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Analysis of Various Whispering Gallery Modes in an Octagonal Silica Toroidal Microcavity

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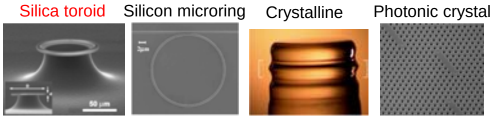
Abstract

Controlled coupling is demonstrated with a whispering-gallery-mode octagonal silica toroidal microcavity. We found two different modes, one of which exhibits a theoretical Q of 8.8×10^6 and an experimental Q of 2.2×10^4. The coupling coefficient is controlled by changing the contacting point of the cavity.

Background: High-Q optical cavity



Q-factor	$Q > 10^8$	$Q \sim 10^6$	$Q > 10^{10}$	$Q \sim 10^6$
size	µm	µm	mm	nm

T. J. Kippenberg *et al.*, *APL* **85**, (2004).
M. Soltani *et al.*, *IEEE J. Quantum Electron.* **46**, (2010).
I. Grudinin *et al.*, *Phys. Rev. A* **74**, (2006).
E. Kuramochi *et al.*, *APL* **88**, (2006).

Application of High-Q cavity
・Optical frequency comb
・Sensing etc.

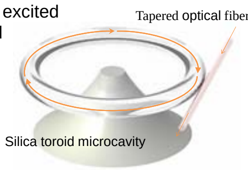
$$Q = \omega \frac{E_{cav}}{P_{diss}} = \omega\tau$$

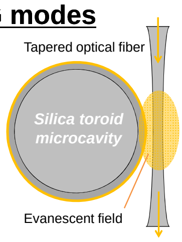
E_{cav} : energy stored in the cavity
P_{diss} : dissipated power
τ : photon life time

Background: Optical coupling of WG modes

Whispering gallery mode is excited through an evanescent field

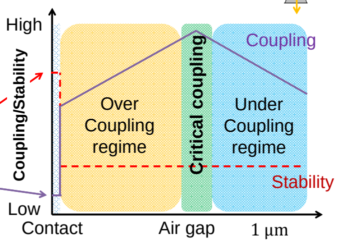
Using tapered fiber





The problem of using tapered fiber
✓Very fragile for disturbance
✓Need sensitive control

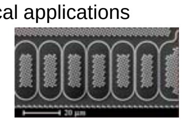
Fiber touches the cavity
✓Highest stability
✓Low coupling due to over coupling



Motivation & proposal

Need for an ultrahigh-Q cavity that is robust for practical applications

➢ By changing the shape of a cavity, design the coupling with waveguide like microring

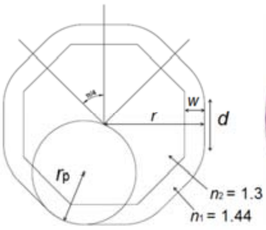


M. L. Cooper *et al.*, Opt. Lett. **35**, (2010).

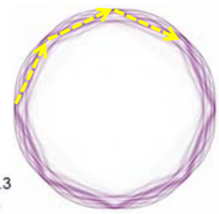
➢ Proposal of "Polygonal silica toroid microcavity"

Simulation

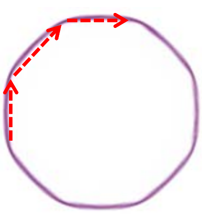
✓ Calculating resonance modes in a silica toroid microcavity by using 2D-FDTD method



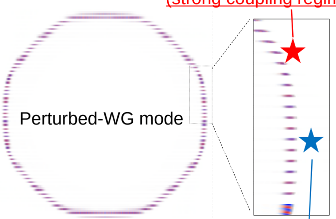
Simulation model
$r = 50$
$r_p = 38.1$
$w = 10$

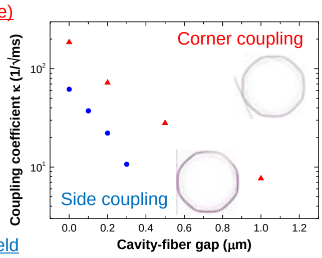


Quasi-WG mode
$Q = 4.5 \times 10^4$

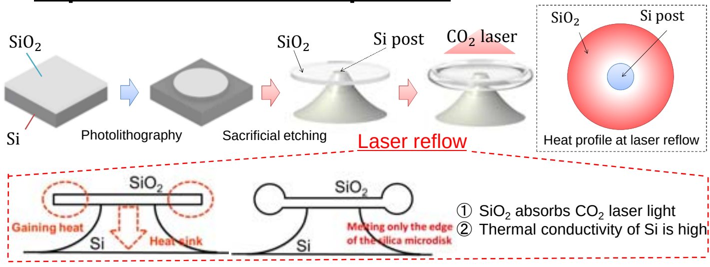


Perturbed-WG mode
$Q = 8.8 \times 10^6$

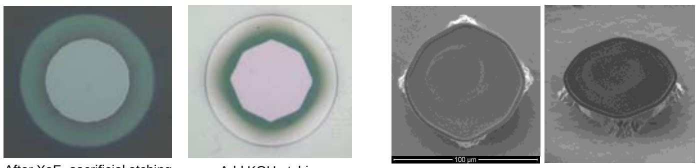




Experiment: Fabrication process



① KOH etching method



After XeF_2 sacrificial etching — Add KOH etching — SEM images after laser reflow

② Octagonal mask pattern method

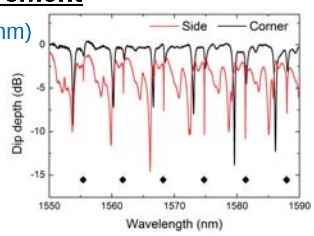
After XeF_2 sacrificial etching — After laser reflow

Experiment: Optical measurement

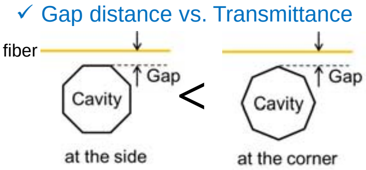
✓ Transmittance spectrum (gap is 0 nm)

We obtained a higher Q at the side because of lower coupling loss.

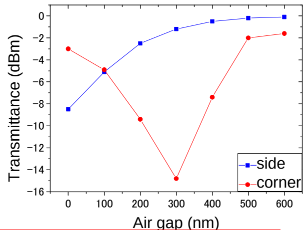
$Q = 2.2 \times 10^4$ (side coupling)
$Q = 6.3 \times 10^3$ (corner coupling)



✓ Gap distance vs. Transmittance



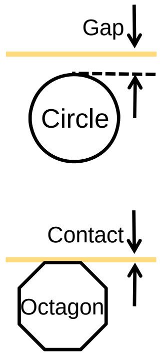
Coupling coefficient is higher at the corner than at the side

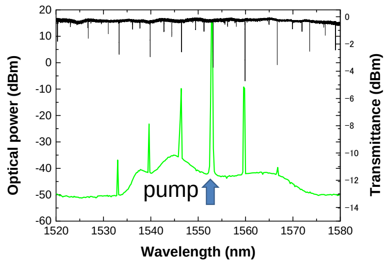


Side coupling prevent cavity-fiber coupling from overcoupling

Potential application: Optical frequency comb

✓ preliminary FWM experiment by using circular toroid





By performing similar experiment with polygonal cavity, we may enable the demonstration of the robust micro-sized frequency comb generator.

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Canon

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