DRIVE LASER AND OPTICAL TRANSPORT LINE FOR PHOTOINJECTOR*

Zhigang He [#], Qika Jia, Xiaoen Wang

National Synchrotron Radiation Laboratory, University of Science and Technology of China, Hefei, Anhui 230029, China

Abstract

A Photo-Cathode RF Gun is under development at NSRL. In this paper, the drive laser system is introduced and performance parameters are presented. We adopt a BNL type gun with laser illuminating the cathode at oblique incidence. To correct "time slew" and "elliptical spot" problems arisen on the cathode, an adjustable optical transport line is designed.

INTRODUCTION

Drive laser system is the key component of photocathode high-brightness injector. To ensure the high quality of electron beams offered for FEL, the injector request a reliable laser with prominent performance parameters, such as: pulse duration, beam profile, energy stability, pulse to pulse stability, pointing stability and phase jitter. We adopted a BNL type gun with p-polarized laser at oblique incidence, as to acquire high quantum efficiency and low thermal emittance [1]. But, the problems of "time slew" and "elliptical spot" will arise on the cathode. To correct them, an adjustable optical transport line was designed.

DRIVE LASER SYSTEM

We employed a drive laser system developed by High Q Laser Production GmbH [2]. It consisted of three main parts: oscillator with a timing stabilizer, a regenerative amplifier, and the frequency conversion part. Fig.1 is the layout of the drive laser system.

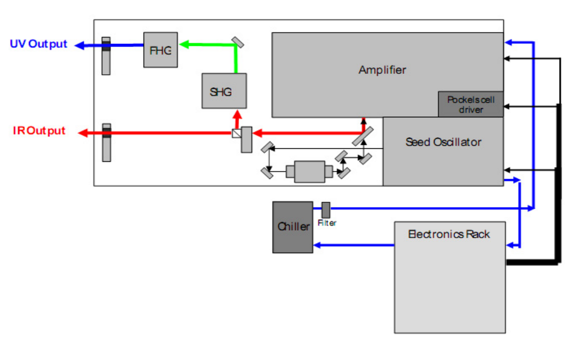

Figure 1: Layout of the drive laser system

Oscillator

The seeding laser is a passive mode-locked laser with a semiconductor absorber mirror (SESAM). Its repetition rate is 102*MHz*, equal to 1/28 of 2856*MHz* S-band radio frequency, which is used for RF-gun. The timing stabilizer measure the phase offset between laser pulses and reference RF signal, then adjust the cavity length by putting one laser resonator mirror on a voltage controlled piezo to synchronize the two signals.

Regenerative Amplifier

The Pockels Cell captures pulses from the continuous seeding laser and determines the pass times of pulse in the regenerative amplifier cavity. The repetition rate of amplified pulses is optional from 10 to 100*Hz*.

Frequency Conversion Part

The SHG convert the IR light (1047*nm*) to green light (523*nm*), then the FHG convert the green light to UV light (262*nm*). The conversion efficiency is about 20% from the fundamental to the 4-th harmonics.

LASER PERFORMANCE

Pulse Duration

The autocorrelation measurement result of IR pulse width was 8.3ps FWHW (deconvolved value taken from the Fig.2). The UV pulse width could be close to this value.

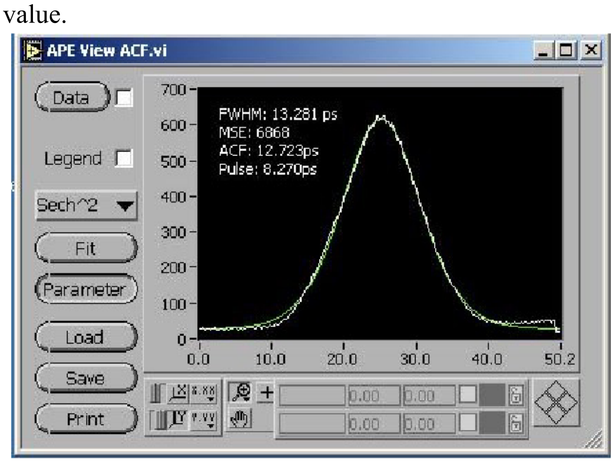

Figure 2: Pulse width @ 1047 nm measured after Regenerative Amplifier @ 10Hz

Beam Profile and Diameter

The beam profile and diameter of UV laser pulse was measured by a CCD camera. Beam profile was shown as Fig.3. The beam diameter in X and Y direction were 2.051*mm* and 1.927*mm* respectively, which were statistical results of 300 shots.

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[#]hezhg@mail.ustc.edu.cn

Pulse to Pulse Stability

The UV pulse to pulse stability was measured by a photodiode connected with an oscilloscope. The area integration was measured. The fluctuation was calculated as: σ/μ∗100%. The result was about 0.8% over two hours, as shown in Fig.4.

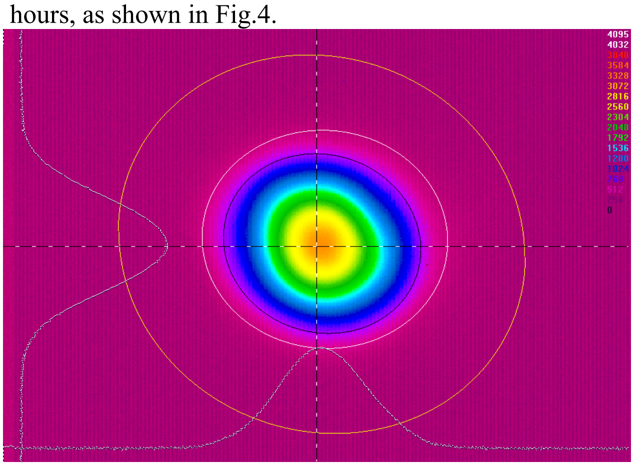

Figure 3: Beam profile of UV laser

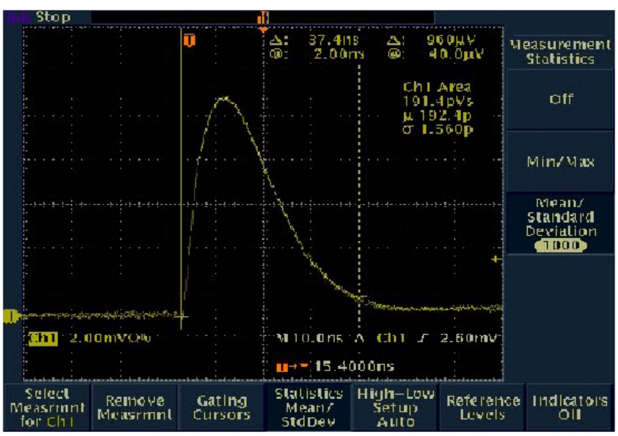

Figure 4: Pulse stability of UV over 2h: measured with 50 Ohm feed-through-terminated input; 500 MHz Bandwidth Tektronix TDS 3052, DC-coupled)

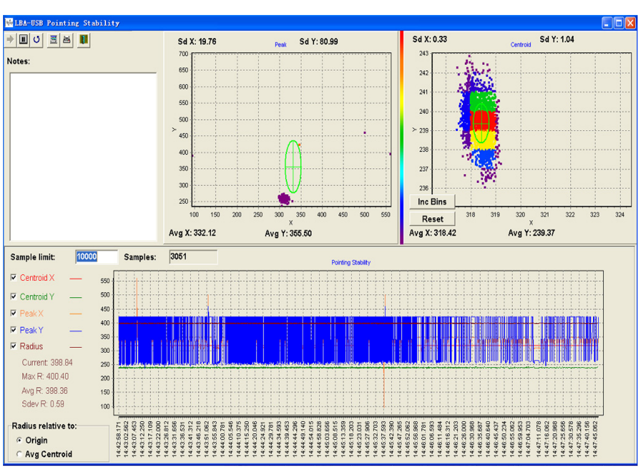

Figure 5: Pointing stability measurement

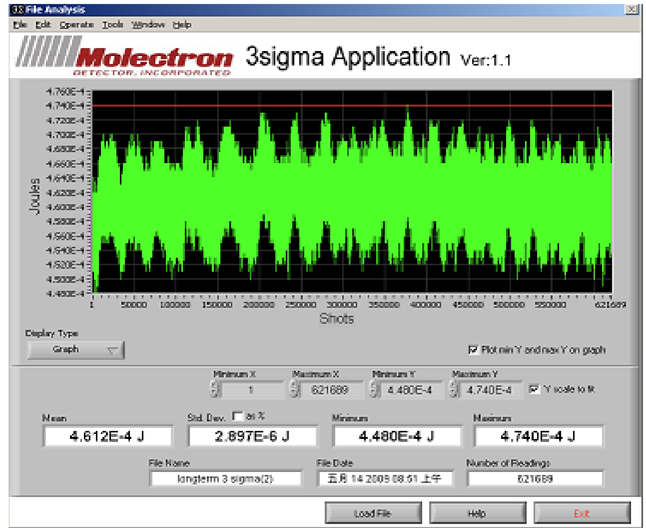

Figure 6:Long term energy stability measurement results

Pointing Stability

Beam pointing stability was measured with a lens of 600*mm* focal length. The CCD camera was placed at a distance of 700*mm* from the lens. Pointing stability of the beam centroid were 6.13μrad *rms* in X direction and 19.31μrad *rms* in Y direction. Fig.5 showed us the measured pointing stability of centroid point and also peak point.

Energy Stability

The long term (over 17 hours) energy fluctuation of UV measured by an energy meter was about 0.6% *rms*, as shown in Fig.6. The measurement precision is dependent on resolution of energy sensor. We think the actual value is higher than the measured one.

Phase Jitter

The phase jitter between oscillator and reference signal (signal generator: E8257D) was measured. The output signal was presented in Fig.7. Jitter calculation as:

$$Jitter_{rms} = U_{rms}\frac{1}{f_{OSC}\times 360^{\circ}} = 14.2mV\frac{1}{102*10^{6}Hz\times 360^{0}}$$

$$Jitter_{rms} = 387\,fs$$

Scaling: $1000mV = 1^{\circ}$

To gain a low jitter, a signal generator with low phase noise is required. Signal generators E8257D and E8663B from Agilent are suitable. All of the laser performance parameters were listed on Table 1.

OPTICAL TRANSPORT LINE

Because of oblique incidence design of BNL type gun, two problems of "time slew" and "elliptical spot" will arise on photo-cathode. To correct them, two prisms were used to add appropriate negative time slew and ellipticity on laser pulse wave front. The added time slew is: $\tau=f(r,\alpha)$, α is the angle of prism, r is the laser diameter on the prism. A variable beam expander was used to adjust the r . Therefore, the added time slew can be adjustable. The beam diameter on cathode can be controlled by a movable lens at the end of optical line. The Y direction beam diameter was also fore-adjusted by prisms. The sketch of optical transport line was shown as Fig.8. The beam profile after the two prisms was measured by a CCD camera, which was showed in Fig.9. The X direction diameter was compressed to 1.0*mm*, The Y direction diameter was still about 1.9*mm*. To compress the Y direction diameter, one just needs to rotate the prisms. The transmission efficiency of the two prisms is about 92%.

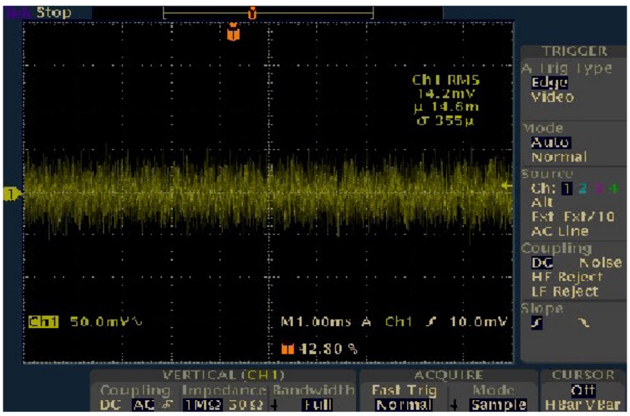

Figure 7: SYNC-phase output signal, RMS=14.2mV

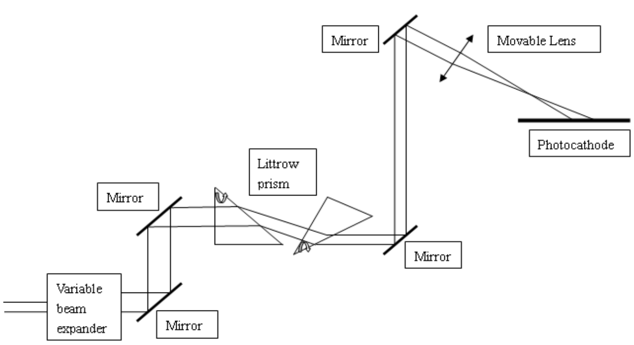

Figure 8: Sketch of optical transport line

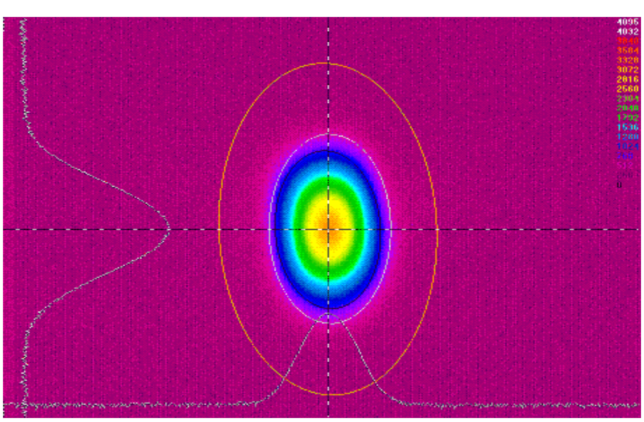

Figure 9: Beam profile after two prisms

Table 1: The performance of drive laser system

1	Wave length/*nm*	262
2	Pulse duration (FWHM) /*ps*	8.3
3	Oscillator frequency/*MHz*	102
4	UV repeat rate/*Hz*	10-100
5	UV energy/*mJ*	0-0.65
6	Energy fluctuation/*rms*	0.6%
7	Pulse to pulse stability/*rms*	0.8%
8	X direction Point stability/μrad	6.13
9	Y direction Point stability/μrad	19.31
10	Phase jitter/*fs*	387
11	X direction beam diameter/($1/e^2 mm$)	2.051
12	Y direction beam diameter/($1/e^2 mm$)	1.927

SUMMARY

We described the drive laser system and presented the measured laser performance parameters. We also reported a preparatory design of optical transport line used to correct "time slew" and "elliptical spot" problems. We are going to reshape the laser pulse. In the aspect of spatial shaping, a commercial production from pi-shaper [3] and GBS-UVH [4] may be considered. Both of them showed favourable shaping effects [5] [6]. In the aspect of temporal shaping, we are going to try the pulse stacking method [6] [7].

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