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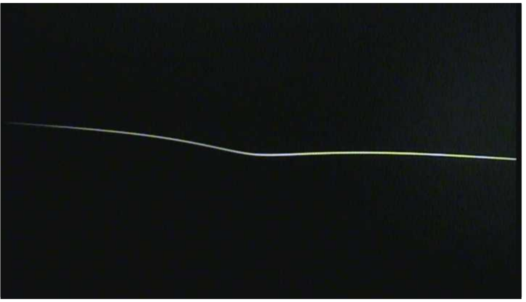

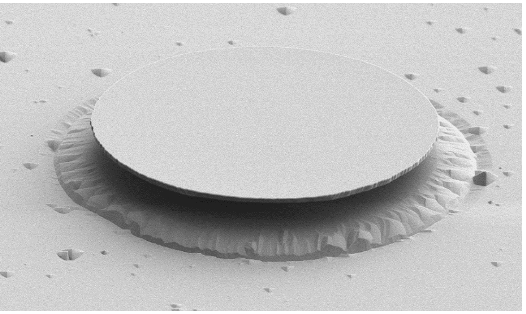

Towards Synthesis of UV lasers using doubly-resonant, ultra-thin LiNbO3 microdisk resonators

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ME1

Outline

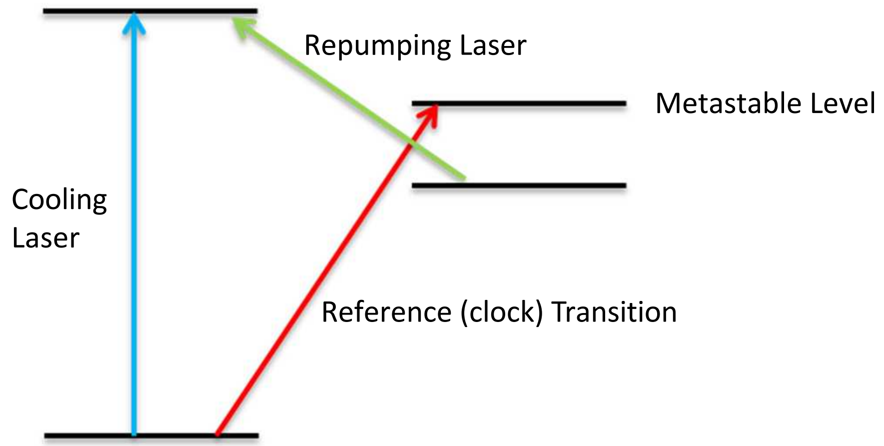
- Motivation
- Coupled Mode Theory
  - Mode volume and quality factor enhancements in doubly-resonant SHG
  - Maximum conversion efficiency and power “threshold” in lossy doubly-resonant cavities
- Device Design
  - Phase Matching
- Fabrication
- Experimental Setup
- Results
  - Q Factor
  - Second Harmonic Generation
- Application to UV source
- Conclusion

Slide 2

ME1 Added bullet for fabrication and theoeretical background
Eichenfield, Matt, 5/13/2015

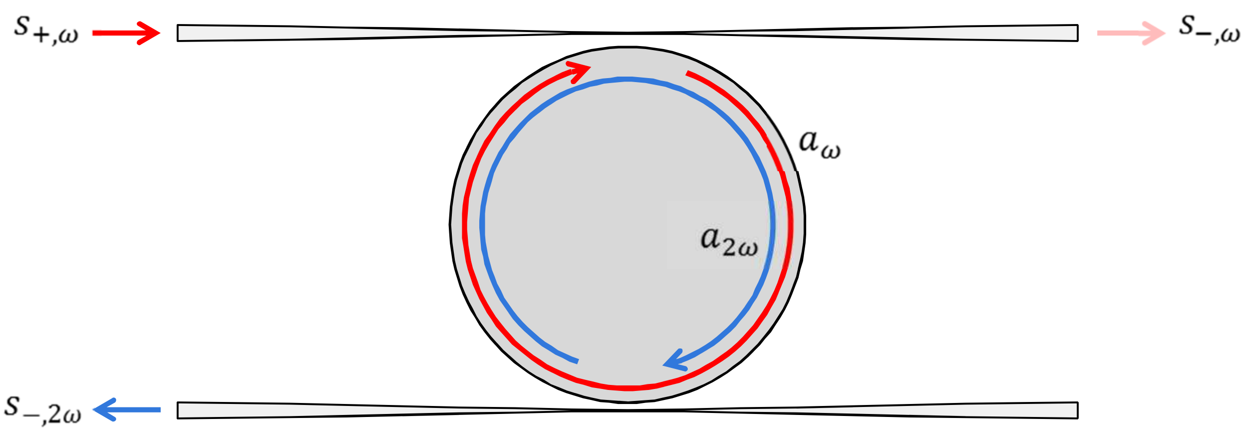
Motivation

- Frequency doubling from 1550nm to 775nm
  - Allows transmission with ultra-low-loss in fiber but detection at 775
  - Near peak efficiency for silicon detectors and photon counters
- Next generation Yb+ ion atomic clock
  - 369nm for cooling
  - Ti:sapphire laser



Atomic Clock Schematic

Coupled Mode Theory



$$\frac{da_\omega}{dt} = \left(i\omega - \frac{\Gamma_\omega}{2}\right) a_\omega - i\omega\eta a_\omega^* a_{2\omega} + \sqrt{\Gamma_{s,\omega}} s_{1+}$$

$$s_{-,\omega} = -s_{+,\omega} + \sqrt{\Gamma_{s,\omega}}\, a_\omega$$

$$\frac{da_{2\omega}}{dt} = \left(i2\omega - \frac{\Gamma_{2\omega}}{2}\right) a_{2\omega} - i2\omega\eta^* a_\omega^2$$

$$s_{-,2\omega} = \sqrt{\Gamma_{s,2\omega}}\, a_{2\omega}$$

Coupled Mode Theory

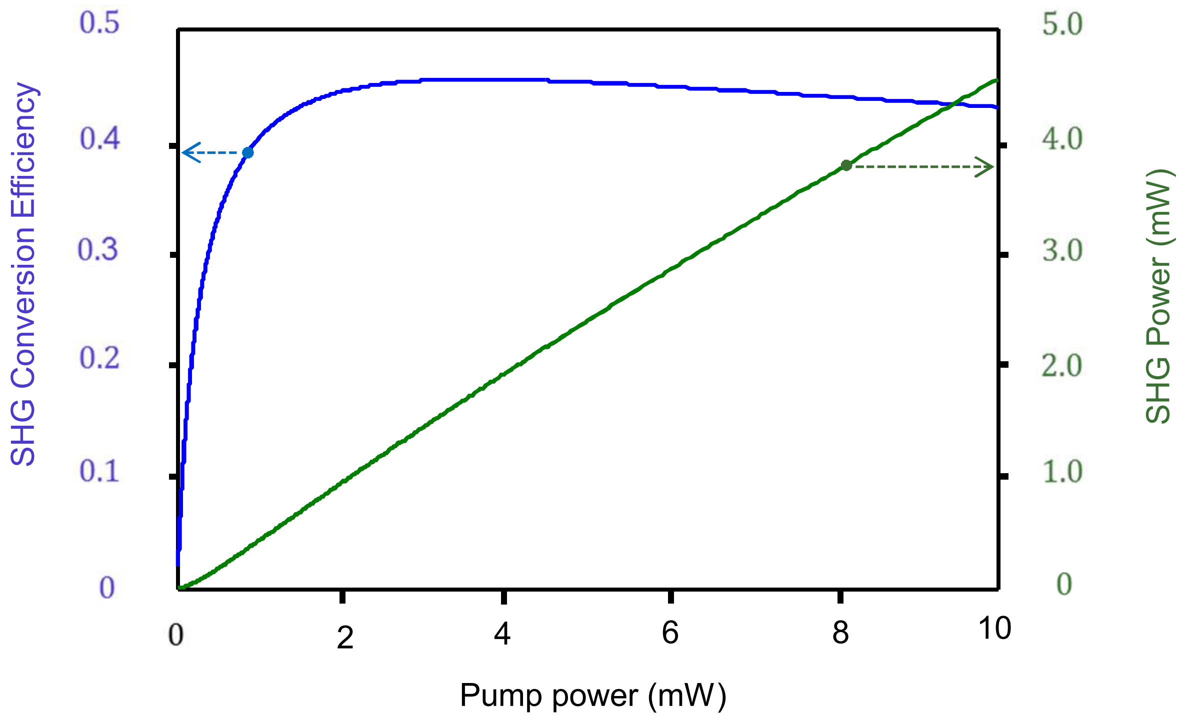
$$\eta = \frac{1}{2}\frac{\int d^3x \sum_{ijk} \varepsilon\, \chi^{(2)}_{ijk} E^i_\omega E_{\omega j} E^*_{\omega k}}{\left[\int d^3x\, \varepsilon\, |E_\omega|^2\right]\left[\int d^3x\, \varepsilon\, |E_{2\omega}|^2\right]^{1/2}}$$

$$P^*_\omega = \frac{\omega}{2|\eta|^2}\,\frac{(1+K_\omega)^2}{Q^2_{i,\omega}}\,\frac{(1+K_{2\omega})}{Q_{i,2\omega}}\left(1+\frac{1}{K_\omega}\right)$$

$$\max\left(\frac{P_{2\omega}}{P^*_\omega}\right) = \left(1+\frac{1}{K_\omega}\right)^{-1}\left(1+\frac{1}{K_{2\omega}}\right)^{-1}$$

Coupled Mode Theory

- Parameters
  - $Q_{i\omega} = 300,000$
  - $Q_{i2\omega} = 7,000$
  - $K_{\omega} = 10$
  - $K_{2\omega} = 1$



Device Design

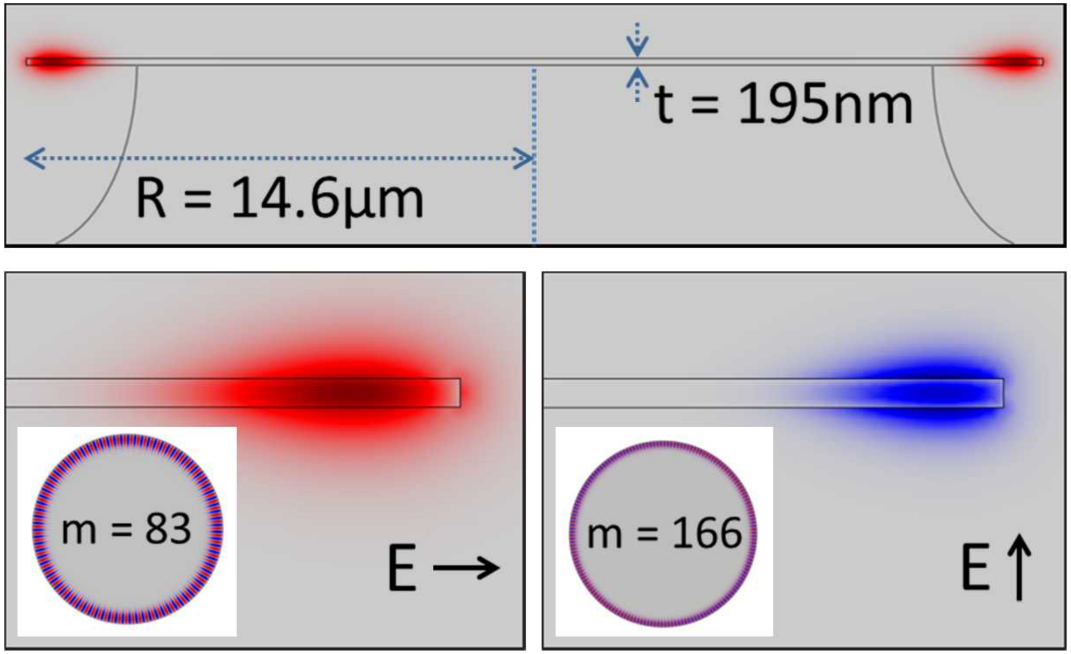
Phase Matching

Momentum Conservation

$$\Delta m = 2m_{\omega} - m_{2\omega} = 0$$

Energy Conservation

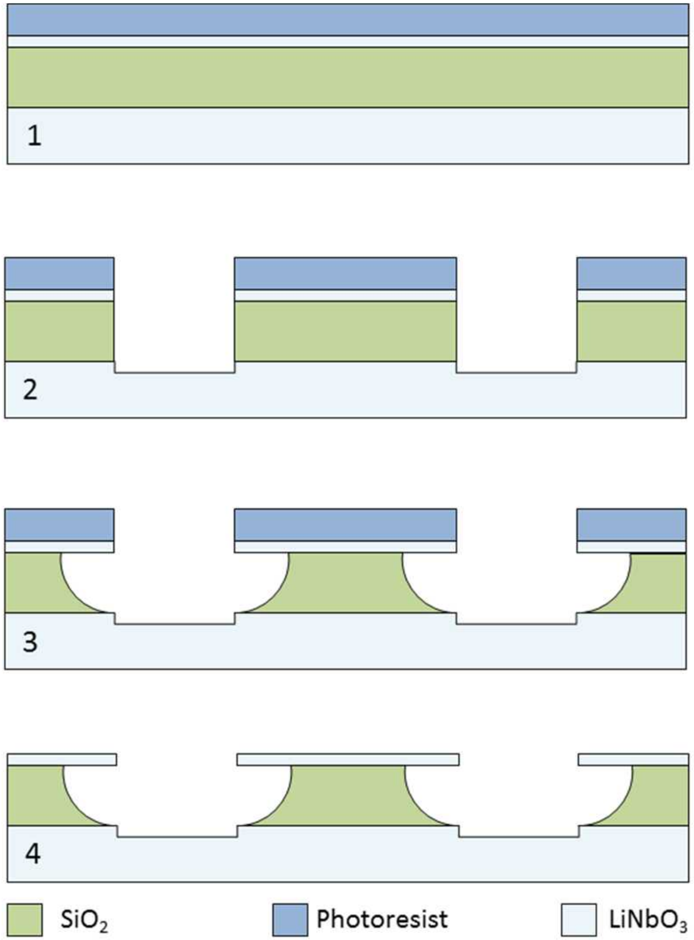
$$\Delta f = 2f_{\omega} - f_{2\omega} \rightarrow 0$$



Simulated pump (1476nm) and second harmonic (738nm) modes of $LiNbO_3$ microdisk. Geometric dispersion allows the two modes to be phased matched.

Fabrication

1. Spin PR
2. 8' CAIBE Dry Etch
3. Vapor HF Release
4. Remove PR



Experimental Setup

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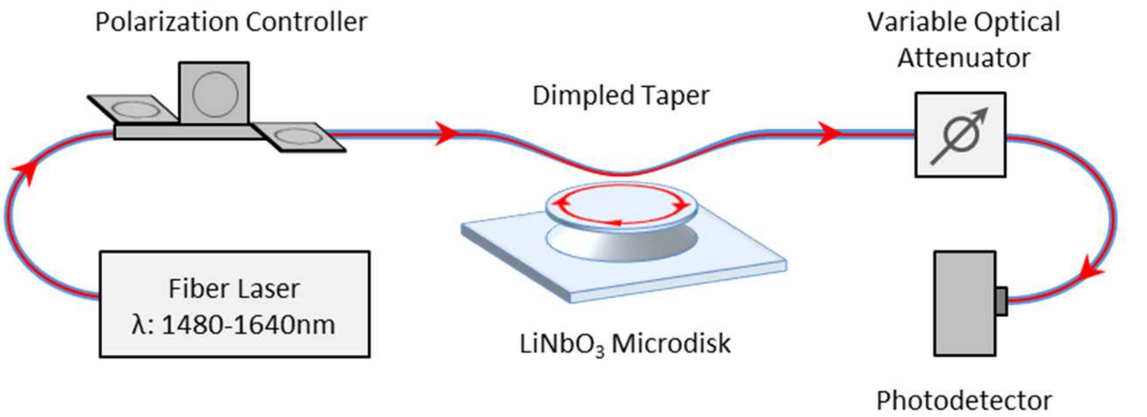
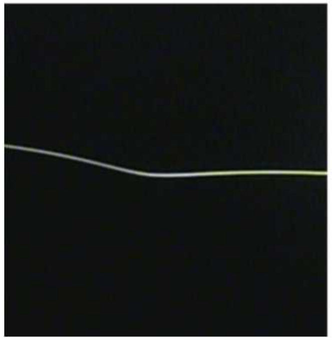
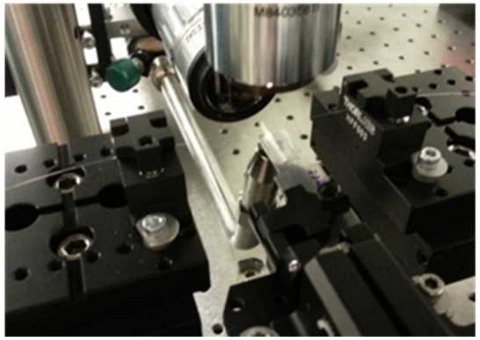
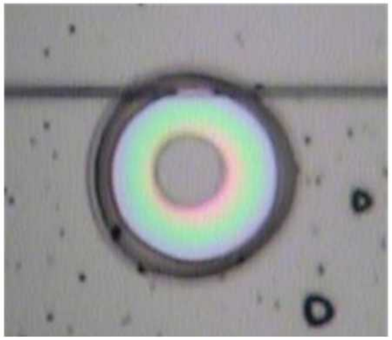




Dimpled Fiber



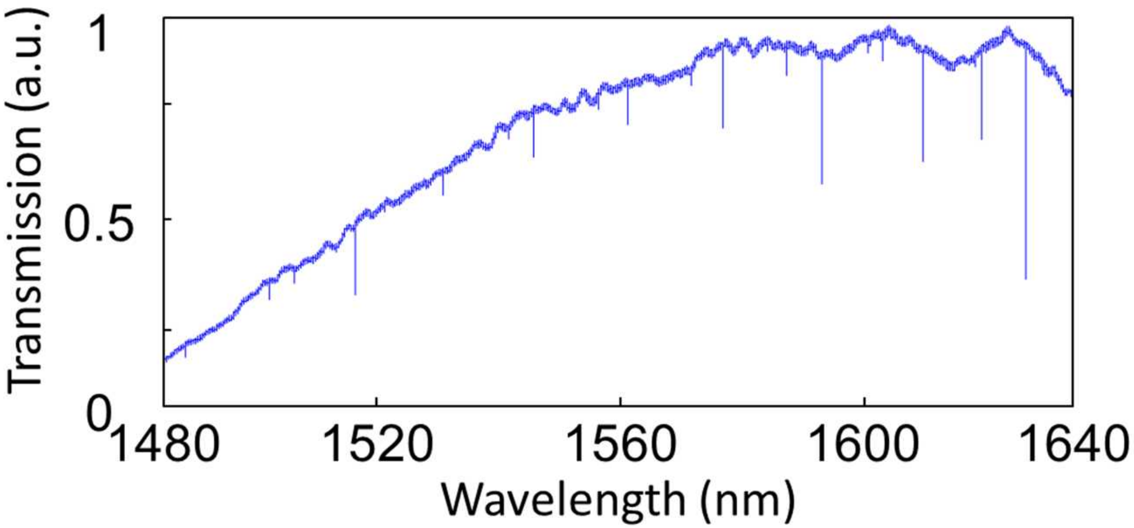
Experiment

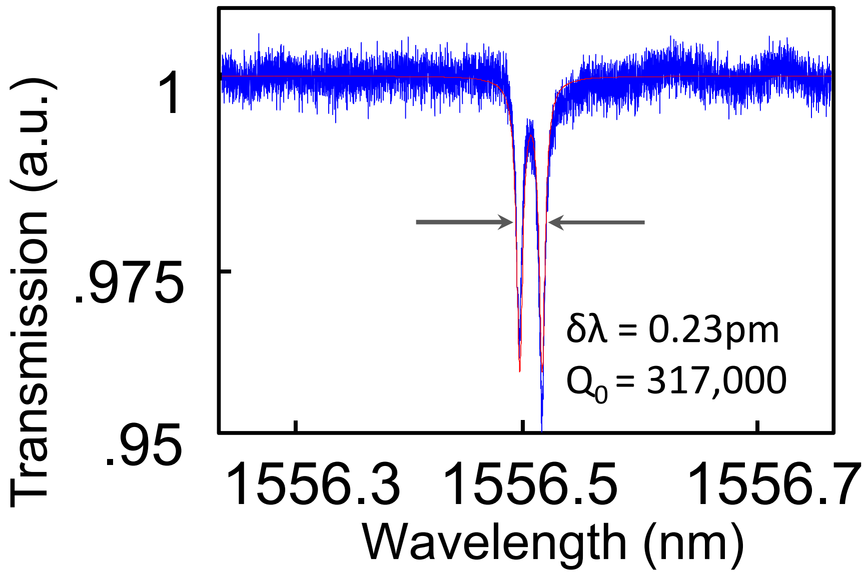


Device Testing

Results

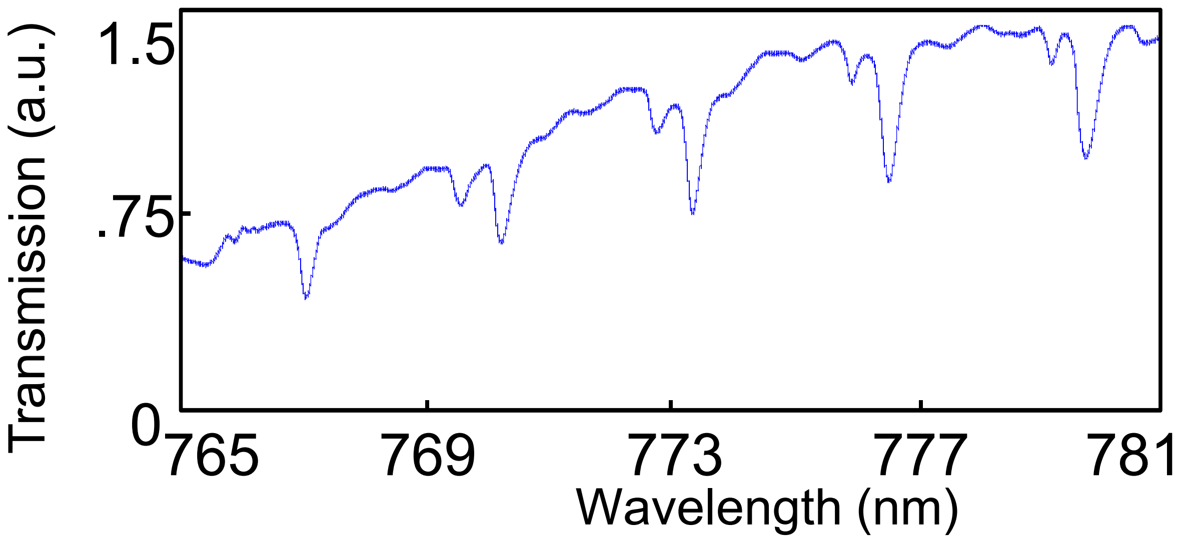
- $Q_{1550} = 500,000$

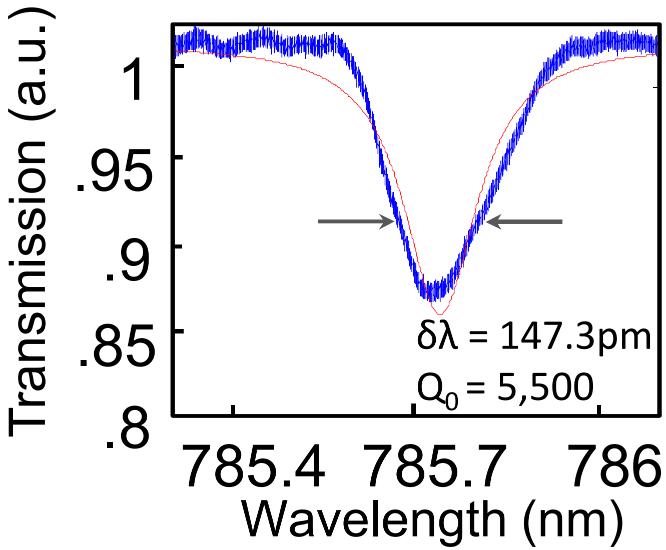




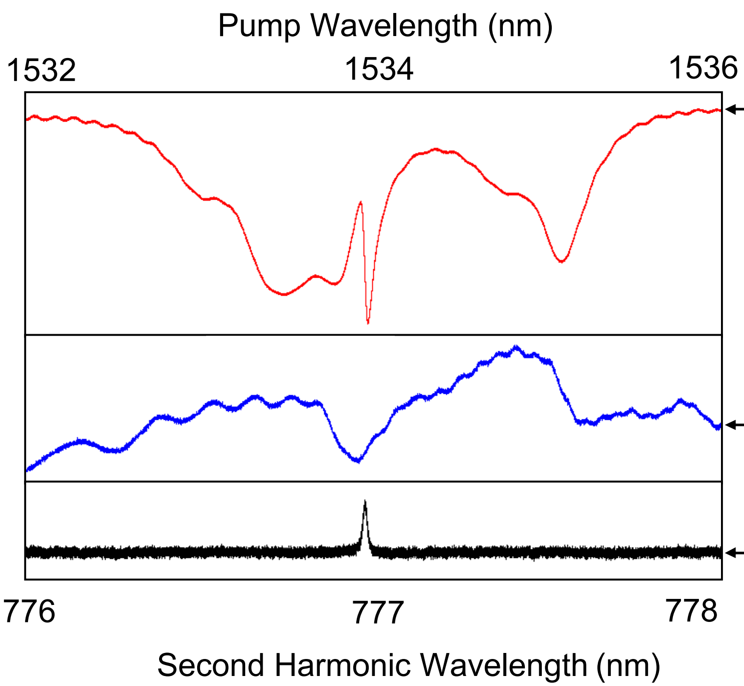
Results

- Q_{775} = 7,000





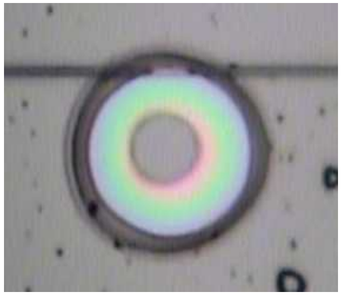
Results



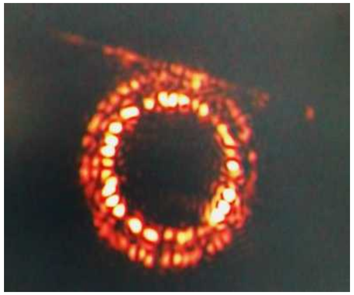
1550nm transmission

775nm transmission

SHG signal on 775nm detector during 1550nm wavelength sweep with appx. 5mW pump power



Disk illuminated with room light



SHG observed on visible camera when pumping with infrared light

Applications to UV Source

- Scaling of the device dimensions
- Q's must be increased so that device can be loaded harder
- Surface roughness must be improved due to loss rate at lower wavelength

Conclusion

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- Frequency doubling from 1550nm to 775nm
- Yb+ atomic clock
  - Cooling wavelength of 369nm
- Geometric phase matching
  - Different index of refraction for 1550nm and 775nm
- Second harmonic generation
  - Q_{1550} = 500,000
  - Q_{775} = 7,000

Support

Questions?