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Q-factor optimization in photonic crystal nanobeam cavities based on elliptical nanopillars for refractive index sensing

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Label free sensing applications based on refractive index (RI) require new encapsulated high Q-factor cavity designs, that can overcome the inaccuracies inherent in the fabrication process. The required fine tuning of the current RI sensors based on PhCNC makes them highly sensitive to disparities found in the fabrication. These imperfections can dramatically decrease the performance, in designs which possess strict features along the whole design parameters space [1-4]. To limit this behaviour, we propose elliptically shaped nanopillars in which the optimum zone of operation is extended. The schematics of the PhCNC and the fabricated device considered in this work are shown in Fig. 1(a) and (b), respectively. Fig. 1(a), depicts three different cross sections of the PhCNC immersed in different analyte refractive index (n_A) that can vary from 1 (refractive index that can be considered for gases) to 1.45 (SiO_2). The vertical widths ($W_y(i)$) of the dielectric pillars are quadratically modulated ($W_y(i) = W_y(0) + i^2(W_y(i_{max})-W_y(0))/i_{max}^2$), from the center to both sides where i increases from 0 to i_{max} (see Fig. 1(a)-left). Fig. 1 (c) shows the behavior of the Q-factor calculated by means of 3D-FDTD simulations [5], against different nanopillar widths W_x in two extreme shape cases: rectangular and elliptical ones.

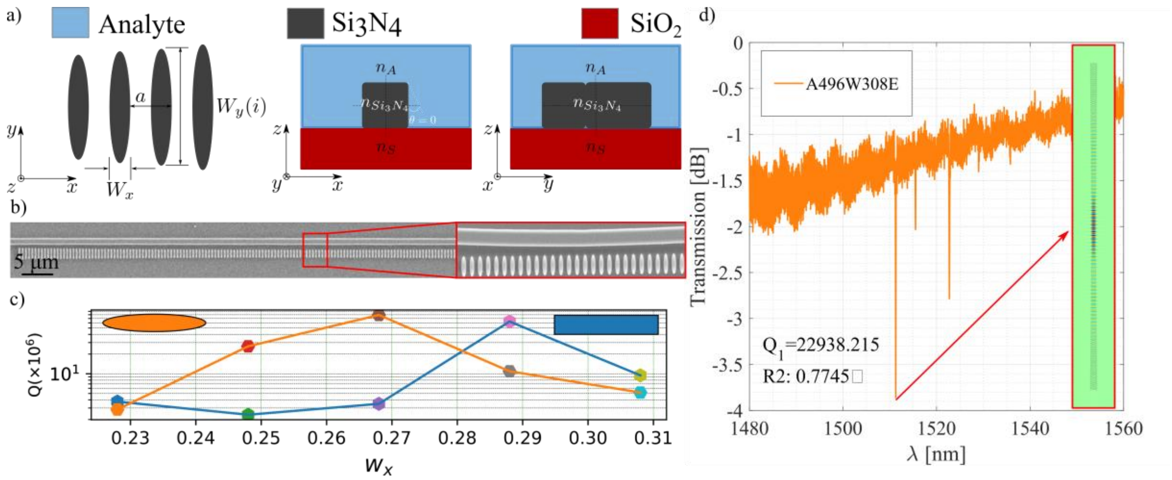

Fig. 1 (a) Lateral views of a segment shape of picture (b) where *a = 496 nm* (lattice period), $W_x = 308$ *nm* and W_y parabolically modulated from $W_y(0) = 2.8a$ in the centre to $W_y(92) = 4.0a$ on either side. (b) SEM image of proposed side-coupled PhCNC (top view) (c) Q-factor for elliptical (orange) and rectangular (blue) nanopillars for different widths (n_A = 1.45). (d) Experimental transmission spectra of two fabricated devices as in (b) by a S-Bend waveguide side-coupling.

The proposed device exhibits calculated Q-factors upper than 10^6 (see fig.1(c)) for a broad range (~100nm) of elliptical nanopillar widths, against rectangular counterparts with a localized optimal width. In contrast, Fig. 1(d) shows the experimental measurement of the proposed device and the calculated mode profile associated with the fundamental optical mode supported by the structure. The experimental Q-factors are in the range of (1.0-2.3) 10^4, in line with the measurements report in the same type of cavities [4].

In conclusion we presented a novel High-Q 1D PhCNC design based on elliptical nanopillars, with compact size (~$100\cdot 10$ μm^2), and resilient against fabrication errors (+/-40 nm) as a promising option for label free sensing applications among many others.

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