Frequency comb generation using silicon oxynitride optical resonators

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Abbreviated abstract: Ultra-high quality factor (UHQ) optical resonant cavities are able to store light for long periods of time, resulting in the build-up of large optical fields. Past work with silica cavities has leveraged these high powers to create frequency combs. Unfortunately, silica attracts water, degrading the cavity *Q*. An alternative, environmentally-stable material system is silicon oxynitride. In this work, UHQ toroidal cavities are fabricated from silicon oxynitride, and frequency comb generation is demonstrated.

Related publications:
– D. Chen *et al*, Applied Physics Letters 115 (5), 1105 (2019)
– D. Chen *et al*, ACS Photonics 4 (9), 2376-2381 (2017)

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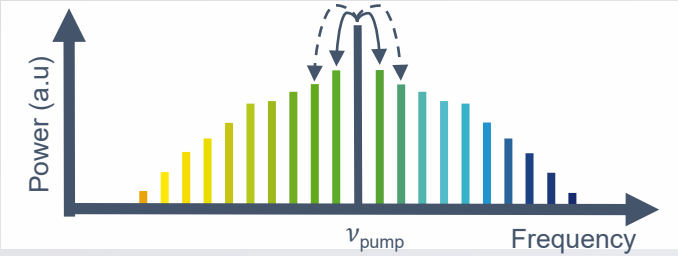
Previous work and challenge

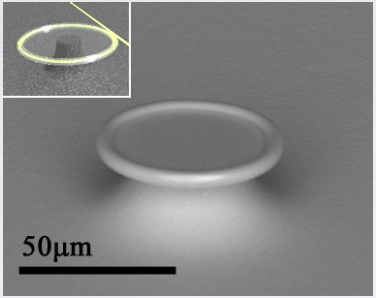


A comb converts a single laser source into symmetrically and equally spaced emission lines (f_r) at higher and lower wavelengths.

Requires:

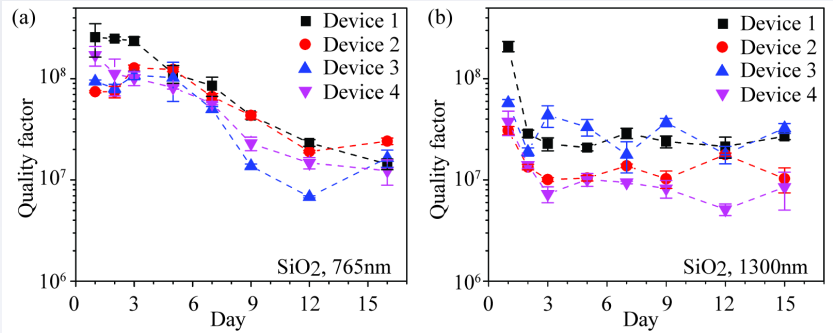
- High nonlinearity ($\chi^{(3)}$)
- Large number of photons

<u>One Approach</u>: Silica optical microcavities



High optical fields due to 10^8 quality factors.

However, these *Q* values decrease in air.



<u>Solution</u>: *Replace Silica with Silicon Oxynitride*

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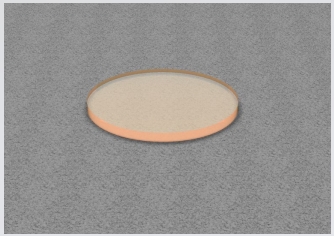
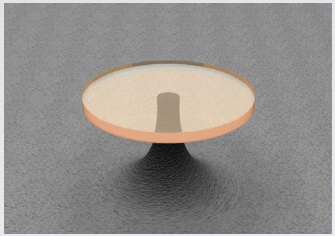
Technique

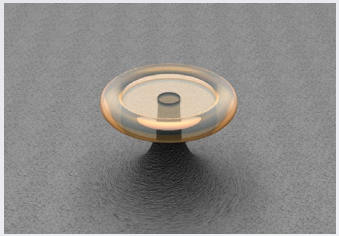
SiO_xN_y Device Fabrication



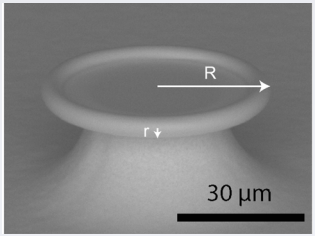
Pattern SiO_xN_y film using photolithography



Undercut using XeF_2



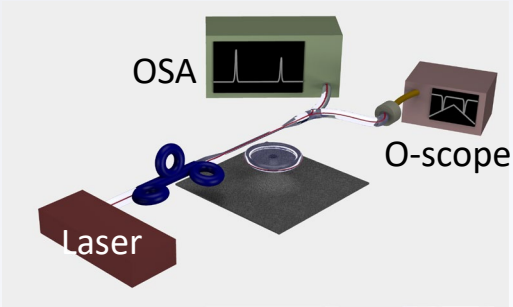
Reflow using CO_2 laser



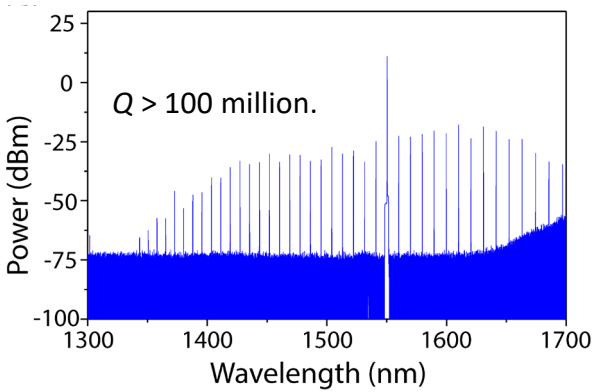
SEM of SiO_xN_y device

Testing Methods

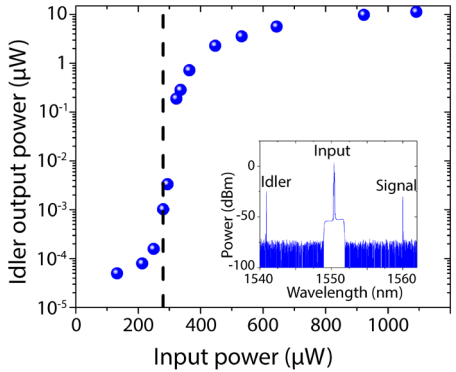
- 1550 nm laser is coupled into cavity using fiber waveguide.
- Frequency comb coupled out using waveguide and is detected on OSA.
- Transmission spectrum is monitored on o-scope (and *Q* is determined).



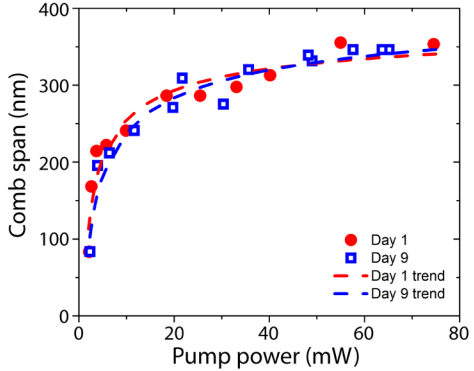
Findings: Comb generation and Parametric threshold



Optical spectrum of a 350 nm wide frequency comb with a pump wavelength at 1551 nm and an input power of 60 mW.



Power of the idler signal recorded on OSA as a function of the input power coupled into the resonator. The threshold is estimated to be around 280 μW.



The relationship between the comb span and the input power measured on Day 1 and Day 9 after the device fabrication.