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Computational Design of Optical Micro-Seismometer

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MOTIVATION / ABSTRACT

- Develop and optimize a coupled ring micro-resonator waveguide system as part of a novel miniature micro-seismometer
- Measuring the transmission spectrum shift due to disturbance of evanescent field
- Could be used as an accelerometer
- In planetary exploration, it would be beneficial to have a small seismometer that can provide reliable measurements
- Create a seismometer responsive to a very wide range of frequencies

PROBLEM STATEMENT

- Using MEEP, design a waveguide-ring system, which optimizes power to the sensor and quality factor
- Assess output signal strength and resonance quality factors
- Compute transmission spectra and shift to observe resonances and Whispering Gallery Modes (WGMs)
- Reduce power losses due to coupling

MEASUREMENT PRINCIPLES

- Resonant condition:
  $2\,\pi\,R\,n = l\,\lambda$
  where: R – radius, n – index of refraction, l - mode number (positive integer), λ - wavelength

- Free Spectral Range:
  $$\Delta\lambda_{FSR} = \frac{\lambda^2}{2\pi R n}$$
  where: $\Delta\lambda_{FSR}$ – distance between two peaks of the same mode

- Normalized power:
  $np_i = \frac{t_i}{t_1}$

APPROACH/EXPERIMENTAL TECHNIQUES

As a proof of concept we designed a system composed of: a 0.5μm wide input waveguide, a 5μm-radius ring resonator, with width w_r of 0.25μm.

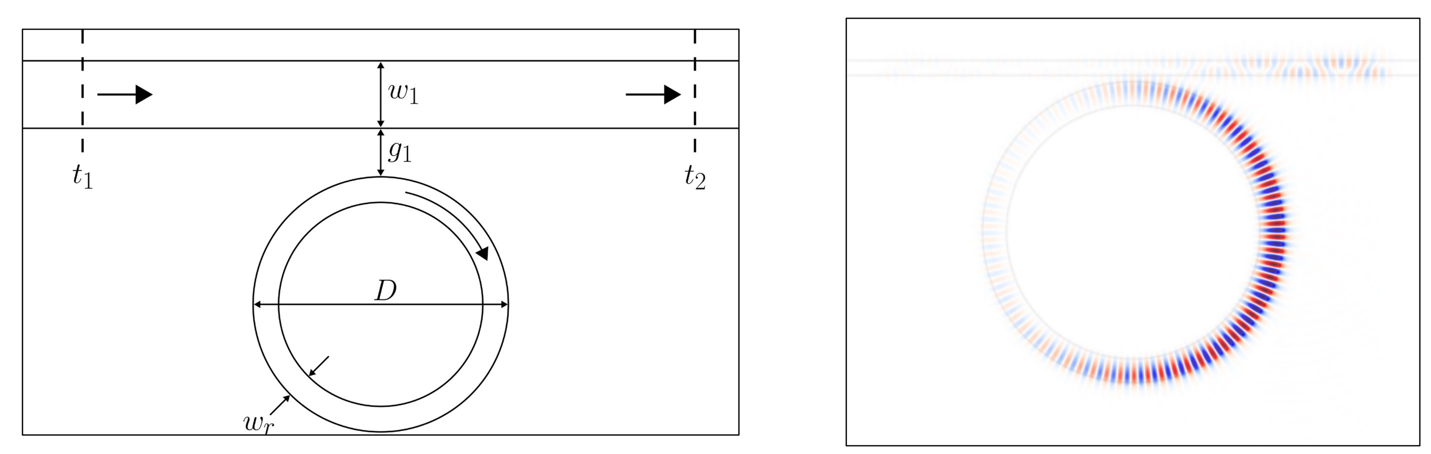

Figure 1 – (left) Schematics of 2D ring resonator; (right) Electric field in the ring during resonance

Our strategy was to send a Gaussian pulse ($\lambda \rightarrow$ 640 nm) from a source located just before t_1 and allowed it to propagate through the waveguide, then measure the power at locations t_1 and use it to find the optimal values of g_1. Additionally, we expect to observe resonances/WGMs in the transmission spectrum.

RESULTS

To compute the transmission spectrum (Fig. 2) we normalized the power measured at t_2.

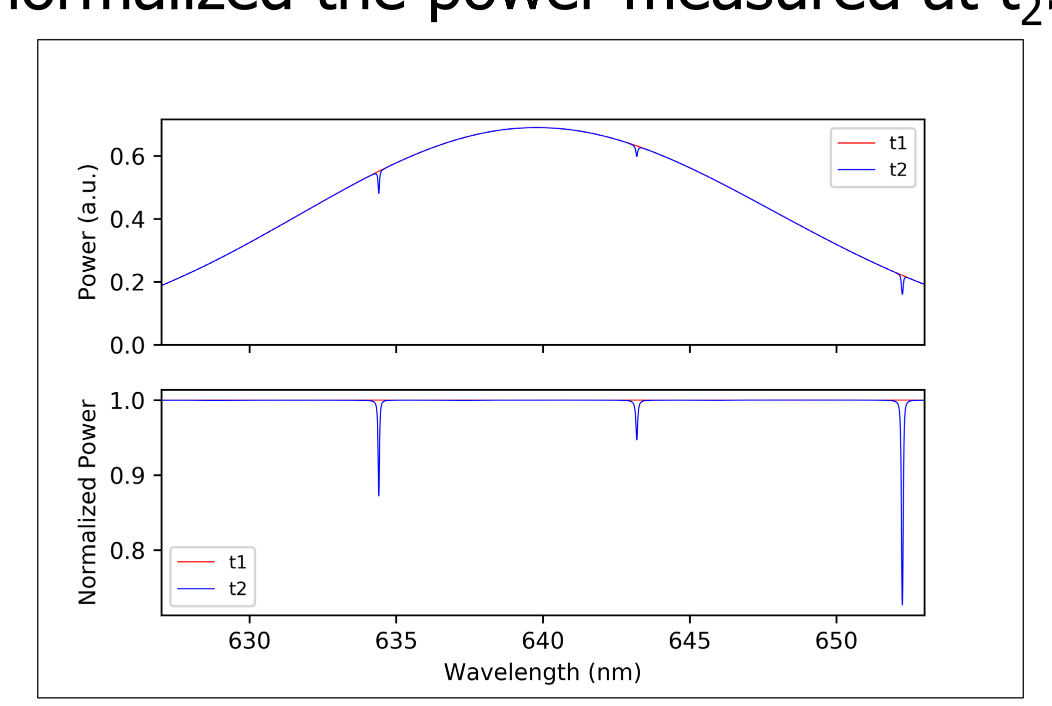

Figure 2 – Transmission Spectrum

With the normalized transmission spectrum, we found that the optimal value for g_1 is 0.25μm.

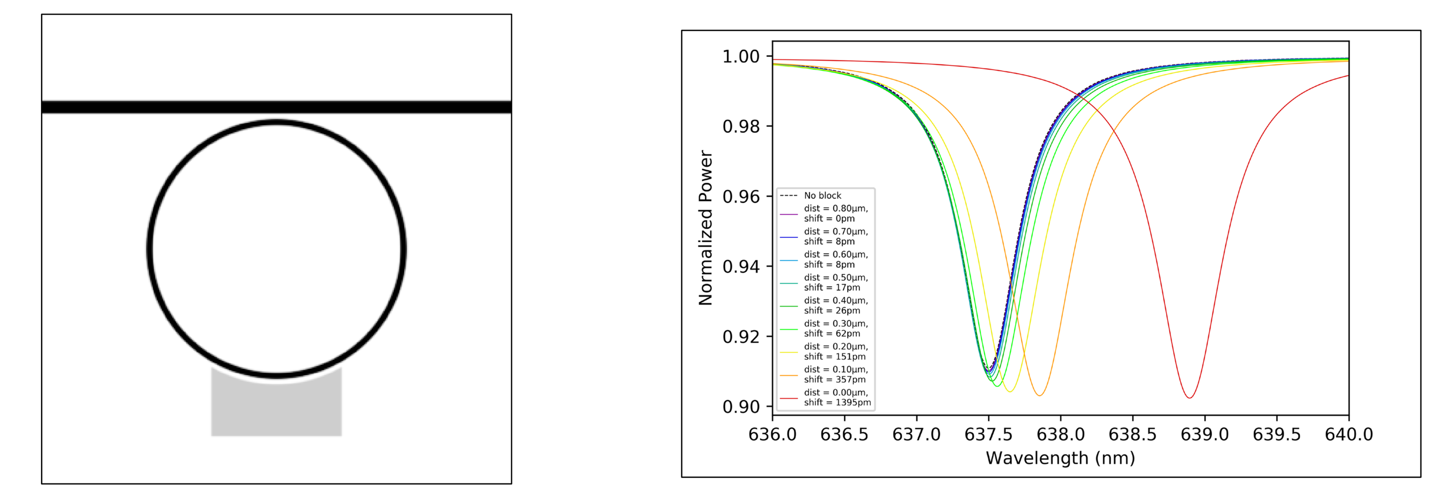

Figure 3 – (left) Geometry of the system; (right) transmission for different distances

We found that the shift $\Delta\lambda(s) \propto e^{-s}$, where s is the distance and fitting the data we obtained an expression for

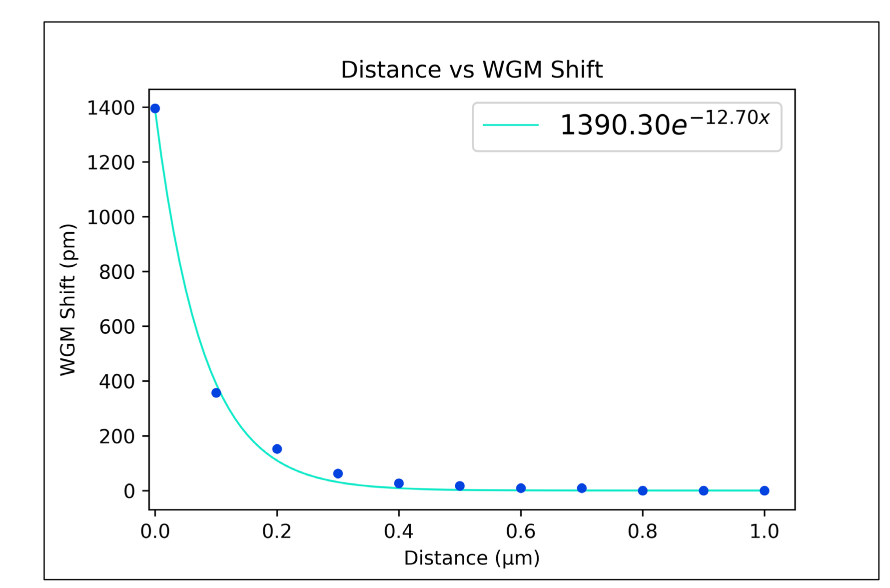

Figure 4 – Exponential fit of distance and shift

CONCLUSIONS

We successfully demonstrated that we can design a compact sensor, use it to observe WGMs and shift the WGMs by using a dielectric object.

FUTURE WORK

- Design a the physical structure of the perturber
- Test against seismic data sets

REFERENCES

1. A.F. Oskooi, D. Roundy, M. Ibanescu, P. Bermel, J.D. Joannopoulos, and S.G. Johnson, MEEP: A flexible free-software package for electromagnetic simulations by the FDTD method, Computer Physics Communications, vol. 181, pp. 687-702 (2010). (pdf)

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