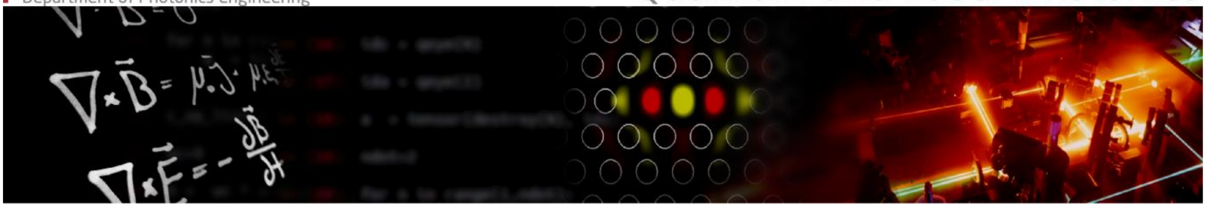

B.Sc or M.Sc. project

Fano lasers

A Fano resonance [1] is a general phenomenon occurring in Nature whenever a continuum of states interacts with a single, discrete state. It was suggested that such a resonance can be used to realize an ultra-small laser with remarkable properties [2], which has led to subsequent analysis and experimental realization [3,4].

The laser is realized in a photonic crystal membrane with embedded quantum dots for active material, as sketched in Figure 1. The Fano resonance occurs due to the interaction of the optical mode in the nanocavity and the continuum of waveguide modes, which leads to a strongly resonant suppression of transmission, effectively forming a narrowband and highly dispersive laser mirror.

Simulations and experiments have demonstrated some remarkable properties of this laser, including the first reported case of laser self-pulsing on a microscopic scale, consistent single-mode lasing and a theoretical frequency modulation bandwidth orders of magnitude larger than conventional semiconductor lasers.

The reflection spectrum may be modified by placing additional air holes in the waveguide below the nanocavity, which can yield asymmetric or inverted spectra compared to the conventional Lorentzian shape, as demonstrated in Figure 2. If the waveguide is completely blocked, the in-plane out-coupling is mediated entirely through the nanocavity, yielding a novel laser structure, which may potentially combine the desirable qualities of both the Fano laser and the conventional line-defect lasers.

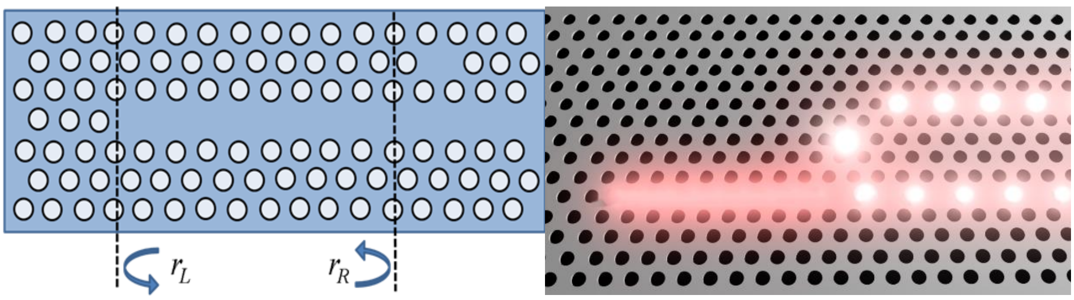

Figure 1:a) Schematic of the Fano laser structure. b) Schematic of the self-pulsing laser operation.

This modified structure is entirely unexplored as of yet, so the project provides the opportunity to work on a novel structure based on bridging the gap between two separate laser designs with different useful qualities, in order to investigate new physics and design light sources for the photonic integrated circuits of the future.

The project can be tailored to cover a suitable combination of theory, numerical modelling, and experimental work, depending on the interests and competencies of the student(s).

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References related to the topic:

[1] A. E. Miroshnichenko, S. Flach, and Y.S. Kivsvar, *Fano resonances in nanoscale structures*, Rev. Mod. Phys., vol 82. 2257 (2010).

[2] J. Mork et al, *Photonic crystal Fano laser: Terahertz modulation and ultrashort pulse generation*. Phys. Rev. Lett., 113:163901, Oct 2014.

[3] Y. Yu et al, *Demonstration of a self-pulsing photonic crystal Fano laser*. Nat Photon, 11(2):81-84, Feb 2017

[4] T. S. Rasmussen et al, *Theory of self-pulsing in photonic crystal Fano lasers*. Laser & Photonics Reviews, 11(5), Sep 2017.

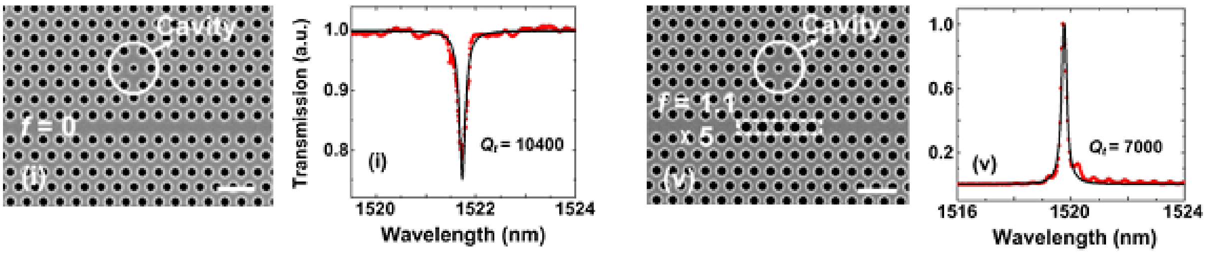

Figure 2: Manipulation of the transmission spectra by addition of holes in the waveguide beneath the nanocavity. If the waveguide is completely blocked, one obtains an inverted transmission spectrum.