Slow light in dispersion-engineered photonic crystal ring resonators

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1 Extended Abstract

Photonic crystal ring resonators (PhCRRs) are hybrid optical devices made by forming a ring with a photonic crystal waveguide (see Figure 1a). A standard ring resonator (RR) shows a spectrum with equally spaced sharp resonances. In a PhCRR, the strong dispersion induced by the periodic perturbation to the dielectric profile of the waveguide causes the appearance of a photonic bandgap and a variable spacing between the resonances close to it (as can be appreciated in measured transmission spectrum shown in Figure 1b). This photonic bandgap results in slow light and enhanced light-matter interaction.

![Figure 1. a) Scanning electron microscope image of a fabricated PhCRR. b) Transmission spectrum measured from a PhCRR with a 20 \(\mu m\) radius.](image)

We have fabricated PhCRRs using a CMOS-compatible, 193-nm deep-UV lithography process (ePIXfab IMEC Standard Passives). We have measured transmission spectra from thirty different devices designed to present a photonic band edge resonance at 1550 nm\(^{[1]}\). We find a mean wavelength for the photonic band edge of 1546.2 ± 5.8 nm, a 0.2% variation from our target. The fabricated devices also show noticeable slow-light effects, with a maximum slow-down factor of \(\approx 13\) and a maximum intrinsic quality factor \(\approx 83,300\). The quality factors of the PhCRRs (and a control set of thirty similar RRs) were analyzed using a linear model to fit the measured transmission. The dispersive behaviour of the photonic crystal waveguide can be approximated by assuming a frequency-dependent phase shift\(^{[2]}\). The slow-down factor was calculated using the known mode numbers, ring radius and measured resonant wavelengths. The obtained mean values for both quantities are shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>10 (\mu m) RRs</th>
<th>20 (\mu m) RRs</th>
<th>10 (\mu m) PhCRRs</th>
<th>20 (\mu m) PhCRRs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean intrinsic quality factor</td>
<td>(8.26 \times 10^4)</td>
<td>(1.50 \times 10^3)</td>
<td>(2.72 \times 10^4)</td>
<td>(4.31 \times 10^4)</td>
</tr>
<tr>
<td>Mean slowdown factor</td>
<td>1.23</td>
<td>1.53</td>
<td>7.08</td>
<td>11.8</td>
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</tbody>
</table>

Table 1. Mean quality and slow-down factors for standard RRs and PhCRRs with different radii.

We see that while the slowdown factor increased by a factor close to 7, the quality factors were decreased by factors around 4. This means that our CMOS-compatible-produced PhCRRs can slow down light without only a small penalty in terms of quality factor.

References
