Maxwell Matter Waves: Coherence Properties, Generation, and Applications

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This talk introduces a class of matter waves that are temporally coherent, and that are particularly useful for applications such as inertial and other kinds of sensing. The coherence of these waves is of the same type that characterizes electromagnetic fields, such as those associated with a laser or a radio wave emitter. Maxwell's equations tell us that an oscillating electric current gives rise to an oscillating electromagnetic field. Certain ultracold atoms, such as ^{87}Rb, interact through s-wave scattering and repel each other in a manner somewhat reminiscent of the repulsion of identical charges. One wonders if an oscillating current of atoms, then, give rise to something analogous to an oscillating electromagnetic field. The answer is, perhaps surprisingly, "yes". Among the revolutions in physics of the past 50 years was the recognition that Maxwell's equations can be derived from a gauge-field treatment of interacting identical charges. That is, the electromagnetic field is the gauge field associated with interacting massive, charged particles. In the same way, there is a gauge field that can be associated with any set of identical interacting atoms. We refer to this gauge field as the Maxwell matter wave field. We are certainly familiar with matter waves - the de Broglie waves that are the quantum-mechanical wave description associated with massive particles, whose wavelength is inversely proportional to the particle velocity. We show that de Broglie waves are the special case of the Maxwell matter wave field at "DC". The "AC" fields correspond to the coherent matter waves of interest. Our topic of Maxwell matter waves is introduced from a practical perspective to utilize these waves for inertial and other classes of atomic sensors. Methods for generating Maxwell matter waves involve the design of open quantum systems in which energy is supplied by a Bose-Einstein condensate, a triple-well atomic potential introduces nonlinear behavior, in particular gain, and output coupling to the vacuum provides a means of energy dissipation along with the emission of the coherent matter waves.

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