DRIVE LASER SYSTEM FOR THE NSRRC PHOTOINJECTOR

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Abstract

A 266nm ultra-violet laser system has been installed as the drive laser of the NSRRC photoinjector. According to beam dynamic studies for the photoinjector, a 10ps uniform cylindrical beam will be generated at the Cu cathode to reduce emittance growth due to space charge and transverse RF fields in the photoinjector cavity. The main part of this system is diode laser pumped, 798nm regenerative IR amplifier that can provide 85fs pulse at 3.85mJ pulse energy. The conversion of frequency from IR to 266nm UV is achieved by a third harmonic generator. UV output pulse energy exceeds 300uJ. Synchronization between seed laser and the high power microwave system can be better than 1ps. In order to produce a uniform cylindrical beam for emittance reduction in the photoinjector, a refractive UV beam shape and a pulse stacking temporal beam shape are being implemented.

INTRODUCTION

The high brightness injector project of NSRRC has been initiated since 2006. The beam injector that consisted of a thermionic cathode RF gun and a laser driven photo-cathode RF gun that share the same 2998 MHz linac system. The rf gun is a 2998MHz 1.6 cell cavity structure that has been modified from the Brookhaven National Laboratory GUN-IV design by scaling the interior wall dimensions. Two 35MW Thales TH2100A klystrons were installed for the linac RF system. One of klystrons is allotted power to gun and the accelerating section. We expect the first linac section will give a maximum energy gain of 50MeV at about 20 MW. Timing jitter between laser and electron bunches is less than 250fs RMS. The energy of electron beam bunch is up to 150MeV after three linac sections that can be used for next generation light source development in the future. Beam dynamics study is simulated by PARMELA. The optimized emittance of 0.7 mm-mrad with a 10 ps uniform cylindrical pulse can be achieved at 1 nC charge, when using 2628 Gauss magnetic field and 37° injection phase. System integration of the photo-injector test stand will be started in spring of 2009 for RF gun high power microwave processing and beam characterization.

DRIVE SYSTEM

The ultrafast laser system was purchased from Coherent Corporation last year. This system consisted of a seed laser (Mira-900), an amplifier (Legend), a third harmonic generator (THG), and a UV stretcher system. The whole system is showed in the Fig. 1.

The 798nm wavelength IR laser, 85fs pulse width was generated from Ti: Sapphire oscillator with 74.95 MHz repetition rate. After that, seed laser pulse was conveyed to a regenerative amplifier. The Legend-F amplifier laser system is composed of three essential elements, an optical pulse stretcher, a regenerative amplifier and an optical pulse compressor. Inside, the amplifier amplifies ultra short pulses from nJ to mJ level and meantime the repetition rate of laser is modulated to 10Hz. The regenerative amplifier pumped by a Q-switch laser raises the energy of the seed laser pulse to 3.85mJ. After the regenerative amplifier, the laser pulse comes into the THG to produce 266 nm wavelength laser pulses. The UV laser pulse is stretched from 100fs to 10ps by UV stretcher so as to obtain suitable pulse width. UV output pulse energy exceeds 300uJ

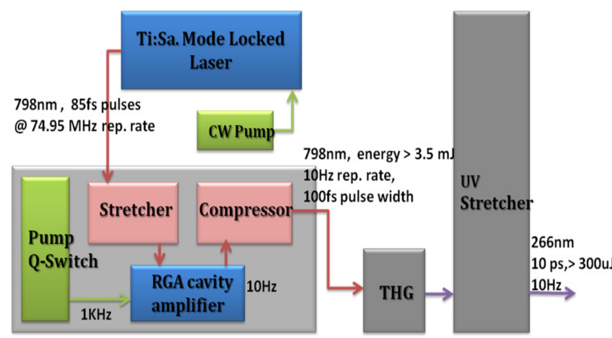

Figure 1: Layout of ultrafast laser system.

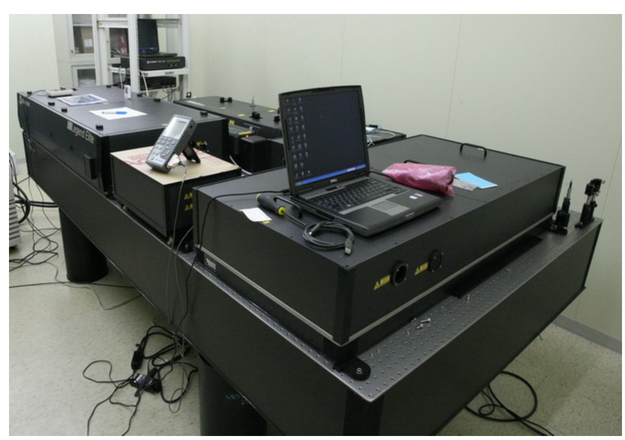

Figure 2: Real picture of ultra fast laser system.

Measurement

We measure ultra short IR pulse length by using a single shot autocorrelator. The basic principle is to split the pulse using a beam splitter to generate two copies and variably delaying one with respect to the other. The copies are then spatially overlapped in an instantaneous nonlinear medium, such as a second harmonic generation crystal (KDP). One can delay the beam line to observe the intensity change of the SHG signal, and acquire pulse length of laser.

Table 1: NSRRC Drive Laser Specification

Parameter	Spec.
UV wavelength	266nm
Pulse energy	>300uJ
Pulse duration	1-15psec (adjustable)
Rep. rate	10Hz
IR pulse duration	100fs
IR beam quality (M^2)	<1.5 (x and y)
Timing jitter	<0.25 ps rms typical

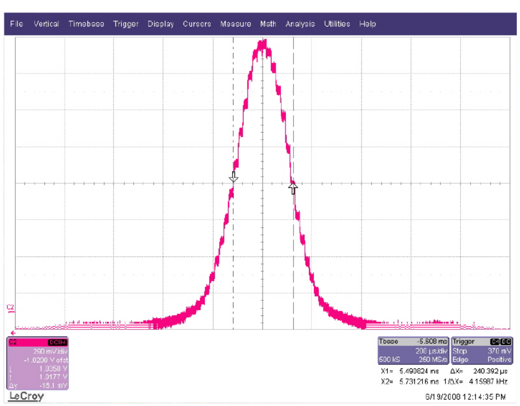

Figure 3: Measurement results of autocorrelator. FWHM= 0.240ms, De-convoluted pulse width FWHM ~ 85fs.

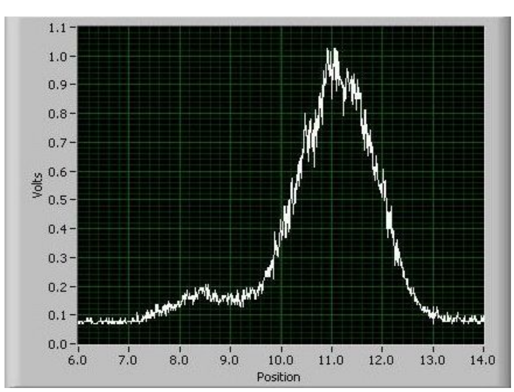

Figure 4: Measurement results of UV crossscorrelator. FWHM = 1.7mm, UV pulse width =11ps.

The UV pulse length was measured by a cross correlator. In order to perform this measurement, one needs to use IR beam and UV beam. Of course proper time overlap is required inside the mixing crystal (BBO) of the UV cross correlator. We obtain the intensity profile of second harmonic generation signal 400nm and this profile is on behalf of the UV beam.

SYNCHRONIZATION WITH RF

To generate and accelerate electron bunches from the photocathode RF gun, one has to make synchronization between the laser and RF system. The synchronization with the RF reference is obtained at the laser oscillator level. A 2998 MHz master clock is reduced 1/40 and oscillator laser was locked with master clock by a synchro-lock. Master clock also triggers pump laser of regenerative amplifier with 1 KHz. The SDG is designed to control the precise timing for a RGA. In order to ensure a single pulse is admitted to the resonator, the Pockels cells must be switched at the same time with respect to the seed pulse train every time. So switching is synchronized to the RF signal generated by the seed laser. The laser jitter is less than 250 fs RMS.

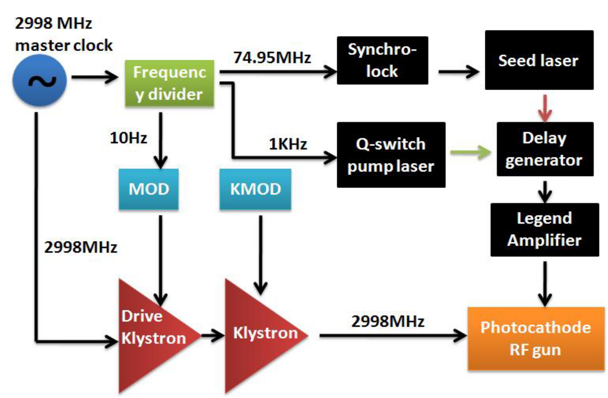

Figure 5: Schematic of synchronization system.

LASER BEAM TRANSPORT

In order to avoid radiation, the gun is placed in another room whose location is several meters far away the laser room. The design of transport line is showed in Fig. 6. The beam diameter of laser on the photocathode surface is anticipated 1 mm. In the laser beam transport line, we use Galilean lens design for laser beam size control.

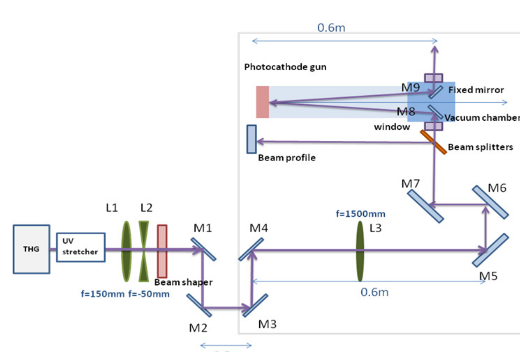

Figure 6: Schematic of beam transport.

There are two choices of laser incidence into photocathode gun, normal incidence and grazing incidence. In our case, we adopt normal incidence. In this operation, the challenge is how to place a tiny mirror in the vacuum chamber and keep electron bunches off this mirror. The last mirror next to vacuum chamber is motorized to align the laser beam at center of Cu cathode.

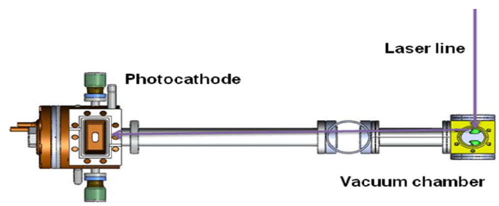

Figure7: Schematic of laser beam couple to cathode.

PULSE SHAPING

To acquire the lower emittance electron bounces from photocathode RF gun. Producing a flat-top temporal and spatial intensity laser pulse is significant. Recently, many schemes of shaping pulse were demonstrated at several Labs.

Spatial Shaping

The spatial profile was shaped by using a refractive UV beam shaper (Nweport Corporation product). The beam is transferred into the beam shaper then refracted by aspheric optics with less than 10% energy loss. Unfortunately, the effect of spatial shaping is not good enough. In fact, there is no satisfying shaper so far now. Spatial shaping is still a challenge. Since the photocathode is located 10 meters far away from the laser room. It is also a problem that how to maintain the shape of laser after a long range transport. Figure 8 shows the laser spatial profile before and after refractive UV beam shaper.

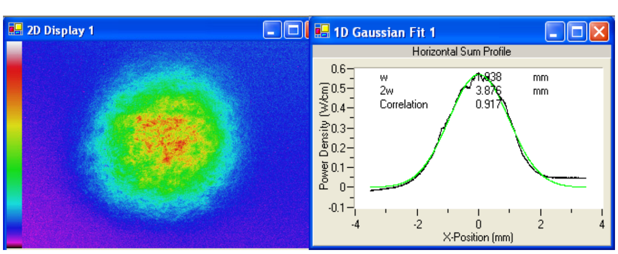

Figure 8a: Laser beam profile before spatial shaper.

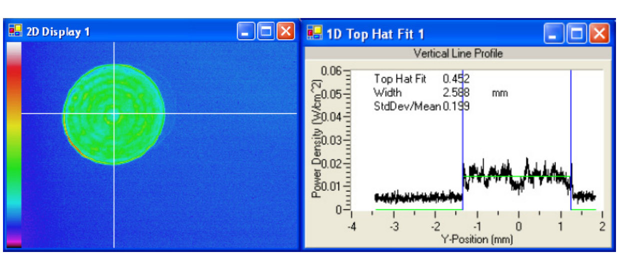

Figure 8b: Laser beam profile after spatial shaper.

Temporal Shaping

In contrast with spatial shaping, the techniques of temporal shaping are much desirable. Recently, several methods are practiced. It includes acousto-optic programmable dispersive filter (DAZZLER), frequency domain pulse shaping and pulse stacking. In our case, we adopt pulse stacking first and we also want to develop other techniques in the future. Pulse stacking is an uncomplicated component of mirrors, wave plates and beamspliters. One can split and recombine the laser because of distinct polarization of light. The drawback of this scheme is difficult to align beam. However, the power of laser is almost lossless after these optical components.

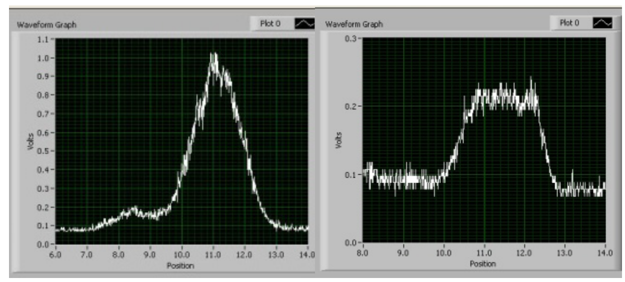

Figure 9: Laser pulse profile before and after pulse stacking.

SUMMARY

In this paper, we report the performance of the NSRRC drive laser system. We have installed this system last year. The test results showed that it meets our requirements for a photoinjector drive laser. Timing and synchronization electronics are ready for use. Measurement system is being fabricated to characterize laser jitter. We expect to finish installation of Cu cathode and acceleration section by this summer.

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