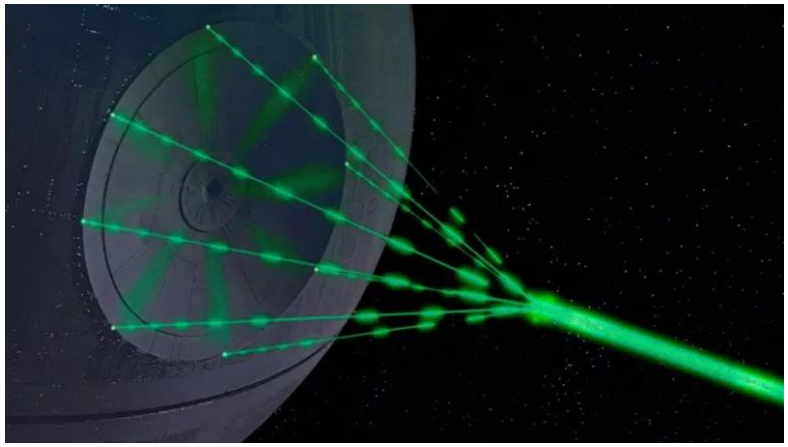
# HOW TO SUM FREQUENCY AND SECOND HARMONIC GENERATION

Jessica DeYoung
Shaw Group
Fall 2018
181105

https://shawgroup.lab.uiowa.edu/equipment






# LASER SAFETY

https://www.lasersafetyindustries.com/35_130_Laser_Safety_Glasses_p/35-130.htm
https://consequenceofsound.net/2016/11/the-death-star-from-star-wars-would-cost-7-7-octillion-to-operate-for-just-one-day/
https://www.pinterest.com/pin/7318418125187062/
http://www.fashionjewelryforeveryone.com/HipHopStatic/HH190.html
https://www.pinterest.ca/pin/18950309679462514O/
https://www.homedepot.com/p/URREA-8-in-Long-Round-Shank-Phillips-Tip-Amber-Handle-Screwdriver-9689/202815050

# THEORY

## 1ST ORDER SUSCEPTIBILITY
- LINEAR RESPONSE OF INDUCED DIPOLE

$$\tilde{P}(t) = \epsilon_0[\chi^{(1)}\tilde{E}(t) + \chi^{(2)}\tilde{E}(t) + \chi^{(3)}\tilde{E}(t) + \cdots]$$

POLARIZATION (INDUCED DIPOLE MOMENT)

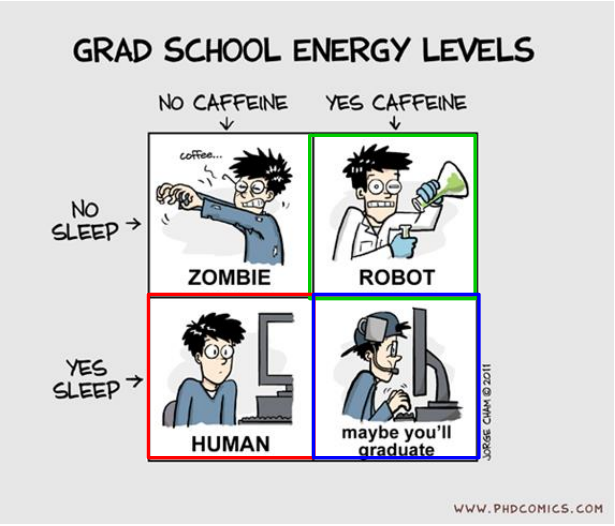
PERMITTIVITY OF VACUUM

APPLIED STRENGTH OF OPTICAL FIELD (FIELD AMPLITUDE)

## 2ND ORDER NONLINEAR SUSCEPTIBILITY
- SFG/ SHG
- SELECTIVITY AT CHANGES OF SYMMETRY

$$P_i = \epsilon_0 \sum_{jk} \sum_{(nm)} \chi^{(2)}_{ijk}(\omega_n + \omega_m, \omega_n, \omega_m) E_j(\omega_n) E_k(\omega_m)$$

## 3RD ORDER NONLINEAR SUSCEPTIBILITY
- NOT SPECIFIC TO CHANGES IN SYMMETRY
- FOUR-WAVE MIXING
- THIRD- HARMONIC GENERATION
- INTENSITY DEPENDENT RI

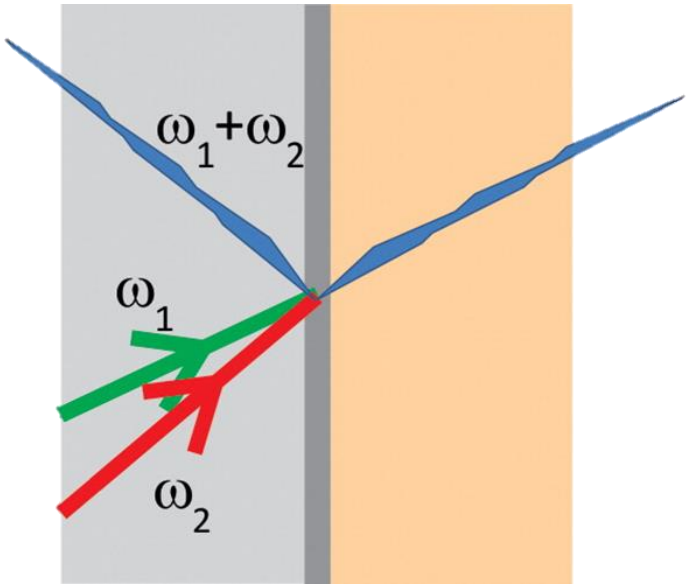



Boyd, R. W., *Nonlinear Optics*. 3rd ed.; 2008.

Boyd, R. W., *Nonlinear Optics*. 3rd ed.; 2008.

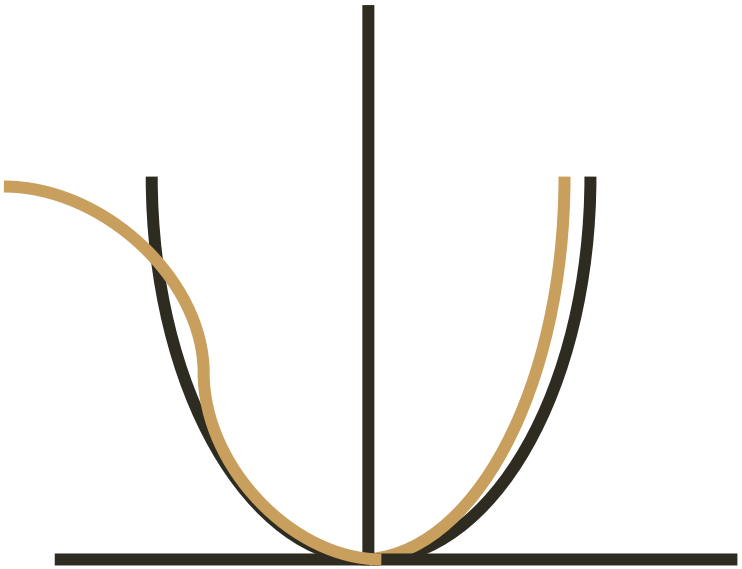
# WHAT YOU NEED

- THIN FILM
- BREAK IN SYMMETRY

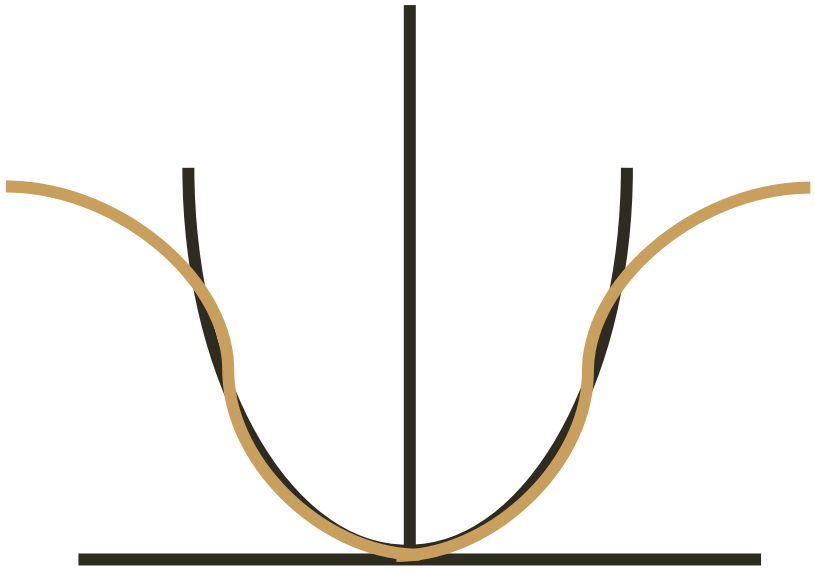



- CHANGE IN HYPERPOLARIZABILITY
- CHANGE IN DIPOLE MOMENT

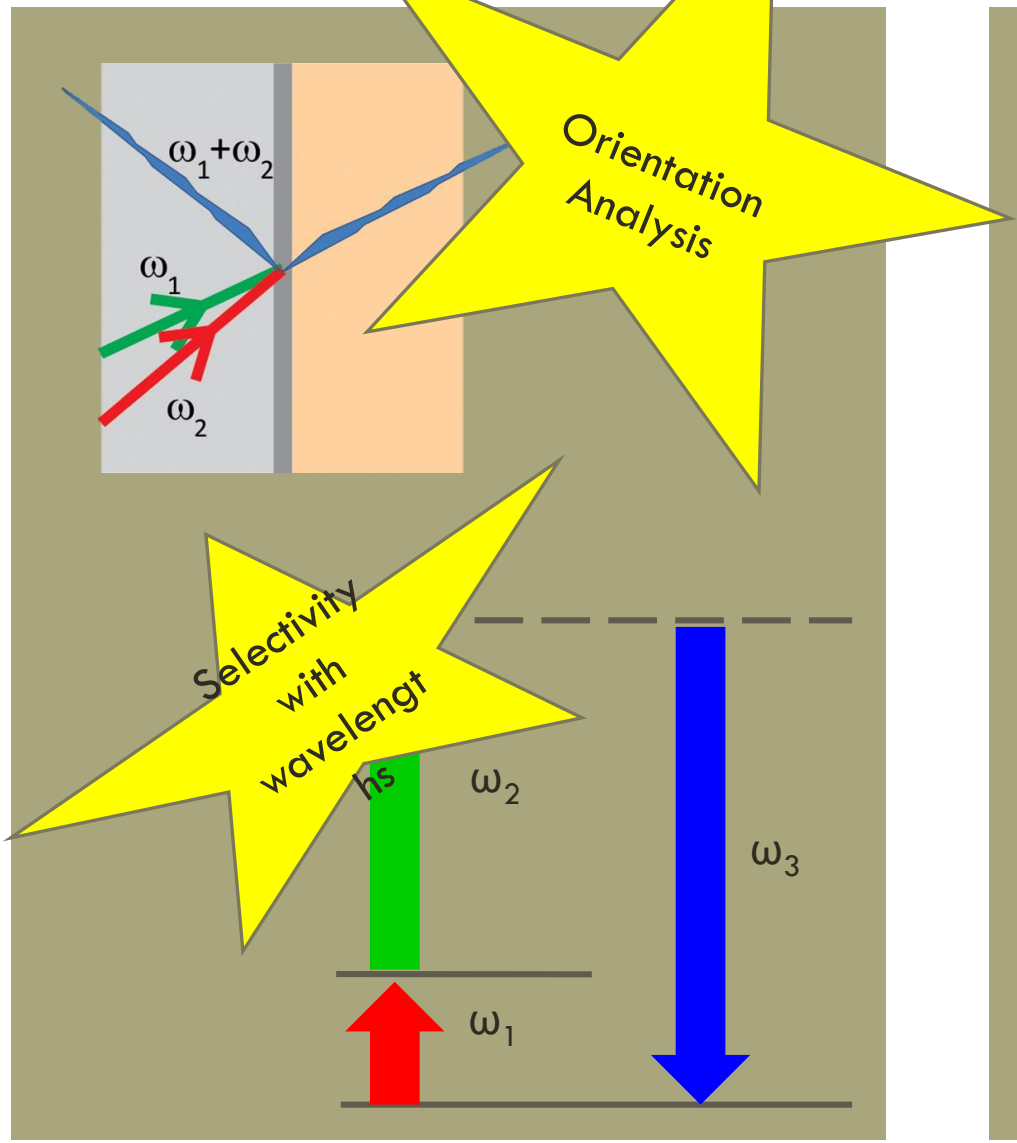
NONCENTROSYMMETRIC

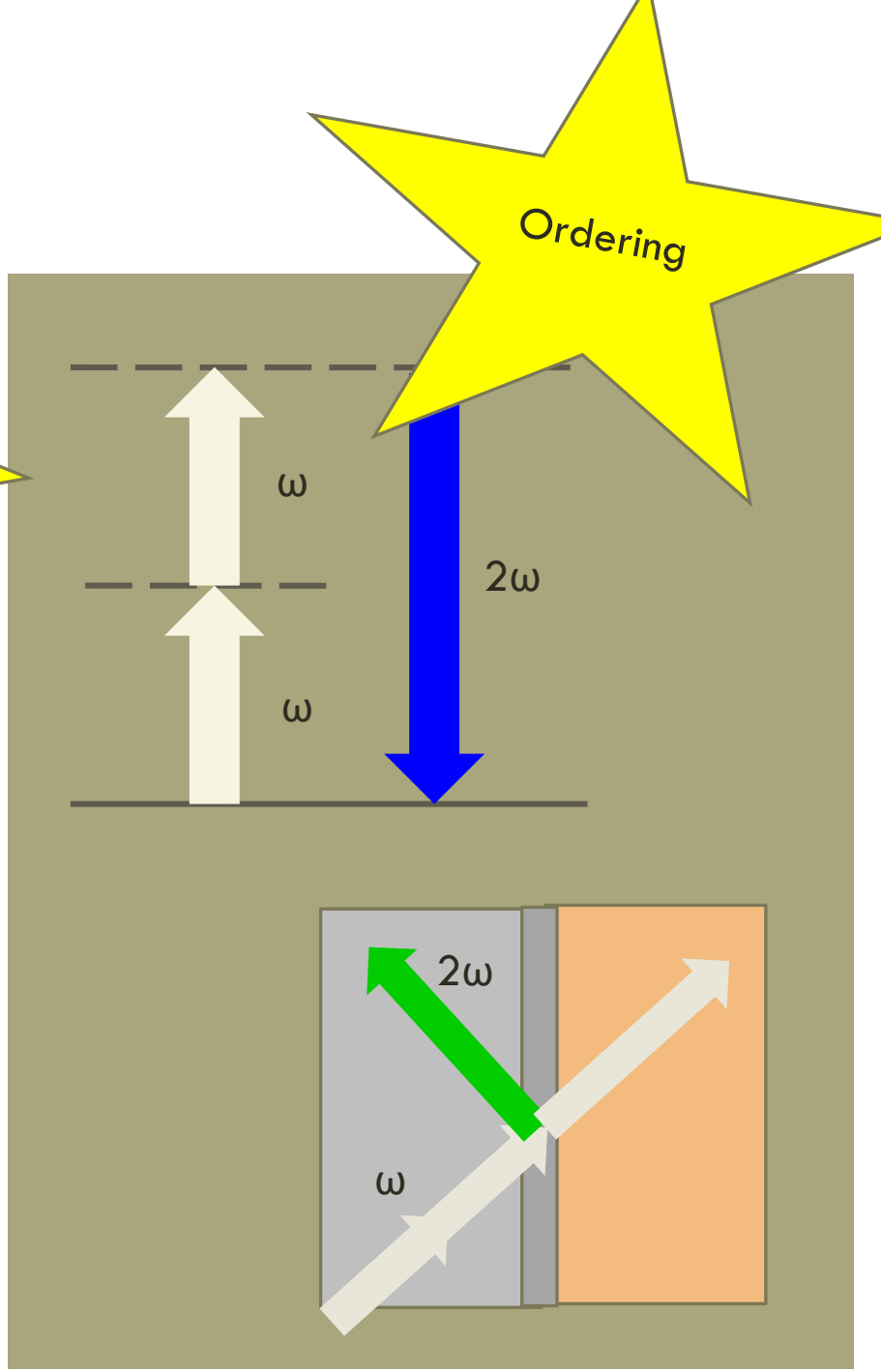


CENTROSYMMETRIC



# WHAT IS SFG/ SHG?



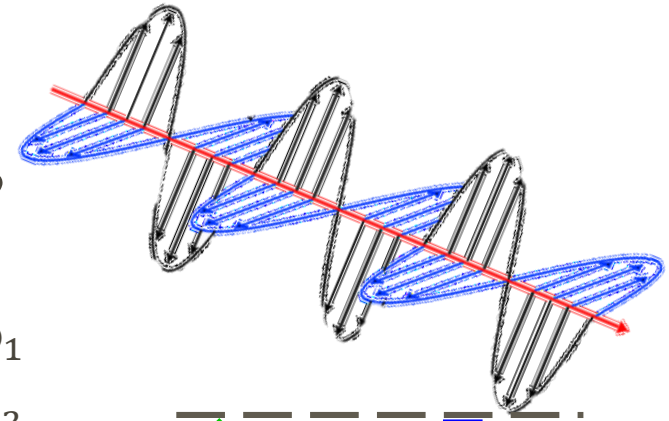



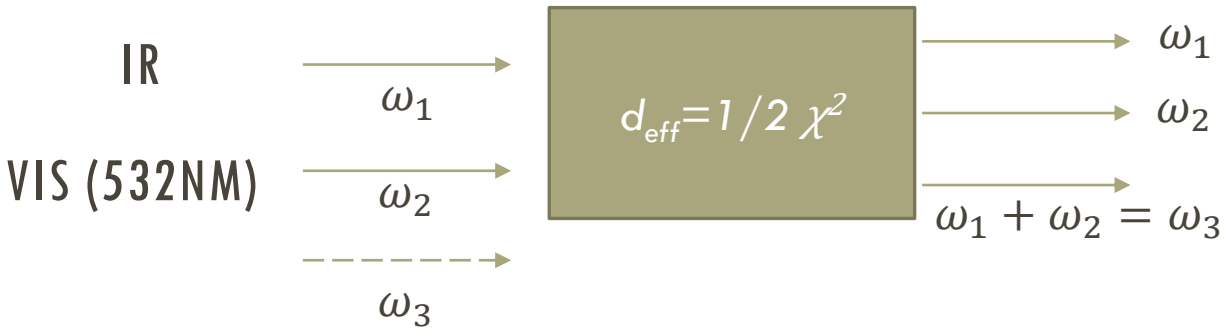
# SFG- UPCONVERSION OF A WEAK IR SIGNAL

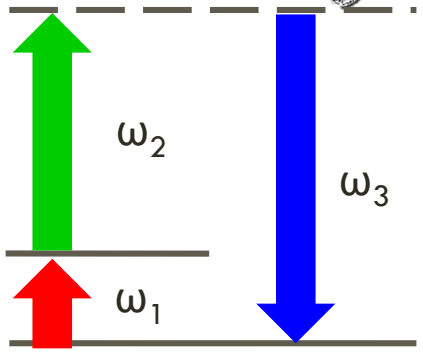
$$P(\omega_1 + \omega_2) = 2\epsilon_0 \chi^{(2)} E_1 E_2$$

- $P$: POLARIZATION (INDUCED DIPOLE MOMENT)
- $\epsilon_0$: PERMITTIVITY OF VACUUM
- $E_1, E_2$: APPLIED STRENGTH OF OPTICAL FIELD (FIELD AMPLITUDE)

A NOTE ON POLARIZATION AND ORIENTATION…
DIFFERENT COMBINATIONS LEAD TO INFORMATION ABOUT YOUR STRETCHING
SSP, PPP, SSS… ETC.





# THE COMPONENTS (THINGS YOU CAN TOUCH)

## SPECTROMETER

- L2
- L1'
- M8'
- M13
- M14
- M16
- POLARIZING ELEMENTS

## OPA/OPG

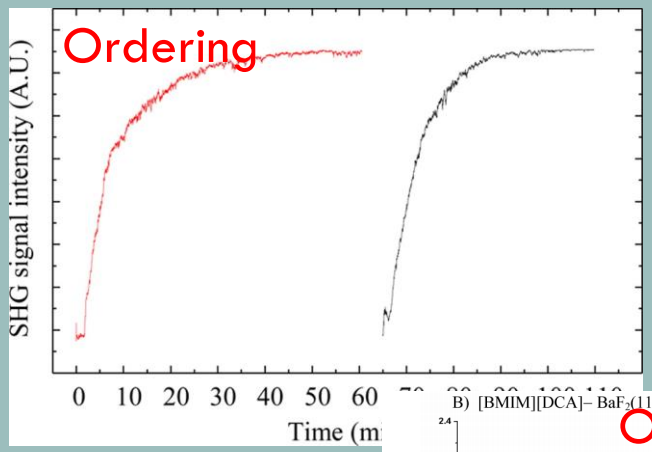

## PICOSECOND LASER

- RAM
- M2

## HARMONICS UNIT (HU)

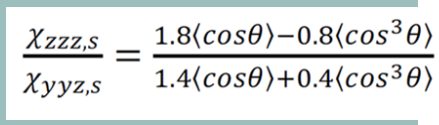
- M13 (IF YOUR POWER IS DROPPING)
- SHG2 (IF SWITCHING TO SHG)

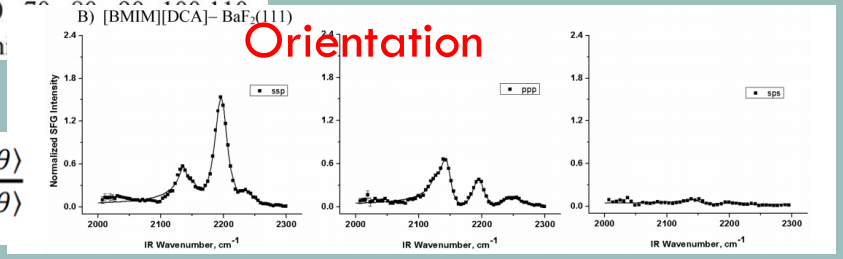
Do not touch VIS beam unless it is severely out of alignment (even then consult a friend)



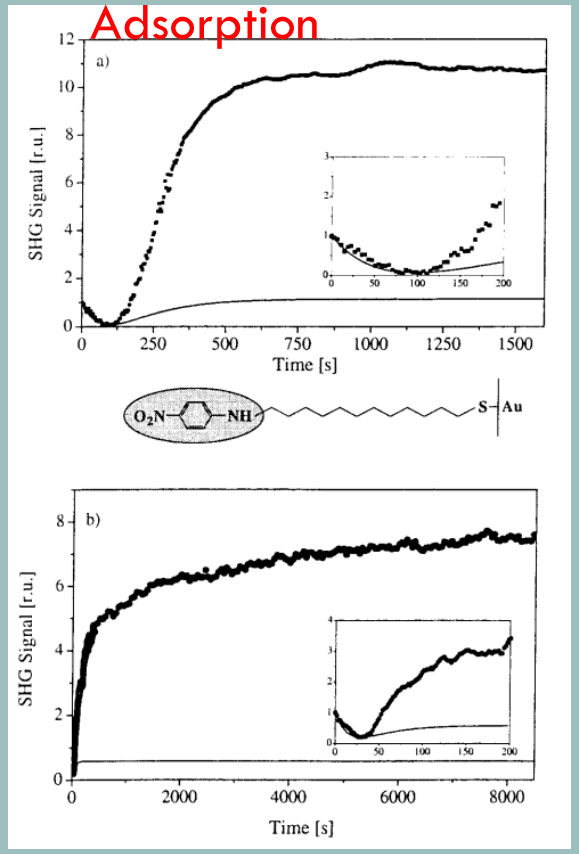

$$r_{\parallel} = \frac{\tan(\theta_i - \theta_t)}{\tan(\theta_i - \theta_t)}$$

$$r_{\perp} = \frac{-\sin(\theta_i - \theta_t)}{\sin(\theta_i - \theta_t)}$$








# WHAT YOU CAN DO WITH SFG AND SHG

$$\vec{P}_{(\omega SFG)} = 2\epsilon_0 X^{(2)} \vec{E}_{(\omega 1)} \vec{E}_{(\omega 2)}$$

$$\vec{P}^{(2)} \quad (t) = 2\epsilon_0 X^{(2)} EE^* + (\epsilon_0 X^{(2)} E^2 e^{-i\omega t} + c.c.)$$

https://research.cbc.osu.edu/allen.697/

# TURNING IT ON


Step1: Turn on the chiller (wait a few minutes)

You can turn it on using the power button enclosed in the red circle

When it is on it will show a temperature

Step2: turn on the laser (back of the laser box) using the key (it is shown in on mode)


Step 3: turn on PMT monochromator

It is shown in on position with green light

Step4: Turn AMP on the control pad to 80

Menu

Amp

Scroll to 80

Esc

run

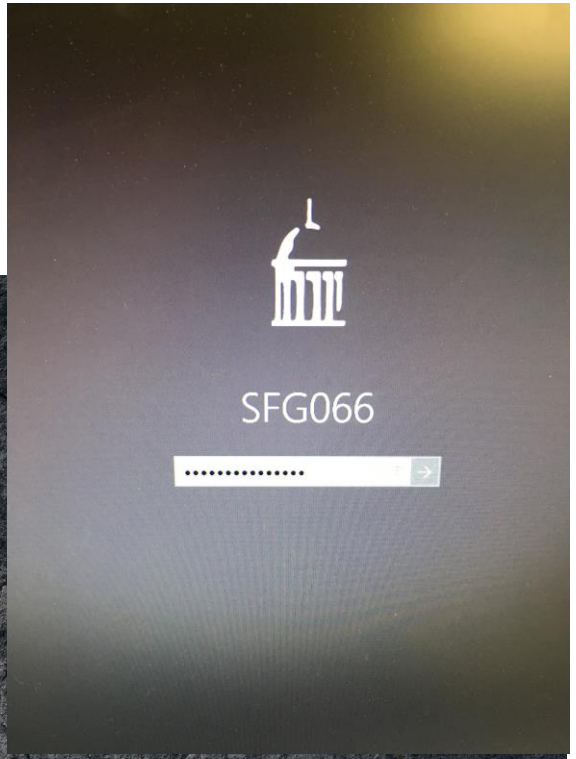
## Step 5: Wait an hour(ish).

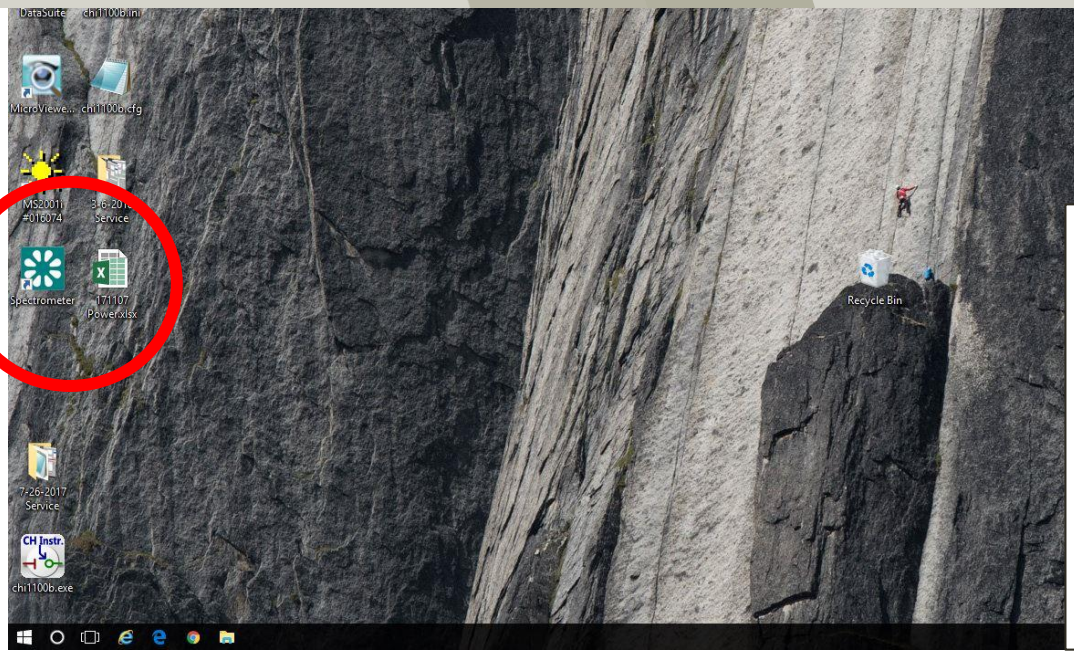
Parameters should be…

E1: 100 or close to previous day values (above 90)

If you are running SFG AMP (80 or so depending on the nature of your sample)

SHG? You probably don't need that much power (try an AMP of 2-10)



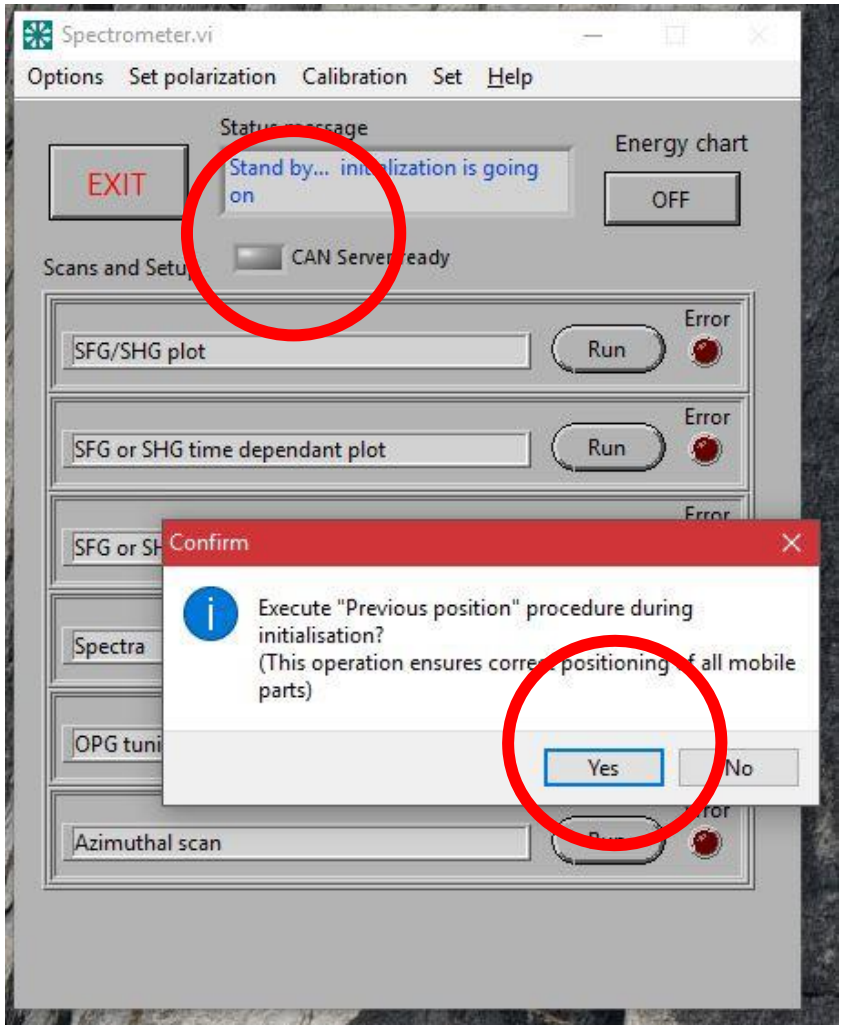



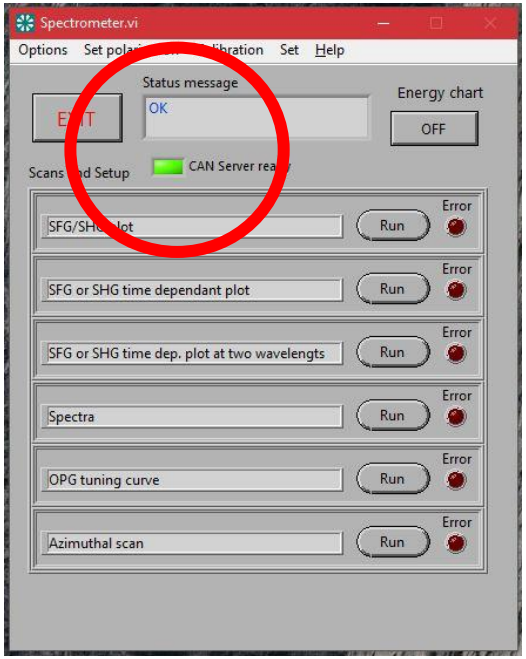

Step6: log in to the computer

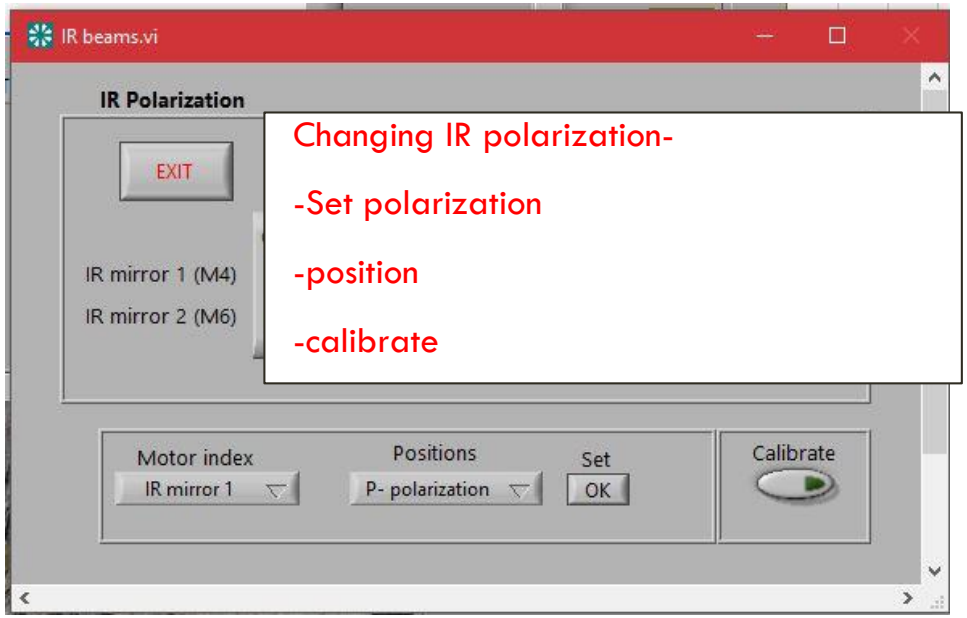
./sfg066

RedPlatinum2017

Click on the spectrometer icon on the desktop



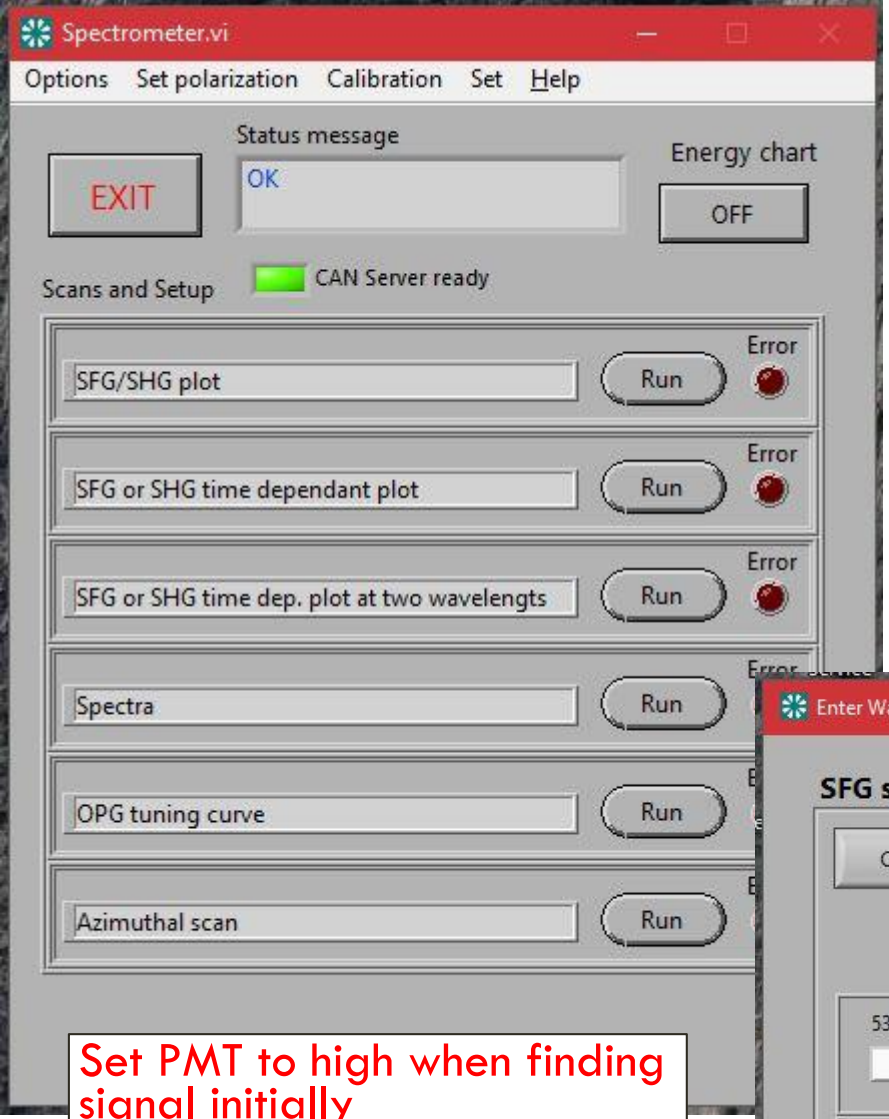




Step 7: Execute previous position

Wait for CAN server

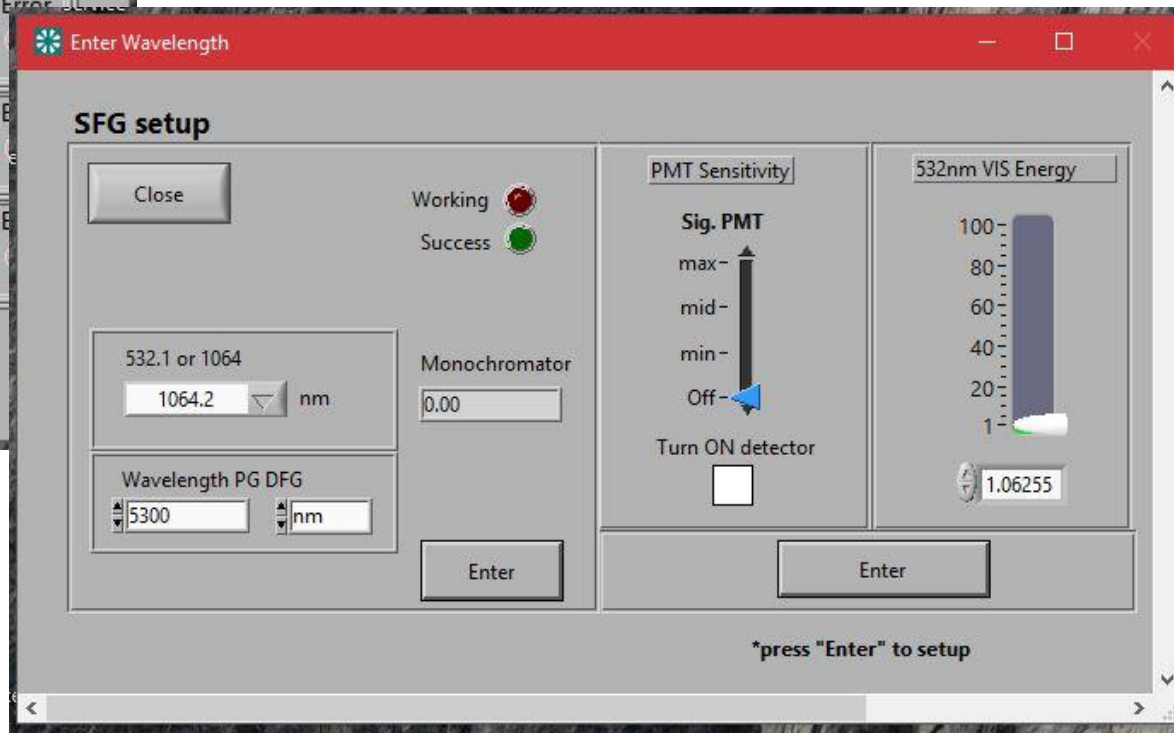
Open Energy Chart




Open SFG setup (set> sfg setup)

PMT wavelength should be 532

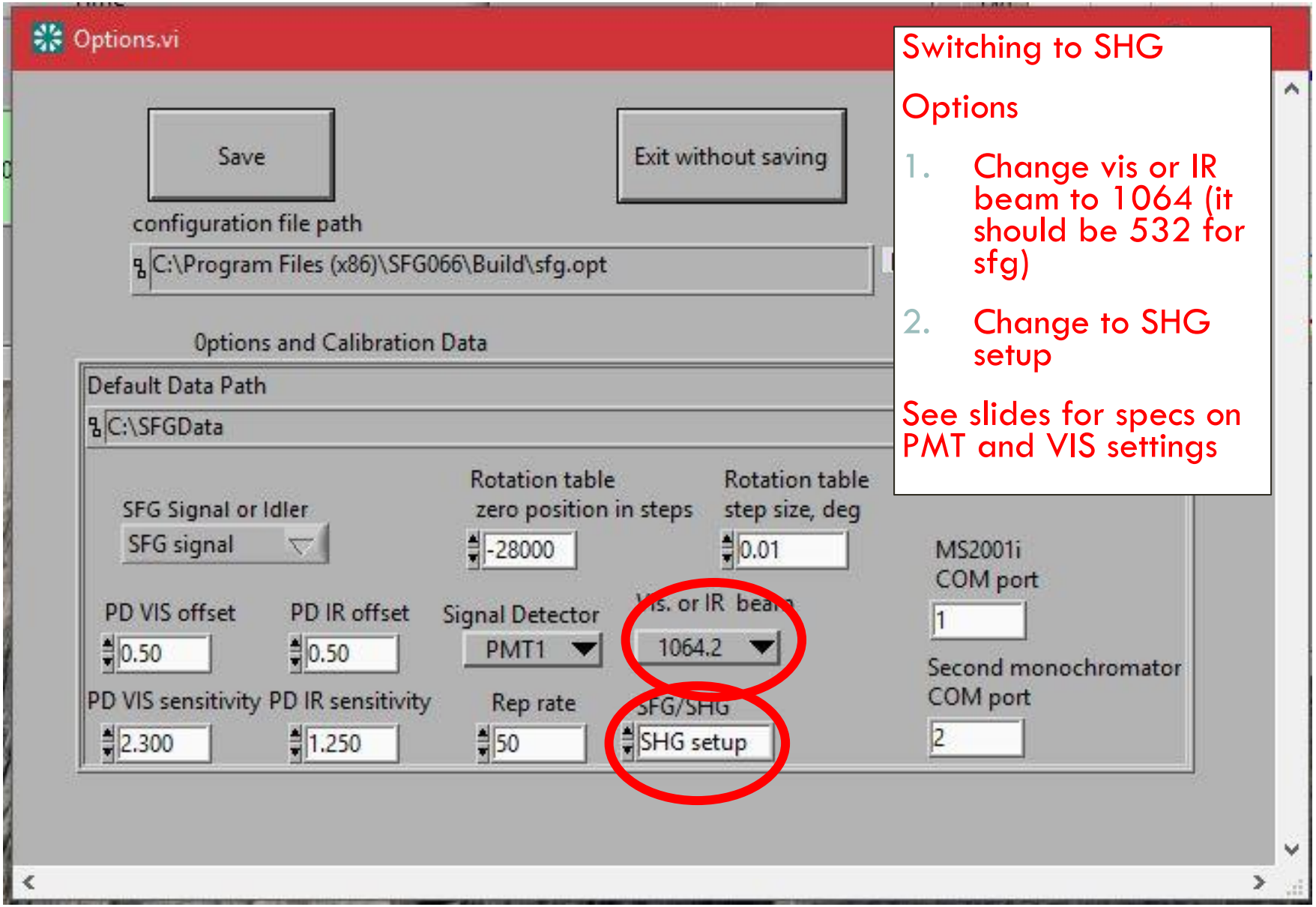
Wavelength PG/ DFG is your tuning wavelength




Set PMT to high when finding signal initially

For organics (thiols, etc.) on your surface set VIS intensity to 3 (adjust as needed)

Vis energy will be 1064 energ

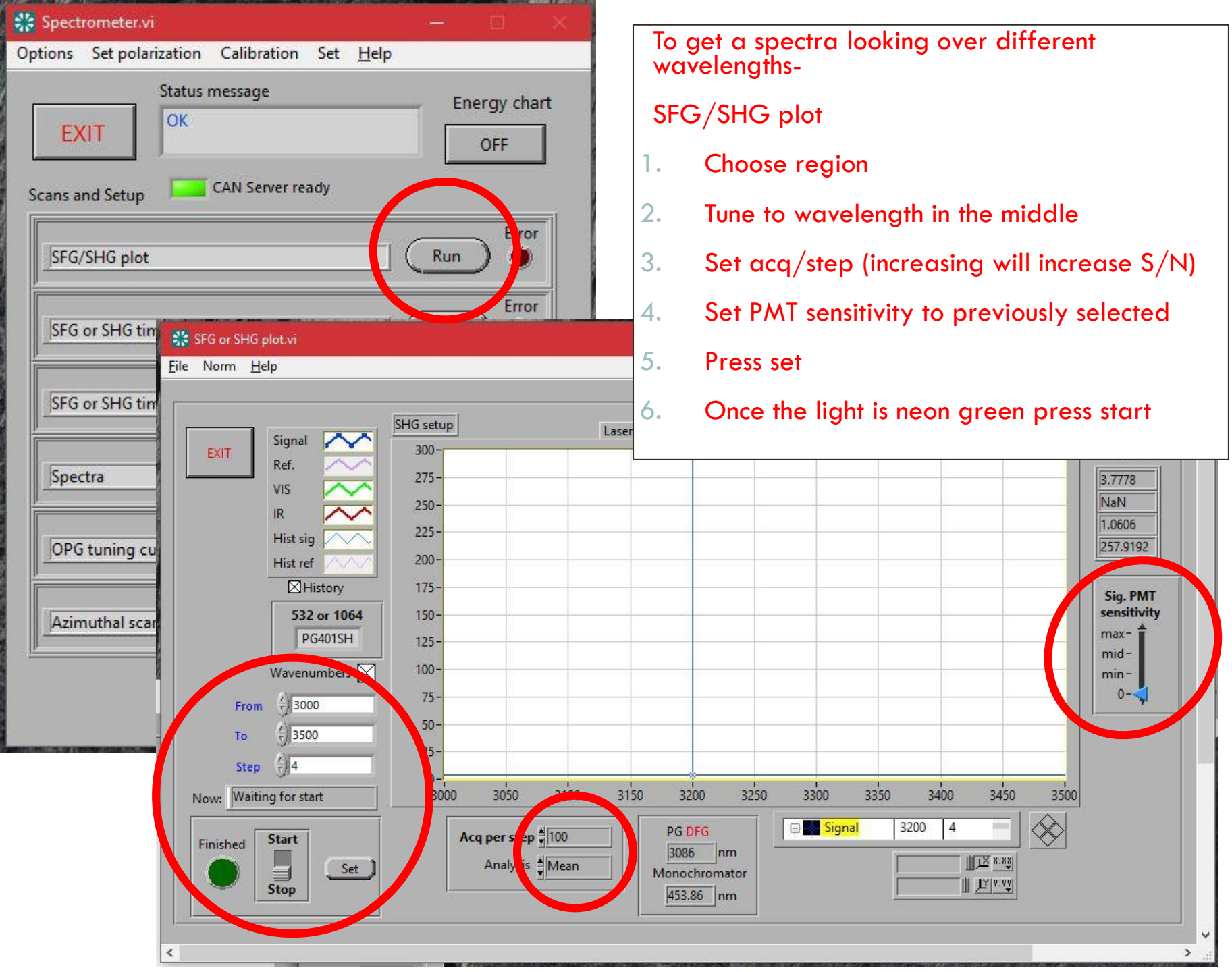



Switching to SHG

Options

1. Change vis or IR beam to 1064 (it should be 532 for sfg)
2. Change to SHG setup

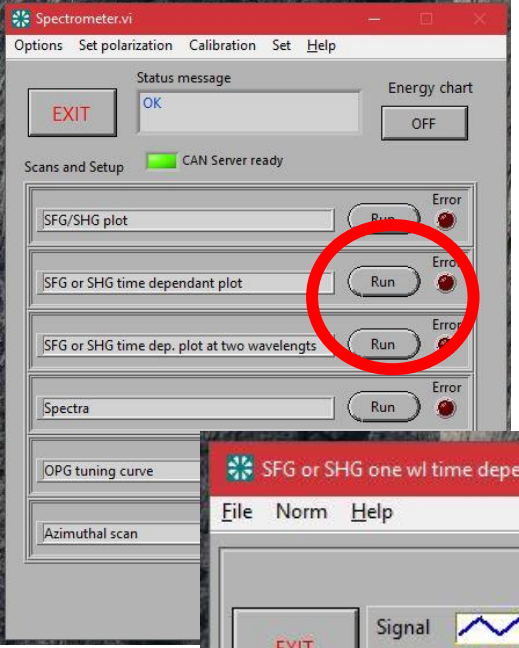
See slides for specs on PMT and VIS settings

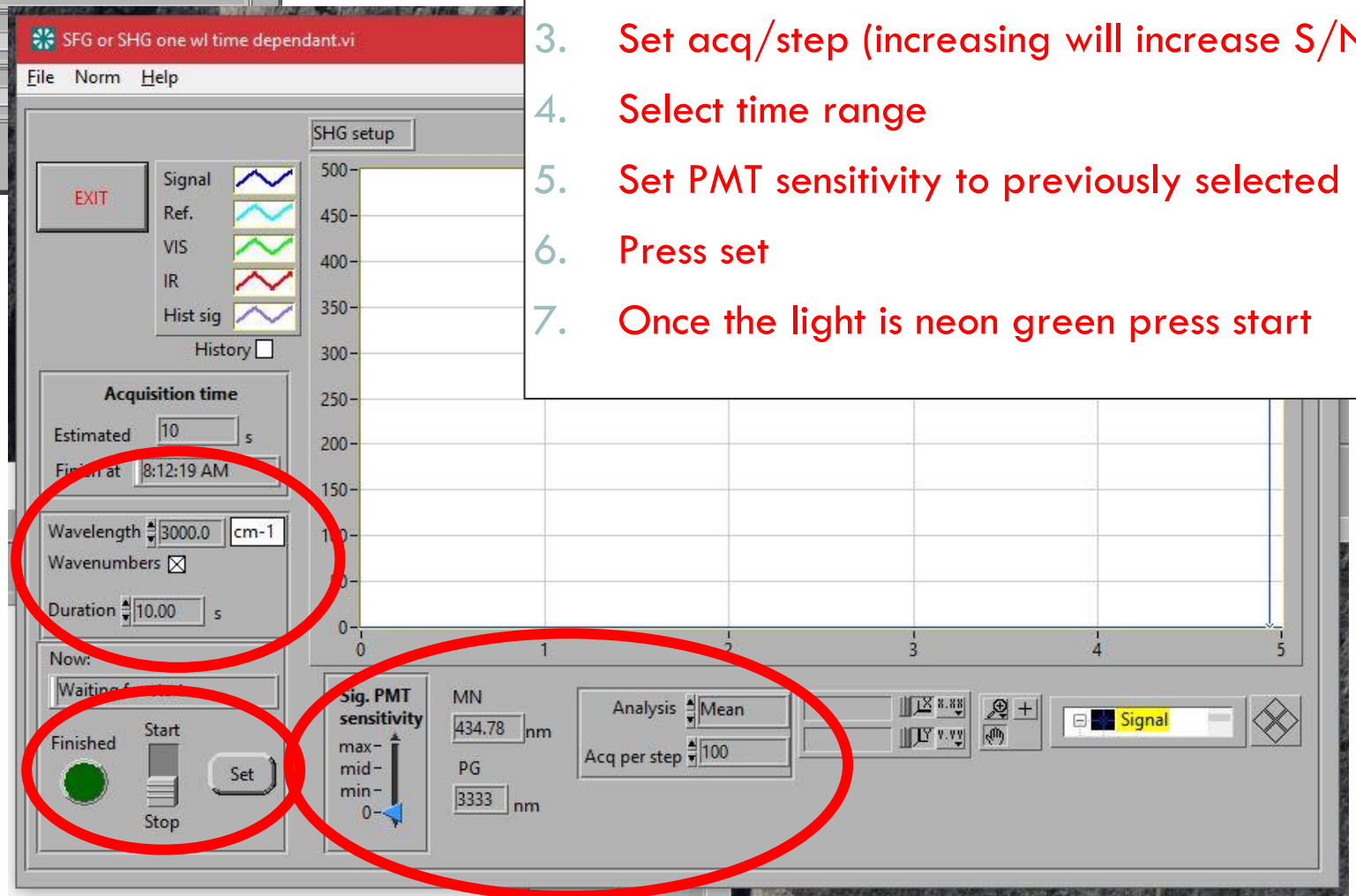



To get a spectra looking over different wavelengths-

SFG/SHG plot

1. Choose region
2. Tune to wavelength in the middle
3. Set acq/step (increasing will increase S/N)
4. Set PMT sensitivity to previously selected
5. Press set
6. Once the light is neon green press start

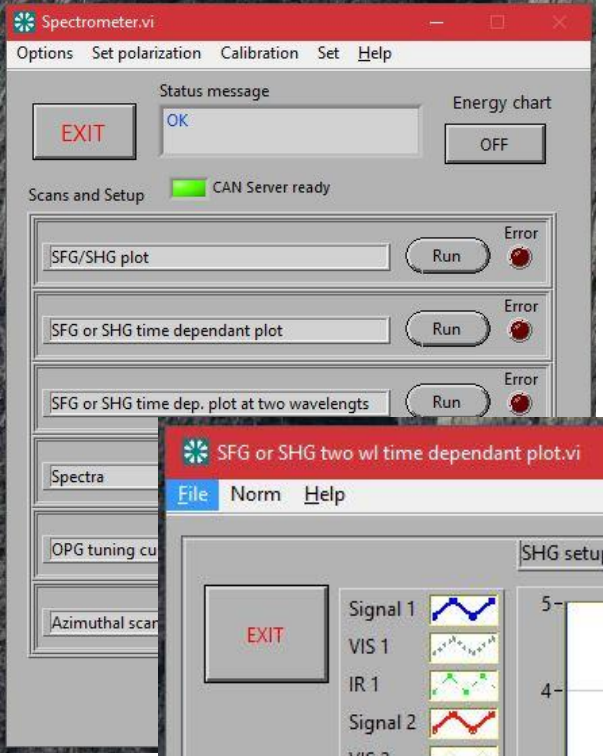


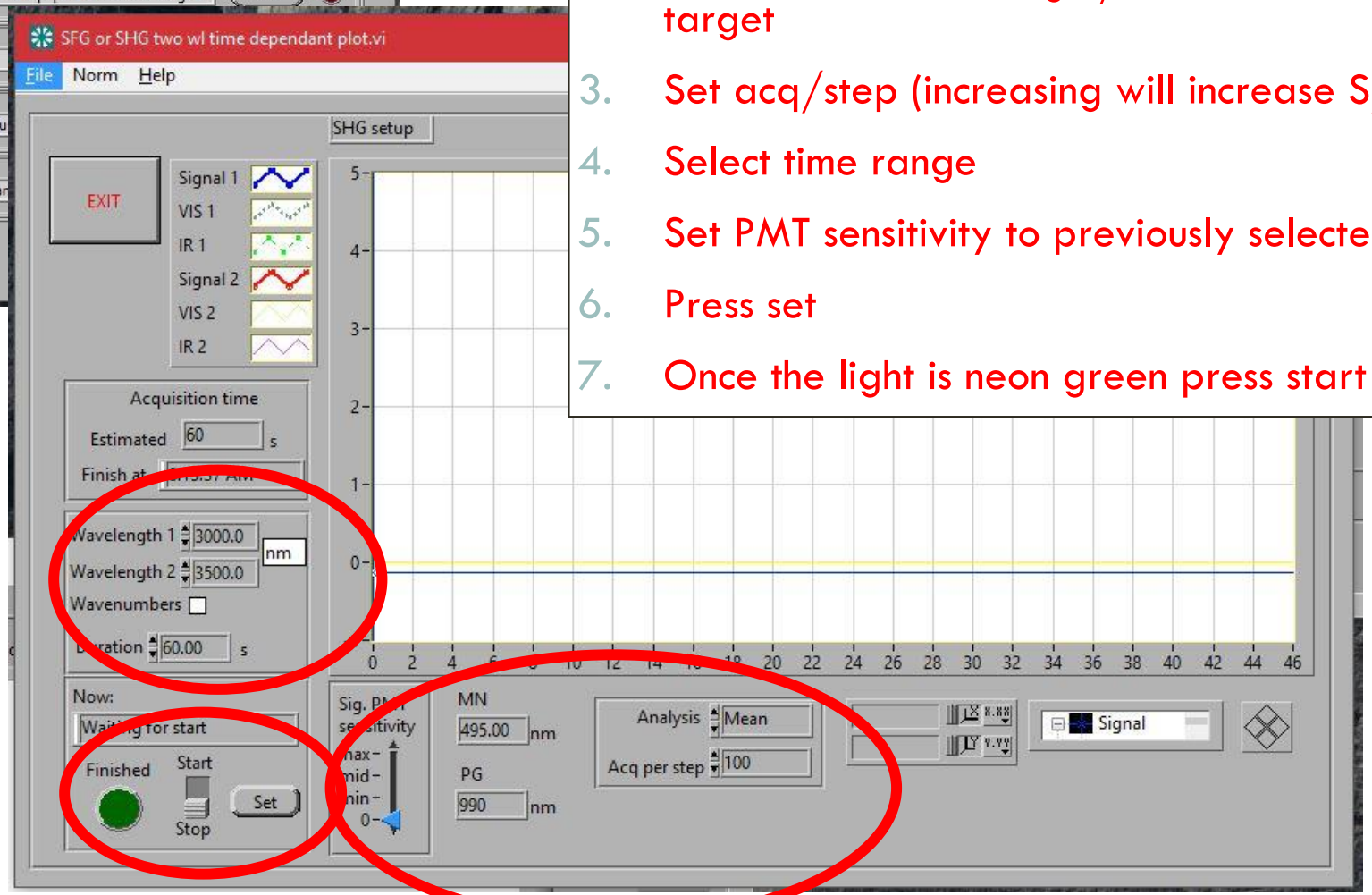




To get a spectra looking at a single wavelength as a function of time

SFG/SHG time dependent plot

1. Choose wavelength of interest (for SHG it will be 532 nm)
2. Tune to max wavelength
3. Set acq/step (increasing will increase S/N)
4. Select time range
5. Set PMT sensitivity to previously selected
6. Press set
7. Once the light is neon green press start

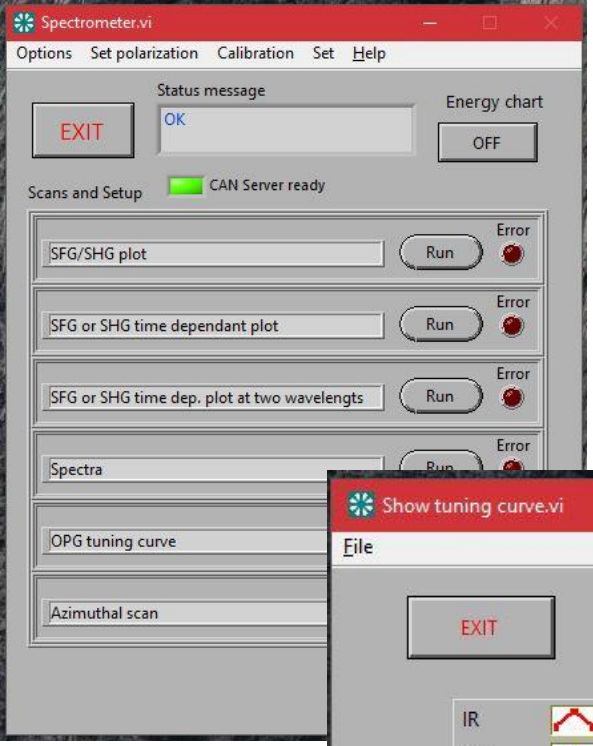


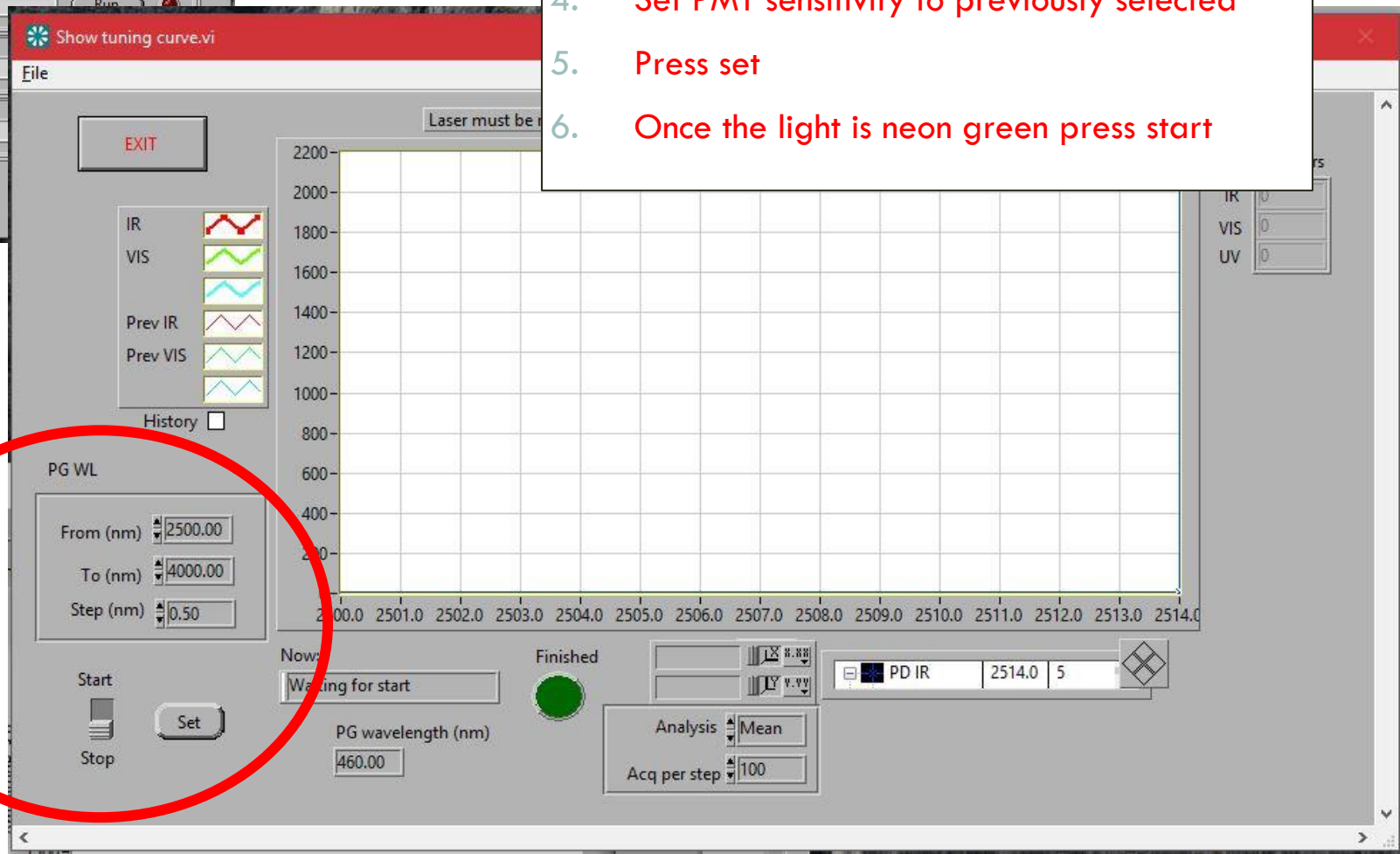




To get a spectra looking at two selective wavelengths as a function of time

SFG/SHG time dependent plot

1. Choose wavelength of interest (for SHG it will be 532 nm)
2. Tune to max wavelength/ max in between target
3. Set acq/step (increasing will increase S/N)
4. Select time range
5. Set PMT sensitivity to previously selected
6. Press set
7. Once the light is neon green press start




To get a spectra looking over different wavelengths-

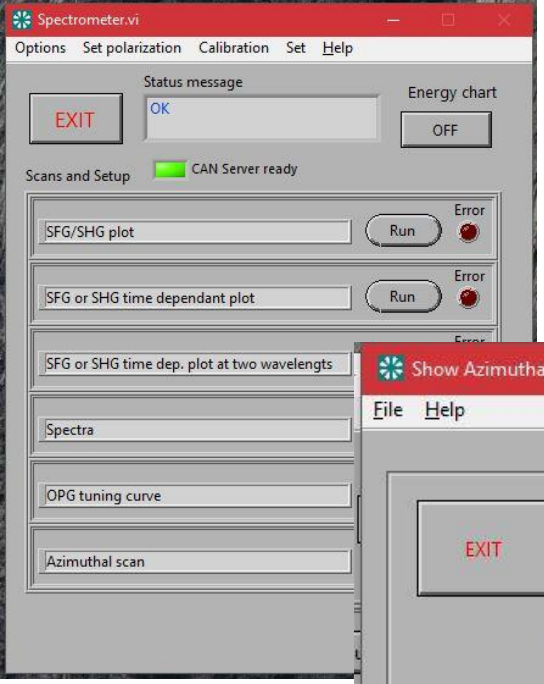
SFG/SHG plot

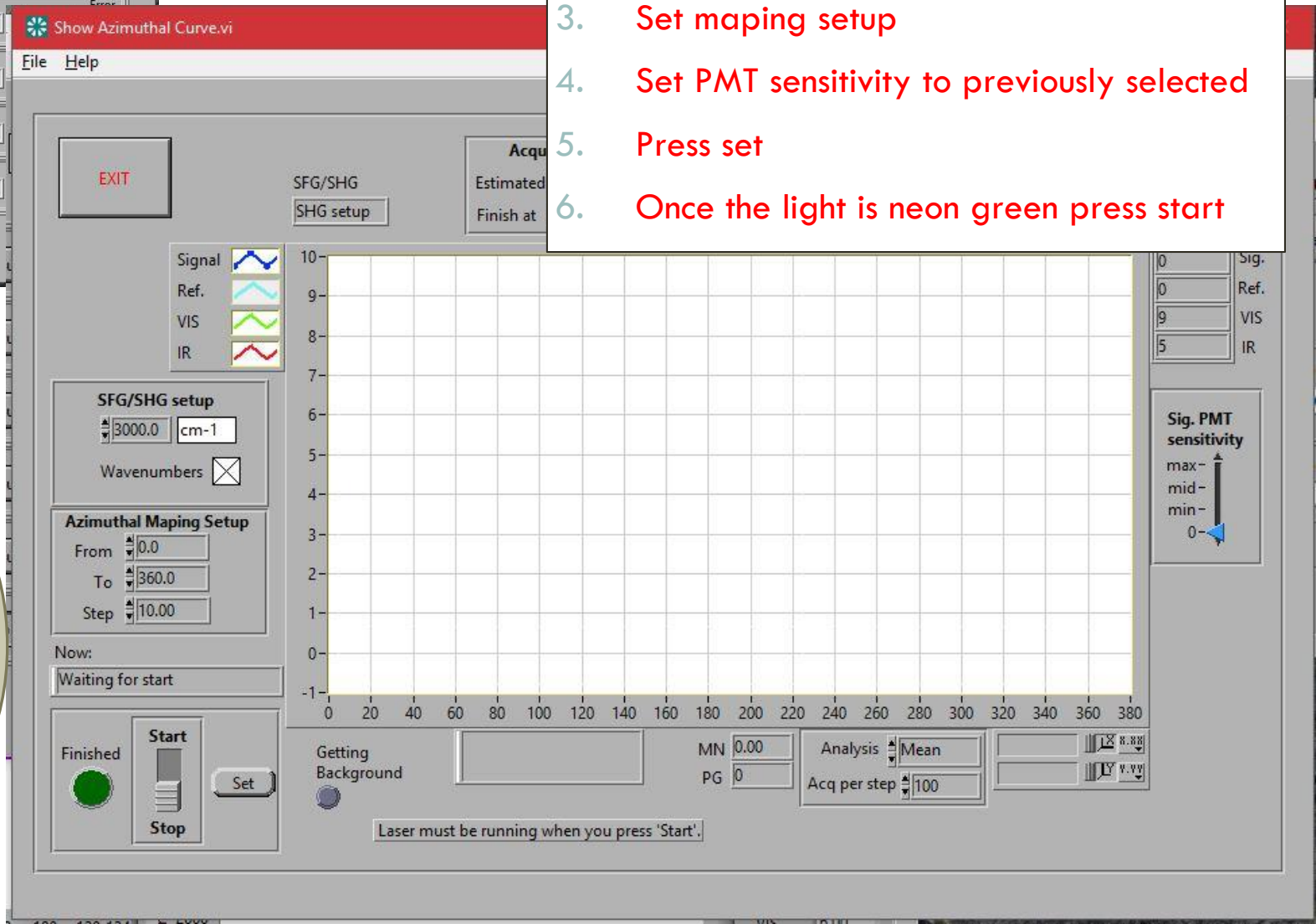
1. Choose region
2. Tune to wavelength in the middle
3. Set acq/step (increasing will increase S/N)
4. Set PMT sensitivity to previously selected
5. Press set
6. Once the light is neon green press start

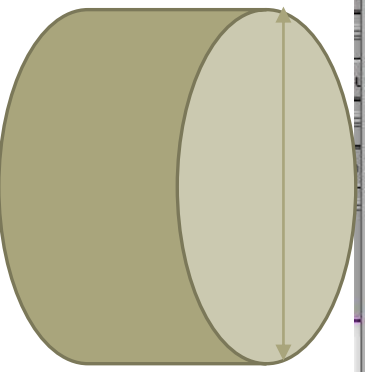
To get a spectra looking over azimuthal orientation

Azimuthal scan

1. Wavelength
2. Tune
3. Set maping setup
4. Set PMT sensitivity to previously selected
5. Press set
6. Once the light is neon green press start



Energy readout

Blue- signal

Green- VIS

Red- IR

If your signal is SFG, then the blue line should drop to zero when closing a shutter at a time

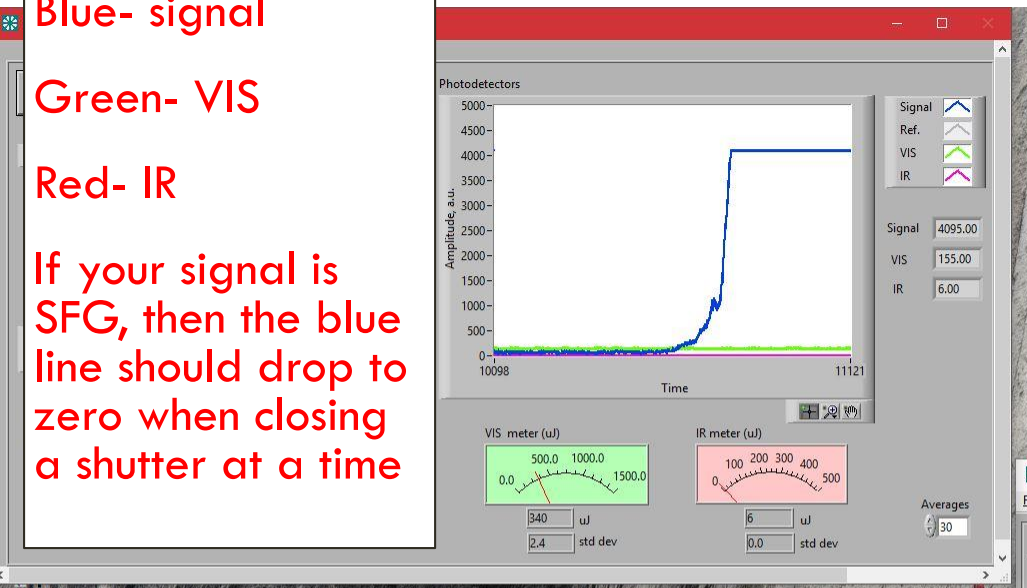
Plot of choice,

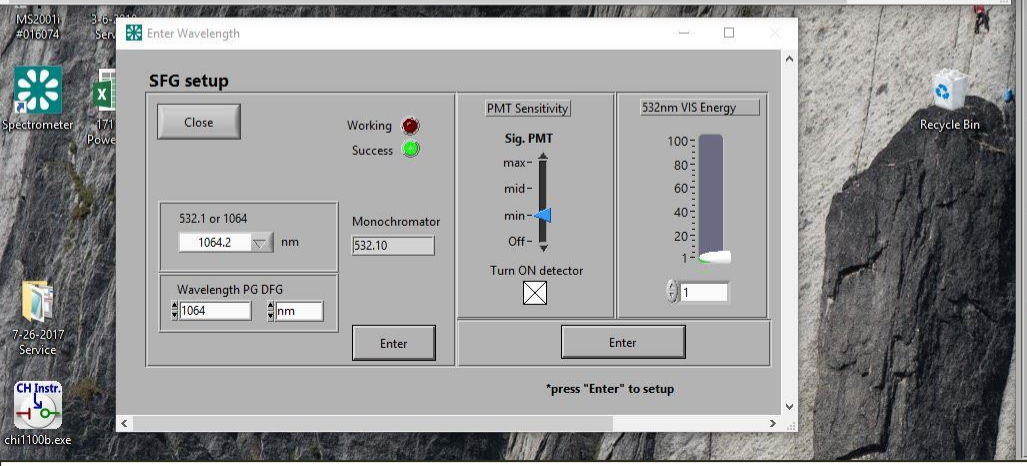
This should display each beam intensity and you can export to correct for drops

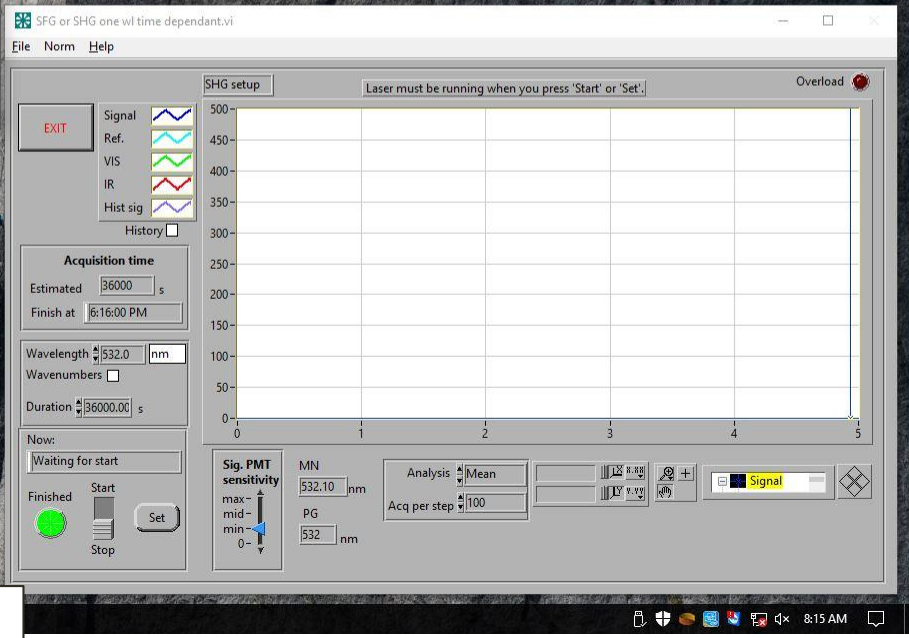
File save as…

You can also click NORM and it will correct for drops in IR intensity only

File export to excel

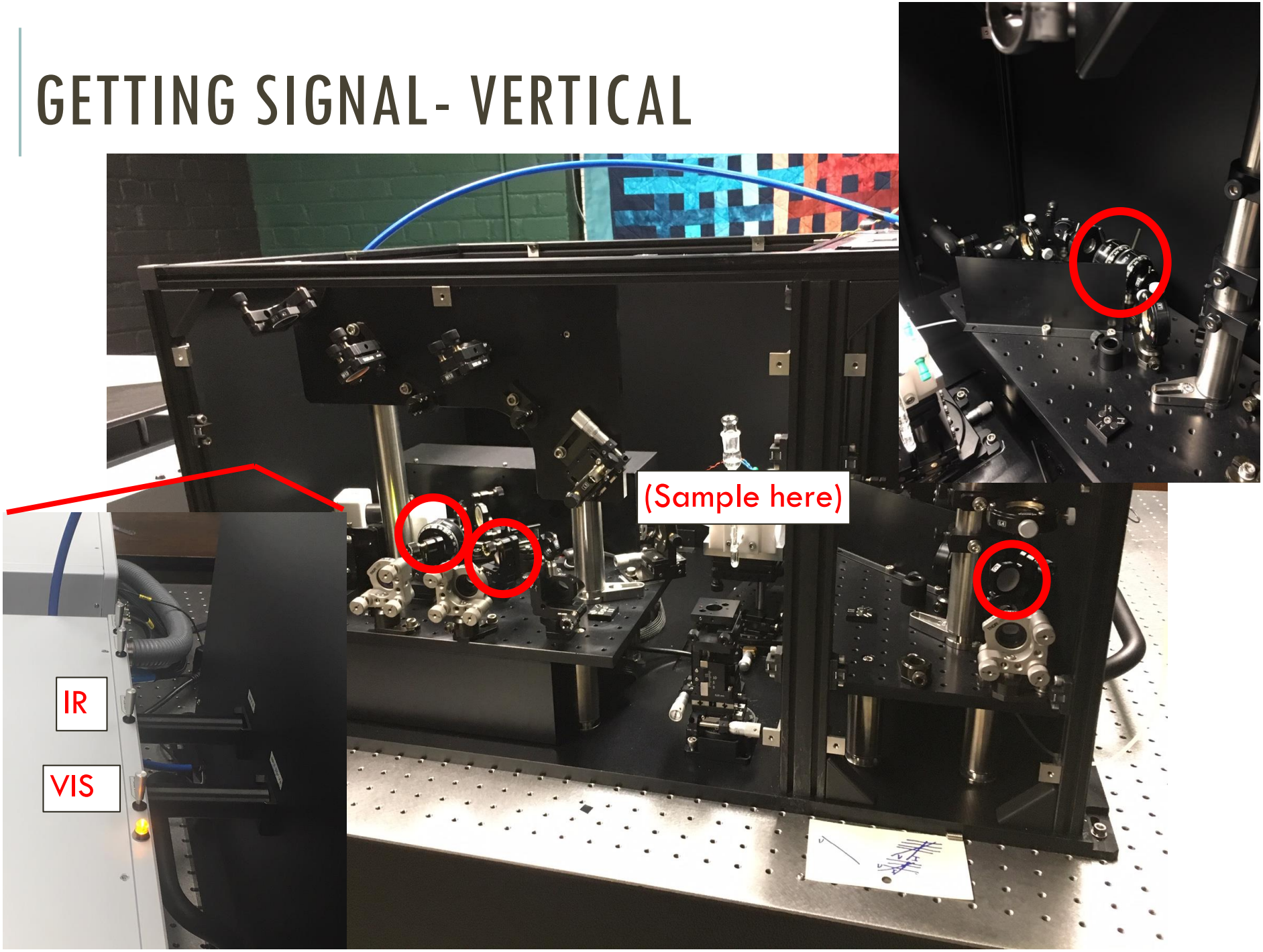


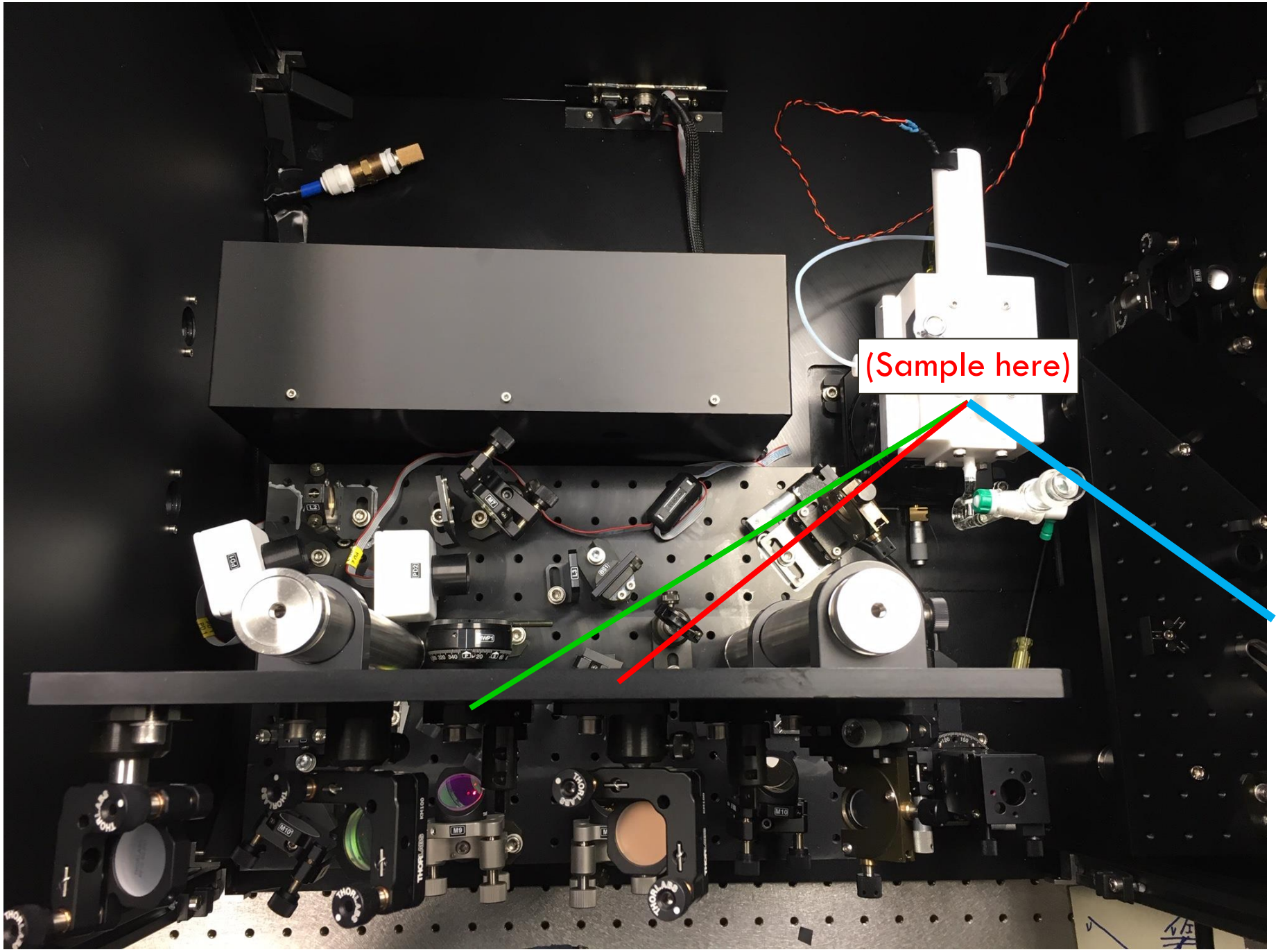




Sfg setup panel- for selecting VIS (SFG)/ 1064 (SHG) , PMT sensitivity, and wavelength (532 (SFG) or 1064 (SHG)

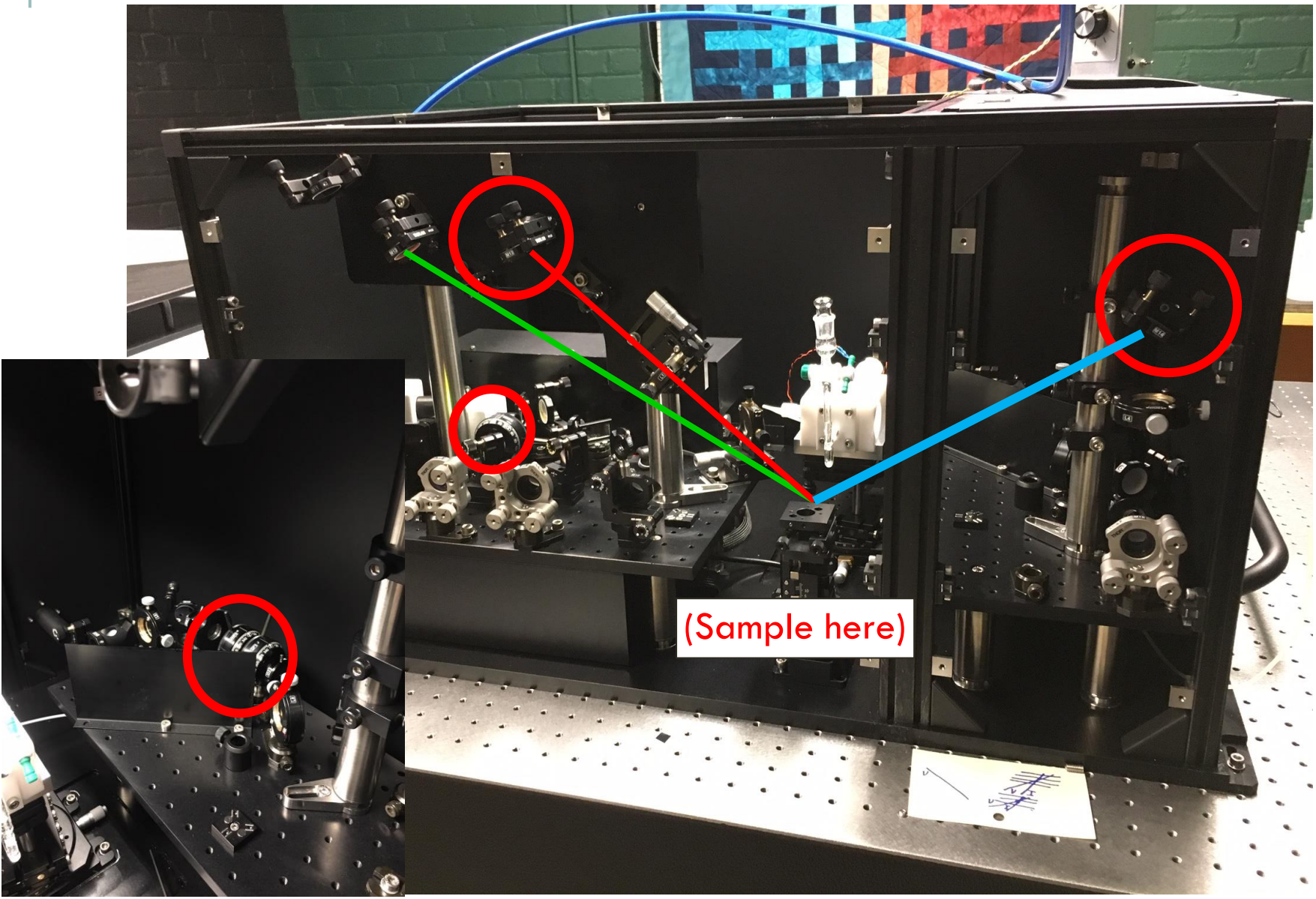
# GETTING SIGNAL- VERTICAL




(Sample here)

# GETTING SIGNAL- HORIZONTAL

Make sure to remove M16!!!



# TROUBLE SHOOTING

| | | | |
|---|---|---|---|
| E1 is down from 100 (drastically) | Check RAM and M2 in Laser | Try Adjusting | Try increasing temperature if no effect, ry increasing current on laser diode |
| No signal? | It is probably your surface or sample try rotating stage or adjusting height | Check parameters (wavelength you are turning to, etc) | Go back to M8, M13 |
| Overloading PMT | Turn down the VIS Power and PMT sensitivity | Turn down AMP | Unfocus the IR beam (L2) |