COMMISSION OF THE DRIVE LASER SYSTEM FOR ADVANCED SUPERCONDUCTING TEST ACCELERATOR*

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Abstract

An advanced superconducting test accelerator (ASTA) is currently being built at Fermilab. The accelerator will consist of a photoelectron gun, ILC-type cryomodules and multiple downstream beam lines for testing cryomodules and carrying advanced accelerator researches. In this paper we will report the commissioning of the drive laser system for this facility. It consists of a fiber laser system locked to the master frequency, a multipass-amplifier, several power amplifiers and final wavelength conversion stage. We will also report the characterization of the whole laser system and the performance of the laser system.

INTRODUCTION

A superconducting RF accelerator test facility is currently being built and commisioned at Fermilab in the former New Muon Lab (NML) building. Once complete, the accelerator will consist of a photoinjector, two booster cavities, a beam acceleration section consisting of 3 ILC-type cryomodules, multiple downstream beam lines 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 drive laser system for this facility. One of the goals is to realize a long pulse train operation consisting of up to 1000 individual pulses at 1 μs intervals or 3000 pulses at 330 ns intervals. Success is crucial in order to meet design goals for the ASTA.

The NML gun laser system is based on the design used in the A0 photoinjector [3]. While the system has performed well thus far, some challenges have surfaced during development:

- The length and stability of the pulse required at the ASTA facility was very difficult to establish and maintain.
- The laser phase lacked stability, wandering on the order of 10 ps over 24 hours of running.
- Limited diagnostic tools have made initial real-time laser monitoring and tuning difficult.
- Lack of a useful user-interface to control the laser system.

Several changes were made in order to address these issues:

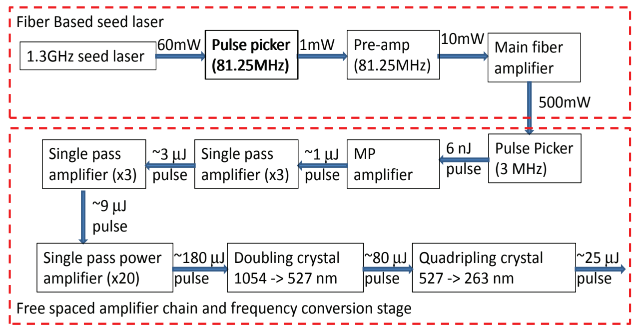

Figure 1: Progression of the photocathode laser system.

- A diode pump and Nd:YLF crystal is used instead of flashlamp-pumped Nd-doped glass.
- A fiber laser seed is used to replace the solid-state laser.
- An array of diagnostic tools, including photodiodes, digitizers, and a streak camera have been imlemented throughout the driver laser chain to assist with real-time monitoring.
- Graphical user interfaces have been implemented using synoptic.

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.

COMMISSIONING AND PRELIMINARY TEST OF THE ASTA LASER SYSTEM

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. Following is an overview of the laser system user interface and a description of each block of the system as well as some of the meausrement results.

User Interface for Laser System

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.

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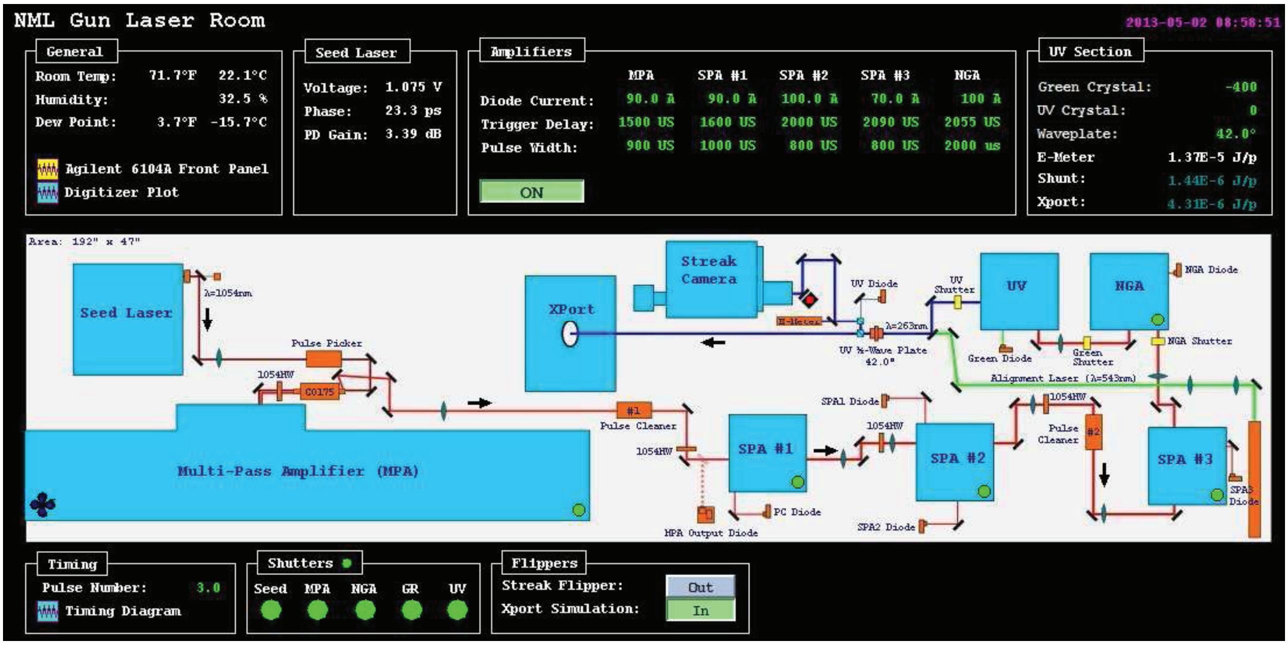

Figure 2: Synoptic user display of the NML Gun Laser system.

As such it is similar to other GUI packages such as ACNET Lex SA, EPICS EDM, and DESY JDDD. In addition to ease 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.[4] Figure 2 is the current version of the ASTA gun laser synoptic overview.

Fiber Based Seed Laser System

The seed laser was designed and built by Calmar Laser Inc. It is an active mode-locked Yb-fiber laser system centered at 1054nm. The laser cavity consists of Yb doped fiber amplifier, output coupler, electro-optics modulator, tunable filter, and fiber to connect each component. A piezo stage is used to adjust the cavity length to achieve stable mode-locking. The pulse width is 3.2 ps RMS as measured in our auto-correlation measurement. The laser is locked to the 1.3GHz signal from our master oscillator. The modulator DC bias voltage requires constant adjustment to ensure proper mode-locking as it typically drifts over time. This adjustment is typically made automatically through a feedback system, but occasional manual adjustment may be required of the users if lock is lost. A study to characterize the seed laser jitter was performed using an Agilent E5052B signal source analyzer, and a phase noise less than 200fs was resolved integrating from 1Hz to 10MHz in range from the seed laser only.

The fiber oscillator pulse is then sent to a pulse picker (Calmar model EPG-01FML12), in which an 81.25MHz pulse train is selected from the 1.3GHz pulse input. The

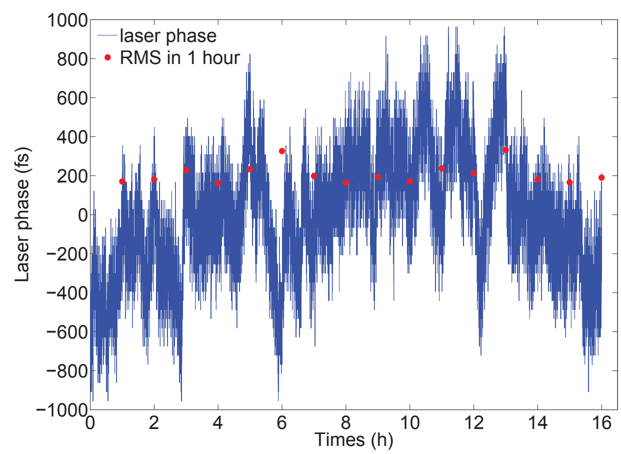

Figure 3: Laser phase measurement over a 16-hour period at steady-state. The blue line is laser phase while the red points represent the standard deviation of the laser phase noise over each hour.

output is amplified in 2 stages to roughly 5 nJ per pulse. To test stability of this, the amplified seed pulse phase was measured over 16 hours after 4 hours of warm-up, as shown in figure 3. The laser phase was found to drift less than one ps over the 16-hour period. Furthermore, the total standard deviation during this span is only about 300 fs and most of the hour-long standard deviation points are less than 200 fs. This is much better than the same measurements with a similar setup on either the GE-100, manufactured by Time-

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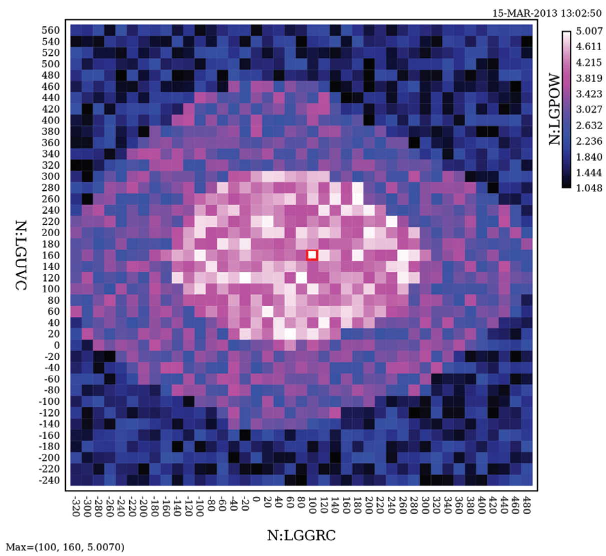

Figure 4: UV intensity map. Horizontal and vertical axis correspond to the green and UV conversion crystal angle respectively.

bandwidth Inc, or Tsunami Laser system, manufactured by Spectra-physics.[5]

Diode Pumped Amplifier Chain and UV Conversion

Output from the seed laser then passes through a pulse picker (Con-optics Model 175), which yields a 3.0MHz train up to 1ms in length as required in this application. The extinguish ratio through the pulse picker is more than 120:1 and the pulse-to-pulse amplitude fluctuation is less than 3%. The pulse train then passes through one multi-pass Amplifier and three single-pass amplifiers. The cavity in the multi-pass amplifier and those in each of the single-pass amplifier use an end-pumped Nd:YLF crystal structure. The diode pump for each is either a 100QCW or 200QCW from Dilas Inc. The laser rod is water-cooled to keep it close to room temperature. The final stage of IR amplification is a single-pass power amplifier made by Northrup Gruman to boost the energy to about 50μJ.

The pulse train is then doubled twice using BBO crystals. Each crystal is mounted on a motorized optical mount which enables the remote tuning of the both crystal. An intensity map is shown in figure 4 with the horizontal and vertical axis corresponding to the green and UV conversion crystal angle respectively, while the color corresponds to the intensity of the resulting UV pulse on a LaserProbe RM-3700 radiometer.

To facilitate real-time monitoring and provide diagnostics for the whole system, seven photodiodes were placed in the system. All the photodiode signals are digitized simultaneously using a 125MHz VME-based digitizer. A single capture of 100 bunches is shown in figure 5. The amplitude fluctuation is less than 5% throughout the amplification and UV conversion sections.

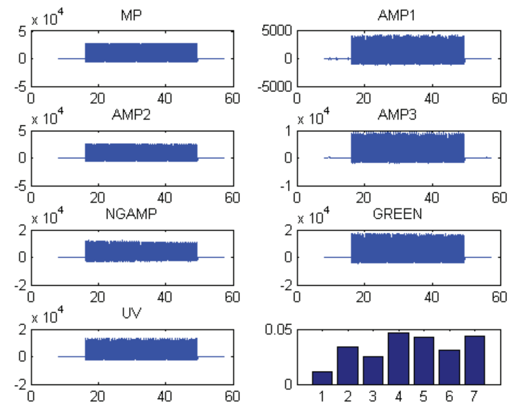

Figure 5: A single capture of 100 bunches on the VME-based digitizer from each of seven photodiodes installed throughout the laser system. The bottom-right corner shows the RMS fluctuation of the amplitude for the pulse train at each stage.

Summary

In conclusion a photocathode drive laser centered around a fiber oscillator seed laser for the Advanced Superconductor Test Facility has been installed and commissioned with UV beam. Work is underway to transport the UV beam to the cathode of the photoelectron gun at the head of the ASTA beamline. Synoptic-based controls have been implemented and continue to be refined with this work.

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