THE STUDY OF DRIVE LASER SYSTEM FOR PHOTO-INJECTOR *

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Abstract

A drive laser system is developed in Peking University. It is a pioneer technical study for Shanghai Light Source, whose purpose is to study DUV-FEL. The beam energy is designed to 300 MeV and the coherent radiation wavelengths from 300nm to 75 nm. The photocathode electron gun will use copper as the cathode material. It requires the drive laser to provide 500μJ, 6~8ps pulse of UV photons (260nm) to the cathode. To satisfy spatial and temporal requirements of the laser pulse, we adopt Ti:sapphire lasers to make up of the main frame of this system. It mainly consists of such lasers: a CW, frequency-doubled, diode-pumped Nd: YAG laser which provides energy to pump a CW mode-locked Ti: sapphire oscillator, a frequency-doubled, Q-switched Nd:YAG laser to pump a multi-pass amplifier, a regenerative amplifier and harmonics crystals. The cavity length of the oscillator should be adjustable in order to lock the pulse frequency with external RF reference, and a phase stability feedback system is also used. Now, the conceptual design of this system is finished.

1 INTRODUCTION

A new superconducting acceleration study platform, named PKU-SCAF (Superconducting Accelerator Facility), is prepared to construct at Institute of Heavy Ion Physics, Peking University [1]. During the past more than ten years, the RF-SC Group of IHIP has been kept the investigations of the key knowledge of SC accelerator. In the near future, the major study of PKU-SCAF is to provide high quality electron beams with high average current. With such electron beams, we can develop the studies of many valuable applications [2]. PKU-SCAF is chiefly composed of the DC-SC photocathode injector [3], the superconducting accelerator and the laser drive system.

The high quality beam means it has low emittance, low energy spread and high brightness, or high average current. Until now, it is well known that the photocathode electron gun is the only solution to achieve high quality electron beams used for FEL. Normally a photocathode electron gun is mainly consists of a gun, a cathode and a drive laser system. Theoretical and experimental studies show that this kind of electron gun needs a drive laser with good performances [4,5]. In this paper, the author would like to discuss the design concept of the drive laser system for the photocathode electron gun in Peking University.

2 LASER SYSTEM REQUIREMENTS

The designed parameters of output electron beams and the cathode materials in the gun determine the requirements of the drive laser system. The requirements of our laser are given in Table 1.

Table 1: The designed requirements of the drive laser system of Shanghai DUV-FEL [6]

System	Requirement
Operating wavelength	260~280 nm
Pulse repetition rate	50 Hz
Number of micropulses per pulse	1
Pulse energy on cathode	~500μJ
Pulse rise time	~1 ps
Pulse duration	6~8psFWHM
Longitudinal pulse form	Various
Transverse pulse form	Uniform
Laser to RF phase jitter	< 1ps rms
Spot diameter jitter at cathode	< 1% ptp
Pointing stability	< 1% ptp

For Shanghai project, it is designed to use a S-band BNL type RF gun. In Table 1, the operation wavelength of drive laser's output is 260~280 nm, which is for the metallic cathodes, such as copper or magnesium. The proposed charge of 1 ~ 1.5 nC in a bunch makes high beam bright. Because the QE of copper is very low (about 10^{-5}), the laser's energy at the Cu cathode will be up to 500μJ. The stability of the laser pulse will directly affect the electron beam's qualities. To limit the transverse

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emittance of the electron beam down to few π mm-mrad, people need both geometry and position stability of the spot on the cathode better than 1%, and the timing stability is less than 1 ps[7]. Those stability requirements are also necessary for depressing beam energy spread.

3 LASER SYSTEM DESCRIPTION

This laser system is hoped to be a reliable one and can be finished in a short developing period, so we will choose available commercial lasers to assemble the system. Fig.1 is the schematic drawing of the system.

As we have said, the lasers in this system are mainly commercial productions. We choose a Ti:sapphire oscillator (for instance, Tsunami™[8]) to produce the seed laser, because Ti:sapphire laser can provide enough bandwidth for the post pulse shaping. Tsunami™ is a CW model-locked oscillator and is pumped by a CW, frequency-doubled, diode-pumped Nd:YAG laser (Millennia™). The average output power of a standard Millennia-pumped Tsunami is about 750 mW, and its pulse width is less than 80 fs.

The seed laser is then amplified by a Ti:sapphire regenerative amplifier (Spitfire™), pumped by a frequency-doubled diode-pumped Nd:YLF laser (Evolution™), and a multi-pass amplifier, which is pumped by a Q-switched, frequence-doubled Nd:YAG laser. The CPA technique [8] is adopted in the multi-pass amplifier to avoid the damage to the Ti:sapphire crystal by the ultra high power. After the amplification process, the laser pulse energy will be 15 to 20 mJ, and the pulse width will be 6 ~ 8 ps. We use a spatial flattener to get the uniform transverse pulse profile. There are two BBO crystals used for the frequency tripling. Then, the laser of 260nm, 500μJ/pulse can be used for the cathode. A combination of focus lens and apertures controls the spot size and the spatial jitter.

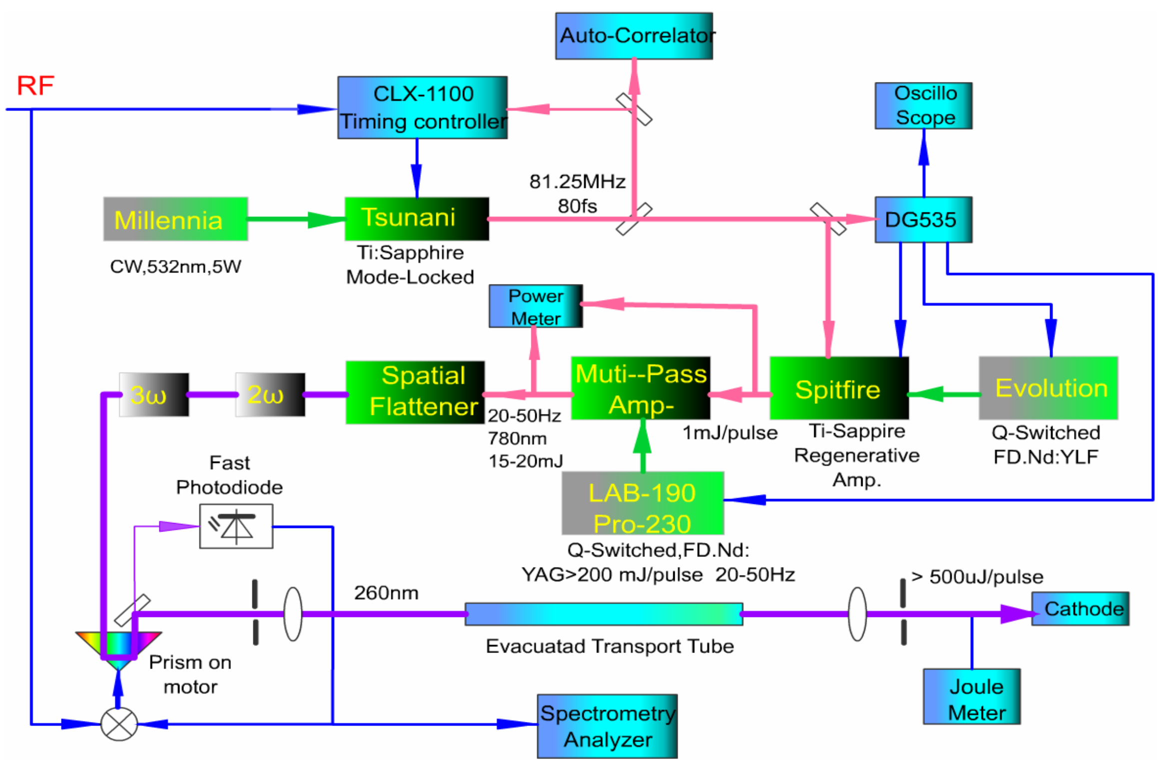

Figure 1: The schematic drawing of the drive laser system

In this system, the timing is stabilized twice. We will use CLX1100 [9] (Time Bandwidth Products, Inc.) as the first stage. CLX1100 measures the phase/frequency offset between laser pulse and the reference clock signal, and adjusts the cavity length to maintain a constant relation between the two signals. CLX1000 series has been used in many laboratories and believed to have the ability to control the timing stability within 1ps. The second stage consists of a picomotor-driven prism to turn the light pass range, a fast diode to pick up the laser pulse signal and the associated feed back control device. This stage is used to compensate the long-term drift and also can adjust the phase of laser pulse referring to the RF.

4 DISCUSSION

The demands of high peak current and copper cathode deliver the requirement of high pulse energy. To improve the RF utilization efficiency, people are trying to increase the pulse repetition rate. Those two factors combined together lead us to face a big challenge. The repetition rate of BNL DUV-FEL is 10 Hz [10]. The people of LCLS hope the rate can reach 120 Hz [7], but until PAC2001, the project has not been finished. The main problem is lacking a good pump for the amplifier. Because most Ti:sapphire laser is pumped by Q-switched, frequence-doubled Nd:YAG laser, which is pumped by flash lamps, but the lifetime of lamps is limited. There is no manufactory like to offer the guarantee for such usage.

In our design, the pulse repetition is 50 Hz, also out of the guarantee range, but it is not so high as LCLS. The character of this design is that we separate the amplification process into two steps. The first is a diode-pumped regenerative amplifier, followed by a multi-pass amplifier. By using the first amplifier, the needed energy gain of multi-pass amplifier is much more reduced. We hope the Nd:YAG amplifier can work in a relative longer period. Because the temporal and spatial characters of pulse are determined by the cavity of regenerative amplifier, the approach of temporal shaping of the seed laser, like LCLS design, can't be used in our system. The energy of the pulses out of the regenerative amplifier is about 1 mJ and the pulse length is kept less than 90 fs [8]. That means the pulse bandwidth is still enough for temporal shaping. The possible problem is that it may reduce the damage threshold of the diffraction gratings and the phase masks.

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