PLANS FOR AN INTEGRATED FRONT-END TEST STAND AT THE SPALLATION NEUTRON SOURCE*

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Abstract

A spare Radio-Frequency Quadrupole (RFQ) is presently being fabricated by industry with delivery to Oak Ridge National Laboratory planned in late 2012. The establishment of a test stand at the Spallation Neutron Source site is underway so that complete acceptance testing can be performed during the winter of 2012-2013. This activity is the first step in the establishment of an integrated front-end test stand that will include an ion source, low-energy beam transport (LEBT), RFQ, medium-energy beam transport, diagnostics, and a beam dump. The test stand will be capable of delivering an H- ion beam of up to 50 mA with a pulse length of 1 ms and a repetition rate of 60 Hz or a proton beam of up to 50 mA, 100us, 1Hz. The test stand will enable the following activities: complete ion source characterization; development of a magnetic LEBT chopper; development of a two-source layout; development of beam diagnostics; and study of beam dynamics of high intensity beam.

INTRODUCTION

The Spallation Neutron Source (SNS) Radio-Frequency Quadrupole (RFQ) was commissioned with beam in 2003. The RFQ performance has been sufficient to enable high-reliability neutron production, but there have been two sudden detuning events that required retuning of the structure, and there is evidence that the RFQ is being operated near the limits of thermal stability, i.e., reliable operation at higher average power is uncertain. The SNS accelerator presently delivers a 1 MW proton beam to the neutron production target. It is planned to ramp up the beam power to 1.4 MW over the next few years.

The RFQ structure twice experienced a sudden resonant frequency shift of a few hundred kHz. The first event occurred in October of 2003 during beam operation, the second in February 2009 during a maintenance period with no RF power in the cavity. A thorough examination of the RFQ cavity was conducted after the first event but nothing abnormal was found. The cavity was retuned using available tuners and successfully returned to operation in both cases. The root cause of the detuning has not been determined with certainty, but there is a similarity in both cases. The detuning was coincident with cooling system problems: in the first case a failure in the controls system caused the RFQ to cool down to 8°C; in the second case the cooling water pressure inadvertently increased over 100 psi. It is postulated that these events could create an abnormal stress causing a partial separation of the braze joint between the inner high-purity copper structure and the outer GlidCop exoskeleton.

The RFQ showed resonance control instabilities when operating at a duty factor larger than ~4.2%, and this was one of the limiting factors in reaching 1 MW beam power. The machine downtime due to this RFQ instability was longer than 30 minutes per day, which affected the overall machine availability. The response time (about 5 minutes) of the Resonance Control Cooling System was a major contributing factor. The auto pulse-width adjustment scheme was added to the low level RF control system to provide faster control [1]. With this improvement the SNS RFQ has been confirmed to be stable up to 5.5% RF duty factor at the cost of using up 60 us of available RF pulse width for the temperature control. It is not clear if this solution will work at 7% duty factor required for achieving 1.4 MW beam power.

In order to mitigate the risk of failure of the original RFQ and to prepare for increased beam power, a contract was made for production of a spare RFQ at Research Instruments GmbH near Cologne, Germany. The RFQ is presently in production and delivery to SNS is expected in late 2012. A test stand is being prepared at SNS to support acceptance testing of the RFQ. The test stand will include all infrastructure needed to demonstrate full performance of the RFQ without beam.

It is planned to further develop the test stand thereafter into a fully-integrated front-end test stand that will include an ion source, low-energy beam transport (LEBT), RFQ, medium-energy beam transport (MEBT), diagnostics, and a beam dump. The test stand will be capable of delivering an H- ion beam of up to 50 mA with a pulse length of 1 ms and a repetition rate of 60 Hz or a proton beam of up to 50 mA, 100us, 1Hz. The test stand will enable the following activities: complete ion source characterization; development of a magnetic LEBT chopper; development of a two-source layout; development of beam diagnostics; and study of beam dynamics of high intensity beam.

TEST STAND SITE

The test stand will be installed in the RF Test Facility Annex, building 8320, at the SNS site, as shown in Figure 1. The RF Test Facility, building 8330, is adjacent and presently houses a high-power RF test stand for testing klystrons, RF devices, and cryomodules. Building 8330 also houses infrastructure for superconducting RF development and maintenance activities. This infrastructure includes a clean room, high-purity water system, high-pressure rinsing system, vertical test stand, cryomodule test stand, and cryomodule assembly area.

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Low-conductivity and industrial chilled water is available at the mutual boundary of these buildings. An additional AC power transformer and distribution panels are being installed in the Annex to service the front-end test stand.

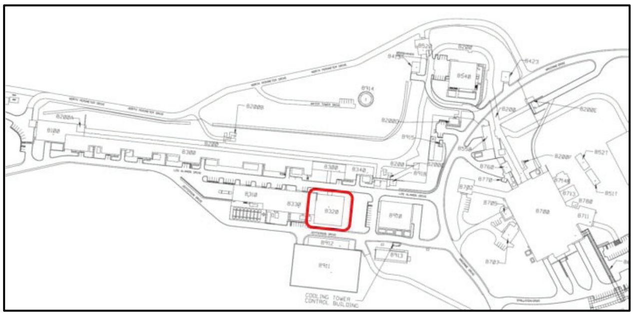

Figure 1: The front-end test stand is being installed in building 8320 across the street from the klystron gallery adjacent to the high-energy end of the superconducting Linac.

TEST STAND LAYOUT AND PROGRESS

The test stand will be installed on the west side of building 8320 under an existing support structure (Figure 2.) This structure was designed to facilitate testing of klystrons and RF components and features cable trays and low-conductivity water distribution on its topside. RF waveguide components will hang from its bottom-side. The waveguide distribution up to the output of the circulator has already been installed. The 2.5 MW, 402.5 MHz klystron and its water cooling skid have been installed as show in Figure 3.

Figure 2: The front-end test stand area as viewed from the position of the beam dump. The RFQ will be to the right of center beneath the blue support structure.

The area where the test stand is being installed will serve several functions in the future. A prototype high-voltage modulator will be installed in the background area of Figure 2 for testing as a collaborative effort with ESS-Bilbao. This modulator was specified to meet SNS superconducting Linac requirements and is presently undergoing factory testing at the Jema company in Spain.

Three 805 MHz, 550 kW klystrons mounted to a single transmitter tank are visible in the Figures 2 and 3. These klystrons are utilized in the superconducting Linac, where 81 klystrons power 81 accelerating cavities. A test stand for these klystrons is being established adjacent to the RFQ test stand. The RF water loads (red) can be seen hanging from the support structure in Figure 2. These klystrons may be powered by the Jema modulator after it passes initial acceptance testing at SNS.

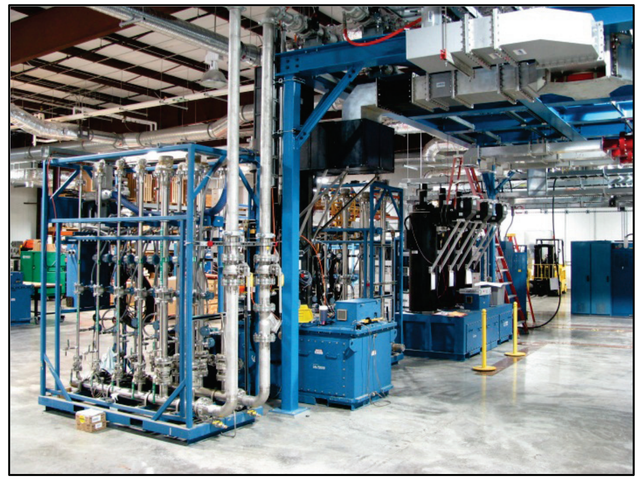

Figure 3: The 402.5 MHz klystron and its cooling cart have already been installed along with a portion of the waveguide system. A trio of 550 kW, 805 MHz klystrons is visible in the background, where a separate klystron testing capability is being established.

The layout of the test stand area is shown in Figure 4. Space has been reserved at the left-end of the RFQ for development of a two-source configuration, which is desirable for high-reliability accelerator operation at SNS. Space has also been reserved immediately beneath the RFQ to support later installation of a MEBT and experimental area for high-intensity beams.

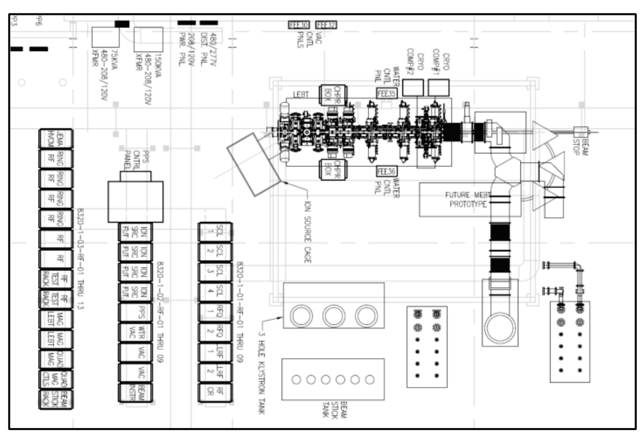

Figure 4: Layout of the front-end test stand. The beam direction is to the right (north).

The 2.5 MW, 402.5 MHz klystron will be powered by an existing high-voltage converter modulator in the RF Test Facility. This modulator is part of a test stand

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(Figure 5) that is used to test modulators, klystrons, cryomodules, and various RF transmission components. A triaxial high-voltage cable has already been installed from this modulator to the kystron that will power the RFQ.

Figure 5: The existing RF test stand features a high-voltage converter modulator (background) which can be used to operate either 2.5 MW, 402.5 MHz or 5 MW, 805 MHz klystrons (foreground).

RFQ DESIGN AND STATUS

The primary requirement on the spare RFQ is that it be a drop-in replacement for the existing RFQ. This implies compatibility in physical size, RF characteristics, beam dynamics, and interfaces to supporting subsystems such as vacuum, water, and RF. In order to meet this requirement, the vane modulation is unchanged from the original SNS RFQ. Design changes include an octagonal cross section, the use of dipole stabilizer rods in the end plates for mode spacing, and construction of high-purity copper. In contrast, the original RFQ utilizes a square cross section, pi-mode stabilizers, and is constructed of a combination of GlydCop and high-purity copper. The spare RFQ features 64 slug tuner ports, 48 RF pickups ports, 10 vacuum ports, 2 RF input coupler ports, and 2 beam ports [2,3]. The spare RFQ is presently in fabrication at Research Instruments GmbH with delivery to SNS expected later this year. The RFQ will be fully assembled at the vendor facilities, where it will undergo RF tuning and measurements, vacuum integrity testing, and water manifold testing. The fully-assembled RFQ will be shipped to Oak Ridge on a girder as depicted in Figure 6.

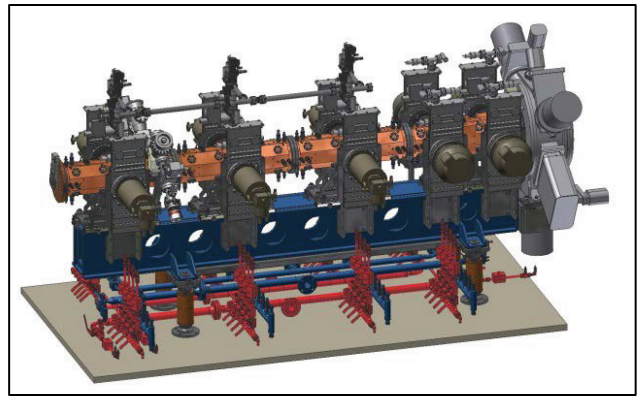

Figure 6: Illustration of the spare RFQ due for delivery to SNS later this year.

EXPERIMENTAL PLANS

Preparations are underway to enable acceptance testing of the spare RFQ during the winter of 2012-1013. Acceptance testing will include verification of the RFQ structure tuning and RF operation up to the design gradient and duty factor. Upon successful completion of this testing, installation of the ion source, LEBT, MEBT, and beam dump will proceed. It is anticipated that this basic configuration will be commissioned with beam in 2013.

The primary initial purpose of the front-end test stand will be complete ion source characterization. Presently this work can be performed only on the SNS accelerator, which is mainly occupied with neutron production.

Other planned experiments include the development of a magnetic LEBT chopper (a prototype exists and awaits testing); development of a two-source configuration that would provide for rapid switchover from one source to the other in case of performance problems; development of beam diagnostics; and study of beam dynamics of high intensity beam.

SUMMARY

The SNS integrated front-end test stand is under construction and will support spare RFQ testing in the upcoming winter. Thereafter it will be outfitted with an ion source, LEBT, MEBT, and beam dump and commissioned with beam in 2013.

REFERENCES

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