DEVELOPMENT AND TESTS OF BEAM TEST FACILITY WITH NEW SPARE RFQ FOR SPALLATION NEUTRON SOURCE *

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Abstract

The Beam Test Facility (BTF) has been constructed to validate the performance of the new RFQ, to study ion source improvements, and to support neutron moderator development and six-dimensional phase space measurements for SNS. The BTF includes an H- ion source, Radio-Frequency Quadrupole (RFQ), and Medium Energy Beam Transport (MEBT) beam diagnostics systems. A spare RFQ was built and fully RF tested in the BTF and will be installed in the SNS linac in the future. The test stand is ready to run with the H- ion beam through the new RFQ to fully validate the RFQ performance. The RFQ was designed to have the beam characteristics identical to the existing RFQ with improved operational reliability and stability. The H- RF plasma ion source system includes new high power RF components for improved front-end system performance.

INTRODUCTION

The construction of the BTF indepent to SNS linac [1] that started in 2014 has been completed. The facility will be used to study upgrades and performance improvement of the SNS front-end systems and to perform experiments of scientific development projects. The facility consists of a 65 keV H- ion source, a 2.5 MeV RFQ, complete MEBT beam diagnostics systems, and a 7.5 kW beam dump. The test stand is ready to run with the H- ion beam through the new RFQ that has been completed and tested with high power RF. The new RFQ was built as a spare of the SNS RFQ with improved operational reliability and stability while maintaining the same beam parameters. Performance verification of the new RFQ for reliable operation with full beam power will be the first task in the BTF. The current layout of the BTF is shown in Figure 1 and the constructed system is shown in Figure 2.

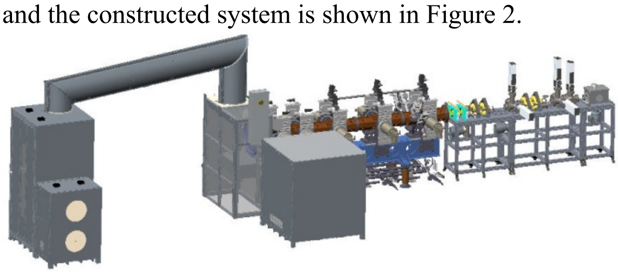

Figure 1: Schematic view of the the BTF. Ion source, RFQ, and MEBT from left to right.

Furthermore, the BTF will provide a platform for testing of the existing equipment and developing new equipment of the front-end systems for improved availability and reliability, and future beam power upgrade of SNS. The tests of the SNS front-end components in the BTF will provide results that can be compared with the SNS front-end systems since they are functionally similar.

The BTF will be the platform for conducting R&D of novel accelerator physics and scientific ideas with high intensity hadron beam generation, acceleration, and measurement. The system can perform as a short pulse neutron source for the SNS Second Target Station moderator development. Other tasks to be performed are optimization of beam diagnostics design, lattice design, data acquisition software, optimization of data processing, and simulations of beam halo with the system. This paper describes the design of the BTF, the result of ongoing tests, and the future scientific development tasks using the facility.

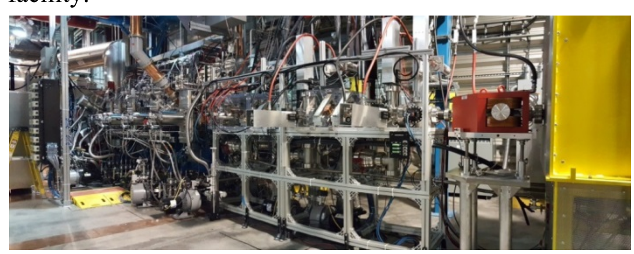

Figure 2: Completed BTF installation including the beam dump at right.

SUBSYSTEMS

After complete construction of the facility, testing of the ion source and its beam with the high voltage and high power RF systems is in progress. Low power beam operation with pulse width limited to 50us and repetition rate up to 5 Hz is to be completed within a couple of months. This will allow characterization of the new RFQ with beam transmission, output energy, and transverse beam emittance. An active Personnel Protection System (PPS) and a beam stop radiation shield have been added to allow safe operation of the facility at the maximum design beam power. The facility is expected to be fully operational later in 2016 together with fully integrated EPICS controls like in the operation of SNS systems at the central control room.

Ion Source and LEBT

The H- ion source of SNS is a cesium-enhanced, multicusp ion source that has been continually updated to become a high beam current source with improved reliability [2]. The same H- ion source and its peripheral equip-

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ment are installed in the BTF. The ion source has been tested successfully with the LEBT and fully operational. Further tuning of the source with beam injection to the RFQ is being performed at this point.

In April 2016 the first LEBT beam current measurements were performed by applying a pulsed transverse voltage (up to 6kV) across segments of the second LEBT lens thereby deflecting the beam onto an isolated electrode. A similar technique is routinely used on the SNS LEBT to measure RFQ input current [3]. Figure 3 shows the intercepted beam current vs. the applied deflection voltage from the ion source in the BTF.

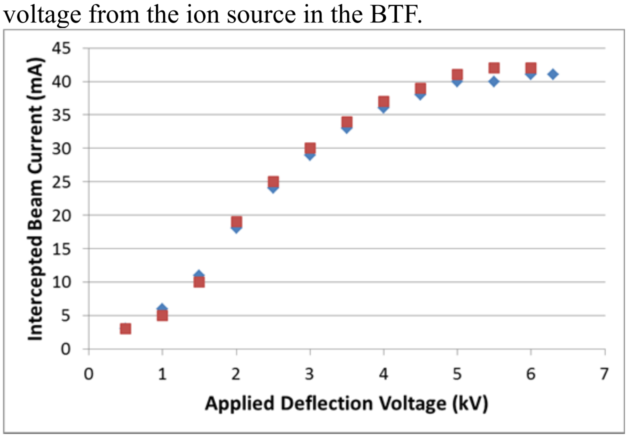

Figure 3: Beam currents in the range of 40-45mA have been measured from a baseline SNS ion source which is within expectation for that particular ion source.

An electrostatic LEBT that is identical to the standard SNS front-end LEBT has been installed and tested. The performance of the short electrostatic LEBT has been reliable. Using the same type of LEBT is to verify the performance of the spare RFQ under the same conditions to the present SNS linac. Other LEBT configurations have been considered for the BTF and changes could be made later after completing the RFQ performance verification. The LEBT choppers will perform the same as in the SNS front-end systems. The LEBT gate valve, separating source vacuum and RFQ vacuum, has not been installed. The valve would be useful from the experience with the SNS main linac to prevent accidental venting of the RFQ.

The external antenna ion source that can have longer lifespan has been successfully developed in SNS [4]. This new ion source needs more tests for performance optimization and will be tested in this facility. The tests will provide valuable information of the new ion source for SNS that can be the preferred over the present internal antenna ion source with shorter source lifespan [5].

RFQ

The BTF is now completely equipped with a new RFQ structure and its RF power supply system for full operation. The new RFQ may replace the RFQ in the SNS linac if the test with full H- beam is successful to achieve more stable and robust beam performance. The improved performance will be needed for the future upgrade of the SNS. The good beam transmission > 80% through the RFQ will be important for the future proton power upgrade project that will be executed with the second target station project of SNS.

The new RFQ was designed and built to maintain the beam characteristics identical to the existing RFQ in the SNS linac but with more reliable mechanical and operational properties. The vane tip shapes and the tip modulations are identical to those of the existing RFQ. Structure body consists of four sections that are made of solid copper with octagonal shape in its cross section. Two RF power couplers with coaxial loop antennas are used as in the present RFQ in SNS linac. The vacuum system was designed to have more robust pumping for improved operating pressure even with high beam current injection with hydrogen gas from the ion source.

The RFQ has been fully tested at maximum RF duty cycle successfully without the beam. The RF power has reached 600 kW average peak power in open loop and 550 kW in closed loop operations in 1 msec, 60 Hz pulses. The thermal stability of the RFQ with cooling system showed that the system can operate reliably with stability with good vacuum system performance. The power couplers performed satisfactorily with improving vacuum activities and corresponding RF trips over time. The RFQ cavity vacuum was maintained below 2x10(-8) torr and the coupler vacuums were around 2x10(-8) torr without the beam. Figure 4 shows the archived test data for a period of the successful RF processing operation with the RFQ.

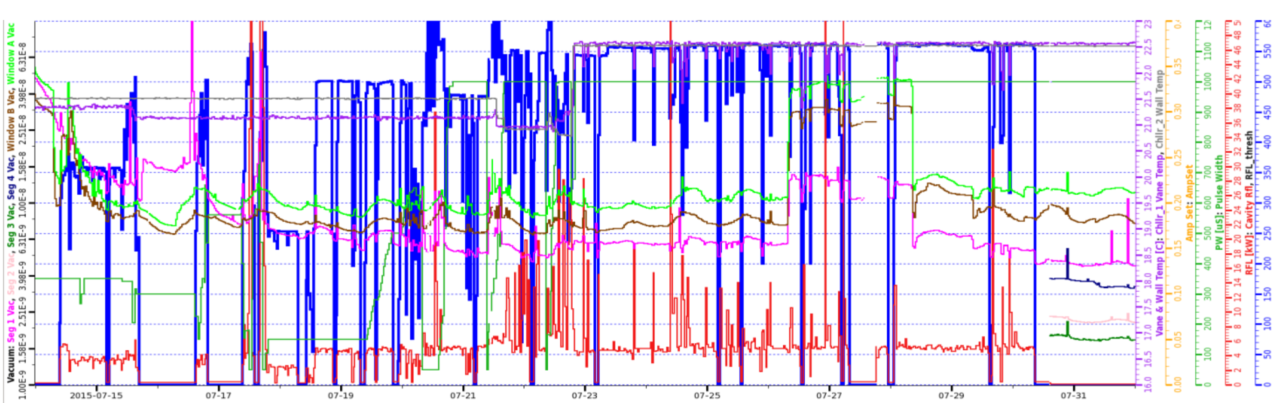

Figure 4: Archived data of the RF test and conditioning of the new spare RFQ.

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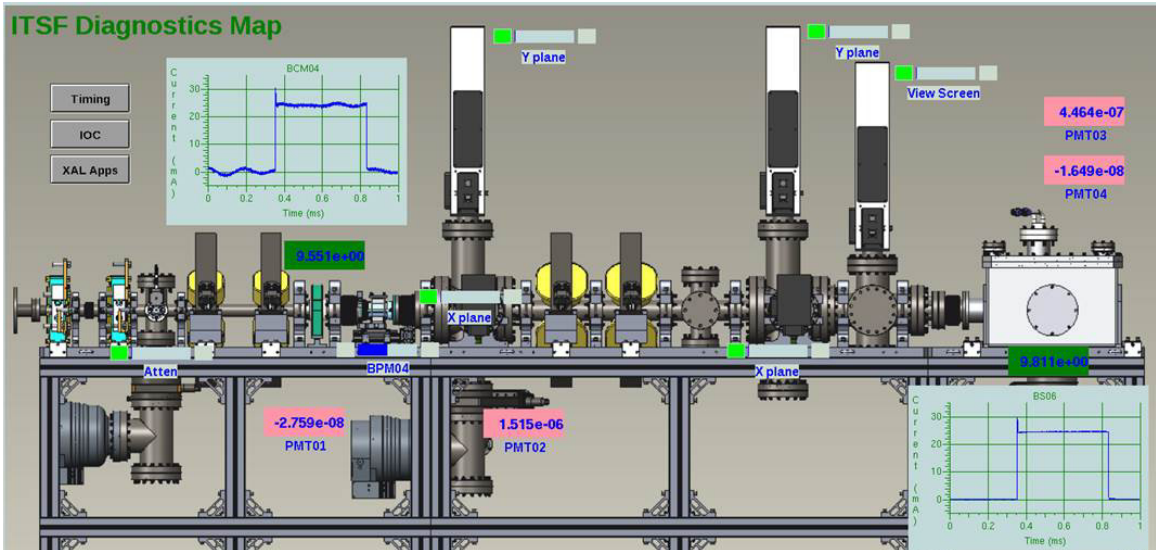

Figure 5: Diagnostics systems shown with EDM screen: 1xBeam Current Monitor, 1x Movable Beam Position and Phase Monitor, 2x pairs of horizontal and vertical slits, View screen, 4x Beam Loss Monitors, 1x Beam Current Attenuator/ Stripping Foil. The 7.5kW beam dump will be placed at the right end.

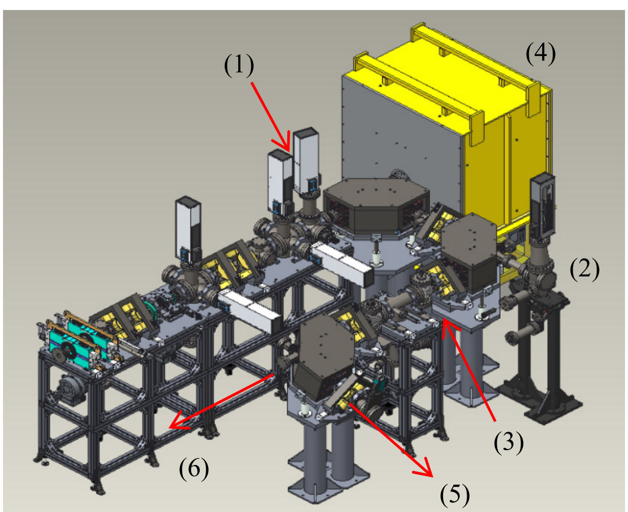

Figure 6: Design of the BTF beam line extension for future experiments: (1) Spectrometer for 6-D phase space energy analyzer, (2) Feschenko Beam Shape Monitor for 6-D phase space time analyzer, (3) Fast chopper to make short neutron pulses, (4) Beam dump, (5) to neutron target, (6) MEBT-2.

MEBT and Beam Diagnostics

The MEBT and the beam stop have been complete with the beam diagnostics systems but with no rebuncher cavities. Presently, no longitudinal bunch focusing is considered. The system is designed to have loss-free beam transport between the RFQ and the beam stop. Extensive and thorough beam measurements and characterization can be done within the system. Transverse beam focusing is provided by six quadrupole magnets. Two of the magnets are equipped with dipole steering coils for the beam trajectory correction. A schematic view of the MEBT and its diagnostic system setup are shown in Figure 5. The beam line is under vacuum end-to-end from the ion source to the beam stop. The diagnostics systems and their components have been tested to the extent possible without beam.

PENDING TESTS

The BTF will be configured as a short pulse neutron source for testing innovative ideas of neutron moderators in preparation for the SNS Second Target Station project [6]. The design of the moderator test facility started in 2014 with the goals to build the proton beam line, the fast chopper, and then the rest of the facility through 2017.

Figure 6 shows the MEBT system in the BTF that is equipped with the beamline extension and the beam stop for future scientific development. The fast chopper will be used to deflect a portion of the beam to a neutron target. The system can also be used for other development by adding another MEBT-2 [1]. The BTF will include a dedicated FODO beam line, to repeat and complete the halo development experiment conducted previously at LEDA [7] without conclusion. With the 6-D phase space diagnostics available in the BTF, the interposed work in understanding the halo formation can be resolved.

More dipole magnets will be added for the neutron source beam line that allows adding more diagnostics for direct beam energy distribution measurements at the location with large dispersion. An RF deflector can be added in the MEBT beamline to allow selection of particles in time within the bunch. These additions along with the existing 4-D emittance scanner will create a system for direct measurement of the bunch charge distribution in the 6-D phase space. The plan is to perform an experimental study of the beam particle distributions in the 6-D phase space with the goal of developing the method for generating initial beam distributions useful for realistic linac simulations.

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