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Highly Sensitive Grating-coupled Bloch Surface Wave Resonance Bio-sensor via Azimuthal Interrogation

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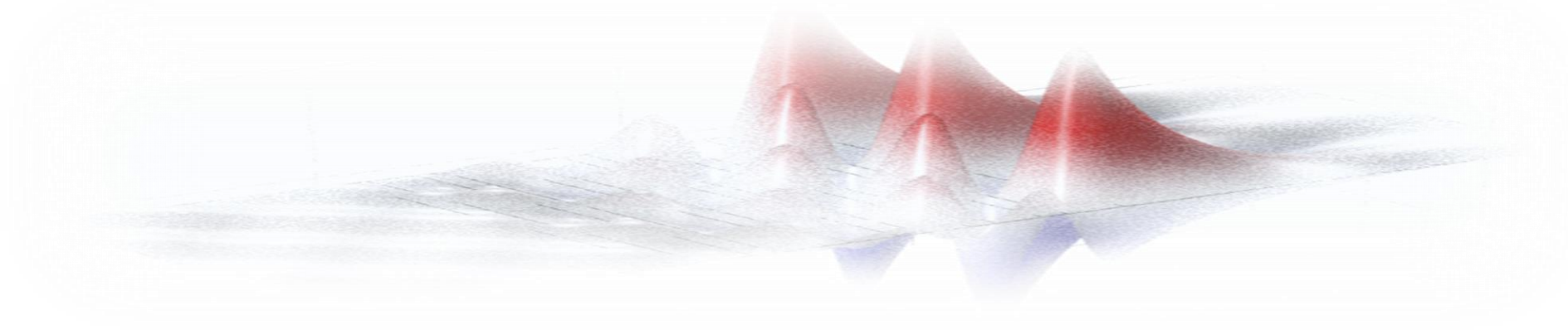
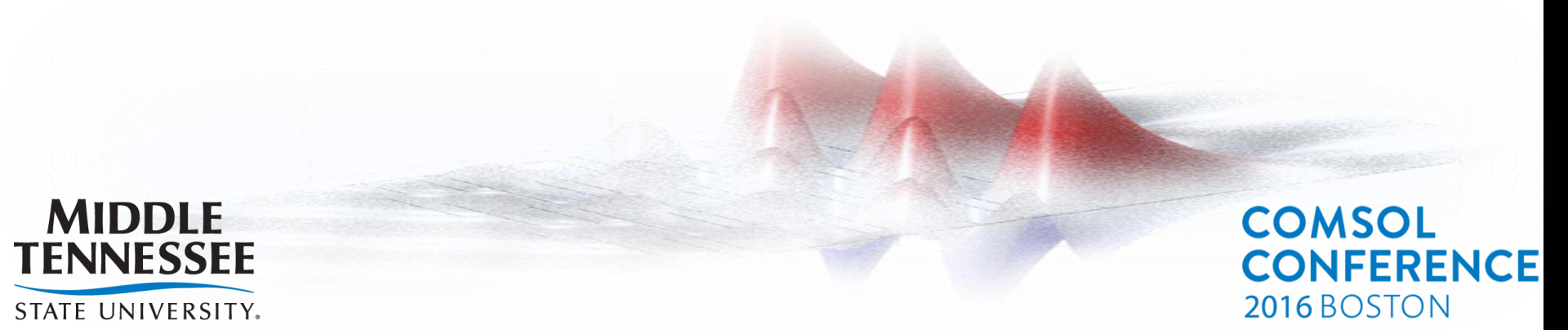
Middle Tennessee State University
6 October 2016



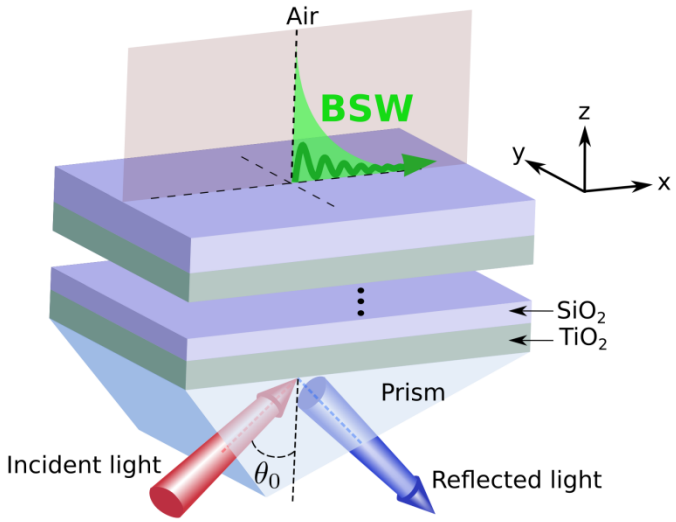
Bloch Surface Wave (BSW)

- Electromagnetic excitations that propagate at the interface between a dielectric-dielectric interface
- Evanescently confined in the perpendicular direction to the propagation
- Enhanced electric field intensity at the confinement
- Applications in label-free and fluorescence bio-sensing

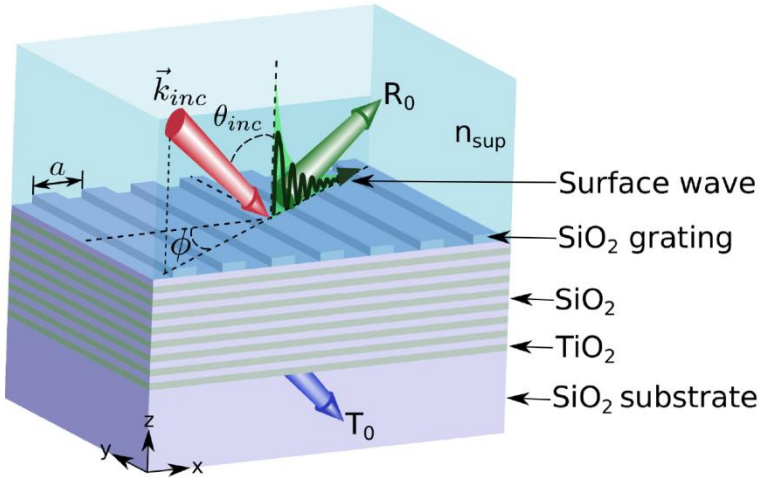


BSW excitation

Prism coupling



Grating coupling



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Physics

- Maxwell's Wave Equation: $\nabla \times \mu_r^{-1}(\nabla \times \vec{E}) - k_0^2\left(\varepsilon_r - \frac{j\sigma}{\omega\varepsilon_0}\right)\vec{E} = \vec{0}$

For: $\mu_r = 1\,, \quad \varepsilon_r = n^2\,, \quad \sigma = 0$

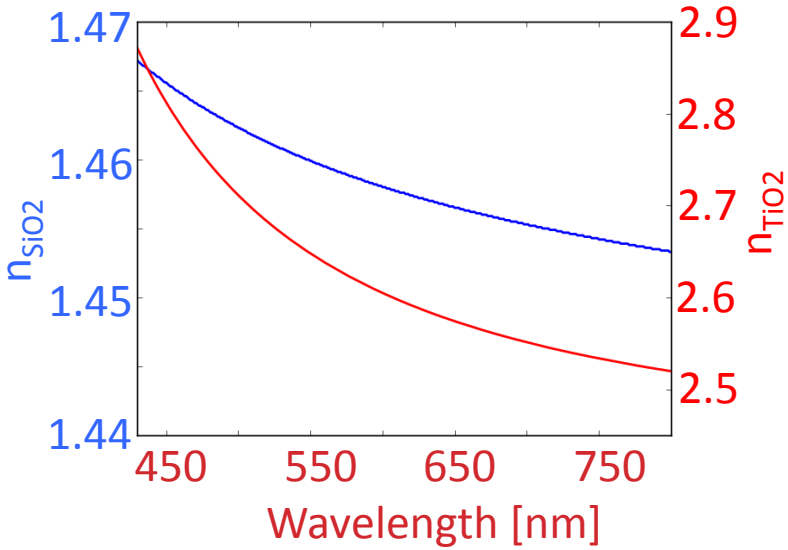
- Reduced Maxwell's Equation: $\nabla \times (\nabla \times \vec{E}) - k_0^2 n^2 \vec{E} = \vec{0}$

- *Electromagnetic Waves, Frequency Domain (emw)* physics interface is used to solve governing equation

Materials Properties

- Titanium Dioxide (TiO_2)

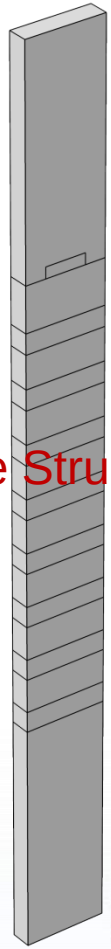
$$n_{TiO_2} = \left(5.913 + \frac{0.2441}{\lambda^2 - 0.0803}\right)^{\frac{1}{2}}$$



- Silicon Dioxide (SiO_2)

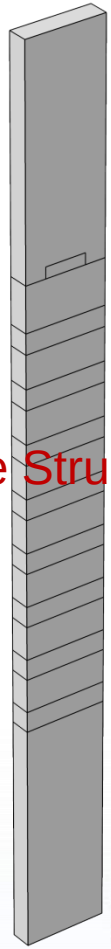
$$n_{SiO_2} = \left(1 + \frac{0.6962\lambda^2}{\lambda^2 - 0.0684^2} + \frac{0.4079\lambda^2}{\lambda^2 - 0.1162^2} + \frac{0.8975\lambda^2}{\lambda^2 - 9.8961^2}\right)^{\frac{1}{2}}$$

COMSOL Model

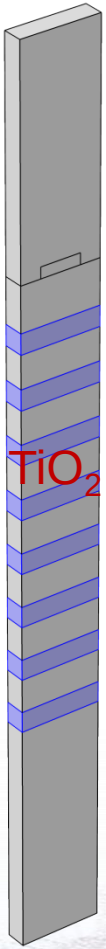


Bare Structure

COMSOL Model

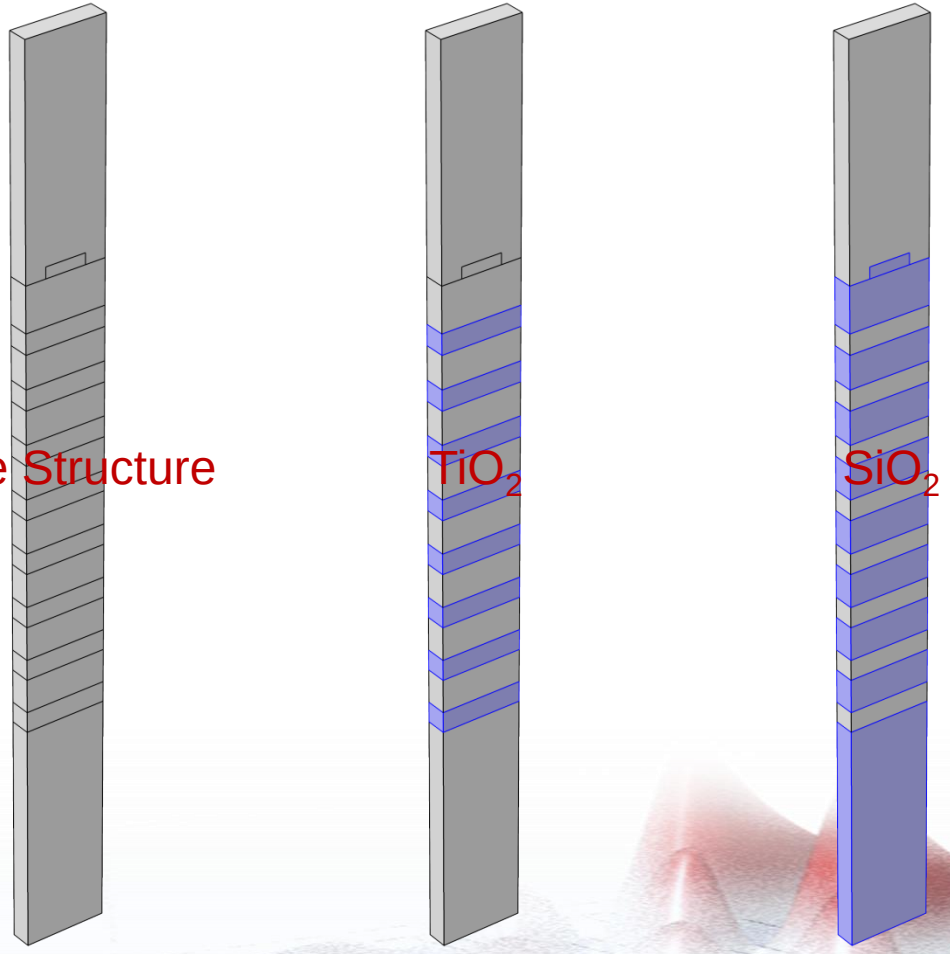


Bare Structure

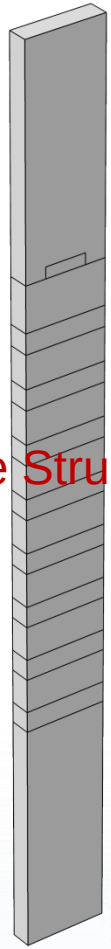


TiO_2

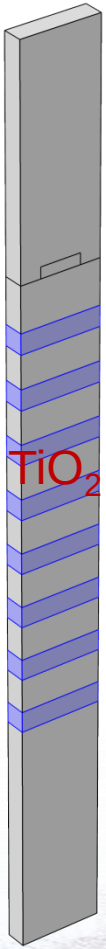
COMSOL Model



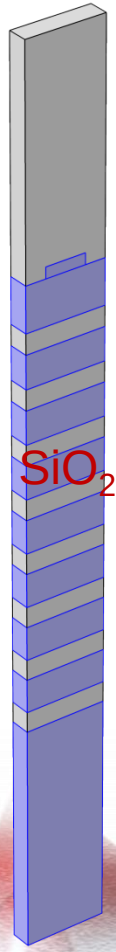
COMSOL Model



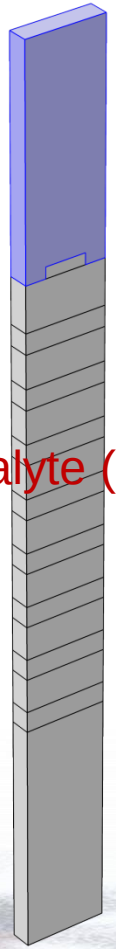
Bare Structure



TiO_2

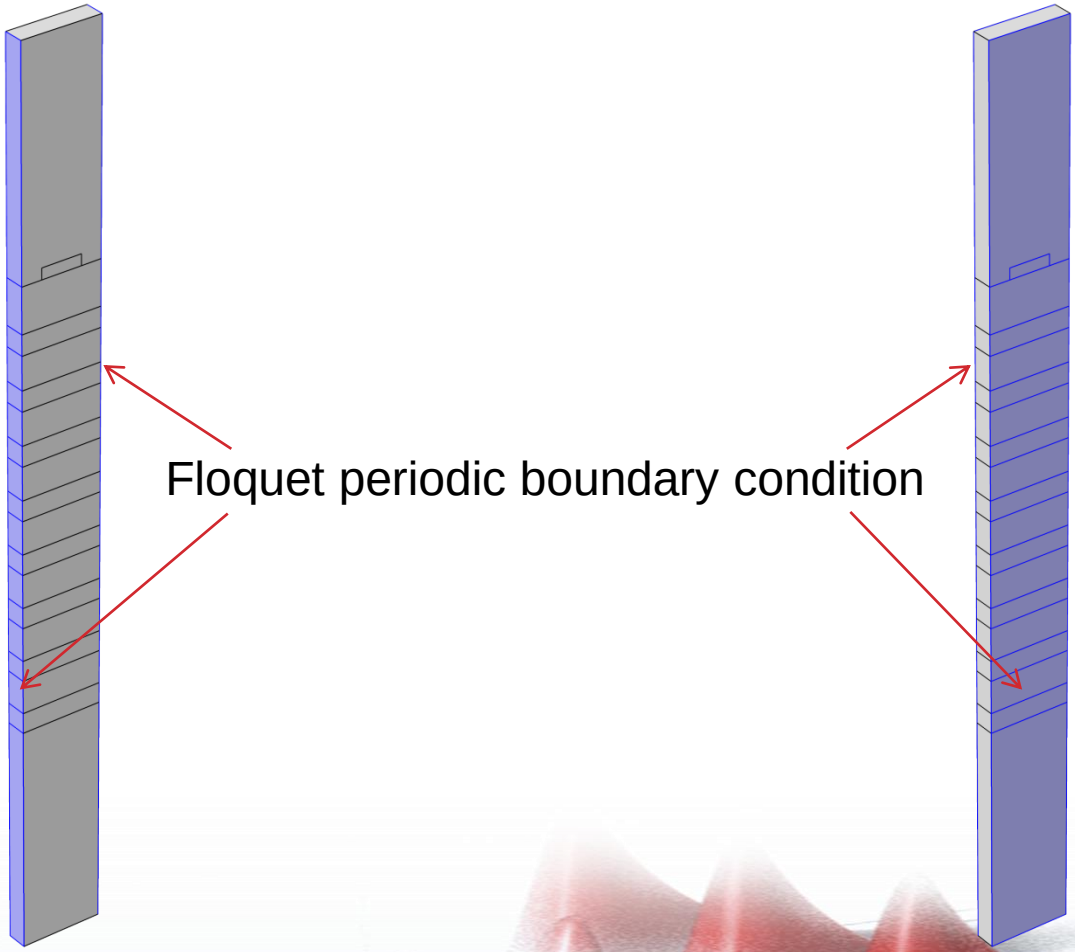


SiO_2

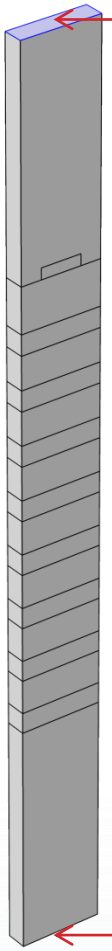


Analyte (Water)

Boundary Conditions



Boundary Conditions



Input Port

Output Port

Input Port parameters

Port Mode Settings

Input quantity:

Electric field

Electric mode field amplitude:

E_0

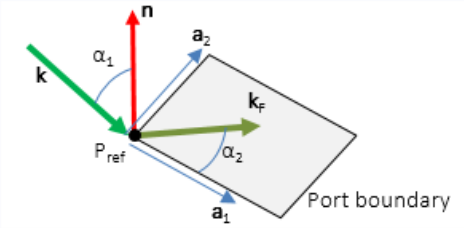
sin(phi)	x	V/m
cos(phi)	y	
0	z	

Elevation angle of incidence:

α_1 theta rad

Azimuth angle of incidence:

α_2 phi rad



Output Port parameters

Port Mode Settings

Input quantity:

Electric field

Electric mode field amplitude:

E_0

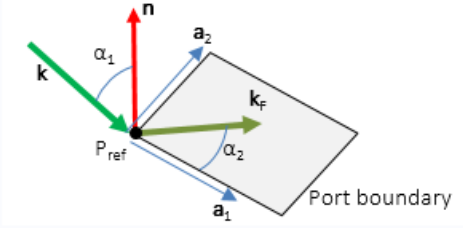
sin(phi)	x	V/m
cos(phi)	y	
0	z	

Elevation angle of incidence:

α_1 -thetab rad

Azimuth angle of incidence:

α_2 -phi+pi/2 rad



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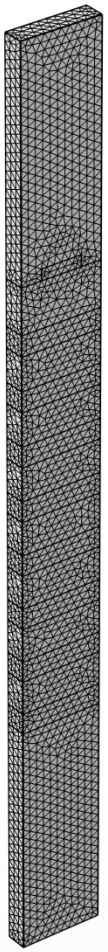
Finite Element Mesh



Element Size Parameters

Maximum element size:
0.555E-7 m

Minimum element size:
1.11E-9 m

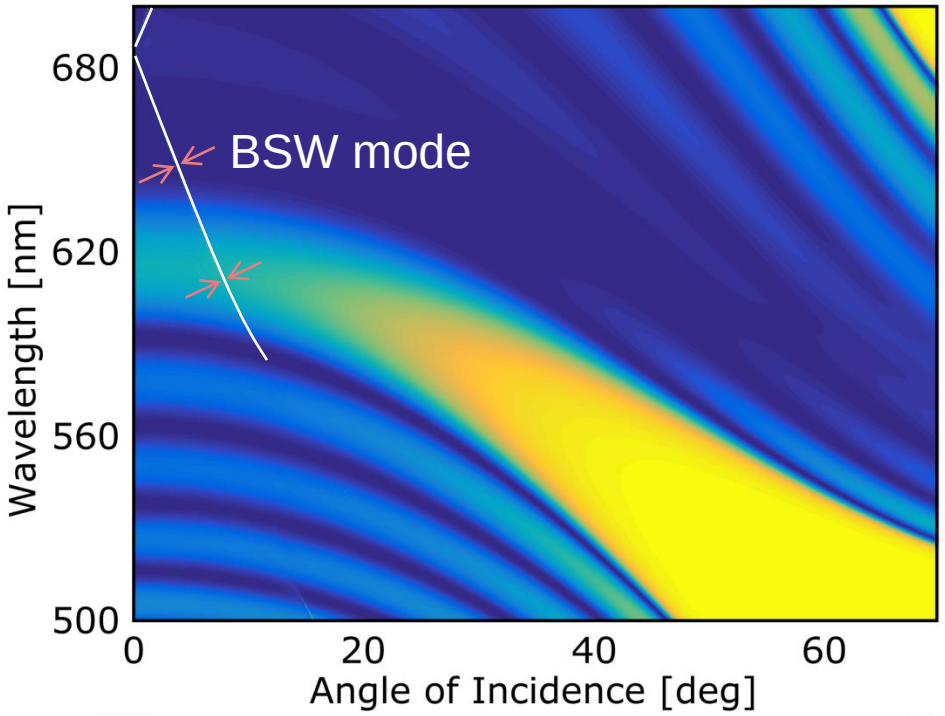
Maximum element growth rate:
1.3

Curvature factor:
0.2

Resolution of narrow regions:
1

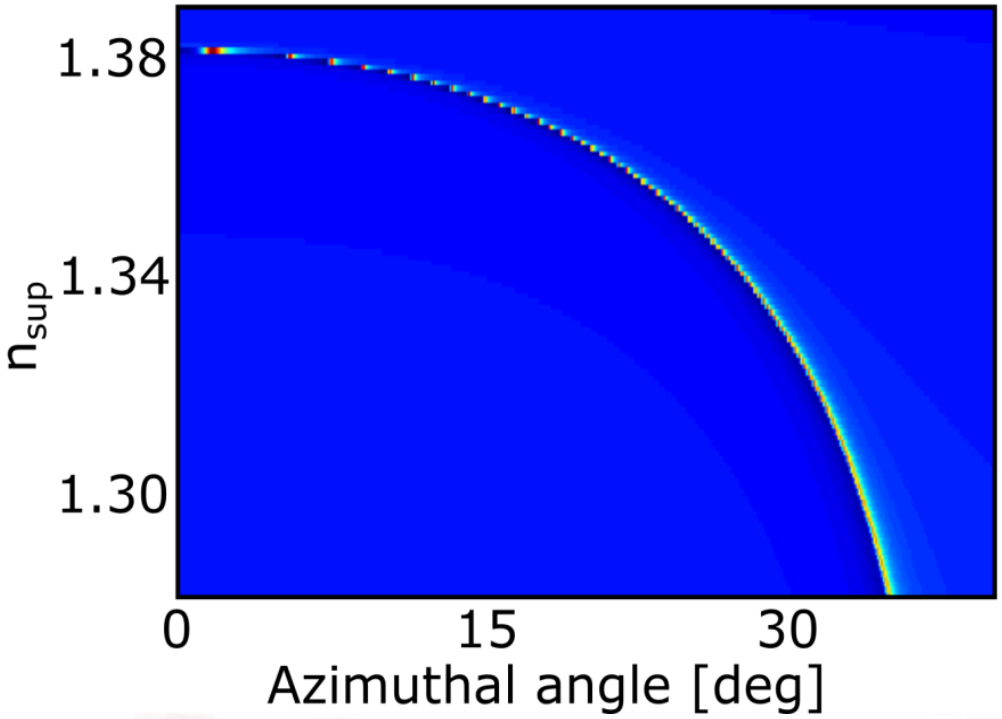
Reflectivity Map

- Azimuthal angle $\varphi = 0$
- Superstrate/Analyte refractive index $n_{sup} = 1.33$

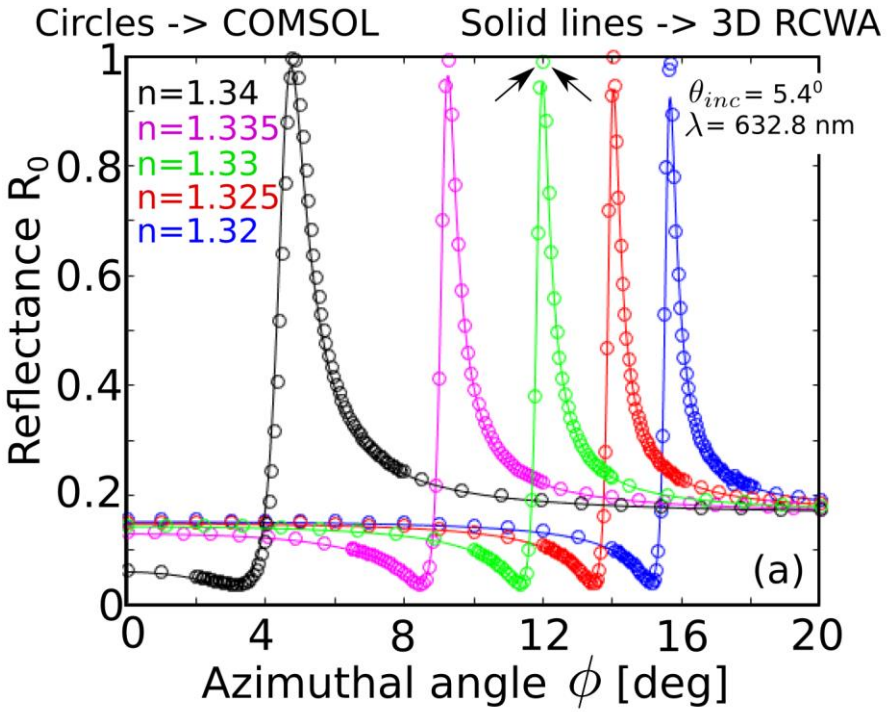


Azimuthal Sensitivity

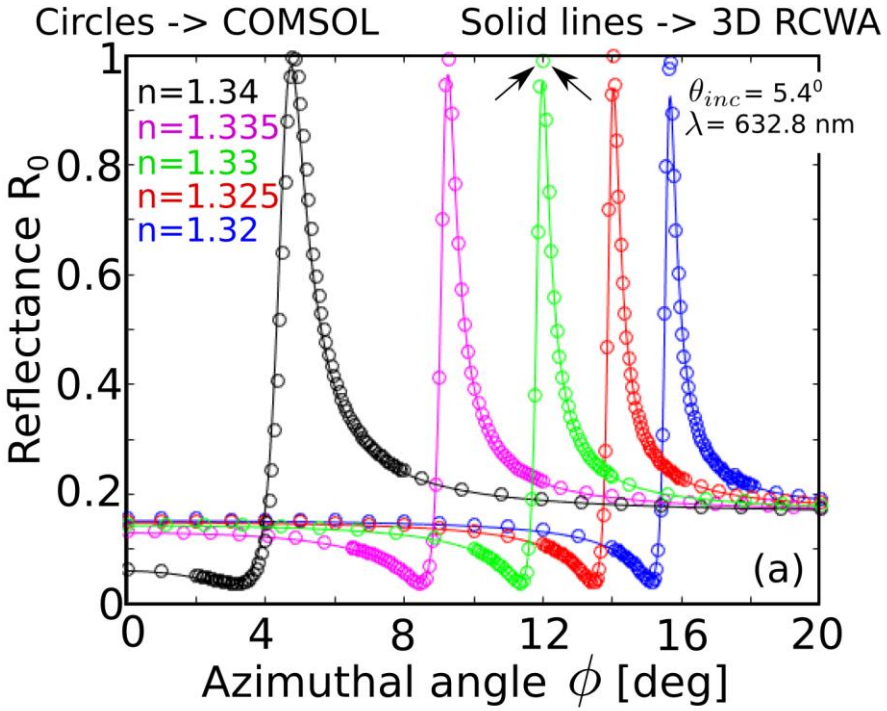
- Wavelength $\lambda = 632.8\,nm$
- Incident angle $\theta_{inc} = 5.8^{o}$
- $S_{n_{sup}} = \dfrac{\Delta\varphi}{\Delta n_{sup}}$
- $S_{n_{sup}} \sim 1200^{o}/RIU$

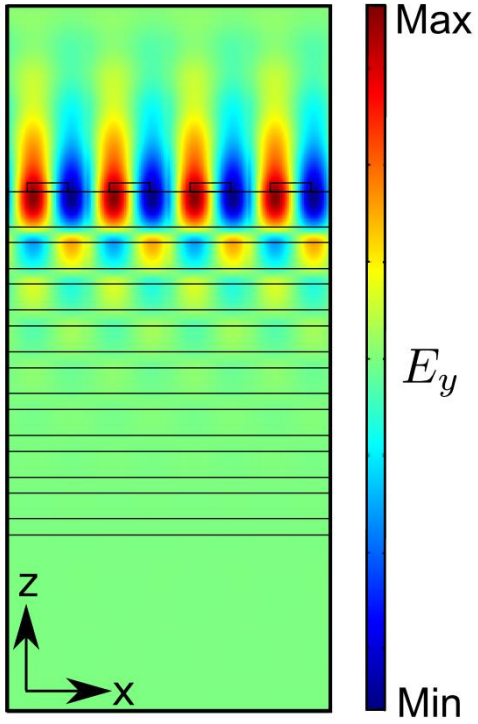


Azimuthal Sensitivity



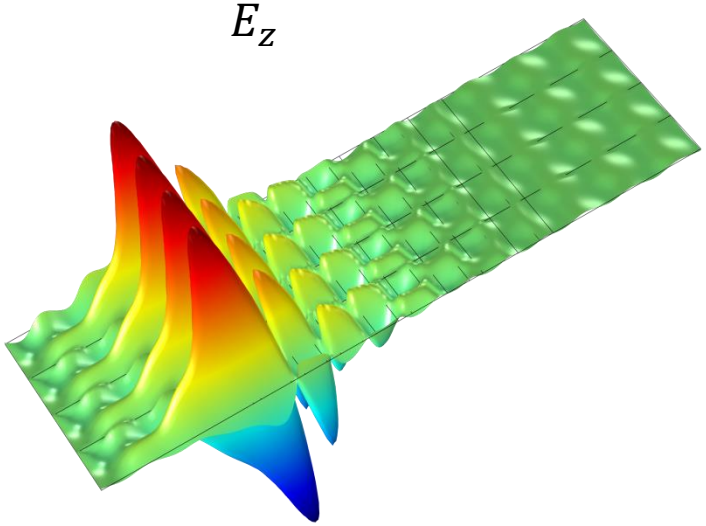
Azimuthal Sensitivity



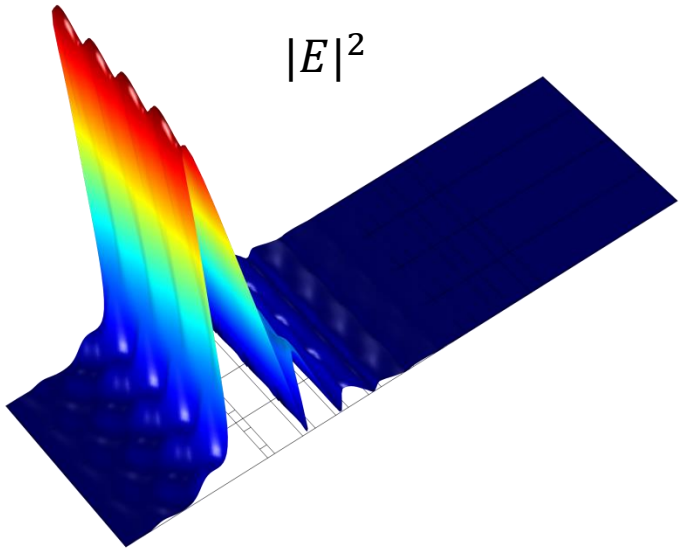


E-Field Profile at BSW Resonance

E_z



$|E|^2$



Summary

- Grating-coupled BSW resonance sensor
- Azimuthal interrogation
- Enhanced refractive index sensitivity