THE ADVANCED PHOTON SOURCE INJECTOR TEST STAND: PHASE TWO*

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Abstract

The high-power S-band feed subsystem and the versatile method of beamline construction have been combined to provide for further testing of a unique gun that incorporates three cavities and requires three separate S-band feeds. Completed in December 2002, this configuration of the injector test stand is intended to investigate performance of the ballistic bunch compression gun [1]. If this gun proves to be desirable for injection at the APS, then the ballistic bunch compression gun together with the S-band feed subsystem and portions of the beamline will be relocated in the APS linac tunnel.

INTRODUCTION

The injector test stand (ITS) began to take shape shortly after the APS commissioning in 1996. The north wall of the room is the original poured concrete wall that was once a part of the linac tunnel, while the south wall is constructed from 8″ × 8″ × 16″ density-enhanced concrete shielding blocks, effectively separating the 116″ × 219″ test room from the gun end of the linac tunnel. In 2001, the test stand was used to commission the third-generation thermionic-cathode rf guns that are used for normal storage ring injection at the APS and which incorporate an improved cathode design [2]. The commissioning of these two guns plus a third unit was quickly achieved with little difficulty because it was facilitated by first-phase design features built into the ITS. These features included quick-disconnect magnets and power supplies, a single rf-port waveguide installation, a 10′ by 44″ slab-style leveled table with ample room for diagnostics, water-cooling provisions [3], and the integration of the diagnostics and controls into the EPICS-based control system. The latter 'helps ensure that the "look and feel" and response of the ITS control system is similar to that of the rest of the APS' [4].

This paper discusses the second phase of the test stand installation involving investigation into performance of the prototype ballistic bunch compression (BBC) gun.

NEW BEAMLINE

The new beamline is presented in Figure 1. Shown are the BBC gun, the modular beamline assembly, the laser port, spectrometer/filter line, and experimental area, which are further described in [3]. Rebuilding the beamline from the previous ITS configuration involved reusing a majority of the previous phase beamline components aligned only to a different lattice and the fabrication of two new breadboards. The use of these breadboards and the versatile method of beamline construction led to quick construction of the new assembly [5]. The beamline components are common linac elements: five quadrupoles, two steering correctors, one gate valve, two dipoles, two current monitors, two Faraday cups and viewscreens, and four 20-l/s ion pumps (two for the beamline and two for the three-chambered BBC gun). Future plans include installation of a beam position monitor (BPM) to permit the testing of new BPM electronics, a Golay-cell-based bunch length monitor, and a pepperpot-based emittance measurement system.

The incorporation of linear bearing rails in the ITS simplifies the alignment of these beamline components. The alignment of the X and Y axes is controlled by the fit between the rail and the mount that interfaces the beamline component to the rail, whereby the rails themselves have been installed and aligned on the breadboards to within 25 microns (0.001″) of nominal. The beamline component assemblies are guided in the Z axis along a master rail, and they are fixed in the X and Y axes to a degree commensurate with the manufacturing tolerance of the machined portion of the mount that mates the master rail. Upon installation to the rails, shims are sometimes employed between the mount and the beamline component to correct for the Y alignment. The more critical adjustments to achieve lattice are in the Z axis, where optical tooling methods are employed. The APS Survey and Alignment (S&A) group maintains a permanent tooling bar setup capable of precise measurement in two perpendicular axes.

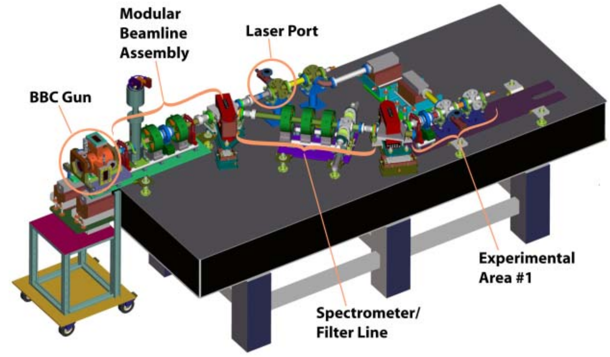

Figure 1: New beamline.

*Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

For example, one constraint was that the distance from dipole 1 to breadboard 2, quad 2 be equal to the distance from quad 2 to dipole 2. This was achieved to three decimal places, noting that typically alignment tolerances of ±0.001″ are achieved with the S&A setup. Placement of other components was not as critical. The rail system has saved much time and effort in alignment of test stand components.

THREE-PORT FEED WAVEGUIDE

A list of the key components incorporated into the feed subsystem and a corresponding block schematic diagram of these components are described in [6]. The majority of the waveguide is pressurized to 32 psig and is constructed of oxygen-free high-conductivity copper, WR-284-sized, extruded rectangular tubing. This is furnace brazed to stainless steel flanges, yielding vacuum-grade waveguide to connect the commercially available pressurized key components. This system uses seven commercially manufactured pressurized key waveguide components to provide isolated rf power feeds to three separate ports of the BBC gun: two variable power dividers, two phase shifters, and three circulators. Three circulators have been purchased from two different manufacturers, while the variable power dividers and phase shifters have been purchased from a third manufacturer.

We had problems during installation of the variable power dividers and phase shifters. In 1996 we encountered similar difficulties when installing this manufacturer's 6061-T6 aluminum ribbed waveguide. Upon applying torque to the aluminum flanges during assembly or leak checking, the flanges became stressed and the leak-tight braze joint opened via a mechanism of micro-cracking to the extent that SF_6 pressure could not be maintained. During the ITS installation, the manufacturer became personally involved with the repair of sub-components for the phase shifters and variable power dividers, such as panty-adapters. This cooperative exercise between the manufacturer and the APS produced a successful installation and uncovered many factors and observations.

1) The manufacturer indicated that the aluminum dip-brazed WR-284 waveguide's 0.2″ nominal wall construction is approaching a pressure limit at 45 psig, not with regard to safety but with regard to seal integrity of the joint. 2) The integrity of the joint sometimes relies on a micro-seal variety epoxy; this is pulled under vacuum during the repair process into microcracks of the braze joint. 3) The manufacturer cautions that a rotational and gradual application of torque to the flange bolts during installation is easiest on the fragile nature of the braze joint. 4) The application of pressure testing at the APS to monitor the integrity of the dip-brazed joints proved to be very valuable. 5) At the APS, pressurization with argon gas both with and without water immersion was employed to investigate the time degradation of pressure over several days. 6) The pressure used during testing should be representative of the maximum value used in service; for the APS pressurized waveguide and switching system this is 35 psig. 7) This investigation should be begun as early as possible in preparation for installation. 8) Professional and persistent communication between the QA representative and the manufacturer may be needed to secure repaired subassemblies qualified for installation.

The isometric view in Figure 2 depicts the three WR-284-size windows that separate the pressurized system from three short legs of the WR-284 waveguide under vacuum. The elevation view in Figure 2 shows these three vacuum legs directed to the BBC gun.

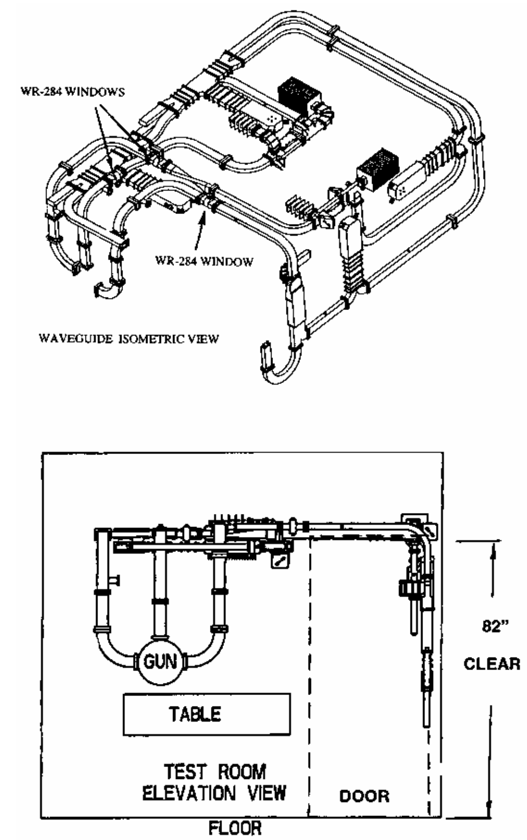

Figure 2: Waveguide isometric and elevation view.

LIMITED VOLUME IN ROOM

The three-port feed subsystem in the injector test room is fed by the pressurized waveguide switching system, as described in [7]. Figure 3 shows how the WR-284 waveguide feeds from the linac tunnel through a penetration in the south wall of the test room to WR-284 switch no. 6. This is the reference point from which the three-port feed and the previous ITS waveguide configuration were constructed.

Ceiling-mounted fluorescent lights were relocated to the south wall, and a unistrut grid was installed on the ceiling and north wall to support the waveguide layout. This schematic called for three separate loops, as shown in Figure 2, and the layout resulted in the following linear lengths: the loop from switch 6 to the BBC gun center port measures 23 feet, the loop from switch 6 to the cathode port of the BBC gun measures 46 feet, and the loop from switch 6 to the forward port of the BBC gun measures 45 feet. Many alternate layouts were considered.

The three-layer proposal described in [5] placed all of the waveguide against the ceiling. Considering the overall loop lengths of that denser layout, crowding the key components offered no clear advantage regarding the impact of waveguide length on overall return loss. Even in that more compact layout, the loop lengths were calculated to be 23 feet, 36 feet, and 33 feet.

CURRENT STATUS

The waveguide layout now installed in the test room maximizes access to key components for the purpose of serviceability. Figures 2 and 3 illustrate how efficient planning has optimized aisle passages, making the injection test area a more practical area in which to work.

Commissioning has begun on the BBC gun; first beam was achieved on 11 March 2003. Efforts are presently focused on high-power conditioning and improving the beam performance of the gun.

REFERENCES

[1] J.W. Lewellen and S.V. Milton, "Preliminary Calculations of Ballistic Bunch Compression with Thermionic Cathode RF Guns," Proc. SPIE – Int. Soc. Opt. Eng (Coherent Electron Beam X-Ray Sources: Techniques and Applications) Vol. 3154, pp. 162-171 (1997).

[2] K.J. Beczek et al., "A Rationalized Approach to Thermionic Gun Design," Proceedings of the 2001 Particle Accelerator Conference, Chicago, IL, pp. 2206-2208 (2001).

[3] J.W. Lewellen et al., "The Advanced Photon Source Injector Test Stand," Proceedings of the 2001 Particle Accelerator Conference, Chicago, IL, pp. 2212-2214 (2001).

[4] J.W. Lewellen, S. Pasky, "An Operator Training Facility at the Advanced Photon Source," these proceedings.

[5] K.J. Beczek, "A Versatile Method of Beamline Construction," Proceedings of the 2001 Particle Accelerator Conference, Chicago, IL, pp. 1462-1464 (2001).

[6] A.E. Grelick, "The High Power S-Band Feed Subsystem for the Advanced Photon Source (APS) Injector Test Stand," Proceedings of the 2001 Particle Accelerator Conference, Chicago, IL, pp. 1393-1395 (2001).

[7] S. Berg et al., "Rebuilding WR-340 and WR-284 Waveguide Switches to Meet Higher Power at the Advanced Photon Source," these proceedings.

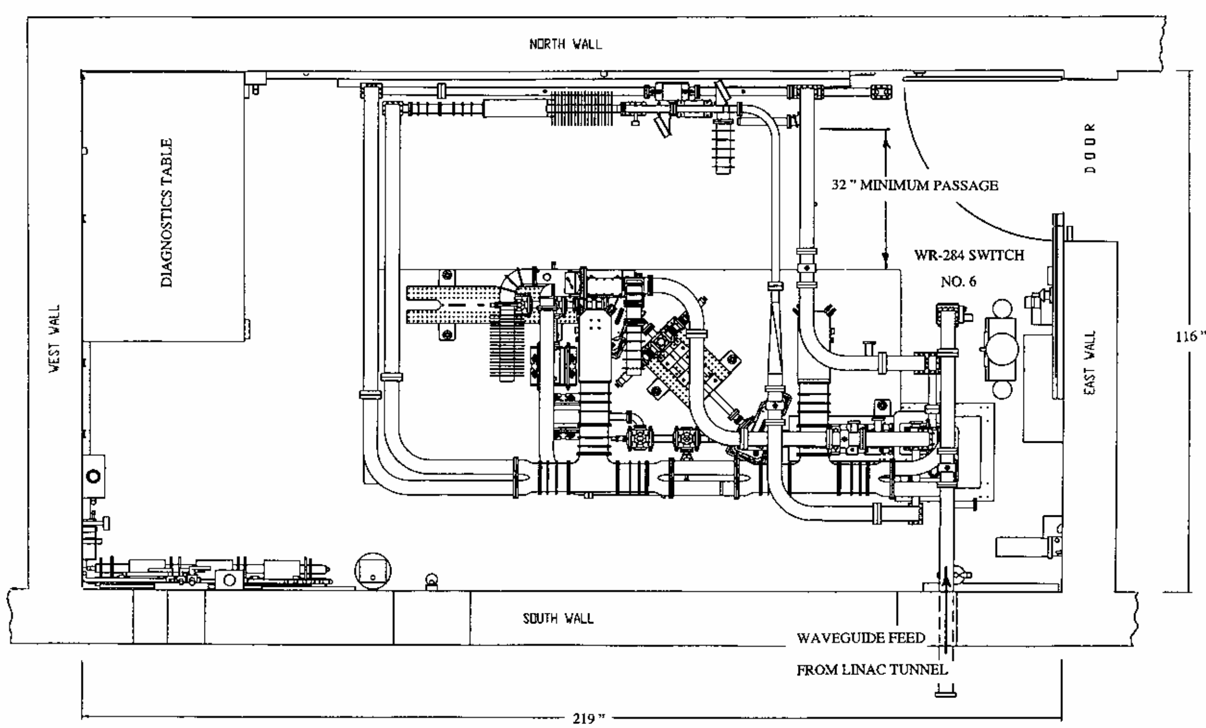

Figure 3: Test room plan view.