An extreme ultraviolet frequency comb for highly charged ion metrology

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Highly charged ions (HCI) have been proposed as extremely sensitive probes for physics beyond the Standard Model, such as a possible α-variation, and as novel frequency standards, due to their insensitivity to external fields [1]. Recent advances have enabled sympathetic laser cooling [2] and quantum logic spectroscopy of HCI [3]. We aim at performing ultra-high precision spectroscopy of HCI in the extreme ultraviolet (XUV) region [4], where many transitions are located. Therefore, we have developed an XUV frequency comb [5].

Femtosecond pulses from a 100 MHz phase-stabilized near-infrared comb are amplified and fed into an enhancement cavity inside an ultra-high vacuum chamber. In the tight focus ($w_0 = 15\,\mu$m) of the astigmatism-compensated cavity, intensities $\sim 10^{14}$ W/cm^2 are reached. As a first application, we perform multi-photon ionization of xenon using the velocity-map imaging technique [6]. The high repetition rate facilitates fast data acquisition even at low intensities, enabling future precision tests in nonlinear physics. Finally, we have observed outcoupled XUV radiation, produced in the cavity focus, up to the 35th harmonic order (42 eV; 30 nm) [7]. No signs of mirror degradation were observed during five hours of continuous operation. Using He:Xe gas mixtures, improved phase-matching conditions led to 49 μW output power at 16 eV.

The intensity of the XUV is sufficient to drive HCI transitions with kHz excitation rates [8]. Successful operation of the comb is an important milestone towards XUV frequency metrology with HCI, for which a superconducting linear Paul trap has recently been commissioned at the MPIK [9].

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