Practical Issues of Retrieving Isolated Attosecond Pulse from CRAB

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Synopsis: The effects of streaking speed, time delay jitter, laser intensity variation and collection angle of streaked electrons on the reconstruction of isolated attosecond extreme ultraviolet (XUV) pulses from the streaked spectrogram are studied.

Single isolated attosecond XUV pulses can be characterized by a technique termed CRAB (Complete Reconstruction of Attosecond Burst) [1]. However, the experimental imperfections of CRAB traces may lead to reconstruction errors. We studied the effects of four major factors on the attosecond retrieval: the streaking speed, the time jitter between the XUV and the streaking field, the streaking laser intensity variation, and the collection angle of streaked electrons [2].

According to the Rayleigh criterion, in order to resolve a sub-100 as XUV pulse, IR laser intensity of at least $5.5\times10^{13} W/cm^2$ is required. Such a high intensity IR field can produce electrons through above-threshold ionization (ATI). When the energy of the ATI electron overlaps with that of the XUV photoelectron, it adds large background noise to the CRAB trace. When the PCGPA algorithm was used on synthetic data, it was found that even with the intensity which is two orders of magnitude smaller than that based on Rayleigh criterion, PCGPA can still retrieve XUV pulse, as shown in Fig.1.

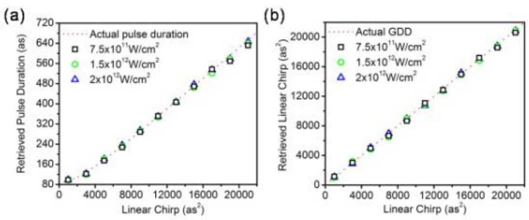

Figure 1 (a) Retrieved XUV pulse duration as a function of input linear chirp for different streaking intensities. (b) Retrieved linear chirp as a function of input linear chirp for different streaking intensities.

The IR streaking beam and XUV beam propagate through different optics. Due to mechanical vibration, the time delay between them changes from one laser shot to the next. This time delay jitter broadens the CRAB trace. In our simulation when the delay jitter goes to one quarter of the IR laser cycle, the XUV pulse duration can still be retrieved within an error of 6% and the linear chirp can be retrieved within an error of 10%. Thus, this property of the CRAB relaxes the need for tight CE phase locking and delay stability in streaking experiments.

The streaked electrons are produced in a finite volume of the gas target. The IR intensity is a function of both transverse and longitudinal positions. In our simulation even when the XUV spot size is comparable to the IR spot size at the focus, the XUV pulse duration and linear chirp can still be retrieved within an accuracy of 5%. This releases the constraint of constant streaking intensity and can easily be realized experimentally.

Due to the low photon flux and small cross section of the XUV interaction with atoms, the streaked electrons are usually collected within a certain range of solid angle. In our simulation, even when the collection angle is increased to 90 degrees, the XUV pulse duration and linear chirp can still be retrieved within an error of 5%. This property of the CRAB opens the door for detection schemes with large collection angles, such as magnetic bottle detectors and velocity map imaging.

In conclusion, four practical issues in attosecond streaking experiments were discussed when PCGPA was applied to retrieve the XUV pulse from the CRAB trace. We found that the streaking can be performed at a laser intensity level much lower than that estimated from the Rayleigh criterion, which is desirable to suppress the ATI background. The reconstruction is robust against time jitter, volume effects and large collection angle, which releases the constraints on the experiments. This material is supported by the U. S. Army Research Office under Grant No. W911NF-07-1-0475, and by the Chemical Sciences, Geosciences, and Biosciences Division, U.S. Department of Energy.

References

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