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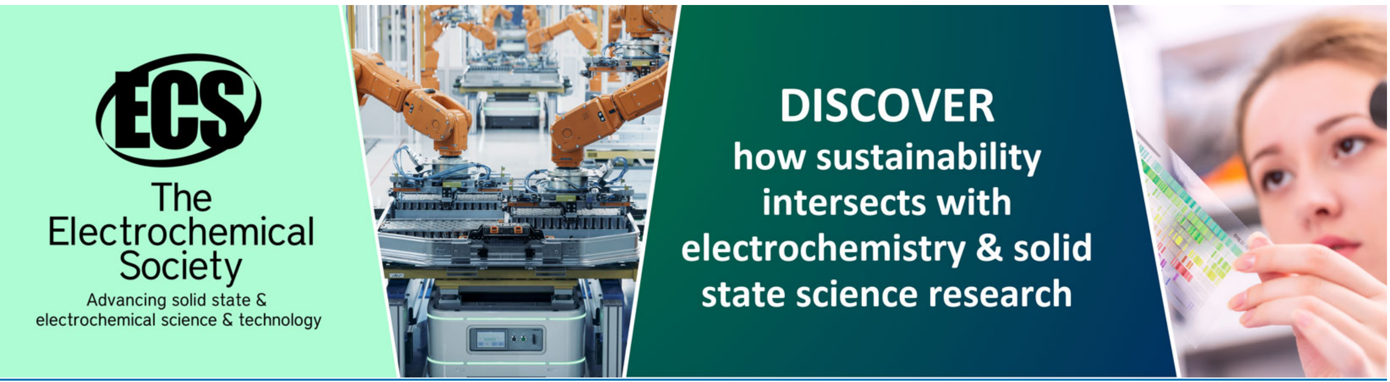


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# High-energy ultrafast mid-IR optical parametric amplifier for strong-field science

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**Synopsis** We present a high-energy mid-infrared optical parametric amplifier source tunable between 2.8 and 3.8 $\mu$m for strong-field applications. We exploited this source in combination with a 800 nm source for generating high-order harmonics in atoms and molecules in a two-color pulse scheme.

Ultrafast laser sources in the mid-infrared region are of great interest for strong-field physics and spectroscopy. In particular, they enable the extension of the cut-off energy of the high-order harmonic generation (HHG) spectrum, thanks to the ponderomotive energy scaling of the rescattering electrons (Up $\propto \lambda^2$). Moreover, they allow to perform time-resolved vibrational spectroscopy of infrared active modes of many organic molecules [1, 2].

We present a 1-kHz broadband, tunable, mid-IR three-stage optical parametric amplifier (OPA) based on Potassium Titanyl Arsenate (KTA) crystals driven by a commercial 25-fs Ti:Sa laser. The mid-IR seed pulse is generated in the first stage via intra-pulse difference frequency generation and subsequently amplified in two stages. The output pulses have sub-90 fs duration, a maximum energy of 300 $\mu$J at 3.25 $\mu$m, and they are tunable in the range 2.8-3.8 $\mu$m.

The mid-IR source was used in combination with the fundamental 800-nm source for generating high-order harmonics in atomic and molecular gases. The mid-IR pulses were tuned to 3.25 $\mu$m with a 200-nm bandwidth FWHM and had an on-target energy of 70 $\mu$J, whereas the 800-nm pulses had an energy of about 170 $\mu$J and a duration of about 50 fs. Fig. 1a shows HHG spectra in Krypton as a function of the delay between the mid-IR and the 800 nm pulses. In the region of temporal overlap between the pulses, a spectral modulation is observed. In particular, sidebands at harmonics of the mid-IR component appear at different delays, along with a strong suppression of the main 800-nm harmonics. In order to understand the origin of this spectral modulation, we performed simulations based on the strong-field approximation (SFA) [3]. The simulation results are reported in figure 1b.

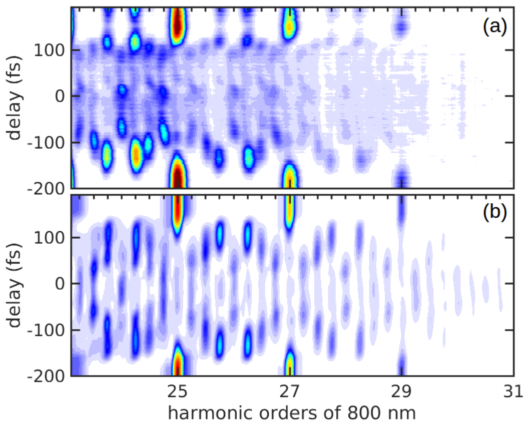


**Figure 1**. HHG spectra in Krypton as a function of the delay between the 800-nm pulse and the mid-IR pulse. (a) Experimental data; (b) theoretical simulation based on SFA.

The good agreement between the theoretical results and the experiment demonstrates that the observed sidebands in the region of the overlap can be ascribed to the perturbation of the electron trajectories induced by the 3.25 $\mu$m field.

Further investigations in both atomic and molecular systems are underway and will be presented.

## References

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