High-Q Two-Dimensional Lithium Niobate Photonic Crystal Slab Nanoresonators

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Primary CNF Tools Used: JEOL 9500, AJA ion mill

Abstract:

We report a 2D LN PhC slab nanoresonators with high optical Q over 3×10^5. Such a high quality enables us to probe the intriguing anisotropy of nonlinear optical phenomena of LN never reported previously.

Summary of Research:

Photonic crystal (PhC) nanoresonators exhibit exceptional capability of controlling light confinement and light matter interactions in the sub-wavelength scale, which forms a crucial foundation for many applications [1,2]. Among various photonic crystal structures, two-dimensional (2D) photonic crystal slabs exhibit significant advantage in the engineering of the density of photonic states. These excellent characteristics have excited tremendous interest in recent years to develop 2D PhC slab nanoresonators on a variety of material platforms.

Lithium niobate (LN), exhibits outstanding electro-optic, nonlinear optical, acousto-optic, piezoelectric, photorefractive, pyroelectric, and photoconductive properties [5], promising for broad applications. The great application potential has attracted significant attention recently to develop LN photonic devices on chip-scale platforms [3,4,7]. However, realizing high-quality 2D LN PhC structures remains significant challenge [6], which becomes the major obstacle hindering the exploration of optical phenomena in the nanoscopic scale that would potentially result in intriguing device characteristics and novel functionalities inaccessible by conventional means.

In this paper, we demonstrate 2D LN PhC slab nanoresonators with optical Q up to 3.51×10^5, about three orders of magnitude higher than other 2D LN photonic crystal nanocavities reported to date [6].

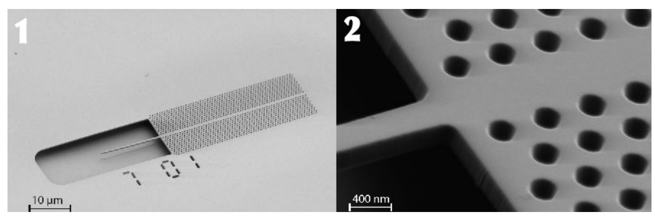

Figure 1: Scanning electron microscopic image of a fabricated 2D LN PhC slab. Figure 2: Zoom-in image of a section of the photonic crystal slab.

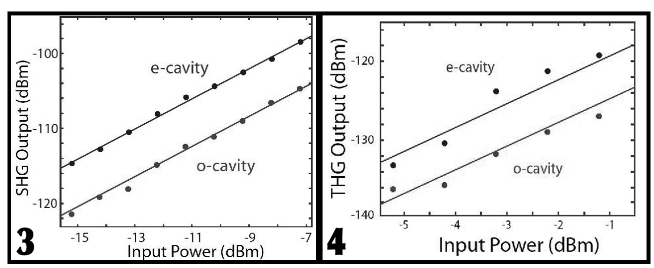

Figure 3: *Recorded power of the generated second harmonic wave as a function of that of the fundamental pump wave, where the dots are experimental recorded data for an e-cavity and o-cavity, respectively. The solid lines show quadratic fitting to the experimental data.* ***Figure 4:*** *Recorded power of the generated third harmonic wave as a function of the fundamental pump wave, where the dots are experimental recorded data for an e-cavity and o-cavity, respectively. The solid lines show cubic fitting to the experimental data.*

Devices are patterned by JEOL 9500. Such a pure polarization enables us to explore intriguing anisotropy of optical phenomena, by making the line-defect cavity either in parallel with or perpendicular to the optical axis. For convenience, we denote the one perpendicular to the optical axis as an e-cavity since the dominant electric field polarizes along the optical axis, corresponding to the extraordinary polarization. Accordingly, we denote the one in parallel with the optical axis as an o-cavity as the dominant cavity field polarizes along the ordinary polarization. In particular, the high optical Q together with the tiny effective mode volume supports extremely strong nonlinear optical interactions, which results in efficient third harmonic generation combined with cascaded second harmonic generation, for the first time in on-chip LN nanophotonic devices [3,4,7]. The demonstrated high-Q 2D LN PhC nanoresonators offer an excellent device platform for the exploration of extreme nonlinear and quantum optics at single-photon and few-photon level, opening up a great avenue towards future development of energy efficient nonlinear photonic and electro-optic signal processing.

In summary, we have demonstrated 2D LN PhC slab nanoresonators with optical Q up to 3.51×10^5 that is about three orders of magnitude higher than other 2D LN PhC nanoresonators reported to date [6]. The high optical Q together with tight optical mode confinement results in intriguing nonlinear optical interactions. We have observed second-harmonic generation, particularly third harmonic generation that is the first time to be observed in on-chip LN nanophtonic devices [3,4,7]. Moreover, the devices exhibits pure polarization of the cavity modes, which enabled us to probe the intriguing anisotropy of nonlinear optical phenomena, which have never been reported previously.

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