 doi:10.1088/1742-6596/875/8/072002

Diffraction in matter-antimatter binding: Positronium formation from C_{60}

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Synopsis Due to the dominant electron capture from its hull, C_{60} acts like a spherical diffractor inducing resonances in the positronium (Ps) formation as a function of the positron impact energy. Results open new avenue of Ps spectroscopy with nanomaterials and push the barrier to motivate level-differential measurements.

Following the impact of positrons with matter, an exotic electron-positron binary, positronium (Ps), transiently forms until their annihilation – a process of great interests in astrophysics, materials, QED, and antimatter gravity.

Ps formation studies accessed materials that include a breathtaking landscape ranging from atoms, molecules, polymers to solids, liquids, surfaces/films, metal-organic-frameworks and embedded nanostructures. However, straddling the line between atoms and condensed matters are nanoparticles that not only have hybrid properties of the two extremes, but also exhibit outstanding spectroscopic behaviors. Here we take the pilot stride toward probing the Ps formation from gas phase fullerene molecules [1].

The structure of a C_{60} molecule is described by the local-density functional approximation augmented by the LB94 exchange-correlation [2]. The positron impact on C_{60} leading to the Ps formation is treated by the continuum distorted-wave-final-state approximation [3].

The cross section of the Ps formation in its 1*s* and 2*s* states by selective captures from various molecular levels of C_{60} are calculated. The shapes of the positron scattering potential by the residual C_{60} ion and the wavefunctions of C_{60} and Ps levels confine the capture process within the C_{60} molecular width. Strong constructive interferences take place as a function of the recoil momentum (Q). When the odd integer multiple of the half-wavelength of *effective* continuum wave in Q fits the C_{60} cavity, systems of peaks (bright-spots) in the energy domain are formed which subsequently results into a single centroid fringe pattern via a dephasing mechanism across the width [1]. The calculated resonances in the ratio of the HOMO-to-HOMO-1 capture are shown in Figure 1 as a function of Q, along with a schematic representation of the underlying diffraction process. As a proof of the prediction, the separation between two neighboring resonances is found to proportionally reduce going from C_{60} to the larger molecule C_{240} in our extended calculations.

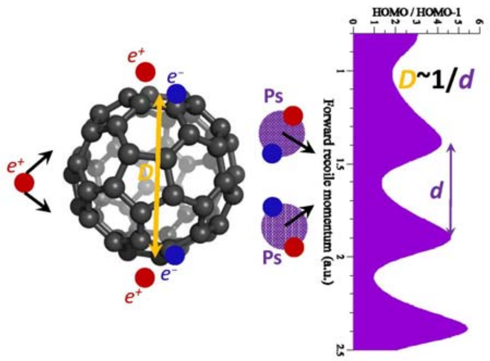

Figure 1. Schematic of a C_{60} diffractor in Ps formation. Resonances in the ratio of cross sections of HOMO and HOMO-1 captures are presented.

The Ps formation off fullerenes thus unearths unique physics and spotlights on a novel direction of Ps spectroscopy with nanosystems that promises to be a great topical field. Of particular interest is the impetus that the current results generate to break new grounds towards target-state differential measurements. The work is supported by the U.S. National Science Foundation Grant PHY1413799.

References

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