**Design of a Waveguide-Cavity System for Quantum Emitter**

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**Motivation**
Enhance collection of photon from quantum emitters of nitrogen vacancy (NV) centers in diamond for quantum information processing applications.
- Find optimized structures of ring resonator and grating coupler by simulation.

**Simulation Method**
I utilize MEEP (Open-source finite-difference time-domain (FDTD) simulation software developed by MIT) for simulation.

FDTD method:
- Technique for solving electromagnetic problems
- Applies finite differences as approximations to derivatives in Maxwell’s equations by staggering electric and magnetic fields in both space and time. (Yee lattice)

Parallel computing is a good way to run simulations faster. We utilize cloud computing in collaboration with the Rehr group at UW to realize parallel computing.

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**Ring Resonator**
Photons are preferentially emitted into the cavity when the cavity is on resonance with the NV transition. The efficiency of photon collection with cavity can be determined mainly by 2 parameters:
- Quality factor $Q$: larger when light is confined for a longer time
- Mode volume $V$: volume in which the electromagnetic field is contained.

For a given height, find the minimum diameter of a ring resonator for $Q$ that can be fabricated in the lab.
Optimize $\frac{Q}{V} \times \frac{|E_{NV}|^2}{|E_{MAX}|^2}$ with fixed $Q$.

| Height (nm) | Mode volume $V$ | $Q$ | $\frac{V}{|E_{NV}|^2} \times \frac{|E_{MAX}|^2}{|E_{NV}|^2}$ |
|-------------|----------------|-----|----------------------------------|
| 100         | 2.76           | 5122|                                  |
| 150         | 2.09           | 4369|                                  |
| 200         | 1.77           | 2014|                                  |
| 250         | 1.79           | 1287|                                  |

**Grating Coupler**
Output grating couplers diffract light from waveguide to certain directions. They are important for my project as an interface between the ring resonator and the optical detector.
As part of my project, I first simulated grating structure for a silicon-on-insulator coupler so I can compare my results to published literature.

**2D simulation results of SOI grating coupler**
I optimized parameters in the following order to obtain the best coupling efficiency.

**Future work:**
1. Design of GaP/diamond grating coupler for quantum information project.
2. Design of polycrystalline GaP/insulator coupler for fundamental study of polycrystalline GaP waveguides.
3. Full 3D simulation for final devices.