Theory of Self-pulsing in Photonic Crystal Fano Lasers

Laser self-pulsing was a phenomenon exclusive to macroscopic lasers until recently, where self-starting laser pulsation in a microscopic photonic crystal Fano laser was reported. In this paper a theoretical model is developed to describe the Fano laser, including descriptions of the highly-dispersive Fano mirror, the laser frequency and the threshold gain. The model is based upon a combination of conventional laser rate equations and coupled-mode theory. The dynamical model is used to demonstrate how the laser has two regimes of operation, continuous-wave output and self-pulsing, and these regimes are characterised using phase diagrams, establishing the regime of self-pulsing numerically. Furthermore, the physics behind the self-pulsing mechanism are explained in detail and it is demonstrated how cavity absorption makes the Fano mirror function as a saturable absorber, leading to Q-switched pulse generation. A stability analysis is used to demonstrate how the dominant mechanism of instability is relaxation oscillations becoming un-damped. Finally the effect of varying key self-pulsing parameters is investigated by characterisation of the change in self-pulsing regions.