Attomicroscopy: Towards imaging the electron motion by 4D Electron Microscopy

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Abstract:

Ultrafast Electron Microscopy (UEM) has been demonstrated to be an effective table-top technique for imaging the temporally-evolving dynamics of matter with subparticle spatial resolution on the time scale of atomic motion [1]. However, imaging the faster motion of electron dynamics has remained beyond reach. A major enhancement of the UEM temporal resolution is a prerequisite for recording snapshots of the electron motion which will provide real-time access to all microscopic motions outside the atomic core and radically change our insight into the workings of the microcosm [2-3]. Here, we demonstrate more than an order of magnitude (16 times) enhancement in the typical temporal resolution of UEM by generating ~ 30 fs electron pulses, accelerated at 200 KeV, via the optical-gating approach, with sufficient intensity for efficiently probing the electronic dynamics of matter. Moreover, we investigate the feasibility of attosecond optical gating to generate subfemtosecond electron pulses utilizing the optical attosecond pulse [4,5], attaining the desired temporal resolution in electron microscopy for establishing the “Attomicroscopy” to allow the imaging of electron motion in the act.

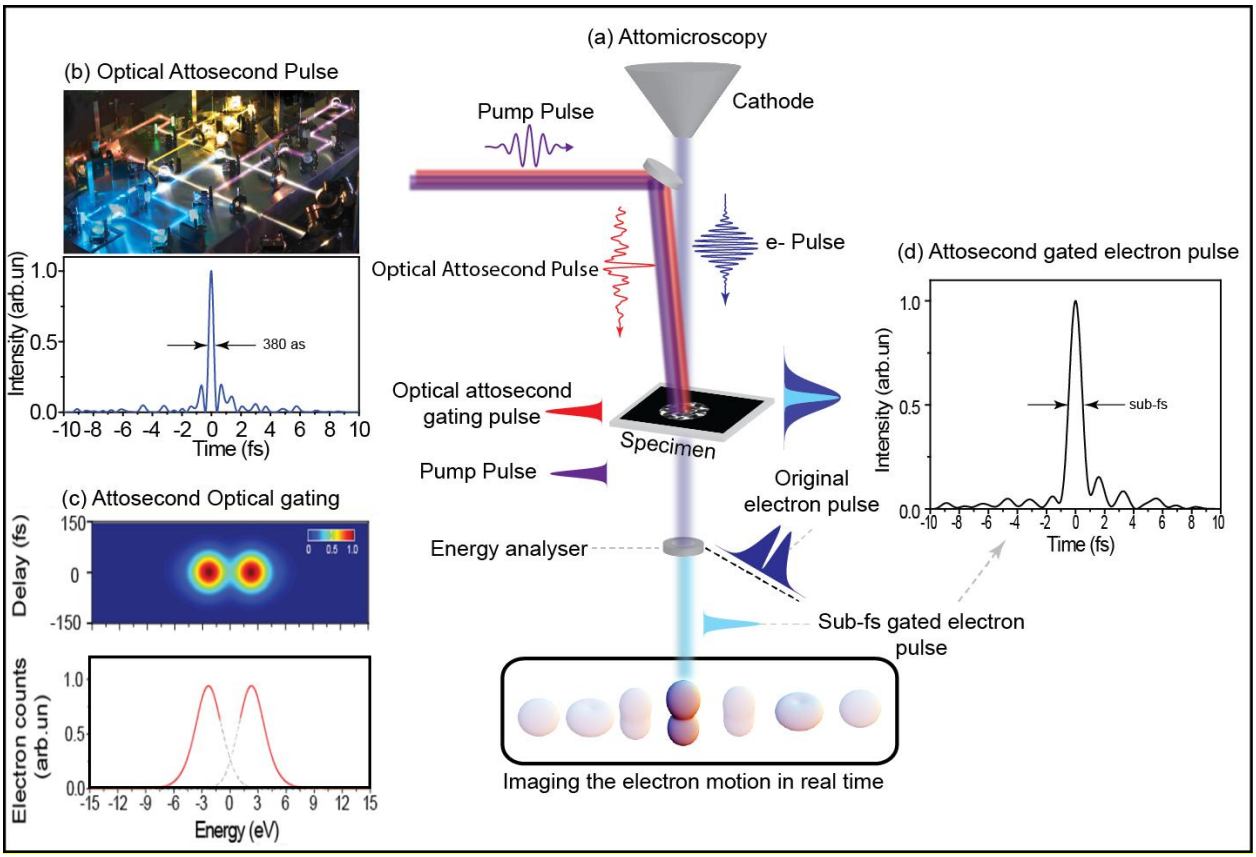

Fig. 1. Attomicroscopy: imaging the electron motion in real time. (a) Attomicroscopy setup, the optical attosecond pulse, synthesized by the light field synthesizer, illustrated in (b) is utilized to gate an ultrafast electron pulse to generate sub-fs electron pulse in (d). The simulated delay and energy dependence of intensity (spectrogram) of the gated electron for coupling between the optical attosecond pulses and 75 fs electron pulses, and the corresponding spectrum at 0 fs delay, is given in (c), with the residual ZLP subtracted for better visualization.

References:

[1] Zewail, A.H. and J.M. Thomas, *4D Electron Microscopy:* Imperial College Press, (2010).

[2] Goulielmakis, E., et al., Nature, **466**, 739-743 (2010).

[3] Calegari, F., et al., Science, **346**, 336-339 (2014).

[4] Hassan, M.T., et al.,Nature, **530**, 66-70 (2016).

[5] Hassan, M.T., et al., Nature Photonics **11**, 425–430 (2017).