EPJ Web of Conferences **267**, 01050 (2022)
EUROPHOTON 2022
https://doi.org/10.1051/epjconf/202226701050

Towards Carrier-Envelope Phase Stabilization of a 110 MW Thin-Disk Oscillator

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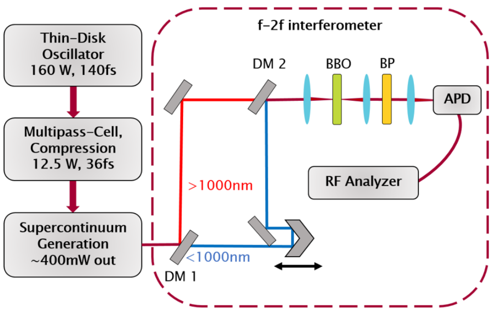
Deep ultraviolet (UV) and extreme ultraviolet (XUV) spectral regions are of high interest for precision spectroscopy and metrology applications. For example, the 1S-2S transition of He^+ ions requires a coherent deep UV source around 60.8 nm. Another appealing application is the possibility to create ultra-precise nuclear clocks based on the transition at approximately 150 nm in Thorium-229 [1].

To reach this spectral region one straightforward approach can be frequency up-conversion via high harmonic generation in a gas jet, driven by an existing near-infrared laser. An ideal starting point for this approach can be a home-built carrier-envelope phase (CEP) stabilized thin-disk oscillator [2], delivering 110 MW output peak power at 14 MHz repetition rates. For high harmonic generation, it is necessary to achieve pulses from the oscillator with a low intensity noise. Additionally, to efficiently reach the spectral region, the laser is required to be CEP and repetition-rate stabilized [3]. So far, first steps towards the stabilization with an intra-cavity acousto-optic modulator were performed and the detection of the carrier envelope offset frequency was implemented.

Here, the detection of the carrier envelope offset frequency is demonstrated. First, 12.5 W of the oscillators output power were sent through a multipass-cell (Fig.1 (a)) to spectrally broaden and temporally compress the pulses down to 36 fs. Then, 1 W of the cell output power was used for the generation of an octave spanning spectrum in a 16 cm long photonic crystal fiber (NKT-Photonics LMA-PM-5) with an efficiency of 50 %. The resulted white light was coupled into a f-2f interferometer (Fig.1 (a)). To achieve a temporal overlap, the interferometer arm, covering the blue part of the spectrum, was delayed. The fundamental wavelength at 1440 nm was frequency doubled in a beta barium borate (BBO) crystal. The beat signal was detected with a highly sensitive avalanche photodiode and optimized up to a magnitude of 30 dB (Fig.1 (b)), measured with an RF spectrum analyzer and a resolution bandwidth of 10 kHz. As a next step towards CEP stabilization of the thin-disk oscillator, this beat signal will be send to a phase locked loop including a digital phase detector and PI^2D controller.



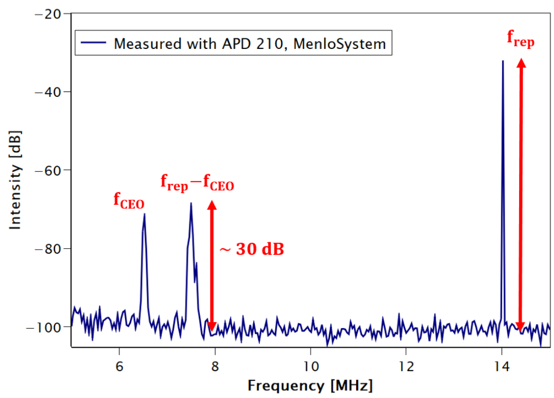


Fig. 1 **(a):** Schematic setup for the f-to-2f interferometer. DM: Dichroic mirror, BBO: Beta-Barium-Borate nonlinear crystal, BP: Bandpass filter at 720 nm, APD: avalanche photo-diode. **(b):** Beat signal and repetition rate with a resolution bandwidth of 10 kHz.

The detection of the beat signal was a first step for CEP stabilisation of the 110 MW thin-disk oscillator. This heterodyning beat signal remained reproducibly and well pronounced. The magnitude of the beat signal needs to be improved to a level of 40 - 50 dB. The stabilization via intra-cavity loss modulation through an acousto-optic modulator and a feedback loop is a work in progress. The CEP stabilization of the thin-disk oscillator paves the way towards the first directly oscillator driven XUV frequency comb.

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