Analysis of Auto- and Cross-correlator

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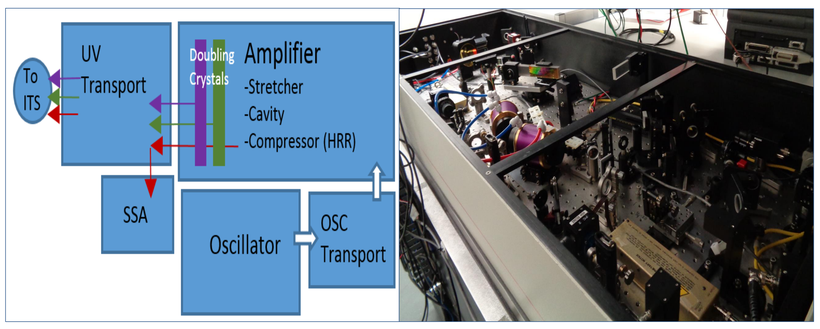
Introduction

The Advance Photon Source Photocathode (PC) drive laser system produces an UV laser beam with a wavelength of 263 nm that is used on the PC gun to generate electrons. This UV laser beam is generated by twice frequency doubling an IR wavelength of 1053 nm using two β-Barium Borate (BBO) Crystals. The pulse duration of such ultra-short pulse laser can be measured from the auto- and or cross- correlation of the laser beam.

APS Photocathode Drive Laser System

The laser system is a generic Nd:Glass chirped-pulse amplication system, which generates a short pulse by first stretching, then amplifying, and finally re-compressing the laser pulse.

Figure 1: (Left) Drive Laser Schematic and (Right) Amplifier



Theory

The interaction of an intense light beam electric field with a given dielectric material may show a nonlinearmaterial polarization $\vec{P}$.

$$P_k = \varepsilon_0 \left(\chi_{ik}^{(1)} E_i + \chi_{ijk}^{(2)} E_i E_j + \ldots \right) \qquad (1)$$

The second order nonlinear polarization response, contains a component that radiates at twice the frequency of the input wave, showing second harmonic generation (SHG).

Intensity Auto-correlation allows to measure the intensity vs time profile of ultrashort pulse lasers. This is done by focusing two identical copies of a beam with a variable time delay into a SHG crystal. The output signal is equal to the auto-correlation (convolution) of the input signals.

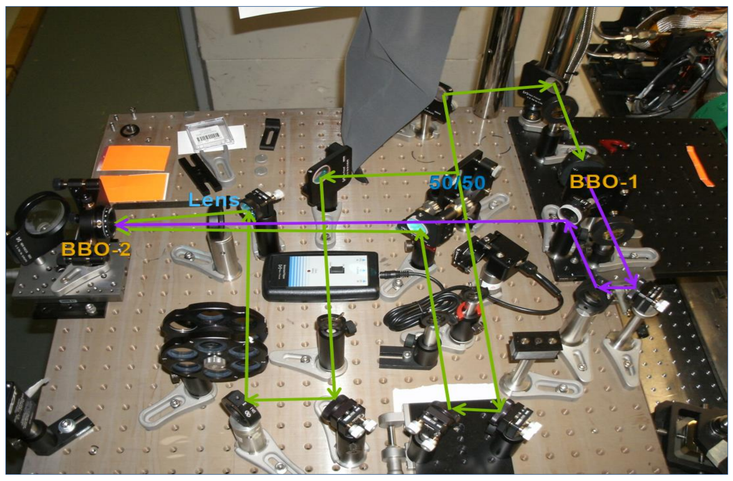
$$I_{AC}(\tau) = \int_{-\infty}^{\infty} I(t) I(t-\tau) dt \qquad (2)$$

Cross-correlation may also be done by focusing two different beams into a crystal. Thereafter by knowing one temporal profile, that of the unknown signal can be analyzed.

Experimental Set Up

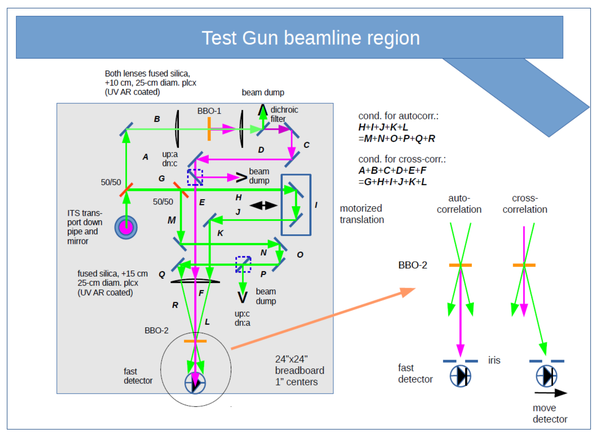
The pulse length was measured at varying and nominal compression of the IR pulse by changing the horizontal retro-reflector (HRR) position in the drive laser system. The ACC optical system was set up in the APS Injector Test Stand (ITS), shown in figure 2.

Figure 2: ACC Arrangement at ITS



A translation station is set up to trace auto-correlation for different pulses with different time delays (varying distance traveled by signal). The signal generated is measured using a Silicon PIN Detector ET – 2070.

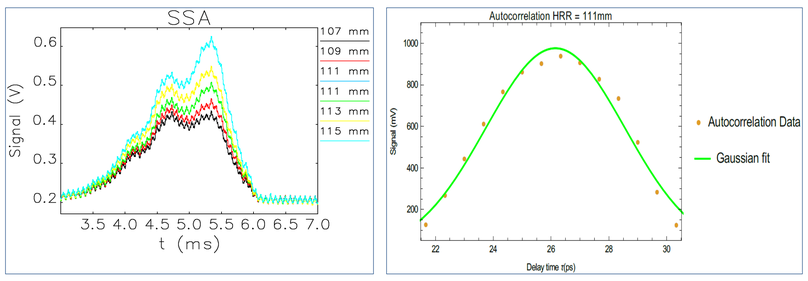
Figure 3: ACC Arrangement Diagram, showing the conditions for the optical instruments for auto- and cross-correlation.



Measurements

The pulse duration of the IR wavelength was measured using a Positive Light Model Single Shot Auto-correlator (SSA), where auto-correlation is traced by a single pulse, whereas the ACC uses multiple pulses with different time delays. Fitting the autocorrelation to a Gaussian distribution and multiplying by a deconvolution factor, the IR wavelength was seen to vary between 2.1 and 2.4 ps (or 4.9 and 5.6 ps FWHM) for maximal and minimal compression respectively.

Figure 4: (Left) Autocorrelation from SSA for IR at different compressions (HRR).(Right): Autocorrelation of green wavelength at nominal compression.

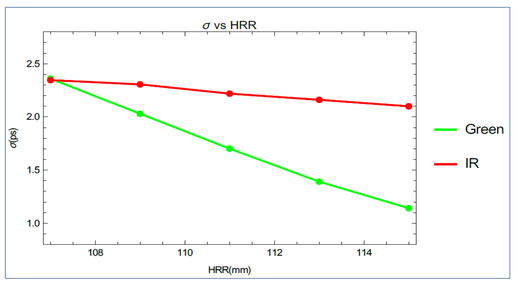


The pulse duration of the green wavelength was measured to vary between 1.14 and 2.36 ps (or 2.66 and 5.5 FWHM) for maximal and minimal compression respectively at an IR amplifier pump current setting of $I_{set} = 160\ A$.

Results and Discussion

The pulse length sigma was compared to the ones calculated for the IR wavelength. Since the power density of the second harmonic is related nonlinearly to that of the fundamental, the pulse length is expected to be lower for higher harmonics. Which is the case for higher compression. The IR is not seen to vary considerably given the different compressions (See Figure 5)

Figure 5: Duration Sigma vs HRR



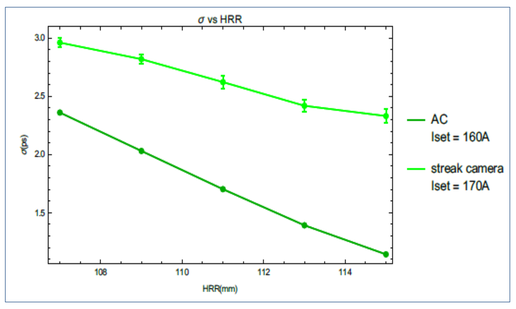
Future Work

Alignment and work is still needed to complete the cross-correlation system. Appropriate focusing of the UV is needed given the dichroism of the optical instruments. When cross-correlation signal is seen the pulse of the UV can be extracted by knowing the profile of the green wavelength.

$$\tau_{cc} = \sqrt{\tau_{UV}^2 + \tau_{green}^2} \qquad (3)$$

Further measurements will be compared with previous measurements from streak camera, to optimize the PC gun beam quality and minimize emittance.

Figure 6: Green Pulse Comparison, Streak Camera measurements were done at $I_{set} = 170\ A$



Acknowledgements

I would like to thank my mentors Jeff Dooling and Yine Sun, the Lee Teng Undergraduate Fellowship, Eric Prebys, and Linda Spentsouris.

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August 10, 2017

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