DEVELOPMENT OF A NEW BEAM DIAGNOSTICS PLATFORM

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Abstract

The Spallation Neutron Source Project (SNS) is an accelerator-based neutron source currently under construction at Oak Ridge National Laboratory (ORNL). The availability of space along completed portions of the accelerator for the addition of beam diagnostics is limited. A new platform for mounting a variety of instruments has been created by replacing part of the Medium Energy Beam Transport (MEBT) section of the accelerator developed by Lawrence Berkeley National Laboratory. The design and current capabilities of this instrument platform will be presented along with plans for future enhancements.

BACKGROUND

During 2003, construction and commissioning activities for the accelerator had progressed well beyond the low and medium energy beam transport structures (LEBT) and (MEBT). A means to permanently replace and expand upon the measurement capabilities of the temporary diagnostics platform known as the "D-Plate" became necessary. In order to provide a concise location for a permanent platform, it was decided to sacrifice the anti-chopper in the MEBT.

The anti-chopper plates were removed from their chamber, and replaced with a beam stop, scintillation screen, scrapers and a beam aperture collimator. Prototypes for compact, motor-driven positioning actuators were developed for use within the tight confines of the anti-chopper vessel.

During 2004, plans were presented to add more capabilities; most notably, an optical interface for two laser systems and an inline emmitance measurement system. The laser systems developed to interface with the ion beam in the new vessel were a Mode-Lock and an Nd-YAG laser for longitudinal and transverse profile measurements.

Additional plans were proposed for the later addition of a beam accounting current measurement system and a Fast-Faraday cup bunch-length measurement system. Provisions for these systems, would force the replacement of the anti-chopper vessel with a much more space efficient design. In order to mount a greater number of instruments within a new vessel limited to essentially the same dimensions, the actuator prototypes would require refinement into an even more compact geometry.

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CHAMBER DESIGN

Two goals for the new purpose-built diagnostics vessel or "D-Box" were identified before the design started: First, the vessel was to be constructed in such a way that it would offer the least amount of difficulty for installation. Second, the vessel was to be capable of housing all of the requested instruments and offer some flexibility for future expansion or configuration changes.

In order to address the first goal, the new vessel was planned to occupy essentially the same size envelope as the anti-chopper chamber. A three-dimensional solid model of the anti-chopper was created in Pro / Engineer to establish key features for the new vessel. The mounting system and essential vacuum flange locations were retained as a skeleton for the new vessel. All subsequent features of the new vessel were modeled within the geometric boundary imposed by this skeleton. Using this approach, the new vessel was developed into a radically different shape that was none the less, a drop in replacement for the old. See Fig. 1 for comparison.

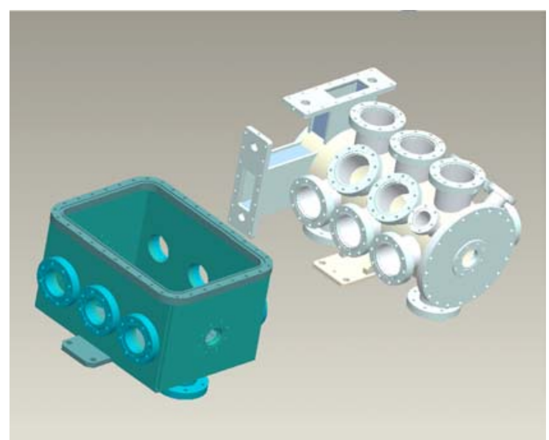

Figure 1: Anti-chopper and new diagnostics chamber.

Port Locations

The anti-chopper chamber had only four ports suitable for mounting instrument actuators because of either internal or external interference. The new vessel would require a minimum of *eight* usable ports. In order to increase the useful space for ports, the concept chosen for the new vessel was a cylindrical body with radial ports.

Early in the design process it became necessary to allocate locations for those systems that were either to be permanent, or that would have specific geometry requirements.

Emmitance System

The emmitance system operates in two planes and consists of an orthogonal pair of slits and collector harps.

The pitch of the harp wires is 0.5mm and in order to achieve the best measurement resolution, it was necessary to locate the slits and harps at the upstream and downstream ends of the vessel.

To maximize the spacing, close fitting, rectangular trunks were used to house the harps immediately against the downstream end wall. The beam stop would be placed upstream from the harps. See Fig. 2 for the general arrangement of the emmitance system.

Laser System

The laser system would also require a fixed relationship in the location and spacing of ports. The optics for the laser are housed externally and the box itself serves as an interface between the laser and ion beams and houses a detector for stripped electrons. The optical interface is a quartz window in a vacuum flange that serves as a mount for the external laser transport system.

The detector was designed specifically for the D-Box and is comprised of two charged steering plates and an electrically isolated multi-channel multiplier plate. It is currently the only stationary instrument in use. As such, its location was established along the rear side of the vessel corresponding to an area of the MEBT inaccessible for actuators. Figure 3 illustrates that the laser port is located on top of the vessel, upstream from the collector at a point selected to form an intersection between the laser and ion beams within the entrance plane of the detector steering plates.

Beam Aperture Collimator

Planning locations for the remaining ports was an exercise in avoiding external interference among the actuators. It was possible to provide four more actuator ports and two smaller ports for the addition of electrical feedthroughs if a future need should arise. The final design of the vessel emerged as a cylinder having a total of *fifteen* ports arranged in five banks; two horizontal, one vertical and two diagonal, within planes oriented at 45 degrees. The most logical location for adding the beam aperture collimator emerged as the front, diagonal port, upstream from the laser window. Figure 4 illustrates the general arrangement of all systems currently in use.

ACTUATOR DESIGN

The design of the new actuators was driven by the much more specialized design of the vacuum vessel. As the locations for the vessel ports were established, it became apparent that the actuators would have to nest closely together in order to avoid external interference. This motivated the most significant change in design philosophy from the prototypes developed for the anti-chopper chamber.

The limited number of accessible ports on the anti-chopper chamber left little flexibility in the location of instruments. An actuator had to be permanently mounted to every accessible port. Relatively large, 2 inch inside diameter bellows were incorporated into the actuators with the thought that changing instruments would be accomplished by moving them from one actuator to another.

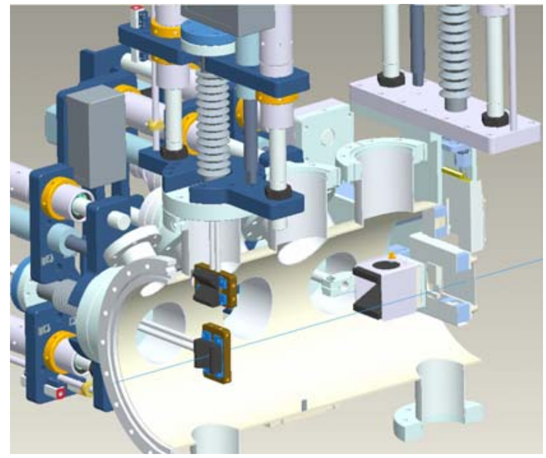

Figure 2: Emmitance system and beam stop.

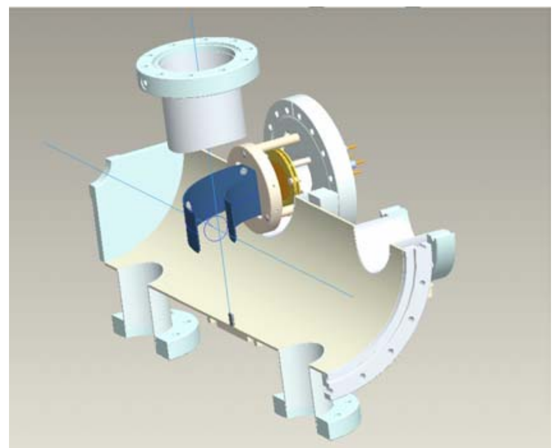

Figure 3: Laser system.

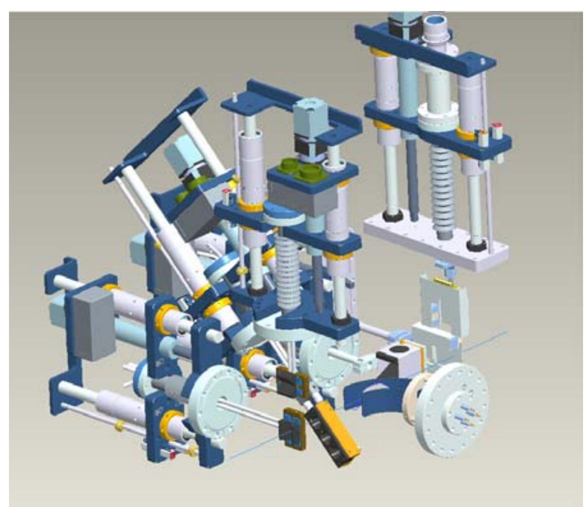

Figure 4: Current instrument arrangement.

The close port spacing on the new vessel would not allow the same size bellows to be used again. The instruments were all modified by incorporating a small bellows to their own mounting flanges. Changing instrument locations would now be accomplished by

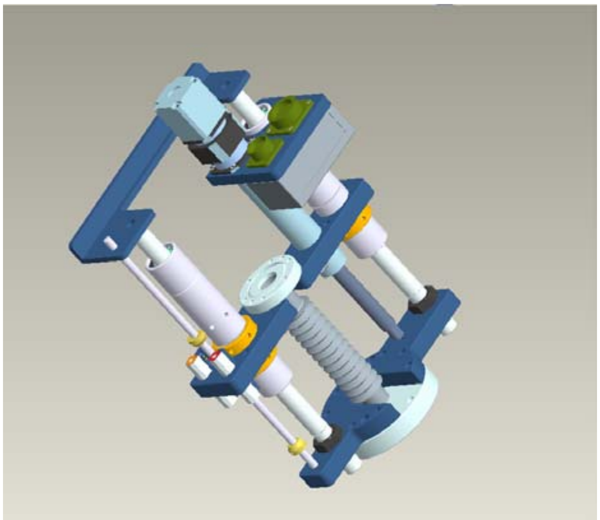

Figure 5: Typical actuator assembly.

moving actuators and instruments as units. This has the advantage of preserving actuator limit switch settings established for specific instruments.

Actuator Performance

The majority of the components purchased for the anti-chopper box prototype actuators were reused in the new design. The linear guide rods from the prototypes are more than adequate to provide excellent stability for the new units, which see far less vacuum load than their predecessors. Figure 5 shows a typical actuator assembly.

Motive power for the actuator carriages is provided by commercially available electric cylinders driven by NEMA 17 single-stack stepper motors through 10:1 ratio planetary gearheads. Position feedback is provided by linear potentiometers built in to the cylinders. These cylinders have proven very successful in other diagnostics applications and a large body of control software has been developed.

A preliminary trial of the new actuators was performed with a simple open-loop motion control program designed to drive the actuator between a retraction limit switch and four position set points. Figure 6 is a representative plot of the axial position errors measured over five trials at one set point. The average open-loop position error for all set points and trials was 25.9 microns, repeatable within 20 microns.

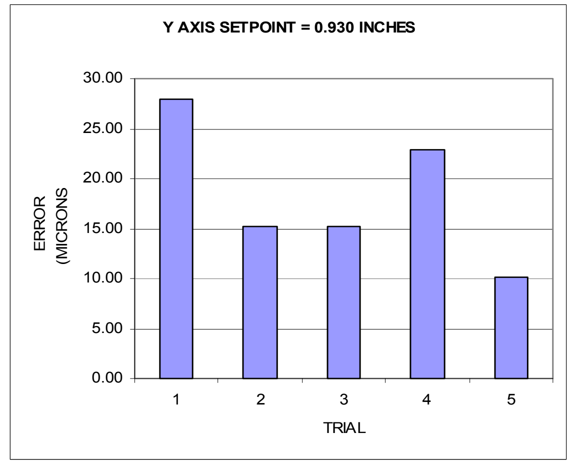

Figure 6: Set point position error.

FUTURE DEVELOPMENTS

The next additions to the D-Box will be a beam accounting current measurement system embedded in the upstream end wall of the vessel. One of the smaller spare ports will be used for the electrical feedthrough. The Mode-Lock Laser will be complemented by a Fast Faraday Cup bunch length measurement system that will operate behind a second aperture collimator. A more thorough structural analysis of the vessel will be undertaken to permit the mounting of a more complex and potentially heavier laser transport system. The actuators will be observed for signs of wear or performance deterioration and a scheduled maintenance program will be developed to address any problems.

The design of the actuators themselves has proven to be very successful and economical. The experience gained in their development is expected to be applied to other diagnostics applications.

SUMMARY

Due to the efforts expended in optimizing the design, the new vessel has met and exceeded all criteria specified for its development. Table 1 summarizes the instrument systems supported.

Table 1: Summary of Supported Measurement Systems

Device	Abbreviation	Description	Status
Fast Faraday Cup	FFC	Longitudinal bunch length measurement system with 20 GHz bandwidth	Future
Beam Current Monitor	BCM	Current and beam accounting	Future
Mode-Lock-Laser	MLL	Non -intrusive longitudinal bunch length measurement for long-pulse, high power operation.	Current
Beam Aperture Collimator	BAP	Three aperture sizes for collimation into a pencil beam	Current
Inline Emmitance System	ES	2D X-Y slit and harp collector pairs	Current
Beam Stop / Slow Faraday Cup	BSSFC	Slow Faraday Cup to limit beam to the MEBT	Current
Phosphor Scintillation Viewing Screen	SCREEN	Crude beam shape monitor	Not Installed

 0-7803-8859-3/05/$20.00