Smartphone Based Nano-device for Human Breath Sensing

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Introduction:

The multiyear goal of our client is to provide a non-invasive test for diagnosing infections in a more portable, cheap, user-friendly package than is currently available with blood tests. The end goal is to have a small spectrometer paired with a smartphone to intake a patient's breath and determine their infection using spectral analysis. This will allow areas with poor health care access to accurate diagnoses that had previously been too expensive or logistically impossible to achieve. We performed spectral analysis with nano-devices to develop the necessary equations that model how the nano-devices respond to different chemicals in their environment. Additionally we developed equations to create a spectrometer that can be used to build the app and spectrometer later.

Design Requirements:

- Small Portable Spectrometer Design Plan
- Design plan for construction of spectrometer app that can plot wavelength vs frequency of light (spectral plotting) entering the spectrometer
- Design plan for analyzing the spectral characteristics that a nano-device emits and determining what environmental conditions cause this to happen accurately
- Testing data to determine equations to make spectrometer work correctly
- Equations based on tests to allow correct operation of smartphone spectrometer

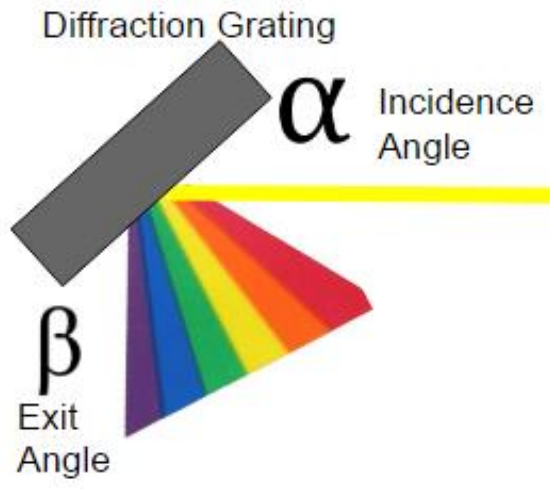
Technical Details:

When light is diffracted into its separate color components and frequencies, an image will shine on the camera similar to this one:

Different frequency light will enter camera in a defined way according to the equation below

$N\lambda = d(\sin\alpha - \sin\beta)$

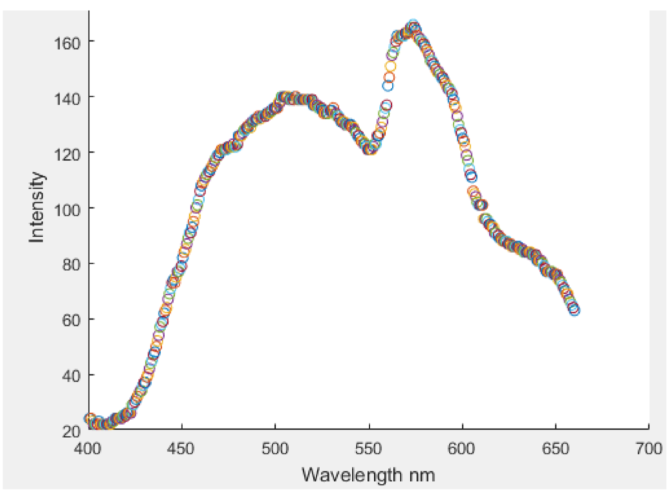
N: diffraction order (use 1)
λ: wavelength (nm)
d: grating groove space (nm)
α: incidence angle on grating
β: exit angle



Rearranging to solve for exit angle, we can determine which camera pixel corresponds to a given wavelength. Intensity of each pixel can be determined by averaging neighboring RGB pixels according to the equation:

$I = 0.2989*R + 0.5870*G + 0.1140*B$

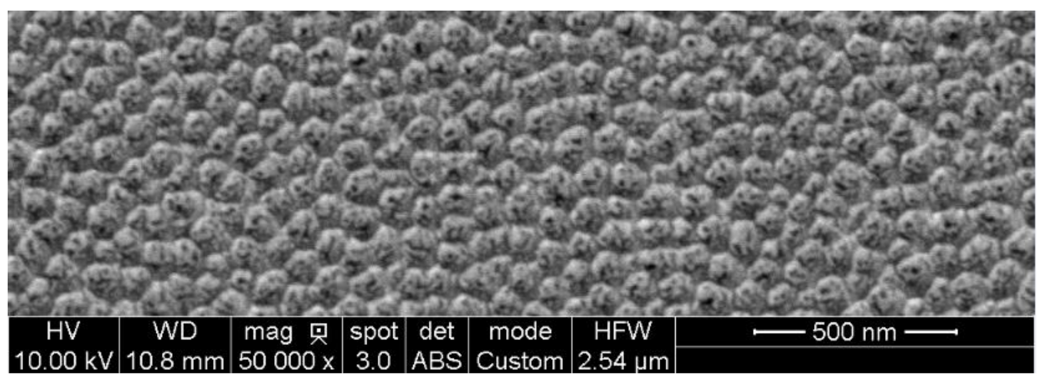
Intensity vs wavelength can be plotted in for each pixel going across a spectra image as shown below:



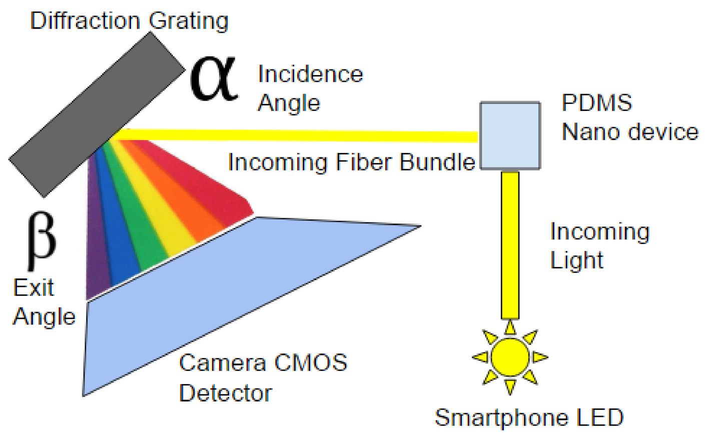
After determining the base state and new intensity spectra of the expanded PDMS, we can determine how much the wavelength changes for each percentage of amount of gas around the PDMS. Doing this several times and using regression we can find how big of intensity increases correspond to gas concentrations in the air.

Design Approach:

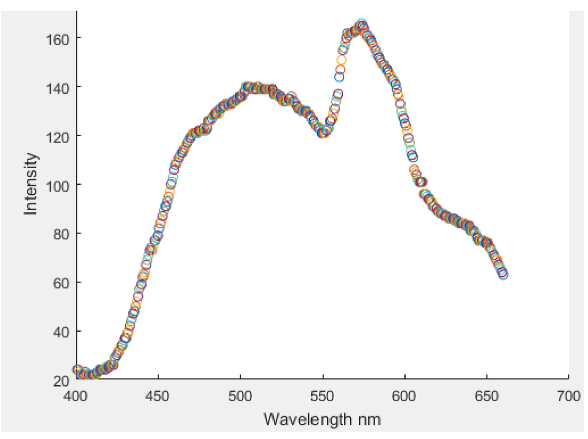
- Spectrometer fits over smartphone camera
- PDMS plastic material and attached diffractive substance are used as nano-device
- In presence of certain gasses, pores in PDMS fill and PDMS expands also expanding the attached diffractive surface
- Diffractive surface creates interference pattern which changes as it swells. The diffractive surface is shown below with grating groove space of approximately 50nm



- Light from smartphone follows optical fiber and is shown on nano-device
- Light reflects from nano-device and follows another optical fiber
- Light hits diffraction grating at certain angle of incidence and different frequencies are reflected at different angles
- Diffracted light is focused on smartphone camera by lens. Below is the spectrometer design.



- Smartphone app graphs intensity vs wavelength of the light on the camera as shown below



- App performs analysis of baseline vs new intensity spectra to determine substance present on PDMS

Testing:

Commercial spectrometers graph the intensity spectra for you. We obtained the same intensity vs wavelength graph as a commercial spectrometer when we used our spectrometer equations to plot the intensity spectra of the same rainbow image that the commercial spectrometer used.

We plotted the intensity graph for the nano-device under varying concentrations of ethanol in the air around it. We obtained the graph below and were able to use regression to find how much the intensity changed per % of ethanol in the air.