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CORRELATED DYNAMICS IN QUANTUM AND OPTICAL FIBERS

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14. ABSTRACT

The objective of this proposal is to explore, experimentally and theoretically, correlated behavior in optical and quantum systems. In particular, the author will use photonic analogues of (partially) condensed systems to explore generic features of wave-kinetic dynamics and many-body interactions. Examples include the condensation process itself, hydrodynamic instabilities in the superfluid domain, and the effects of partial coherence (finite temperature). That this is possible follows from (1) a direct mapping of the underlying equations, and (2) recent developments in nonlinear photonic technology, many of which the investigator has helped pioneer1-4.

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FA9550-09-1-0094: CORRELATED DYNAMICS IN QUANTUM AND OPTICAL FIBERS (Princeton University)

We use classical light to demonstrate experimentally two phase transitions that are typically associated with low-temperature quantum systems: Bose-Einstein condensation and the Berezinskii-Kosterlitz-Thouless transition. The former is a collapse of random-phase waves into a coherent ground state while the latter is a proliferation of vortices that appears as vortex energy competes with entropy production. In both cases, 2+1D beam experiments are performed using an SBN:60 ($Sr_{0.6}Ba_{0.4}Nb_2O_6$) photorefractive crystal. An ensemble of random-phase input beams is created using a spatial light modulator, each with a Gaussian field profile with adjustable spatial correlation length. Interactions between modes are facilitated by a self-defocusing nonlinearity in the crystal, obtained by applying a voltage across its c-axis. Two CCD cameras then record the output, one for position (x) space and one for momentum (k) space. For the condensation experiment, wave equilibration to a Rayleigh-Jeans spectrum is observed, with an accumulation of energy in the fundamental $k_0 \approx 0$ mode and an algebraic k^{-2} spectrum in the tails. For the BKT experiment, the number of new vortices matches mean-field predictions of a photonic x-y model, as do correlation measurements in the transition region. The results demonstrate condensed matter physics using only light and confirm recent theory about classical wave thermodynamics.