Photon BEC in a dye-microcavity system and the effects of interactions

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Photons are bosons, but they don't normally make Bose-Einstein condensates because their number is not conserved in thermal equilibrium. However, light pumped into a fluorescent dye can exchange energy with the dye-solvent mixture, coming to thermal equilibrium without destroying the photons. The electronic structure of the dye sets a minimum energy, preventing the photon from being destroyed altogether. Placing this system between two curved, high-reflectivity mirrors, the light is confined for about a nanosecond, which is much faster than the picosecond it takes for thermalisation. Therefore thermal equilibrium can be achieved at room temperature with a photon number determined by the pumping intensity. At a fixed temperature, and sufficient density, a Bose-Einstein condensate (BEC) will form, as first achieved in 2010 [1].

Recently, we have demonstrated Bose-Einstein condensation in our lab: see Fig. 1. We have confirmed the thermalisation of photons at room temperature, and have achieved sufficient photon density to see the BEC phase transition. The project's aims include measuring the interaction strength, characterising the coherence properties of the condensate, and fabricating mirror shapes which would allow observation of 1D gases of photons as well as photon BECs with mesoscopic numbers.

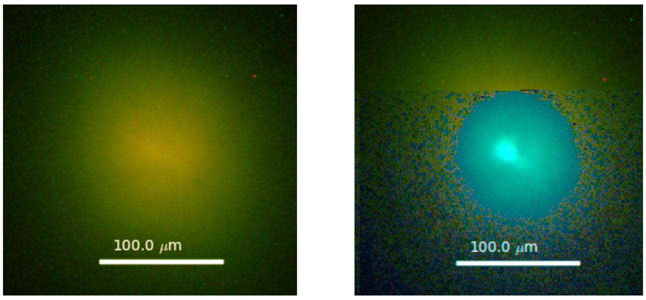

Figure 1: *Real-colour images of thermalised photons in our dye-filled microcavity. Left: just below threshold. Right: just above threshold, showing macroscopic occupation of the lowest energy state.*

The equation of motion which describes a photon BEC is very similar to the Gross-Pitaevskii equation which is familiar from atomic BEC. However, the effects of continual pumping and decay via cavity mirrors also appear, making the equation complex. The parameters of this equation, especially the interactions, are not yet known. We have analysed an experimental method for inferring the strength of interactions in photon BEC, by observing these excitations using angle-resolved spectroscopy of the light that leaks through the mirrors [2]. Even very weak interactions should be detectable this way.

References

[1] J. Klaers *et al.*, Nature, **468**, 545–548 (2010)

[2] R.A. Nyman and M.H. Szymańska, Phys. Rev. A, **89** 033844 (2014)