

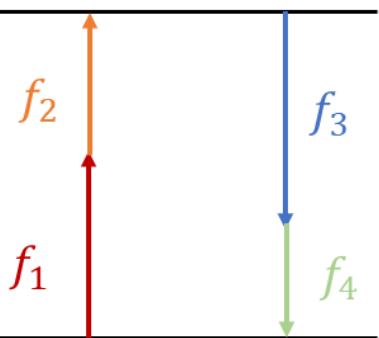
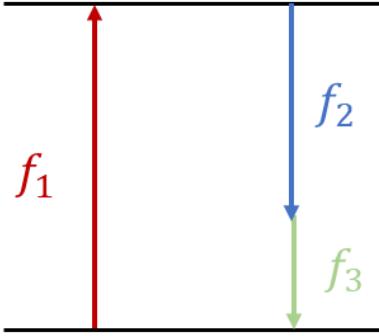
# **Electrically induced adiabatic frequency conversion in an integrated lithium niobate ring resonator**

**Xiaotong He, Luis Cortes-Herrera, Kwadwo Opong-Mensah, Yi Zhang, Meiting Song, Govind P. Agrawal, Jaime Cardenas**

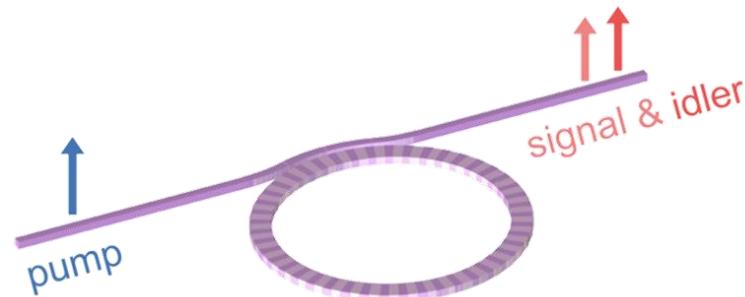
*The Institute of Optics, University of Rochester, Rochester, N.Y. 14627, USA*



# Frequency Conversion

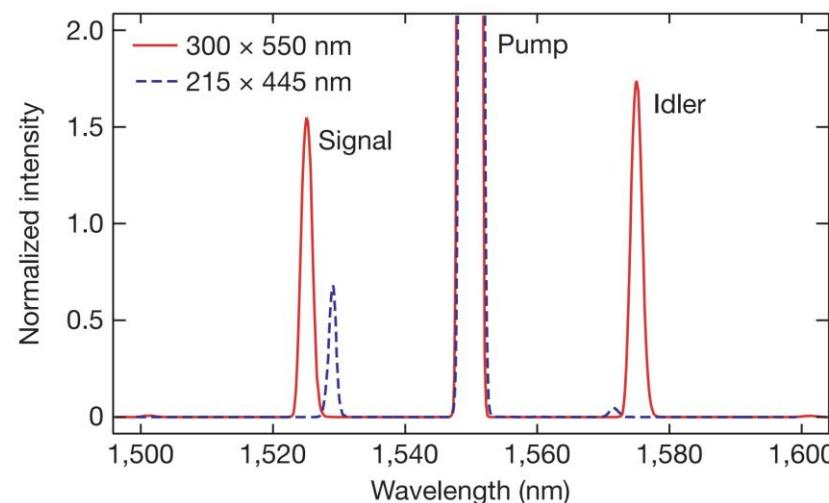


**Optical parametric oscillator**



Lu, Juanjuan, et al. "Ultralow-threshold thin-film lithium niobate optical parametric oscillator." *Optica* 8.4 (2021): 539-544.

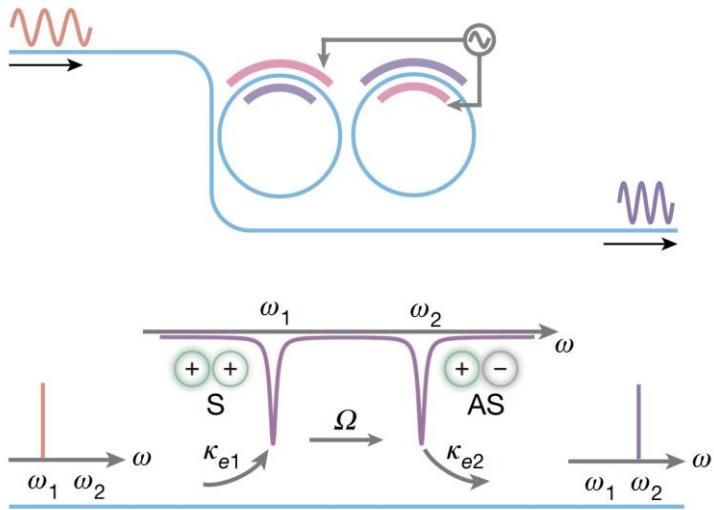
**Four wave mixing**



Foster, Mark A., et al. "Broad-band optical parametric gain on a silicon photonic chip." *Nature* 441.7096 (2006): 960-963.

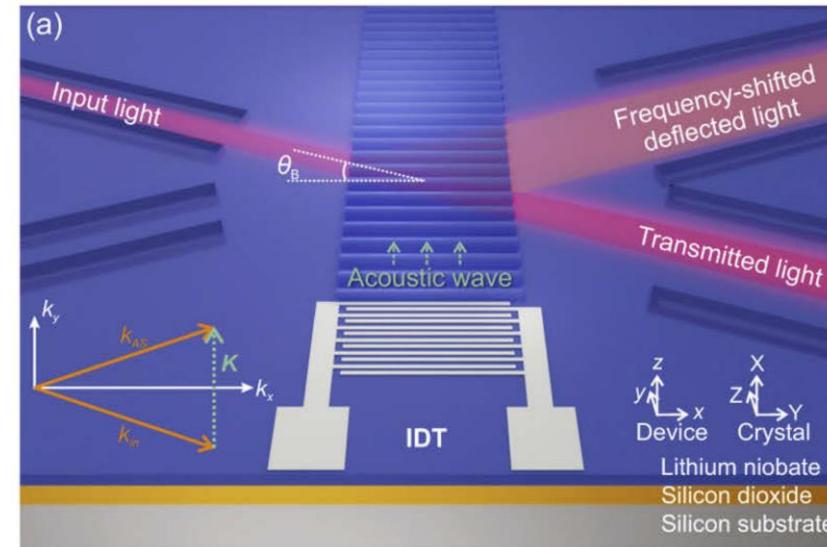
# Frequency Conversion

## Electro-optic frequency shifter



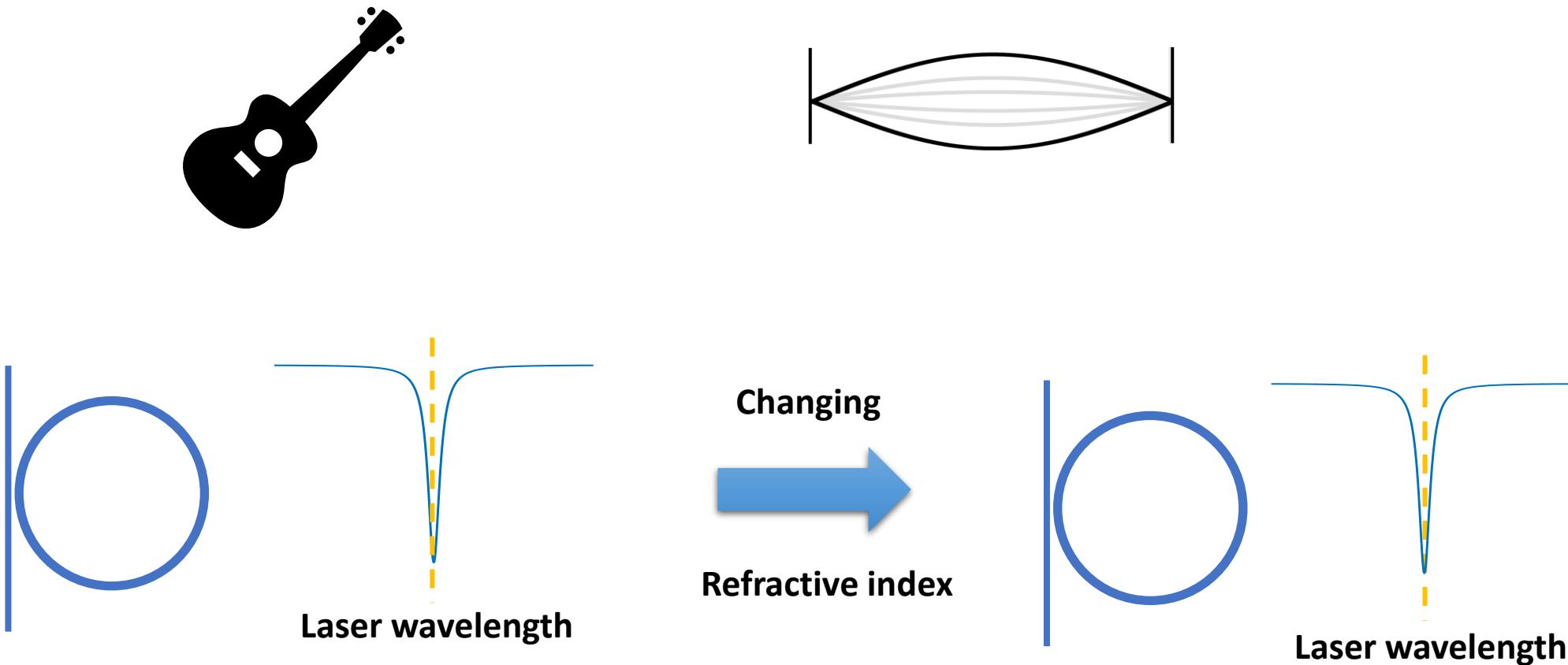
Hu, Yaowen, et al. "On-chip electro-optic frequency shifters and beam splitters." *Nature* 599.7886 (2021): 587-593.

## Acousto-optic Modulator

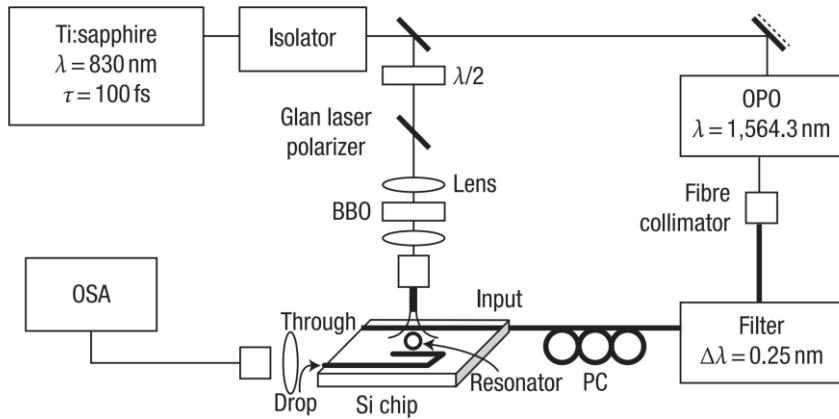


Shao, Linbo, et al. "Integrated microwave acousto-optic frequency shifter on thin-film lithium niobate." *Optics Express* 28.16 (2020): 23728-23738.

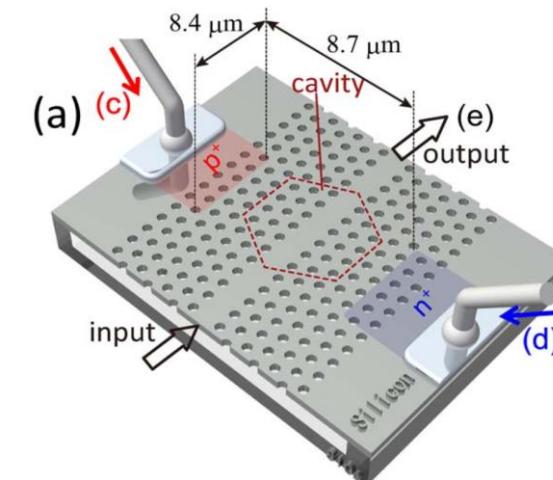
# Adiabatic frequency conversion(AFC)



# Adiabatic frequency conversion



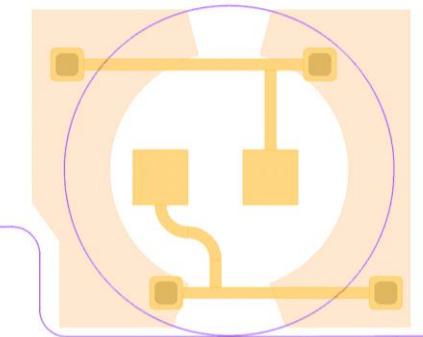
Preble, Stefan F., Qianfan Xu, and Michal Lipson. "Changing the colour of light in a silicon resonator." *Nature Photonics* 1.5 (2007): 293-296.



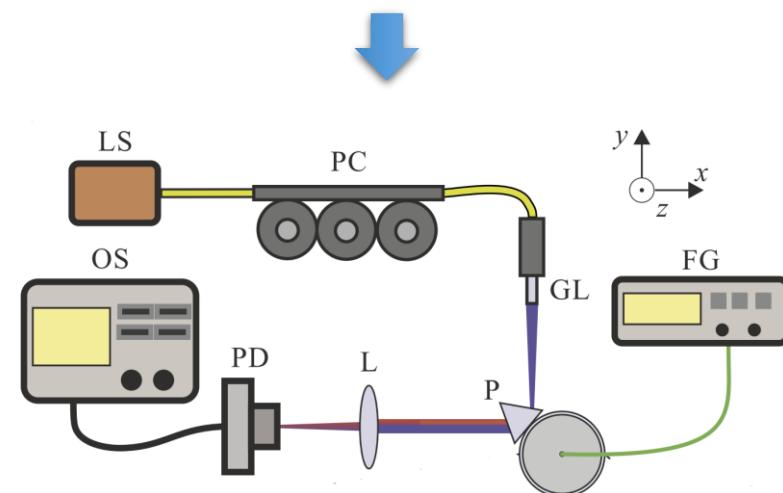
Tanabe, Takasumi, et al. "Dynamic release of trapped light from an ultrahigh-Q nanocavity via adiabatic frequency tuning." *Physical review letters* 102.4 (2009): 043907.

## Our approach

1. Fundamental Lossless
2. Integrated
3. Long photon lifetime[1]
4. Large electric-optic efficiency



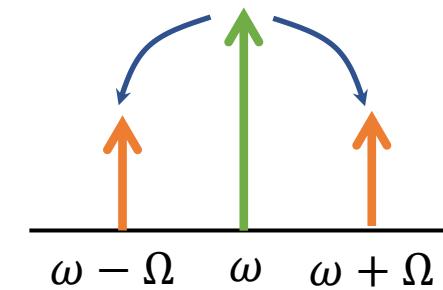
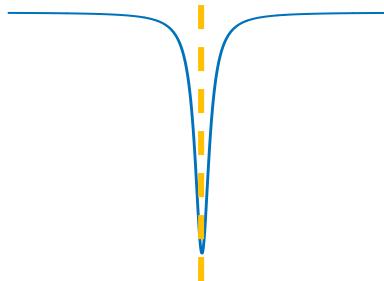
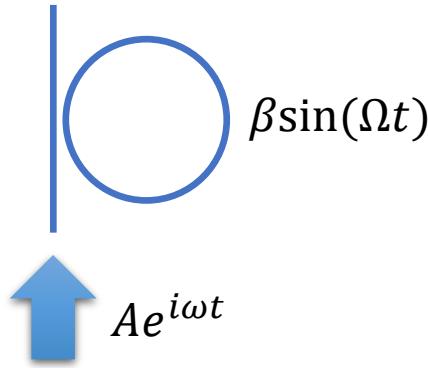
[1]Zhang M, Wang C, Cheng R, et al. Monolithic ultra-high-Q lithium niobate microring resonator. *Optica*, 2017, 4(12): 1536-1537.



Minet, Yannick, et al. "Pockels-effect-based adiabatic frequency conversion in ultrahigh-Q microresonators." *Optics express* 28.3 (2020): 2939-2947.

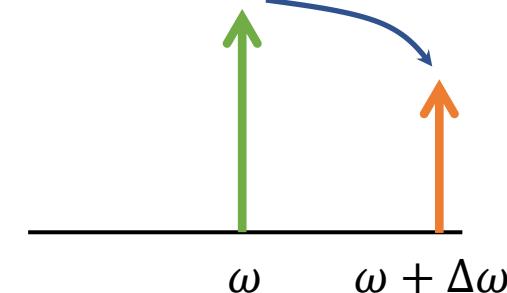
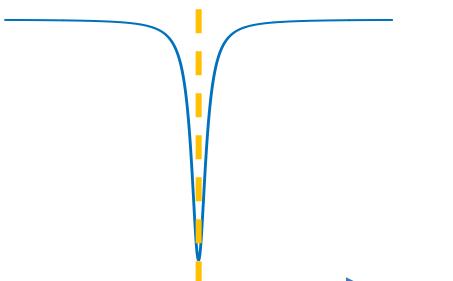
# Comparison with modulation

Electric- Optic Modulation(EOM)

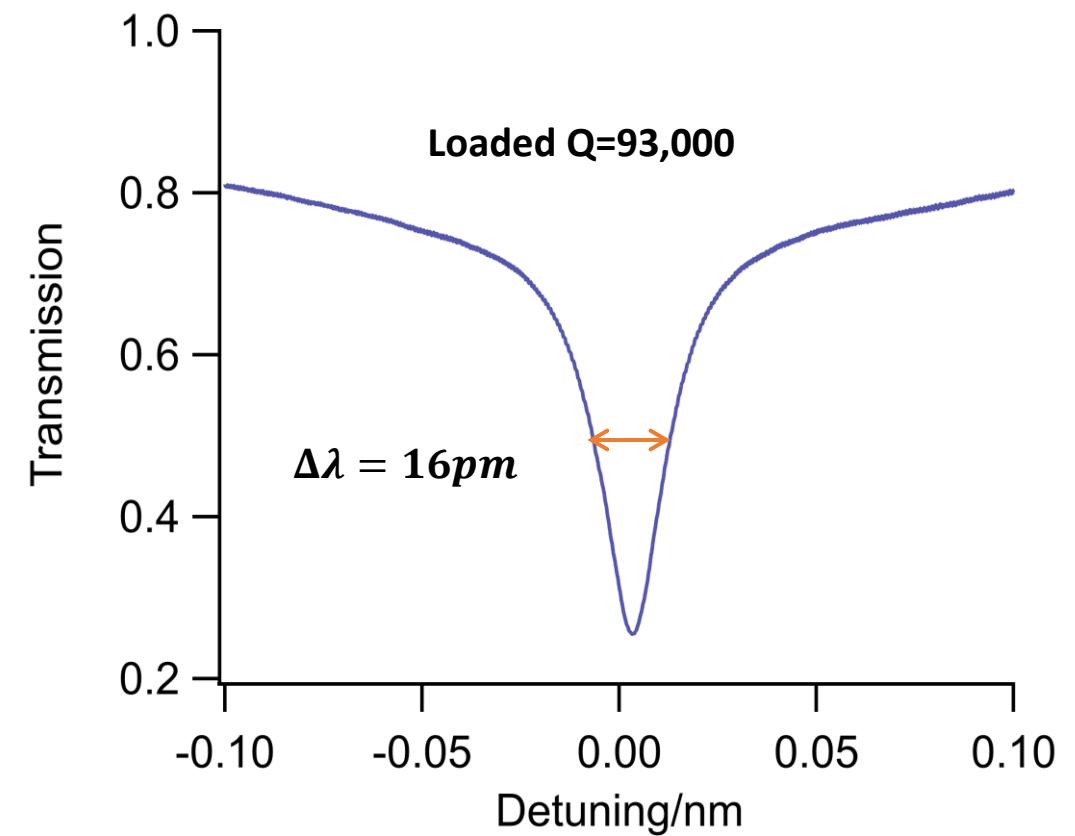
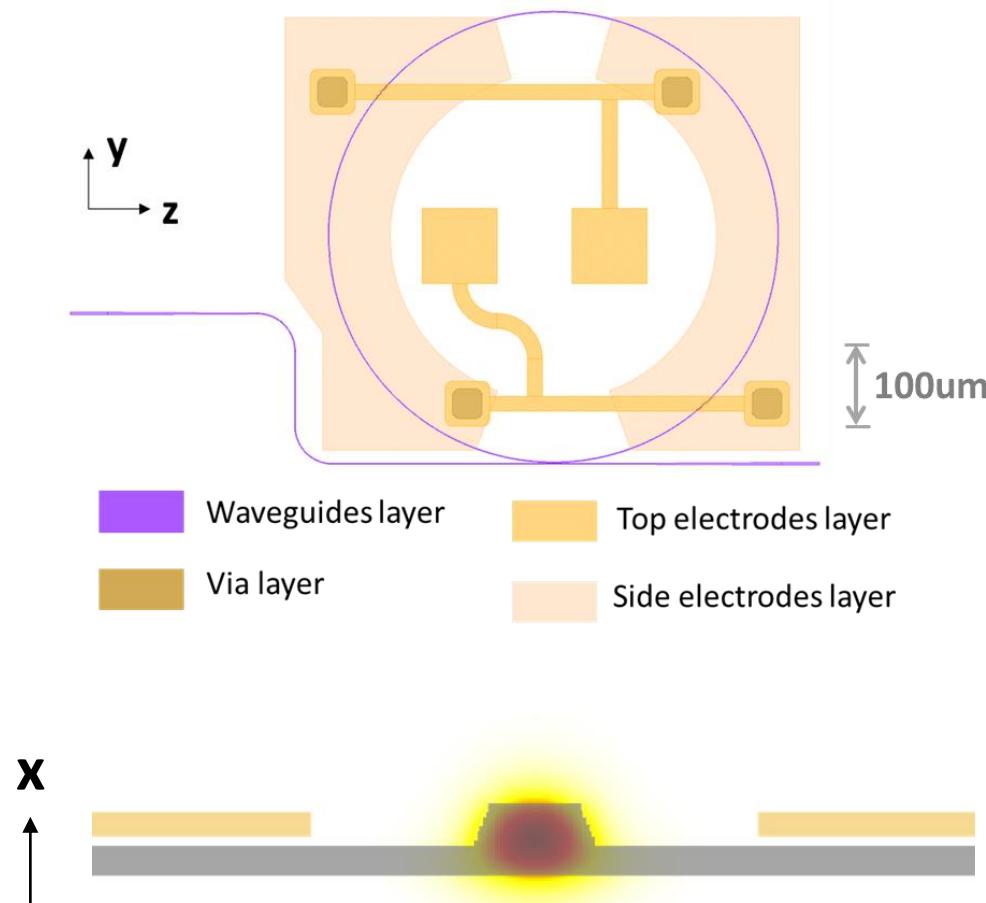


Adiabatic Frequency Conversion

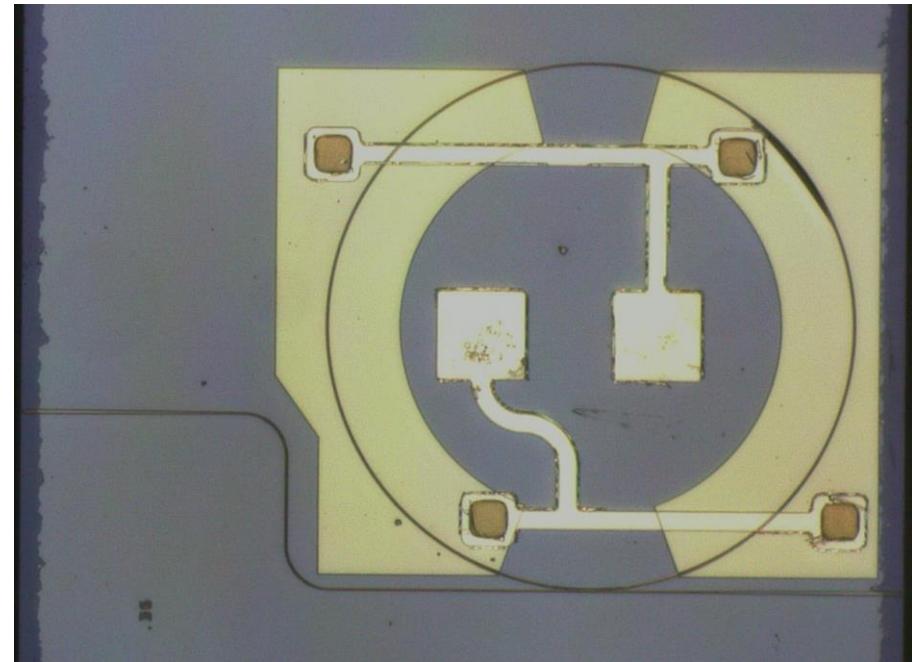
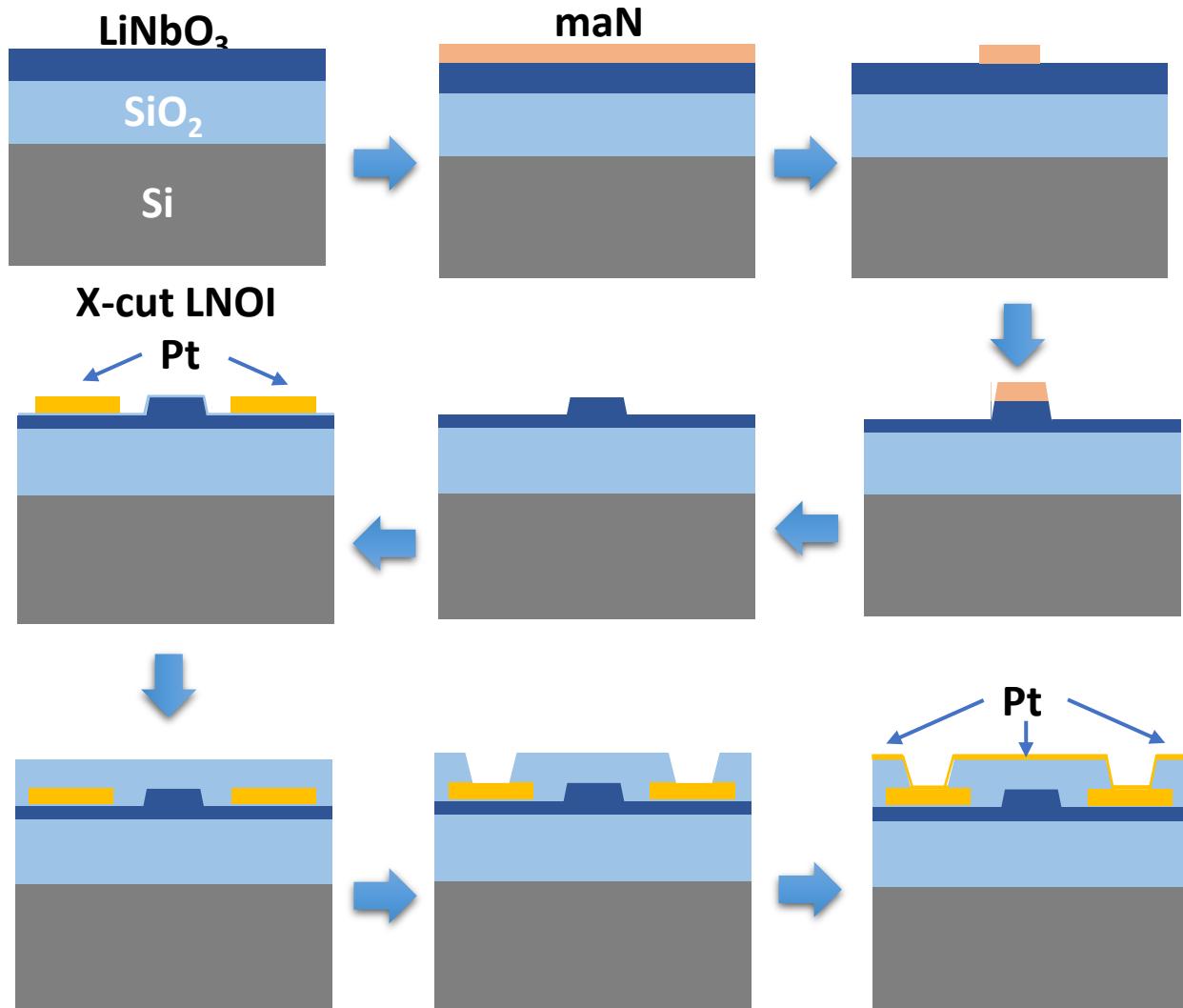
$$\Delta\omega \propto \text{Amplitude}$$



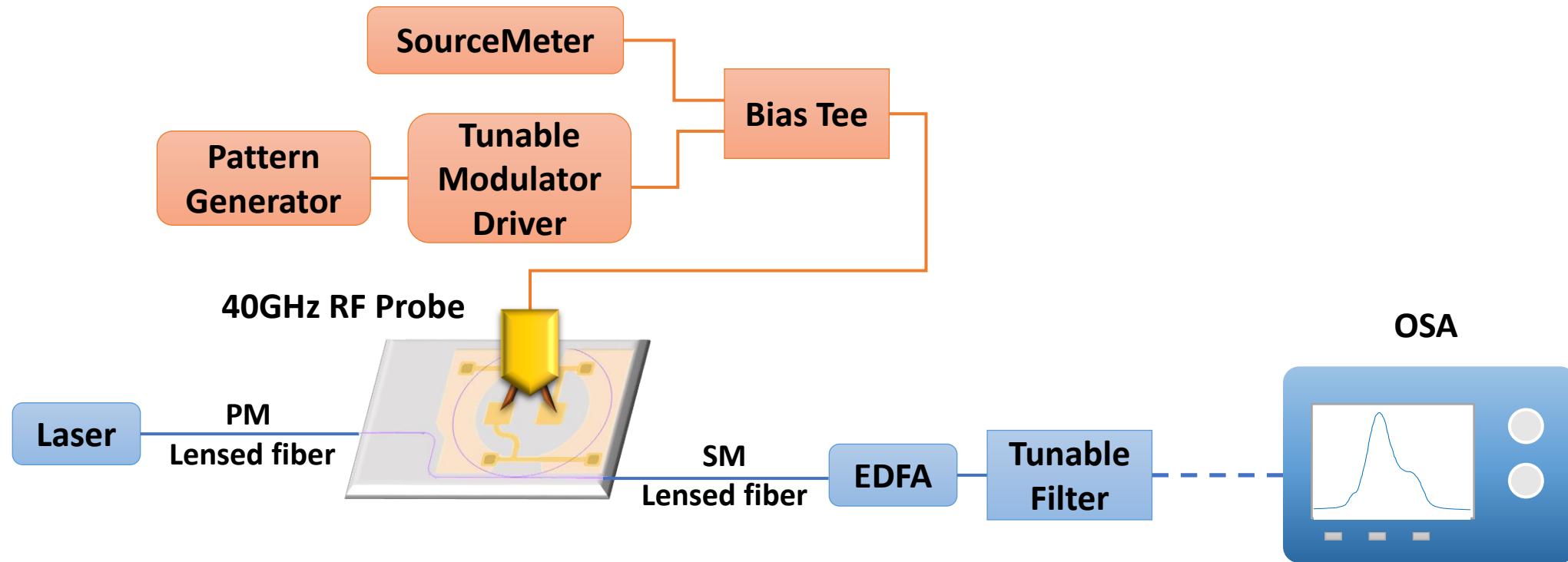
# Device Design



# Fabrication

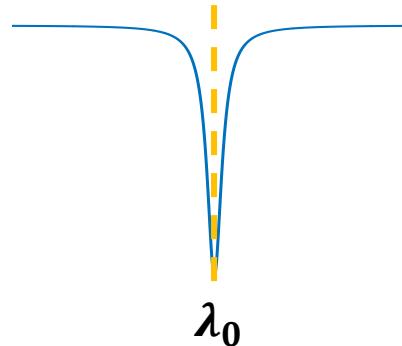


# Testing setup



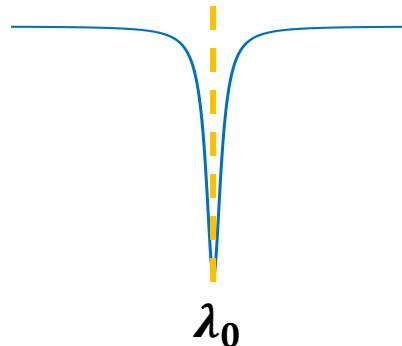
# Testing results

Ring Spectrum



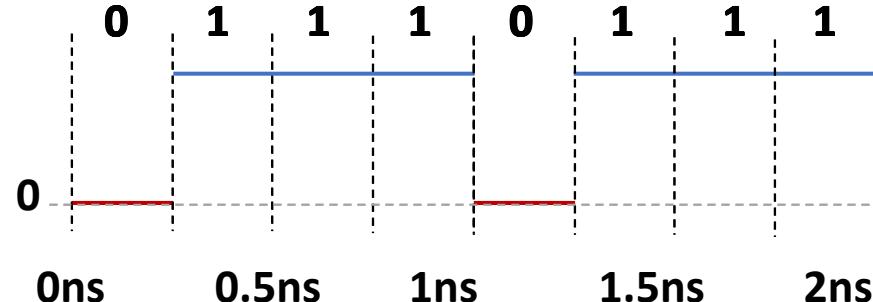
Laser wavelength

Ring Spectrum

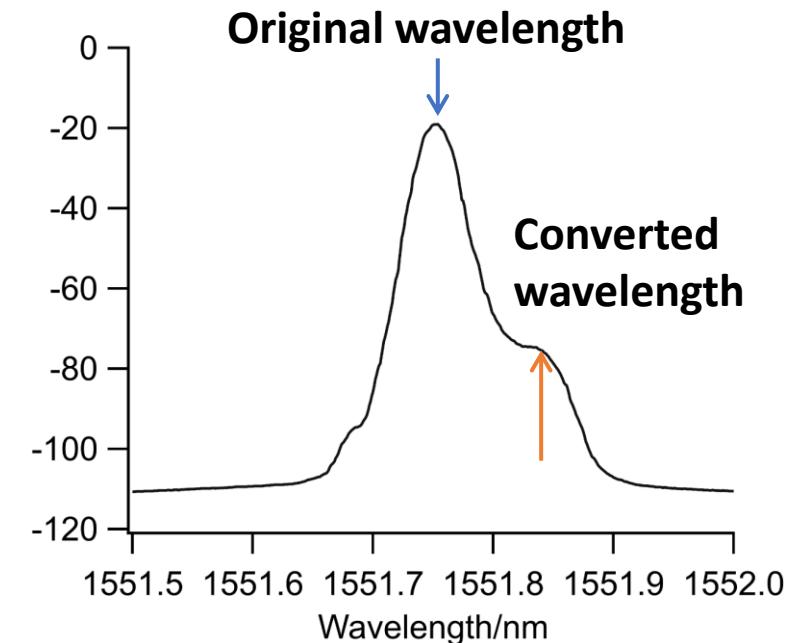


Laser wavelength

RF Signal

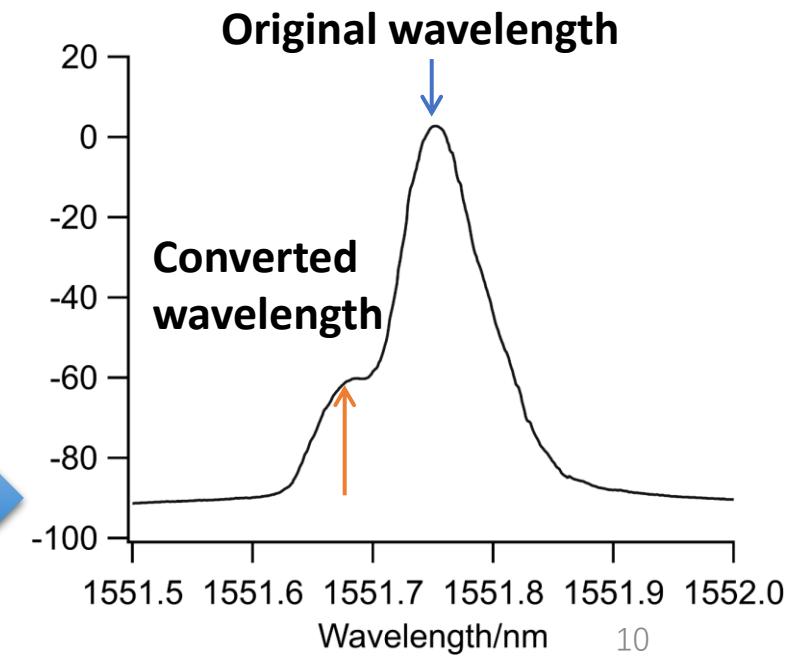


Power/dBm

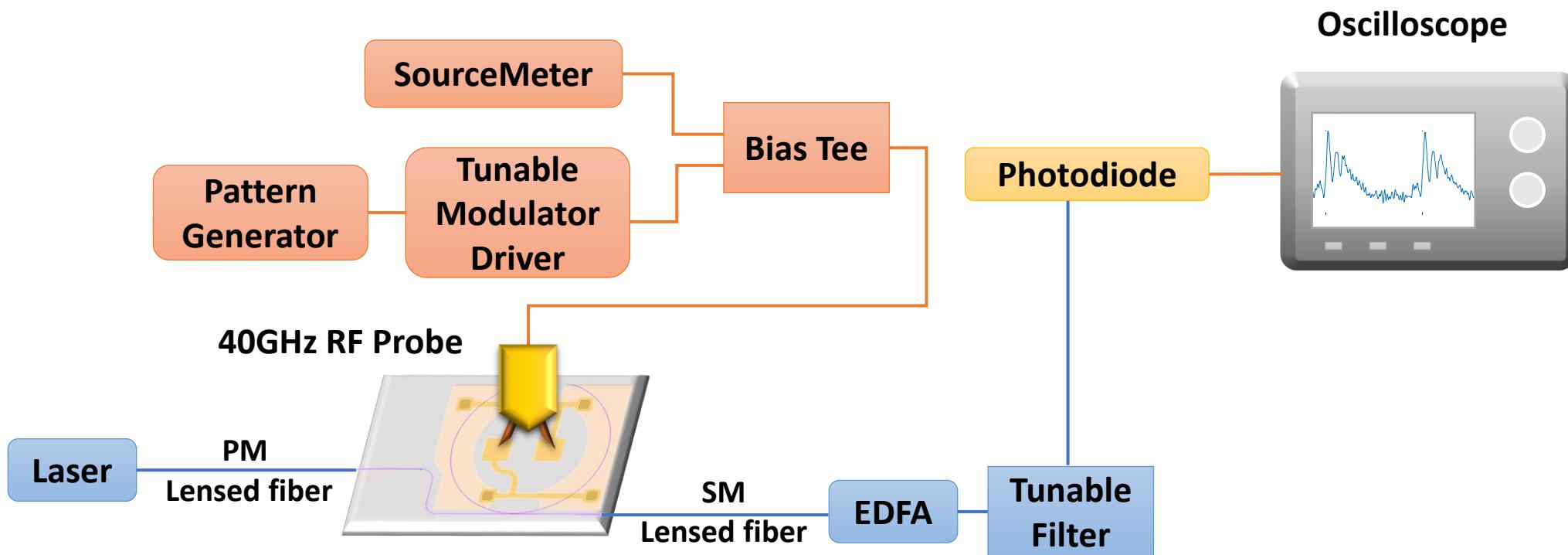


Original wavelength

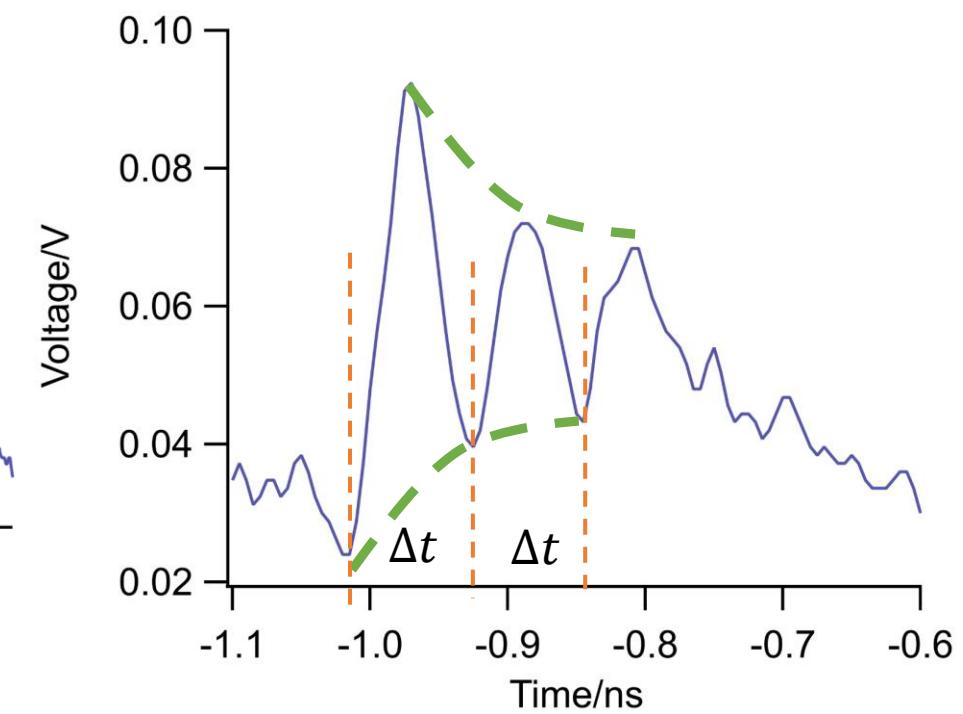
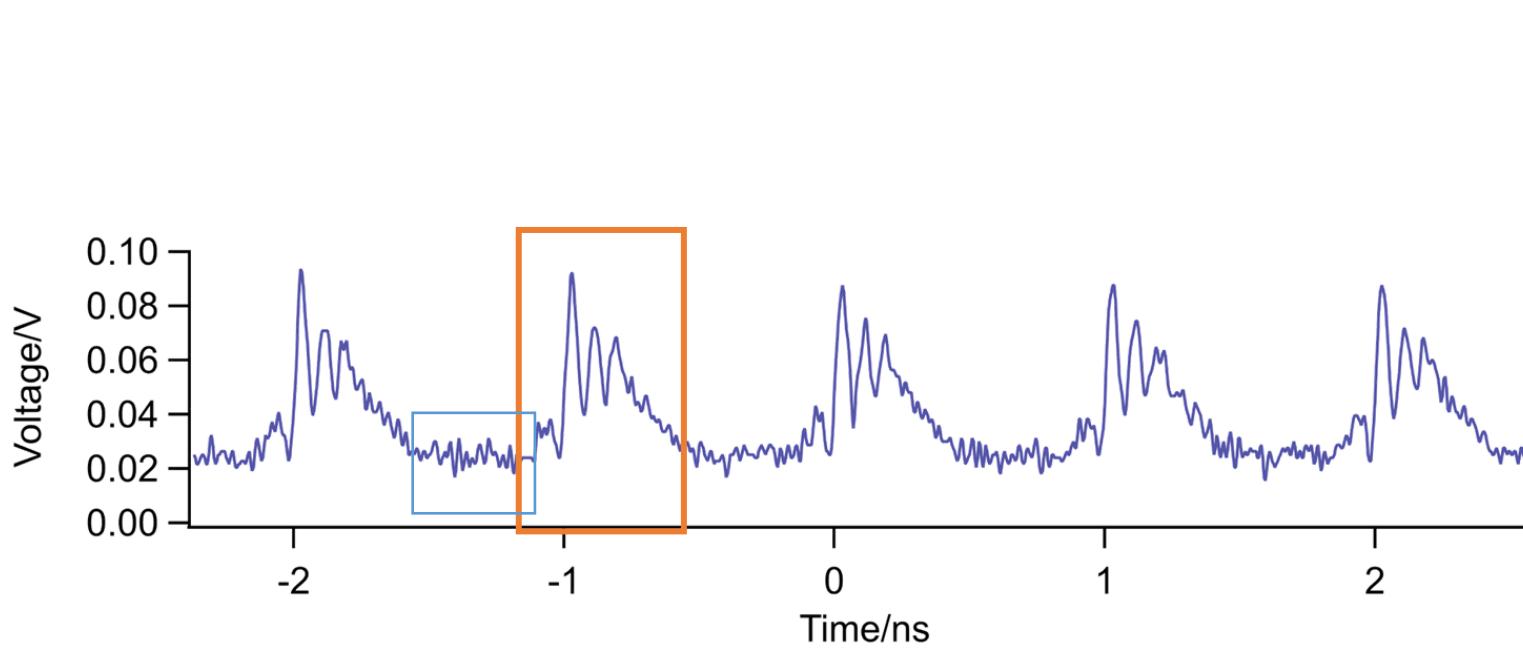
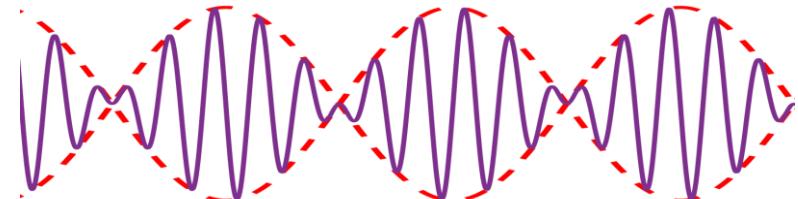
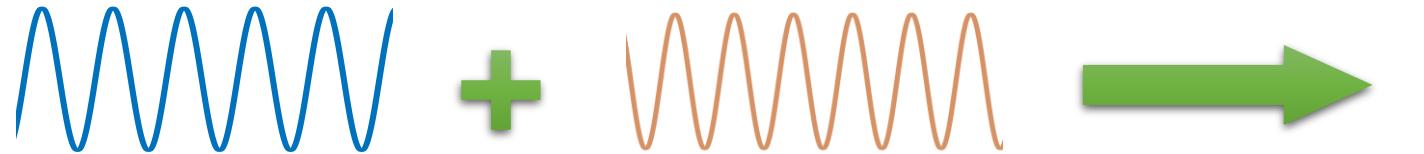
Power/dBm



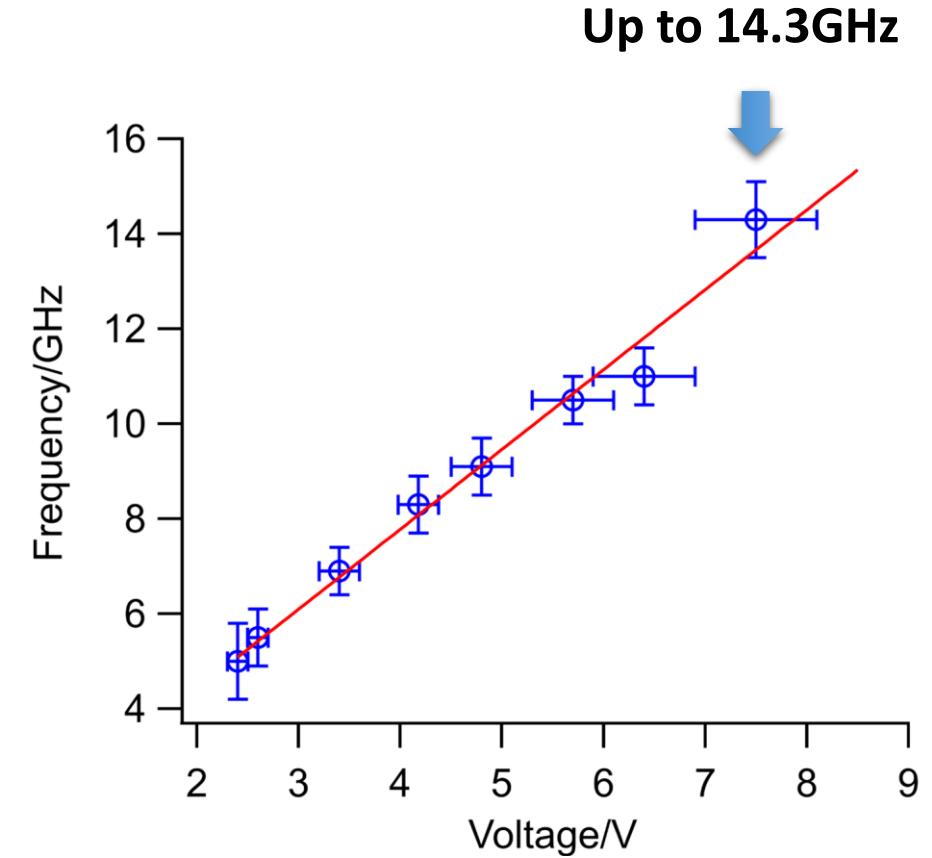
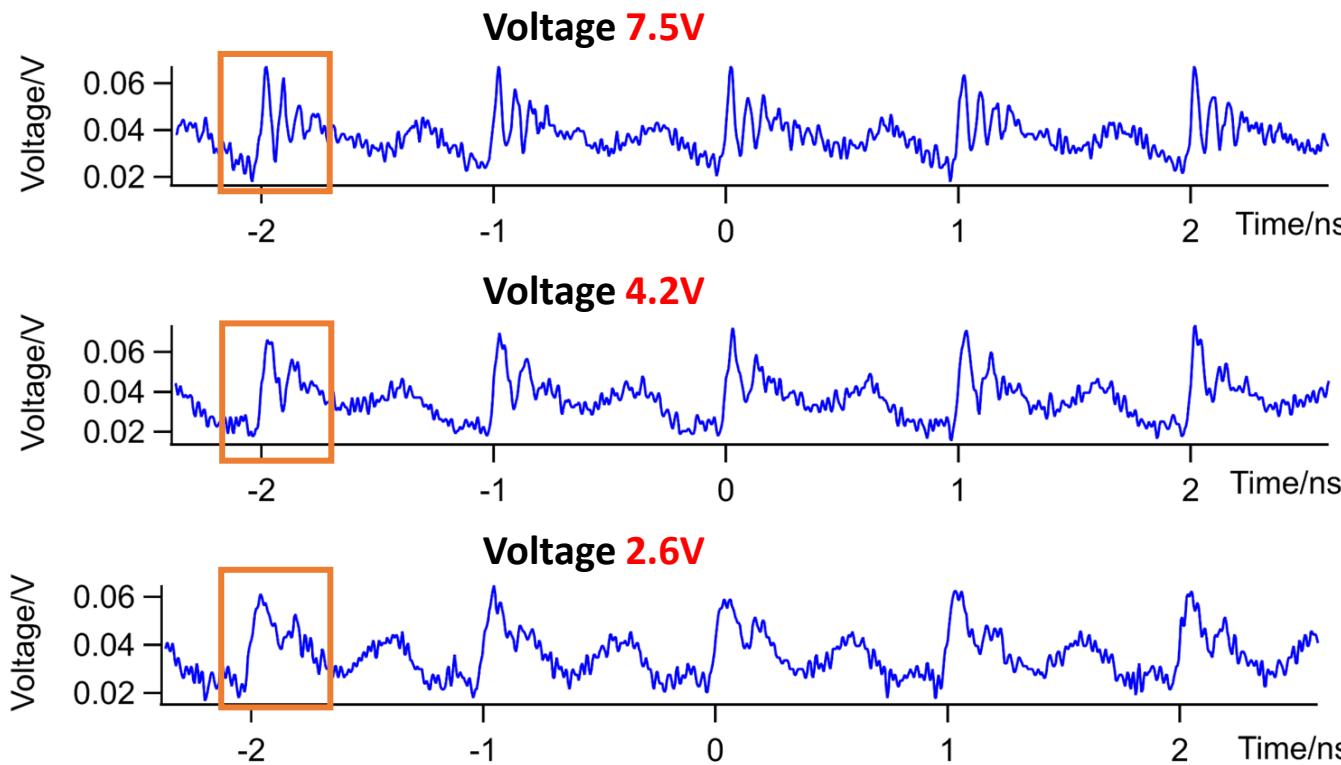
# Testing setup



# Testing results

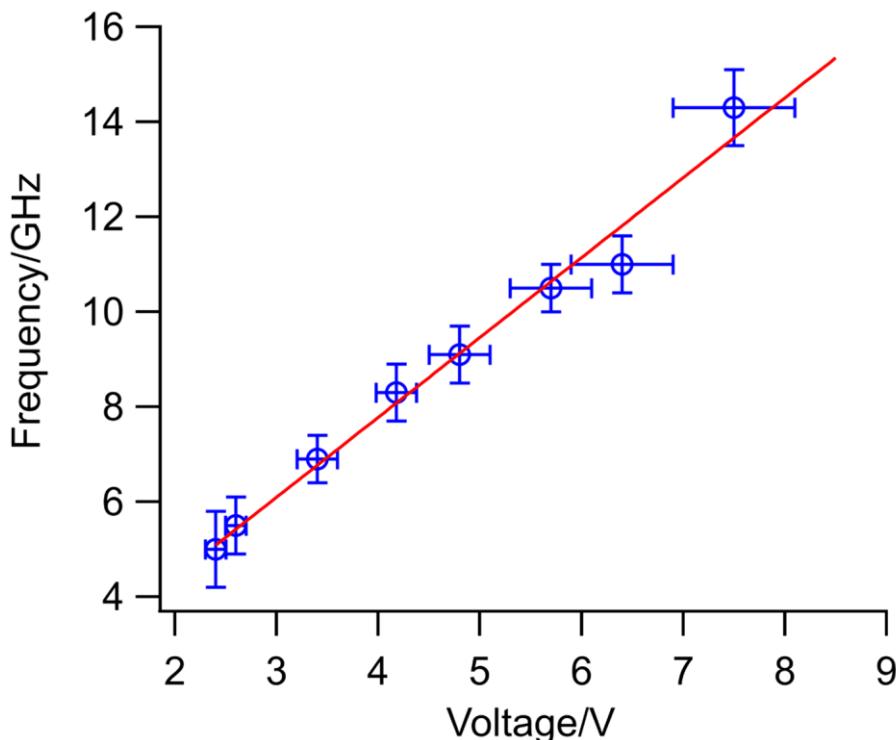


# Tunable frequency conversion



# Summary

- We demonstrate adiabatic frequency conversion on integrated Lithium Niobate Ring resonator.
- Frequency shifts of up to **14.3 GHz** are achieved by adjusting the voltage of an RF control.



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