TW Laser system for Thomson scattering X-ray light source at Tsinghua University*

YAN Li-Xin(颜立新)[1)] DU Ying-Chao(杜应超) DU Qiang(杜强) LI Ren-Kai(李任恺)
HUA Jian-Fei(华剑飞) HUANG Wen-Hui(黄文会) TANG Chuan-Xiang(唐传祥)

(Accelerator Laboratory, Department of Engineering Physics, Tsinghua University, Beijing 100084, China)

Abstract A TW (Tera Watt) laser system based on Ti:sapphire mainly for the Tsinghua Thomson scattering X-ray light source (TTX) is being built. Both UV (ultraviolet) laser pulse for driving the photocathode radio-frequency (RF) gun and the IR (infrared) laser pulse as the electron-beam-scattered-light are provided by the system. Efforts have also been made in laser pulse shaping and laser beam transport to optimize the high-brightness electron beam production by the photocathode RF gun.

Key words Thomson scattering, TW laser, photocathode RF gun

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1 Introduction

As one of the most prospective high-brightness X-ray light sources, Thomson scattering X-ray based on the interactions between relativistic electron beams and ultrashort high power laser pulses will provide a powerful tool for modern scientific research[1]. Due to its many advantages over traditional light sources[2], the Accelerator Laboratory of Tsinghua University began to study this field several years ago aiming at building such an experimental facility TTX[3—7]. And now it is under construction.

In the TTX project, the electron beams will be initiated from a photocathode RF gun driven by UV laser pulses and then accelerated to several tens of MeV. By virtual of low transverse emittance and high peak currents, the high-brightness electron beams based on such a photocathode RF gun also play crucial roles in the 4$^{\text{th}}$ generation light sources[8, 9], international linear collider[10], high-power coherent tera-hertz radiation, time-resolved ultrafast electron diffraction[11], etc. beside the Thomson scattering based X-ray sources. To produce and maintain such a high quality electron beam, shaping of the spatial and temporal distribution of the UV laser is very important. In this paper, a brief introduction of the beam transport line of the UV laser pulse as well as the TW laser system will be presented.

2 TW laser system

To produce applicable ultrashort X-ray source based on Thomson scattering, a 20-TW laser system was proposed to provide the scattering laser beam and now is under construction. In the design, UV laser pulses to drive the photocathode RF gun are also originated from the same TW laser system to avoid the additional timing jitter induced by two separated systems. The design parameters of the system are listed in Table 1.

Figure 1 shows the layout of the TW laser system. Using chirped mirrors for dispersion compensation, a Kerr-lens mode-locked oscillator pumped by Verdi-5 (from Coherent) delivers 79.3 MHz/10 fs/400 mW seeding pulses synchronized with RF signals. After passing through a modified offener stretcher, the seed is lengthened to more than 300 ps and then amplified to 4 mJ pulse energy by the regenerative amplifier

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1) E-mail: yanlx@mail.tsinghua.edu.cn

Table 1. The design parameters for TW laser.

laser media	Ti: Sapphire
central wavelength	800 nm
pulse duration	30 fs
pulse energy	>600 mJ
repetition rate	10 Hz
beam quality	$M^2<1.5$
energy jitter/rms	$<2\%$
	10^7@1 ns
contrast ratio	10^6@100 ps
	10^4@1 ps
pointing jitter	<15μrad

and the 3-pass amplifier which are both pumped by the same source Evolution-30 (from Coherent: 1000 Hz/532 nm /20 W). In front of the pre-multi-pass amplifier the repetition rate of the laser pulse is switched to 10 Hz by a Pockle cell. By part of the green light from the pumping source Pro-350-10 I (from Spectral Physics: 1.4 J/532 nm/10 Hz) 1mJ pulse energy from the regenerative & 3-pass amplifier is boosted to about 70 mJ, where 25 mJ pulse energy is split for photocathode application while the left energy is sent to the main multi-pass amplifier for further amplification. As shown in Fig. 1, we plan to use three Pro-350-10 pumping sources to get 20 TW laser. Currently, only one such pumping source is installed and more than 200 mJ pulse energy can be achieved after the main multi-pass amplifier. So by the end of the first phase, the system can produce more than 3TW laser pulse for Thomson scattering. Next year, two additional Pro-350-10 pump lasers may be ready to upgrade the 3 TW system to more than 20 TW pulse power.

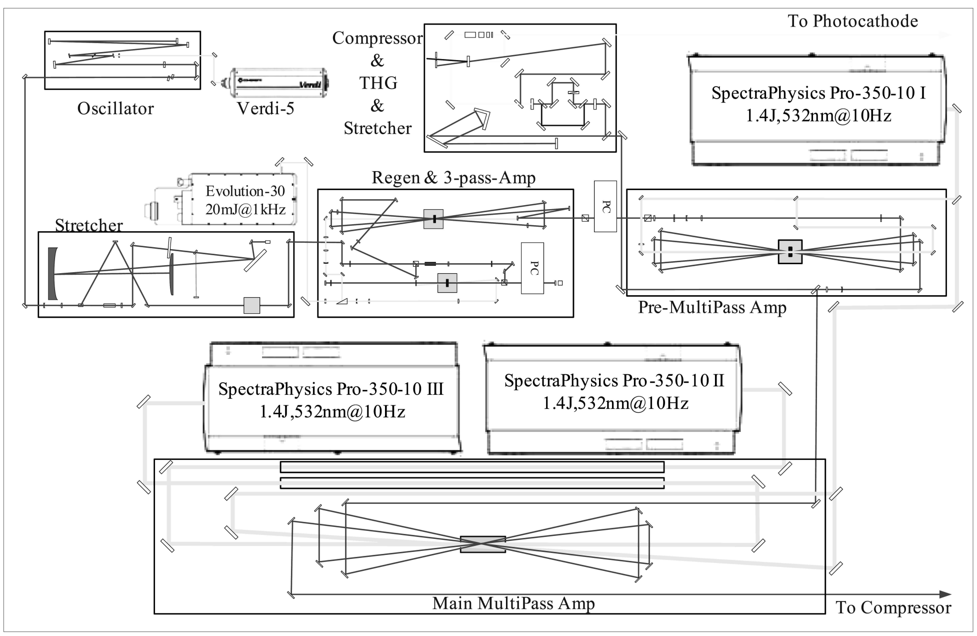

Fig. 1. Layout of the TW laser system.

3 UV laser for the PC

As shown in Fig. 1, the 25 mJ pulse energy separated from the pre-multi-pass amplifier output is compressed to 30 fs and then frequency-tripled by the third-harmonic generator (THG), where more than 1.5 mJ UV pulse energy at 266 nm wavelength is produced. The ultrashort UV pulse can be stretched to sub-ps or several ps by the double prism pairs in the UV stretcher. By stacking 8 or 16 ps or sub-ps UV pulses, the required quasi top-hat temporal shape is formed. After this, a GTF (Gaussian-to-flattened) shaper made from aspheric lenses is used to reshape the natural transverse Gaussian profile into quasi flattened distribution. This kind of UV pulses will be transported for normal illumination of the photocathode.

Table 2. The parameters of UV laser.

wavelength	266 nm
pulse duration	10 ps
pulse energy	>1 mJ
repetition rate	10 Hz
RF timing jitter/rms	<200 fs
energy jitter/rms	$<2\%$

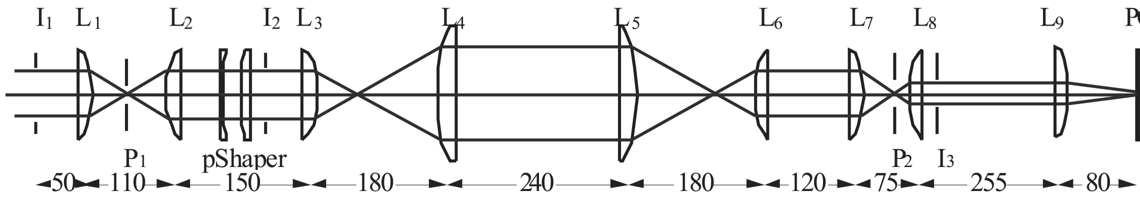

Fig. 2. Schematic of transport beam line for the photocathode.

UV laser pulses to drive the photocathode (PC) RF gun are also provided by the TW laser system. Table 2 shows its specifications.

4 Transport optical beam line

To avoid air-induced perturbation, the UV beam will be encapsulated in a pipe line. The formed transverse distribution is transported to the surface of photocathode by imaging relay principles, as shown in Fig. 2. Parameters are listed in Table 3. Through such a beam line, the initial 10 mm-diameter UV beam is transformed to a 1.0 mm-diameter spot on the photocathode surface, and the quasi flattened profile remains unchanged for electron beam production.

Table 3. Parameters of transport beam line.

lens	focal length/mm	beam diameter/mm
L_1	500	10
L_2, L_3	600	12
L_4, L_5	1200	24
L_6, L_7	600	12
L_8	150	3.0
L_9	600	3.0
PC	–	1.0

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References

1 Recommendations of Basic Energy Sciences Advisory Committee Panel on Novel Coherent Light Sources. http://www.er.doe.gov/production/bes/BESAC/pubs.html

2 Ride S K, Esarey E, Baine M. Phys. Rev. E, 1995, **52**(5): 5425

3 TANG C X, HUANG W H et al. Proc. of 2004 FEL Conf., 2004, 622—624

4 HUANG W H, HE X Z et al. HEP & NP, 2004, **28**(4): 446 (in Chinese)

5 DU Y C, YAN L X, DU Q et al. Chin. Phys. Lett., 2007, **24**: 1876

6 DU Y C, HUANG W H, HUA J F et al. Chin. Phys. C, 2008, **1**: 22

7 YAN L X, DU Y C, XIANG D et al. Chin. Phys. Lett., 2008, **25**: 1640

8 Arthur J, Anfinrud P et al. LCLS CDR SLAC-R-593, 2002

9 KONG X C, WANG J Q et al. CDR of the Shanghai soft X-ray free electron laser test facility, 2007, unpublished

10 Bacala A M, Jim B et al. International linear collider reference design report, 9th ACFA ILC Physics and Detector Workshop & ILC GDE Meeting, 2007

11 WANG X J, XIANG D et al. Korean Phys. Soc., 2006, **48**: 390