A Fano resonance [1] results when a continuum of modes interacts with a discrete resonance and has been observed in a number of different photonic and plasmonic structures [2]. In this paper we will discuss the use of a Fano resonance to implement a laser with properties that strongly distinguish it from conventional lasers [3,4]. In particular, since the Fano resonance results in a mirror with a narrow-band reflectivity, the laser can be modulated via the mirror [3], and the use of cavity enhanced nonlinearities can even lead to self-modulation and self-pulsing.

In a photonic crystal membrane structure, see Fig. 1, a Fano resonance can be realized by side-coupling a point-defect nanocavity with a line-defect waveguide. At the resonance frequency of the nanocavity, an input signal propagating in the waveguide will be reflected due to destructive interference and this may be used as a laser mirror [3]. Theory predicts that this laser can be modulated at terahertz frequencies by modulating the resonance frequency of the nanocavity, since this leads to pure FM modulation of the laser field, without any change in the carrier density [3], and thereby avoiding relaxation oscillations which limit the intrinsic speed of conventional lasers.

In the recent experimental demonstration of a Fano laser [4], the semiconductor membrane was composed of InP and the active material, incorporated in the middle of the membrane, is constituted by three layers of InAs quantum dots. The laser is optically pumped and found to lase in a CW mode at room temperature. However, in some cases, the laser is found to undergo a transition to self-pulsing, where a train of pulses, with duration of the order of 10 ps or larger and with a repetition rate on the order of a few gigahertz, is emitted. The physics of self-pulsing will be explained [5].

Fig. 1. Schematic of a Fano laser implemented in an InP membrane structure. The waveguide and nanocavity are implemented as a line-defect and a point-defect in the crystal lattice of air-holes. The left laser mirror is a conventional photonic crystal mirror and the right mirror is implemented as a Fano resonance. The gain is provided by quantum dots embedded in the membrane structure and are pumped optically in such a way that only the dots in the main laser cavity are excited.