



Review

Progress in 2D photonic crystal Fano resonance photonics

Weidong Zhou^{a,*}, Deyin Zhao^a, Yi-Chen Shuai^a, Hongjun Yang^a,
Santhad Chuwongin^a, Arvinder Chadha^a, Jung-Hun Seo^b, Ken X. Wang^c,
Victor Liu^c, Zhenqiang Ma^{b,**}, Shanhui Fan^{c,***}

^aDepartment of Electrical Engineering, University of Texas at Arlington, Arlington, TX 76019, USA

^bDepartment of Electrical and Computer Engineering, University of Wisconsin-Madison, Madison, WI 53706, USA

^cDepartment of Electrical Engineering, Stanford University, Stanford, CA 94305, USA

Available online 15 February 2014

Abstract

In contrast to a conventional symmetric Lorentzian resonance, Fano resonance is predominantly used to describe asymmetric-shaped resonances, which arise from the constructive and destructive interference of discrete resonance states with broadband continuum states. This phenomenon and the underlying mechanisms, being common and ubiquitous in many realms of physical sciences, can be found in a wide variety of nanophotonic structures and quantum systems, such as quantum dots, photonic crystals, plasmonics, and metamaterials. The asymmetric and steep dispersion of the Fano resonance profile promises applications for a wide range of photonic devices, such as optical filters, switches, sensors, broadband reflectors, lasers, detectors, slow-light and non-linear devices, etc. With advances in nanotechnology, impressive progress has been made in the emerging field of nanophotonic structures. One of the most attractive nanophotonic structures for integrated photonics is the two-dimensional photonic crystal slab (2D PCS), which can be integrated into a wide range of photonic devices. The objective of this manuscript is to provide an in depth review of the progress made in the general area of Fano resonance photonics, focusing on the photonic devices based on 2D PCS structures. General discussions are provided on the origins and characteristics of Fano resonances in 2D PCSs. A nanomembrane transfer printing fabrication technique is also reviewed, which is critical for the heterogeneous integrated Fano resonance photonics. The majority of the remaining sections review progress made on various photonic devices and structures, such as high quality factor filters, membrane reflectors, membrane lasers, detectors and sensors, as well as structures and

*Corresponding author. Tel.: +1 817 272 1227.

**Corresponding author. Tel.: +1 608 261 1095.

***Corresponding author. Tel.: +1 650 724 4759.

E-mail addresses: wzhou@uta.edu (W. Zhou), mazq@engr.wisc.edu (Z. Ma), shanhui@stanford.edu (S. Fan).

phenomena related to Fano resonance slow light effect, nonlinearity, and optical forces in coupled PCSs. It is expected that further advances in the field will lead to more significant advances towards 3D integrated photonics, flat optics, and flexible optoelectronics, with lasting impact in areas ranging from computing, communications, to sensing and imaging systems.

© 2014 Elsevier Ltd. All rights reserved.

Keywords: Fano resonances; Photonic crystals; Membrane lasers; Filters; Slow light; Silicon photonics

Contents

| | |
|--|----|
| 1. Introduction | 3 |
| 2. Principles of Fano resonance in photonic crystal slabs | 5 |
| 2.1. 2D Photonic Crystal Slabs | 5 |
| 2.2. The presence of Fano resonance in photonic crystal slabs | 5 |
| 2.3. Characteristics of Fano resonance in photonic crystal slabs | 6 |
| 3. Transfer printing techniques for Fano resonance photonics | 8 |
| 3.1. Transfer printed semiconductor nanomembranes for Fano resonance photonics | 8 |
| 3.2. Comparison with other epitaxial lift-off (ELO) and wafer bonding processes | 13 |
| 4. Fano resonance photonic crystal filters | 15 |
| 4.1. Single layer filters | 15 |
| 4.2. Coupled double layer filters | 21 |
| 4.3. Fano resonance filter configurations | 24 |
| 4.3.1. Single layer Fano resonance filters | 24 |
| 4.3.2. Double layer Fano resonance filters | 26 |
| 4.3.3. Double layer Fano resonance filters with controlled lattice displacement | 27 |
| 5. Fano resonance photonic crystal membrane reflectors | 30 |
| 5.1. Broadband reflector design | 31 |
| 5.2. Different configurations and buffer layer design | 33 |
| 5.3. Energy and phase penetration properties in membrane reflectors | 34 |
| 5.4. Angle and polarization properties | 36 |
| 6. Fano resonance photonic crystal membrane lasers | 37 |
| 6.1. Photonic crystal functions in light sources | 37 |
| 6.2. Design of MR-VCSELs | 39 |
| 6.3. MR-VCSEL Fabrication and configurations | 42 |
| 6.3.1. Epitaxial growth approach | 42 |
| 6.3.2. Wafer bonding and CMP techniques | 43 |
| 6.3.3. Transfer printing techniques | 43 |
| 7. Fano resonance photonic crystal field localization and absorption engineering | 46 |
| 7.1. Electromagnetic field localization and enhancement in photonic crystal cavities | 46 |
| 7.2. Demonstration of spectral-selective absorption enhancement and IR detectors | 49 |
| 7.2.1. CQD integrated Si-NM Fano filters | 49 |
| 7.2.2. Fano resonance enhanced photonic crystal Infrared Photodetectors | 51 |
| 8. Fano resonance photonic crystal sensors | 54 |
| 8.1. Asymmetric Fano resonance line shape and high Q cavities | 54 |
| 8.2. Fano resonance PCS sensor configurations | 55 |
| 9. Fano resonance photonic crystal cavity optomechanics | 57 |
| 9.1. Optical forces in nano-scale cavities | 57 |
| 9.2. Optical forces in coupled Fano resonance PCSs | 58 |

Download English Version:

<https://daneshyari.com/en/article/1549137>

Download Persian Version:

<https://daneshyari.com/article/1549137>

[Daneshyari.com](https://daneshyari.com)