

# ASSEMBLY AND INSTALLATION OF THE UV LASER DELIVERY AND DIAGNOSTIC PLATFORM AND THE PHOTOCATHODE IMAGING SYSTEM FOR THE ASTA FRONT-END\*

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## Abstract

The Advanced Superconducting Test Accelerator (ASTA) is in the early stage of commissioning. The front-end consists of a 1.5 cell normal conducting RF Gun resonating at 1.3 GHz with a gradient of up to 40 MV/m, a cesium telluride (Cs<sub>2</sub>Te) cathode for photoelectron production, a pulsed 263 nm ultra-violet (UV) laser delivery system, and a diagnostic area for measuring the characteristics of the photoelectron beam. We report on the design, construction, and early experience of the UV Laser Delivery and Diagnostic Platform and the Photocathode Imaging System.

## INTRODUCTION

The ASTA front-end generates, at 3 MHz, high brightness electron bunches by the photoelectric effect where a 263 nm UV laser illuminates a Cs<sub>2</sub>Te photocathode on the upstream wall of the 1.5 cell copper RF Gun operating at 1.3 GHz [1]. A Diagnostic table is immediately downstream of the RF Gun. Figure 1 shows the layout of the ASTA front-end. The table contains 2 beam crosses (a 9-way cross and a 6-way cross), 2 diagnostic cameras with associated lens tube hardware, 2 sets of horizontal and vertical beam position monitors (BPM), and a Wall Current Monitor (WCM).

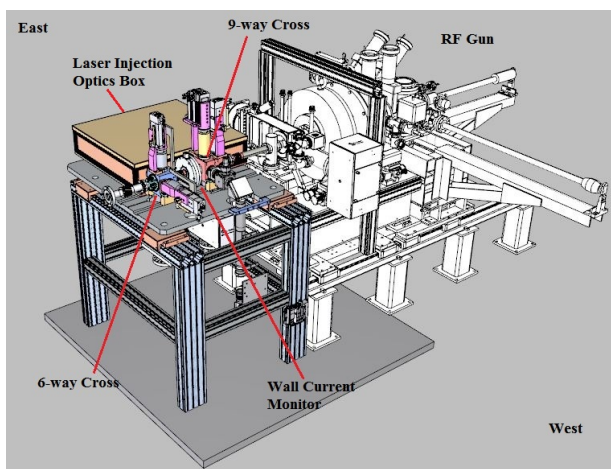


Figure 1: 3D model of the ASTA front-end. The Diagnostic table is shown with color.

The 9-way Cross provides many functions. The upstream east viewport has an anti-reflection (AR) coated

fused-silica window to allow the UV laser to enter the vacuum system and reflect off a polished solid aluminum mirror, directing it to the photocathode inside the RF Gun. A mirror can be inserted via an actuator to direct UV, reflected off of the photocathode, to a UV sensitive CCD camera attached to the upstream west side AR coated fused-silica window. This allows for visible images of the photocathode surface. A double actuator assembly is mounted on the downstream end of the cross which inserts a target or cerium doped YAG crystal contained within a dual position holder.

## CONSTRUCTION AND ASSEMBLY

Because ASTA uses Superconducting RF cavities for electron beam acceleration downstream of the front-end, all components connected to the ultra-high vacuum (UHV) system are required to be cleaned, assembled, and installed in cleanrooms using particle free techniques. Once the 9-way Cross assembly was completed, 2.75" blank conflat (CF) flanges were installed on the upstream and downstream beam tubes. The assemblies were then vacuum leak checked with helium to a sensitivity of 10<sup>-14</sup> Amps.

All machined materials common to the UHV system are made from 316L stainless steel. This material has a low magnetic permeability and retains its hardness after repeated bakeouts.

### Laser Injection Optics Box

The UV drive laser is a Class 4 laser, so for personnel safety the light must be contained. The laser is transported by high-reflectance (HR) dual-coat mirrors (263nm drive laser and HeNe alignment laser) from the adjacent Laser Room to the ASTA beamline enclosure via the stainless steel Laser Transport Vacuum System. From there, the laser is directed down through a removable ABS plastic tube to the Laser Injection Optics Box (Optics Box) on the 9-way Cross Diagnostic table. In the Optics Box, the laser is bent horizontally, adjusted, and transported to the Laser-In mirror inside the 9-way Cross vacuum chamber. The Optics Box is constructed from 1" black anodized extruded T-slot aluminum rails and light-tight panels of black double-sided aluminum with a corrugated plastic core. Inside the Optics Box is a standard black anodized aluminum optics breadboard. It is all secured to the east side of the Diagnostic table. Since the Optics Box is in an interlocked radiation enclosure, all popular adjustments are done remotely through the Synoptic control system interface [2], see Fig. 2. Inside the Optics Box, fine position adjustments

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of the UV laser on the photocathode are made with a closed-loop Picomotor actuated mirror mount on the last mirror in air before the 9-way Cross. An image relay telescope and masking iris are also Picomotor actuated through Synoptic control to provide spot size adjustments on the cathode. Parasitic laser reflections are imaged into a UV CCD camera to provide a calibrated Virtual Cathode image. Other parasitic laser reflections are also imaged into an energy meter and photocathode for continuous intensity and temporal measurements. Figure 3 shows the Laser Injection Optics Box with the cover and the ABS plastic transport tube removed.

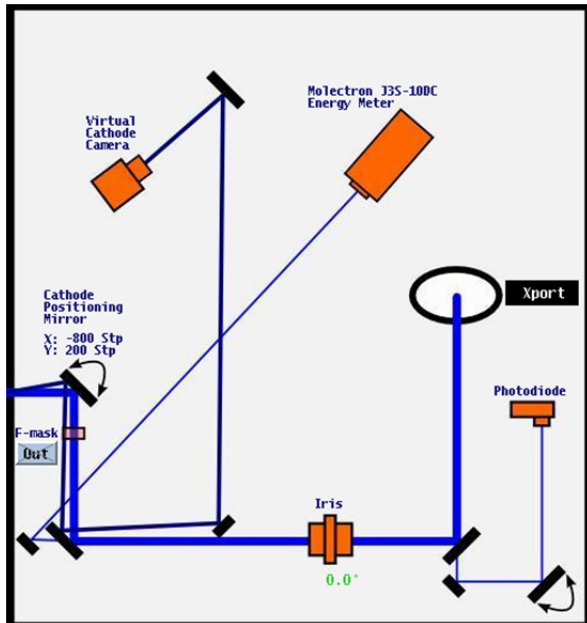


Figure 2: Synoptic control layout for Optics Box.

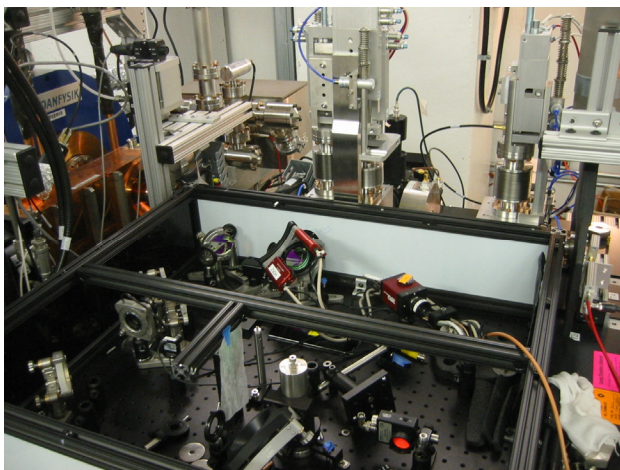


Figure 3: Laser Injection Optics Box with cover and ABS plastic transport tube removed.

### Laser-In Mirror Assembly

The Laser-In mirror assembly connects to the upstream east side of the 9-way Cross. The UV laser exits the Optics Box and enters the 9-way Cross through the AR coated fused-silica window. The coating on the window

allows for over 96% transmission of the UV laser. The UV laser reflects off of the HR coated solid aluminum mirror (flatness 1/10 lambda @632nm, surface roughness 12 Angstroms, reflectance 96.2% @ 263nm) and strikes the photocathode 982.63 mm upstream.

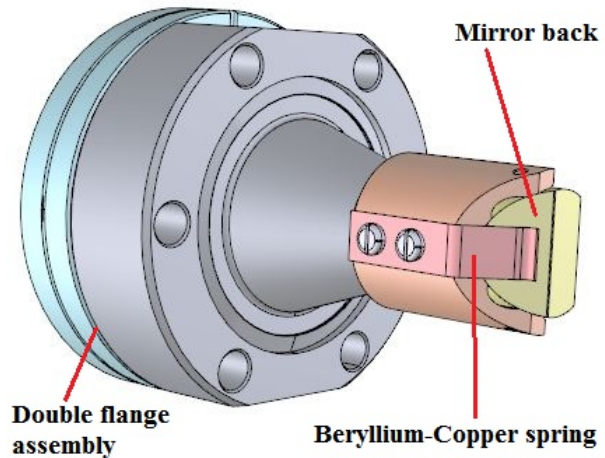


Figure 4: 3D CAD model of Laser-In mirror assembly.

The mirror holder, see Fig. 4, is constructed of 316L stainless steel. When the mirror is inserted into the holder a beryllium-copper spring is affixed with two screws which provide the appropriate tension to keep the mirror in place.

This is a double flange assembly requiring 2 copper gaskets. The mirror holder is integrated into one flange and the window is the other. Installation requires six 50 mm long threaded titanium studs.

### Cathode Viewing Mirror Assembly

The Cathode Viewing Mirror (CVM) assembly is comprised of a 25 mm diameter X 4 mm thick aluminum mirror, mirror holder, actuator-flange, actuator, AR coated fused-silica window, 50 mm travel edge-welded bellows, lens tube, and CCD camera. Figure 5 shows the 3D model of the CVM assembly.

When an image of the photocathode is needed, the CVM can be inserted into the 9-way Cross via a pneumatic actuator on the cross. The RF Gun pulse will be inhibited due to the mirror being placed in the beam path. Scattered UV light from the photocathode is directed out of the 9-way Cross and to a 5 megapixel networked GigE Vision interfaced camera, sensitive to UV frequencies, for inspection.

The holder is machined from 316L round stock and the fastening hardware is titanium screws. The screws used for connecting the holder to the actuator-flange are vented, as required, so as not to trap any gas in the vacuum system. The actuator-flange is also made from 316L round stock and is fastened to the actuator.

The mirror face has a 25 mm diameter aluminum coating on a 4 mm thick substrate of fused-silica. The mirror surface is enhanced to efficiently reflect UV. Three screws hold the mirror in place on the holder.

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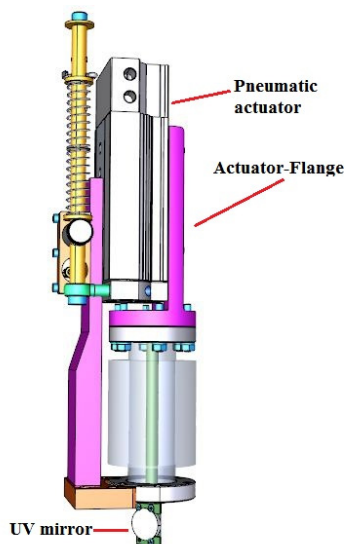


Figure 5: 3D CAD model of the CVM assembly.

The CVM is vertically mounted to the upstream end of the 9-way Cross with six titanium studs and silicon-bronze nuts. An AR coated fused-silica window, identical to the Laser-In mirror window, is located at the upstream west side of the cross. The window is connected with similar hardware as the CVM assembly. A 3" lens tube with an internal O-ring 1/8" thick is placed over the window. The O-ring makes a light tight seal around the window flange. The lens tube has a c-mount adapter attached to it for connecting the CCD camera.

### INSTALLATION

Once the assembly of the 9-way Cross, 6-way Cross, WCM, and vacuum system was completed, the Diagnostic table was transported into the ASTA enclosure. The stand was secured to the floor, vacuum connections were made to the RF Gun within a portable cleanroom, pneumatics were connected, and the UV Laser system was installed. Figure 6 shows the Diagnostic table after installation.

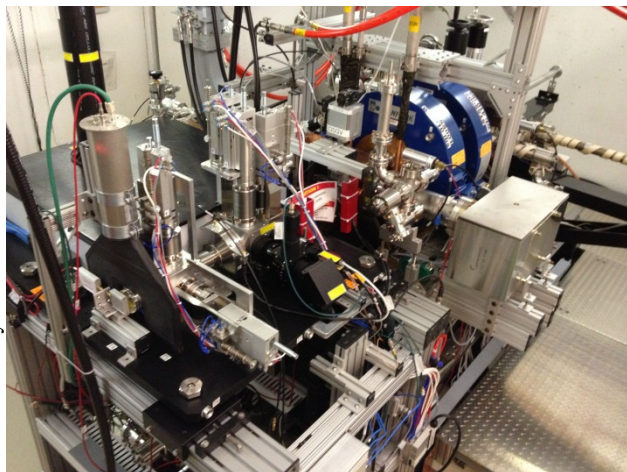


Figure 6: Diagnostic table connected to the RF Gun.

### OPERATION

Control of the CVM actuator is through the Fermilab Accelerator Division ACNET control system. Image Tool, an in-house written interface to the ASTA GigE cameras, is used for displaying the UV camera image. Figure 7 shows the cathode illuminated by the UV laser.

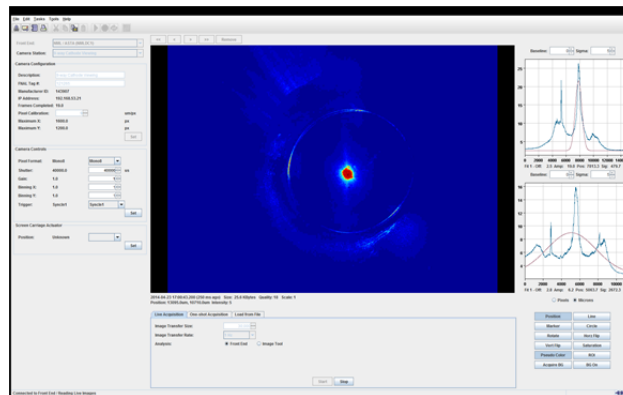


Figure 7: Image Tool display of photocathode illuminated with the UV laser.

### SUMMARY

The ASTA front-end has been installed and commissioned. Assembly of the Diagnostic table began on October 4<sup>th</sup>, 2012 and installation was completed by June 11<sup>th</sup>, 2013. Once all instrumentation was calibrated and connected to the control system, power was applied to the RF Gun. The photocathode imaging system has been successfully used for alignment of the HeNe and UV laser incident to the photocathode and for documentation of the photocathode condition. The Laser Transport Vacuum System along with the Laser Injection Optics Box installations were completed and commissioned by June 19<sup>th</sup>, 2013. First UV laser light was established to the photocathode at 11:45 am on June 20<sup>th</sup>, 2013 followed by first detected photoelectrons at 4:00 pm. The ASTA front-end is currently supplying 3000, 3.2 nJ, high brightness, photoelectron bunches at a repetition rate of 3 MHz every second.

### ACKNOWLEDGEMENTS

The author recognizes the diverse and capable expertise of the technical staffs of the Fermilab Accelerator Division.

### REFERENCES

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- [2] D. Edstrom, et al., "GUI Development for the Drive Laser at Fermilab's ASTA Facility," THPME193, IPAC'14, Dresden, Germany, June, 2014.