Strategies For Reducing The Size and Power Of Air Quality Monitors

AAPCA 2016 Fall Business Meeting

Dr. John Muth

muth@ncsu.edu

Professor ECE Department, NC State University

Deputy Director PowerAmerica

Next Generation Power Electronics Manufacturing Institute

Co-Founder of ASSIST Engineering Research Center

POWERAMERICA

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ASSIST:
Advanced Self-Powered Systems of Integrated Sensors and Technologies

An NSF Nanosystems Engineering Research Center

NC STATE UNIVERSITY

University of Virginia School of Engineering

FIU Florida International University

PennState 1855

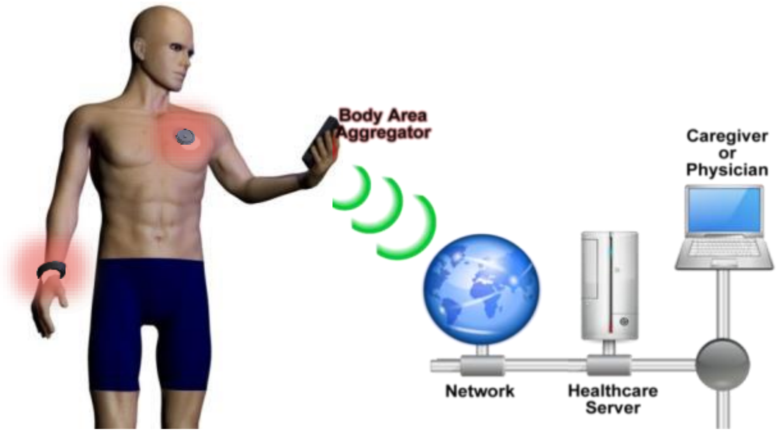
Michigan

UNC School of Medicine

KAIST

The University of Adelaide Australia

東京工業大学 Tokyo Institute of Technology



Nanotechnology enabled miniature, self-powered, wireless wearable sensors for Personal Health and Personal Environment monitoring

Contact: Dr. Veena Misra, vmisra@ncsu.edu

Holy Grail: Exposure Monitoring

Concentrations of particles and gasses

\+ Physiology of person, respiration rate, exertion

(Under realistic conditions work, and play)

\+ Location and other Contextual Information

= Actionable Information

Caveats:

- How much Data?
- Who looks at the Data?
- What Quality of Data?

What Surrogates for Exposure Dose?

- Minute Ventilation rate?
- Heart Rate?
- Motion/Activity?
- Biochemistry

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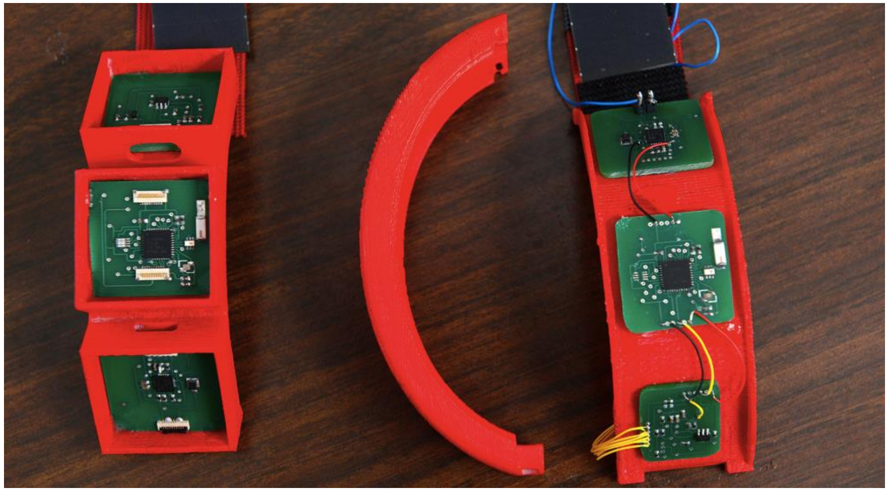
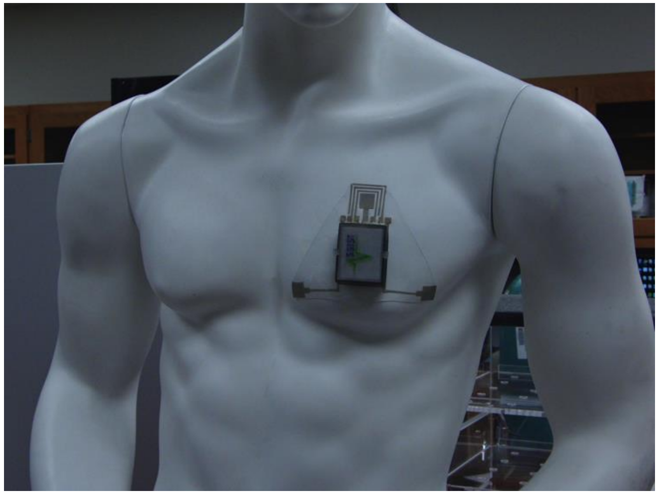
Muth, **"Strategies for Reducing the size and power of Particle Exposure Monitors", AAAR, Portland 2013**

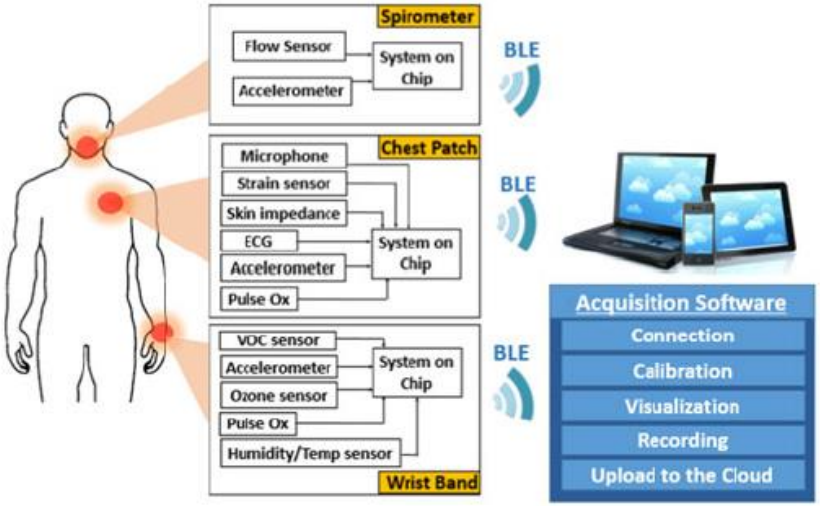
Some Recent ASSIST Activities

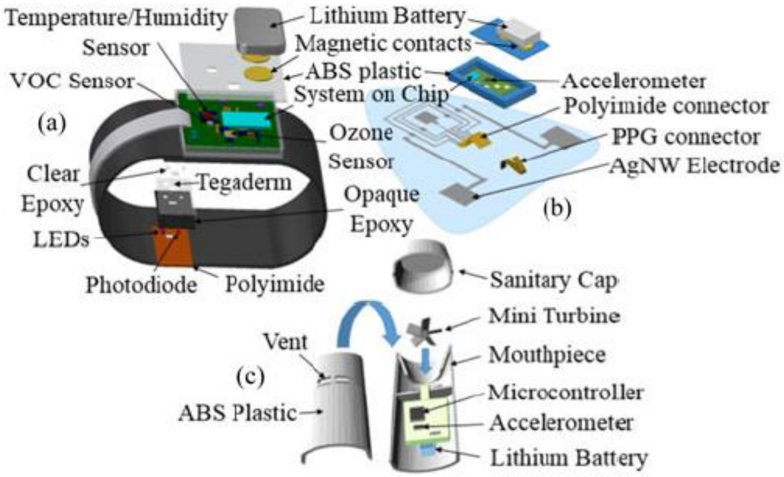


A prototype of the Human Exposure Tracker wristband.



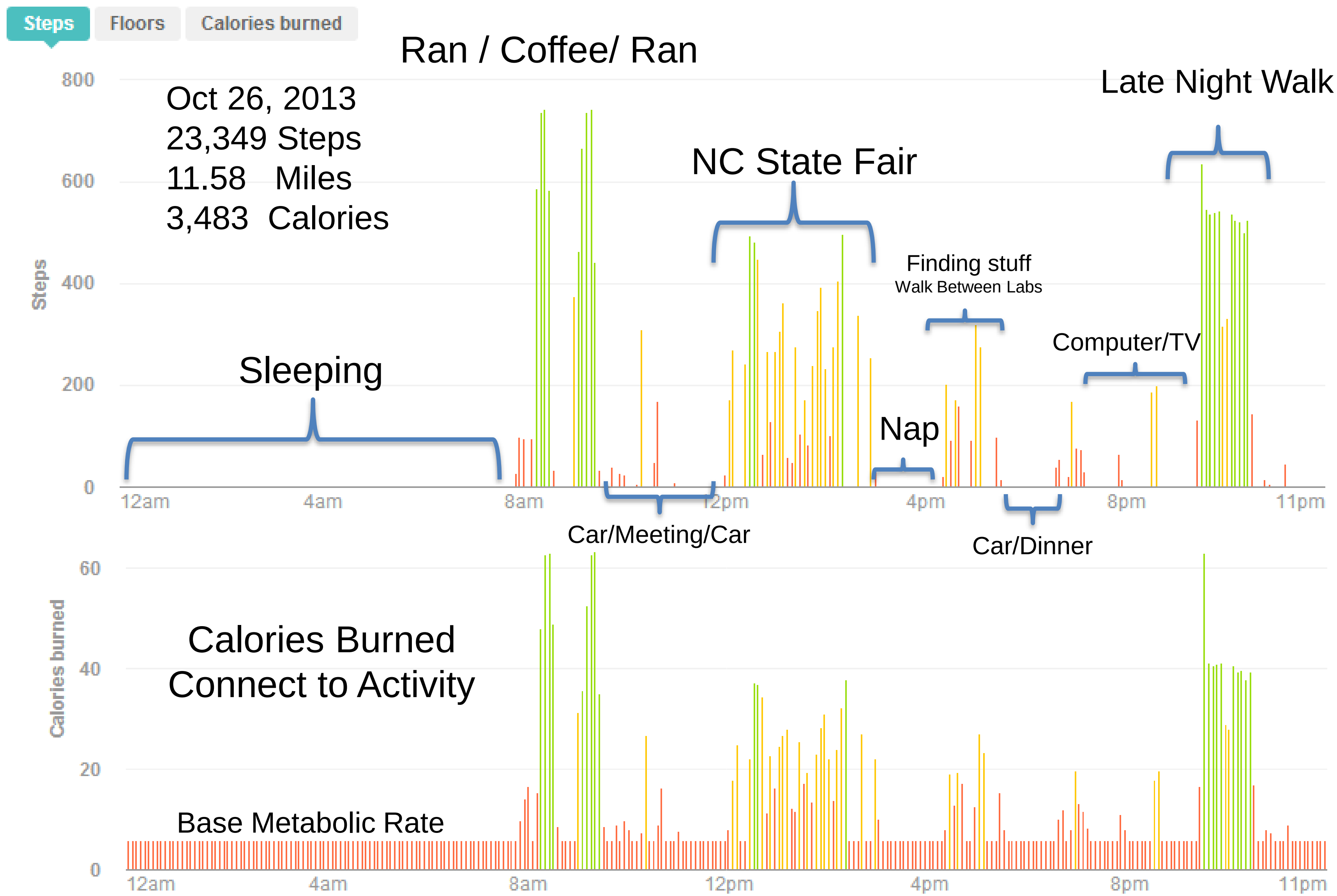
Prototype of Human Exposure Tracker Chest Patch



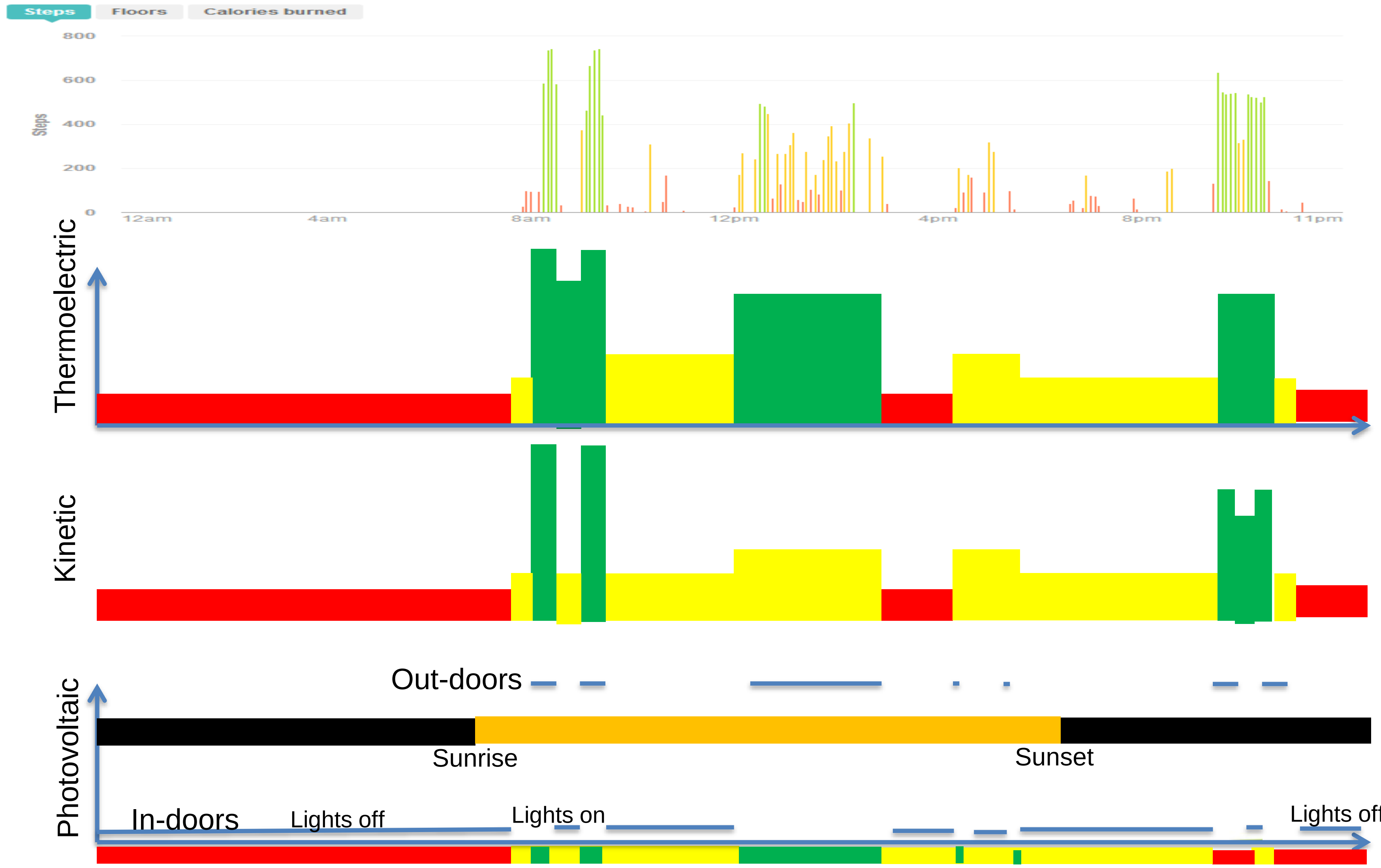


Dieffenderfer, et.al " Low-Power Wearable Systems for Continuous Monitoring of Environment and Health for Chronic Respiratory Disease, Journal of Biomedical and health informatics, Vol. 20, No.5, September 2016, https://news.ncsu.edu/2016/06/wearable-tech-asthma-2016/

Human Dimension to Energy



Energy Availability



A low Energy Day?

Sept 4, 2013
4,351 Steps
2.09 Miles
2070 Calories

Calorie, on your nutritional package is actually a kilocalorie = 4184 Joules

The Energetic Day was about 3483 C, while this low energy Day is about 2070 C

The difference is almost 6 million Joules ,

or an additional 68.4 W averaged over 24 Hrs

So for the active day, if 0.01 percent were captured 6 mW would be available.

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Accelerometers on Humans

Interest is now being driven by:

Form Factor, Application, Data Analysis.

Fitbit One

Motorola MotoActv

Striiv Play

Fitbit Flex

Jawbone UP

BodyMedia Fit Core

Fitbug Air

Larklife

Pebble Activity Tracker
Fitlinxx

Fitbit Zip

Misfit Shine

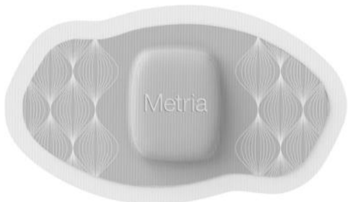
Nike+ FuelBand

http://www.pcmag.com/article2/0,2817,2404445,00.asp

http://www.indiegogo.com/projects/misfit-shine-an-elegant-wireless-activity-tracker

http://www.fitlinxx.net/pebble-activity-monitor.htm https://www.fitbug.com/

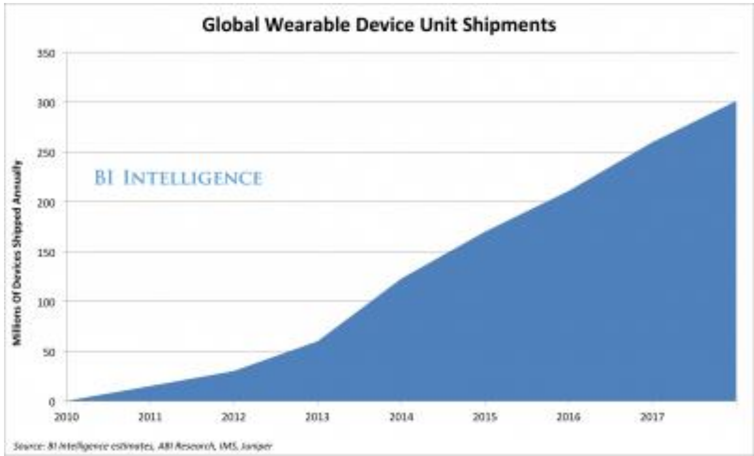
State of the Art: Wearable Devices



Metria Patch by Vancive

BodyMedia

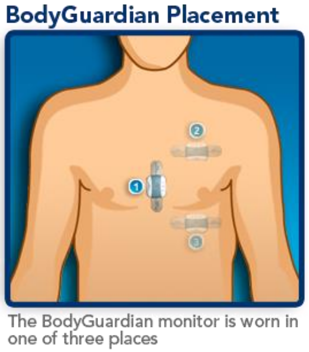
FitBit



Sotera Wireless

Piix Heart Monitor

Proteus Digital Health



Preventice

HealthSTATS

MC10 Hydration Sensor

Wearable Air Quality Sensing?

- Many Challenges:
  - Power Hungry
    - Sensors and computation power dropping, but still need to move and filter air.
  - Form Factor
    - How to be unobtrusive, needs to fit in a persons lifestyle
  - Quality of Data, Interference from human activity
    - Colognes and perfumes, cooking, gasoline etc.
    - Dust from carpets, skin, stirred by human movement
- Current Research Thoughts:
  - Micro-Optics to reduce size of Particle Monitors. –
  - Eventually leads to integrated silicon photonics approach.
  - Novel Resonance Sensing Circuit for very Low Power using Selective Polymers for Gas Sensing.

Micro Optics for Particle Sensor

- Basic Premise:
  - Light scattering sensors require relatively long lengths, and sensitive photo-detectors.
  - Micro-Optics potentially allow occlusion of light by the particles to be detected instead.

- Advantages:
  - Extremely Compact
  - Less Sensitive Photodetectors
  - Potentially Very low Power.

- Disadvantages:
  - Less sensitive for Small (<1 um) Particles
  - Particle Handling needed to direct particles through small area.

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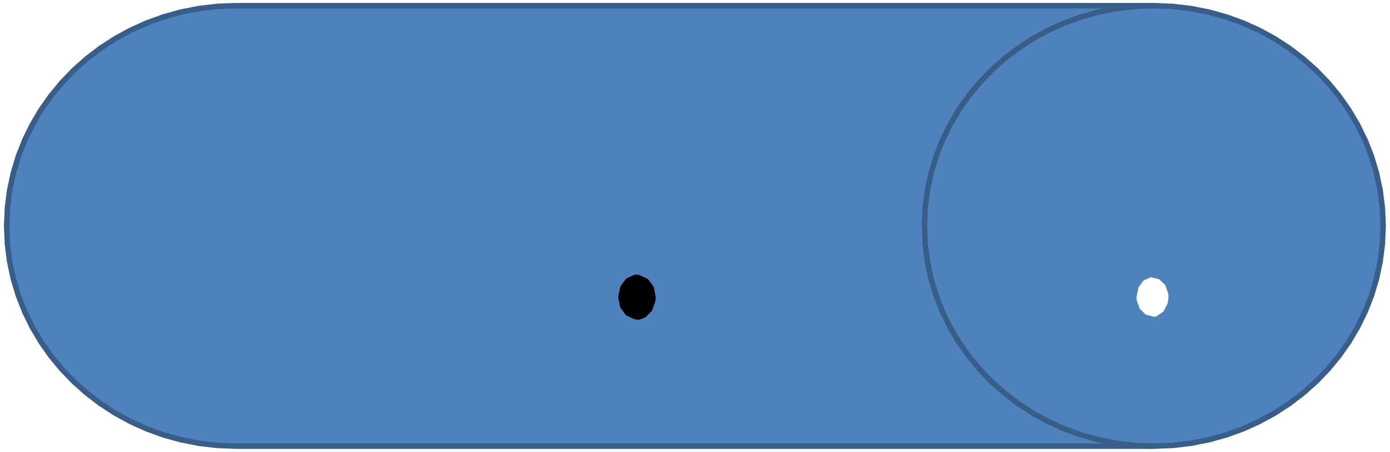
Tiny Particle: Big Beam



Small
Change

VS

Tiny Particle: Tiny Beam

Big
Change

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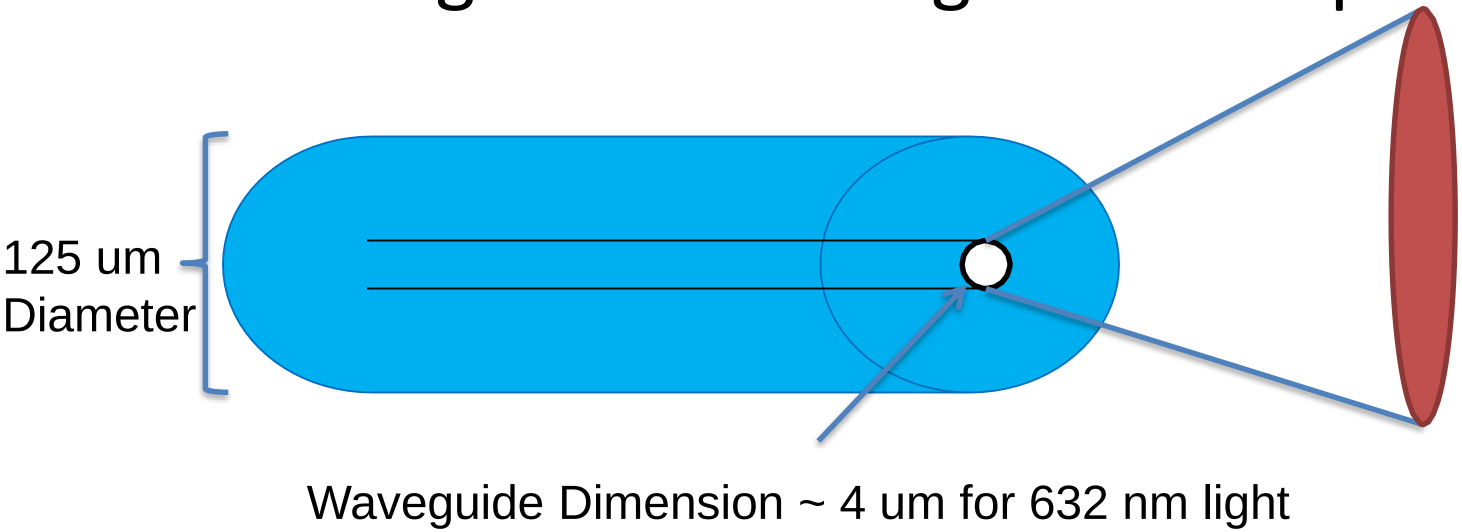
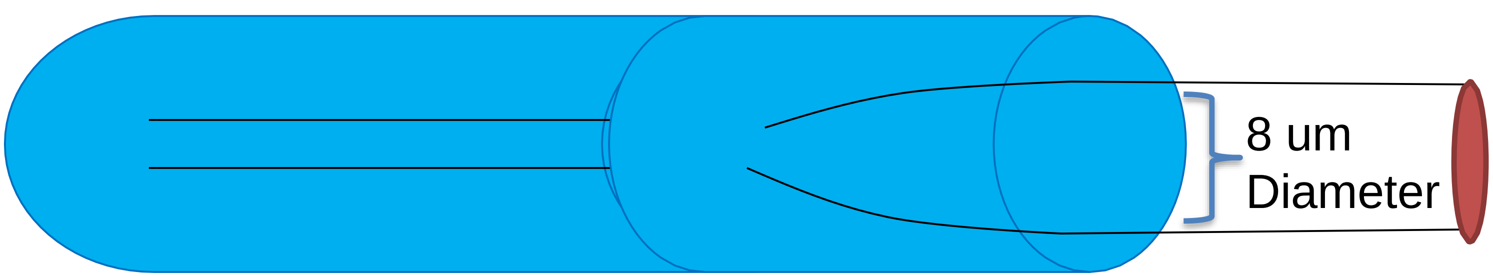
How to make a very small beam?

- Use waveguides: i.e. Single mode Optical Fiber



- But Fusing a Graded Index Fiber Lens collimates the beam



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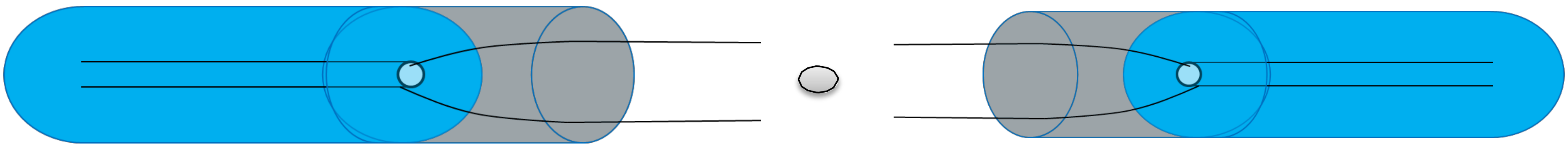
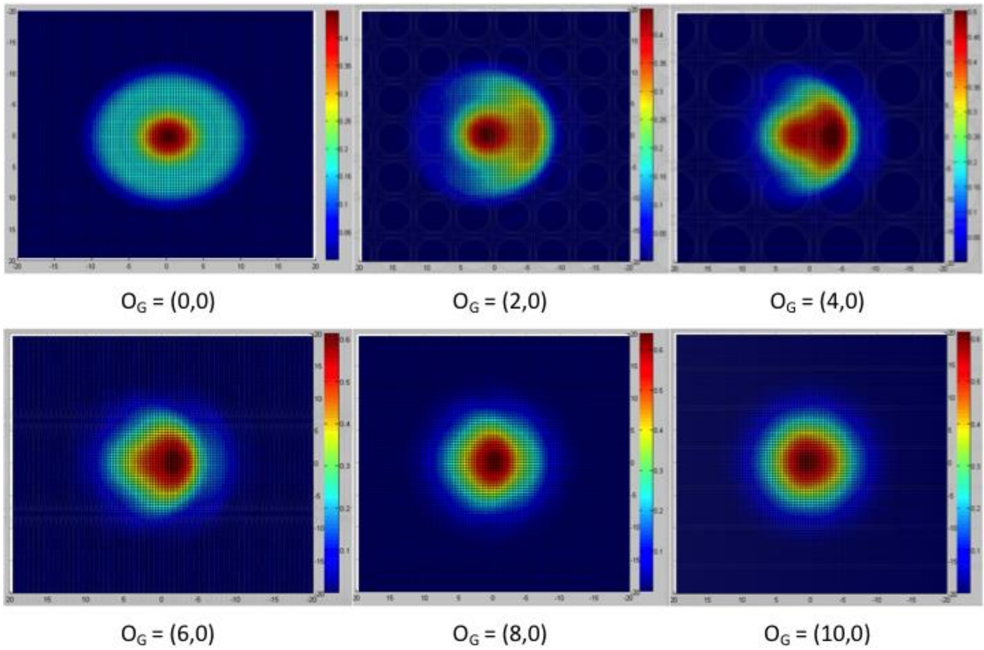
Transmitter/Receiver Pair



- Geometric optical Picture is not the whole story, need to consider Scattering, Modes

- **Important Point:**
  Need to MATCH the electromagnetic mode to have efficient coupling!!!



Intensity diagrams show effect of particle on electromagnetic mode

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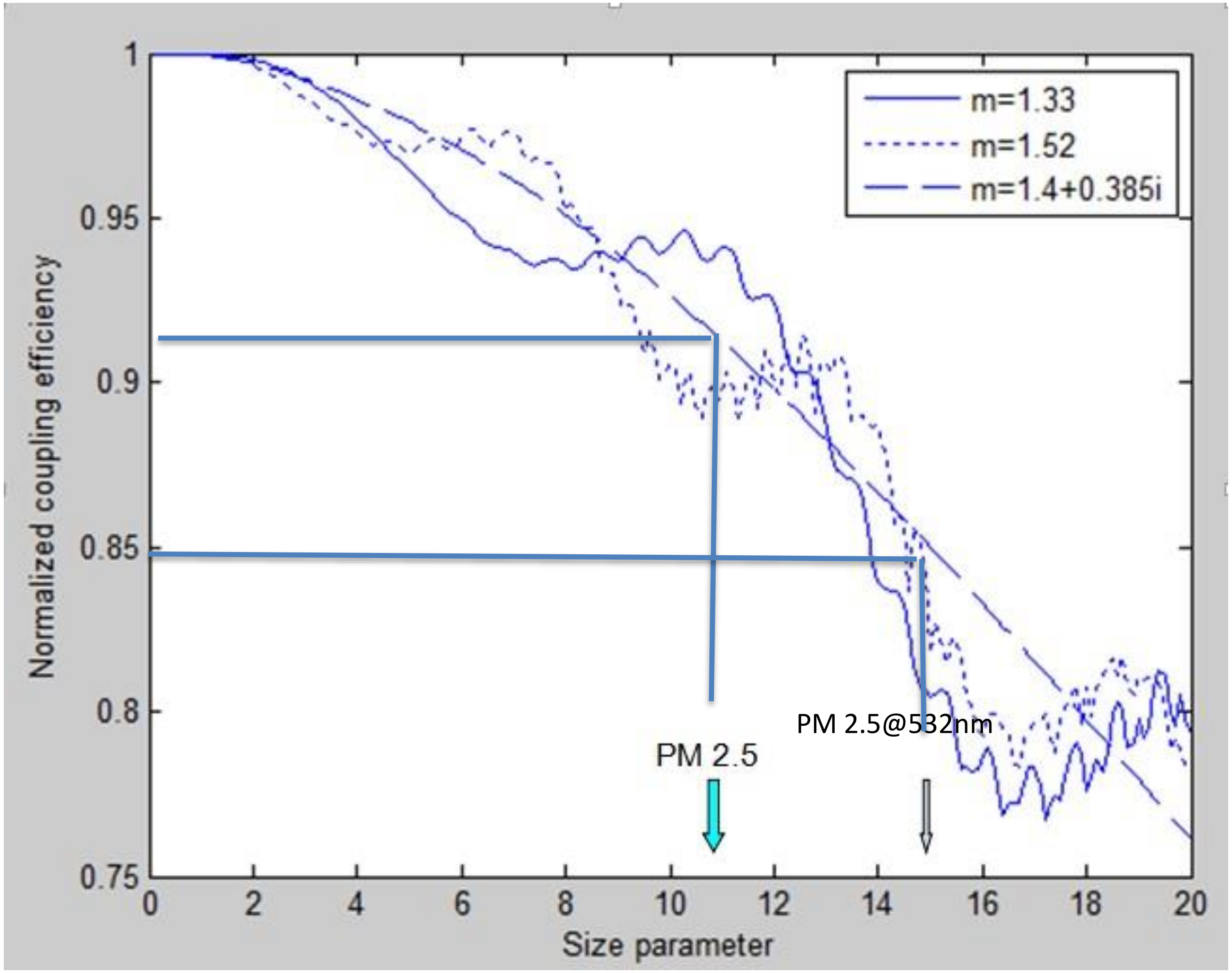
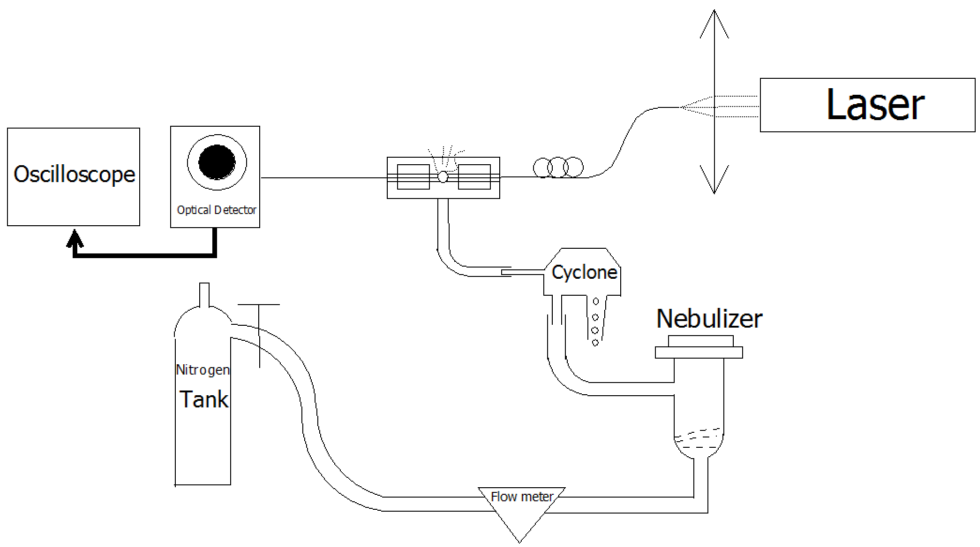
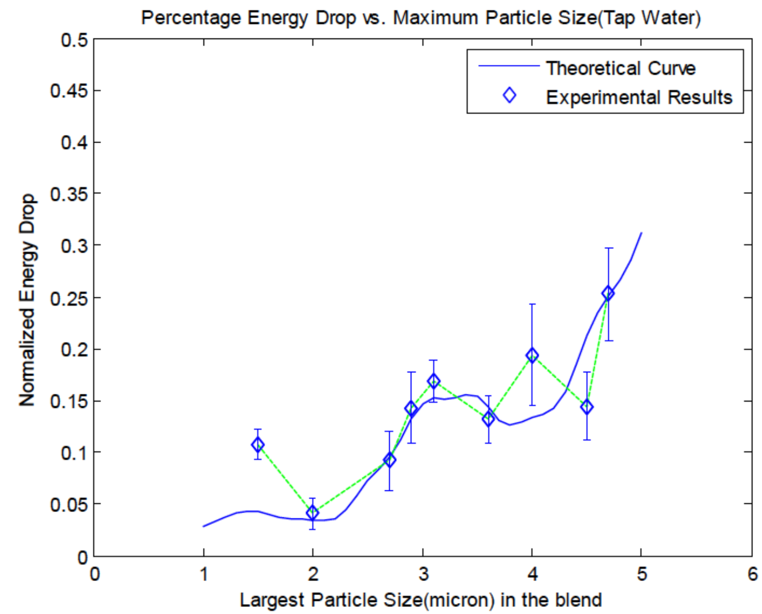
Mismatched Modes Decrease Coupling Significantly

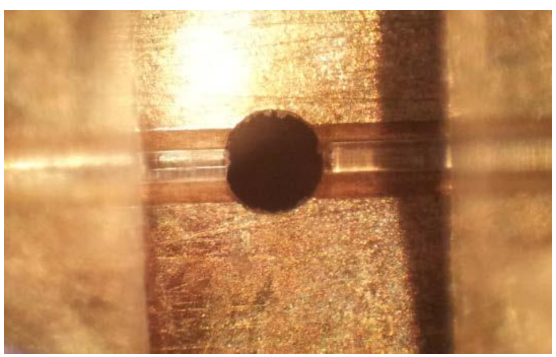


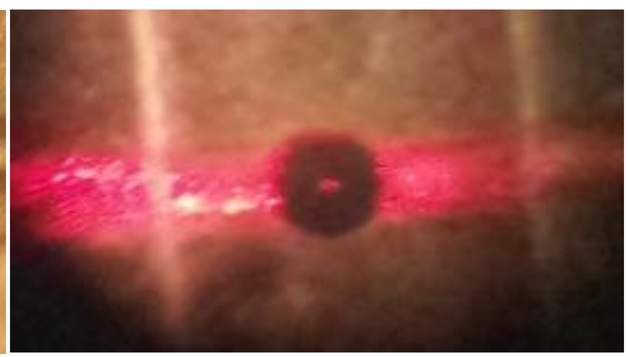
- We're currently using 633nm laser;
- If we use laser with shorter wavelength-- for example 532nm, the coupling power drop may be more obvious

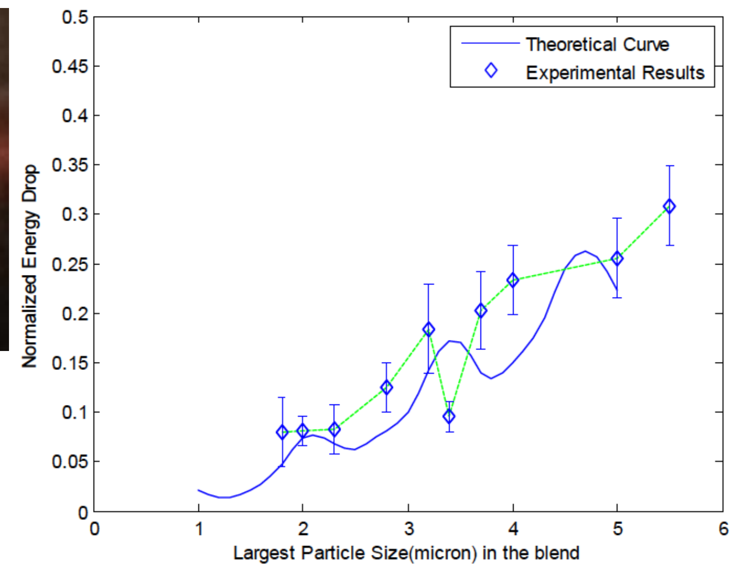
Testing: Good agreement with theory









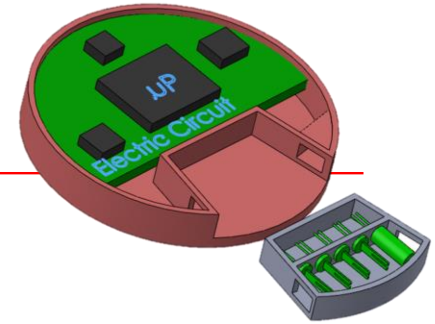


a) ~ 125 um Hole with optical fibers, b) System operating with large particles showing scattering

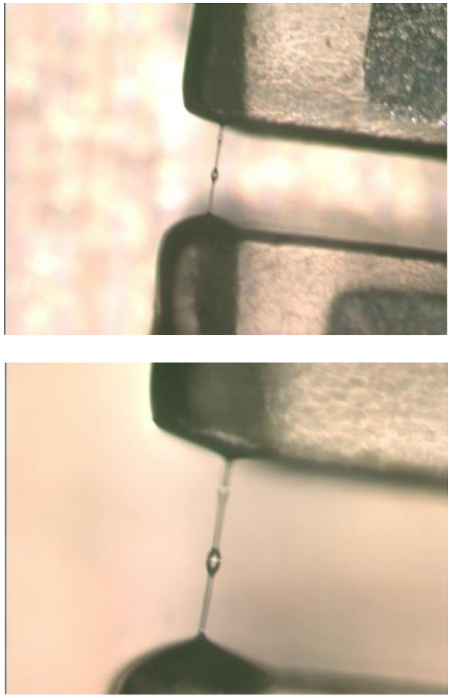
Design of an Ozone Sensing Wristwatch Using Quartz Oscillators

Tuning Fork crystal

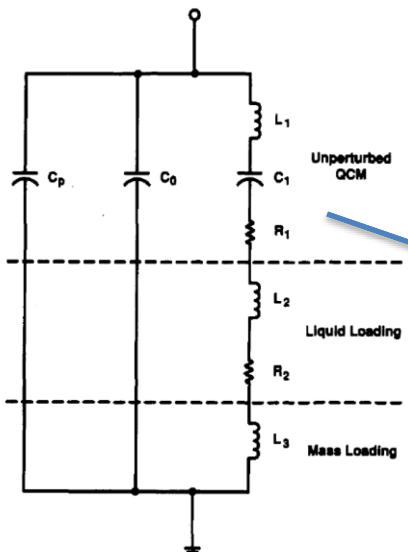
- Tuning fork crystals were used to detect changes in physical properties of polybutadiene when it reacts with ozone.
- When polybutadiene reacts with ozone, the resonant frequency shifts due to the change in loading on the crystal
- This can be detected by performing a frequency sweep and comparing with the resonant frequency of a reference crystal



Concept of final design



Crystal prongs coated with polybutadiene



Equivalent circuit of loaded crystal

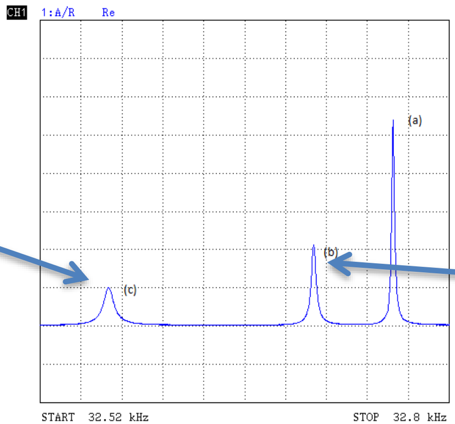
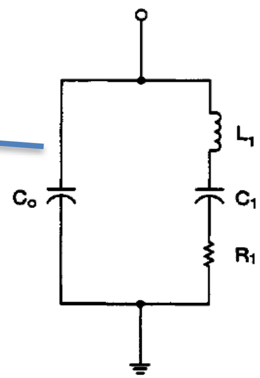


Fig. Resonance peaks. (a) Crystal in cover, (b) crystal without cover and (c) crystal coated with polybutadiene



Equivalent circuit of unloaded crystal

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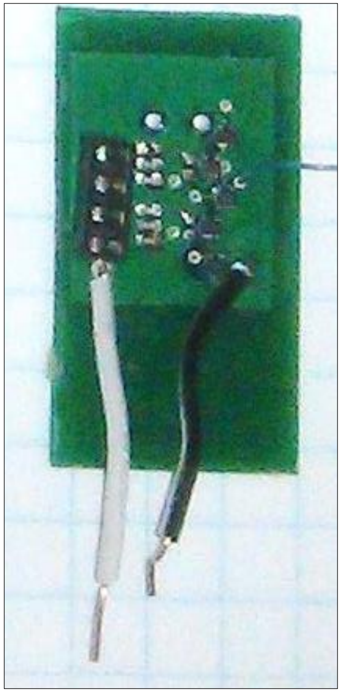
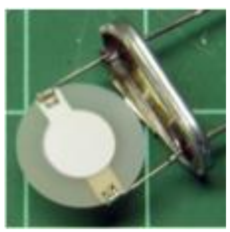
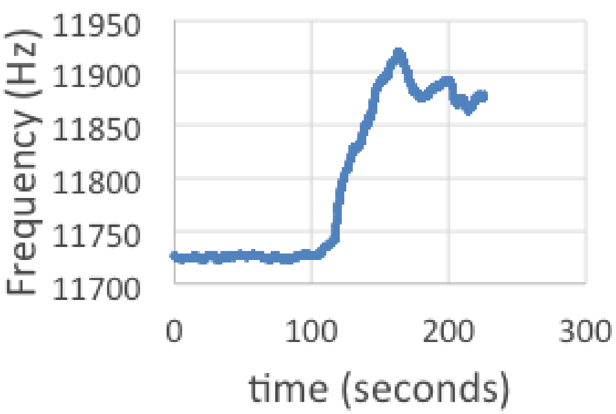
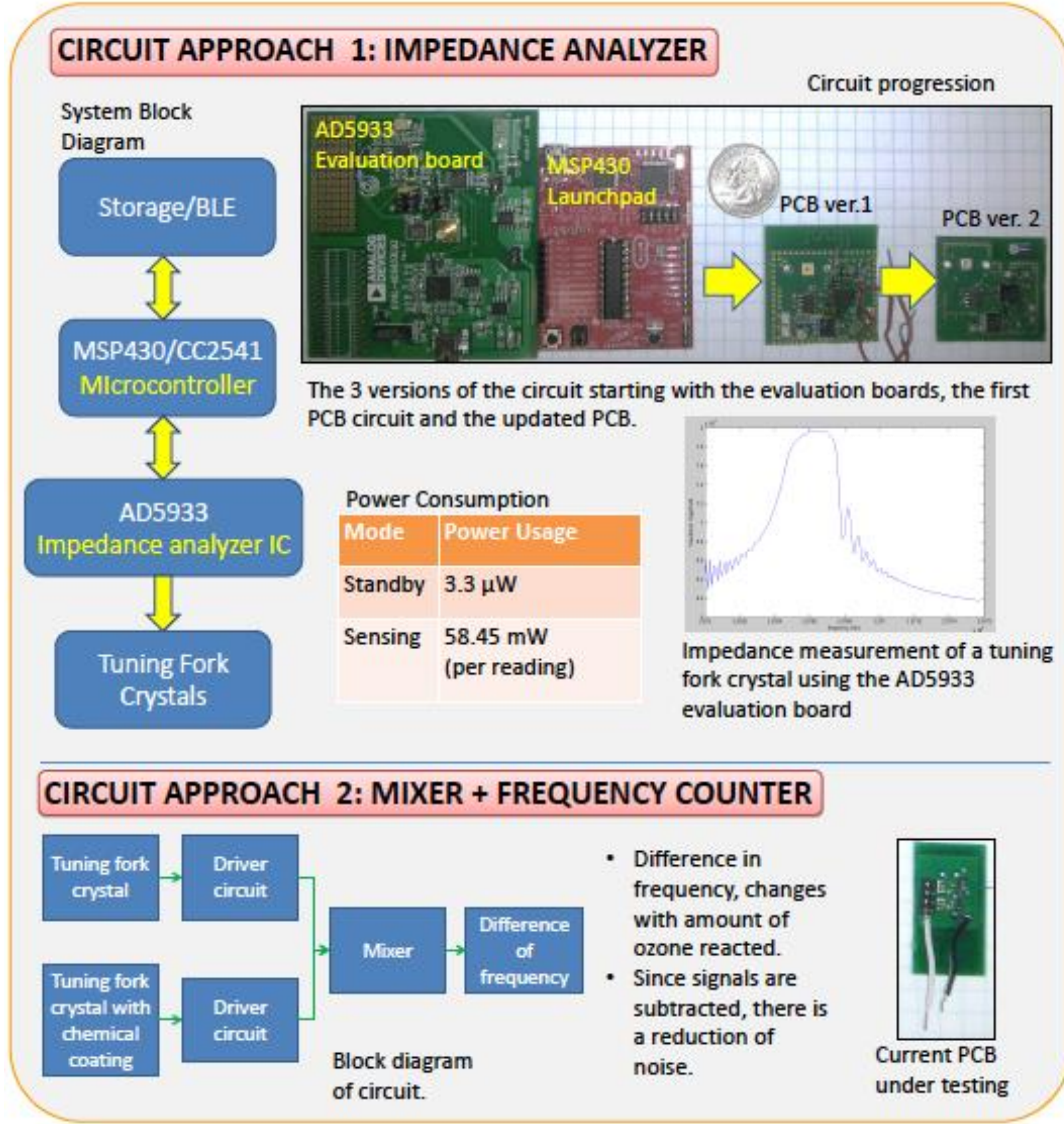
Mixer Circuit: Show Response with input power as low as 14 microWatts



Recent version of the mixer circuit. Power consumption - 14μW







Thank You

Questions?

Example: low power, low cost spirometer