COMMISSIONING OF THE NEW EXPERIMENTAL FODO LINE
AT THE SNS BEAM TEST FACILITY*

A. Aleksandrov†, S. Cousineau, K. Ruisard, V. Tzoganis, A. Zhukov, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA
Z. Zhang, University of Tennessee, Knoxville TN 37966, USA

Abstract

The Spallation Neutron Source Beam Test Facility (SNS BTF) consists of a 2.5 MeV proton accelerator and a beam line with various diagnostics for high intensity beam dynamics study. A beam line consisting of 19 identical quadrupole magnets arranged in FODO configuration, and a large dynamic range emittance monitor has been added recently. The new setup is designed for experimental study of mechanisms of halo formation in mismatched high intensity beams. We present results of the new beam line commissioning with beam.

THE BTF BEAM LINE

The main purpose of the latest beam line extension is to provide tools for experimental investigation of halo formation in high intensity hadron beam and beam dynamics simulation codes benchmarking. A layout of the beam line is shown in Fig. 2, and a photograph in Fig. 3. The H-beam is produced by the ion source (1), accelerated to 2.5 MeV by the RFQ (2), the six-dimensional phase space distribution is measured by the 6D scanner (3) [3], the beam is turned in the achromatic bend (4), and injected into the FODO line (6) with the Twiss parameters adjusted in the matching section (5). The output transverse phase space is measured by the high dynamic range scanner (7). The need to turn the beam by 180° is dictated by the available space in the building.

* This manuscript has been authored by UT-Battelle, LLC, under Contract No. DE-AC05-000R22725 with the U.S. Department of Energy. The United States Government retains, and the publisher, by accepting the article for publication, acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes. The Department of Energy will provide public access to these results of federally sponsored research in accordance with the DOE Public Access Plan (http://energy.gov/downloads/doe-public-access-plan).

† sasha@ornl.gov

MOPTS120

A08 Linear Accelerators
The FODO Line Design

The FODO arrangement of quadrupole magnets was chosen as a benchmark beamline because of its simplicity and widely accepted proposition that halo can develop in a beam propagating through a FODO line if the input conditions are not matched [4]. The optics design is described in detail in [5]. The FODO line consists of 19 identical permanent magnet quadrupoles, shown in Fig. 4, with integrated gradient of 1.8 T. The maximum number of magnets is limited by the available space. The magnets are mounted on rails as shown in Fig. 5 and can be moved to adjust the phase advance in the FODO line. The initial assembly for commissioning is done with 90 degrees per cell phase advance. The whole beam line was assembled and aligned in the lab before moving to the BTF, Fig. 6. The design beam size is shown in Fig. 7 for the matched (a) and mismatched (b) conditions. Multi-particle PIC simulation predicts the halo development in the mismatched case as shown in Fig. 8.

Figure 4: Permanent magnet quadrupole used in the BTF FODO line.

Figure 5: The PMQs assembly on a rail inside the vacuum pipe.

Figure 6: The FODO line assembled in the lab.

The High Dynamic Range Emittance Scanner

The minimum dimensionality of the phase space projections useful for simulation benchmarking is 2, therefore slit-slit emittance scanners are placed at the beginning of the BTF beam line and the FODO line exit to measure the horizontal and vertical emittances. For unambiguous characterization of the halo, a dynamic range of $10^6$ or higher is required [6], which is beyond the demonstrated state-of-the-art of today. The key features of the scanners that allow achieving the highest dynamic range are the slit-slit design and addition of a dipole magnet after the second slit. The purpose of the magnet is to eliminate the ions that are scattered by the first slit and, typically, are the major limitation to the dynamic range in slit-based emittance measurement systems. The ions are collected by a Faraday Cup after passing through the two slits and the magnet. The charge is measured by a combination of a transimpedance amplifier and a high-resolution ADC.

THE NEW BEAM LINE COMMISSIONING RESULTS

The goals of the first commissioning run were to verify beam transport to the end of the beam line, to ensure good alignment and correct polarity of the magnets, and to check correct operation of the diagnostics.

A relatively good transmission of 97% was quickly achieved by manual tuning of the magnetic elements. The beam current was measured at three locations: close to the
RFQ exit, close to the FODO line entrance, and at the end of the beam line. A typical result is shown in Fig. 9. There are only two pairs of dipole correctors located right after the RFQ exit, therefore a good alignment of the focusing elements is required for good beam transport, which was confirmed to be the case. Good transmission is also an indicator of the correct assembly of the permanent magnets in the FODO line.

A typical high dynamic range emittance scan result is shown in Fig. 10. The up to date demonstrated dynamic range of $10^5$ is believed to be limited by the readout electronics dynamic range. The phase space particle density, calculated from the data in Fig. 10 using the algorithm described in [6], is shown in Fig. 11.

**CONCLUSION AND FUTURE PLANS**

The next step will be to develop good understanding and control of the beam optics; to improve the dynamic range of the emittance measurements; to identify need for more optics control elements and, possibly, need for halo scrapers to prepare clean initial distribution at the FODO entrance.

**ACKNOWLEDGMENTS**

This work has been partially supported by NSF Accelerator Science grant 1535312.

**REFERENCES**


