

# MEASUREMENTS OF LASER TEMPORAL PROFILE AND POLARIZATION-DEPENDENT QUANTUM EFFICIENCY\*

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## Abstract

The ultrashort ultraviolet (UV) laser system and the optical transport line for driving the photocathode RF gun at Accelerator Laboratory of Tsinghua University are introduced in the article. Temporal profile of the UV pulse was measured by non-colinear difference frequency generation (DFG) between the UV pulse itself and the jitter-free residual IR laser pulse after third harmonic generation (THG) process. Experiments to measure the dependence of quantum efficiency (QE) on laser polarization state are also performed. Results show that in our case the ratio of QE between p- and s- polarization is more than 2.6.

## INTRODUCTION

Due to its high photon energy and high temporal resolution, high-brightness ultrashort hard x-ray light source is probably one of the most attractive tools for modern science. Currently the rapid development of ultrashort laser technology has provided feasibilities for Tsinghua University to build such x-ray source based on Thomson scattering between high-brightness relativistic electron beams and terawatt laser pulses with an acceptable investment [1-3]. In the project, electron beams are initiated from a Cu (or Mg) photocathode driven by UV laser pulses via photoemission effect. Electron beams with less transverse emittance and more

electron charge are crucial for even higher brightness x-ray production [4]. For the purpose, the UV laser pulse to drive the photocathode has to be manipulated for the optimal electron beam initiation [5]. In the article, experiments were performed to measure the UV laser temporal profile and the polarization-dependent QE of the photocathode.

## THE DRIVING LASER SYSTEM

The UV laser system was provided by Coherent. It includes a Ti:sapphire oscillator (Mira), a Regen (Legend), a third harmonic generator (THG), a stretcher and two pump lasers (Verdi and Evolution). Part of the main parameters of the system is listed in Table 1.

Table 1: Parameters of Laser System

Components	Parameters
IR bandwidth	>12nm
UV wavelength	266.7nm
UV Energy	250 $\mu$ J
UV duration	1~ 10ps
Energy stability	<1%
Timing jitter	<200fs
Polarization	Horizontal

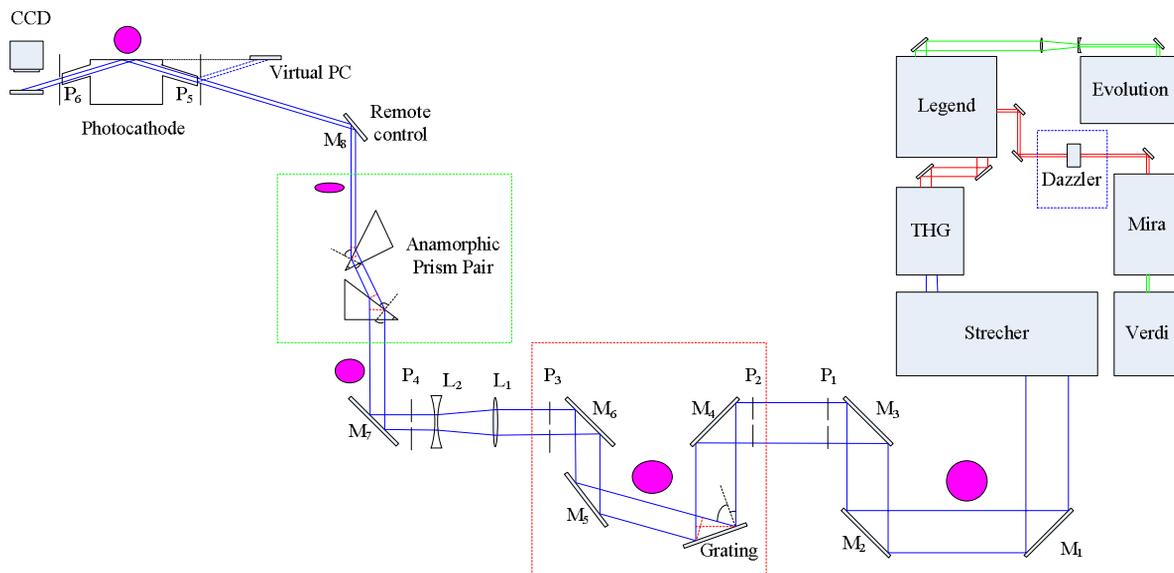


Figure 1: Setup of the photocathode driving laser system and the optical transport line

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The UV laser pulse was incident on the photocathode at an angle of  $67.5^\circ$ . Spot size on the photocathode was set

to be 1mm in diameter. To lower the electron beam's emittance, the driving laser pulse has to be spatially and temporally reshaped ahead of the photocathode. A grating blazed at 266nm wavelength with high diffraction efficiency was designed to correct the time slew effect induced by grazing incidence of the laser beam. The circular output of the laser system was ellipticized with anamorphic prism pairs after zooming out of the beam by a telescope. To achieve a flattop temporal profile, the spectrum of the seeded pulse for the regenerative amplifier was properly manipulated by an AOPDF. Aspheric lenses were designed to redistribute the natural Gaussian profile to be a flattop distribution. Imaging relay technique was applied to improve the pointing stability of laser spots on the photocathode. Set up of the UV laser

system and part of the optical transport line (with some components not shown) is shown in Fig 1.

### TEMPORAL PROFILE MEASUREMENT

The temporal distribution of the stretched UV pulse is crucial for the optimization of low emittance electron beam production. Flattop temporal profile has been testified to be more favourable for this objective. Such kind of UV pulses can be obtained by properly manipulating the spectrum of the IR seeded pulses for the regenerative amplifier. It is important to determine its temporal profile to know if the OAPDF device does a good job.

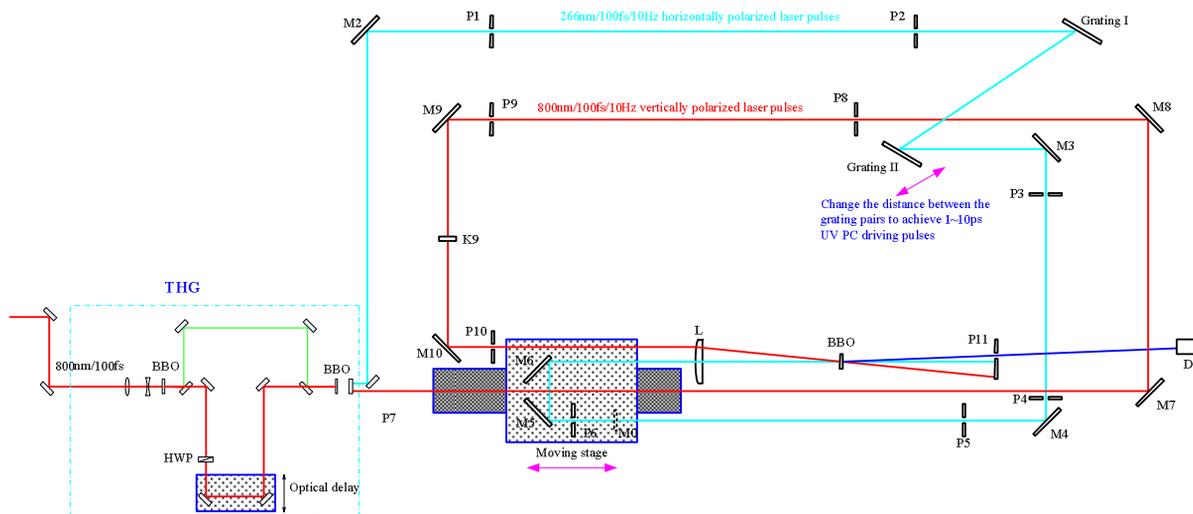


Fig 2: Setup for the temporal profile measurement of the UV laser pulses

The stretched UV pulse was measured by non-collinear difference frequency generation (DFG) between the UV pulse itself and the jitter-free residual IR laser pulse after third harmonic generation (THG) process, as is shown in Fig 2. When the horizontally parallel 100fs IR beam (vertically polarized) and 10ps UV beam (horizontally polarized) were focused into a 2-mm-thick BBO crystal by a 100mm-focal-length fused silica lens, the two beams crossed in the crystal with an angle of  $6.7^\circ$ , where the UV pulse was collinear with the axes of the lens. BBO was cut with  $\phi = 46.5^\circ, \theta = 0^\circ$ , so it was determined by type I ( $o + o = e$ ) phase matching condition that the output difference-frequency (DF) pulse would be produced at an angle of  $3.3^\circ$  by the other side of UV beams if the IR and UV beams encountered in the crystal at the same time. Temporal overlap of the two beams can be changed by the moving stage controlled by a digital motorized controller. The DF signal was collected by a fast diode detector (D) at each position of the moving stage. By this means, the temporal profile of the UV pulse was obtained, shown in Fig 3. The pulse duration was measured to be 10.6ps (FWHM), as was in good agreement with calculations. Without temporal reshaping, the UV pulse has a Gaussian distribution.

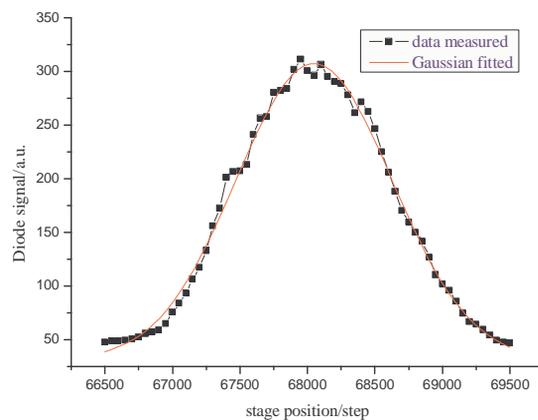


Fig 3: Measured temporal profile of the UV pulse

### RESULTS OF QE VS POLARIZATION

Quantum efficiency (QE) of the photocathode is influenced by a lot of factors including the surface roughness, the accelerating electric field, et al. For oblique incidence of driving laser, Xiang et al proposed that great improvement of QE can be achieved by using p-polarized pulses [6]. In order to find out the dependence

of QE on the polarization state of the driving laser, an experiment depicted in Fig 4 was performed.

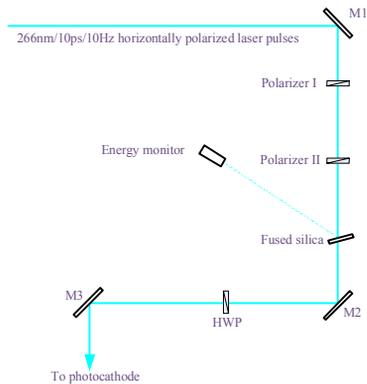


Figure 4: Setup for measurement of polarization-dependent QE

In the experiment, the polarization state of the stretched UV laser pulse (10ps@FWHM) was manipulated by a pair of polarizer and a half-wave plate (HWP) at 266nm. Polarizer II was fixed to maintain the polarization state of the input beam. Pulse energy was continuously changed by rotating polarizer I, which was monitored by deflecting a small amount of UV light with a fused silica plate using an energy monitor. Then the polarization state of the driving laser was changed by rotating the HWP. Pulse energy of the UV laser illuminated on the photocathode is about 20 $\mu$ J. Power fed to the rf gun was 4.5MW, corresponding to electric field of about 75MV/m. The experimental results are shown in Fig 5.

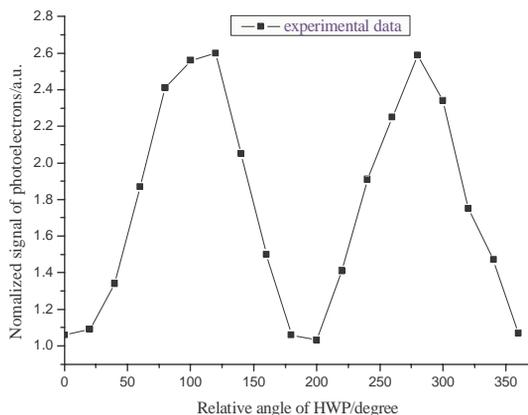


Fig 5: Measured polarization-dependent QE

Results show that in our case, the ratio of QE between p- and s- polarization state is more than 2.6.

## CONCLUSION

The ultrashort UV laser system and the optical transport line for driving the photocathode RF gun at Accelerator Laboratory of Tsinghua University are introduced in the article. Temporal profile of the UV pulse was measured by non-collinear DFG between the UV pulse itself and the jitter-free residual IR laser pulse after THG process. Experiments to measure the dependence of QE on laser

polarization state are also performed. Results show that in our case the ratio of QE between p- and s- polarization is more than 2.6.

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