Contribution ID: **22** Type: **Poster**

New apparatus for single-photon Doppler-free VUV/XUV spectroscopy

Monday 10 June 2024 18:00 (2 hours)

The ionisation energies of many atoms and molecules lie in the vacuum ultraviolet (VUV) and extreme ultraviolet (XUV) parts of the electromagnetic spectrum, which correspond to wavelengths (frequencies) of light of < 200 nm ($> 1.5 \times 10^{15}$ Hz) and < 105 nm ($> 2.9 \times 10^{15}$ Hz), respectively [1]. Laser radiation generated at these wavelengths can therefore be utilised to perform single photon excitation from the ground electronic state of an atom or molecule to highly excited electronic states, including direct excitation to Rydberg states with a large value of the principal quantum number, n [1]. However, although VUV/XUV laser sources with < 250 MHz bandwidths have been achieved [2-6], large Doppler broadening of transitions at VUV/XUV wavelengths (with Doppler widths typically > 100 MHz) often limit the achievable resolution of single-photon VUV/XUV spectroscopy. Additionally, large Doppler shifts can result in > 100 MHz systematic shifts to measured transition frequencies in the VUV/XUV. We present the development of a new experimental apparatus for performing Doppler-free spectroscopy at VUV/XUV frequencies. This method is based on combining an imaging-assisted single-photon Doppler-free spectroscopy technique, recently developed for precision spectroscopy of Rydberg states of He atoms [7], with a long-pulse-length (~ 100 ns - 1.0 μs) narrow-bandwidth VUV/XUV laser. The initial aim of such an experiment is to generate laser radiation with a wavelength of ~ 80 nm, for use in performing precision single-photon XUV spectroscopy of H_2 molecules excited to high-n ($n > 30$) Rydberg states from the ground $X\,{}^1\Sigma_g^+$ state.

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Session Classification: Poster Session 1