キャリア包絡線位相制御されたサブサイクル近赤外光パラメトリック増幅システムの開発

Development of an optical parametric amplifier laser system delivering CEP-stabilized sub-cycle pulses in SWIR region

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Development of a laser system generating an intense single- or sub-cycle pulse with controllable carrier-envelope phases (CEPs) have grown into a worldwide trend in the research fields of ultrafast optics, since it is promising for various pioneer applications in strong-field physics, such as the generation of isolated attosecond pulses, electron acceleration, the wave-packet dynamics in atoms and molecules, and so on. In this talk, we will first introduce our recent work on the development of a sub-cycle short-wave infrared (SWIR) optical parametric amplification (OPA) system and its related works [1-3]. In the second part, we will show the arbitrary control of the CEPs for the resultant sub-cycle pulses.

In the OPA system, we adopted two key features for realizing such an extreme laser source with over-octave bandwidth and sub-cycle optical pulse duration. One is by carefully tuning the wavelength of the pump pulse to obtain a gain bandwidth of more than one octave for a BBO crystal. The other is to divide and synthesize the spectral components of the ultra-broadband pulse in a Mach-Zehnder-type interferometer set in front of the final amplifier, which enabled us to control the dispersion of each spectral component with an acousto-optics programmable dispersive filter (AOPDF) inserted in each arm of the interferometer. As a result, sub-cycle pulses of 0.73 cycles at 1.8 μm with a pulse energy of 32 μJ were successfully generated.

The CEP of the generated sub-cycle pulses consisting of two adjacent spectral components is controlled by operating the two individual AOPDFs applied to each of the two spectral components [4]. The total CEP shift of the synthesized sub-cycle pulse is modulated with simultaneous scans of the CEPs. The resultant error of the controlled CEP was 642 mrad in an open-loop operation and it is useful for searching for zero CEP of the synthesized pulse with the maximum amplitude. Furthermore, we perform a closed feedback loop to compensate for the CEP fluctuation by employing the two AOPDFs simultaneously. For the CEP stabilization, we successfully showed that the RMS error for the CEP shift of the output pulses can be reduced from 399 mrad to 237 mrad by using the two AOPDFs with a feedback bandwidth of only 12 Hz.

In the last part, we will report recent employment of the SWIR light source to generate a CEP controllable, sub-cycle optical vortex beam [5] for further applications in singular optics and light-matter interaction.

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