Designing High Efficiency Electron Emission Devices

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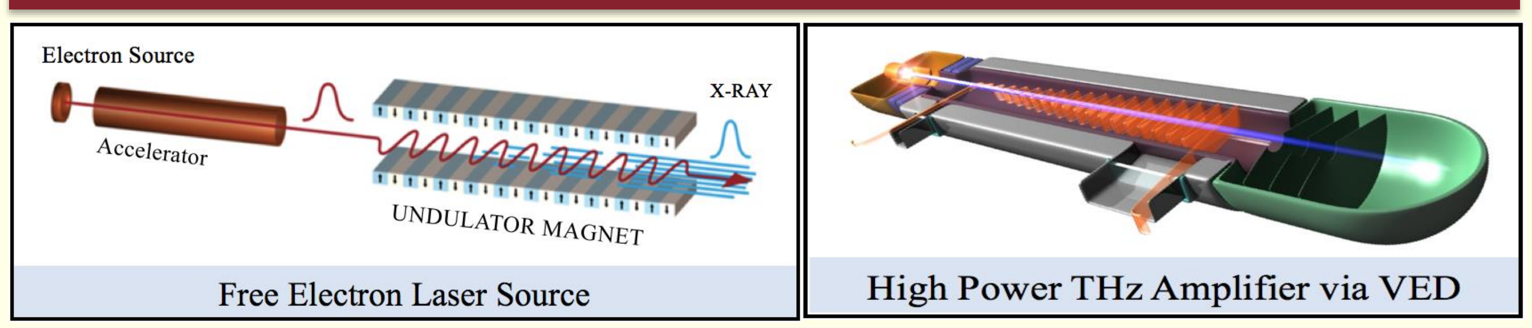
SHINE Summer High School Intensive in Next-Generation Engineering

Introduction

In Dr. Kapadia's lab, we are trying to design and fabricate a high efficiency electron source at the THz level. By passing a wave through a ring resonator, we can confine its energy and convert it to electrons through a graphene layer at a higher efficiency than a waveguide could. Instead of the usual designs at the 1550 nm wavelength, we are designing these devices at shorter wavelengths in the 405-650 nm range. At these shorter wavelengths, the waves have more energy, resulting in higher electron emissions. The difficulty in fabricating at these wavelengths is that the high energy wave is harder to couple and confine through waveguides. As a result, these devices often have high losses.

Objectives and Impact of Research



Free Electron Laser Source

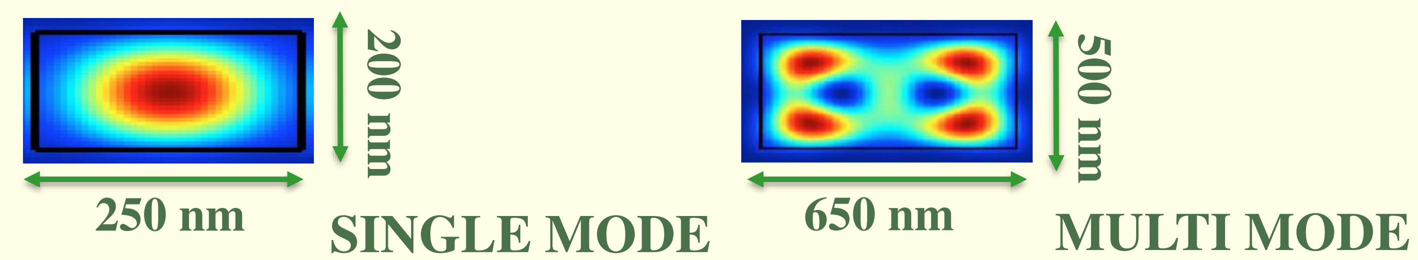
High Power THz Amplifier via VED

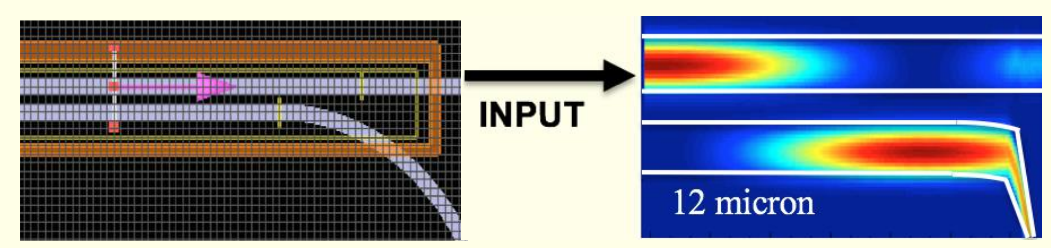
By creating a high efficiency electron source, we can produce and shoot electrons at a faster rate. This opens doors to new technological advancements as devices like the time-resolved electron microscope, free electron laser source, and high power amplifier, require an electron source with a high emission rate to work. By raising the electron emission rate to an emission per picosecond, these devices can finally come into fruition and be fabricated and experimented. The time-resolved electron microscope is especially important as it would allow researchers to view objects in 4D with time being the fourth variable.

Methods

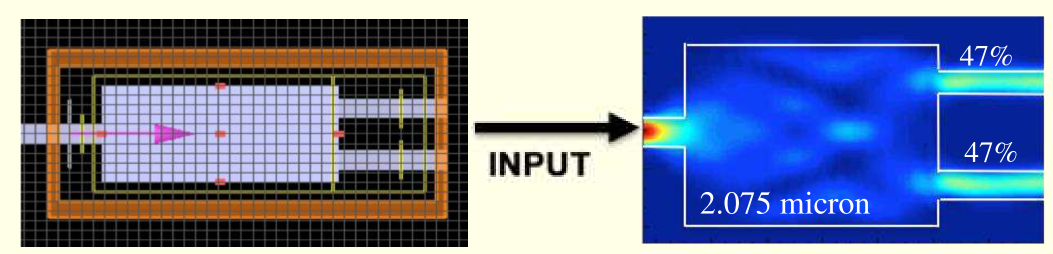
Through the use of FDTD Solutions, I designed and simulated a high efficiency MMI splitter, directional coupler, grating coupler and ring resonator at various wavelengths. In order to retain a high effective index at such short wavelengths, I used Si_3N_4 as the material and SiO_2 as a substrate. The usual silicon material at these wavelengths results in high losses. A single mode waveguide was used in order to avoid any internal reflections that may hinder the efficiency. After several sweeps, the results are shown to the side.

Results



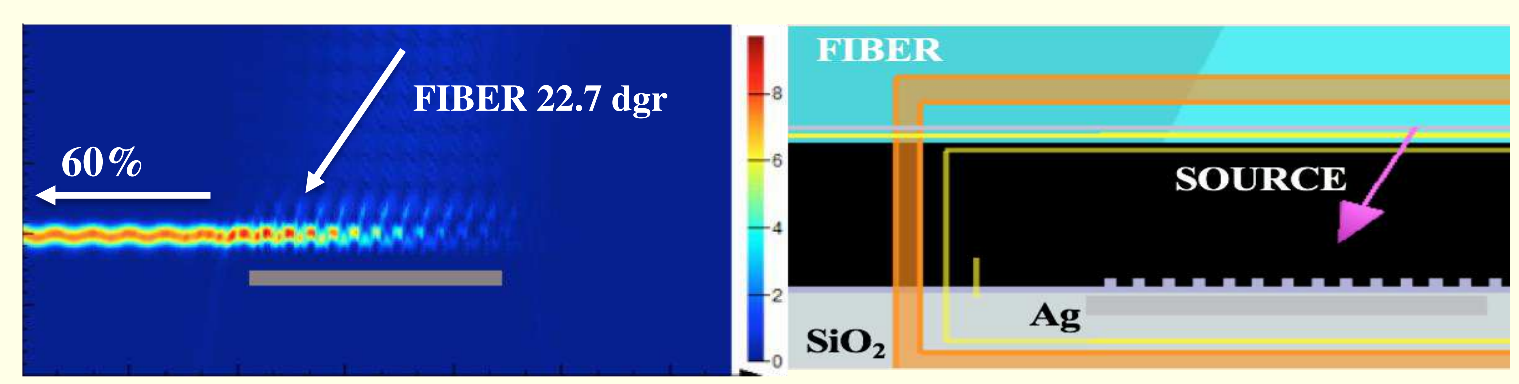


DIRECTIONAL COUPLER
405 nm 80% coupling

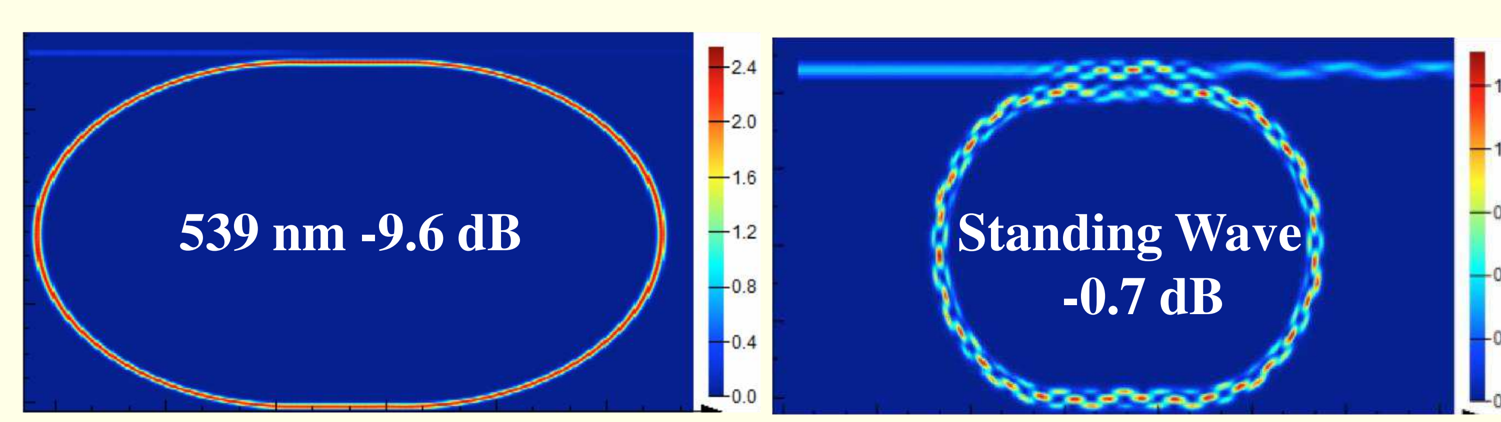


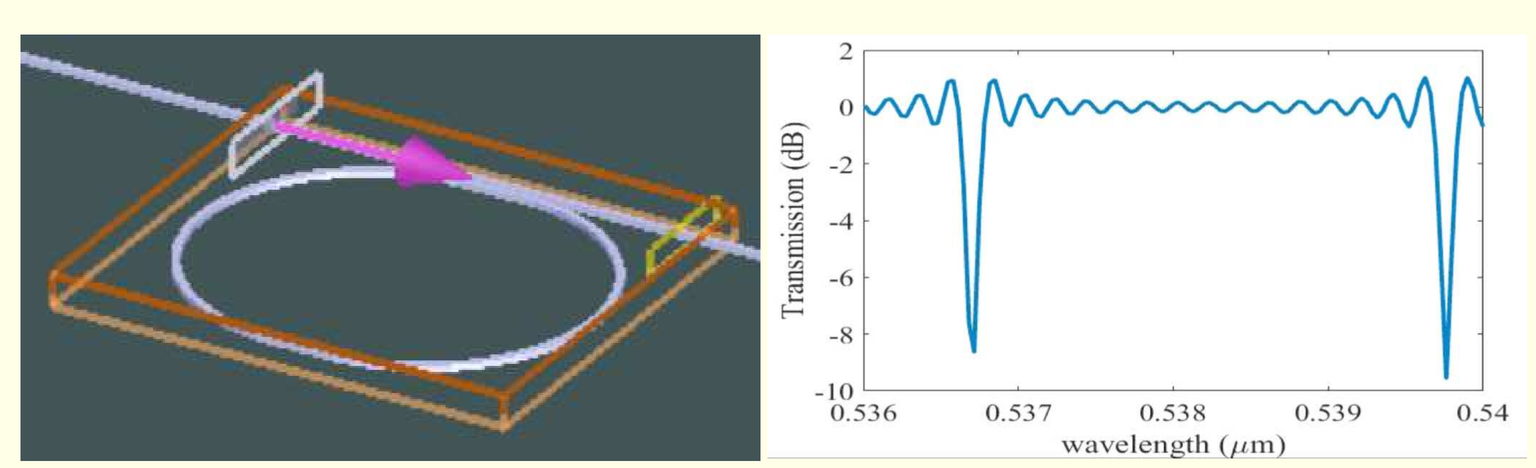
MMI SPLITTER
405 nm 94% power

GRATING COUPLER
415 nm 60% coupling efficiency



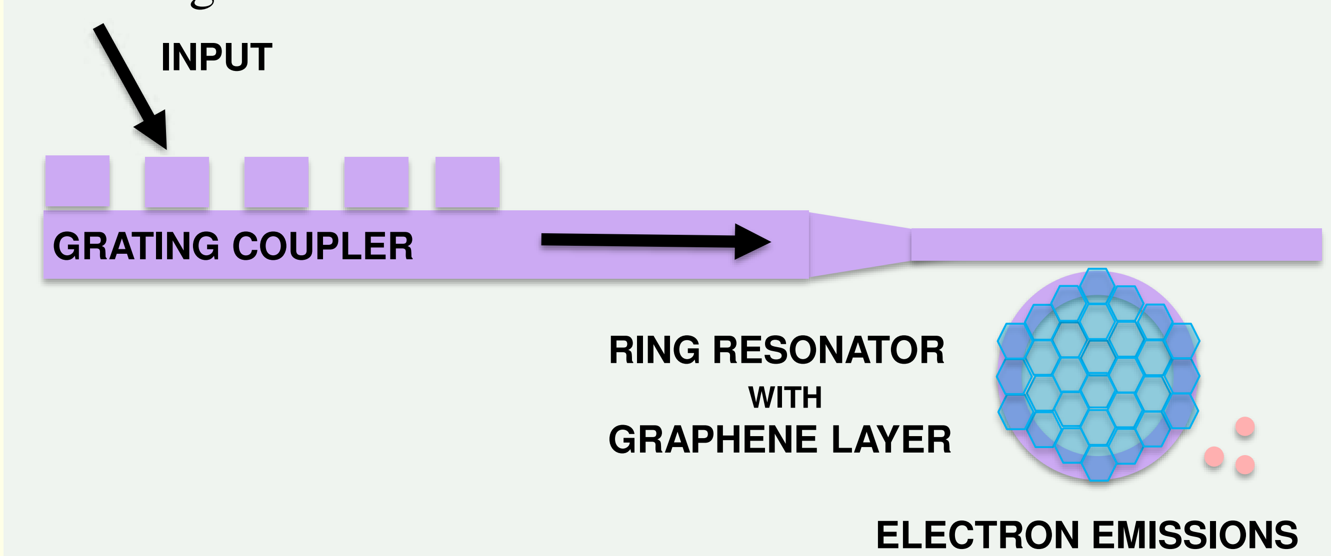
RING RESONATOR
418 nm: -7.6 dB / Q = 7000
539 nm: -9.6 dB / Q = 4800



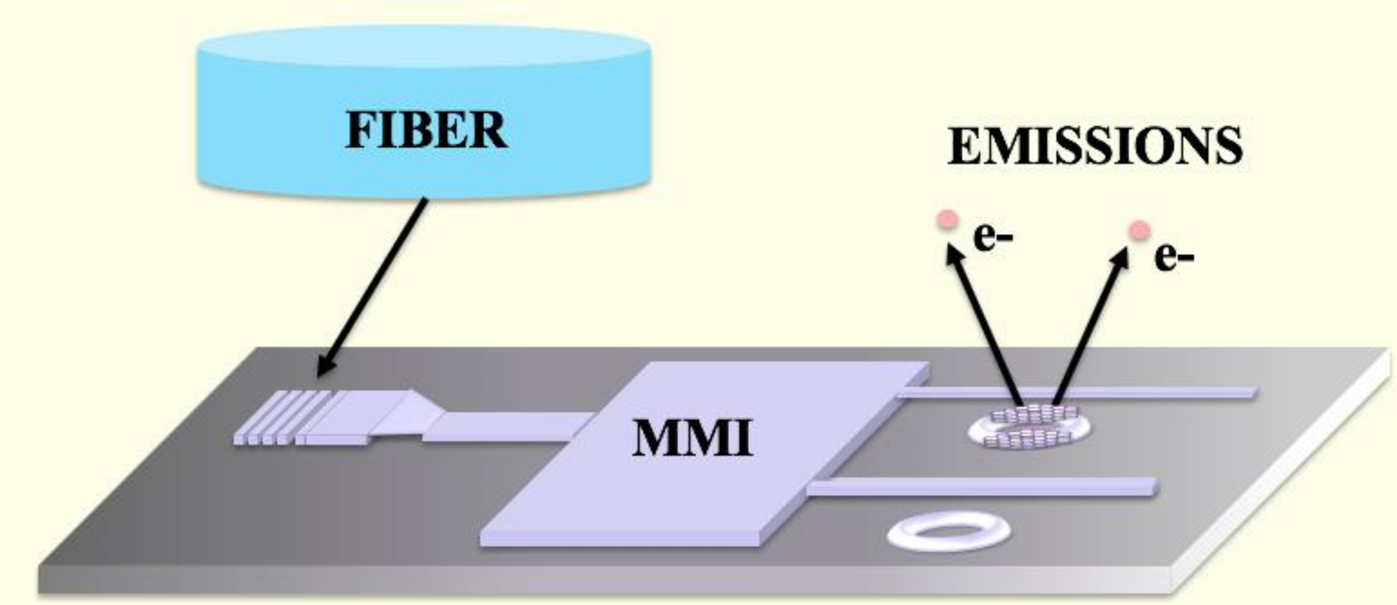


Next Steps of the Research

After we finish designing these integrated photonic devices, my PhD mentor, Mrs. Rezaeifar, will be using these designs to fabricate a ring resonator assisted electron emitter. This device has a grating coupler that couples the laser from an external source into the waveguide. The light will then be guided to the ring resonator which stores and couples the light to a monolayer of graphene placed above the ring resonator as an electron emitter.



Ring Resonator Assisted Electron Emitter



How This Relates to My STEM Coursework

In my time here, I've learned how to use a super computer and simulation programs (FDTD and MatLab). Through this research, I have developed a deep interest in photonics research and hope to major in this field in college.

Acknowledgements

I'd like to thank my professor, Dr. Kapadia, and PhD mentor, Mrs. Fatemeh Rezaeifar, for their guidance and support throughout my time here. I'd also like to thank Dr. Mills and Dr. Herrold for the weekly cohort sessions and mentorship. Additionally, thanks to the other PhD student in my lab, Jun Tao and graduate student Hyun Uk Chae.