THE ADVANCED PHOTON SOURCE INJECTOR TEST STAND*

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Abstract

The Advanced Photon Source's (APS's) primary and backup injector sources consist of two thermionic-cathode rf guns. These are being upgraded to provide enhanced and more consistent performance, improve ease of maintenance, and reduce the downtime required to repair or replace a failed injector. As part of the upgrade process an injector test stand is being prepared. The stand will be effectively independent of the APS linac and will allow for complete characterization and validation of an injector before its installation. Multiple high-power rf ports, several types of cathode drive lasers, and a flexible suite of magnets and diagnostics will support testing and characterization of new beam sources as well as the APS injector guns. The ready accessibility of the test stand and independence from the main APS linac will also allow beam-based testing and validation of new or replacement diagnostics before their installation into the APS linac line.

1 INTRODUCTION

The Advanced Photon Source (APS) is a high-brightness, third-generation light source user facility. In addition to providing brilliant x-ray beams to our user community, we are actively engaged in research toward fourth-generation linac-based light sources [1]. The former activity requires a consistent, reliable and stable electron beam source for storage ring injection. The latter requires high-performance, state-of-the-art electron gun technology.

In order to support these two areas of activity, an rf test area is currently under construction at the APS linac. The initial implementation allows for the repair and characterization of the APS main injector electron guns. This will be followed by the addition of several high-power rf feeds and other facilities to support more complex experiments or simultaneous testing of multiple rf devices.

2 CAPABILITIES AND FEATURES

The design goals for the APS linac rf test area have two distinct branches: APS main injector support and experimental facilities for advanced electron gun research.

2.1 Main Injector Upgrade

Our two presently installed main injectors, thermionic-cathode rf electron guns [2,3], have proven in practice to be reliable performers. They are of different design, however, and were initially intended for research rather than "production" use; as such, maintainability is sometimes problematic and spare parts procurement and validation has been an ongoing problem.

This difficulty is being addressed by the purchase of three new thermionic-cathode rf guns [4]. Two will be installed in the APS linac, while the third will remain in the linac rf test area and act as a "warm spare." In the event of failure, the test-area gun will be swapped with the failed linac injector. The failed injector can then be repaired and fully tested, including its ability to generate beam, within the linac rf test area. This ensures that a functional beam source will always be available for APS user operations.

As the requirements of the APS storage ring change (for instance, to top-up operation [5]) the demands on the injectors will also change. The permanently installed injector test beamline can be used to test proposed changes to the APS linac injectors before committing to a permanent change that could impact user operation. An example of this would be the use of a long-pulse drive laser to gate the beam from the cathode, for single-bucket injection into the booster synchrotron. The test area also provides a convenient location for training and gun repair.

2.2 Injector Research

The APS linac rf test area also provides a natural location to pursue research into advanced photoinjector design and related topics as part of our fourth-generation light source research program. To that end, the rf test area incorporates features to enable it to support a wide variety of research topics, and to be rapidly configured between experiments.

Most aspects of the test area facilities design are based upon the desire to maintain flexibility and the ability to rapidly reconfigure the room, depending on the needs of the present experiment [6]. For instance, all magnets are fitted with quick-disconnect fittings; this allows beamline sections to be pre-aligned outside the room, dropped into place, and connected to their appropriate power supplies with guaranteed-correct connections. The diagnostics suite is similarly flexible and also incorporates multiplexing capabilities to allow a single set of control electronics to interact with different beamlines.

The mechanical facilities in the room include a 1 m × 3 m optical table that provides support for the beamlines and a convenient surface for external diagnostics mountings. Overhead and back-wall unistrut support grids allow the ready placement of almost any desired rf network configuration. Compressed air supplies and

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process and cooling water are available in several different temperature, pressure, and flow rate ranges. These allow us to support any physical device for testing that we can fit through the door.

The planned three high-power rf feeds [7] will allow for the testing of new gun designs requiring multiple rf inputs, to provide for tests involving multiple rf structures (e.g., a photoinjector gun and short capture linac section). Each rf port has independent rf phase and power control, and includes a circulator to protect the rf network from reflections. The power is distributed to the ports via a series of mechanical high-power phase shifters and variable power dividers and is sourced from a single klystron, guaranteeing stable power and phase relationships between the ports. The ports have varying power output capabilities but the lowest-power port can deliver up to 5 MW and the highest-power port can deliver the full capacity of the klystron feeding the network.

The injector test area is adjacent to the APS photocathode rf gun drive laser room. Much of the hardware required to transport the drive laser beam into the rf test area is already in place, and the remainder of the drive laser transport line will be reinstalled shortly. Thus, most facilities are already in place and operational for using the room as a photoinjector test area and for supporting hybrid thermionic/photocathode studies.

2.3 Other Benefits

Because an rf gun will always be present in the room and capable of providing beam (as part of the APS main injector support role), the linac rf test area offers an excellent opportunity to validate accelerator components before installation. This will help to improve the reliability of existing designs and provide a useful test facility for new designs.

Since the room will contain all of the elements of an accelerator (albeit a very low-energy one compared with the APS linac), it also provides a general test bed for any proposed modifications to the APS linac as a whole. For instance, new control software for the APS injectors can be tested without possible impact on APS operations. Or a new power supply design can be tested with beam in an operational environment, and its behavior and performance determined via beam-based measurements. Similarly, the room can be used for the orientation and training of technicians, APS operations personnel, etc.

3 CURRENT STATUS

The APS linac rf test area is being built in three stages. The first stage, currently nearing completion, is focused on the creation of the APS main injector test beamline. Thus, only one high-power rf port is required and will be supplied, and the water requirements are limited to those for a single device over a small temperature range. However, in general, the installation is proceeding toward final configurations wherever possible. For instance, all of the magnets and power supplies have been fitted with quick-disconnects. The second phase of the installation consists mainly of adding two more high-power rf ports to the room, along with additional phase and power readbacks. The first gun to use this configuration will likely be a ballistic bunch compression rf gun run in thermionic-cathode mode [8]. The third phase of the installation includes the addition of additional water circuits, to allow multiple rf devices to be operated simultaneously (e.g., photoinjector, short high-gradient linac section, and post-linac deflector cavity, all of which may have different water temperature and flow requirements).

The main injectors installed in the APS linac use alpha magnets to compress their beams and inject them into the APS linac line. The injector test stand beamline uses an identical magnetic lattice from the exit of the gun to the equivalent location of the alpha magnet entrance. Instead of an alpha magnet, however, the test stand injector test beamline uses a double-bend achromat to provide for energy spectrum and emittance measurements. Dedicated hardware test areas are located straight through the first dipole and beyond the second dipole in the achromat. (A schematic view is shown in Figure 1.) There is ample space on the table for a second beamline, perhaps at a different elevation from the main injector test line or with a cross-through chamber.

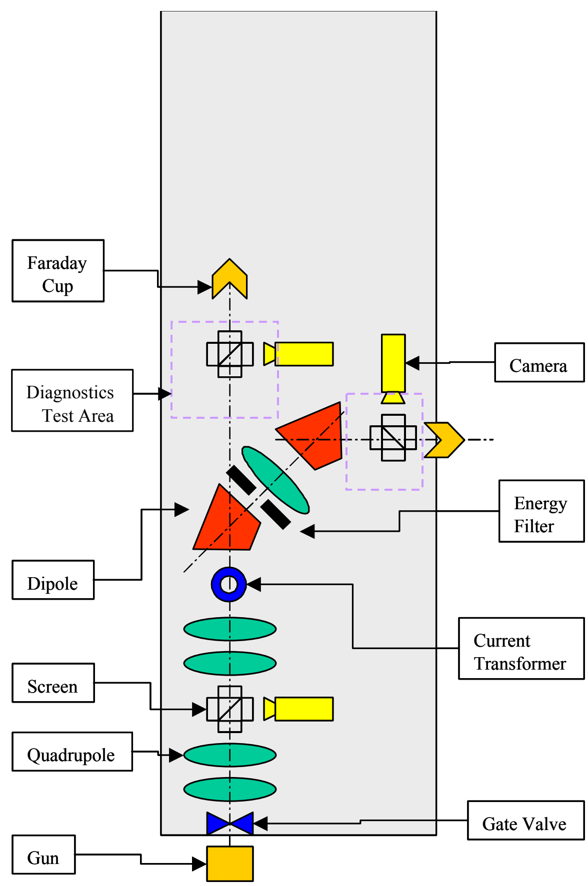

Figure 1: Injector test stand schematic beamline layout for the main injector test line.

4 FUTURE PLANS

4.1 Main Injector beamline

The first of the three replacement main injector thermionic-cathode rf guns has been delivered. Initial testing of this gun will commence in June 2001, with the intent of certifying it for installation into the APS linac during the July 2001 maintenance period; at this time it will become our primary injector.

The remaining two new main injector guns are expected to be delivered by the end of July 2001. They will undergo the same conditioning and checkout as the first gun. One gun will be removed from the beamline and installed into the backup injector position in the APS linac, probably during the October 2001 shutdown, and the third will remain as a "warm spare" in the test area beamline.

Several experiments are already planned for the main injector beamline. The first will be the installation of an aerogel scintillator, supplied by DESY-Zeuthen, for tests with high delivered electron beam powers. As part of our main injector maintenance program, we will also be testing modifications to the injector beamline magnetic lattice. Finally, the diagnostics test areas will be used to check the performance of a new linac flag design with beam, and to characterize a waveguide-based bunch length monitor.

The injector test line also incorporates some features that will eventually, if proven successful over the long term, be migrated to the main APS injectors. These include improved thermionic cathode filament power supplies and upgraded water systems.

4.2 Other Injector Research

We intend to proceed with the installation of the full three-port rf network, and with expanded water and diagnostics capabilities. Our first experiments involving a new injector will most likely center on high-power and beam tests of a ballistic bunch compression rf gun, already built and awaiting installation. Depending on the success of cold testing with a cavity mockup, we may consider building and testing a second-generation design variant of a higher-order-mode rf gun. Other possibilities include research into photocathode materials and performance, the installation of a small high-gradient linac section and undulator, or studies of thermoelectric temperature stabilization for rf guns.

5 CONCLUSIONS

The first phase of construction of an injector test stand at the APS linac is nearing completion. In this initial implementation, the test stand will be providing direct support for the upcoming main injector upgrade. It will also, via diagnostics areas included in the design of the injector test beamline, provide beam for testing of various diagnostics devices. The test area facilities also incorporate design elements which, if successful, will be migrated for use in the APS linac.

We are also proceeding with plans to install a far more flexible rf network and a second beamline. The initial rf gun installation in this beamline will most likely be an already-built ballistic bunch compression rf gun. We are currently considering follow-on experiments, using the ballistic bunch compression gun and/or other high-performance designs.

6 REFERENCES

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