Measurement of the positronium fine structure

Speaker: **David Cassidy**, University College London, UCL

Monday, September 13, 2021, 10:30 - 11:00

Since positronium (Ps) atoms are composed only of leptons they are, for all practical purposes, pure QED systems, unaffected by nuclear structure effects. Also, being composed of a particle-antiparticle pair, Ps atoms are metastable, and may decay via self-annihilation, as well as through the usual radiative decay channels seen in regular atoms. The energy levels of Ps can be calculated to arbitrary precision (in principle), and precision spectroscopy of Ps can therefore be used to perform rigorous tests of bound-state QED theory. However, because Ps is short lived, and its production requires a source of slow positrons, such experiments are technically challenging.
In this talk I will review the current state of the art in Ps spectroscopy, and also describe some recent measurements of the Ps n = 2 fine structure. The new experiments were performed using a positron trap which allows intense positron pulses to be converted into a dilute Ps gas in vacuum. A pulsed dye laser was used to optically excite atoms to the 2 $^3S_1$ level, and microwave radiation was used to drive transitions from there to the 2 ^3P_J (J = 0,1,2) levels, which decay radiatively to the ground state before annihilation. The different annihilation decay rates of the ground and excited (S) states allows the microwave induced transitions to be monitored via the time spectrum of the Ps annihilation radiation.
We found that the measured J = 1 and J = 2 lineshapes exhibited significant asymmetries, whereas a symmetric lineshape was observed for the J = 0 transition. The observed asymmetries are not consistent with quantum interference or line-pulling phenomena arising from nearby (off-resonant) transitions. In the absence of a quantitative explanation for the asymmetries we are therefore unable to determine the fine structure intervals for these transitions. Since the J = 0 lineshape did not exhibit any significant asymmetry it was possible to extract a value for the centre frequency: however, the obtained interval was found to disagree with theory by 2.77 MHz, which amounts to 4.2 standard deviations. New measurements and extensive simulations have been performed: these data suggest that the observations may be related to subtle microwave reflections in the waveguide, and point the way to further experiments that are expected to close the gap between experiment and QED theory for the first time in 30 years.