Quantifying X-ray/Laser Timing Jitter at Interaction Points

Doron R. Sumeruk\textsuperscript{1, 2}, Mat Britton\textsuperscript{1}, Mike Glownia\textsuperscript{1}, Mina R. Bionta\textsuperscript{1}

Introduction and Motivation

- Many LCLS experiments must know the time delay between x-ray and optical laser pulses to perform pump-probe measurements.
- However, XFELs have significant (>100fs) shot-to-shot timing jitter, preventing the study of ultrafast dynamics unless corrected for.
- The Arrival Time Monitor (ATM) uses x-ray induced reflectance changes in a dielectric thin film sample to measure and correct for timing jitter [1].
- Some hutch ATMs are >1m upstream from the interaction point (IP), but the potential additional timing jitter between the ATM and IP is unknown.
- The additional jitter is not measured by the ATM, so we conducted an experiment to quantify it by placing a second ATM at the interaction point.
- Our results will motivate and inform future timing solutions that take into account the additional jitter introduced between the ATM and IP.

Experimental Method

- To quantify the additional jitter, a second temporary arrival time monitor was constructed at the XCS hutch interaction point as shown below.
- A calibration time scan was performed by repeatedly sweeping the nominal delay between laser and x-ray pulses over a several-picosecond window about zero-delay. Several minutes of events were then recorded at a nominal delay of zero with a repetition rate of 120Hz.

Experimental Setup

- The double arrival time monitor experimental setup. The existing spectral ATM was left untouched while a temporary spatial ATM was constructed at the interaction point. The principle of operation for the time-to-pixel position mapping is illustrated with a correlation between spatial and temporal coordinates. The onset of the x-ray induced change in reflectivity manifests as a 'timing edge' between brighter and dimmer regions of the imaged laser spot. The vertically averaged pixel intensity, exhibiting a sharp timing edge, is shown below the raw image. The image shown is of a real timing edge on a YAG sample.

Additional Project: Sample Characterization for 1µm

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Extracting Timing Information

- Divide x-ray event by background, normalize and average over vertical arc.
- Convolve averaged signal with a differential Gaussian. Fit Gaussian to peak of convolved signal.
- Timing edge is located at the peak position of the fitted Gaussian.

Above: Edge-finding algorithm flowchart. Background events consisting of only the optical laser spot were used to isolate the x-ray induced reflectivity change and find timing edges through a convolution and fitting process.

Left: Time-to-space calibration. A calibration line was fitted to the timing edges located during a time scan which swept over nominal delays. The calibration is used to convert timing edge positions into jitters during runs conducted at a nominal delay of zero.

Results

- Above Left: Time-resolved relative reflectance change of a 266nm UV-pumped GaAs thin film. Reflectance was measured with a 1030nm probe. A sharp reflectance increase is present immediately after pumping.
- All hutchs will be upgraded to a ~1μm laser system (1030nm) as part of LCLS-II-HE. Current ATM targets (optimized for 800nm Ti:Sapphire lasers) must therefore be replaced.
- Ideal ATM samples should have a reflectance node near 1030nm, leading to the greatest relative reflectivity change when pumped.

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Conclusions and Future Work

- It is necessary to account for the ~70fs rms of additional jitter to achieve higher time resolution at the interaction point.
- Motivation has been provided for installing a permanent second ATM near the IP which would also enable the correction of long-term timing drifts introduced along the optical laser path.
- We wish to measure IP jitter at hutchs other than XCS (attempts at other hard x-ray hutchs need follow up).

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References