between each set of stabilizers has been chosen to be 15.5 cm, from a horizontal pair to a vertical one (and vice-versa). This resulted in a predicted quadrupole mode shift of –11 MHz and of the dipole modes of +36 MHz. These effects were factored in the main frequency calculations performed with Superfish to determine the reference shape of the cavity. The measurements on the cold model proved the validity of this method.

3 COLD MODEL

A full size, 93 cm long RFQ cold model has been built, representing one quarter of the actual length of the full RFQ. This model is intended to validate the computer studies performed and to help defining the geometry to a better degree of accuracy than is achievable with MAFIA.

The model is made of aluminum, with a hard (acid) copper plating to guarantee a stable and strong surface to make good rf contacts between adjacent quarter sections. A picture of the cold model is shown in Fig. 2. This model has all vacuum penetrations, power coupling ports and tuner ports, but it is not built to operate under vacuum or with substantial rf power. Piston tuners are also provided,

* This research is sponsored by the Lockheed Martin Energy Research Corporation under the U.S. Department of Energy, Contract No. DE-AC05-96OR22464, through the Lawrence Berkeley National Laboratory under Contract No. DE-AC03-6SF00098

as well as adjustable end flanges to properly define the tuning of the vane ends. A set of six π-mode stabilizers, three in the horizontal and three in the vertical plane, is installed to validate the mode separation analysis.

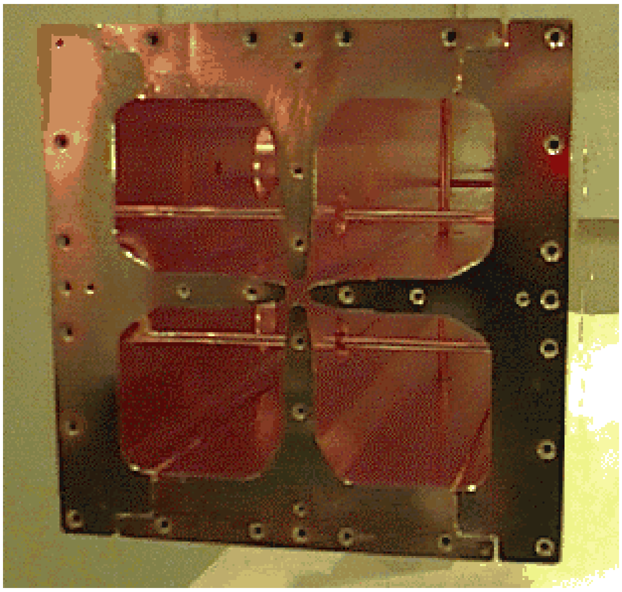

Figure 2 - The Cold Model Cavity

A computer based motion control and data acquisition system has been used to perform field perturbation measurements with the well known bead-pull method. The setup has been modified from the existing structure that was used at LBNL to map the higher order mode structure of PEP-II cavities [4]. In order to be able to observe both the H and the E fields, a set of four alumina spheres were run along the vane tips, whereas a set of four aluminum beads were run along the wall of each quadrant. To accomplish this, four motors were employed, with each motor servicing one quadrant and controlling one dielectric and one metallic bead.

The data acquisition system, based on the IGOR commercial software package running on a Macintosh platform, controls the motors via the RS232 bus. The program determines the bead positions and ensures that only one bead is inside the cavity at any given time. An HP8510 network analyzer is used to perform the S21 measurement that is used to observe the effects of the beads on the cavity. The instrument is software controlled via the GPIB bus which allows also for the transfer of the acquired data to the computer. Data analysis is later performed using separate software.

4 COLD MODEL TEST RESULTS

The perturbation measurements allowed the validation of the chosen cavity geometry. The waveguide cut-off frequency was found at 402.18 MHz, close to the required 402.5 MHz frequency. The tuners will bring the cavity to the operating frequency. This means that the cavity cross-sectional dimensions do not need to be changed, given the chosen stabilizer bars spacing. Figure 1 shows the measured quadrupole mode in comparison with the results from computer simulations.

Quadrant perturbation tests were performed using the available 12 tuners with the goal of judging the quality of the π-mode stabilization. The perturbation of one quadrant by 1.53 MHz changes the azimuthal field symmetry by less than 2.7 %. This satisfactory result finalized the current stabilization scheme.

Another important result obtained from the cold model perturbation measurements is the tuning of the end plates. The vane to end plate capacitance is balanced against the inductance of the vane undercut at a resonant frequency of 402.5 MHz that matches the cut-off frequency of the wave guide. With the help of detachable vane ends of various length it has been possible to find the optimum vane termination geometry.

The overall performance of the tuners was also verified. By moving all twelve tuners to their fully inserted and fully extracted position, a total tuning range in excess of 2 MHz was measured.

5 HOT MODEL

The hot model is designed to test rf sealing configurations on fully annealed OFE copper as well as tuner designs. To accomplish these tasks a quarterwave geometry was chosen for its simplicity and ease of fabrication. The cavity is designed to reach peak surface currents of the same density as the ones reached in the RFQ walls. This implies that the cavity operate under vacuum and be capable of taking a 6% duty factor rf high power pulse.

The cavity is powered by a tetrode-based 15 kW peak power amplifier, the components of which were provided by LANL. Using the energy stored in a capacitor bank, the system will run at a 1 ms long pulse with 60 Hz repetition rate, thus matching the operating conditions of the SNS RFQ.

The less than 1 kW average power is removed from the cavity by a spit-tube flooding the inner conductor of the resonator. The power coupling loop is also cooled in its outside wall.

The rf sealing geometry is designed to allow for testing of several types of seals. In particular, a copper-to-copper configuration was compared to sealing techniques based upon indium or tin. The hot model cavity is shown in Fig. 3.

Figure 3 - The Hot Model Cavity

The rf tuner is designed to help optimizing the piston. Clearance gap, moving rf contacts and vacuum sealing techniques will be tested under power.

6 HOT MODEL TEST RESULTS

The hot model measurement program is still underway. So far, the low level measurements have been completed.

The cavity quality factor Q has been calculated by measuring the reflection coefficient as seen on the optimally matched power coupling loop. These measurements showed no improvement in the rf performance of the cavity by adopting an indium or a tin seal. The observed values are listed in Table 1.

Configuration	Quality Factor Q
Calculated (Sfish)	4600
Cu-cu	4160
In	4140
Tin	4125

Table 1 – Rf seal measurements results.

The good performance of the copper-to-copper seal led to the decision to adopt it as the baseline in the first RFQ test module currently under design. This avoids the problems associated with using a metal seal on the fully annealed OFE surfaces and allows for the use of a rubber elastometer as the main vacuum seal.

The cavity is going to be powered soon to develop the tuner design. This phase will also allow to validate the adopted rf seal.

7 STATUS

The final dimensions of the RFQ cavity, including the vane undercuts and end plate positions have been determined and finalized aided by the measurements performed on the cold model. The bead-pull setup is now available for use to characterize the fields and assembly accuracy during the cavity manufacturing, assembly and brazing processes.

The baseline rf and vacuum sealing design has been established and will be tested in the hot model power tests that are soon to begin. These tests will also allow the conceptual development of the rf tuners.

8 ACKNOWLEDGMENTS

The authors would like to acknowledge the support received from the Beam Electrodynamics Group at LBNL, who made available the bead-pull test laboratory and provided the hardware used in the measurements. John Corlett, Bob Rimmer and John Byrd also contributed with their extensive experience in the field of cavity design and measurements.

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