Measuring the $2\,^3S_1$ lifetime of metastable helium

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Helium - the simplest multi-electron atom - is a favoured testbed for QED predictions of atomic structure. Knowledge of the He $2\,^3S_1$ state (He*) lifetime is important not just to verify QED, but also because of the key role that He* plays in many environments. In addition to being the longest-lived (metastable) state, the $2\,^3S_1$ level is the most energetic first excited state of any atomic species - some 20 eV above the ground state. Consequently He* is an important source of stored energy in ionospheric and discharge plasmas, where its large scattering cross-sections also play an important role. Furthermore, the large stored energy not only allows efficient detection of He* atoms using charged particle techniques, but the long lifetime means that the $2\,^3S_1$ level acts as an effective ground state for laser cooling via the efficient 1083nm transition to the $2\,^3P_2$ level. This makes He* a useful species for atom optics experiments where detection of individual particles is important.

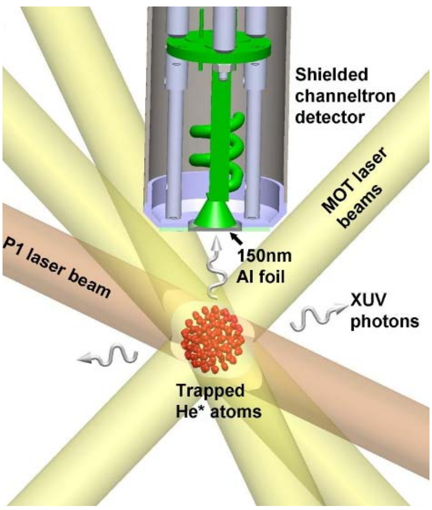

Fig. 1: Experimental schematic. The geometry of the 1083nm trapping and excitation laser beams is shown relative to the detection system, comprising the channeltron with aluminium filters and shield (quadrupole magnetic field coils not shown).

The extremely long metastable lifetime arises from the fact that direct photon decay of the $2\,^3S_1$ state to the $1\,^1S_0$ ground state is doubly forbidden by quantum mechanical selection rules. First, the metastable state shares the same angular momentum quantum number (S, l=0) as the ground state, which forbids decay via a single-photon electric dipole transition. Second, the two electrons in the metastable state have parallel spins, while the ground state is a spin anti-parallel configuration, requiring a low probability spin flip for the decay process. As a consequence, the most rapid decay process from the metastable to the ground state is via a magnetic-dipole-allowed, single-photon transition at 62.6 nm in the extreme ultraviolet (XUV), which can be readily detected.

We have determined experimentally the lifetime of the longest-lived atomic valence state yet measured - the first excited ($2\,^3S_1$) state of helium. We laser cool and magnetically trap a cloud of metastable helium atoms and measure the decay rate to the ground state via extreme ultraviolet photon emission. Two 100 nm thick aluminium filters block all ions, electrons and He* atoms from our detector while allowing the XUV photons to pass. This ensures we only count events related to a $2\,^3S_1$ atomic decay (see Fig. 1). This is the first measurement using an unperturbed ensemble of isolated helium atoms and yields a value of 7920(510) seconds, in excellent agreement with quantum electrodynamic theory [1, 2].

References

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