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COMMISSIONING STATUS OF THE ADVANCED SUPERCONDUCTING TEST ACCELERATOR AT FERMILAB*

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Abstract

The Advanced Superconducting Test Accelerator (ASTA) is under construction at Fermilab. This accelerator will consist of a photo-electron gun, injector, ILC-type cryomodules, and multiple downstream beam-lines. Its purpose is to be a user-based facility for advanced accelerator R&D. Following the successful commissioning of the photoinjector gun, a Tesla style 8-cavity cryomodule and a high-gradient capture cavity have been cooled down to 2 K and powered commissioning and performance characterization has begun. We will report on the commissioning status and near-term future plans for the facility.

INTRODUCTION

A superconducting RF accelerator test facility is currently being built and commissioned at Fermilab in the NML building. Once complete, the accelerator will consist of a photoinjector, two superconducting booster cavities, a beam acceleration section consisting of one ILC-type cryomodule, multiple downstream beamlines and an integrable optics storage ring (IOTA) with various diagnostics to conduct beam tests, and a high-power beam dump [1, 2]. This paper describes the commissioning effort of the facility. It will include the drive laser system, photocathode gun section, beamline construction and some commissioning results for the ILC style cryomodule.

LASER SYSTEM

The NML gun laser system is based on the design used in the A0 photoinjector [3]. Figure 1 shows the progression of the photocathode laser system from the IR fiber-based seed laser in the top box through the chain of solid-state amplifiers and frequency multiplication to UV in the bottom box. Expected power levels are given at each stage.

Construction of the laser room at the ASTA facility in NML was completed near the beginning of the August, 2012. UV laser pulses were produced by the end of 2012. Our laser system interface is a synoptic display, which is a client-server system for graphical data representation through the Fermilab accelerator control system, ACNET. As such it is similar to other GUI packages such as ACNET Lex SA, EPICS EDM, and DESY JDDD. In addition to ease

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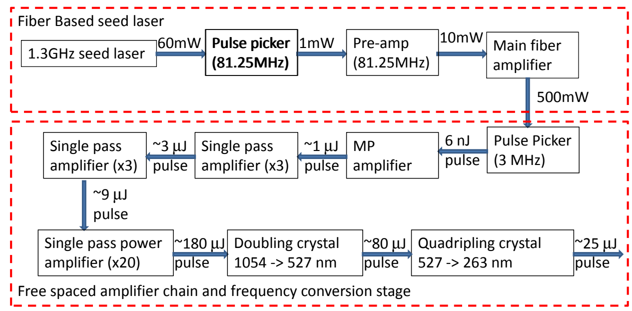

Figure 1: Progression of the photocathode laser system.

of development, and a modern look and feel, live synoptic pages can be viewed as SVG, PNG, or other web-friendly formats through most common web browsers with relatively low use of bandwidth. More details about the laser control interface can be found in this conference. [4]

PHOTO INJECTOR GUN

The RF photocathode electron gun is identical to the guns recently developed at DESY Zeuthen (PITZ) for the FLASH facility [5]. It is a normal conducting 1½ cell 1.3 GHz gun operated in the TM010 π mode, with a Q_L of 11,700, and driven by a 5 MW klystron. The power is coupled into the gun via a coaxial RF coupler at the downstream end of the gun. The gun is capable of average DC power dissipation of 20 kW, and a temperature feedback system will regulate cooling water temperature to less than ±0.02 °C for good phase stability. The gun will be routinely operated at peak gradients of 40-45 MV/m, and output beam kinetic energy of 4.5 MeV.

The photocathode is a 10 mm diameter molybdenum disk coated with Cs_2Te with 5 mm diameter photosensitive area. It is illuminated by 263 mm wavelength laser light which is directed onto the photocathode by a 45° off-axis mirror downstream of the RF coupler. The photocathodes are coated at a separate facility on the Fermilab site, transported under vacuum to the photocathode transfer chamber mounted on the upstream end of the gun, and inserted into the upstream end of the gun via external manipulators, all under vacuum. Several photocathodes have already been prepared and their quantum efficiency measured to be 4-5%. The photocathode preparation, transport, and transfer

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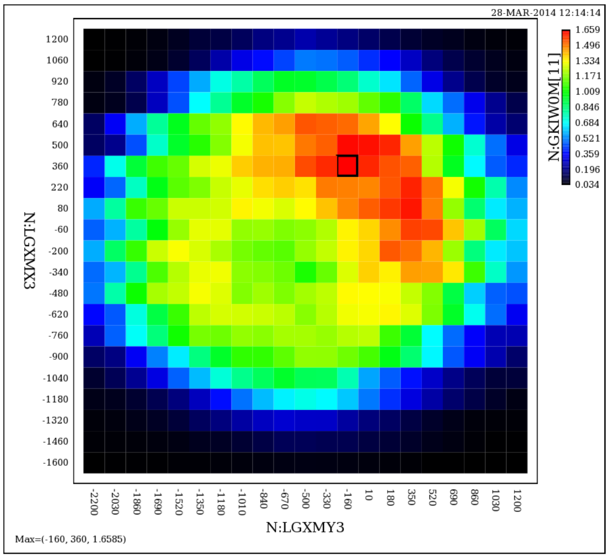

Figure 2: QE map of the photo cathode used in March 2014.

chambers were developed and built by D. Sertore at INFN Milano [6] and commissioned at Fermilab.

For emittance compensation the gun is surrounded by 2 solenoid magnets built by Danfysik. Each magnet has a peak field of 0.28 T at 500 A. Normally the magnet currents are set so the field at the photocathode is 0 in order to minimize the beam emittance; however, the field can also be set to > 1kG at the photocathode for the production of angular-momentum dominated beams and flat beam production.

There are four primary types of diagnotics in the injection section: BPMs to measure beam position, transverse profile monitors to measure beam size, resistive wall current monitors to measure beam current and loss monitors to measure beam losses and serve as the primary protection element in the machine protection system. Those diagnostics are further explained in the poster [7].

ASTA successfully produced its first photoelectron beam from the gun to a Faraday cup on June 20th, 2013. The initial beam was produced using the bare molybdenum disk, about 8-15 laser pulses at 1 Hz rep rate and electrons were observed on three of the primary diagnostics immediately downstream of the gun: loss monitor, resistive wall current monitor, and yttrium aluminum garnet (YAG) screen. Due to the limited quantum efficiency (QE) of the bare molybdenum disk the charge produced is very low. Subsequently a coated cathode was inserted into the gun in March 2014. We are able to extract up to 4nC charge from the photo injectors. The measured quantum efficiency was about 1.5-2%. This is lower than the value measured at the time of coating. The QE map of the cathode surface is shown in figure 2. It does show us some hot spot on the cathode surface. After extensive conditioning of the gun and careful retune of the laser system we are able to put a 1ms pulse into the photo injector. Figure 3 shows the response of the faraday cup from the 1ms macropulse. The pulse train is strikingly flat except for some fluctuation near the beginning.

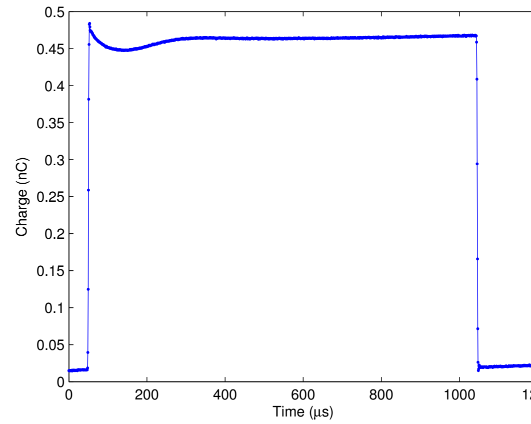

Figure 3: Faraday cup response with a 1ms laser pulse train into the gun cathode.

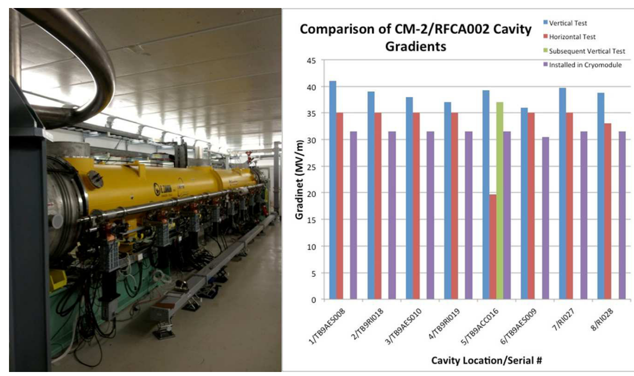

Figure 4: Left: photos of the CM-2 installed at ASTA. Right: Recent results from cold single cavity test, most cavities were run to the 31.5MV/m, which is our target gradient at this stage.

CYROMODULE COMMISSIONING

The left side of figure 4 is a photograph of a single TTF type III+ cryomodule installed at ASTA. It is driven by a single 1.3 GHz 5 MW klystron, and RF power is distributed to the eight seperate cavities by variable tap-offs in the waveguide structure alongside the cryomodule. This cryomodule consists a string of eight 9-cell superconducting cavities. The goal for these cavities is to reach an operational gradient of 31.5MV/m at 2 K under full ILC beam conditions. This will yield a total acceleration of 250 MeV per cryomodule.

All 8 cavities for the current cryomodules were built by industry and subsequently went through vertical and horizontal testing at FNAL or Jlab. All 8 cavities showed the capability of more than 35MV/m during those tests. It was assembled at Fermilab and installed at ASTA in April , 2013. Cold operation had started since November 2013. As seen from the right side of Fig. 4 all but one were able to reach 31.5MV/m, used as the administrative limit for our single cavity conditioning. Full cryomodule test testing will be underway shortly after.

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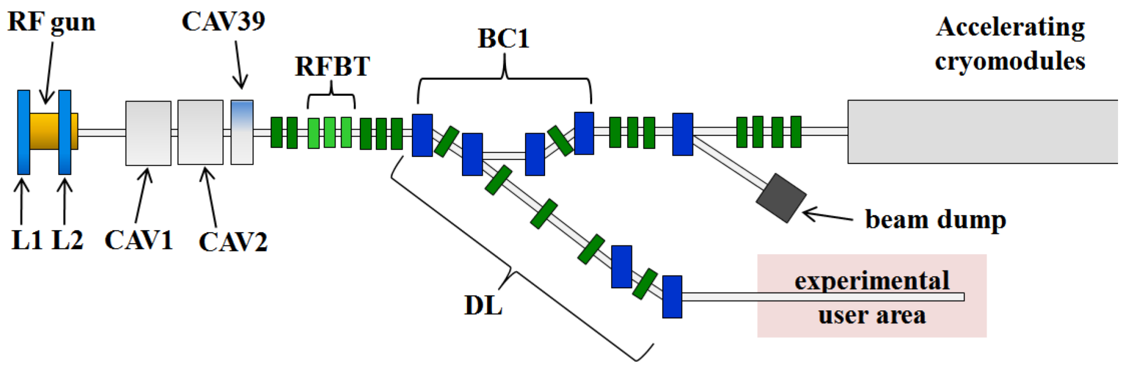

Figure 5: Overview of the ASTA photoinjector. L1 and L2 are the gun solenid lenses, Cav1 and Cav2 are the single cavity modules. BC1 is a magnetic bunch compressor. DL is a dogleg. The blue rectangles are dipoles while green rectangles are quadrople magnets. RFBT stands for round-to-flat-beam transformer.

BEAMLINE INSTALLATION

Installation of the 50 MeV beamline is underway. A schematic beamline is shown in figure 5. However installation and commissioning of this beamline will occur in phases. In the first phase, beam will be accelerated through one capture cavity (CC2) to an energy of 20 MeV to achieve first beam to the low energy dump. In this first-beam configuration, a subset of beamline instrumentation will be installed and commissioned in the straight-through beamline: BPMs, toroids, and transverse profile monitors. Plans call for first beam to the low energy dump in Summer of 2014.

In the second phase, the beamline will be upgraded to the 50 MeV configuration, enabled by the installation of Capture Cavity 1 in Fall 2014. Magnet elements allowing use of the chicane will be installed. In parallelle, the full suite of instrumentation and early experiments will be brought online, including a goniometer and slit experiments.

CONCLUSION

Commissioning of the ASTA facility is well-underway. Bunch trains up to 1ms have been established from the photo injector. The quantum efficiency of the cathode has been investigated. The beamline for 20 MeV electrons is being installed at the time of writing this paper. Finally, all but one cavities reached the traget 31.5 MV/m.

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