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A Levitating Droplet as a Toy Atom

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There very first example a student learns in quantum mechanics is the square potential well. However, when working with atoms we use spherical coordinates and a spherical potential well would be a much closer analogy. After writing the Schrödinger equation in spherical coordinates, the centrifugal barrier ($\ell(\ell+1)/r^2$) appears, which, when added to a square potential well in the radial coordinate, results in a wedged potential well.

In this work, we use an optical trap and a water droplet to create an experiment with exactly such wedged potential wells. The equation for the scattering intensity obtained directly from the Maxwell equations turns out identical to the radial, Schrödinger equation, where the light trapped in resonating modes inside the droplet is analogous to an electron trapped in an atomic potential.

The width of the radial square well is smoothly changed by changing the radius of the droplet resulting in a directional Mie scattering spectrum consisting of a series of Fano resonances. This again points to the analogy with an atom, since Fano resonances were first discovered for inelastic electron scattering by helium atoms. The resonances are ordered by the integer angular momentum value, ℓ, associated with the rotation of the light as it reflects inside the surface of the droplet. In an atomic system, this would be the angular momentum of the electron.

The full spectrum consists of a series of consecutive Fano Combs, each with dozens of individual resonances evolving from wide Lorentzian shapes to sharp asymmetrical Fano profiles. We use the analogy with the Schrödinger equation to fully and intuitively explain the Fano Comb structure. This results in a model experiment for an atom with a knob to control the atom's properties including the potential's width and depth, that \textbf{scans over a wide range of angular momenta}. The spectrum gives a full picture of the range of possible resonances in such a toy atomic system.

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