Towards an XUV frequency comb for precision spectroscopy of trapped highly charged ions

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Highly charged ions (HCI) are atomic systems with a few tightly bound electrons. They offer many advantages over neutral and singly charged ions for probing fundamental physics and recently, they have been proposed as candidates for novel frequency standards [1]. Many optical transitions of HCI are located in the extreme ultraviolet (XUV). To study these transitions with high precision, a coherent ultra-narrow light source in this spectral region is required. For these reasons, we are developing an XUV frequency comb. High-harmonic generation (HHG) is used to transfer the coherence and stability of a near infrared frequency comb to the far ultraviolet [2-4]. Reaching intensity levels ($\sim 10^{14}$ W/cm$^2$) necessary for HHG, while operating at high repetition rates to achieve adequate comb-line spacing, is challenging. Therefore, the comb laser pulses are first amplified in a chirped-pulse fiber amplification setup and then resonantly overlapped in an astigmatism-compensated femtosecond enhancement cavity. To achieve high stability and low-noise performance, the cavity is placed on a rigid titanium structure with vibrational decoupling from the vacuum pumps. High-harmonics are generated in a target gas in the tight focus of the cavity. In other experiments, mirror degradation due to hydrocarbon aggregation is observed, which limits continuous operation time of XUV combs [4, 5]. To avoid this, we operate the cavity under ultra-high vacuum conditions. A differential pump setup will enable a high pressures of the HHG target gas without impairing the vacuum in the chamber, as shown in Fig. 1.

![Fig. 1: Overview of the femtosecond enhancement cavity focus region. High-harmonics are generated in a gas jet in the cavity focus. The collinearly propagating XUV pulses are coupled out by a grating etched into a flat cavity mirror. A differential pump setup around the gas jet prevents gas from entering the main vacuum chamber to maintain ultra-high vacuum conditions.](image)

The generated XUV light will be coupled out of the cavity by minus-first order diffraction of a small-period grating etched into a high-reflective cavity mirror directly behind the gas target [6]. Then, the light can be guided to trapped and sympathetically cooled HCI in a superconductive cryogenic linear Paul trap (CryPTEx II experiment at MPIK, based on [7]). By driving narrow transitions with individual comb lines, high-precision XUV spectroscopy of HCI will become possible for the first time [8].

References


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