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Ultra-high Q SiO_xN_y toroidal microcavities

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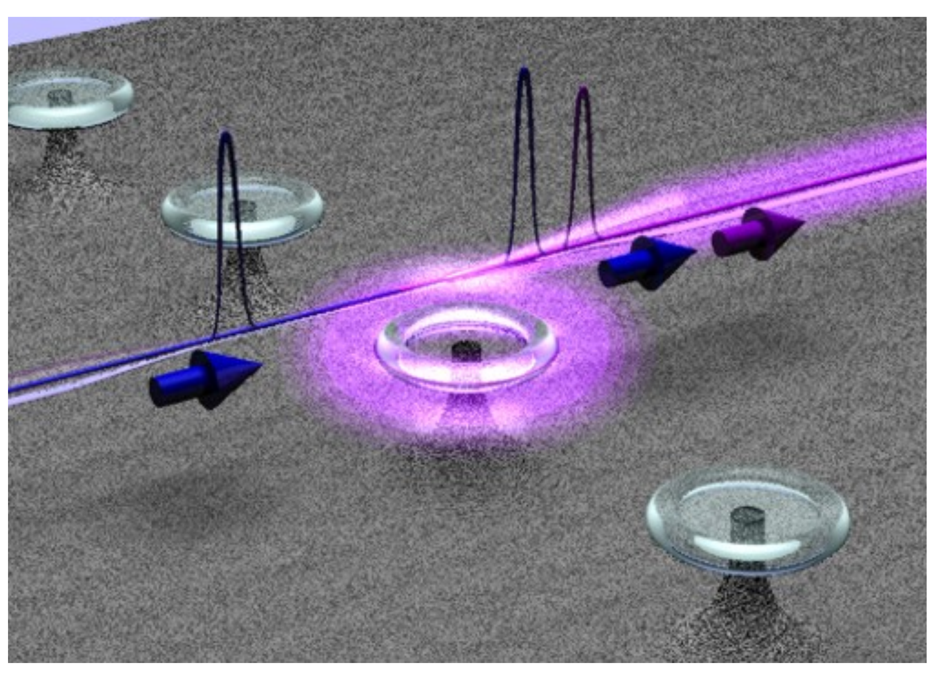
Background

Optical microtoriod is an excellent platform for nonlinear optics because light can be confined in the cavity for long time, which makes the optical field inside the cavity strong enough to generate nonlinear behavior.

Silicon oxynitride is a promising material for nonlinear research because of its low loss and high nonlinear coefficient. We showed that silicon oxynitride can be used to make microtoroid and tested its Q-factor, which is ultra-high.

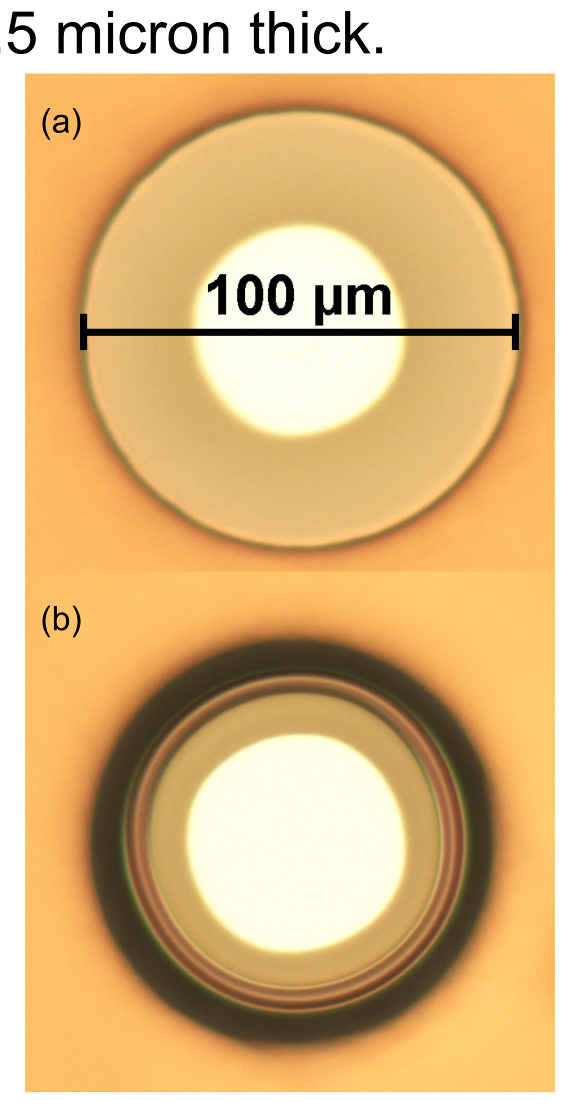


Rendering of a microcavity coupled to a tapered optical fiber.

Fabrication and Testing

The SiO_xN_y wafers were grown at Northrop Grumman. The O:N ratio determines the refractive index of the overall film and governs the chemical resistance of the material, which plays a critical role in the fabrication process. For the initial set of wafers, the oxynitride layer was 1.5 micron thick.

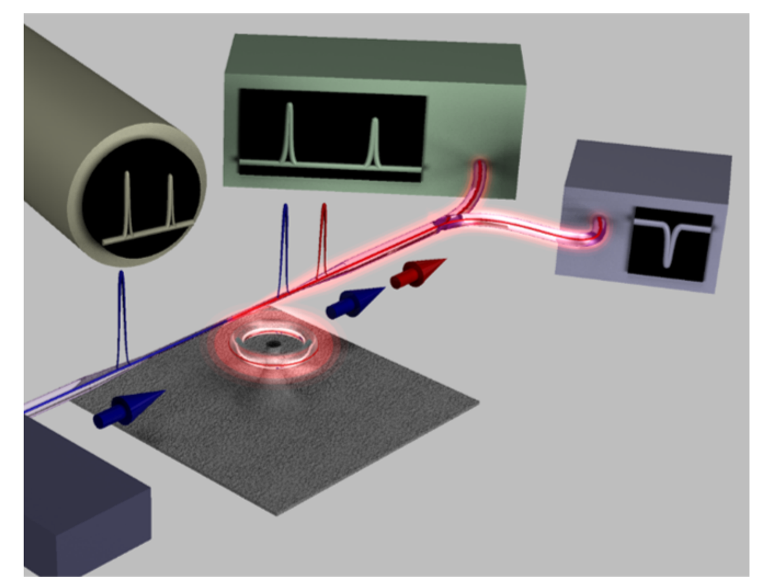
We used a standard microelectronic fabrication method to make SiO_xN_y microtoroid. First, we patterned our wafer with photoresist using photolithography, followed by a series of etching steps to form a SiO_xN_y microdisk on a silicon pillar. Then we use a CO_2 laser to reflow the microdisk into a toroid structure. The diameter of the microdisk before reflow is 100 μm. After reflow, the diameter of the microtoroid is about 70 μm. The ability to reflow the SiO_xN_y using the CO_2 laser indicates that the SiO_xN_y has a high absorbance in the mid-IR wavelength range.



Microscope images of
(a) microdisk
(b) microtoroid

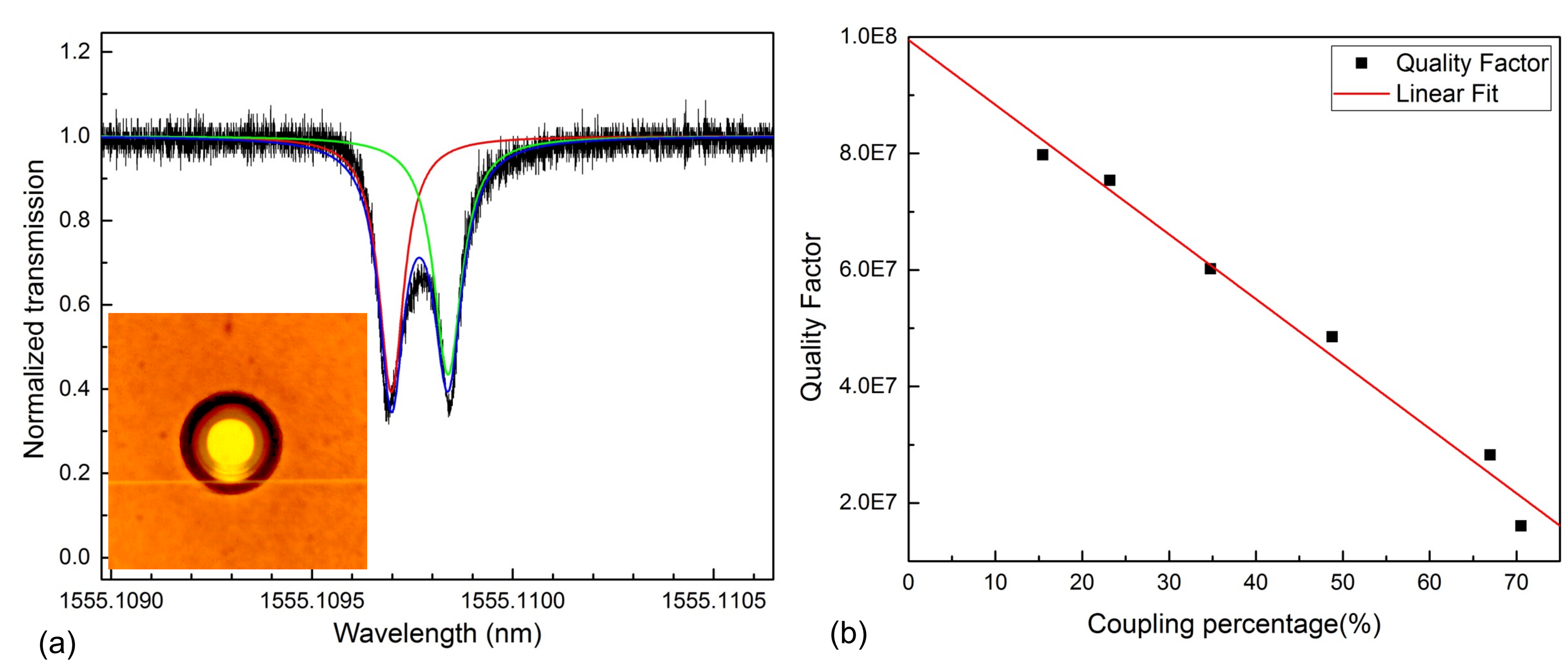
Data

A standard figure of merit for optical cavities is the quality factor (Q). The Q describes the photon lifetime inside the cavity, and conversely, the optical losses of the cavity. To determine the Q, a tunable laser is scanned across the resonant wavelength , and the transmission spectra is recorded. A tapered optical fiber waveguide is used to couple light into and out of the cavity.



A schematic of the testing set-up showing the laser and oscilloscope. An OSA and a spectrograph are also attached.

An example transmission spectra taken at 1550nm is shown in the figure below. The resonance exhibited a phenomena known as line-splitting. This occurs when the optical field is coupled into the cavity in both the clock-wise (CW) and counter-clockwise (CCW) directions. In ultra-high-Q cavities, this difference can be detected because the linewidth is extremely narrow. In order to accurately determine the Q of the cavity at a specific coupled power, the peak is fit to a dual-Lorentzian (blue line), and the FWHM of each mode is analyzed separately.



(a) Transmission spectra of an UHQ SiO_xN_y toroidal microcavity. The split resonance is because the taper coupled into both the CW and CCW modes. Inset: a picture of a SiO_xN_y toroidal microcavity coupled to a taper. (b) To determine the intrinsic cavity Q, the loaded Q is measured over a series of coupling conditions.

However, the Q is comprised of both intrinsic losses (e.g. material loss of the cavity) and extrinsic losses (e.g. coupling losses). To de-convolve these two distinct loss mechanisms, the Q is measured over a series of coupling conditions. From the second result, the intrinsic cavity Q is determined to be nearly 1E8. This is unprecedented for a SiO_xN_y device.

Discussion & Future Work

We have shown that our devices have Q-factors up to 10^8, which is sufficient to generate multiple nonlinear effects, like Raman laser, frequency combs. Next we would investigate into the nonlinear behavior of our devices, as well as the impact of the O:N ratio. We want to optimize our devices and use them for applications like low threshold Raman lasers, board bandwidth frequency combs.

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