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Precision Microwave Spectroscopy of the Positronium n = 2 Fine Structure

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Since positronium (Ps) atoms are composed only of leptons they are, for all practical purposes, pure QED systems and can therefore be used to perform rigorous tests of bound-state QED theory. Moreover, since the theoretical description is limited only by the order of the calculations performed, rather than unknown physical constants or incalculable terms, any observed (and confirmed) disagreement with theory could indicate the existence of "new physics" such as particles or fields not currently included in the Standard Model. In this talk I will describe some new measurements of the Ps n = 2 fine structure intervals. The experiments were performed using a buffer gas positron trap which allows a dilute Ps gas with a number density on the order of 10^6 cm^{-3}. A pulsed dye laser was used to optically excite atoms to the 2 ^{3}S$_1$ level, and microwave radiation was used to drive transitions to the 2 ^{3}P$_J$ levels (J = 0,1,2), which decay radiatively to the ground state before annihilation. The different annihilation decay rates of the ground and excited (S) states allows the fine structure 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 the most obvious quantum interference or line-pulling phenomena arising from nearby (off-resonant) transitions, and in the absence of a complete lineshape model 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 4.5 standard deviations. No mechanism for a line shift of this magnitude has so far been identified.