Physics & Astrophysics Colloquium

Oscillator Response to Applied Fields

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4:00 PM Friday, March 24, 2023, Room 211, Witmer Hall

Abstract: A year or so ago, we saw a presentation on the surface magneto-optical Kerr effect. I became interested in the optical response of an oscillator subjected to an applied field. Here I will present preliminary studies of a three-dimensional oscillator responding to a magnetic field and an electric field gradient. Raman scattering amplitudes (second order) thus simulate a Kerr effect induced by the static fields. This is usually calculated in higher order.

Why are we interested in harmonic oscillators? Because, as we all know from mechanics, an arbitrary smooth potential can usually be approximated as a harmonic potential at the vicinity of a stable equilibrium, the oscillator is one of the most important model systems in either classical or quantum mechanics. In this talk, for instance, one can imagine that the oscillator represents vibrational modes of a molecule. Also, one of the few *n*-body system solvable analytically comprises a collection of masses interacting by strictly harmonic forces. The harmonic oscillator belongs to the set of simple physical model systems for which the Hamiltonian is a quadradic function of coordinates and momentum. Apart from the problem of finding polynomial roots, all of these quadratic systems are solvable exactly.

In the talk, I review the quantum oscillator. This includes why ladder operators should exist and how to find them, and then how to use them to form generating functions for the oscillator eigenfunctions and matrix elements. The general idea of finding and using generating functions will also be reviewed briefly.

When terms are added to the Hamiltonian to represent applied electric and magnetic fields, one finds interesting responses of the energy levels.

$$H = \frac{1}{2m} p^2 + \frac{1}{2} m\omega_o^2 r^2 - \frac{1}{2}\frac{qB_o}{m}\left(x\, p_y - y\, p_x\right) + \frac{1}{8}\left(\frac{qB_o}{m}\right)^2 \left(x^2 + y^2\right)$$
$$+\, q_{11}x^2 + q_{22}y^2 - (q_{11}+q_{22})\, z^2 + q_{12}\, x\, y + q_{23}\, y\, z + q_{31} z\, x.$$

Energy levels are shown as functions of the field strengths. For sufficiently strong electric field gradient, the oscillator states are all ionized, and the discrete levels give way to scattering resonances.

Quantization of the radiation field is reviewed briefly, where again the oscillator formalism enters in quantizing the modes. Then the additional, quantized optical fields are coupled to the oscillator. Using matrix-element generating functions, the Raman scattering is studied in a way simulating the surface Kerr effect from vibrational states of molecules (in this case harmonic oscillators) showing response to strong, applied magnetic field in the polar Kerr-effect set up and with an additional electric field gradient perpendicular to the surface. This allows calculating scattering amplitude and rotation of the polarization states as a function of photon energy, scattering angles, initial polarization and the applied magnetic field and electric field gradient.

Refreshments at 3:30 PM in Witmer Hall, Room 215

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