DEVELOPMENT OF THE LASER SYSTEM FOR THE PROOF-OF-PRINCIPLE EXPERIMENT OF CRAB CROSSING LASER-COMPTON SCATTERING

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Abstract

An X-ray source via laser-Compton scattering has the advantage of small source, energy tunability and quasi-monochromaticity and is expected to be applied in a wide range of fields such as the industry and medical care. In laser-Compton scattering, the luminosity, which represents the collision frequency between the electrons and the photons, is very important. Increasing the luminosity is strongly required for increasing the scattered photon flux. One way to increase the luminosity is tilting electron bunches at the collision point, which is called crab crossing. It is the way to create the head-on collision artificially. The purpose of this study is the proof-of-principle of crab crossing laser-Compton scattering. In this conference, we will report the design optimization and construction of the laser system for the collision and future prospects.

INTRODUCTION

Laser-Compton scattering is utilized for X-ray production using the collision between the high-energy electron beam and the laser beam. For increasing the scattered photon flux, a method using an optical cavity for laser stacking has been studied [1]. In this way, for the optical elements don't interfere with the electron beam, the electron beam and laser beam have to collide at a certain angle and the luminosity gets smaller compared with the head-on collision.

Crab Crossing

To overcome this problem, we try to apply crab crossing [2] to the laser-Compton scattering. Crab crossing is the way to create the head-on collision artificially by tilting the electron and positron bunches at the collision point. In the laser-Compton scattering, the luminosity becomes the largest when the electron bunches tilt at half the collision angle (Fig. 1).

For the proof-of-principle of crab crossing laser-Compton scattering, a high power and ultrashort pulse laser system is needed [3]. Figure 2 shows the relationship between the intensity ratio by crab crossing and the pulse length of the laser, and Table 1 shows the parameters used in the calculation. From these results, we decided 10mJ and 1ps (FWHM) for laser parameters and the purpose of this study is the development of the laser system for the collision.

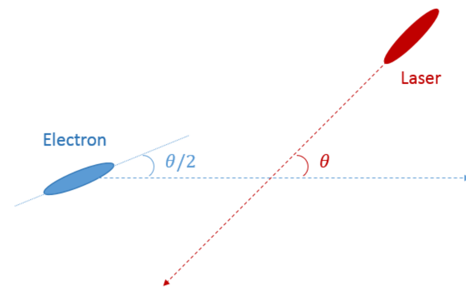

Figure 1: Crab Crossing Laser-Compton Scattering.

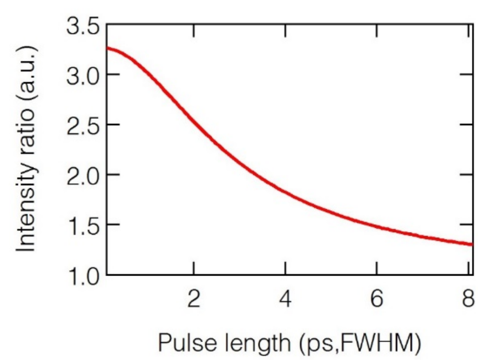

Figure 2: Relationship between Intensity Ratio and Pulse Length.

Table 1: Parameters of the Electron Beam and Laser

Electron beam	
Beam size (rms)	100μm
Bunch length (rms)	3ps
Laser	
Beam size (rms)	50μm

CHIRPED PULSE AMPLIFICATION

Chirped pulse amplification (CPA) is a popular technique for generating a high power and ultrashort laser pulse [4]. A seed pulse generated by the oscillator is stretched to a much longer duration and amplified, which prevents nonlinear distortion and destruction of optical elements. After that, the pulse is compressed and becomes a high-peak-power ultrashort laser pulse (Figure 3).

In this study, we apply an Yb fiber laser to the oscillator and a thindisk to the amplifier. The fiber laser can generate high power and chirped laser pulses [5]. By using pulse compression outside, sub-picosecond pulse duration can be realized. The thin-disk has a very thin gain medium and shows very high cooling efficiency [6]. Reducing a thermal lens effect, a very high energy laser pulse can be generated with high quality. Thus, we decide to use this configuration for the proof-of-principle experiment.

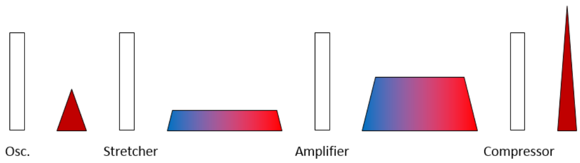

Figure 3: Chirped Pulse Amplification.

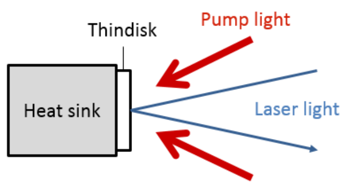

Figure 4: Thindisk Amplifier.

EXPERIMENTAL SETUP AND RESULTS

The experimental setup is shown in Figure 5. The laser system consists of the Oscillator, preamp 1, Stretcher, preamp 2, thindisk amplifier and compressor, and has been completed before the thindisk amplifier. The parameters at the respective positions are shown in Table 2. The laser pulse from the oscillator is high power and appropriate pulse duration. Using the preamp and stretcher, we can get an enough power and long duration laser pulse for the amplification.

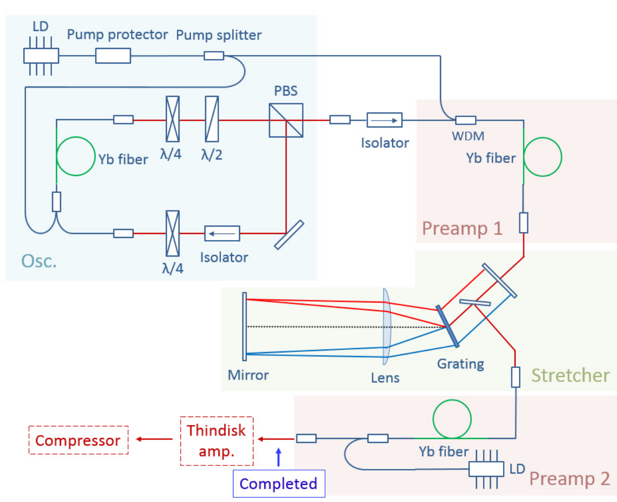

Figure 5: Experimental Setup.

Table 2: Laser Parameters

Position	Power	Pulse Duration	TLP
Oscillator	50mW	3.06ps	181fs
Preamp 1	180mW	6.01ps	148fs
Stretcher	73.4mW	173ps	NA
Preamp 2	400mW	161ps	203fs

THINDISK AMPLIFIER DESIGN

We designed the thindisk amplifier by using the simulation soft "reZonator" [7]. The requirements for the design are as follows. First, there is a resonator mode in the thindisk amplifier in order to construct a regenerative amplifier. Second, the curvature of the thindisk is +4000 to +5000 mm [8]. Third, the mode size on the surface of thindisk is 1.5 to 2.0 mm for suppressing the thermal effect. Fourth, the cavity length is less than 2.5m and as small as possible.

The setup of the thindisk amplifier is shown Figure 5. M2 is a concave mirror and M3 is a convex mirror. We determine that the length between M1 and M2 is L1, M2 and M3 is L2, M3 and the thindisk is L3, and the thindisk and M4 is L4.

The simulation results are shown in Table 3 and Figure 7. Table 3 shows the optimized parameters. Figure 7 shows the mode size in the resonator. The horizontal line shows the distance from M1 and the vertical one shows the beam radius (2σ).

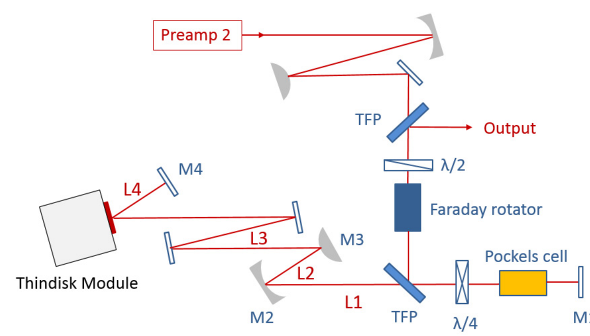

Figure 6: Setup of the thindisk amplifier.

Table 3: Parameters of the Optical Elements

Optical Element	Value
L1	400mm
M2 (concave)	R=5000mm
L2	200mm
M3 (convex)	R=−2000mm
L3	1200mm
Thindisk	R=4500mm
L4	200mm

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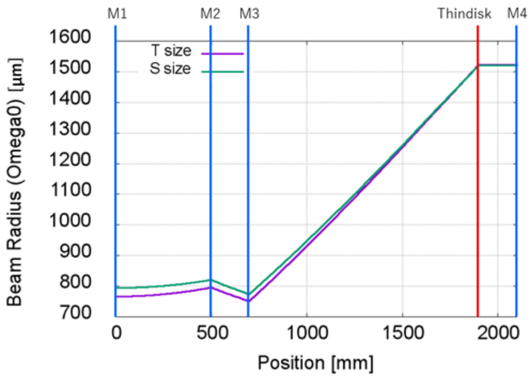

Figure 7: Mode size in the resonator.

As you can see in Figure 7, the mode size at the thin-disk falls within 1.5 to 2.0 mm and this setup meets all the requirements. For the future, we measure the curvature of the thindisk used in the experiment and redesign the thin-disk amplifier.

CONCLUSIONS

At Waseda University, we have been developing the laser system for the proof-of-principle of crab crossing laser-Compton scattering. The laser system has been completed before the thin-disk amplifier and we have achieved generating an enough power and long duration laser pulse. We designed the thindisk amplifier by using the simulation soft reZonator and optimize the condition to meet all the requirements.

In the actual experiment, we need to measure the curvature of the thindisk used in the experiment and redesign the thindisk amplifier. When finished, we go into the collision experiment with an electron beam.

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