Attosecond Pulse Trains Generated using Two Color Laser Fields

J. Mauritsson[1, 2], P. Johnsson[1], E. Gustafsson[1], A. L'Huillier[1], K. J. Schafer[2] and M. B. Gaarde[2]
[1] *Dept. of Physics, Lund University, P.O. Box 118, S-221 00 Lund, Sweden*
[2] *Dept. of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803-4001 USA*

We present the generation of attosecond pulse trains from a superposition of an infrared (IR) laser field and its second harmonic. Our attosecond pulses are synthesized by selecting a number of synchronized harmonics generated in argon. By adding the second harmonic to the driving field the inversion symmetry of generation process is broken and both odd and even harmonics are generated. Consecutive half cycles in the two color field differ beyond the simple sign change that occurs in a one color field and have very different shapes and amplitudes. This sub-cycle structure of the field, which governs the generation of the attosecond pulses, depends strongly on the relative phase and intensity of the two fields, thereby providing additional control over the generation process.

The generation of attosecond pulses is frequently described using the semi-classical three step model where an electron is: (1) ionized through tunneling ionization during one half cycle; (2) reaccelerated back towards the ion core by the next half cycle; where it (3) recombines with the ground-state releasing the access energy in a short burst of light. In the two color field the symmetry between the ionizing and reaccelerating field is broken, which leads to two possible scenarios: the electron can either be ionized during a strong half cycle and reaccelerated by a weaker field or vice versa. The periodicity is a full IR cycle in both cases and hence two trains of attosecond pulses are generated which are offset from each other. The generation efficiency, however, is very different for the two cases since it is determined mainly by the electric field strength at the time of tunneling and one of the trains will therefore dominate the other.

We investigate experimentally both the spectral and temporal structure of the generated attosecond pulse trains as a function of the relative phase between the two driving fields. We find that for a wide range of parameters trains of attosecond pulses with only one pulse per IR cycle are generated. The presence of one attosecond pulse per IR cycle may furthermore be taken as evidence that consecutive pulses in the train have the same carrier envelope phase. When the attosecond pulses interact with a gas of atoms, electron wave packets are created if the photon energy exceeds the ionization potential. The wave packets are temporally localized with properties that are directly inherited from the attosecond pulses. If the ionization takes place in the presence of a strong IR field an energy exchange between the electrons and the field occurs. The amount of energy exchanged depends on the timing with respect to the phase of the IR field when the electrons are injected into the continuum. Using trains with only one pulse per IR cycle, all the wave packets are injected with the same timing with respect to the IR field, thus enabling us to measure their dynamics in the dressed continuum. Using a velocity map imaging spectrometer we can measure a projection of the three dimensional electron distributions.

Corresponding author: Johan Mauritsson, Johan.Mauritsson@fysik.lth.se