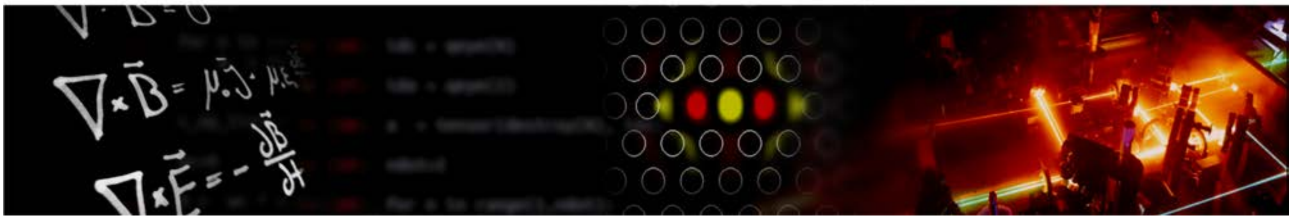

# B.Sc or M.Sc. project

## Theory of quantum effects in nanolasers

Present nanofabrication technology allows making lasers with a size on the order of the optical wavelength or smaller. Such lasers display a wealth of interesting phenomena. In particular, it becomes necessary to take into account the discrete nature of photons and electrons, leading to interesting quantum mechanical properties. For instance, if the discrete emitters are quantum mechanically coupled via the radiation field, they may enter a collective state. Spontaneous emission from such a state leads to the phenomenon of *superradiance*, where intense photon bunches may be emitted.

In this project we will investigate the role of superradiance in nanolasers, which is a current hot topic within laser physics [1]. We have recently developed an analytical theory accounting for some of the important superradiant effects occurring in lasers [2], but in this project the aim is to develop a more comprehensive model of the phenomenon, including quantum mechanical Monte Carlo simulations. We also wish to apply the model to the actual case of photonic crystal nanolasers, which can be fabricated at DTU Fotonik.

Interested students should have a good background in quantum mechanics and mathematics and preferably in laser physics. Depending on interests, the project can emphasize semi-analytical modelling or numerical simulations.

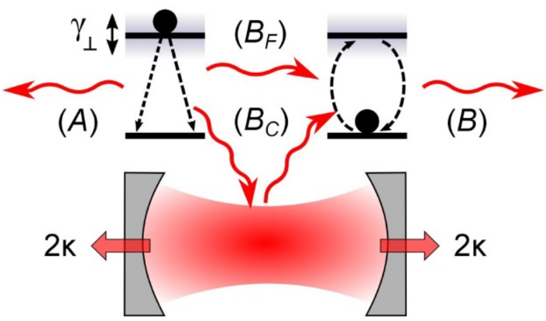


**Figure**: Illustration of collective effects in a nanolaser. Discrete emitters are coupled via the radiation field, leading to the possibility of superradiant processes, where many emitters emit spontaneously in a collective fashion. This gives rises to intense bursts of photons being emitted from the laser.

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**References:**

[1] F. Jahnke *et al.*, "Giant photon bunching, superradiant pulse emission and excitation trapping in quantum-dot nanolasers," *Nat. Commun.*, vol. 7, no. May, p. 11540, May 2016.

[2] I. Protsenko, E. C. André, A. Uskov, J. Mørk, and M. Wubs, "Collective Effects in Nanolasers Explained by Generalized Rate Equations," arXiv 1709.08200, 2017.