Developing Whispering Gallery Mode Resonators for Quantum Optics Applications

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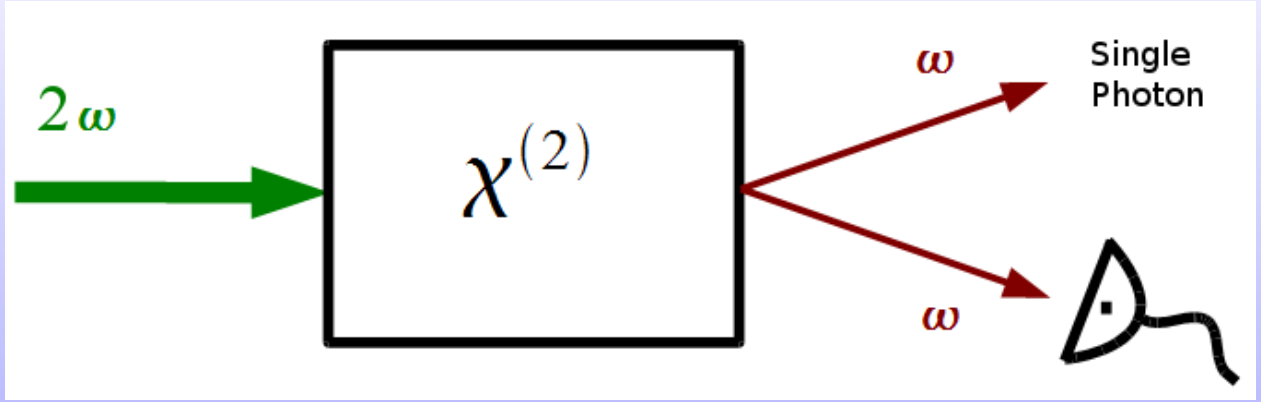
Motivation

Develop a quantum memory scheme

- Mapping quantum states of light onto a gas of atoms
- Light states are read back out at a later time

Develop a source of nonclassical light

- Narrow-band single photons for storage
- Source of bright squeezed light



Frequency conversion

- Optical nonlinear effects are small $\rightarrow$ high intensity

$$P(t) = \epsilon_0(\chi^1 E(t) + \chi^2 E^2(t) + \chi^3 E^3(t) + \ldots) \tag{1}$$

- Atom-based quantum optics applications need sub-MHz bandwidth

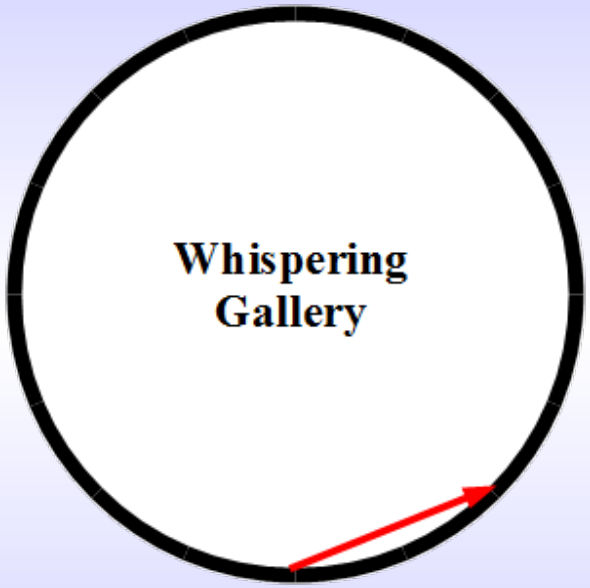
Solution: High quality factor (Q) cavities

$$Q = \frac{\nu_0}{FWHM} \tag{2}$$

$$I_{cavity} \sim \frac{1 - r^2}{(1 - e^{\alpha/Q})^2} I_0 \tag{3}$$

Whispering gallery mode resonators

A whispering gallery is a circular cavity



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The field contained inside is a *whispering gallery mode* (WGM)

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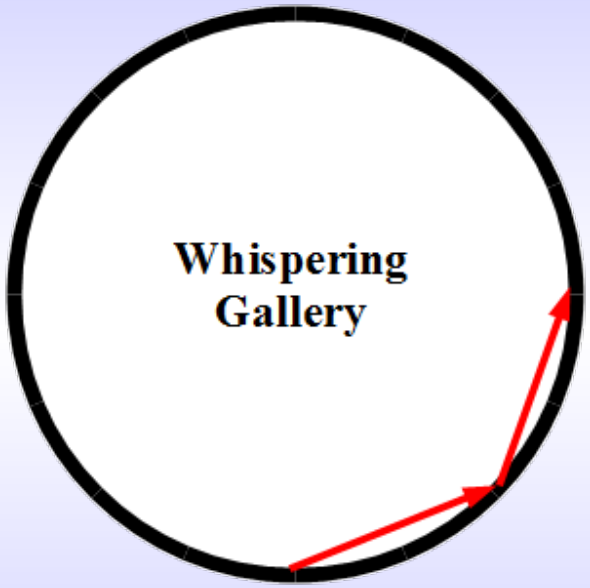

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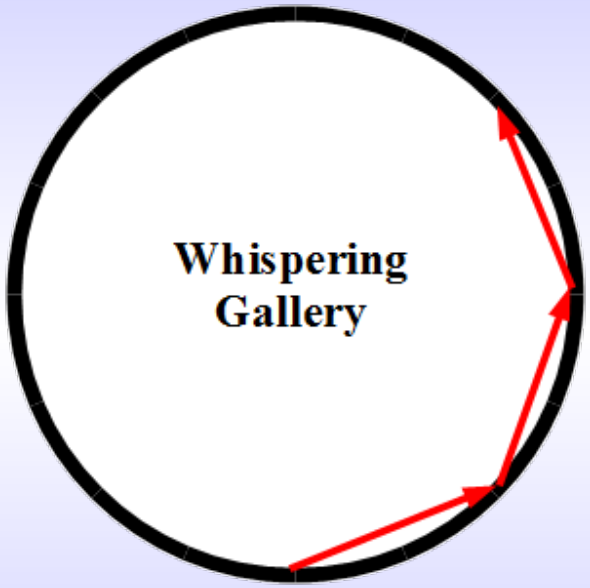

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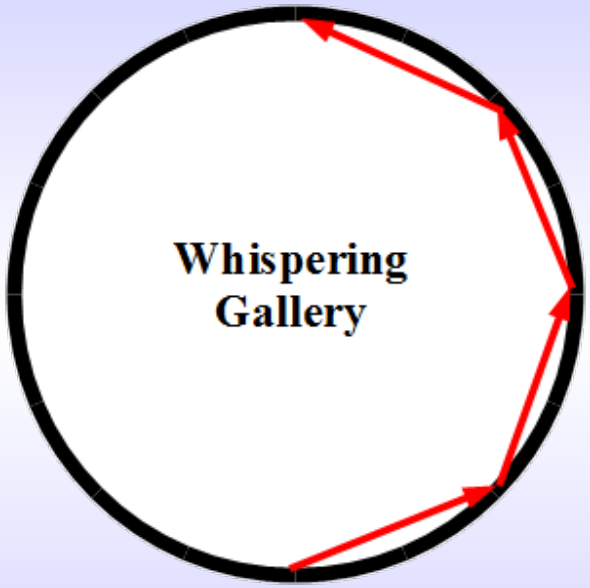

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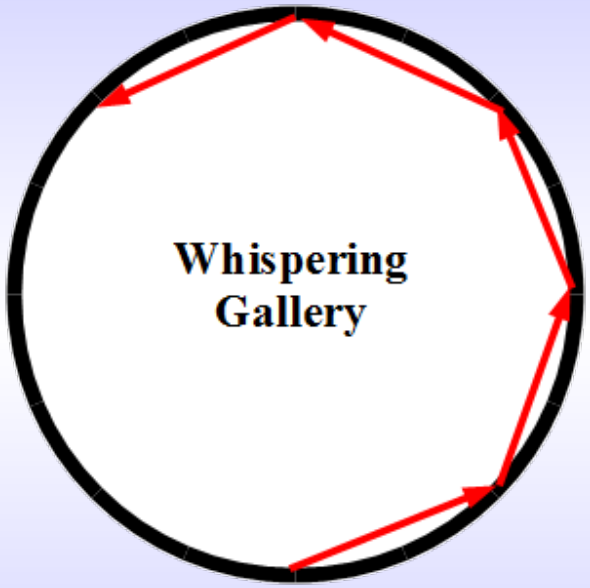

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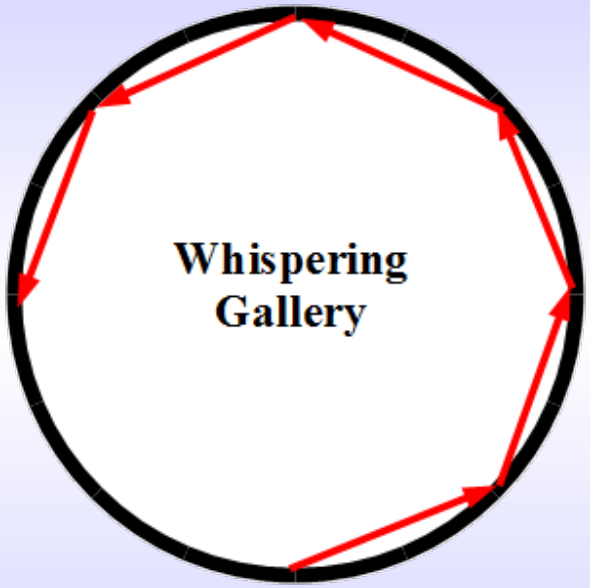

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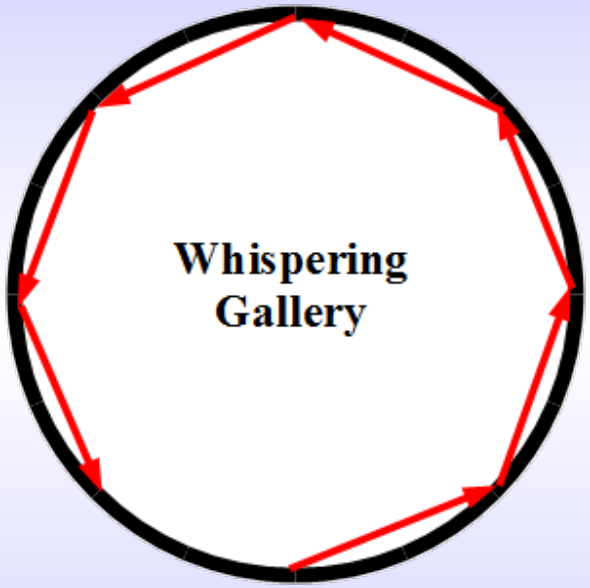

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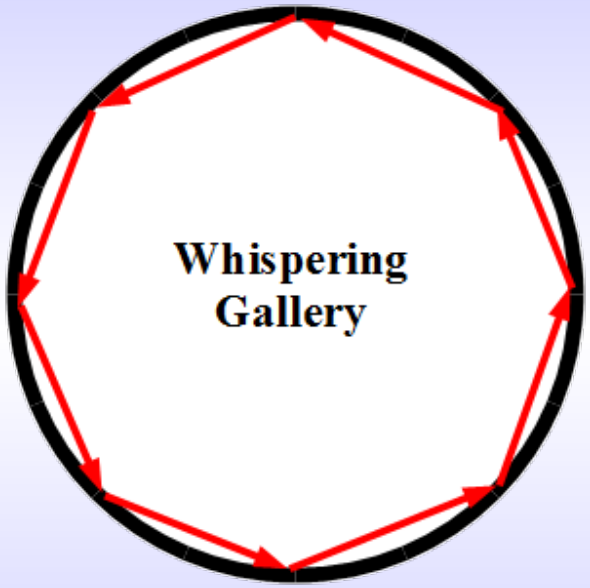

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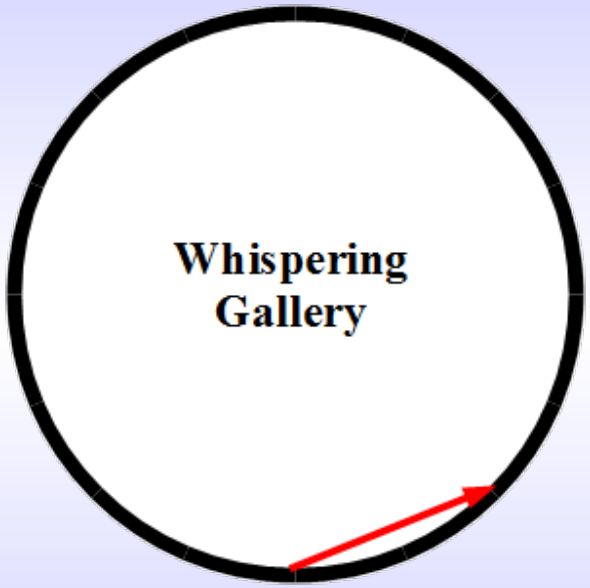

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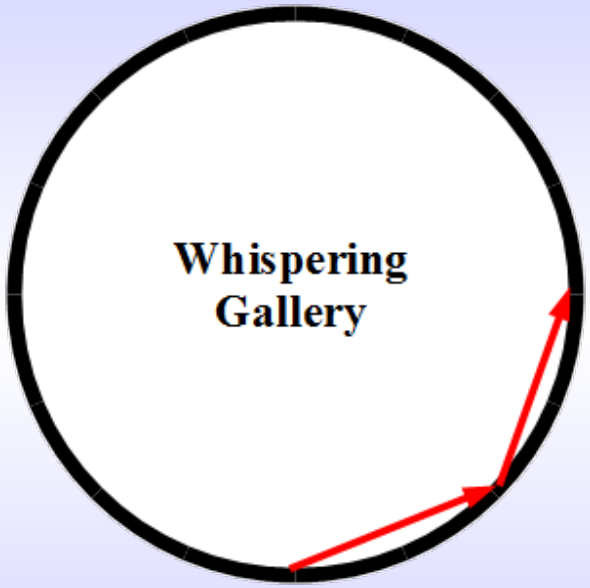

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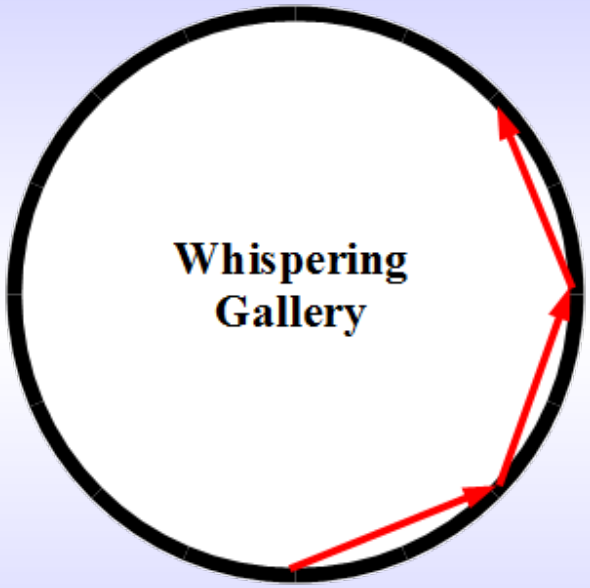

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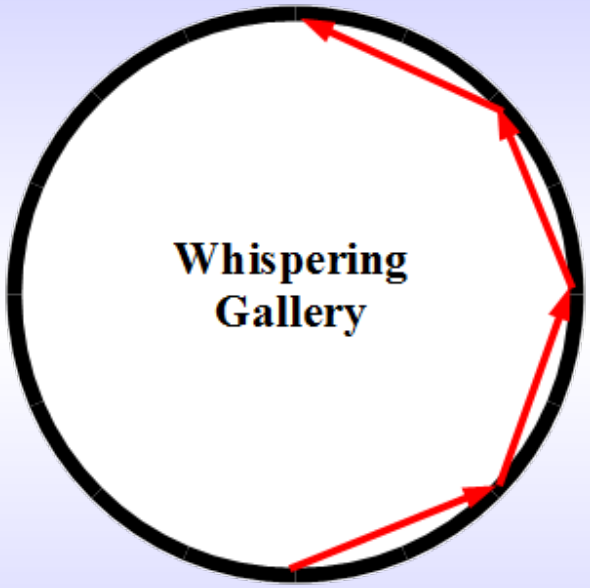

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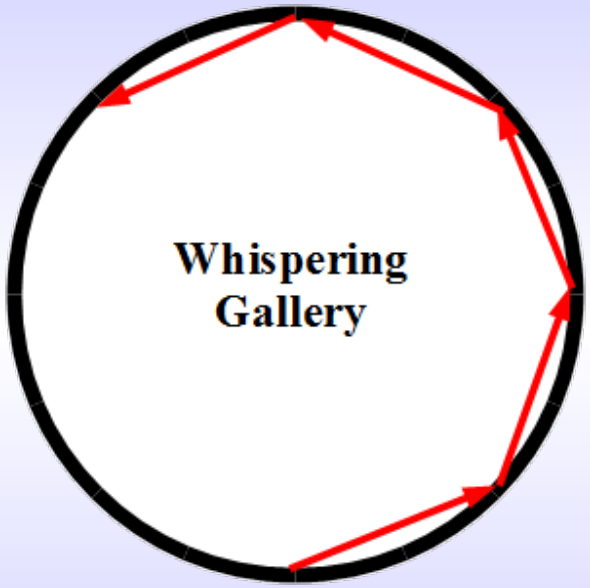

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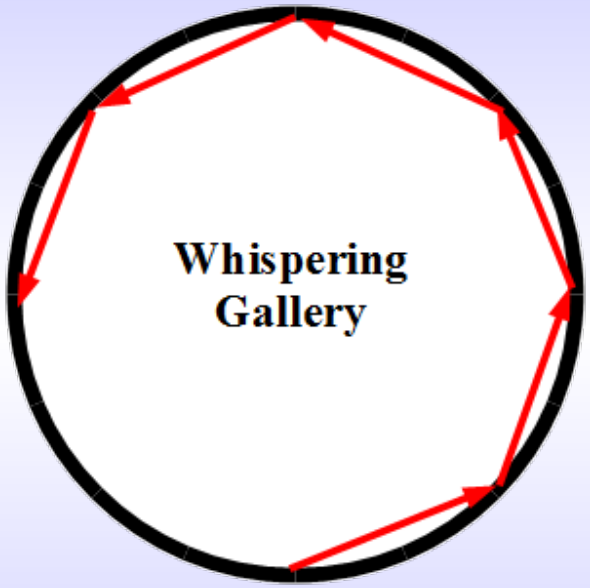

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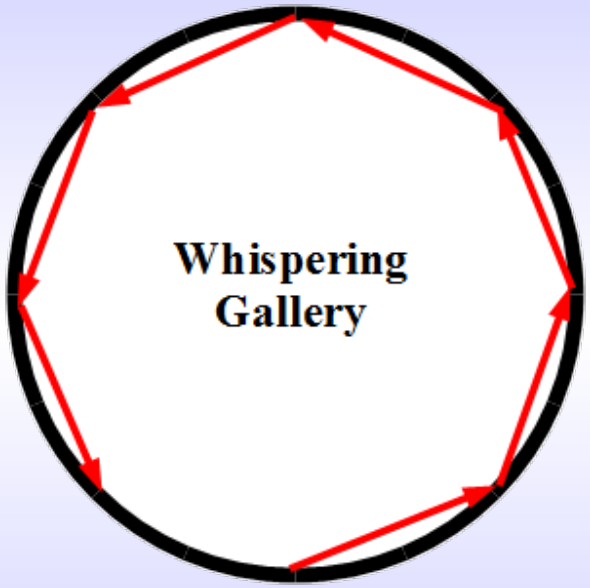

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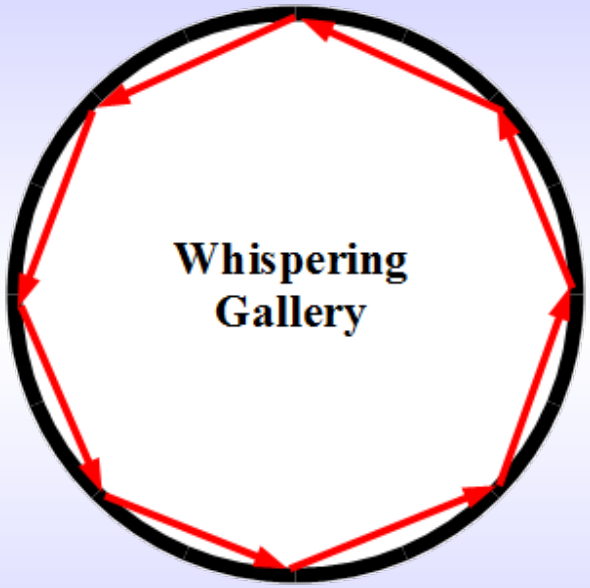

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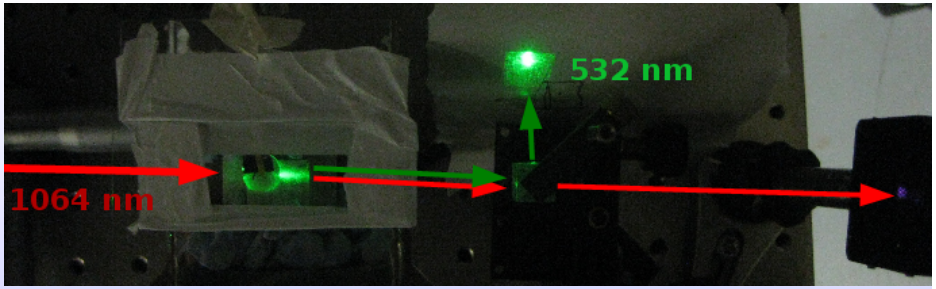
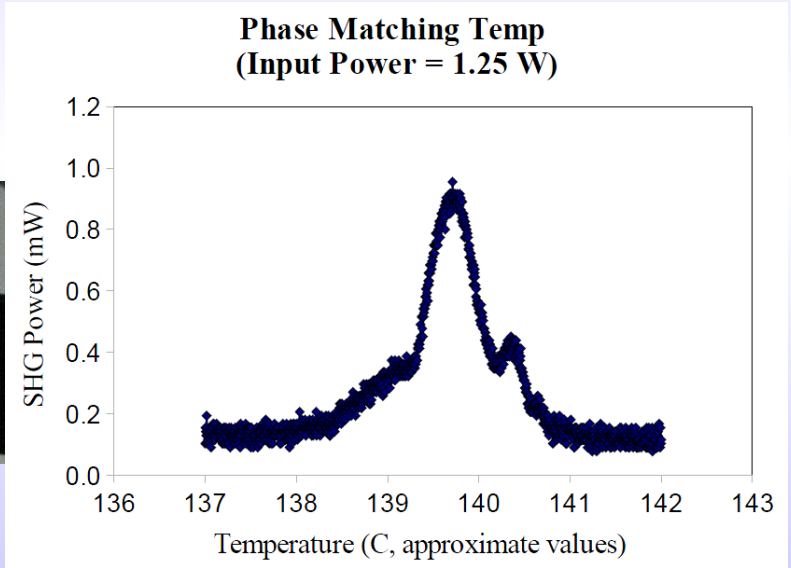
Making whispering gallery mode resonators

- Made from lithium niobate ($LiNbO_3$)
- Edge shaped with sandpaper
- Polished with diamond lapping film
- Polish quality affects quality factor (Q-factor)
- Diameters $7mm \sim 10mm$

Single-pass SHG

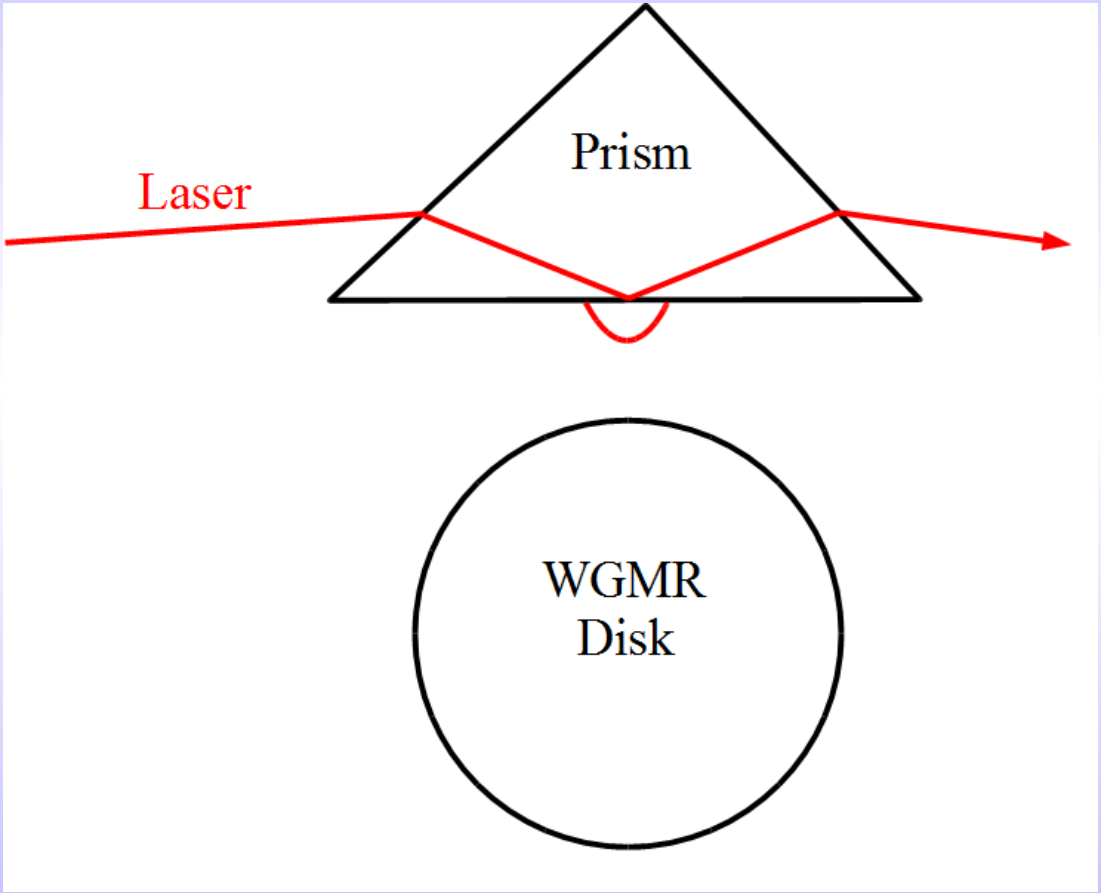
- Stoichiometric $LiNbO_3$ (Li/Nb ratio near 1)
- $T_{PM} = 140°C$ for $\lambda = 1064nm \rightarrow \lambda = 532nm$





For single-pass, conversion efficiency is very small ($\sim 0.1\%$).

Whispering gallery mode excitation



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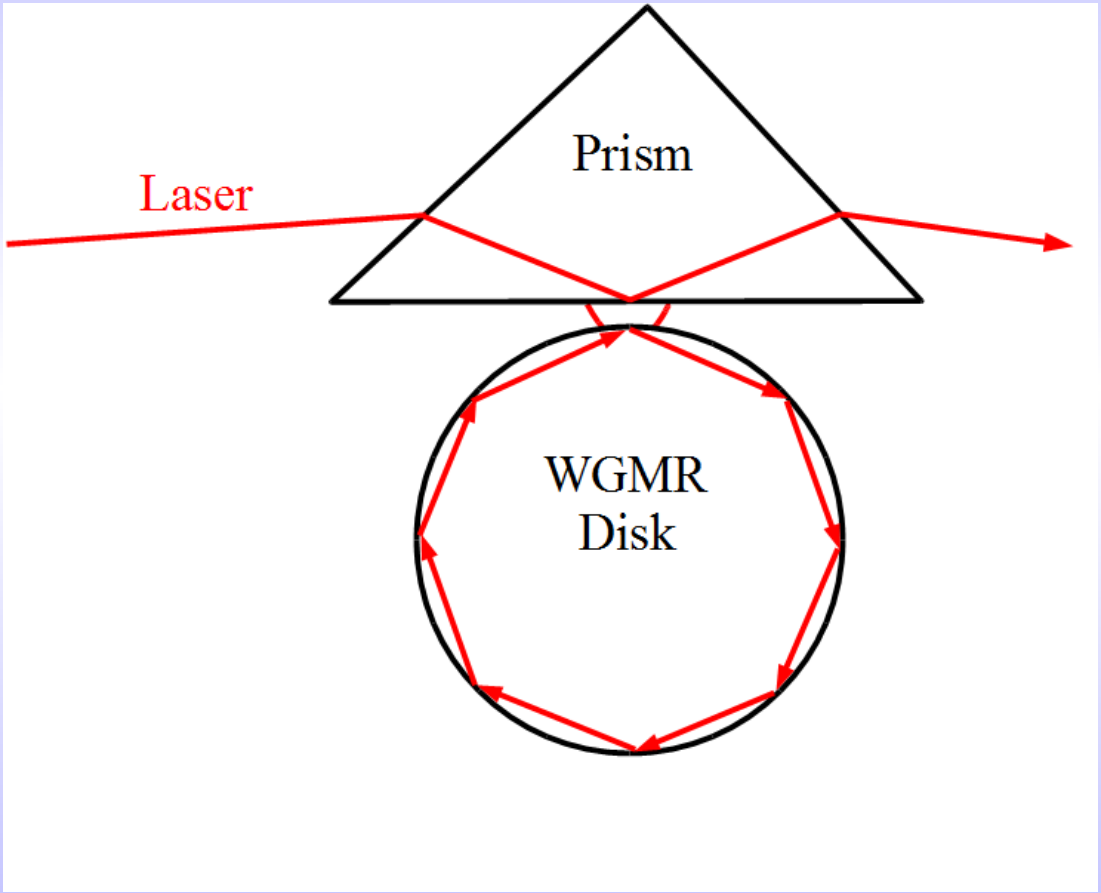
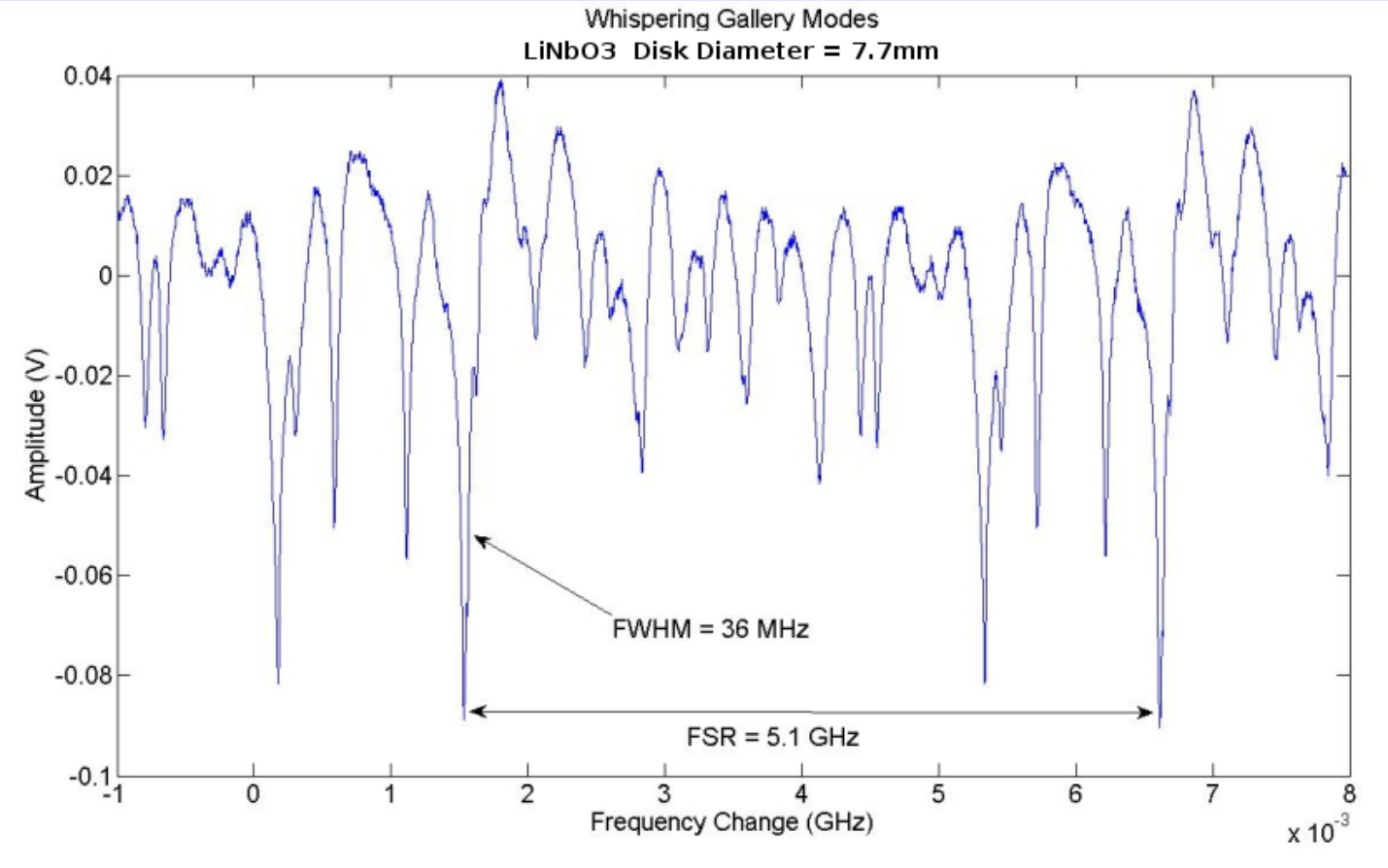


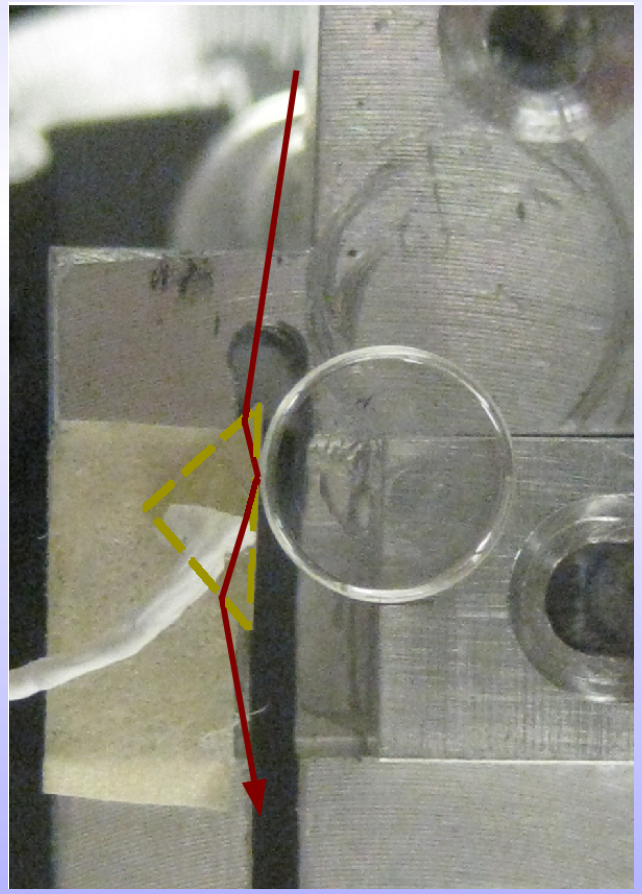
Whispering gallery mode excitation

Frequency scanned output from our $LiNbO_3$ WGMR disk near 795nm, with a Q-factor of $Q = 10^7$



Second harmonic generation in a whispering gallery mode resonator

$T = 23°C$



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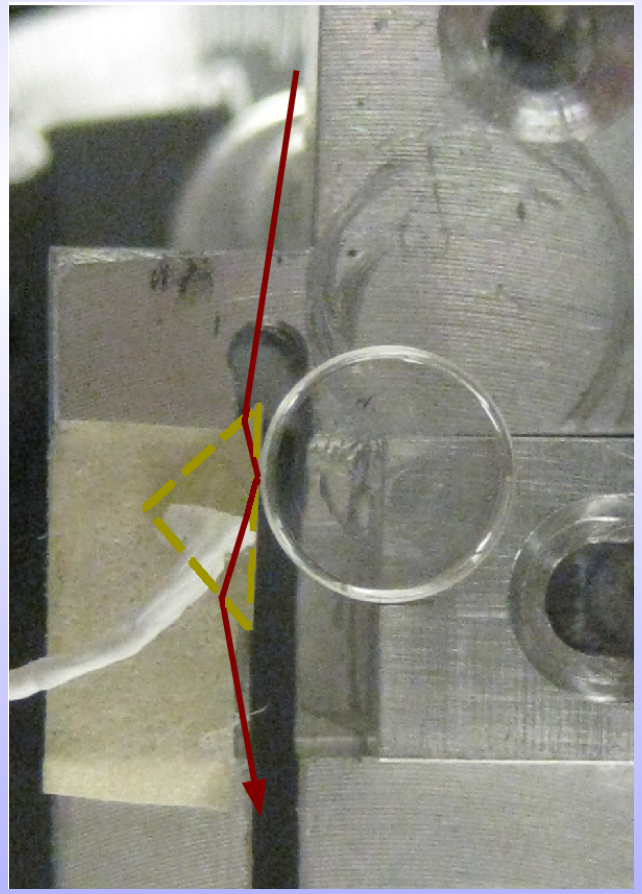
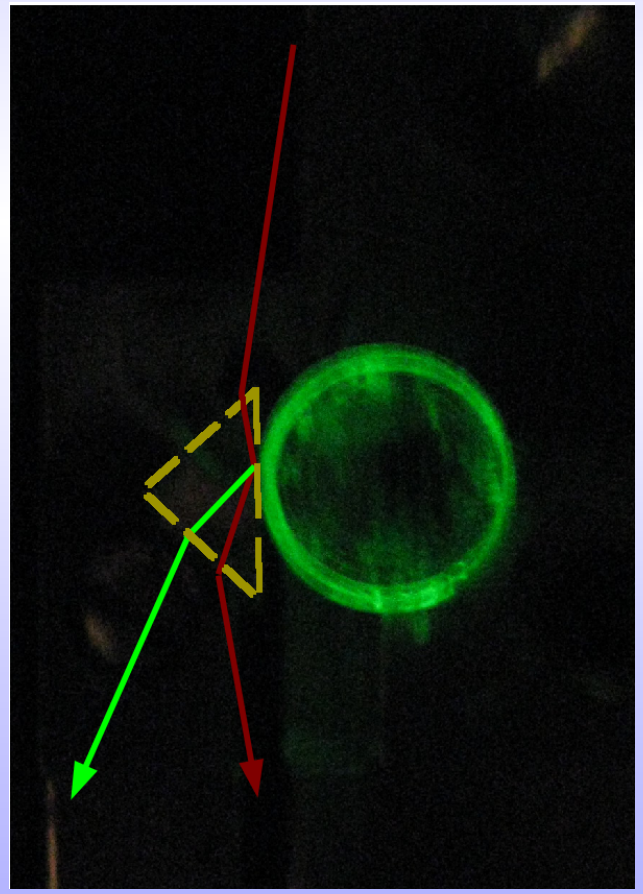
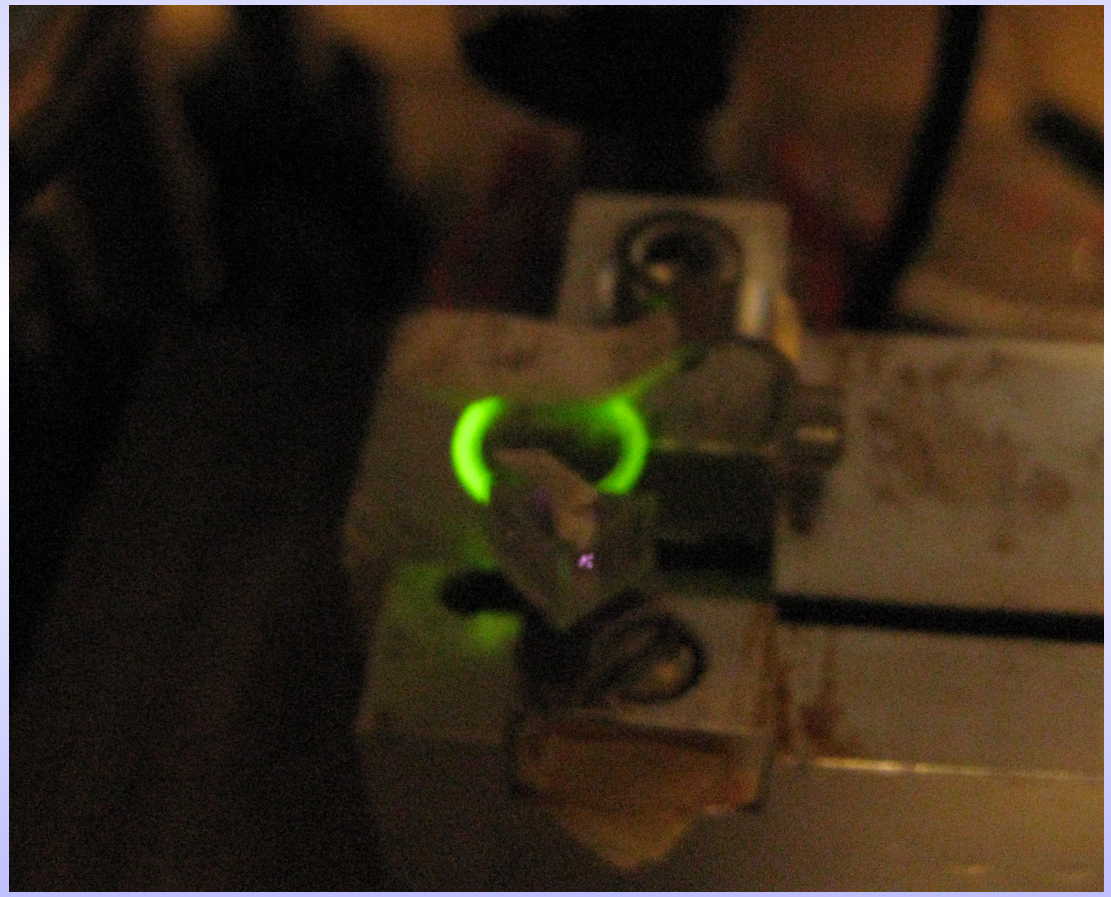


$T = 140°$



Second harmonic generation at room temperature



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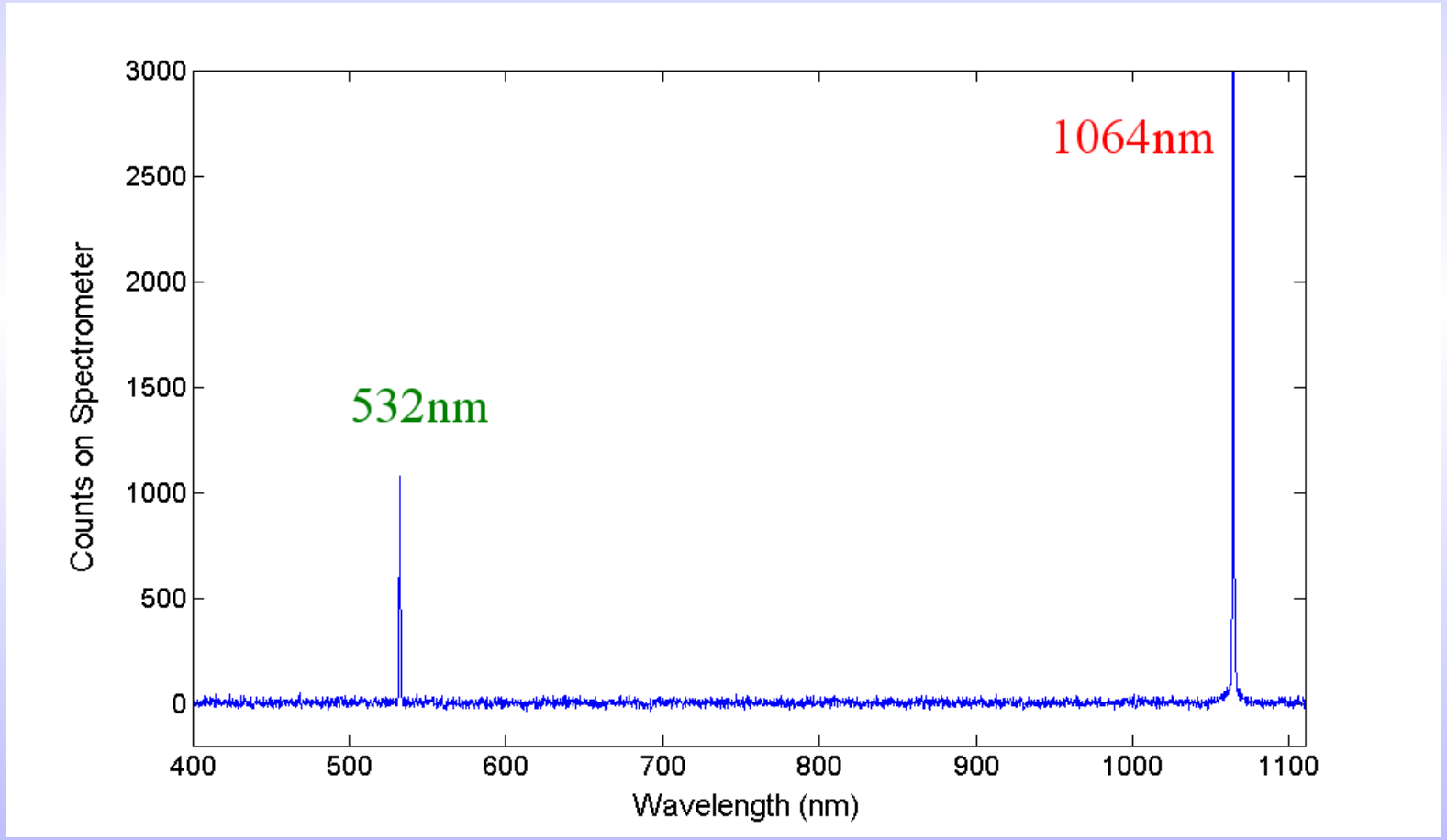

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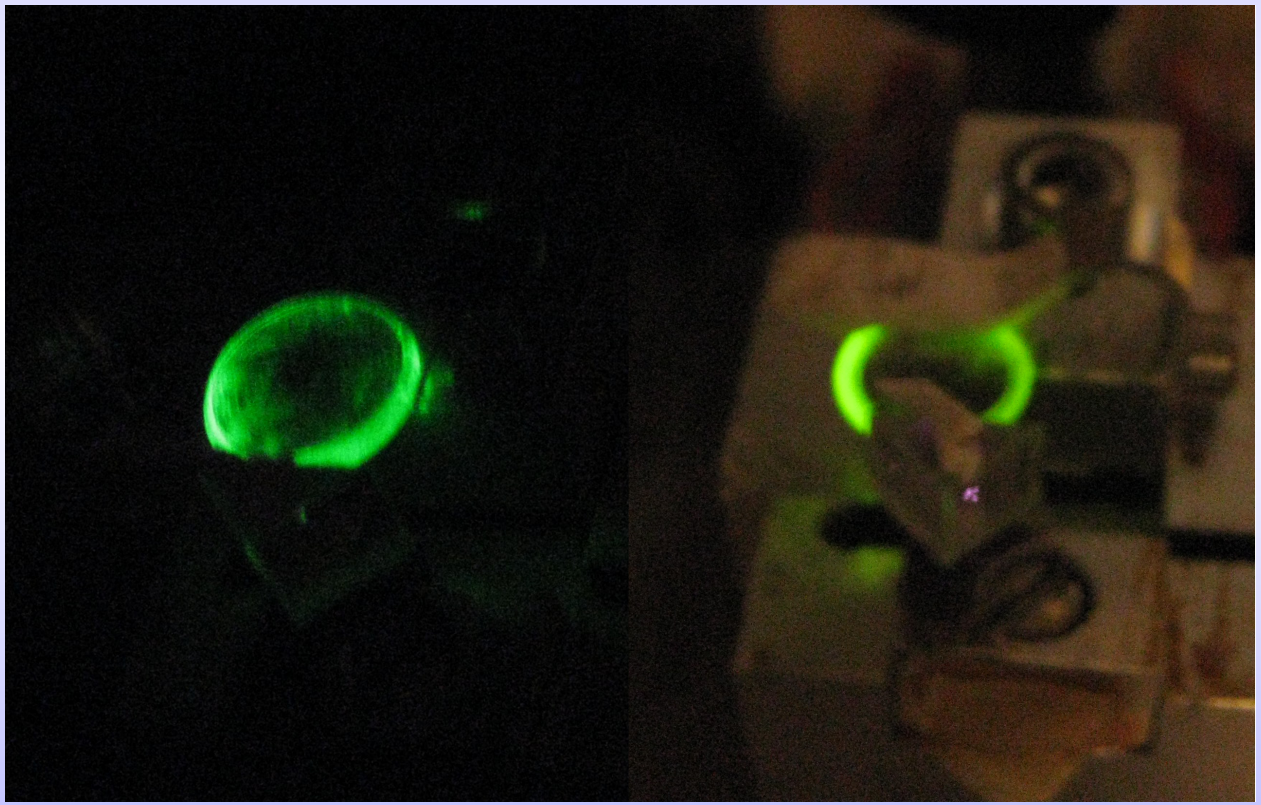
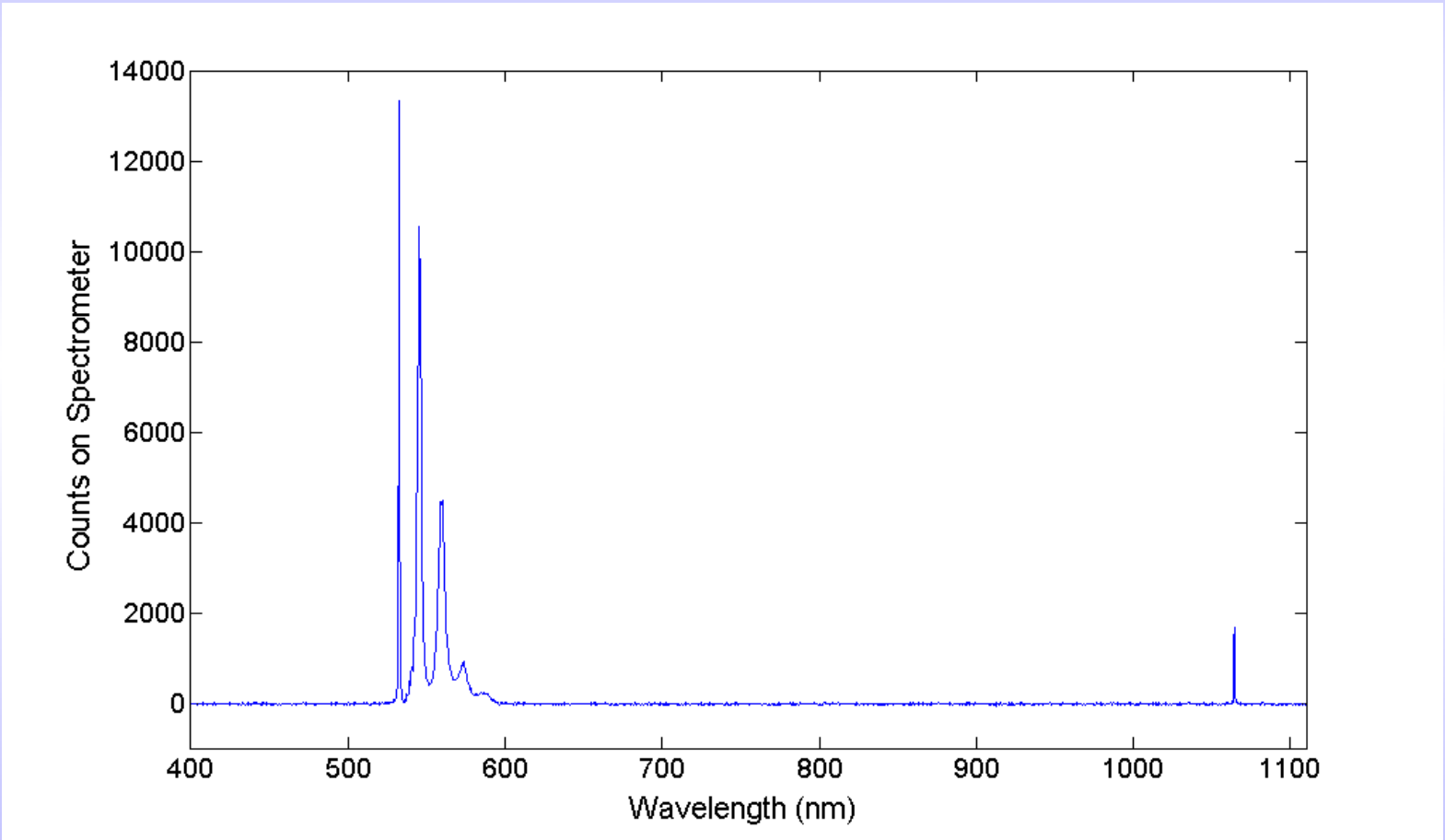


Unexpected results



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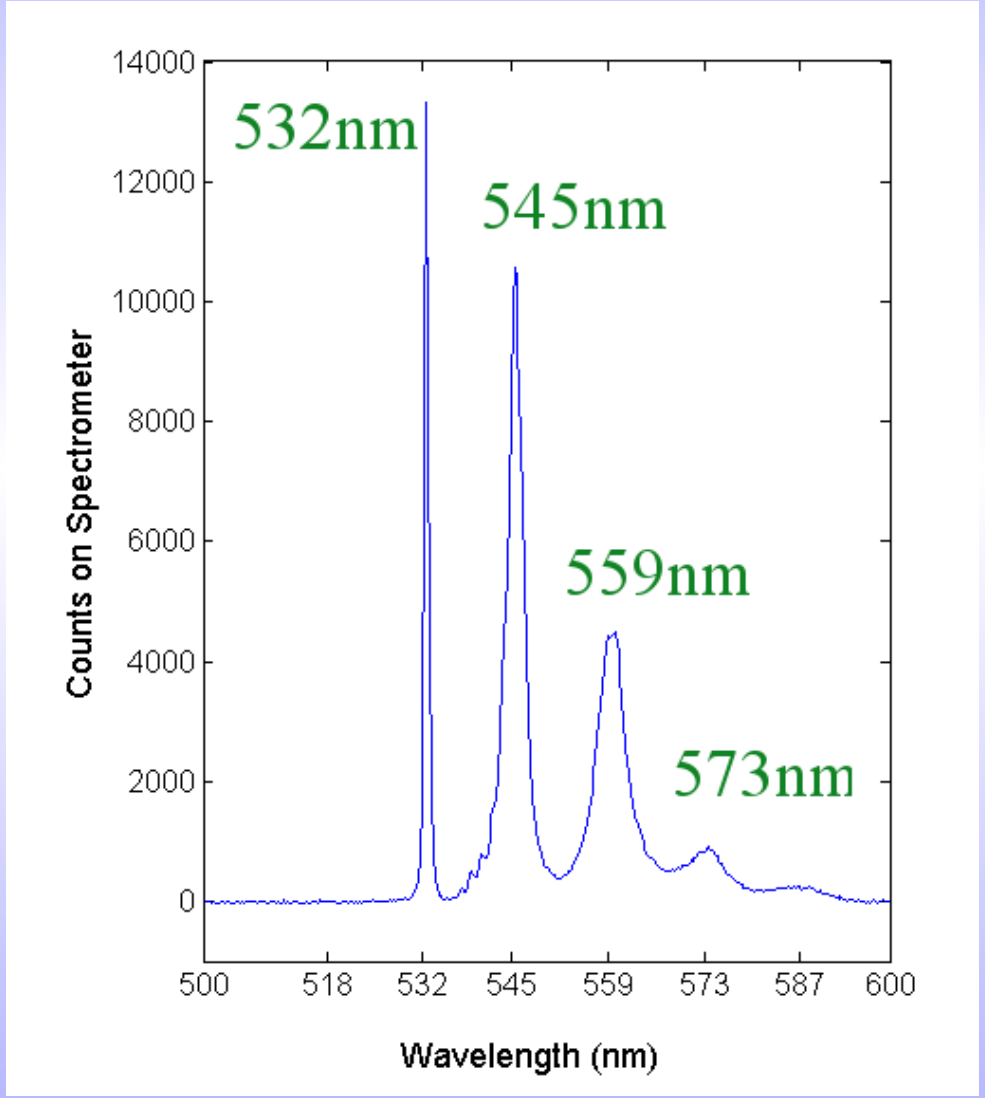
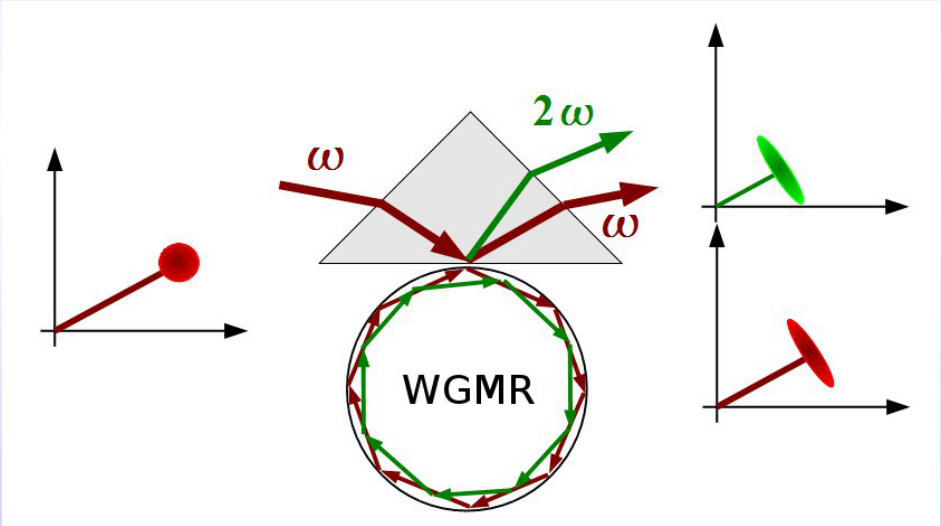
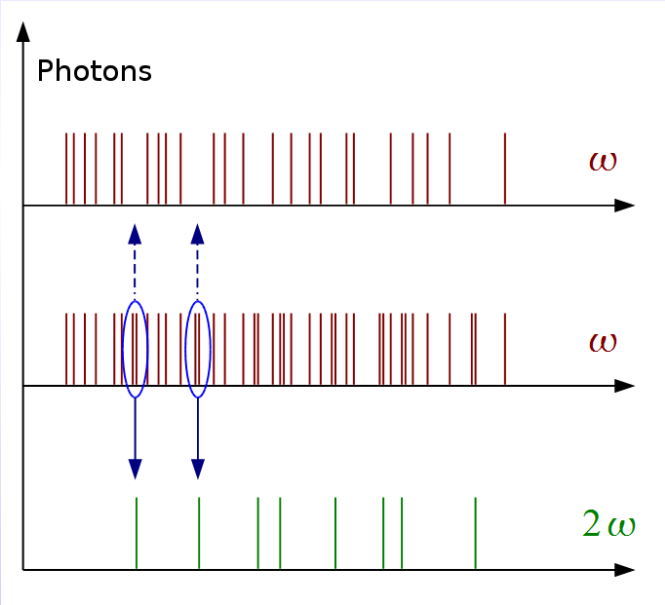


Future plans

- Explore yellow-shifted emission
- Produce bright squeezed light from phase matched SHG



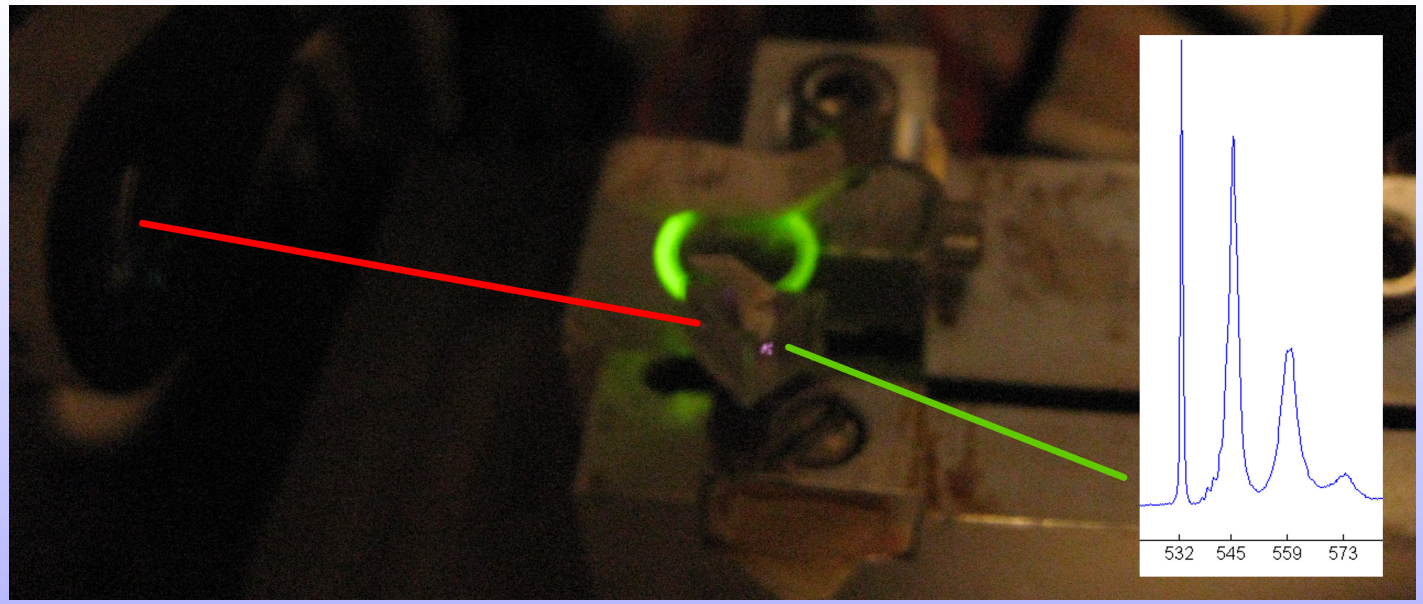


- Observe parametric down conversion in WGMR
- Produce narrowband single photons

Summary

Recent Developments:

- Produced high quality factor whispering gallery mode resonators
- Achieved noncritically phase matched SHG in a WGMR
- Observed non-phase matched SHG in a WGMR at low power
- Observed unexpected emission from WGMR at high power



Acknowledgements

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- Seth Aubin (W&M)
- Virginia Space Grant Consortium & the NSF