ULTRAFAST ELECTRON SHADOW IMAGING FOR SUB-PS SYNCHRONIZATION OF FEMTOSECOND LASER AND ELECTRON PULSES

H. Park, X. Wang, S. Nie, R. Clinite and J. Cao (FSU, Physics)

Introduction

Recent advances in time-resolved electron diffraction have provided the capability of direct measurement of ultrafast structural changes on the picosecond (ps) and sub-ps time scale. However, one of the most critical issues of synchronizing the femtosecond excitation laser (pump) and probe electron pulses in the interaction region on the sub-ps timescale, remains unresolved. Here we report an independent means for determining the time zero point with sub-ps precision, irrespective of the structural dynamics under investigation. The principle of this approach should be applicable to a variety of diffraction setups, including cross-beam gas phase and transmission diffraction for solids, different target geometry and materials, and laser excitation pulses of different wavelengths.

Results and Discussion

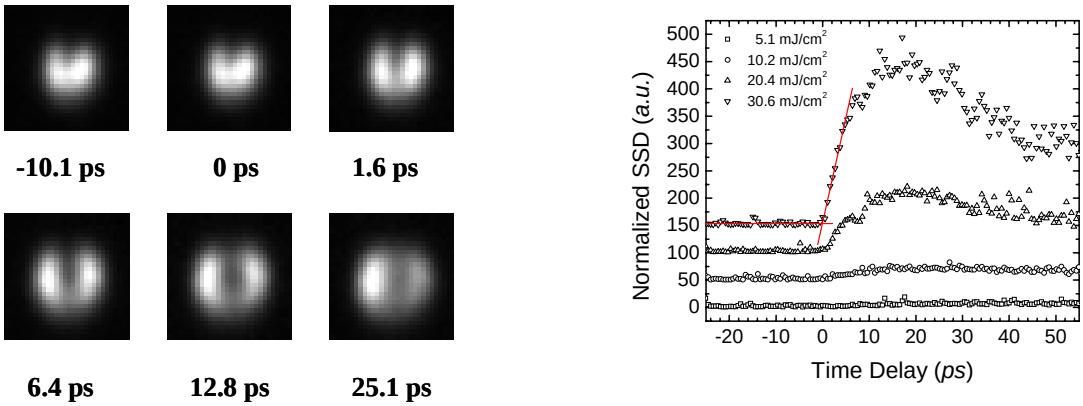

Fig. 1. Dynamics of electron shadow image. Left panel: Temporal evolution of electron shadow images of the silver needle. Each image was recorded using fs electron pulse containing an average of 500 electrons per pulse with 0.5-s integration time. The excitation laser fluence was 30.6 mJ/cm^2 and the corresponding time delays are shown at the bottom of each image. Right panel: Temporal evolution of the SSD curves at different excitation laser fluences. The time step is ~ 530 fs. Positive time delays correspond to the electron pulses arriving after excitation laser pulses. The time zero is defined by the crossing point of two linear fittings, one for the background (horizontal) before laser excitation and the other for the rising edge, shown in the SSD curve at fluence of 30.6 mJ/cm^2.

The method of synchronization is based on the real time imaging of the profile change of an electron beam via its interaction with an intermediary: a transient space-charge field resulting from the laser excitation of a metal surface in a high or ultra-high vacuum. Following intense fs laser excitation, the majority of low energy electrons ejected from the metal surface via both multiphoton photoemission and subsequent thermionic emission stay and accumulate at the photoexcited surface area. The resulting high density electron cloud creates a strong local electric field, commonly referred to as the space-charge effect. This transient space-charge field, if sufficiently large, will perturb a beam of charged particles (such as electrons). Real time and quantitative measurement of this perturbation to the charged particle permits accurate determination of time zero on the timescale primarily determined by dynamics of the transient field's buildup. By quantitatively analyzing the evolution of these shadow images, we are able to synchronize the fs pump laser and probe electron pulses with 700 fs precision, as shownin Fig.1. This sub-ps ultrafast shadow imaging approach can be used to monitor the dynamics of plasma plume injected during pulse laser deposition for optimizing the deposition conditions.

Acknowledgements

The project is supported by the National Science Foundation under the grant number DMR-0305519.

References

[1] H. Park, *et al.*, Rev. Sci. Instrum., **76**, 083905 (2005).