The Mechanics of Maxwell Matter Waves

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The understanding of circuits that involve ultracold atoms for sensing and other practical purposes is very much a topic of quantum thermodynamics since, by definition, ultracold atoms are governed by the laws of quantum mechanics, while useful circuit behavior is a consequence of a system that is in non-thermal equilibrium. The purpose of a circuit is generally to generate and manipulate *signals* – that is, for example, time-varying currents that are some way meaningful information bearers for the tasks at hand. Such signals explicitly involve, of course, AC currents. The physics of alternating matter currents and associated matter waves is far richer than one might expect from conceptually generalizing familiar single particle and many-body treatments of matter waves. In earlier work we have shown that a gauge field treatment of identical interacting through neutral particles (such as neutral atoms) leads to a set of matter-wave duals to Maxwell's equations. These, in turn lead to matter-wave duals to electromagnetic waves which we refer to as "Maxwell matter waves" or simply as "AC matter waves". The objective of this talk is two-fold: first to present the mechanics of Maxwell matter waves through a set of standard wave-propagation problems such as reflection from a potential step and transmission through potential barriers. The behavior of Maxwell matter waves proves to be dramatically different from the de Broglie (DC) waves described by Schrödinger's equations. For example, AC matter waves will propagate through a barrier with high transmission even when the corresponding particle energy is far less than the potential energy height of the barrier. Likewise, a low-particle-energy AC matter wave will have transmission through a step where a de Broglie wave is reflected with unit probability. The difference between AC and DC is due to the temporal coherence of the former, which itself of the reflection of the fact that a single-mode AC wave is characterized by two quantum numbers: the particle energy and the oscillation frequency, rather than just the particle energy as the case with a de Broglie wave. The other objective of this talk is to draw the connection between DC and AC, that is, between solutions of the time-independent Schrödinger equation and solutions to the matter wave duals to Maxwell's equations. We show that DC matter waves are comprised of a superposition of AC waves having a spectrum of oscillation frequencies. It is *not* the case that a DC wave corresponds to the limit in which the frequency of an AC wave goes to zero. Rather, an AC wave corresponds to the limit in which the spectral width of a DC wave becomes zero. Finally, I will give a brief peak at, and description of, how AC matter waves can be generated.