Progress Towards a Precise Measurement of the He^+ 2S Lamb Shift

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Recent calculations of QED corrections to the Lamb shift in hydrogenic systems have turned out to be rather surprising. In particular, some two-loop binding corrections starting in order $m\alpha^2(Z\alpha)^5$ exhibit remarkably nonperturbative behaviour[1, 2, 3, 4]. Although up until now measurements in hydrogen have constituted the most accurate tests of QED, these recently calculated terms are obscured in hydrogen by the experimental error in the proton charge radius. The situation in He^+ is more favourable; the alpha particle radius is known well enough to make He^+ Lamb shift measurements sensitive to the two-loop contributions. This is the primary motivation for our experiment. If our new measurement confirms the QED theory then existing Lamb shift measurements in hydrogen can be used to determine a new value for the proton charge radius.

We are making a precise measurement of the He^+ 2S-3S interval by Doppler-free two-photon spectroscopy of a slow He^+ 2S metastable ion beam, using UV radiation at 328 nm. We have constructed a very stable source at this wavelength by frequency doubling the 656 nm output from a dye laser using a BBO crystal in an external enhancement cavity. This source presently generates 70 mW of 328 nm light. The 328 nm light is then coupled into a UV enhancement cavity, with a finesse of 4000, placed inside the vacuum system. This provides the intense, counter-propagating beams required for the Doppler-free excitation of the two-photon transition. It is expected that the 328 nm power inside the cavity will be several watts.

The metastable He^+ 2S ions (1.9 ms lifetime) are produced in an electron bombardment source of the type used by Hinds et al.[5], which has now been built and is presently being optimised. In this scheme, the neutral species are ionised and excited in a single step by collisions with electrons in a field-free region. A Pierce lens is used to extract an ion beam from this region, which is decelerated to about 2 eV and focused into the waist of the enhancement cavity mode. An ion beam of several nA has so far been produced, but the metastable fraction has not yet been determined. It is anticipated that 1% of the He^+ ions in the final beam will be in the 2S metastable state. Latest results will be presented at the conference.

We will detect fluorescence from the 3S-2P-1S decay cascade (164 nm and 30 nm) using both a silicon photodiode and a channeltron, yielding an expected S/N of almost 1000 in 1 second. A heterodyne technique will be used to measure the frequency offset between the dye laser, at 656 nm, and a calibrated iodine-stabilised diode laser, to give an absolute frequency measurement. This should enable us to determine the frequency of the 2S-3S transition to better than 10% of its 16 MHz linewidth, which will be sufficient to probe QED theory at the level of the new two-loop calculations.

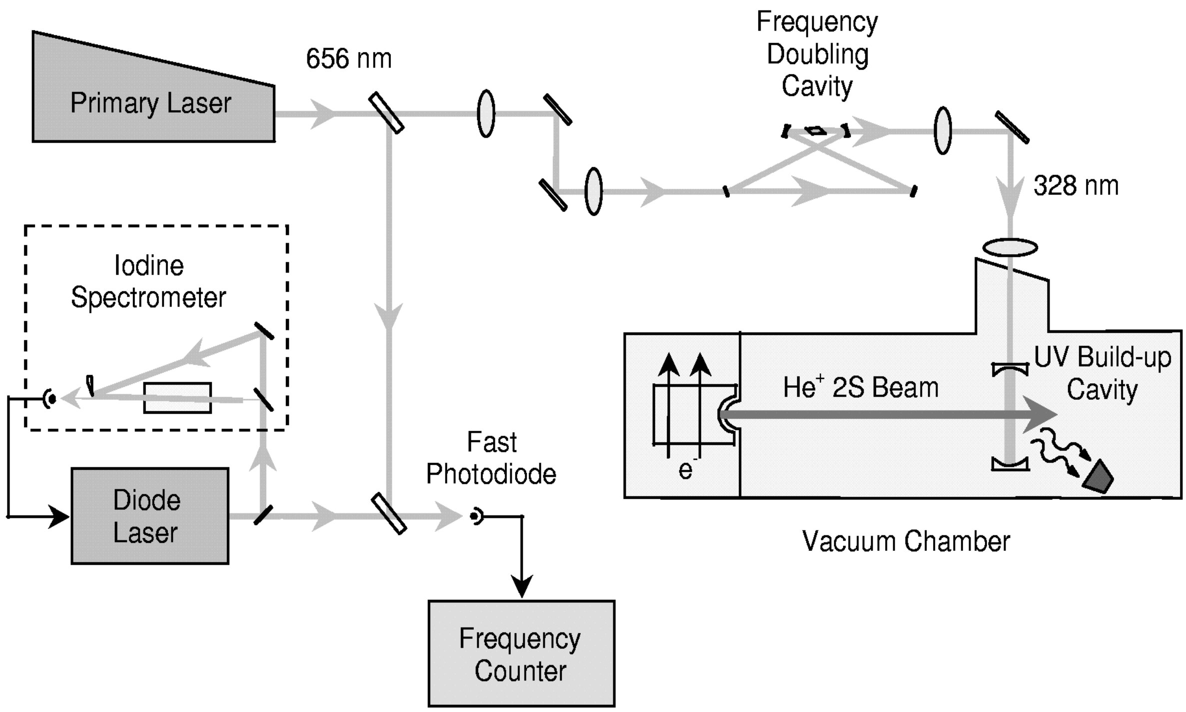

Figure 1: Schematic of the experimental setup.

Acknowledgment. This work is funded by the EPSRC.

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