New condensates of matter and light

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Macroscopic phase coherence is one of the most remarkable manifestations of quantum mechanics, yet it seems to be the inevitable ground state of interacting many-body systems. In the last two decades, the familiar examples of superfluid He and conventional superconductors have been joined by exotic and high temperature superconductors, ultra-cold atomic gases, both bosonic and fermionic, and recently systems of excitons, magnons, and exciton-photon superpositions called polaritons, the subject of this talk.

An exciton is the solid-state analogue of positronium, made up of an electron and a hole in a semiconductor, bound together by the Coulomb interaction. The idea that a dense system of electrons and holes would be unstable toward an excitonic (electrical) insulator is one of the key ideas underlying metal-insulator transition physics. The further possibility that an exciton fluid would be a Bose-Einstein condensate was raised over 40 years ago, and has been the subject of an extensive experimental search in a variety of condensed matter systems. Such a condensate would naturally exhibit phase coherence.

Lately, some novel experiments with planar optical microcavities make use of the mixing of excitons with photons to create a composite boson called a polaritons that has a very light mass, and is thus a good candidate for a high-temperature Bose condensate. Good evidence for spontaneous coherence has now been obtained1, though there are special issues to resolve2 considering the effects of low dimensionality, disorder, strong interactions, and especially strong decoherence associated with decay of the condensate into environmental photons3 — since the condensate is a special kind of laser.

[1] J. Kasprzak, et al. *Nature* **443** 409-415 (2006).

[2] J. Keeling, F. M. Marchetti, M. H. Szymanska, P. B. Littlewood, *Semiconductor Science and Technology*,**22** R1-26 (2007).

[3] M. H. Szymanska, J. Keeling, P. B. Littlewood, *Phys. Rev. B* **75** 195331 (2007).