The Argonne Wakefield Accelerator (AWA) Laser System and Its Laser Pulse Shaper

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Abstract

Generating a 100 nC, 20 ps (FWHM) pulse length electron beam at the AWA requires a stable laser system capable of producing 1 - 3 ps, 1 mJ pulses at 248 nm and the capability of shaping the wave front. A wave front shaping device has been designed and built. It consists of nine concentric cylindrical mirrors. Each cylinder's position can be adjusted relative to the others by a system of computer controlled stepping motors. The reflecting surfaces were optically polished and dielectric coated. Detailed characterizations of the laser pulse shaper's performance using a streak camera and its associated optics are presented.

1. Introduction

The Argonne Wake-field Accelerator (AWA) is under construction. Phase I of the AWA includes a linac which can produce 100 nC, 20 ps (FWHM) electron bunches at 20 MeV. An L-band photocathode gun and standing wave preaccelerator are used to generate such high electron beam currents. One of the key components of the gun is a pulsed laser system which produces 2 ps, 1 mJ pulses at 248 nm and operates at a maximum repetition rate of 30 Hz. A laser system constructed jointly by Coherent-Lambda Physik has been purchased to fulfill these requirements. Details of AWA design and construction status are discussed in reference [1]. The design requires that the electron beam have a roughly spherically concave shape as it is emitted from the cathode, with the first electrons emitted from the outer diameter of the cathode. A sagitta of about 17 ps has been identified as a reasonable starting point. This curvature has two important benefits. First, it reduces significantly the radial space charge forces as the electrons are accelerated because of relativistic effects. Second, it produces an energy and radial spatial correlation which permits a smaller beam spot at the end when combined with nonlinear focussing.

In this paper, we discuss the laser set up and the laser pulse shaping device. The pulse shaper consists by nine concentric cylinders. The axial position of each cylinder can be adjusted relative to its neighbor by a stepping motor. The front surface of each cylinder is optically polished and coated with dielectric to increase UV reflectivity. Laser pulses are incident normally on these surfaces. By adjusting each cylinder's axial position, the reflected wave front is shaped accordingly. This scheme is flexible in its configuration and permits the production of nearly arbitrary wavefront shapes.

2. Laser system configuration

The schematic diagram of the laser system is shown in the Figure 1. The system uses well known technologies[2]. The central component of the "front end" is a synchronously pumped mode locked dye oscillator (Coherent 702). The dye laser is tuned to the desired wavelength of 497 nm by a single-plate birefringence filter. Coumarin 102 dissolved in benzyl alcohol and ethylene glycol is the lasing medium, and DOCI dissolved in benzyl alcohol and ethylene glycol is the saturable absorber. A harmonic tripled mode locked Nd:YAG laser is used to pump the dye laser. The frequency of the mode locker is 40.625 MHz which is the 32nd harmonic of 1.3 GHz rf frequency exactly.

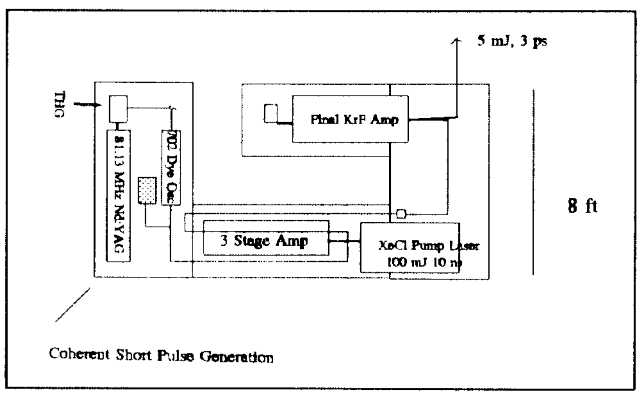

Figure 1 Schematic Diagram of the AWA laser system

A single pulse from the dye laser output train is amplified to 300 μJ through a three-stage dye amplifier. The dye amplifier is Lambda-Physik FL2003 pumped by 100 mJ, 308 nm pulses from a Lambda-Phyisk LPX105i

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excimer laser. The duration of the pump pulse is shortened to 10 ns so only one pulse from the dye oscillator is selected and amplified. The output from the dye amplifier is frequency doubled in a 3x3x7mm angle matched BBO crystal. Output at 248 nm is typically 25 - 30 μJ.

Amplification of the ultra-short UV pulses is done in a single stage KrF excimer laser (Lambda-Physik LPX105i). The input pulses pass through the amplifier twice in order to utilize its fully stored energy. The output energy from final amplifier is measured by using Molectron J25 joule meter. An output energy of 8 - 10 mJ is obtained routinely. Depending on the discharge HV, the ASE is ~ 5 - 10% measured at 20 cm from the output window. The length of the final pulse is measured by Hamamatsu streak camera (model C1587) which has resolution of 2 ps. The typical measured pulse length (FWHM) is 3 - 4 ps. No satellite pulses are observed. The repetition rate of the of the laser can be as high as 35 Hz.

3 Laser Pulse Shaper and Its Characterizations

Figure 2 shows the mechanical drawing of the laser pulse shaper. All the cylinders have a wall thickness of 1 mm except the 4 mm diameter center rod. The diameter of the outer most cylinder is 2 cm. The cylinders are made of carbon steel and machined for a lapped fit inside each other. Each cylinder is controlled by a stepping motor with 1/2 inch of motion with increments of 0.001 inch. The front surfaces of the cylinders were optically polished at Argonne's machine shop, and subsequently a high reflection coating was applied at CVI lab. The measured reflection at 248 nm is about 65 % for normal incidence.

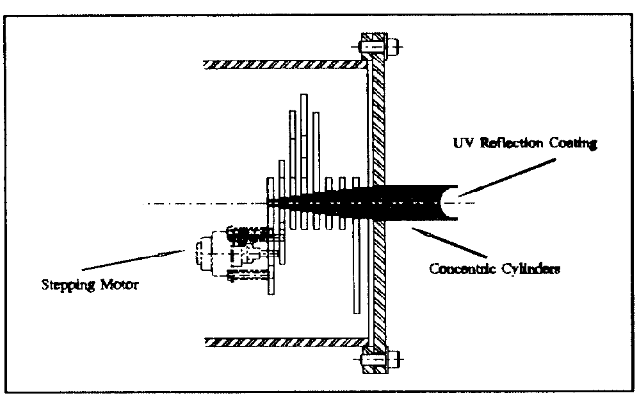

Figure 2 Mechanical drawing of the pulse shaper

The configuration for the initial tests of the shaper is shown in Figure 3. A small amount of the laser beam were split off from output of the final amplifier for the test because of full intensity laser beam would damage the streak camera. The laser beam passed through a diffuser, and illuminated the pulse shaper. In order to preserve the timing and spatial distribution of the reflected laser beam, a focusing lens was used to image the pulse shaper at the target. For these tests, the target was the input window of the streak camera. The lens was made of CaF_2 and had a focal length of 15 cm, and the arrangement produced a spatial magnification of 1/7. The data acquired by the streak camera were sent to the data acquisition system and stored in a computer for further analysis[3].

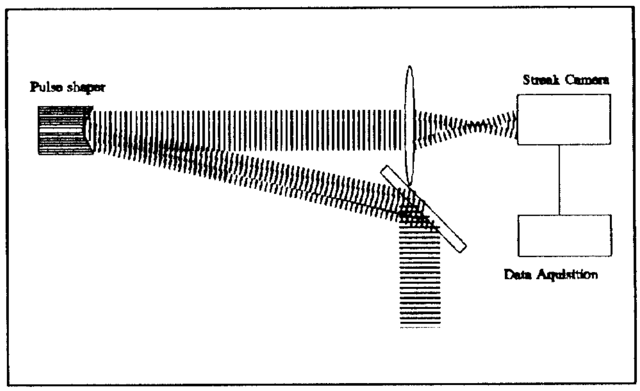

Figure 3 Experimental setup for pulse shaper measurement

As discussed in the introduction, the near optimal design parameters for short electron beam generation requires a circularly shaped laser pulse with sagitta of about 17 ps. Figure 4 shows the reflected image on the streak camera monitor for this case. The laser pulse width is about 3 ps. The apparently longer pulse is a result of the slit of the streak camera being opened wider than normal in order to capture all the image (the slit width is not exactly uniform across its width and streak tube sensitivity also varies due to the years of abuse. This explains why intensity of the data is not uniform). The full scale from top to bottom is 170 ps, and detailed data analysis show the pulse does indeed have a 17 ps sagitta.

We also have taken the data for a circular shaped laser pulse front with a 30 ps sagitta. The streak camera image for this case is shown in Figure 5.

A mountain range plot of the data in figure 6 was done to show the detailed reflected laser pulse shape.

Some other forms of laser wave front were also tested, for example, parabolic and linear etc. All the data show good agreements with experimental set up.

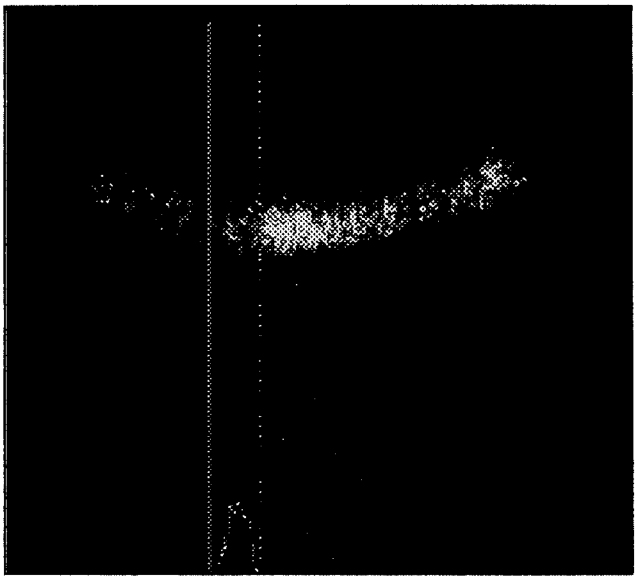

Figure 4 The streak camera image of 17 ps sagitta setting.

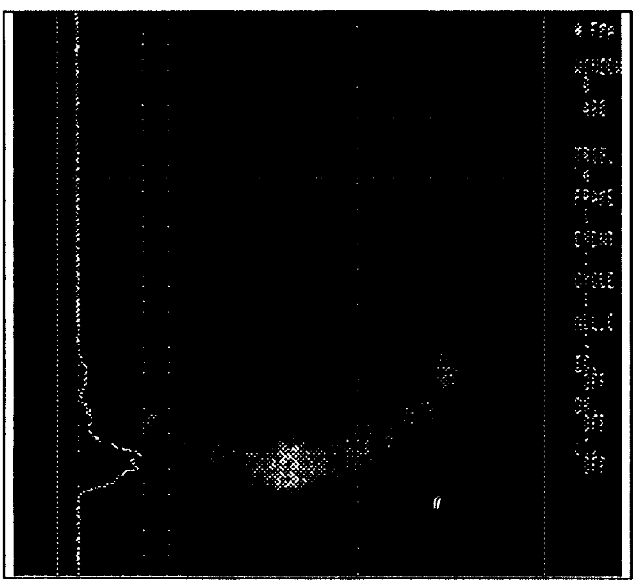

Figure 5 Streak image of circular shaped 30 ps sagitta setting

4. Summary

The AWA laser system has been installed and tested. The results show that the system is ready for

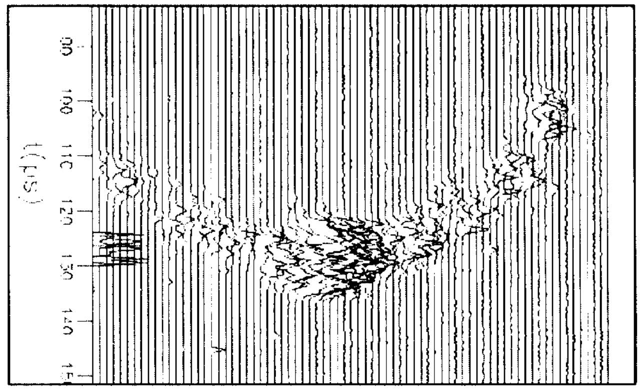

Figure 6 Mountain range plot of data in Figure 5.

initial AWA operation. The laser pulse shaper was designed and fabricated. Laboratory testing shows that this laser pulse shaping method will satisfy our present demands. A higher reflection coating is planned to further enhance the system's performance.

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References:

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3. P. Schoessow, C. Ho, J. Power, E. Chojnacki, "Control, Timing, and Data Acquisition for the Argonne Wakefield Accelerator", these proceedings.