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Opto-Mechanical Surface Acoustic Waves on Micro-sphere

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This work was performed under the guidance of Prof. Tal Carmon and Dr. Gaurav Bahl while Captain Zehnpfennig completed his M.S.Eng. Thesis at the University of Michigan, Ann Arbor

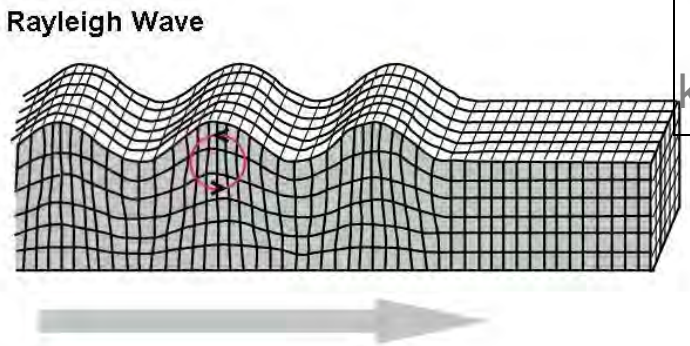
Motivation

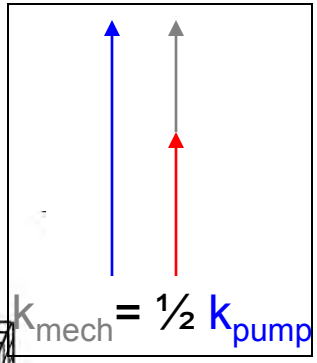
- Surface Opto-mechanics pushing toward quantum limits of measurement
- Cheap, non-toxic local oscillation
- Cheap, easy to deploy chemical detectors to benefit machine olfactorization

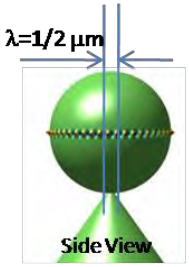
Agenda

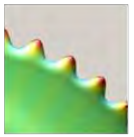
- Opto-mechanical Theory
- Opto-mechanical Interaction
- Modal Velocities
- High-Order Surface Acoustic Wave Modes
- Experimental Method
- Measured and Simulated Results
- Summary

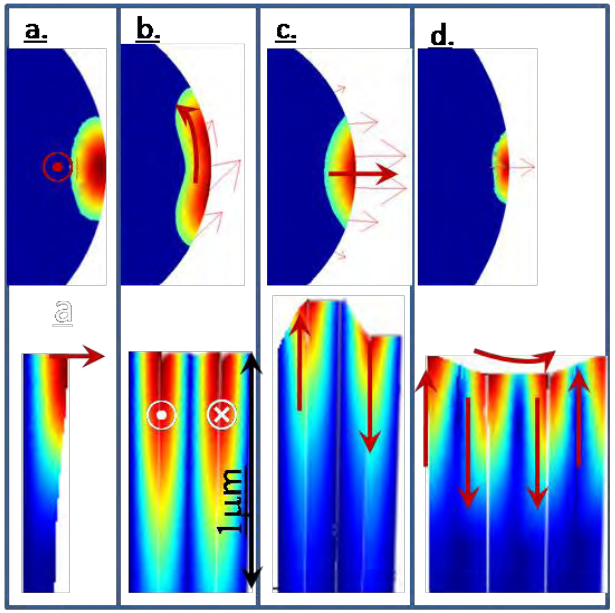
Theory





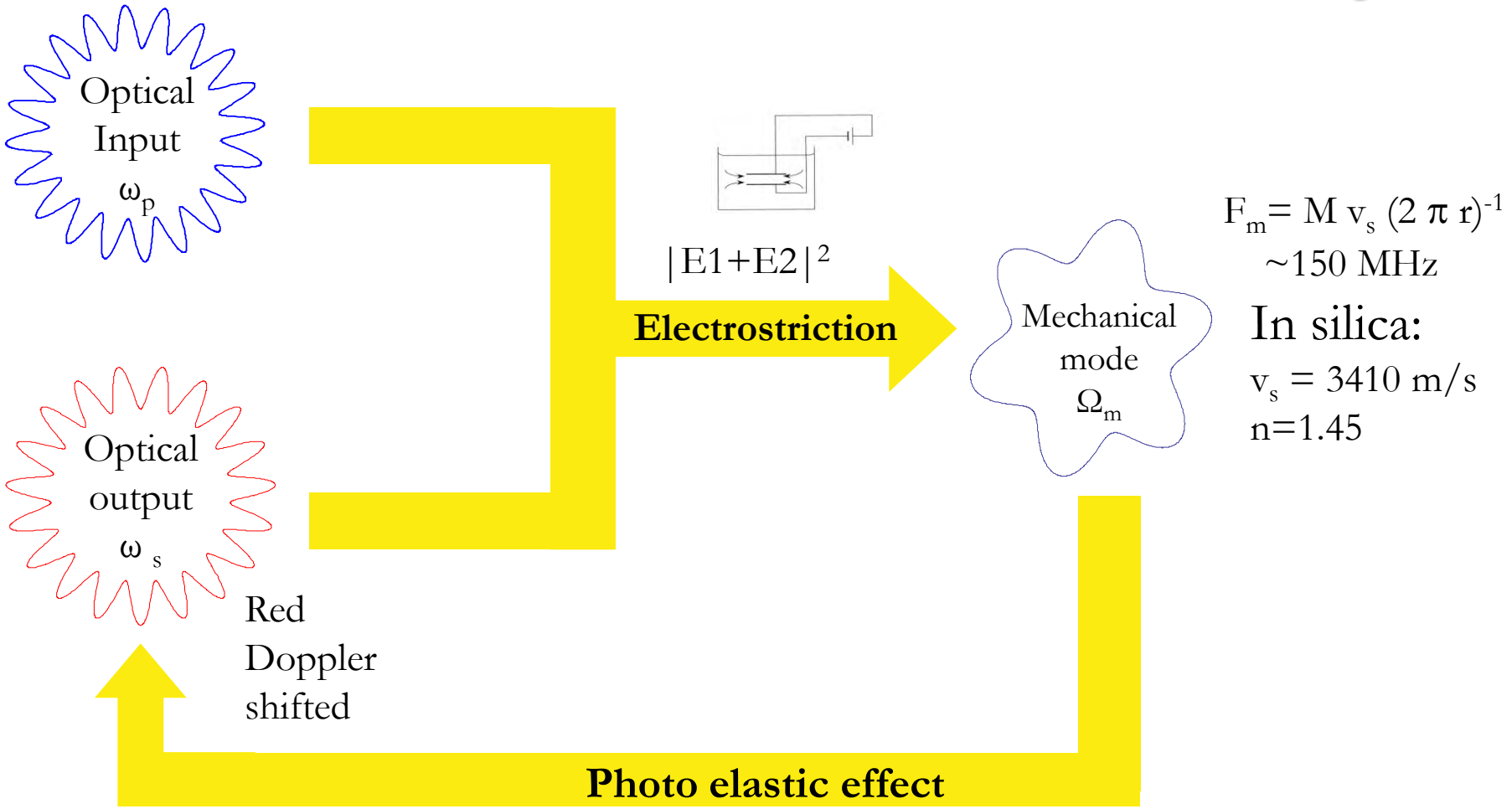






Analytic Solution on Bulk SiO_2		COMSOL Calculation, SiO_2 Sphere, M_φ=2000		
Wave	**Velocity [m/s]**	**Mode**	**Deformation**	**Velocity [m/s]**
Longitudinal	$V_L = \left(\frac{E(\nu-1)}{\rho(2\nu^2+\nu-1)}\right)^{1/2} = 5972$	*Longitudinal*	Azimuthal	5957
Transverse	$V_T = \left(\frac{E}{2\rho(\nu+1)}\right)^{1/2} = 3766$	*Transverse*	Polar	3787
Rayleigh	$V_R = \frac{V_T(0.87+1.12\nu)}{(1+\nu)} = 3413$	*Rayleigh*	Radial-Polar	3420

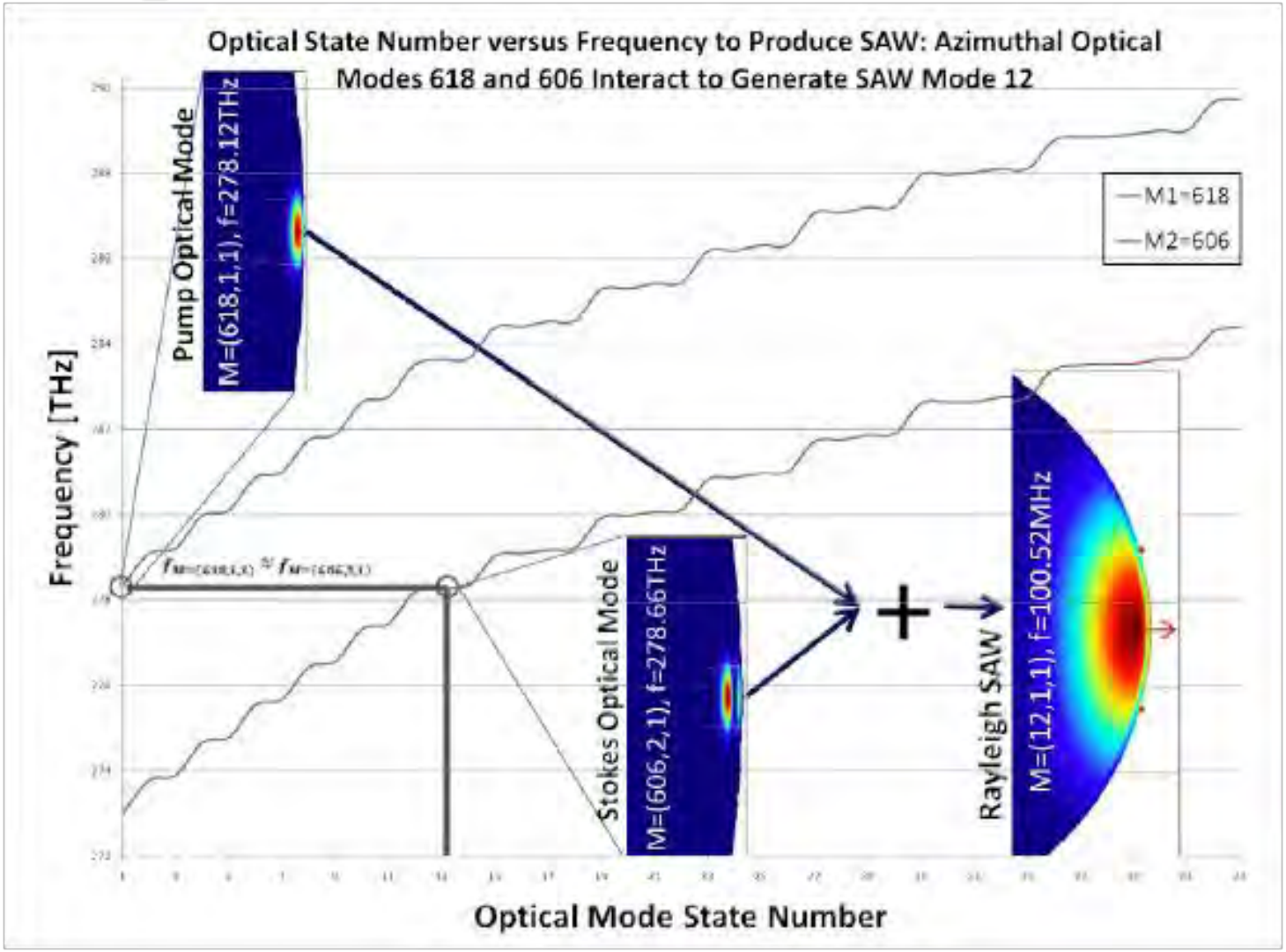
SAW Mode, Self Consistency



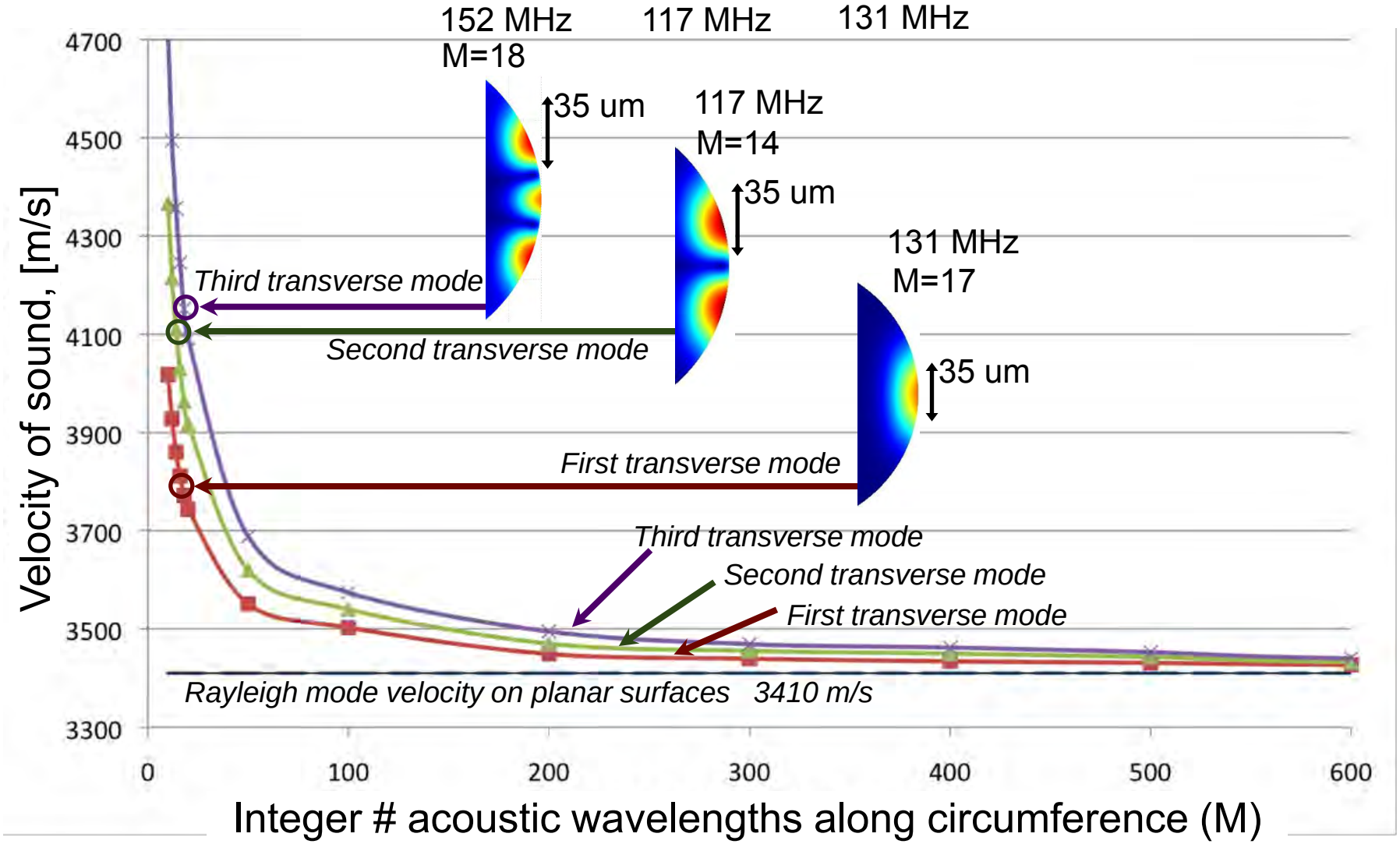
Effective propagation is 100 meters in a micron scaled device

A. Yariv, Quantum Electronics (Wiley, New York, 1975).

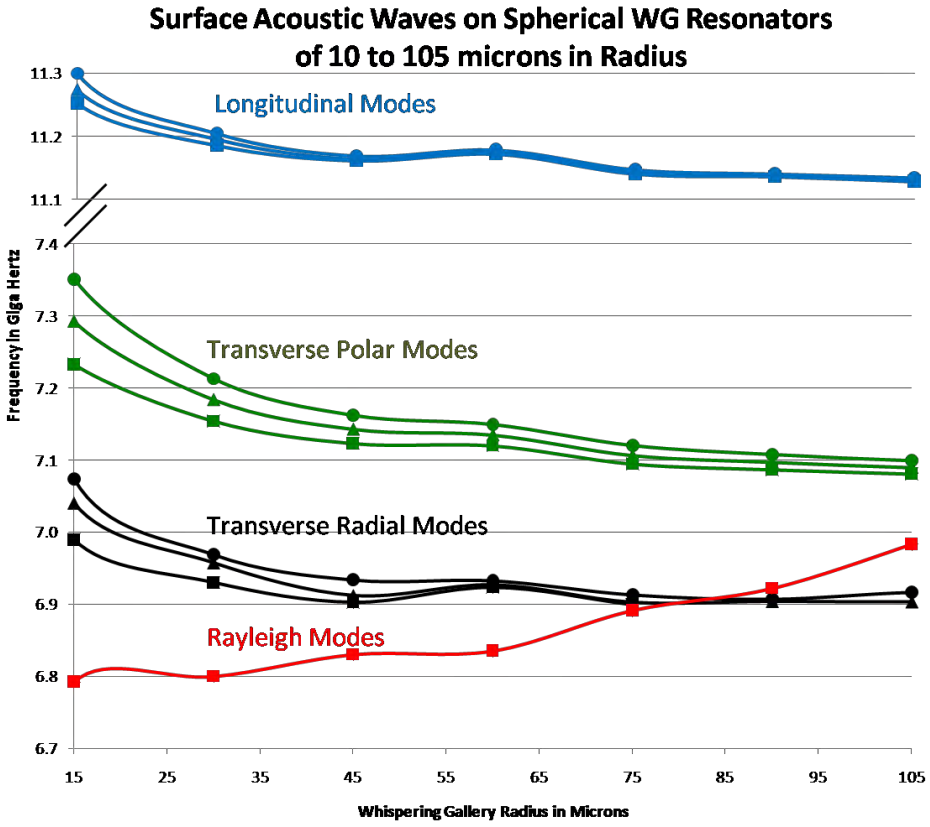
Opto-Mechanical Interaction

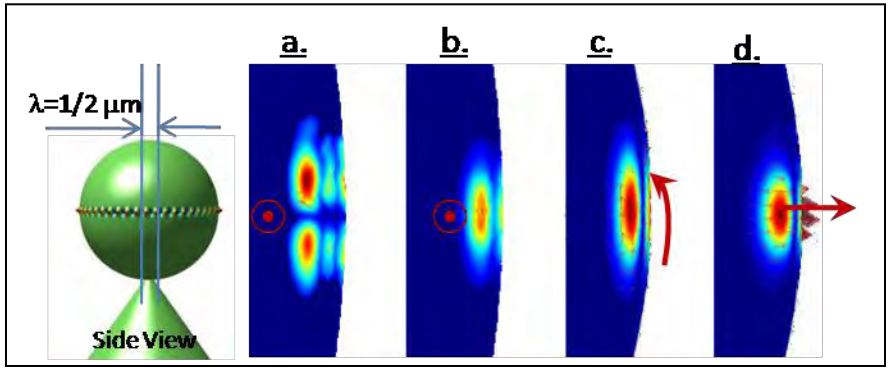


Modal Velocities

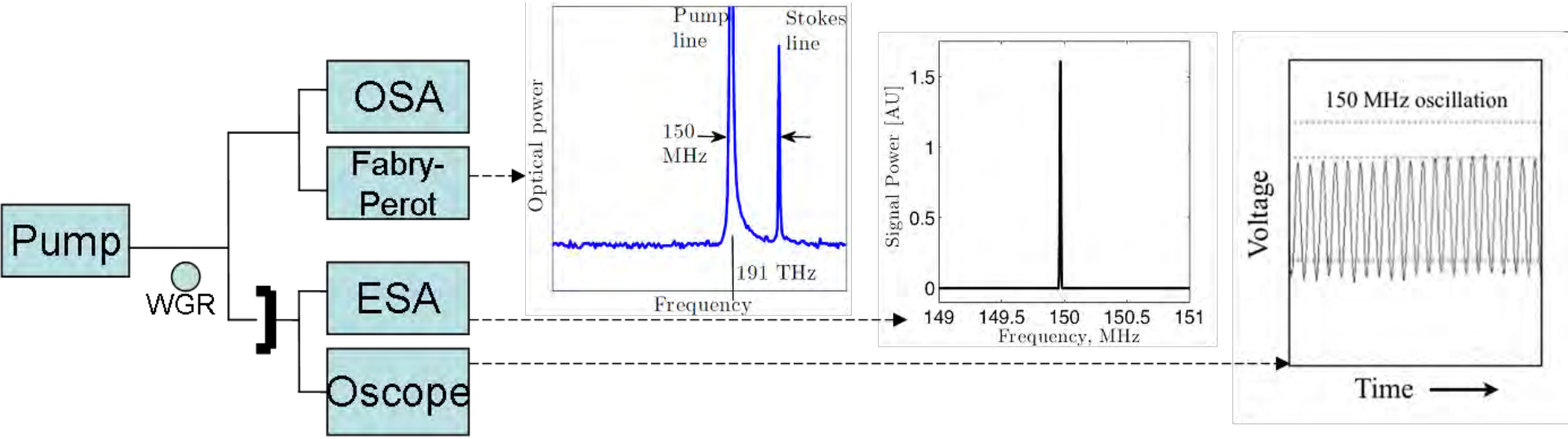


Modal Spectroscopy – High Order SAW





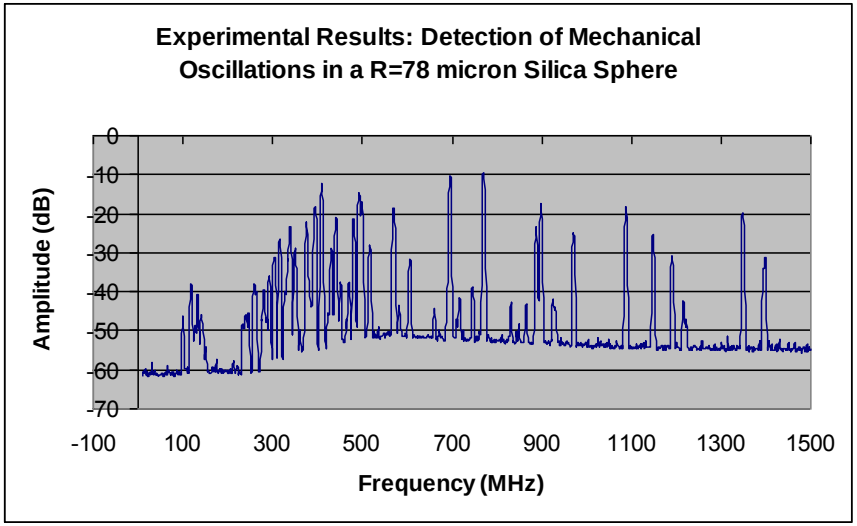
Experimental Method



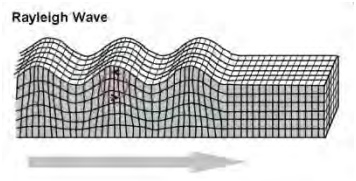
OSA: Optical Spectrum Analyzer
ESA: Electrical Spectrum Analyzer
Pump: wavelength=1.55 micron, continuous wave
WGR: Whispering Gallery (Micro-)Resonator

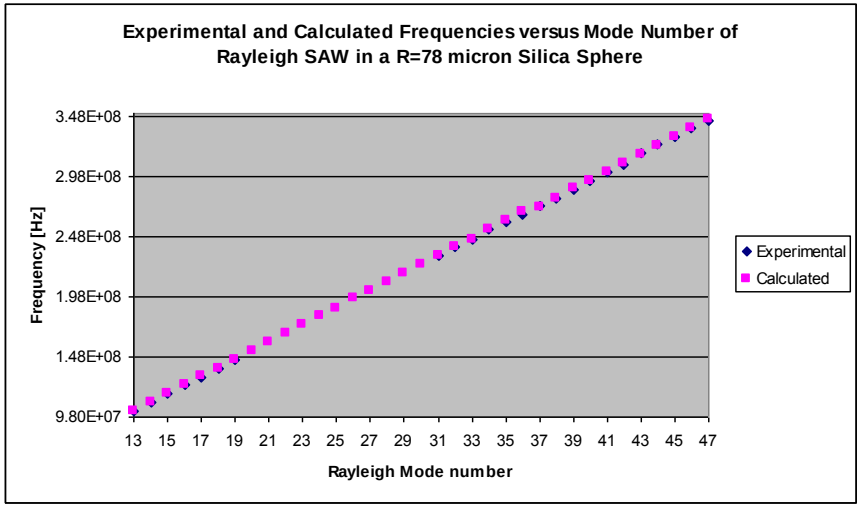
Measured and Simulated Results

Top: Excited SAW Frequencies in a Single WGR



Bottom: Experimental AND Calculated Results: Frequency vs Azimuthal Mode Number





Summary

- COMSOL Calculated, Analytical, and Experimental results agree within 1%
- COMSOL enabled me to run hundreds of iterations of a simulation automatically – freeing time for the lab

For Further Info

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