Inner Shell Excitations through Laser Induced Electron Recollision

Gilad Marcus* [1], **Yunpei Deng**†, **Zhinan Zeng**‡, **Zhengmao Jia**‡, **Pavel, Komm***, **Yinhui Zheng**‡, **Xiao-chun Ge**‡ **and Ruxin Li**‡

* Department of Applied Physics, Hebrew University of Jerusalem, Jerusalem 91904, Israel.
† SwissFEL, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland.
‡ State Key Laboratory of High Field Laser Physics, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Shanghai 201800, China

Synopsis Sub-femtosecond excitation of inner-shell electrons is a prerequisite step toward time domain "pump-probe" study of core-hole dynamics. By using a few cycles 1800nm source, we show that the recolliding electron might provide this necessary step.

Excitations of electron from deep inner shells are usually accompanied by multi-electron dynamics such as double excitation, the Auger decay, Cooper minima, and the giant resonance, which cannot be explained by the single active electron approximation. Such excitations are unstable and usually decay on a timescale ranging from few femtosecond to few attosecond. The decay may take place in a single step, but more often occurs as a cascade of radiative and non-radiative channels. To follow such dynamics, one resorts to a time domain pump-probe spectroscopy Since the relevant timescale for such dynamics spans from attosecond to femtosecond and the relevant energy-scale spans from 10^2 -10^5 eV, x-ray attosecond bursts may be the choice to serve as the pump and the probe events. However, with the low photon flux of current soft x-ray attosecond sources (hν >300 eV) and the low absorption cross-sections in this spectral range, it is currently impossible to both pump and probe these processes with attosecond x-ray pulses. Excitation of inner-shell dynamics by laser-induced electron recollision might be the solution. Such an excitation process occurs in a sub-femtosecond timescale, thus, provides the necessary "pump" step in "pump-probe" studies of inner-shell dynamics.

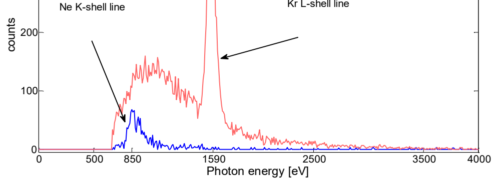

Figure 1. Characteristic fluorescence lines and continuum x-ray induced by electron recollision (Ne K-shell: blue, Kr L-shell: red).

In this work, we show core-hole excitation by the recolliding electron [1], as opposed to previous indirect evidences [2,3]. In our experiment, we focus a 12 fs, 1mJ infrared radiation source (λ_0 =1.8 μm) on a pulsed gas-jet and observed the soft x-ray radiation from the interaction region. The reason for using infrared laser instead of 800 nm laser is the quadratic scaling of the ponderomotive energy with the wavelength of the drive laser. According to the semi-classical three steps model, the maximum energy an electron may come back with, when it collides with the parent ion is equal to $3.17U_p$ and proportional to $I_0\lambda^2$. Here, U_p is the ponderomotive energy, I_0 and λ are the peak intensity and the central wavelength of the drive field respectively. This quadratic scaling with the laser wavelength allow for high kinetic energy of the recolliding electron without ionizing the target atoms too much. We observed x-ray fluorescence radiation from krypton L-shell and neon K-shell along with a continuum x-ray (see figure 1). To prove that this excitation is coming from recollision and not just from mere heating of the plasma, we measured both the directionality of the x-ray emission with respect to laser linear polarization and the x-ray yield against the laser polarization

References

[1] Y. Deng *et.al.2016 Phys. Rev. Lett.* **116**, 073901
[2] G. Marcus *et.al 2012 Phys. Rev. Lett.* ***108**, 023201*
[3] A. D. Shiner *et al*. 2011 *Nature Physics 7, 464–467*

[1] E-mail: Gilad.marcus@mail.huji.ac.il