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Laserové centrum Hilase Vás zve na seminář

A Kerr Lens Mode-locked Thin-disk Ring Oscillator Enabling Intra-cavity High-order Harmonic Generation Beyond 10 MHz Repetition Rate

(RIKEN Center for Advanced Photonics)

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The repetition rate of lasers used for high-order harmonic generation (HHG) in the extreme ultraviolet (EUV) spectral region is much less than 600 kHz, due to thermal lensing and other obstacles in development of high-average-power laser amplifiers. To apply high-order harmonic (HH) pulses in research areas such as photoelectron spectroscopy, bio studies or EUV lithography mask inspection, a much higher repetition rate of the order of several MHz is required. To address this issue, we propose a novel route of HHG inside a mode-locked thin-disk ring oscillator. In this talk, we will present the current status of development of our thin-disk ring oscillator and its application in intra-cavity HHG at a repetition rate beyond 10 MHz.
Progressive development of commercial thin disk heads has enabled generation of kW average power laser beams inside an oscillator. However, efficient HHG requires short femtosecond laser pulses with a pulse energy of at least 100 µJ, which calls for a scalable and reproducible mode-locking technique. Kerr lens mode-locking (KLM) having a high modulation depth and a short relaxation time can yield short laser pulses. Besides, this technique is widely accessible to the scientific community. These features have made KLM an alternative technique of mode-locking in thin-disk oscillators. However, KLM involves a high nonlinear phase shift due to self phase modulation (SPM), which limits the intra-cavity pulse energy and can result in multiple pulses in the sub-ns range. By balancing SPM with high-dispersion (GDD=-2000 fs2) GTI mirrors, we could increase the intra-cavity pulse energy of our ring oscillator to 68 µJ with a pulse duration of 470 fs at 15.48 MHz.

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As an upgrade of our thin-disk ring oscillator, we replaced the thin disk head and rebuilt the ring oscillator on a water-cooled optical table to avoid alignment changes. As a result, we could obtain 73.6±0.43 W of output power with a pulse duration of 522 fs at 13.08 MHz at a pump power of 305 W. To the best of our knowledge, the obtained intra-cavity pulse energy of ~80 µJ is the highest value ever reported in a Kerr lens mode-locked oscillator with a repetition rate higher than 10 MHz. Further intra-cavity pulse energy scaling is limited to SPM of the air inside such a giant laser cavity. Since only a single pulse is generated inside the ring oscillator, the estimated peak intensity inside the Kerr medium is 0.2 TW/cm2, which has enabled generation up to the third harmonic directly in this medium. Recently, by adding another vacuum chamber inside our ring oscillator, which contains a compact HHG setup, we have been able to observe generation of a bright plasma in Xe and Kr target gases near the focal point of a concave mirror pair under an estimated peak intensity of 28 TW/cm2. This should enable us to out couple HH pulses in a spectral region of 100 nm, in the near future.

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