NSNS RFQ MECHANICAL DESIGN†

Matthew D. Hoff, Craig Fong, Martin Fong, John W. Staples
Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, California, 94720

Abstract

A 402.5 MHz, 6% duty factor RFQ is being designed for the National Spallation Neutron Source (NSNS). The 6% duty factor and RFQ length will present formidable design challenges. To this end, an RFQ materials test program is underway. A cold model test facility is being designed. Results of cooling calculations have begun. Plans for cavity construction, rf and vacuum seals, alignment, structural support and hot models are discussed.

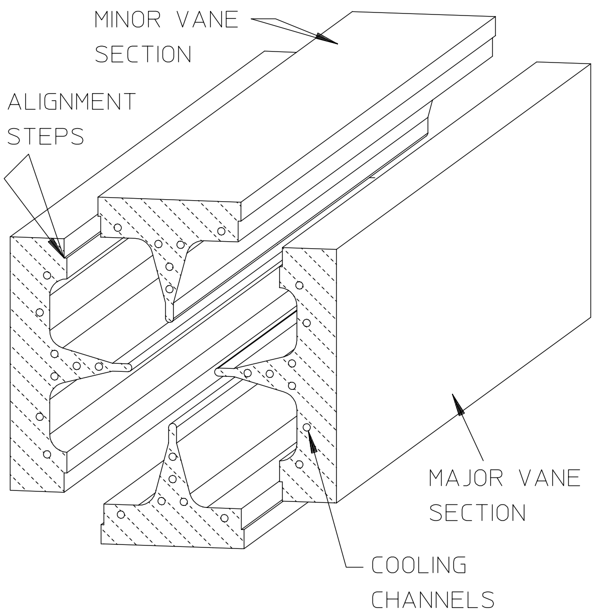

Figure 1. Vacuum-furnace Braze Assembly
Exploded view
Flanges and ports not shown for clarity.

CONSTRUCTION

We have designed the basic size of the RFQ at 3.7 meters long by 215 mm square cross-section, not including the flange, which is 292 mm square. The RFQ will be divided into four modules of varying length. The longest module is 950 mm in length while the shortest module is 900 mm. We are studying a vacuum-furnace brazed, self-aligning technique for fabrication, (See Figure 1) We plan to braze together four vane sections to create modules that in turn bolt together to form the full length RFQ as shown in Figure 2.

The RFQ is divided into four modules all under one meter in length to simplify fabrication, oven brazing and handling. A development program will be integrated with the hot model testing to verify this construction technique.

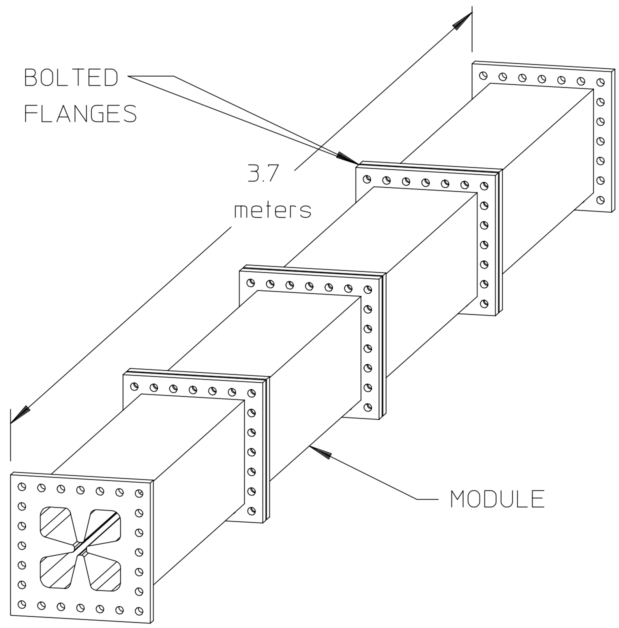

Figure 2. Four Module RFQ Assembly

MATERIALS

We have currently selected Glidcop AL-15 [1] (an alumina dispersion-strengthened copper) because of the vacuum-furnace braze technique and the close tolerance requirements for the cavity. Glidcop will not anneal in the brazing oven and will not creep from residual stress, making it ideal for our close tolerance application. Module connecting flanges can be fabricated of either Glidcop or stainless steel. Raw Glidcop billets can be sized to include the flanges, saving an oven brazing cycle, but requiring more material and machining. Stainless steel flanges would have greater strength than Glidcop, but would require a braze cycle. We will investigate both options. Anticipating accelerated erosion due to ion sputtering by the 6% duty factor, we plan on investigating the hardening of vanetips by ion implantation of a refractory metal such as tantalum. The Plasma Applications Group at LBNL has developed advanced techniques of surface modification using ion guns to harden copper surfaces.

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RF TUNING

The coarse frequency will be determined by computation with 3-D electro-dynamic codes and refined by physical modeling. The actual RFQ modules will be fabricated with a frequency slightly higher than required and a groove machined in the length of the cavity wall to bring the frequency into the desired tolerances. The groove will be cut using a wire EDM machine with a throat opening greater than the length of the modules. The RFQ design incorporates forty-eight tuners, (See Figure 3). We plan to adapt the design of the PEP-II tuners [2] which have been developed for a similar wall power density and 476 MHz frequency, but a 100% duty factor. The PEP-II tuner has a piston area of 7500 sq. mm, while the NSNS tuner will be 200 sq. mm with a motion of ± 2 mm. The tuners use silver-plated Glidcop rf contacts sliding on rhodium-plated copper piston. Hence, we need only to scale down the size of the design. Because of the anticipated rf losses, the tuners are water cooled. The physics design of the RFQ is further discussed in a companion paper at this conference[3].

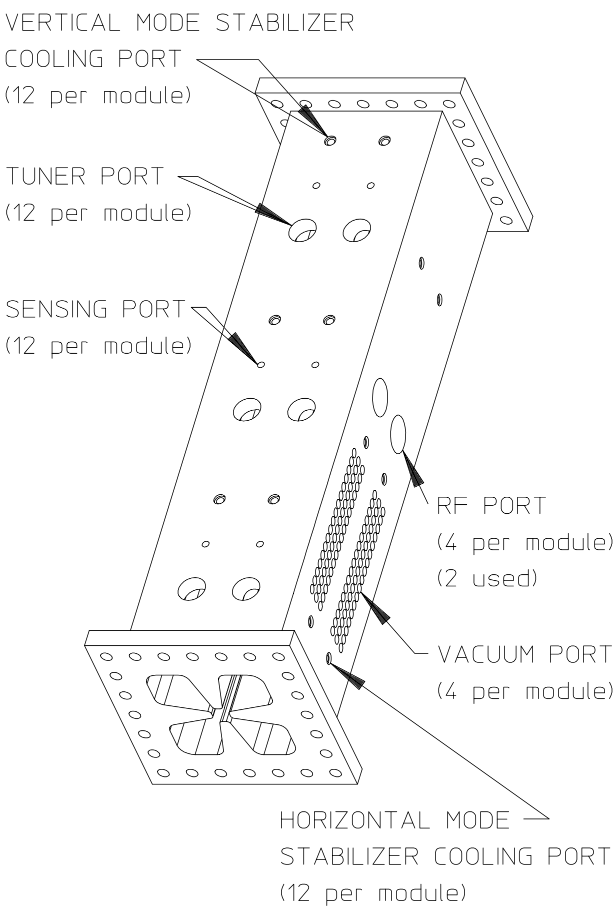

Figure 3. Module Port Configuration
Port configuration is identical
on the opposing hidden surface.

DRIVE LOOPS

We plan to distribute 800 kW of rf power into the RFQ at eight locations. At 100 kW per input, eight water cooled drive loops will be used. Drive loops will be located, in pairs, in the center of each module. Drive loop pairs will be located in opposing quadrants. To promote even power distribution, drive loops will alternate between adjacent quadrants in adjacent modules. To maintain symmetry in the cavity design, all modules will have four drive ports in the center, but only two will be used, with the other two capped off.

VACUUM SYSTEM

An array of holes with diameters small enough to attenuate rf leakage will be machined into each major vane component resulting in four pump-out ports per module. Conceptual design indicates that four turbomolecular and two cryo pumps should be used for pumping the entire RFQ. Each vacuum pump manifold covers two adjacent ports on a module side. Unused vacuum ports will be covered. Vacuum calculations indicate this arrangement can pump down to a pressure of 10^{-7} torr, which will meet operational requirements.

SEALS

Current plans are to join RFQ modules with a bolted flange utilizing a Helicoflex[4] seal, backed up with an O-ring. The Helicoflex seal fulfills both the rf and vacuum requirements. We expect the rf current across the bolted joint to be low, well within the capabilities of the metal clad, high contact pressure Helicoflex seal. We view the back-up O-ring seal as cheap insurance for a major vacuum joint. Local rf current will be sustained at the vanetips by capturing a canted spring ring between them. Large flanges, such as the vacuum ports will be sealed with O-rings. Smaller seals, such as the tuners, may use copper knife-edge type seals.

π MODE STABILIZER BARS

LBNL has chosen to use π Mode Stabilizer bars that were pioneered at KEK [5]. These stabilizers are mechanically simple, inexpensive to fabricate and easy to cool. Preliminary design calls for six pairs per module, twenty-four pairs total.

ANSYS CALCULATIONS

Initial ANSYS [6] analysis of the nominal RFQ cross-section showed the following results. Thermal distribution calculations show a 5˚ C rise for the cross-section. Thermal stress, along with vacuum loading, is calculated at less then 650 psi. Net thermal deflection at the vanetip and cavity wall is less then .001 mm resulting in a calculated frequency shift of .001%. Further analysis of the RFQ vane end region and other potential hot spots will be carried out as the design matures. The cooling water flowing through the vane is calculated to rise less than 3˚ C.

COOLING CIRCUITS

Multiple cooling circuits will be gun bored and their locations are based on ANSYS analysis. The gun boring method allows us to place cooling closer to the vane tips. In locations where a port must cross a cooling passage, a port sleeve with a cooling channel on the outside bore will be inserted (during a furnace braze cycle) to allow the coolant to flow around the port, (See Figure 4). The cooling passages will be brazed shut at the ends and connecting water passages radially bored in from the outside.

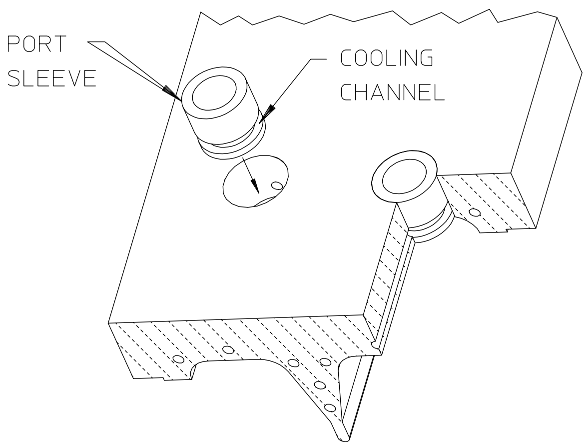

Figure 4. Port Sleeve Cooling

ALIGNMENT

We plan to address the alignment of vanetips in the individual modules by machining alignment steps into the major and minor vane sections and braze using a "zero gap" technique, (See Figure 1). The "zero gap" technique entails fixturing the components with metal to metal contact and placing the wire braze material in machined grooves that open to the contact surface. The groove location and size is designed to deposit the correct amount of braze material through out the joint. The metal to metal contact assures precise alignment and tolerance control. The four modules will then be mounted on a strongback structure (raft) that will align the modules to each other, support vacuum pumps and facilitate transportation.

STRUCTURAL SUPPORT

The smaller strongback structures (rafts) holding the modules will be mounted on a larger, overall support structure (girder) holding the entire NSNS Front End. This girder will facilitate easy instrumentation access and modification, yet provide stiff, rugged support. This structure may also double as a shipping fixture.

COLD MODELING

A modular cold model structure has been designed for low power rf testing without vacuum. Starting with short, standard sections, we will work our way up to a final full length model. Preliminary test are planned for the mode stabilizer rod spacing and location. Vanetip end geometry, tuners, rf drive ports and absolute frequency will also be tested.

HOT MODELING

Design is progressing on a test stand for testing small RFQ structures under vacuum and full rf power, hence the term "hot". We plan on testing rf joints, multipactoring reduction techniques, rf feed loops and cooling on this test stand. Initial test will be on a short two vane structure to simplify fabrication, eventually working our way up to a full scale cross-section.

INSTRUMENTATION

Instrumentation design is in the discussion stage only at this time. Forty-eight wall-field sensing loops are planned, as are four spark detectors and cavity temperature monitors. Full monitoring of the water cooling system is anticipated to include flow rate, temperature and water quality. All rf tuners will be monitored for temperature and position during operation.

CONCLUSION

We have presented a four-vane, oven-brazed, Glidcop RFQ, assembled in four modular sections. Initial ANSYS calculations indicate an excellent thermal design showing thermal stress below 650 psi and thermal frequency shift under .001%. We are confident that our development program will verify our fabrication technique and successfully overcome the challenge of a 6% duty factor, 3.7 meter long RFQ.

REFERENCES

[1] Glidcop Products Information Bulletin, SCM Metal products Inc., 1988

[2] H.D. Schwarz et. al., *Development of a Movable Plunger Tuner for the High-Power RF Cavity for the PEP-II B Factory.* this conference.

[3] J. W. Staples et al, *The NSNS Front End Accelerator System*, this conference.

[4] Helicoflex is a registered trademark. Helicoflex Company, Columbia, SC., USA

[5] A. Ueno et al., *Beam Test of the Pre-Injector and the 3-MeV H- RFQ with a New Field Stabilizer PISL*, Linac 96

[6] ANSYS finite element code, Rev 5.3, ANSYS, Inc. Canonsburg, Pa. USA