

# Investigation of Fabry-Pérot cavities based on 2D Photonic crystals fabricated in InP membranes

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The properties of Fabry-Pérot cavities based on photonic crystals etched in suspended InP membranes are presented. For a cavity with 2-hole mirrors and a resonance wavelength around 1.55  $\mu\text{m}$ , a quality factor of 3200 is achieved.

**Keywords:** photonic crystals, wavelength division multiplexing, optical filters

## Introduction

Two-dimensional photonic crystal (2D PhC) structures with a photonic bandgap opening in the near-infrared wavelength range are widely studied for applications in integrated optics. In particular, PhC based high finesse resonant cavities are attractive for DWDM applications [1].

In order to confine the light in the third dimension, 2D PhCs are usually realized in a step-index planar waveguide. Such a structure is called quasi-2D PhC. Quasi-2D PhCs suffer from out-of-plane losses since drilling holes through the planar waveguide induces out-of-plane coupling of guided modes into radiative modes into the claddings. However, step index waveguides with high index contrast between the core and the cladding layers feature theoretically lossless propagation compared to the low index contrast alternative [2]. The main disadvantage of high index contrast quasi-2D PhCs is their high sensitivity to any breaking of the crystal periodicity: engineered irregularities or defects within the PhC lattice, such as resonant cavities, may result in drastically increased out-of-plane radiation [2]. This is why careful design is required to achieve better quality factors in PhC cavities etched in semiconductor membranes [3].

In this work, we investigate Fabry-Pérot (FP) cavities based on 2D PhCs etched in InP suspended membranes. The transmission spectra of the FP cavities are measured using the end-fire method. Out-of-plane radiation sources are identified by imaging the sample with a Vidicon infrared camera.

## Design

The fabricated structures are entirely designed from a perfectly periodic 2D PhC. The PhC is a triangular array of air holes with a 450 nm period and a hole size of 270 nm, resulting in an air-filling factor of 35%. The FP cavity is integrated within a waveguide that is obtained by removing the central row of the PhC. This type of waveguide is often referred as W1 waveguide. The cavity is formed by putting back air holes as mirrors (see Fig. 1). The length of the FP cavity is 30 PhC periods, which corresponds to about 13.5  $\mu\text{m}$ . Cavities with mirrors formed of one and two holes have been realized.

## Fabrication

The InP/InGaAs heterostructure consists of a 400 nm thick InGaAs layer and of a 400 nm thick InP layer grown by metal-organic vapor-phase epitaxy on an n-doped InP substrate [4]. The 2D PhCs were patterned into the InP-based heterostructure using electron beam lithography and subsequent chemical assisted ion beam etching (Ar/Cl<sub>2</sub>). The sample is then cleaved a few microns before both ends of the 340  $\mu\text{m}$  long PhCs to obtain direct access to the W1 waveguides. The sacrificial InGaAs layer is selectively removed using a FeCl<sub>3</sub>/H<sub>2</sub>O etch solution. The etch solution

reaches the InGaAs layer by diffusing through the holes of the PhCs. As a result, a high refractive index contrast slab waveguide is created.

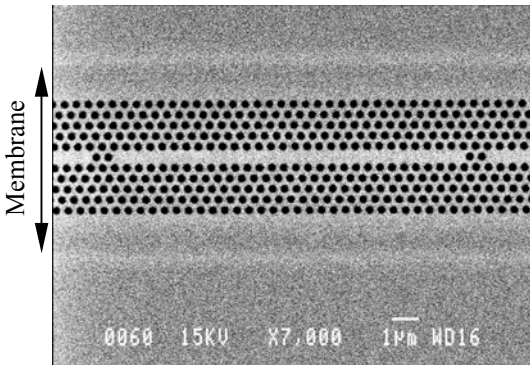


Fig. 1: top view of a photonic crystal based Fabry-Pérot cavity with 2-hole mirrors.

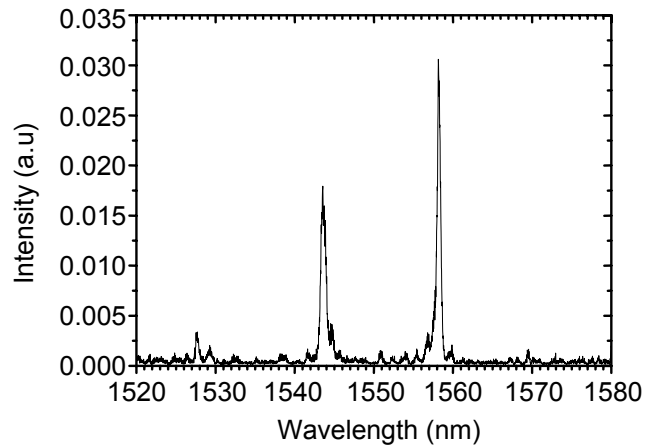


Fig. 2: transmission spectrum for the Fabry-Pérot cavity with 2-hole mirrors.

### Transmission measurements

The transmission spectra of the FP cavities are measured using the end-fire method. Light from a tuneable laser passes through an optical polarizer. With the help of a GRIN lens, the linearly polarized light is launched into the input W1 waveguide and excites TE-like polarized fundamental modes. On the output side, the guided light passes through an optical analyzer, which filters out any residual TM polarization component in the transmitted light. A microscope objective focuses the output light on a multimode fiber (core diameter 64  $\mu\text{m}$ ) that is connected to an InGaAs photodiode.

The transmission spectrum of the FP cavity with 2-hole mirrors shows two resonance peaks (Fig. 2). The maximum intensity of the resonance peaks follows the transmission profile for the W1 waveguide. The bandwidth of the largest resonance peaks ( $\lambda=1558.3$  nm) is 60 GHz, which corresponds to a quality factor  $Q=f/\Delta f$  of 3200. In comparison, we measured a quality factor of 2800 for a FP cavity with 1-hole mirror ( $\lambda=1553.4$  nm).

At resonance, the transmission through the FP cavity does not exceed a few percent of that for a simple W1 waveguide for the same wavelength. This suggests that out-of-plane radiation losses are important in the structure. Top views of the cavity recorded with a Vidicon infrared camera show that the cavity mirrors are major scattering sources in the structure. Consequently, a better design of the mirrors would improve the transmission at resonance as well as the quality factor of the FP cavities.

### Conclusion

PhC based Fabry-Pérot cavities fabricated into 400 nm thick InP membranes were characterized. A quality factor as high as 3200 was obtained for resonant cavities with 2-hole mirrors. The quality factor as well as the transmission at resonance is limited by out-of-plane scattering from the cavity mirrors.

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