Ponderomotive streaking of the ionization potential as a method for measuring pulse durations in the XUV domain with fs resolution

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We present a new method for measuring ultrashort XUV pulses that can be synchronized with an intense infrared pulse of similar duration. The method is based on the change of the photoelectron energy spectrum resulting from ionization with the high-frequency pulse due to the ponderomotive shift of the atomic ionization potential induced by the more intense pulse of longer wavelength. We demonstrate our method by measuring the duration of high-harmonics generated by an infrared laser beam in an Ar gas jet. These harmonics are sent on a second Ar jet to ionize atoms that are exposed simultaneously to part of the fundamental beam. This "dressing" infrared shifts the ionization threshold of the Ar atoms, but is not intense enough to ionize the atoms by multiphoton processes. The XUV photons are energetic enough to ionize the atoms in an one-photon process.

The ionization potential increases ponderomotively when the atoms interact with a strong electric field. This ponderomotive shift equals the time-averaged kinetic energy of an electron oscillating in a laser field and depends on intensity I as: $U_p[\mathrm{eV}]=\alpha\times I\ [\mathrm{W/cm^2}]$, with $\alpha=9.33\times10^{14}\times\lambda^2\ [\mu\mathrm{m}^2]$. The energy of the photoelectrons is dependent on the instantaneous value of the ionization potential, which is changing rapidly in time according to the variation of the infrared-pulse intensity. The region of quasi-linear variation of the infrared intensity in time is the most suited for time measurements of short XUV pulses, because it implies a linear dependence on time for the U_p mapping the duration of the pulse into broadening of electron peaks. The duration of the XUV pulse can then be derived as the FWHM of the corresponding photoelectron peak over the variation speed of the ionization threshold. The natural width of the peaks and the presence of sidebands in the spectrum set a lower limit on the pulse duration for which this method can be applied to about $\simeq$3 fs.

The method has a potential resolution of 1 fs. Results of numerical simulations are also presented.