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Title:
A non-equilibrium model of photon condensation

Abstract:
Recent experiments [Klaers et al, Nature, 468, 545 (2010)] have shown a thermalised gas of weakly interacting photons which obeys the Bose-Einstein distribution, and undergoes a transition to a Bose condensed state above a critical density. The photons are able to reach this thermalised state by repeated absorption and emission from a background of dye molecules, held at room temperature. While the results presented so far match closely the equilibrium Bose-Einstein distribution, it is not clear from these results what exactly is the distinction between this system and an exotic laser.

We address this question [Kirton and Keeling, arXiv:1303.3459] by starting from a laser-like model and developing a full out-of-equilibrium quantum mechanical treatment of this system. Our model consists of a series of photon modes coupled to the background dye molecules which are in turn coupled to a thermal equilibrium bath. We examine in detail the nature of the thermalisation process induced by absorption and emission of photons by the dye molecules, and investigate when the photons are able to reach a thermal equilibrium distribution. This lasing theory reproduces the equilibrium BEC predictions seen experimentally as long as losses are small, but switches to more conventional laser behaviour as losses increase or temperature decreases.