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Environmentally stable ultra-high Q SiO_xN_y toroidal microcavities

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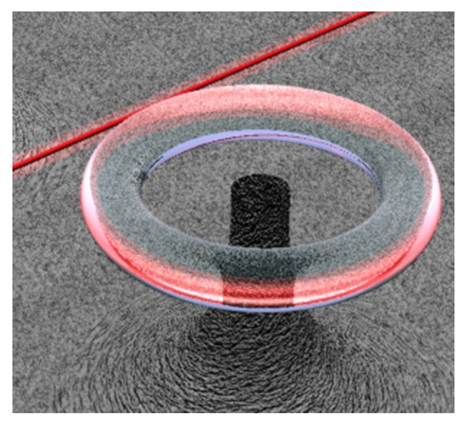
Background



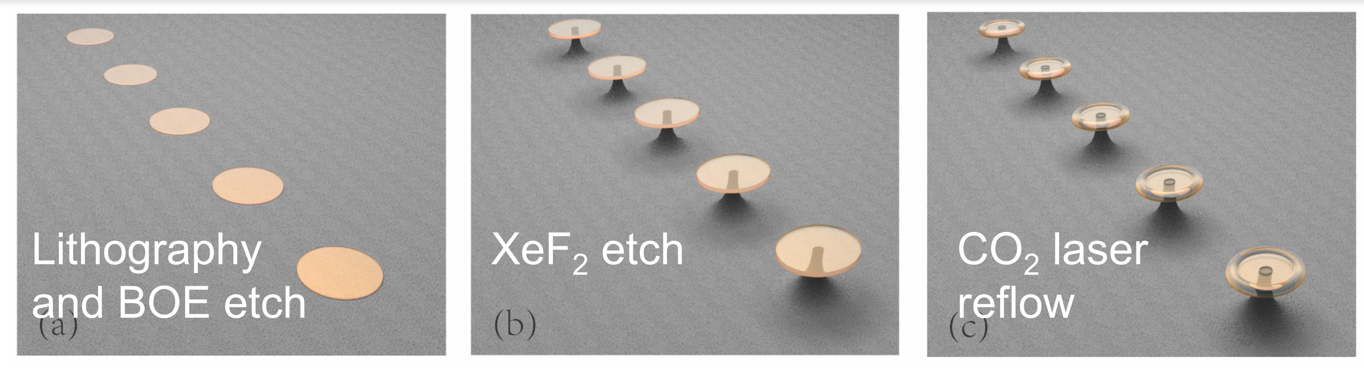
Rendering of toroidal cavity.

Optical resonant cavities behave like optical amplifiers for input light. In whispering gallery mode optical cavities, the optical field orbits around the periphery of the cavity, and the efficiency of the amplification can be quantified by the cavity quality factor (Q). In ultra-high-Q (UHQ) silica devices, input powers as low as 1mW can be amplified to 110W, enabling fundamental science investigations as well as numerous applied technologies. However, when silica devices are left in ambient environments, the UHQ factors degrade due to the formation of highly optically absorbing water monolayers Therefore, the development of devices from materials that inhibit this process is desirable.

$$Q_{mat} = \frac{2\pi n}{\lambda\alpha}$$

Q_{mat}=material-limited Q
n=refractive index
α=optical absorption

Fabrication

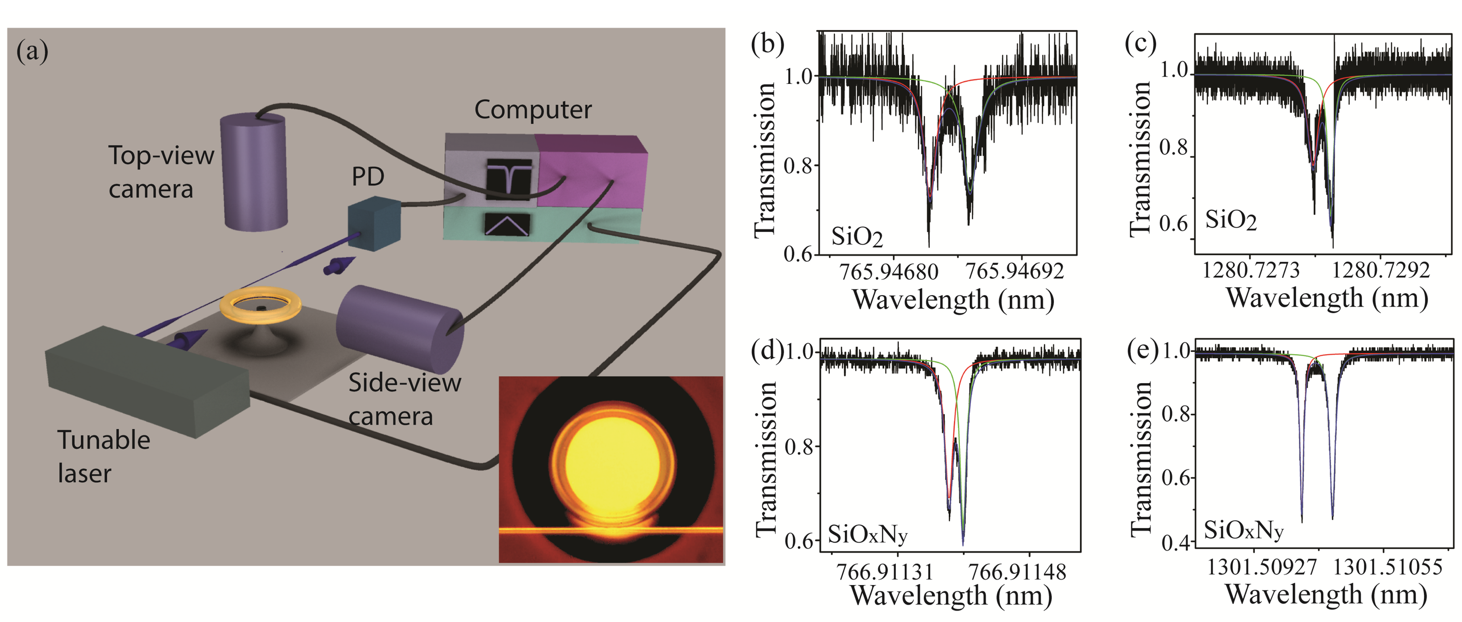


Rendering of the fabrication process.

The SiO_xN_y wafers were grown at Northrop Grumman with a refractive index of 1.50 and thickness of 1.5 micron. 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 used a CO_2 laser to reflow the microdisk into a toroid structure. The diameter of the microdisk before reflow is 150 μm. After reflow, the diameter of the microtoroid is about 110 μm.

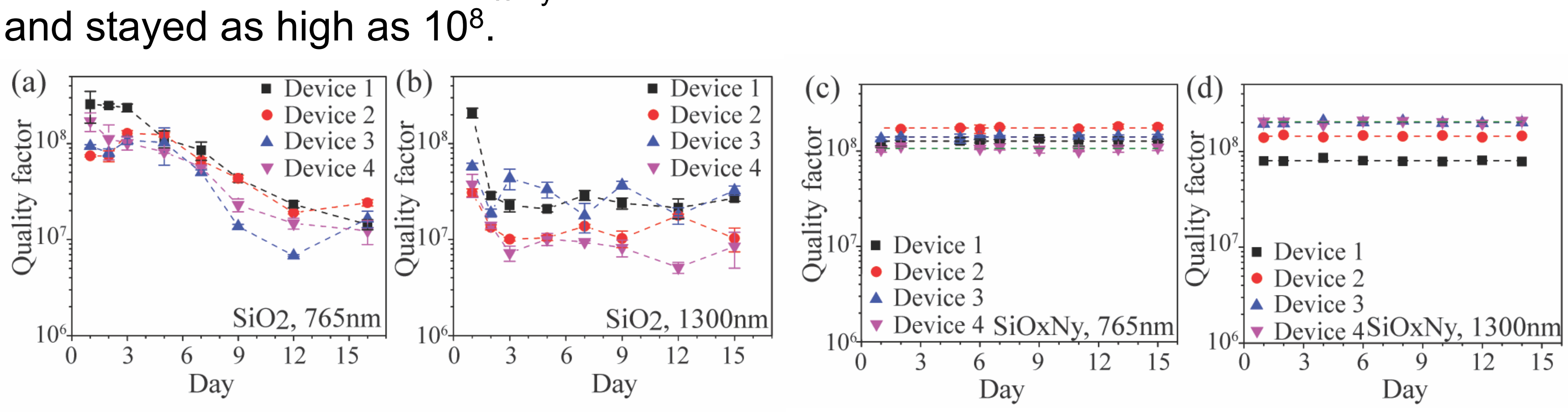
Surface Characterization and Device Testing Results

To experimentally determine the cavity Q, the cavity linewidth (δλ) is measured using a set-up like the one shown below. The Q at that input power is then calculated from Q=λ/δλ. Example spectra are also shown. Both SiO_2 and SiO_xN_y are fabricated.



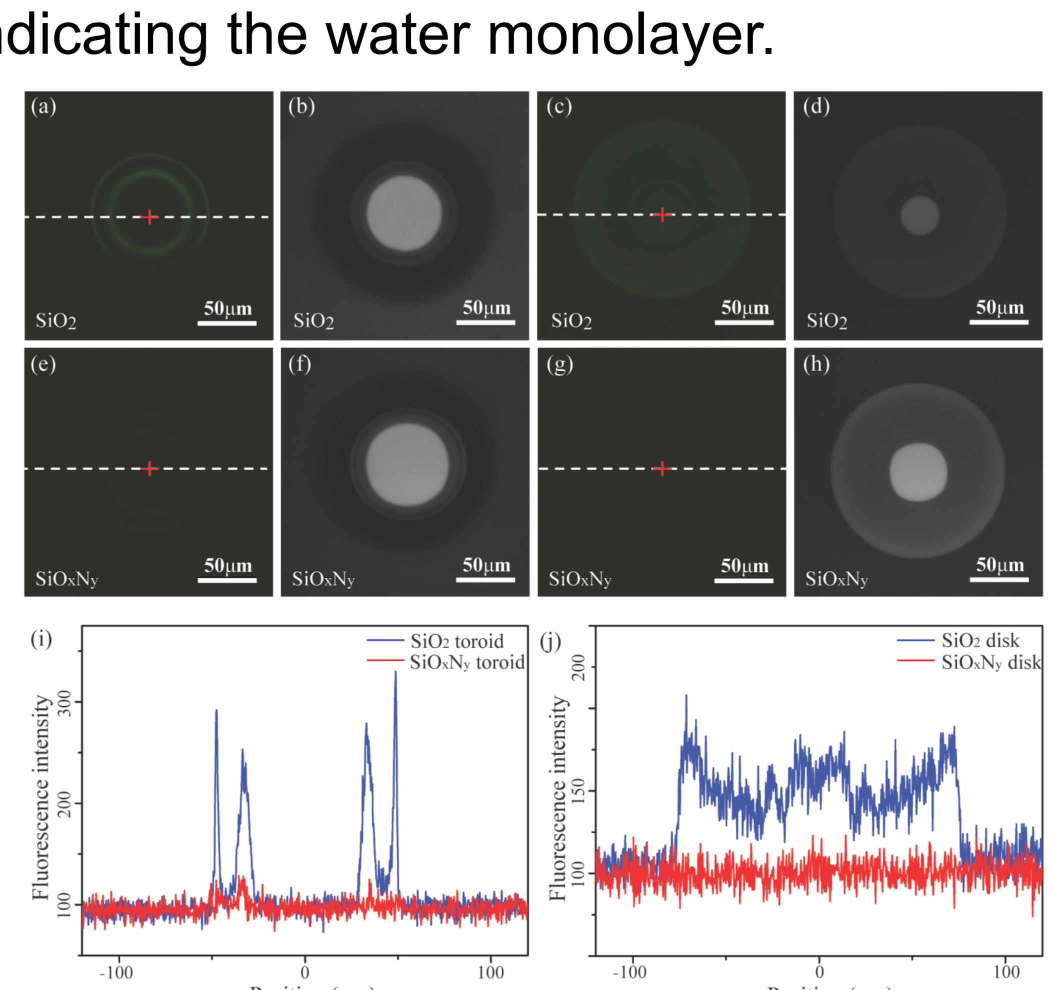
(a) A schematic of the testing set-up showing the laser, photodetector, cameras and the computer (with oscilloscope). (b)-(e) Q spectra at 765nm and 1300nm of SiO_2 and SiO_xN_y toroidal cavities. The splitting of the linewidth is commonly observed in UHQ cavities.

The time dependent Q of both the SiO_2 and SiO_xN_y cavities are measured over a 14 day window. For SiO_2 devices, the Qs decreased from around 10^8 to 10^7. In contrast, the Qs of the SiO_xN_y devices did not change over the two week test period and stayed as high as 10^8.



Measured Q factors of the (a)/(b) SiO_2 and (c)/(d)SiO_xN_y devices at 765 and 1300 nm over 14 days.

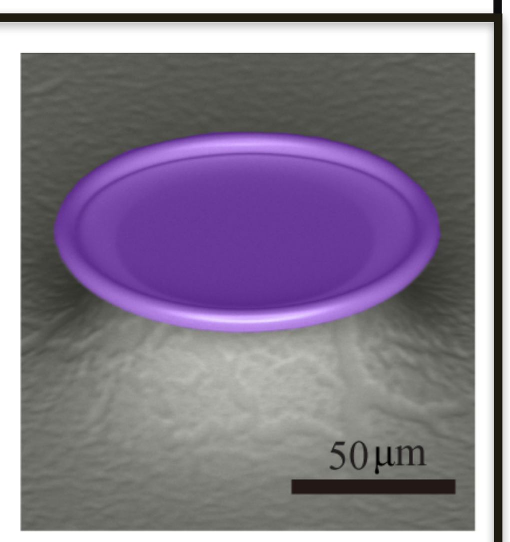
To confirm that the improved stability is due to the lack of a water monolayer, surface characterization is performed using fluorescence microscopy and a fluorescent indicator that targets the hydroxyl group. Both disks and toroids are studied. The results show that SiO_2 devices have significantly higher fluorescence intensity, indicating the water monolayer.



(a)-(h) Fluorescence/bright field images of SiO_2 and SiO_xN_y disks and toroids. (i,j) Fluorescence intensity maps of the corresponding devices.

Discussion & Future Work

We have shown that our SiO_xN_y devices have Q-factors up to 10^8 and are environmentally stable. In the future, we plan to leverage the improved third-order nonlinear coefficient to investigate the nonlinear behavior of our devices in telecommunications applications, such as Raman lasing and frequency comb generation.



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