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Azimuthal dependence of planar orbits in the crossed fields diamagnetic Kepler problem in silicon

The diamagnetic Kepler problem has been the basis of much work since the observation of oscillations in the spectrum of Barium in an external magnetic field by Garton & Tomkins [1]. These oscillations were related to the chaotic motion of the electron perpendicular to the applied magnetic field. Further work lead to a great understanding of the effects classical chaos has on quantum atomic systems. Much of the work was focused on systems with cylindrical symmetry in which the azimuthal dependence of classical trajectories was of little importance. However, if an electric field is applied perpendicular to the magnetic field, this breaks the rotational symmetry and complicates the investigation [2,3,4]. In 2009, oscillations were first observed in phosphorus doped silicon [5]. This system is not spherically symmetric due to the presence of conduction band valleys. One would expect that classical orbits launching, and returning, in the vicinity of these conduction band valleys to contribute stronger oscillations to experimental data than they may otherwise.

This work analyzes the azimuthal dependence of planar orbits in the crossed field diamagnetic Kepler problem utilizing a much simplified theoretical framework we recently proposed [6]. In the numerical calculations, the magnetic field is aligned along z-axis with the two identical conduction band valleys of silicon, and the electric field along one of four equal conduction band valleys in the x-y plane. We look to identify if varying the ratio of applied fields of the electron will shift the positions of closed orbits in the x-y plane to align themselves with the positions of the four conduction band valleys. We find that for zero classical and low electric field, the so called "Garton-Tomkins" orbit, and the majority of its associated harmonics, shows a two-fold azimuthal dependence as expected. The minimum return distance for these orbits fall outside the conduction band valleys and we therefore expect a significant drop in the recurrence strengths associated with these orbits. However, every third harmonic shows much higher stability to changes in electric field strength and instead yield a four-fold azimuthal dependence as the electric field is increased. Not only has this not been noted in previous , the minimum return distances all fall on conduction band valleys. We would therefore expect the influence of these harmonics to be greatly enhanced in experimental measurements.

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