Precision atomic spectroscopy with phase-coherent VUV pulses

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Electromagnetic (EM) wave, whichever it is microwave or optical radiation, is basically described by amplitude, phase and polarization. Among them, the phase is the most important parameter on which lots of applications rely. When we trace back the history of our effort to use EM wave, we notice that the key was how accurately we can define the phase in a higher carrier frequency. Skillful manipulation of the microwave (~GHz) phase instead of radio wave (~MHz) phase allowed many people to share limited frequency band for cell phones. The optical phase as stable as microwave phase is realized by lasers which dramatically expanded the capability of EM wave oscillator. Therefore, it is quite natural as the next step to pursue phase stabilized vacuum ultraviolet (VUV) or higher radiation. It is not straightforward, however, to extend the laser's stable optical phase to higher frequency because the elements used to build optical lasers normally don't work for VUV or higher due to strong absorption of material. This difficulty made optical physicists pursue the high harmonic generation (HHG) of near infrared (NIR) pulses. The HHG technique has enabled latest progress of atto-second physics and the short coherent radiation reaching water window.

So far, the HHG of near infrared pulses is normally based on intense pulses obtained by chirped pulse amplification (CPA). However active amplification normally add extra phase noise which prevents metrological application where clock makers like me require stringent phase stability. In addition, the low repetition frequency of CPA system limits the capability to use the HHG pulses as a frequency comb. Based on this point, my JST-PRESTO research proposal aims passive enhancement of NIR pulses and its HHG. Matching the repetition frequency of a homemade titanium sapphire oscillator to a passive optical ring cavity with low group delay dispersion (GDD), NIR pulses are for 300 times piled up in a cavity with a coupling bandwidth of 20nm. This corresponds to an intra-cavity averaging intensity of 150W, and the peak intensity at the cavity focus is slightly less than 10^{13} W/cm^2. Providing xenon gas-jet at the focus of the tight cavity focus, plasma ions caused by multi-photon ionization process were successfully detected. All parameters of experiments have not been fully optimized yet. After gaining a few times of extra intra-cavity intensity, coherent VUV radiation of repetition frequency 110MHz is expected to be generated.

When my research proposal was initiated with same title as described above, I planned to perform precision atomic spectroscopy by using the phase-coherent VUV pulses. Although that plan is not realized yet, the possible application including my current interest will be also presented.

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Personal history

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