Dr. Dana Z. Anderson

Professor of the Department of Physics

Professor of the Department of Electrical, Computer and Energy and Engineering

University of Colorado

Talk Title: Matter Waves, Matterons, and the Atomtronic Transistor Oscillator

Abstract: In previous work we had reported on experiments presenting evidence that an appropriately configured circuit comprised of a triple-well atomtronic transistor operated with atoms having a sufficiently low temperature will oscillate and also emit a coherent matterwave. We furthermore outlined a four-level theoretical model that revealed the origin of transistor gain and insight into the physics of matterwave generation. By now the model has been considerably extended to a many-body framework that treats the middle, gate, well of the transistor as a harmonic potential having a finite height. This talk is meant to be a pedagogical presentation of the underlying physics and results derived from a self-consistent treatment of the circuit dynamics. Indeed, much of the physics of the atomtronic transistor oscillator can be understood through analysis of a classical equivalent circuit. The treatment leads to three, at first wholly non-intuitive, conclusions that we think are especially interesting. We have already shown experimentally and explained theoretically that a Bose-condensate forms in an initially empty gate well. The first interesting result of our treatment is that the condensate forms not in the ground state of the harmonic oscillator as we are accustomed, but in a displaced ground state: that is, it undergoes large-amplitude coherent oscillation. We refer to this state as a “truncated coherent state”; truncated, because the harmonic oscillator is comprised of a finite number of levels and thus does not support the canonical coherent state. One would ordinarily expect that the kinetic energy of an oscillating condensate would simply be converted into heat that melts the condensate, but this does not occur in the circuit configuration. The second interesting conclusion, which also arises in the simpler model, lies in the nature of transistor current gain, which is unlike other gain mechanisms one is accustomed to in, say, quantum optics, such as stimulated or parametric gain. Gain instead appears as an impedance matching transformation that arises through a phase-dependent interaction energy between states tunneling into and out of the gate well and the oscillating condensate. The third conclusion regards the emission of the matterwave from the circuit and is for us the most thought provoking, because it causes us to reconsider the meaning of “coherent matterwave”. In particular, we extrapolate to the classical limit, writing the emitted matterwave in terms of a pair of fields related by a matterwave impedance of the vacuum. The fields are in some sense analogous to the electric and magnetic fields of an electromagnetic wave. If one chooses to quantize these waves and ask what is

the matterwave equivalent of a photon, it is NOT an atom, even though the matterwaves are indeed associated with a flux of atoms produced from the circuit. Rather, one is forced identify matterwave particles as something else, which, for lack of a more compelling term, we refer to as "matterons". Like photons, matterons are associated with well-defined energy packets (associated with the frequency of the oscillator) and well-defined momentum packets that are not the same as the energy and momentum of the individual atoms. One can make a detector that senses matterons but not atoms, for example.