Microcomb Generation in Nanophotonics

Sanjith Cherumandanda | scherumandanda24@mylcusd.net
Yu Lab
La Cañada High School, Class of 2024
USC Viterbi Department of Electrical and Computer Engineering, SHINE 2023

Introduction

What is optical frequency comb?
Optical frequency combs (OFCs) are a sequence of equidistant laser frequencies and provide extremely accurate measurements of light.

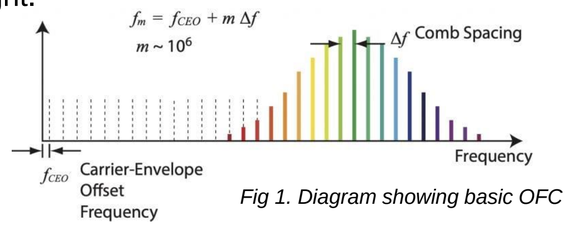


Fig 1. Diagram showing basic OFC

Generating OFC in integrated photonic chip
This is a very small and compact method of generating OFC

Objective & Impact of Professor's Research

My professor's lab is about designing, manufacturing and using integrated nonlinear photonic chips for classical and quantum applications. Some of these applications include optical communications, computing, sensing, ranging and metrology. This lab largely focuses on thin-film lithium niobate ($LiNbO_3$). When performing tests, lasers with a variety of wavelengths are shined through waveguides and resonators upon the surface of the chip in order to see how it reacts.

Acknowledgements

I would like to thank Professor Yu for giving me an opportunity and space to perform this research and learn about something that is completely new to me. I would also like to thank my mentors, Dr. Chunho Lee and Dr. Xinyi Ren. Finally, I would like to thank Clayton Cheung, Shaoyuan Ou, and my lab-mate Lilly Dembo for helping me throughout my research.

Research & Learning Process

Research flow

Design → Fabrication → Measurement → Analysis

Fig 2. CAD of ring resonator used for microcomb generation

Design
In the image on the right, there is a ring resonator with a radius of 80 μm and a bus waveguide through which the light travels through. Although they are not directly connect, light is still able to be coupled into the ring resonator due to the small gap size of 800 nm

Fabrication
There are many step to fabricate a chip of this type however, there is extensive training needed to be able to use the machines needed for fabrication, so I shadowed my mentor as he used the e-beam lithography machine.

Measurement

-Transmission and comb spectrum

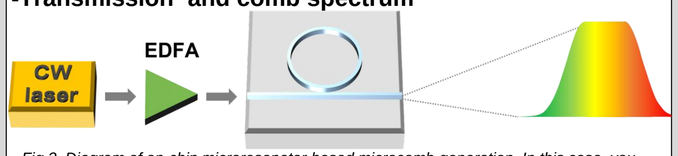


Fig 3. Diagram of on-chip microresonator based microcomb generation. In this case, you need continuous wave(CW) laser to excite target optical resonance in the ring.

-Second harmonic generation

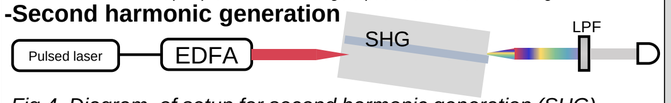


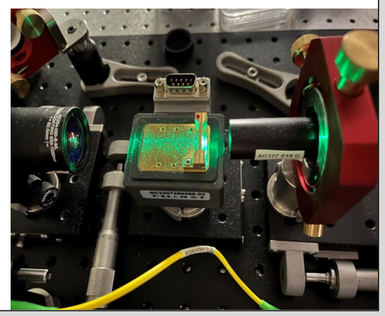
Fig 4. Diagram of setup for second harmonic generation (SHG) Nonlinear light generation such as SHG requires pulsed laser source with high peak power.

I learned how to couple a laser from fiber to chip, while also using a polarization controller. Along with this, I also learned to couple the chip's output through free space through a polarizer and collimating lens back into fiber.

Analysis
I learned how to use OriginPro, an analysis software, in order to process data and get comprehensible results.

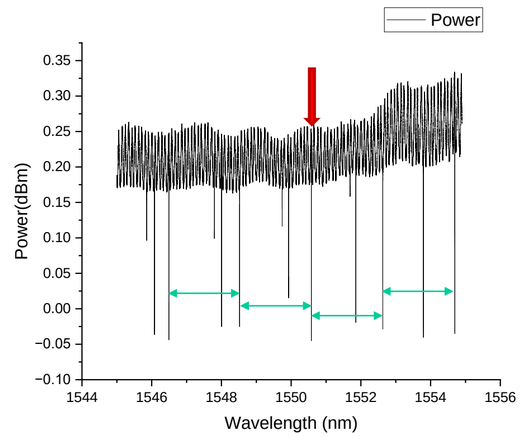
In addition to microcomb generation, we also did some second-harmonic generation. Second harmonics are generated when two photons with the same frequency interact and result in a photon with twice the energy of the origin photons (twice the frequency and half the wavelength).

Fig 5. Setup for SHG



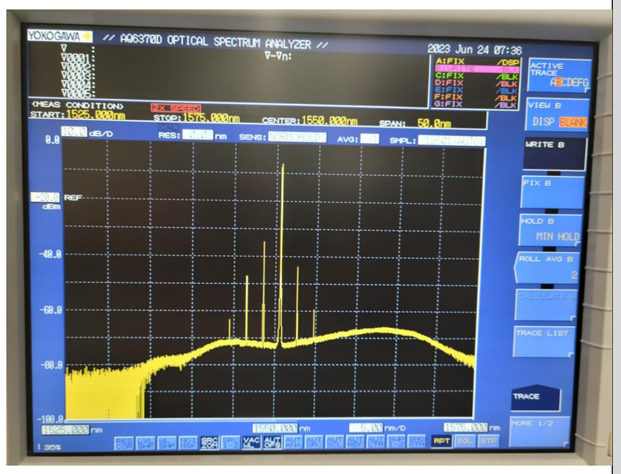
Results

Fig 6. Transmission spectrum from ring resonator



- Free spectral range(FSR) of target resonance is fixed by radius of the ring resonator to be 2 nm
- Second order transverse electric(TE) modes on the left of the fundamental TE modes
- To generate OFC, we pump the laser at the target resonance indicated by the red arrow

Fig 7. OFC generation on the ring resonator



-With pump power (80 mW), we observed OFC from the ring resonator

- The distance between peaks are equivalent to the FSR in the transmission spectrum.
- OFC can be broader with higher pump power and better designed ring resonators.

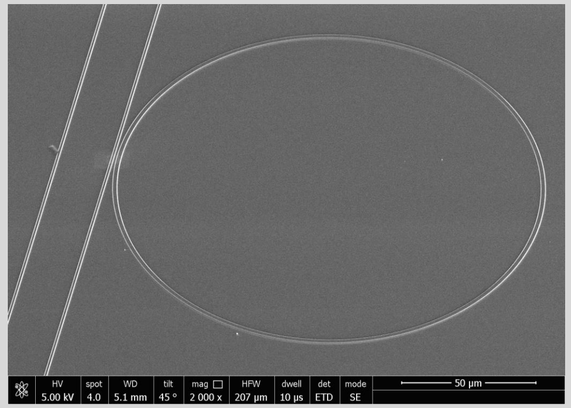


Fig 6. Scanning Electron Microscopy (SEM) image of ring resonator and bus waveguide

Next Steps

I can use the knowledge and skills that I have gained during my time in Shine to help me in any research that I do in the future, whether it be undergraduate or beyond.

Citations

Zhang, M., Buscaino, B., Wang, C., Shams-Ansari, A., Reimer, C., Zhu, R., Kahn, J. M., & Lončar, M. (2019). Broadband electro-optic frequency comb generation in a lithium niobate microring resonator. *Nature*, *568*(7752), 373–377. https://doi.org/10.1038/s41586-019-1008-7

Zhu, D., Shao, L., Yu, M., Cheng, R., Desiatov, B., Xin, C. J., Hu, Y., Holzgrafe, J., Ghosh, S., Shams-Ansari, A., Puma, E., Sinclair, N., Reimer, C., Zhang, M., & Lončar, M. (2021). Integrated photonics on thin-film lithium niobate. Advances in Optics and Photonics, 13(2), 242. https://doi.org/10.1364/aop.411024