Doubly resonant AlGaAs photonic crystal cavity

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Second Harmonic Generation

Non linear effects are usually small and poorly efficient Our goal: highly efficient second harmonic generation (SHG)



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Z. Lin, X. Liang, M. Lončar, S. G. Johnson, and A. W. Rodriguez Optica, 3(3):233-238, Mar 2016.

Doubly resonant cavity in AlGaAs suited for SHG in telecom wavelengths:

- $\lambda_{FH} \approx 1550\,\text{nm}$
- $\lambda_{SH} \approx 775\,\text{nm}$

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SHG in Photonic cavities

- Temporal confinement \rightarrow High quality factor Q
- Spatial confinement \rightarrow modal volume $\approx (\lambda/n)^3$
- High overlap $\overline{\beta}$ between first (FH) and second harmonic (SH)

$$\bar{\beta} = \frac{\int d\mathbf{r} \sum_{ijk} \bar{\chi}_{ijk}^{(2)} E_{2\omega i}^* E_{\omega j} E_{\omega k}}{\left(\int d\mathbf{r} \, \varepsilon_{\omega}(\mathbf{r}) |\mathbf{E}_{\omega}|^2\right) \left(\int d\mathbf{r} \, \varepsilon_{2\omega}(\mathbf{r}) |\mathbf{E}_{2\omega}|^2\right)^{1/2}} \sqrt{\lambda_{\text{FH}}^3} \qquad (1)$$

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- Calculate photonic bandstructure with finite difference time domain (FDTD)
- 2 Tune photonic FH and SH modes to doubly resonance: $\omega_2 = 2\omega_1$ with particle swarm optimization (PSO)
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- Main [1,0,0] AlGaAs χ⁽²⁾ elements are xyz and permutations
- PH below the light line
- SH above the light line, in the continuum of "leaky modes"

- TE-like (even) polarization for FH and TM-like (odd) for SH
- FH mode has naturally infinite Q
- SH = bound state in the continuum, infinite Q despite it lies in the light cone



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Calculated photonic bandstructures



Different refractive index for TE- and TM-like simulations



Doubly resonance tuning with PSO

PSO parameters:

• FOM =
$$\left| \frac{\omega_{\text{SH}} - 2\omega_{\text{FH}}}{\omega_{\text{SH}}} \right|$$

- $r^*/a = 0.175$
- $d^*/a = 0.24$
- $(\omega_{\text{FH}}a)/(2\pi c) \approx 0.335$
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$$\frac{\omega_{\mathsf{SH}}-2\omega_{\mathsf{FH}}}{\omega_{\mathsf{SH}}}<1\%$$



Final cavity

Heterostructure with gentle confinment: inner radius r^* , gradually increasing



 $Q_{\mathsf{FH}} pprox 10^5$, $Q_{\mathsf{SH}} pprox 10^3$, $|ar{eta}|^2 pprox 10^{-5}$,



Final cavity



Optica, 3(3):233-238, Mar 2016



Topological properties



Phase discontinuity \rightarrow topological charge +1 Emission of vortex beam





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- Future perspectives: possible realisation and experimental measurements





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Thanks for the attention.

