Attosecond Quantum Eraser

A J Verhoef[1], A Fernández[1], A M Zheltikov[1], M Y Ivanov[2], A Baltuska[3], and M O Scully[1]

[1] *Institute for Quantum Science and Engineering (IQSE) , Texas A&M University, College Station TX, USA*
[2] *Theory Department, Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Berlin, Germany*
[3] *Photonics Institute, TU Wien, Vienna, Austria*
Contact Email: aart.verhoef@tamu.edu

The quantum eraser experiment is one of the most intriguing phenomena to demonstrate consequences of entanglement. In basic terms, when using entangled particles in a double slit experiment, interference is erased when one of the entangled particles can reveal information on the path of the second particle. In our attosecond experiment, we observe spectral interference when we couple Auger decay and resonant Auger decay pathways after broadband soft X-ray excitation, in a similar way as interference was observed in the attosecond double slit (ATI) experiment [1]. One could consider this experiment to be complementary to a delayed-choice quantum eraser experiment, where the point of birth information of the second particle can erased (by design of the experiment) after detection of the first. In the attosecond quantum eraser experiment, the path information is deleted by optically addressing an observer electron-ion pair during the decay, which, in other words, "erases" the memory of the observers after the path was chosen.

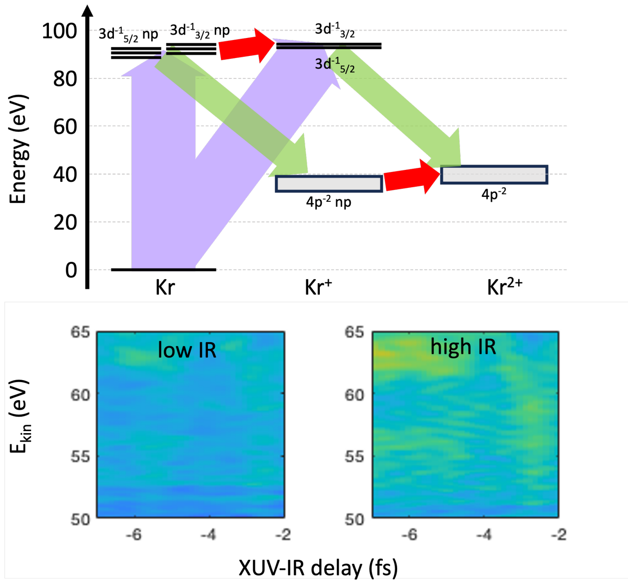

Figure 1: Schematic representation of the excitation-decay paths in our attosecond quantum eraser experiment. The red arrows indicate the IR pulse erasing the path information. Bottom: the observed spectral interference of the Auger electrons when the IR pulse comes after the attosecond soft X-ray pulse

The attosecond quantum eraser scheme is as follows: A broadband soft X-ray pulse excites or ionizes a core-shell electron (3d) from a krypton atom [2]. Following this pulse, the highly excited krypton atom or ion will emit an Auger electron from the 4p shell when another 4p electron fills the 3d hole. Under normal conditions, even when the emitted 4p (resonant) Auger electrons can have overlapping energy spectra, no interference of these electrons can be observed, as there is the option for detection of the charge state of the resulting Kr ion, as well as the presence or absence of a low-energy electron, to allow determination of the excitation-decay path. Thus, to erase the path information, two factors need to be addressed: First of all, the Rydberg electron needs to be removed from the resonantly excited krypton; and second, this electron needs to be made indistinguishable from the low-energy electron that is emitted when the 3d electron is ionized. We achieved this with a strong infrared field slightly delayed to the soft X-ray pulse. At this point, the Auger decay is well underway, and the infrared field can efficiently address the possibly present Rydberg electron, ionize it and mix it with the possibly present ionized (from the 3d shell) electron. Thus, we erase which-path information from a 3-particle "entangled" state. An intriguing part in this experiment is that while in essence a single photon process, infrared ionization from the Rydberg state is very weak, and its probability is strongly modulated by the Auger decay: Therefore, we observe that the interference pattern shifts with delay (see figure 1) between the soft X-ray pump and infrared probe pulse.

References

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