Quantum State Preparation and Holography

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The ability to prepare and observe arbitrary quantum superpositions is an important step towards tailored chemistry. We explore the ability to use a tailored sequence of pulses to prepare an arbitrary electron wave packet (EWP) in He I. To observe that the desired wave packet was formed, we use a holographic technique, pioneered in [1, 2]: a XUV pump pulse (P_1) is used to excite an ensemble of bound states simultaneously as a continuum EWP is produced. By applying a VUV probe pulse (P_3) at a later time, the excited electrons can be ionized and interfere with the continuum wave packet. The tailoring is achieved by adding an extra pulse (P_2) resonant with the 1s2p–1s3s transition of He I (see figure 1). By tuning the intensity of this control pulse, we are able to shift the population between the different states, later probed by P_3 (see figure 2).

The calculations are done by solving the time-dependent Schrödinger equation in the single active electron approximation, with a very fast, newly developed GPU code that can process ~ 70 k grid points/ms.

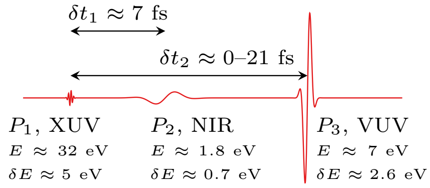

Figure 1: *The pulse scheme: P_1 is a XUV pump pulse, with broad bandwidth, capable of exciting/ionizing the atom to many bound/continuum states. P_2 is a control pulse in resonance with a bound transtition. P_3 is a probe pulse, ionizing the remaining bound states into the continuum, where they will interfere with the states ionized by the pump pulse.*

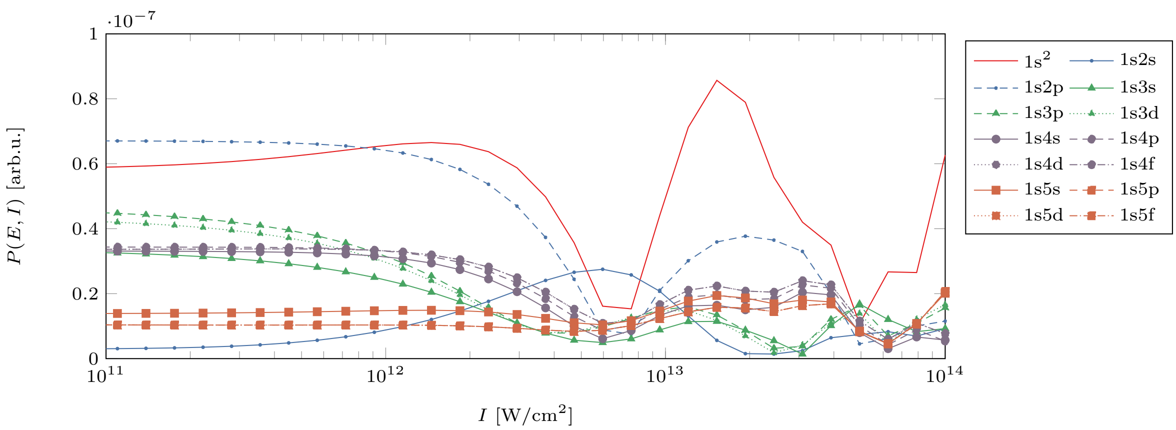

Figure 2: *Amplitude of the different photoelectron peaks, corresponding to bound states of He I, as a function of control pulse (P_2) intensity. The peaks are those found in the β_1 coefficient in the Legendre decomposition of the angular photoelectron spectrum, corresponding to transitions driven with an odd number of photons.*

References

[1] J. Mauritsson *et al.* Phys. Rev. Lett. **105** 053001 (2010), doi:10.1103/PhysRevLett.105.053001

[2] K. Klünder *et al.* Phys. Rev. A **88**(3) 033404 (2013), doi:10.1103/PhysRevA.88.033404