Senior Design May 15-29

High-Frequency Ultrasonic Detector Using Photonic Crystal

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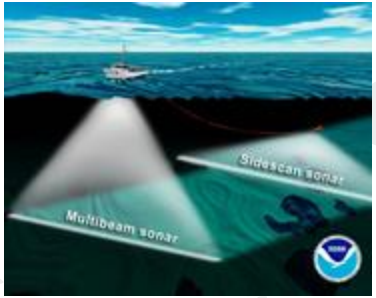
Background

Application of High-frequency ultrasound

- Precision-targeted therapy
- Medical imaging
- Health care (Teeth cleaning)
- Underwater distance measurement (Sonar)



Introduction

Traditional detector

Piezoelectric sensor

- Limited detectable acoustic frequency range (Narrow bandwidth)
- Poor sensitivity
- Expensive

VS

Our Project

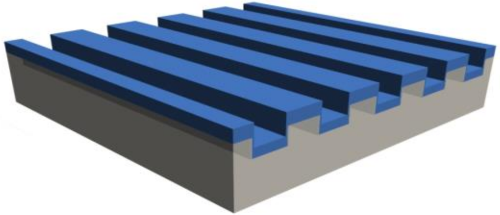
Optical sensor (Photonic crystal)

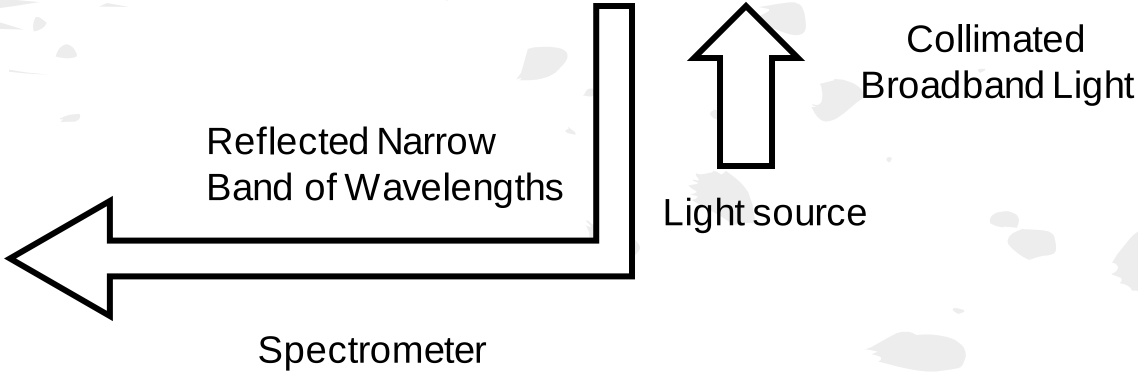
- Broad bandwidth
- High sensitivity
- Cost Less
- Smaller size

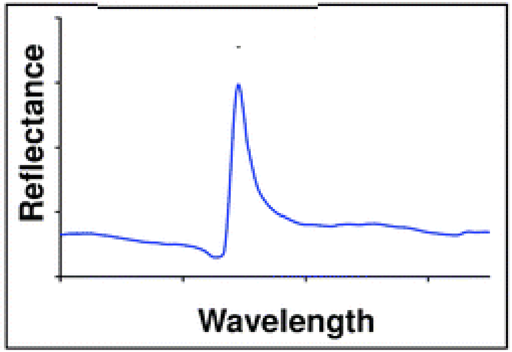
Principle

Photonic crystal (PC) sensor

- Sub-wavelength dielectric grating
- Reflects light at resonant wavelength



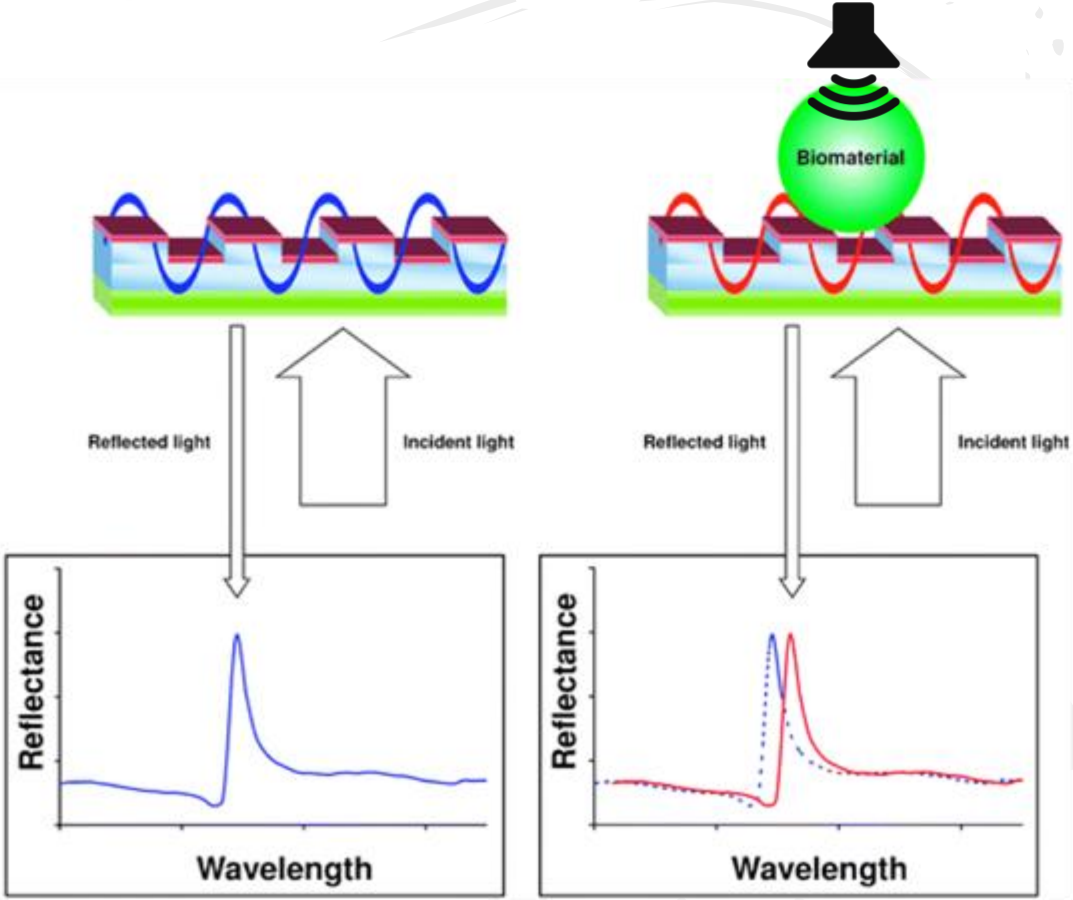




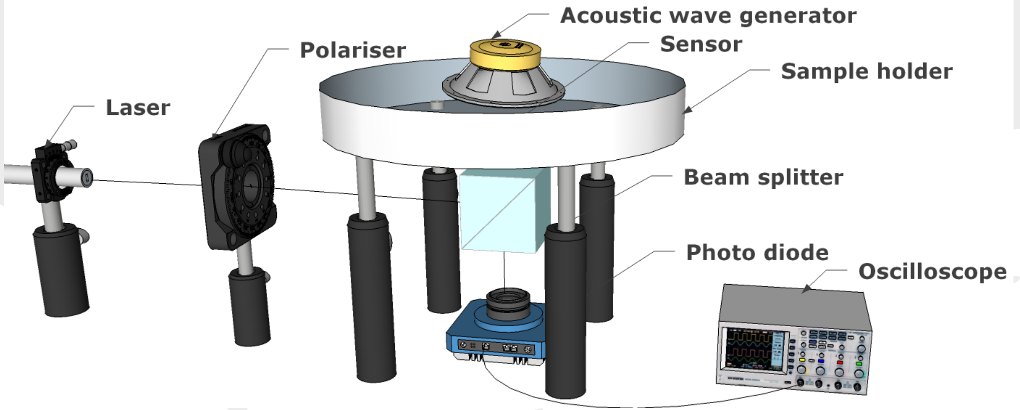
Principle

- Acoustic wave can result in a shift of resonant wavelength

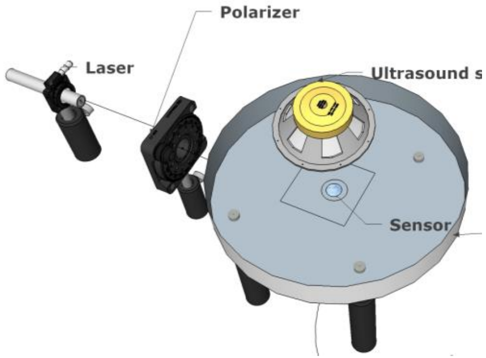
- Shift can be estimated by measuring the reflection from the PC substrate using a laser and a photo detector



Optical Setup



Top view



Laser Diode
- Generate laser light which has wavelength as 845nm

→

Polarizer
- Only let the specific stragith light pass through

↓

Beam Splitter
- Half of light reflected to the upper side
- Half of light transimitted to back side

→

Photonic Crystal Sensor
- Most of light (70%) reflected back to the beam splitter
- 30% of light transimitted to the upper side

↓

Beam Splitter
- Half of light reflected to the upper side
- Half of light transimitted to back side

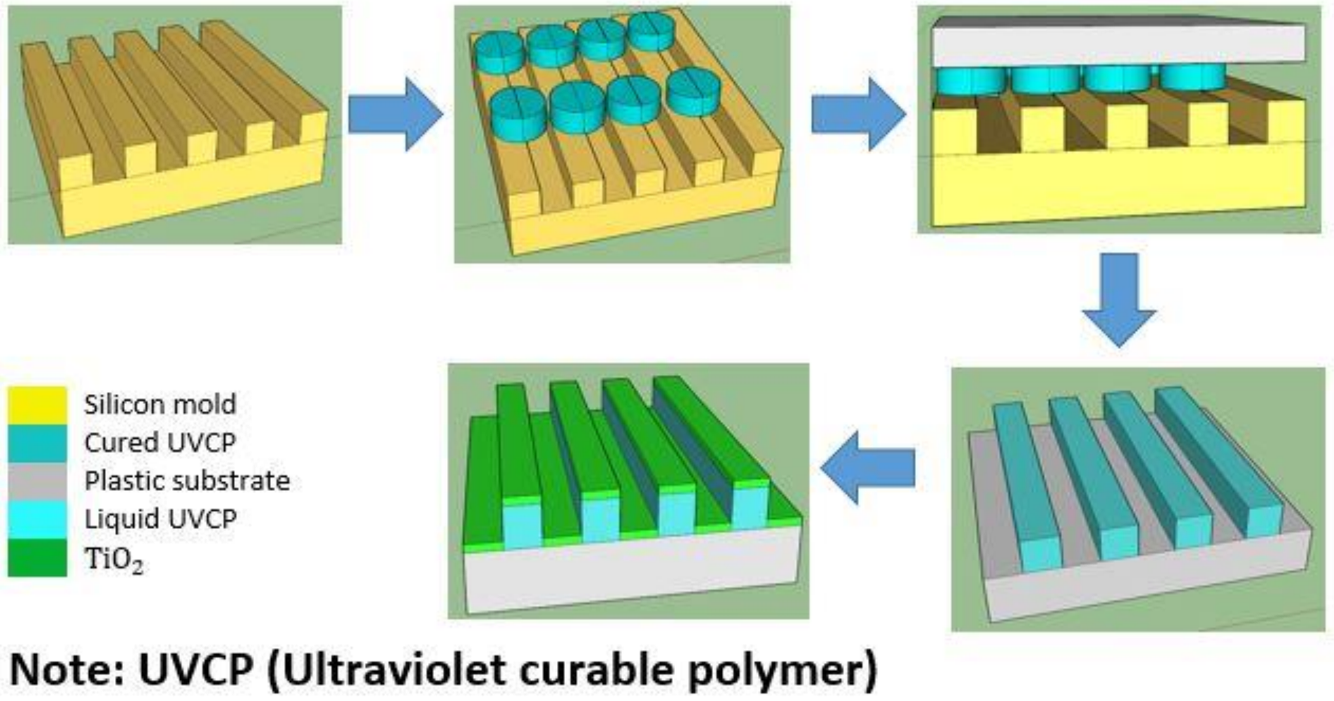
→

Photodetector
- Detect the signal under the beam splitter

↓

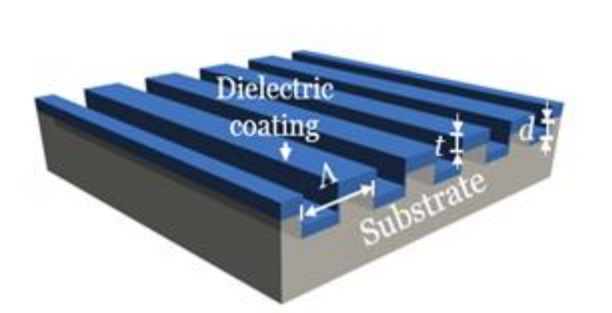
Oscilloscope
- Plot the waveform of the signal

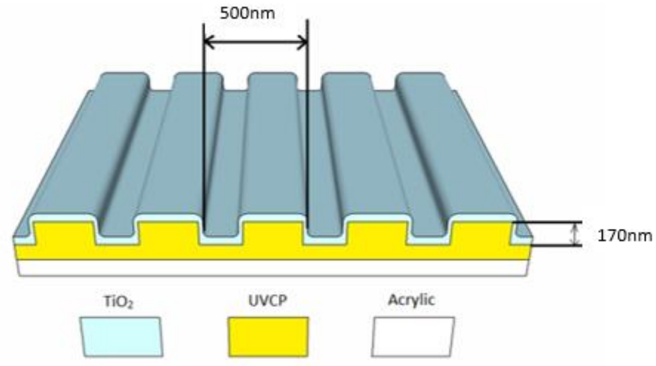
Photonic Crystal Sensor Fabrication



Photonic Crystal Sensor structure

3-D view of photonic crystal

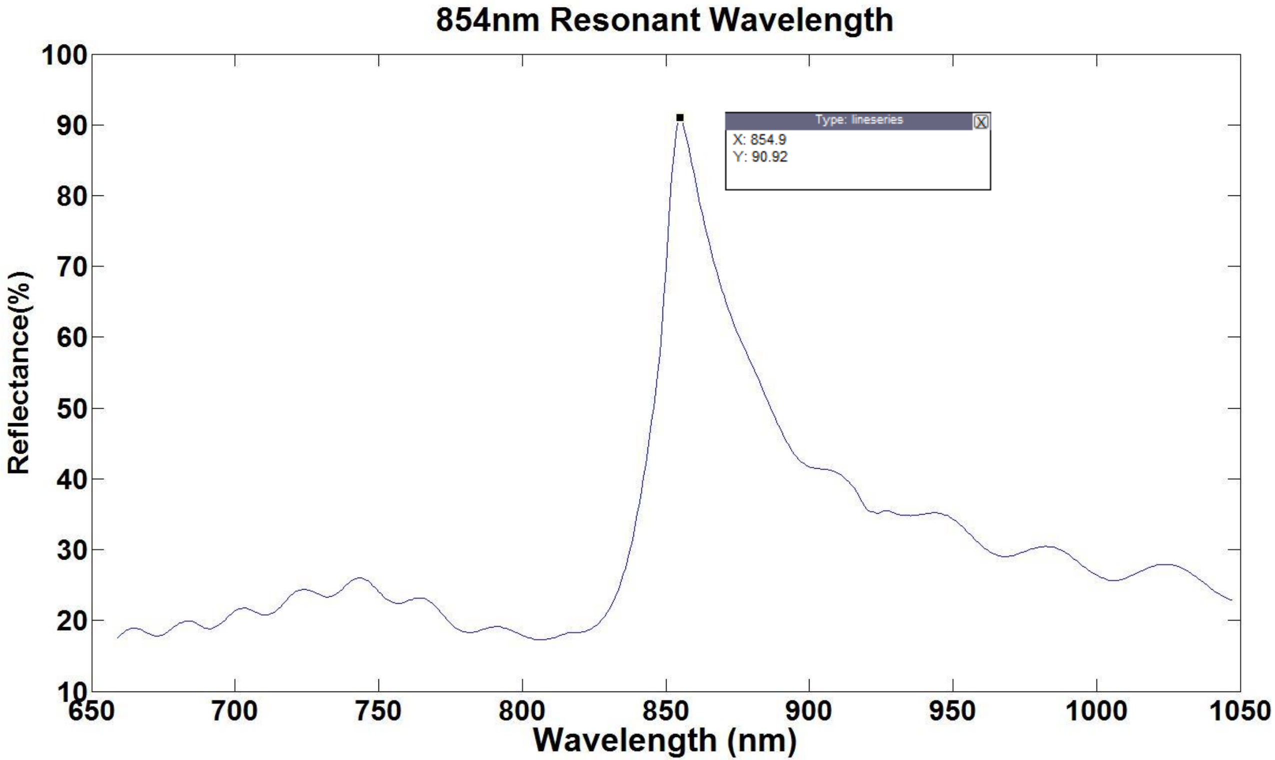




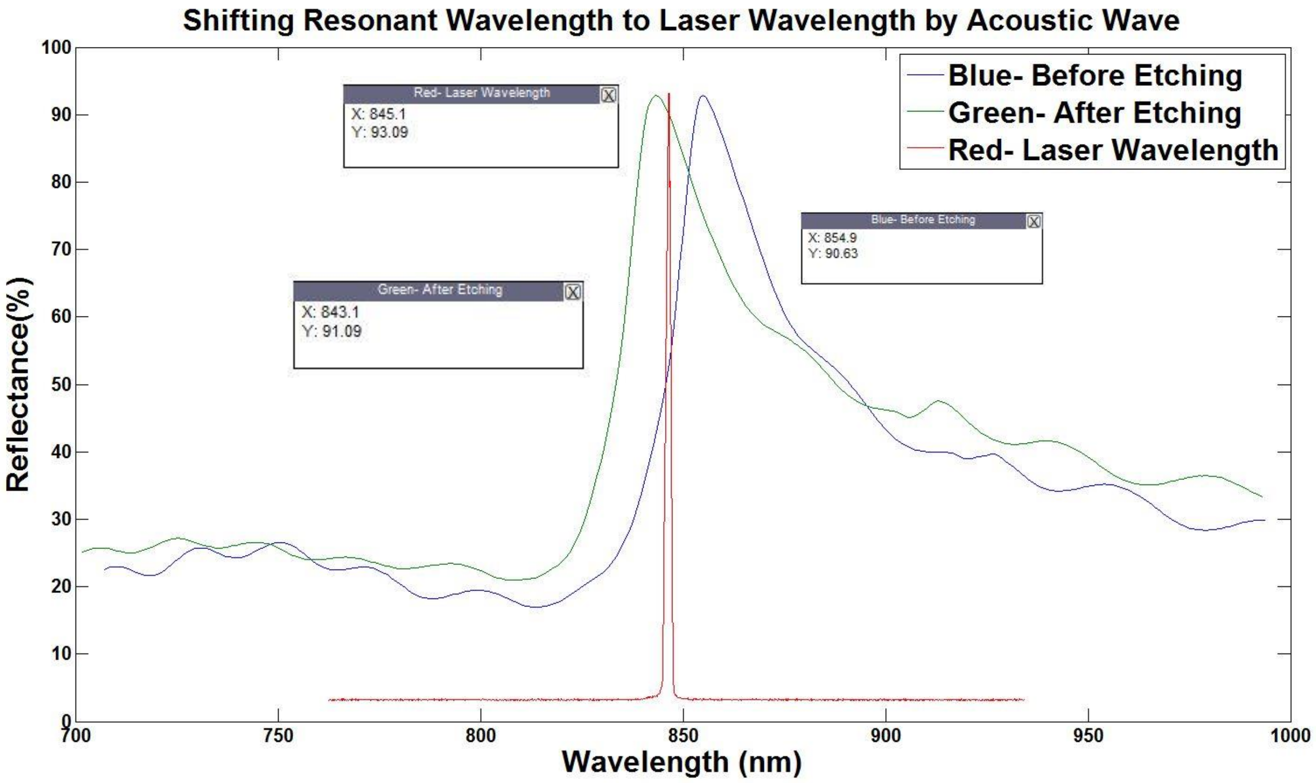
Cross-sectional view of a PC substrate

The formula for resonant wavelength: $\lambda = \frac{2n_{eff}\Lambda}{m}$

Before Etching Resonant Wavelength

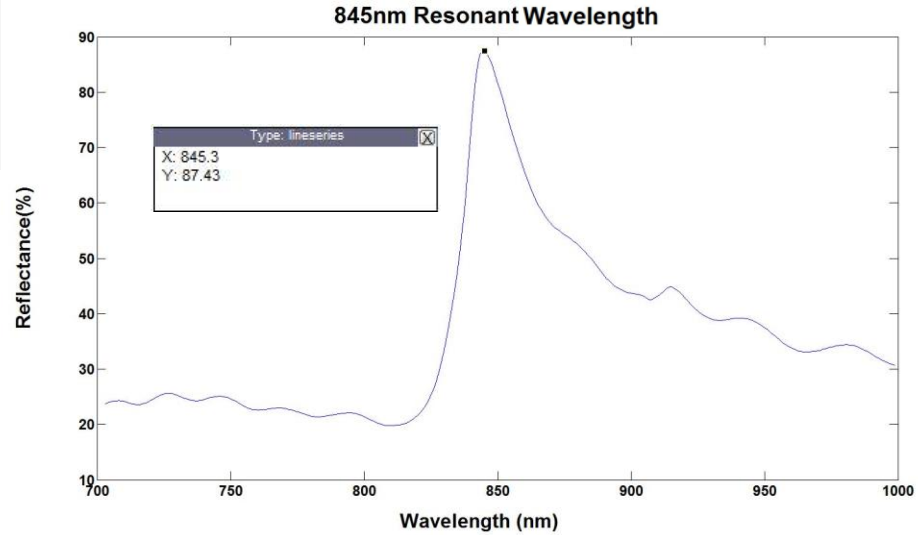


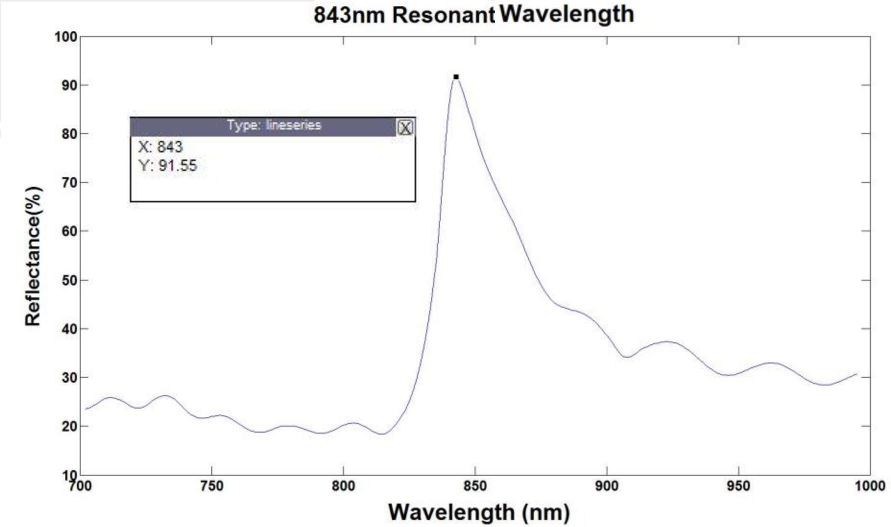
Changing Resonant Wavelength by Acoustic Wave



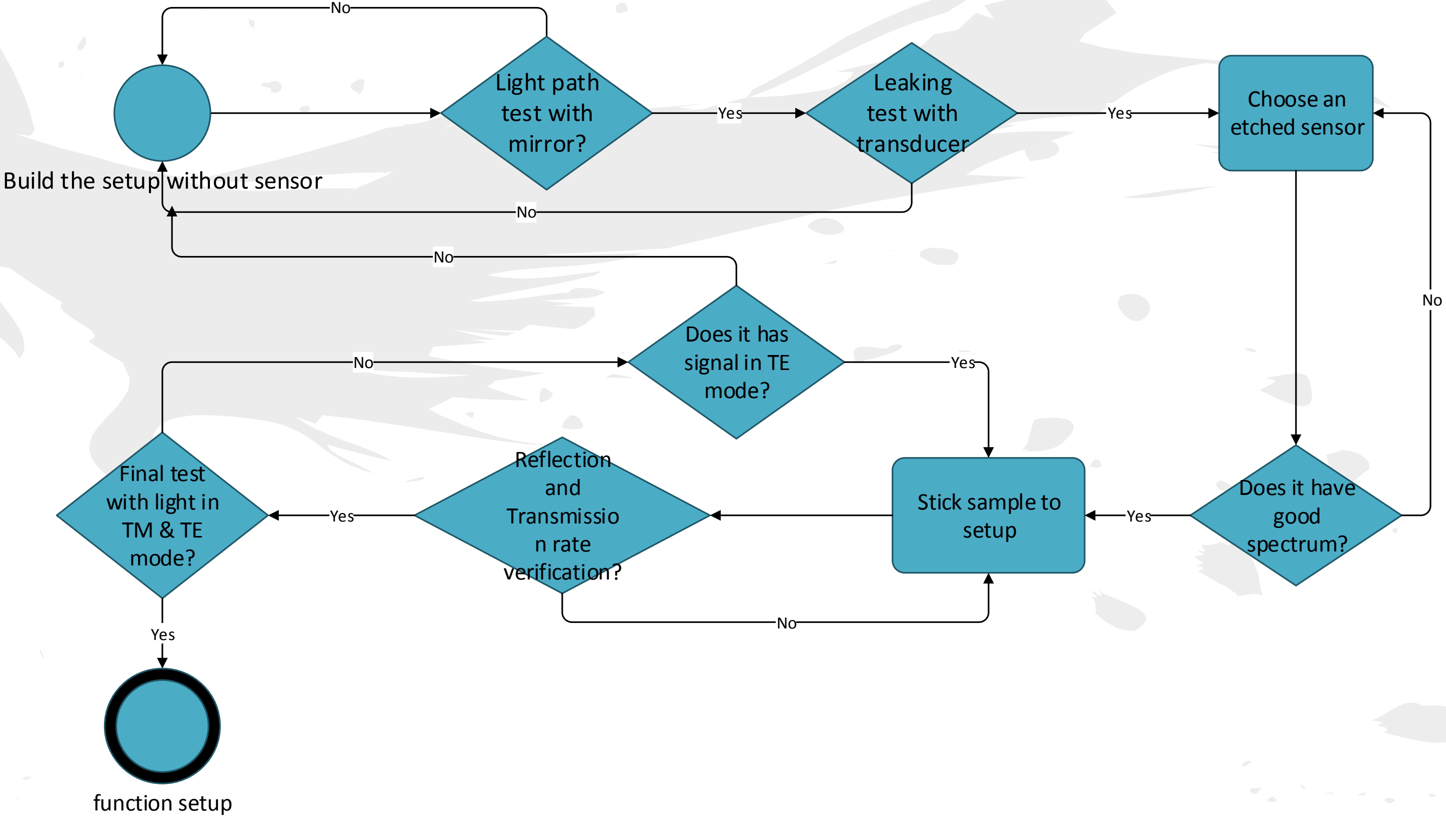
After Etching Resonant Wavelength

Wavelength at 845 nm, 843nm.





Test Plan

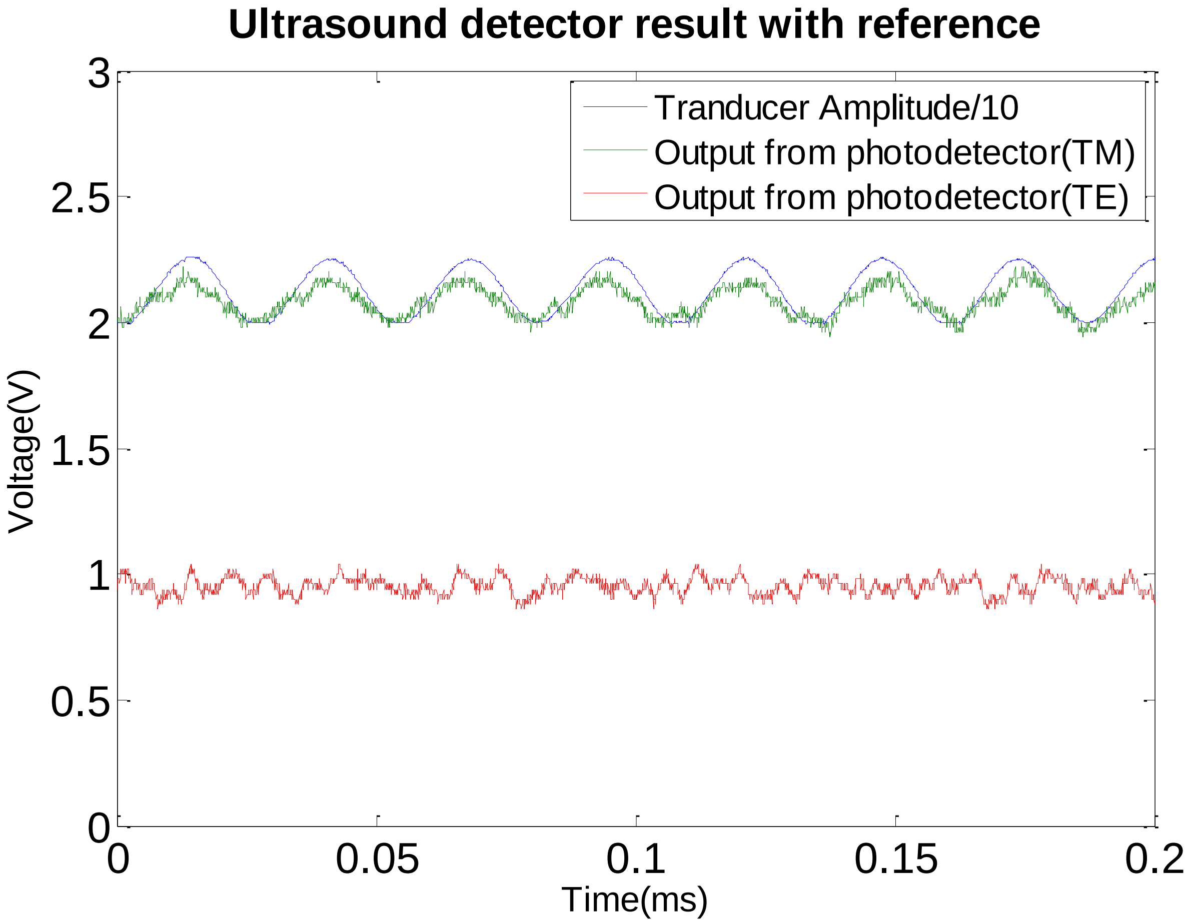

No
Light path test with mirror?
Yes
Leaking test with transducer
Yes
Choose an etched sensor
Build the setup without sensor
No
No
No
Does it has signal in TE mode?
No
Yes
Final test with light in TM & TE mode?
Yes
Reflection and Transmission rate verification?
Stick sample to setup
Yes
Does it have good spectrum?
No
Yes
function setup

Results

1. We measure the waveform of the transducer (40KHz) that we use to test the *Ultrasonic Detector*. BULE

2. We test the detector with laser in TM Mode. GREEN

3. We test the detector with laser in in TE Mode as a reference. RED



Extra Challenge - Ultrasound Generation

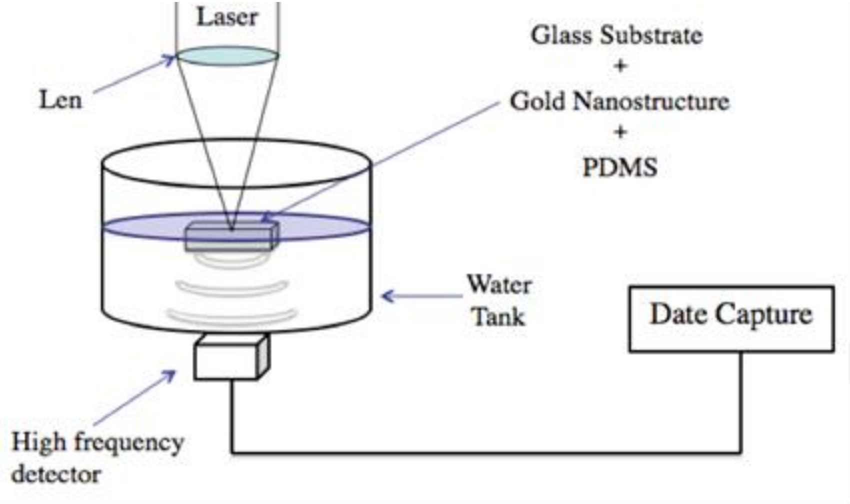
Our goal

- To generate the ultrasound with up to 20MHz frequency

To accomplish the goal

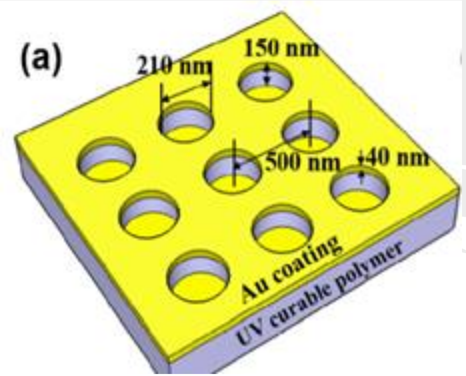
- High-energy Pulse laser system:
  Generate a 5ns laser pulse with energy of 25mJ at 1064nm
- Plasmonic substrate
- Detector (Photodiode and Oscilloscope)

Optical setup

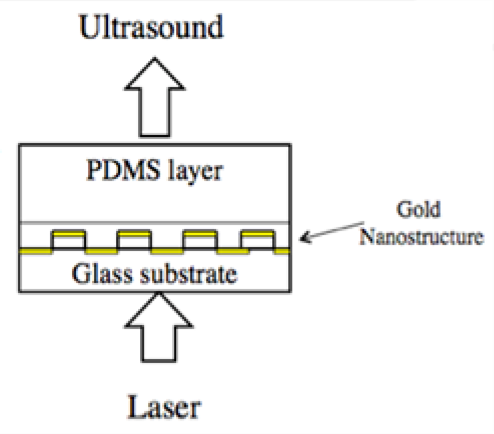


Extra Challenge - Ultrasound Generation

Plasmonic structure



Plasmonic Sensor



Function

1. Light absorption
2. Convertion: Light energy to thermal energy
3. Transport thermal energy to PDMS layer
4. Resulting thermal expansion of PDMS layer
5. Launch acoustic wave

Questions?

Thank you!

Storyline

Fall2014

Week1
- Get started with the senior design project
- Get familiar with the key idea

Week4
- First Version of sample holder has been made via 3D print
- Test the wavelenght for PDMS & J-91

Week7
- Get power supply for acoustic wave transducer
- Setup for acoustic wave transducer
- Attach sensor sample onto the sample holder

Week11
- Laser diode has been installed
- Setup for detector almost complete

Spring 2015

Week1
- First test for detection setup
- Extra challenge- generation part

Week3
- etch sample to adjust the most useful wavelength
- New idea for sample holder

Week5
- First version of data for acoustic wave generator
- Anaylsis the input and output waveform

Week7
- Get the reference waveform or the 40k Hz acoustic wave
- Test again for the detection part

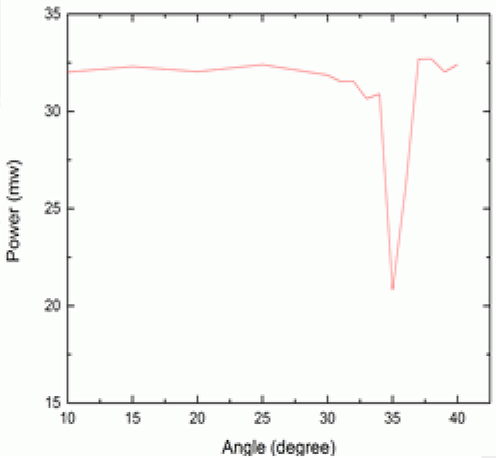
Week 9
- Get the prefect waveform as the output results!
- Senior design for the detection part finished!

Extra Challenge - Ultrasound Generation

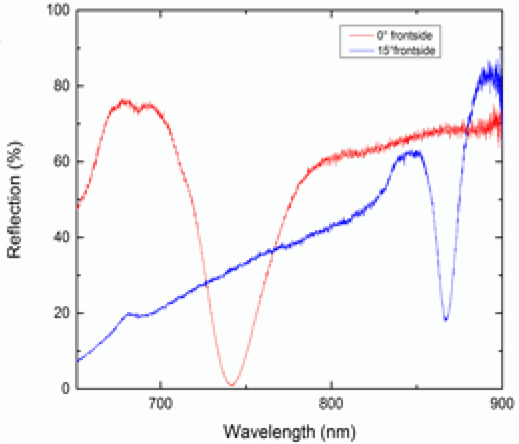
Method of ultrasound generation

To generate a acoustic pulse :

- Enough thermal energy : 35% light absorption
- Resonance of plasmonic substrate pulse
- Incident angle adjustment



Light absorption in air



Resonance change by changing the angle

Characterization of Laser beam

- The laser beam has been already polarized.
- Calibrate laser source to 45 degree
- Have the TM light transmit through polarizer