Bose-Einstein condensation in semiconductors and beyond

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The idea of Bose-Einstein condensation was sparked in the mid-twenties of the last century, when Albert Einstein, inspired by the Indian physicist Satyendra Nath Bose working on the statistical properties of optical radiation, predicted a particular type of phase transition in the system of non-interacting bosons at temperature close to the absolute zero. In 1938, Fritz London linked this phenomenon with the recently discovered superfluidity of helium, thereby pointing to the first practical application of this rather abstract concept. The observation of a Bose-Einstein condensate (BEC) of dilute atomic gases was achieved much later, in 1995, opening a new chapter in the field of atomic and molecular physics and quantum optics. In an ideal condensate, all particles “share” a common wavefunction. Thus, there is a long range coherence over the whole system. Taking into account the interactions between particles results in another peculiar property. The gas of particles becomes a superfluid, which means that the flow of particles is not subject to dissipation forces if the flow velocity is below a certain critical value. In two dimensions, true BEC is not strictly possible, but a related phase transition known as the (Berezinskii-)Kosterlitz-Thouless superfluid transition can occur. In this case, spontaneous phase coherence of particles occurs but does not persist at large distances.

The idea of Bose-Einstein condensation of excitons dates back to the 60’s, when first theoretical proposals were put forward. However, due to the intrinsic properties of excitons, which are characterized by a limited lifetime and are sensitive to disorder, the observation of this phenomenon proved to be a difficult task. In 2006, condensation of semiconductor exciton-polaritons was reported [1]. This major breakthrough inspired a new field of research in both fundamental and applied solid state physics. Polariton condensates are typically achieved away from ideal thermal equilibrium, in a gas of particles with only picosecond lifetime. The ability to achieve polariton condensation at room temperature [2] and in organic materials [3] gives promise for practical applications, such as low-threshold lasers, precise interferometric measurements and spinoptronic devices.

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