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Light-Trapping Architecture for Room Temperature Bose-Einstein Condensation of Exciton-Polaritons near Telecommunication Frequencies

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While normally quantum mechanical effects are observable at cryogenic temperatures and at very small length scales, our work brings these quantum phenomena to the macroscopic length scale and to room temperature. Our work focuses on the possibility of room-temperature thermal equilibrium Bose-Einstein condensation (BEC) of quantum well exciton-polaritons in micrometer scale cavities composed of photonic band gap materials. Using cavities composed of double slanted pore (SP2) photonic crystals embedded with InGaAs quantum wells, we predict the formation of a 10 μm to 1 cm sized thermal equilibrium Bose-Einstein condensate at room temperature that allows for the emission of light near the telecommunications band of $\sim$1300 nm. The three-dimensional photonic band gap of the SP2 crystal allows for light to be strongly confined to the quantum wells, resulting in strong light-matter coupling in the exciton-polaritons and vacuum Rabi splittings that are $\sim$2% of the bare exciton recombination energy. The photonic band gap also strongly inhibits the radiative decay of the exciton-polaritons and due to the slow non-radiative decay of excitons as well as fast exciton-phonon scattering in InGaAs at room temperature, the exciton-polaritons that form the BEC are able to reach thermal equilibrium with their host lattice. We consider three InGaAs quantum wells (of width 3 nm surrounded by 7 nm InP barriers) judiciously placed in a 33 nm cavity between SP2 crystals with a lattice constant of 471 nm and polaritons consisting of a superposition of excitons and photons that are tuned below the excitonic recombination energy. This detuning increases the polariton's dispersion depth and increases the number of available photon-like states to enhance the formation of a BEC. We predict the onset of a BEC at a temperature of 364 K in a box-trap of side length 10 μm at a polariton density of 1.6×10^{11} cm^{-2}, indicating that a room temperature, thermal equilibrium BEC can be obtained with light emission near the telecommunications band.

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