Octagonal toroid microcavity for mechanically robust coupling with optical fiber

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Abstract

Critical coupling and mechanically robust coupling between a whispering-gallery mode and a tapered fiber is simultaneously demonstrated by using an octagonal toroid microcavity with a theoretical $Q$ of $8.8 \times 10^6$ and an experimental value of $4.3 \times 10^4$.

Background: High-$Q$ optical cavity

<table>
<thead>
<tr>
<th>Photonic Crystal</th>
<th>Silicon Microring</th>
<th>Silica Toroid</th>
<th>Crystaline</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q$-factor</td>
<td>$10^9$</td>
<td>$10^7$</td>
<td>$10^6$</td>
</tr>
<tr>
<td>Mode volume</td>
<td>$10^{-4}$ m$^3$</td>
<td>$10^{-3}$ m$^3$</td>
<td>$10^{-2}$ m$^3$</td>
</tr>
</tbody>
</table>

High $Q$-factor optical cavities are used for sensing, frequency comb generation, opto-mechanics, etc.

Background: Optical coupling

The whispering-gallery mode is excited through an evanescent field with a tapered fiber.

<table>
<thead>
<tr>
<th>Toroid</th>
<th>Tapered fiber</th>
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<tbody>
<tr>
<td>Evanescent field</td>
<td>Gap between cavity and fiber</td>
</tr>
</tbody>
</table>

Difficulty

To obtain maximum coupling efficiency (critical coupling), we need sub-μm gap control between the cavity and the fiber.

Motivation

Design the cavity shape

Design the cavity shape to achieve critical coupling
Design the cavity shape to achieve mechanical robustness

Fabrication

Other fabrication method

Using an octagonal silica disk, we do not need anisotropic etching.

Conclusion

We designed the coupling $κ$ by making WGM cavities octagonal. Higher $κ$ is obtained for corner coupling and lower $κ$ is obtained for side-wall coupling. The coupling is closer to the critical coupling even when we touch the fiber to the surface of the cavity.

Acknowledgement

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FDTD simulation (Mode calculation)

$Q_{\text{unload}} = Q_{\text{optical}} = Q_{\text{coup}} + Q_{\text{load}}$

$Q_{\text{load}}$ : Loaded $Q$ (w/ waveguide)
$Q_{\text{coup}}$ : Coupling $Q$ ($\omega / \kappa$)
$
\Rightarrow$ Different coupling can be obtained by changing the contact point.

Spectrum measurement method

Experiment: Measurement results

Comparing with gap distances @ critical coupling

Comparing with $Q$-factors (resonance wavelength $\measuredangle$)

Conclusion

We designed the coupling $κ$ by making WGM cavities octagonal. Higher $κ$ is obtained for corner coupling and lower $κ$ is obtained for side-wall coupling. The coupling is closer to the critical coupling even when we touch the fiber to the surface of the cavity.

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