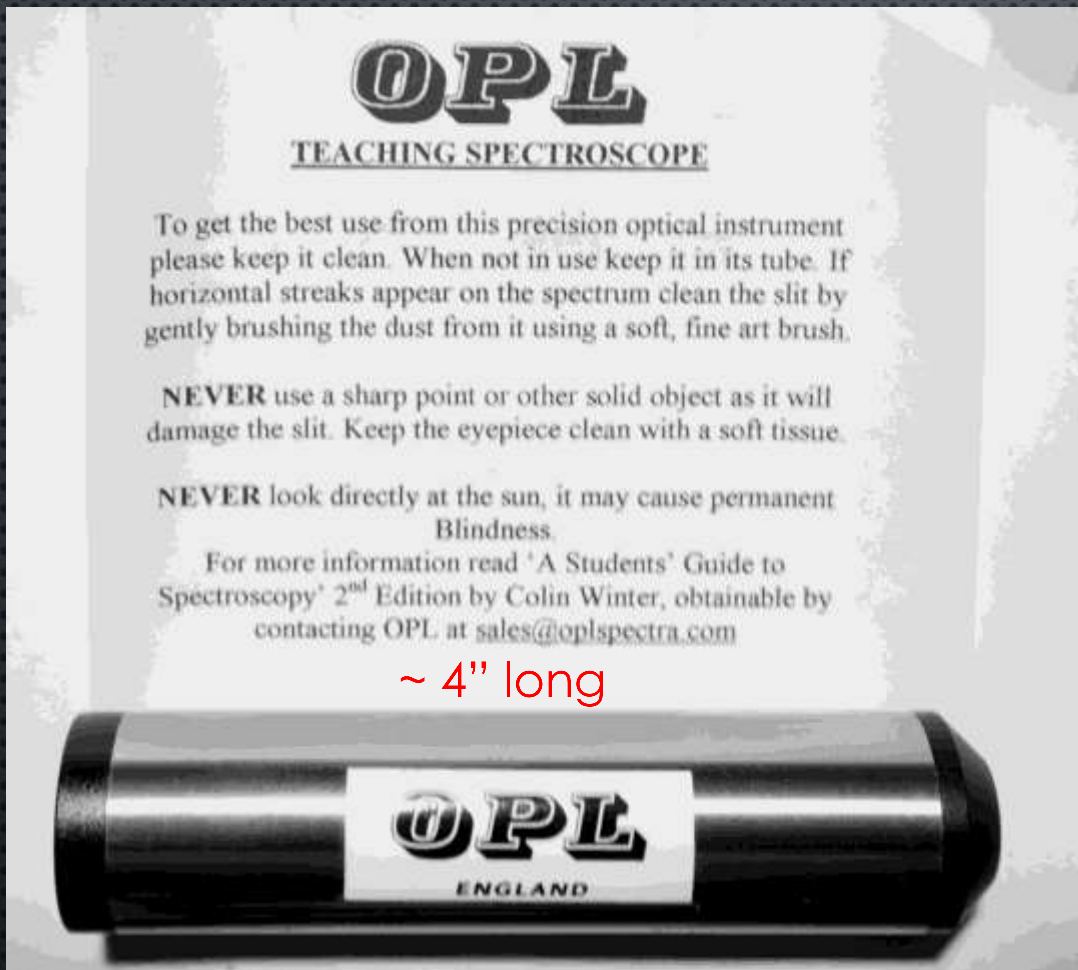
Turning a Teaching Spectroscope into a Spectrometer

Paul M. Adams
January 3, 2020

Use teaching spectroscope to observe fluorescence.
Record spectrum with Olympus TG camera



OD of spectroscope is 0.975-0.980"

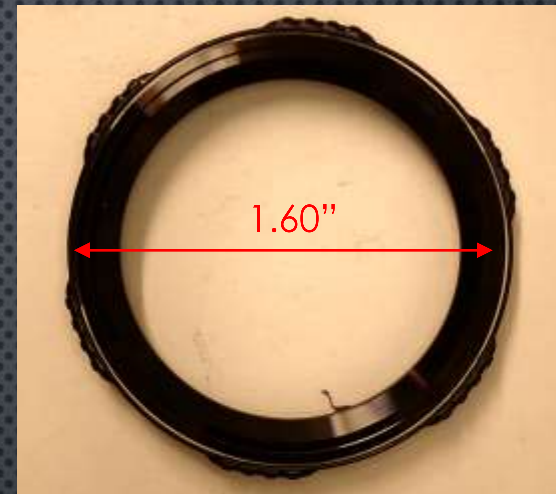
This would be ~ ID of the adapter, + 0.005"?

Will have to remove OPL sticker if it interferes?

Purchased ($100) from Mathais of Mikon (also Shannon Minerals)
https://www.shannonsminerals.com/shop/index.php/shannonsminerals/opl-teaching-spectroscope-1.html

Camera with bayonet ring installed

Outside of ring



1.60” = OD of adapter

Camera with bayonet ring removed

Inside of ring with bayonet

Create adapter from PVC fitting epoxied to camera bayonet mount

Camera: A-mode, Auto WB, 16M
Adjust exposure offset as necessary.

The adapter should be centered and level on the bayonet ring. I tried using a circular bubble level when doing the epoxy job but screwed up because the bubble level was ~ the same diameter as the PVC tube and wasn't level on the tube. As a result the spectroscope is tilted with respect to the camera. The ID of the PVC coupler was machined out to the OD of the spectroscope. The set screws hold the scope in place but also allow some alignment adjustment. Spectroscope was inserted all the way to the camera window.

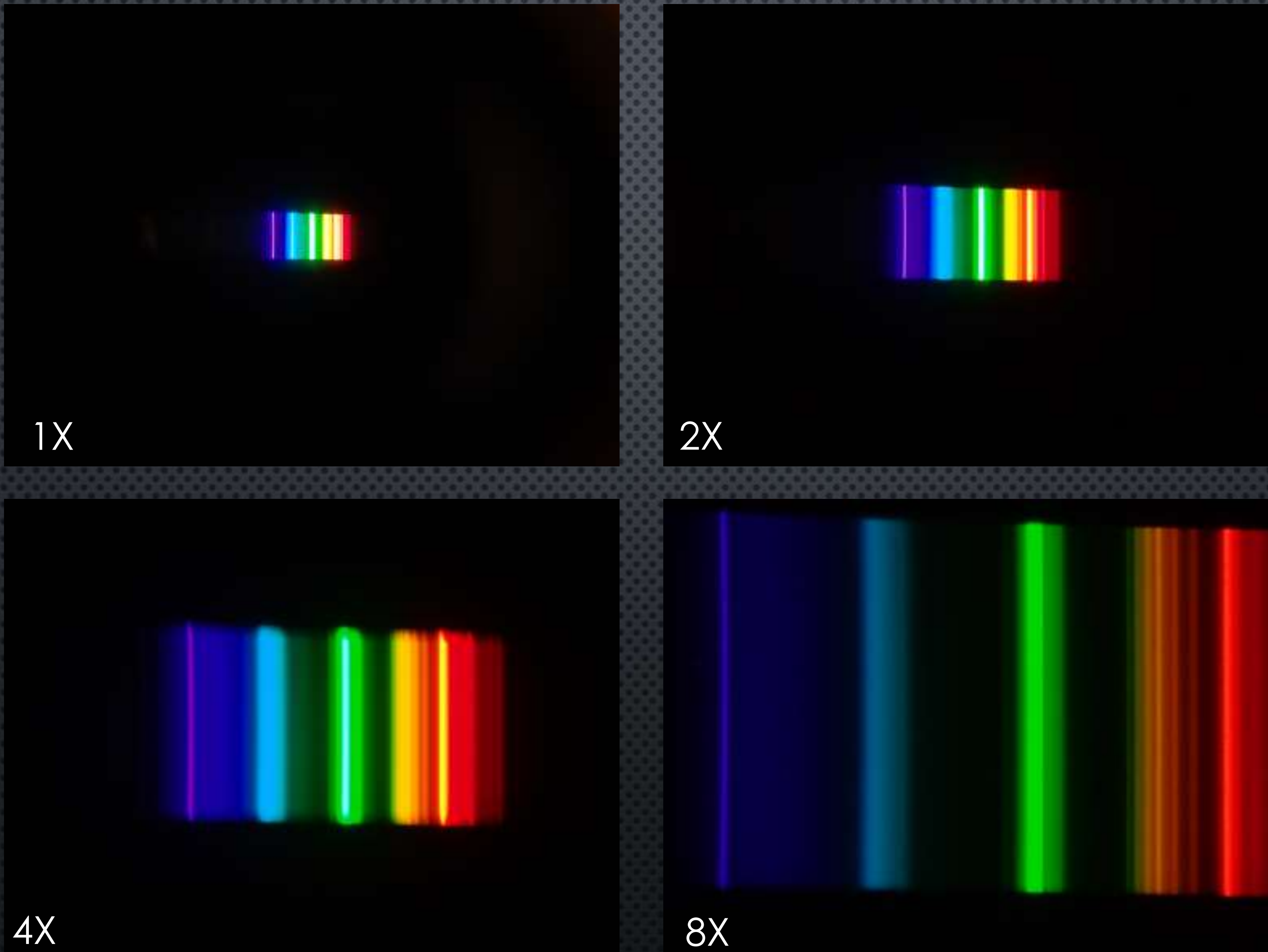
Olympus TG-3 camera

Epoxy adapter tube to bayonet mount that came with camera, but which is removed to use ring light

Spectroscope

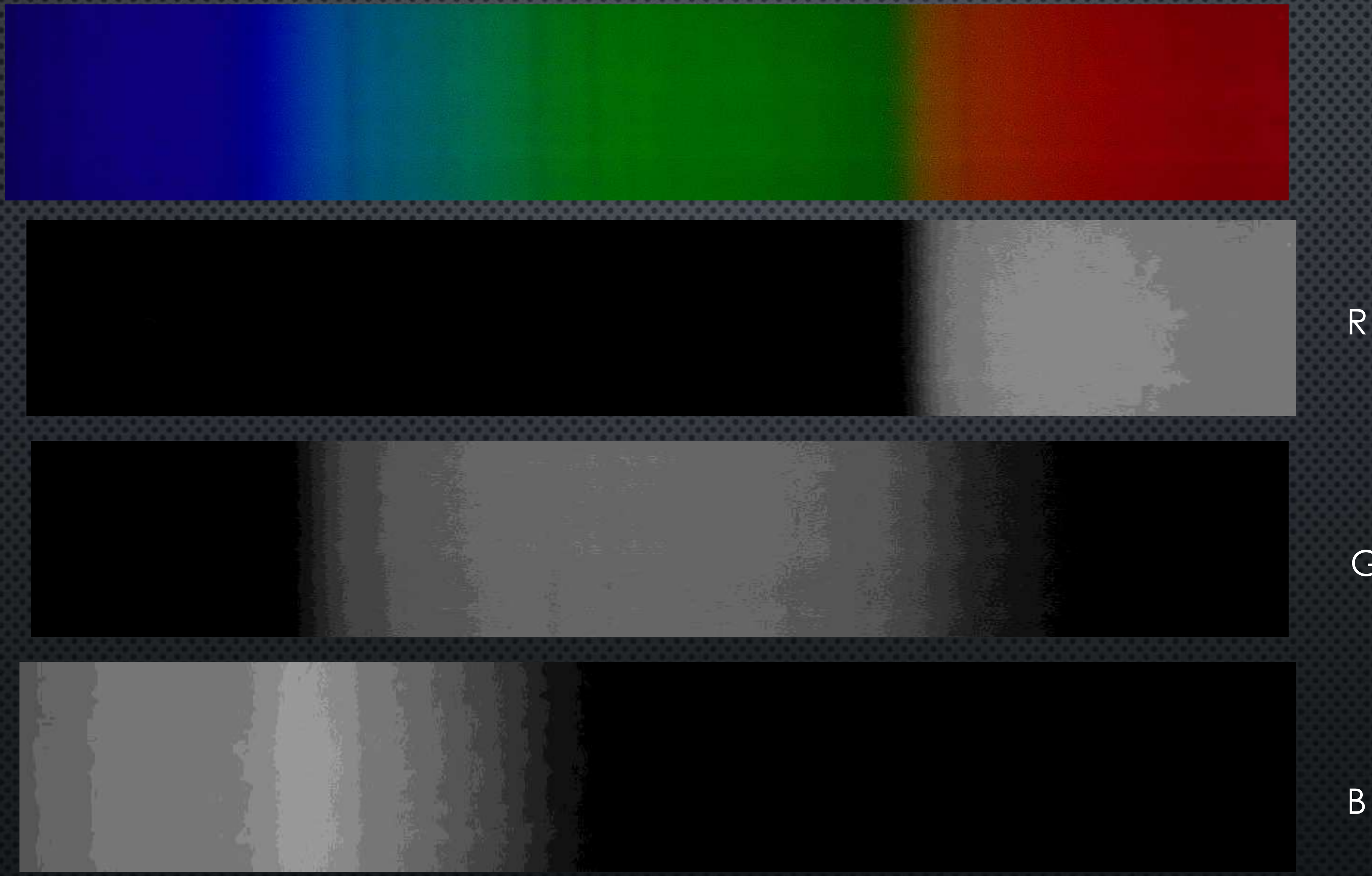
Zoom lens to maximum so spectrum fills field of view. Keep zoom setting the same for wavelength calibration and recording samples!

Compact Fluorescent Lamp Calibration Spectrum as a Function of Camera Zoom Level

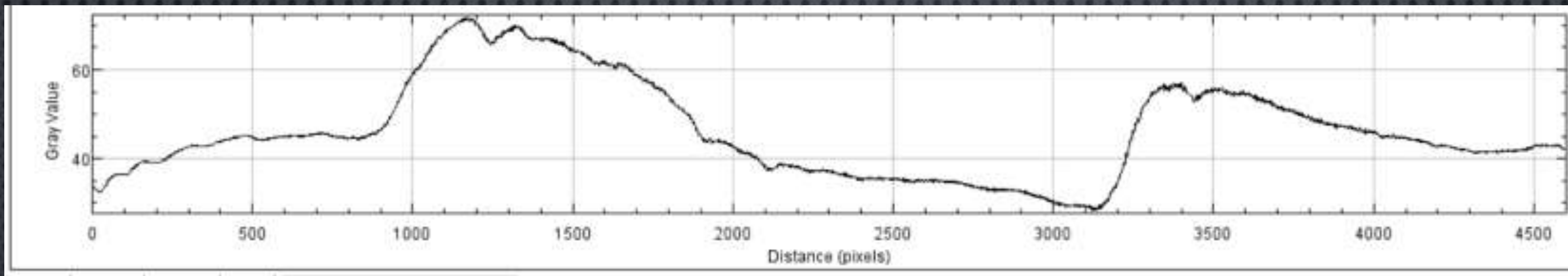


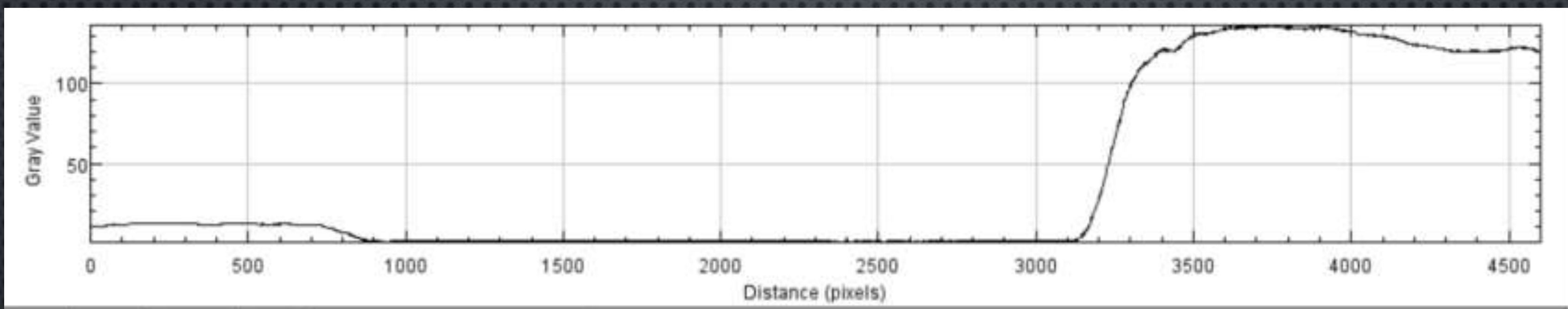
Note: spectrum is not optimally aligned

Solar Spectrum with Fraunhofer Lines broken into RGB Channels

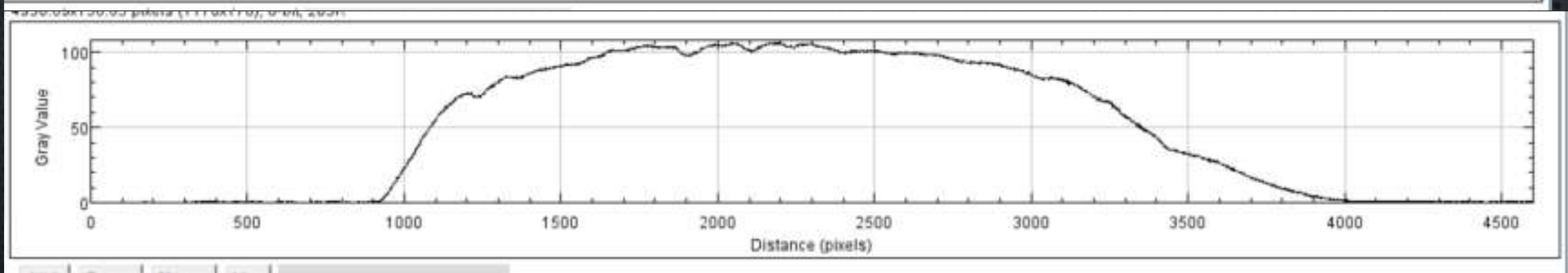


Solar Spectrum with Fraunhofer Lines

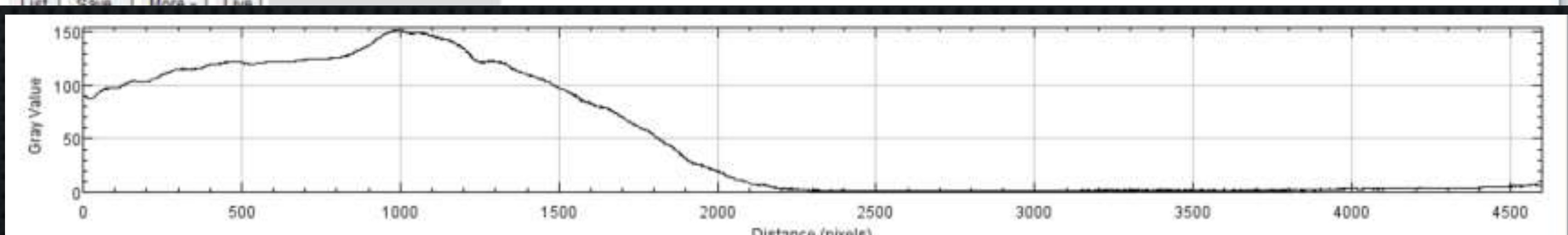




R

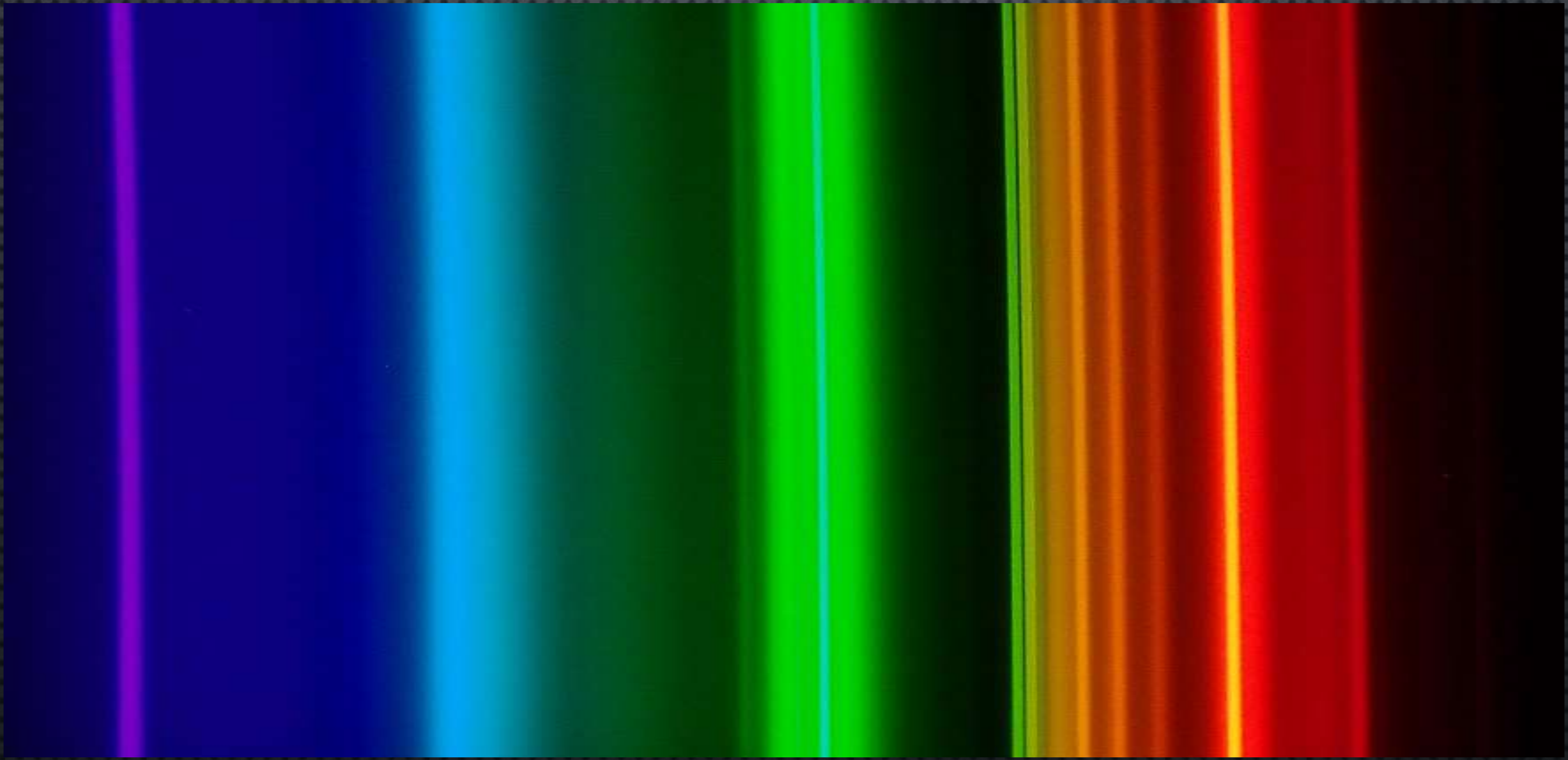


G

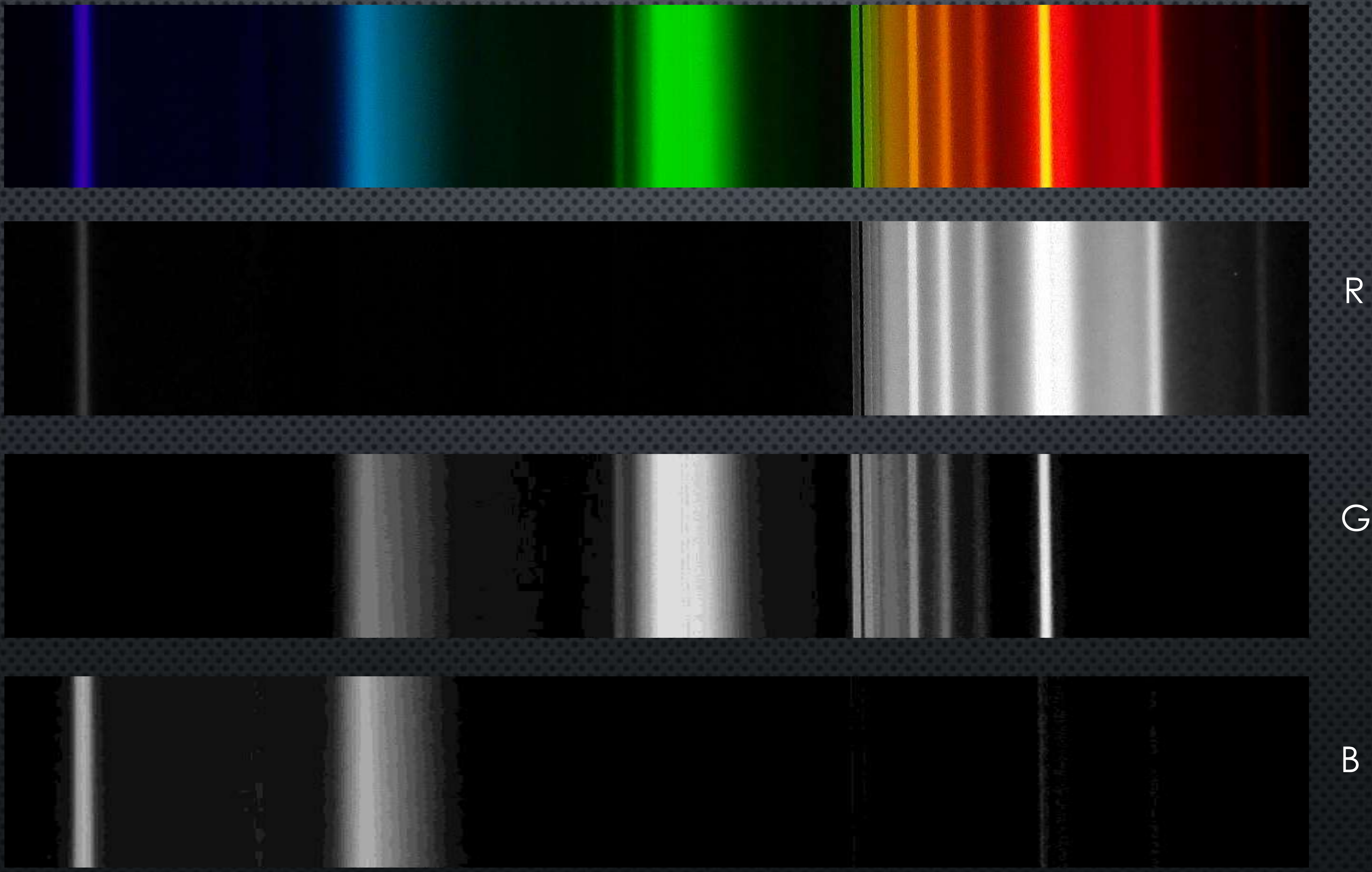


B

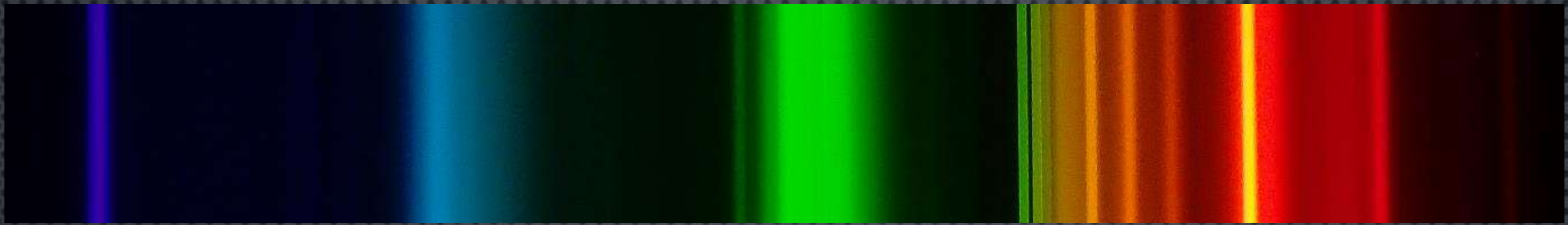
Compact Fluorescent Lamp Calibration Spectrum

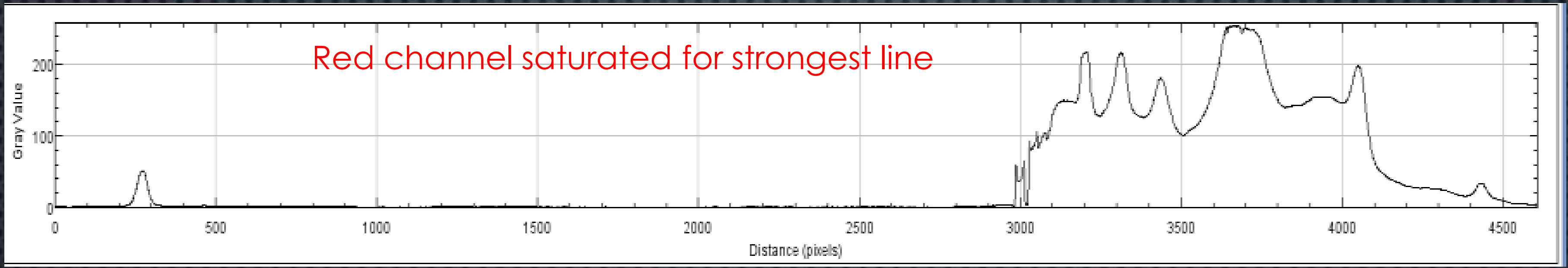


Compact Fluorescent Cal Spectrum Broken Down into Red-Green-Blue Channels

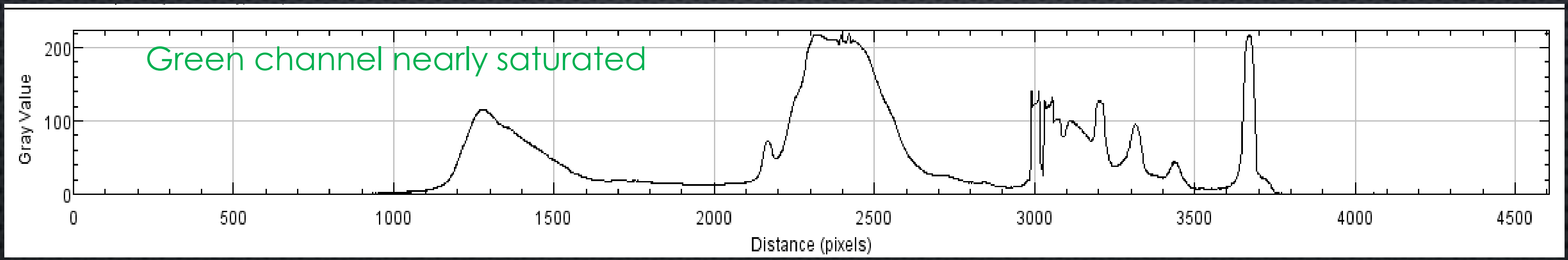


Compact Fluorescent Cal Spectrum





R



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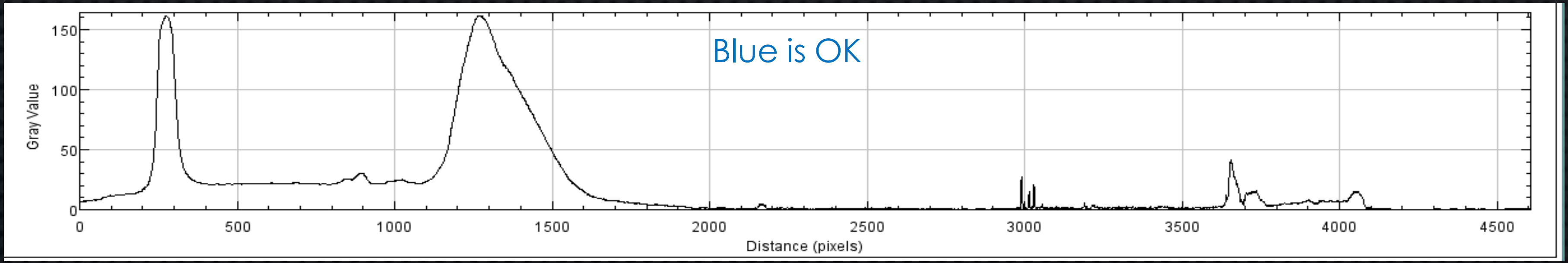


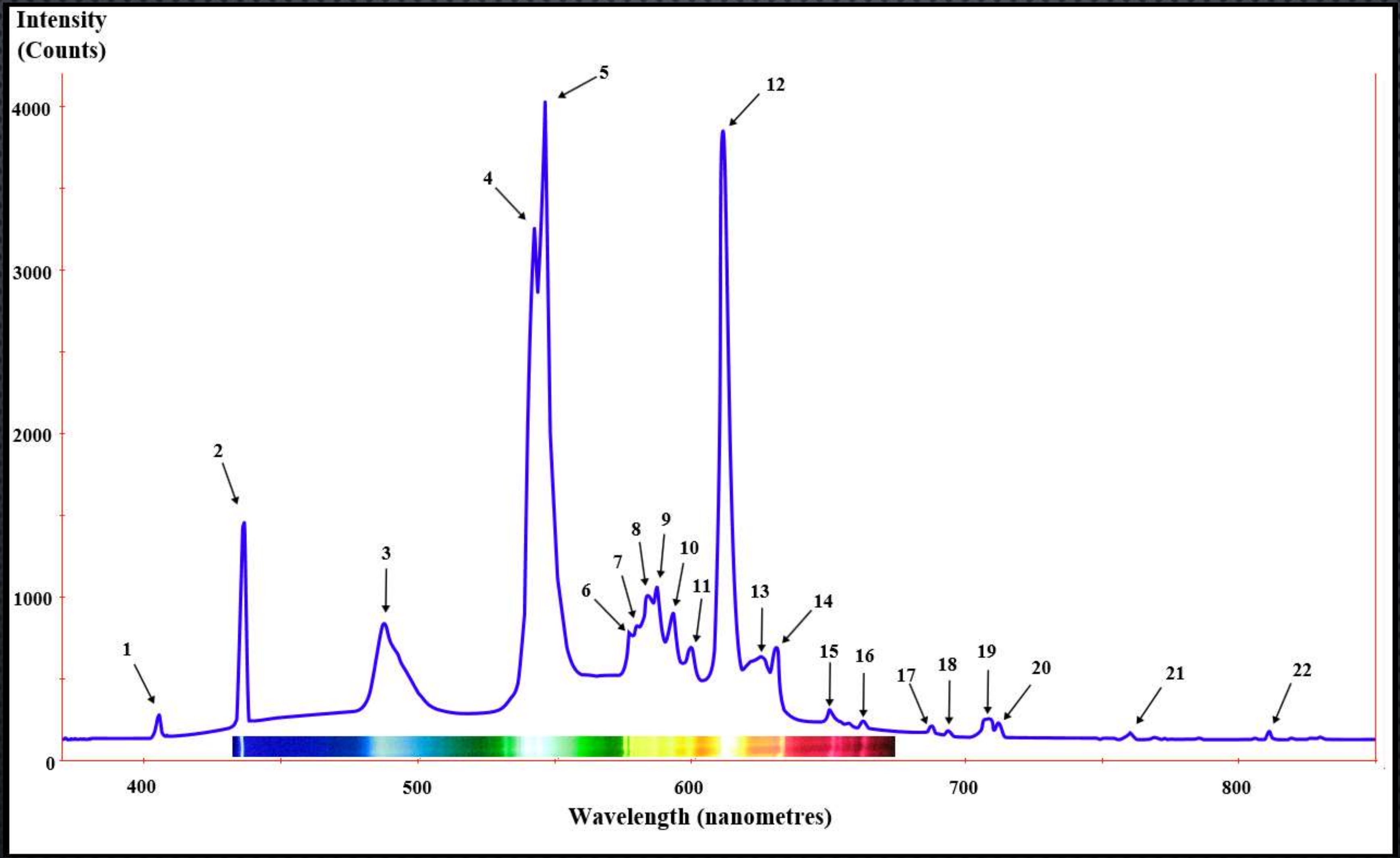
B

Press "Info" button on TG (repeatedly) until live histogram is displayed.
Used to optimize exposure

Slightly underexposed, not all levels used. Increase exposure compensation > -2

Some channels overexposed, 255 max reached. Dial back exposure compensation < +2

Fluorescent Lamp Spectrum



https://commons.wikimedia.org/wiki/File:Fluorescent_lighting_spectrum_peaks_labelled.gif

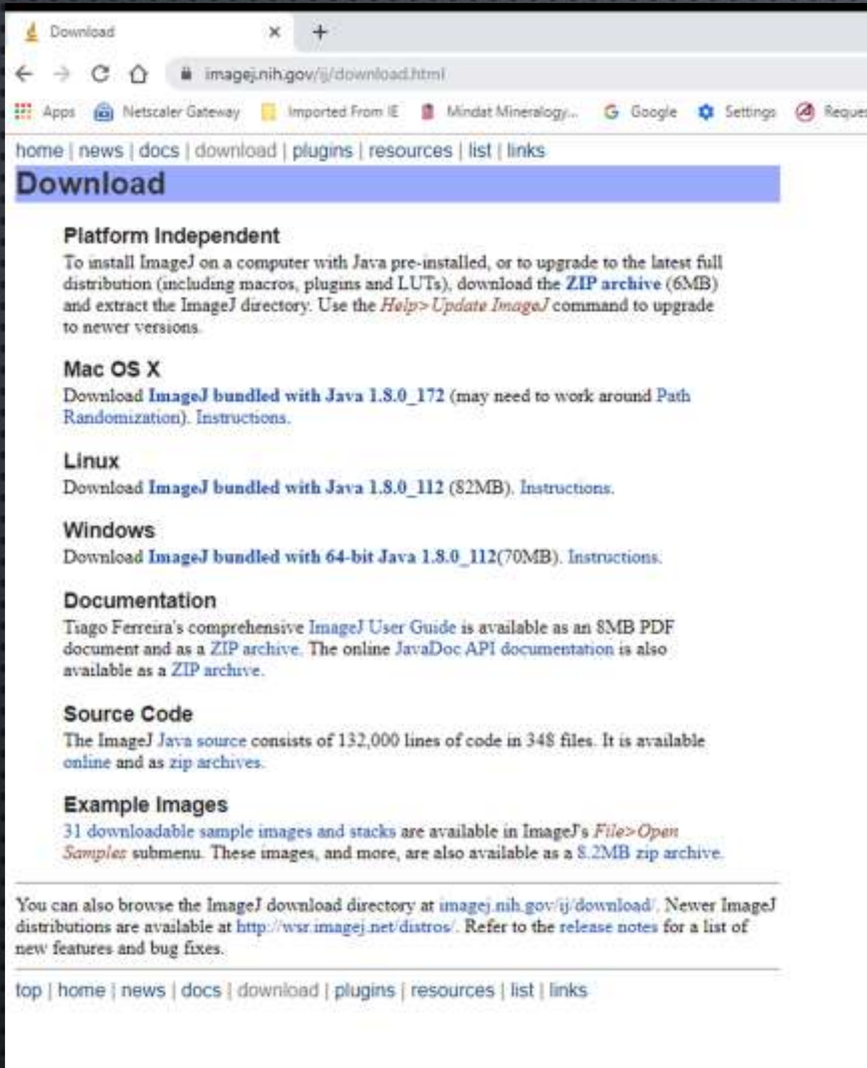
Fluorescent Lamp

Peak number	Wavelength of peak (nm)	Species producing peak	Actual line location (nm)
1	405.4	mercury	404.656
2	436.6	mercury	435.833
3	487.7	terbium from Tb^{3+}	~485 to 490
4	542.4	terbium from Tb^{3+}	~543 to 544
5	546.5	mercury	546.074
6	577.7	likely terbium from Tb^{3+} or mercury	576.960 for Hg or ~578 for Tb
7	580.2	mercury or terbium from Tb^{3+}	579.066 for Hg or ~580 for Tb
8	584.0	possibly terbium from Tb^{3+} or europium in $Eu^{+3}:Y_2O_3$	~580
9	587.6	likely europium in $Eu^{+3}:Y_2O_3$	~587
10	593.4	likely europium in $Eu^{+3}:Y_2O_3$	~593
11	599.7	likely europium in $Eu^{+3}:Y_2O_3$	~598
12	611.6	europium in $Eu^{+3}:Y_2O_3$	~611
13	625.7	likely terbium from Tb^{3+}	~625
14	631.1	likely europium in $Eu^{+3}:Y_2O_3$	~630
15	650.8	likely europium in $Eu^{+3}:Y_2O_3$	~650
16	662.6	likely europium in $Eu^{+3}:Y_2O_3$	~661
17	687.7	likely europium in $Eu^{+3}:Y_2O_3$	~687-688
18	693.7	likely europium in $Eu^{+3}:Y_2O_3$	~693
19	707 and 709	likely europium in $Eu^{+3}:Y_2O_3$	~707 and ~709
20	712.3	likely europium in $Eu^{+3}:Y_2O_3$	~712
21	760.0	likely argon	758.9315 or 763.5106 (??)
22	811.0	likely argon	811.531

- Note that the terbium could be either Tb^{3+}, $Ce^{3+}:LaPO_4$ **or** $Tb^{3+}:CeMgAl_{11}O_{19}$.

https://commons.wikimedia.org/wiki/File:Fluorescent_lighting_spectrum_peaks_labelled.gif

Image-J/FIJI Download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imagej.nih.gov/ij/download.html

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Platform Independent

To install ImageJ on a computer with Java pre-installed, or to upgrade to the latest full distribution (including macros, plugins and LUTs), download the **ZIP archive** (6MB) and extract the ImageJ directory. Use the *Help>Update ImageJ* command to upgrade to newer versions.

Mac OS X

Download **ImageJ bundled with Java 1.8.0_172** (may need to work around Path Randomization). Instructions.

Linux

Download **ImageJ bundled with Java 1.8.0_112** (82MB). Instructions.

Windows

Download **ImageJ bundled with 64-bit Java 1.8.0_112**(70MB). Instructions.

Documentation

Tiago Ferreira's comprehensive ImageJ User Guide is available as an 8MB PDF document and as a ZIP archive. The online JavaDoc API documentation is also available as a ZIP archive.

Source Code

The ImageJ Java source consists of 132,000 lines of code in 348 files. It is available online and as zip archives.

Example Images

31 downloadable sample images and stacks are available in ImageJ's *File>Open Samples* submenu. These images, and more, are also available as a 8.2MB zip archive.

You can also browse the ImageJ download directory at imagej.nih.gov/ij/download/. Newer ImageJ distributions are available at http://wsr.imagej.net/distros/. Refer to the release notes for a list of new features and bug fixes.

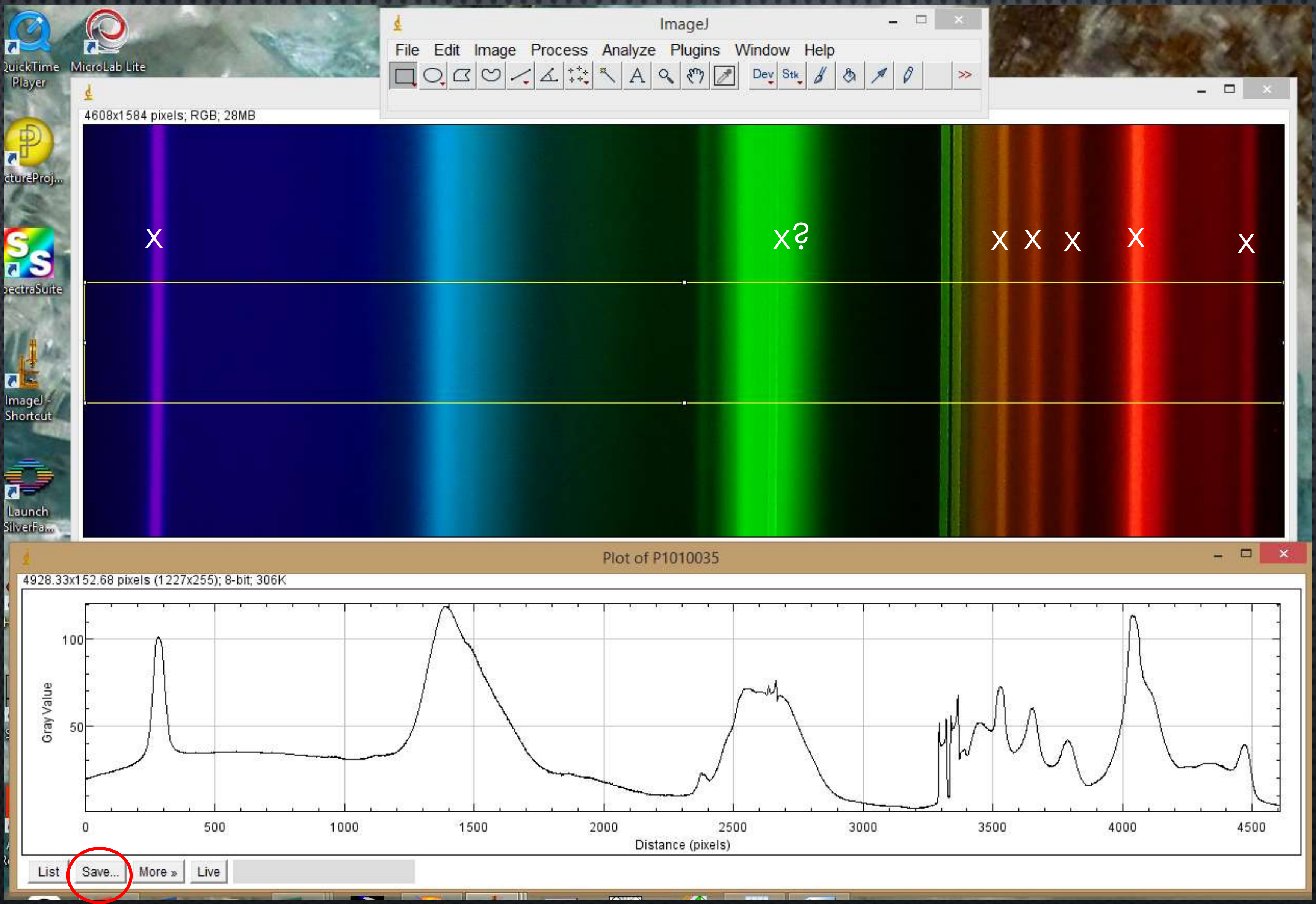
top | home | news | docs | download | plugins | resources | list | links

FIJI = Full Image-J Implementation

Includes all plugins-macros already installed . They are not necessary for using the spectroscope, but do take up more memory.

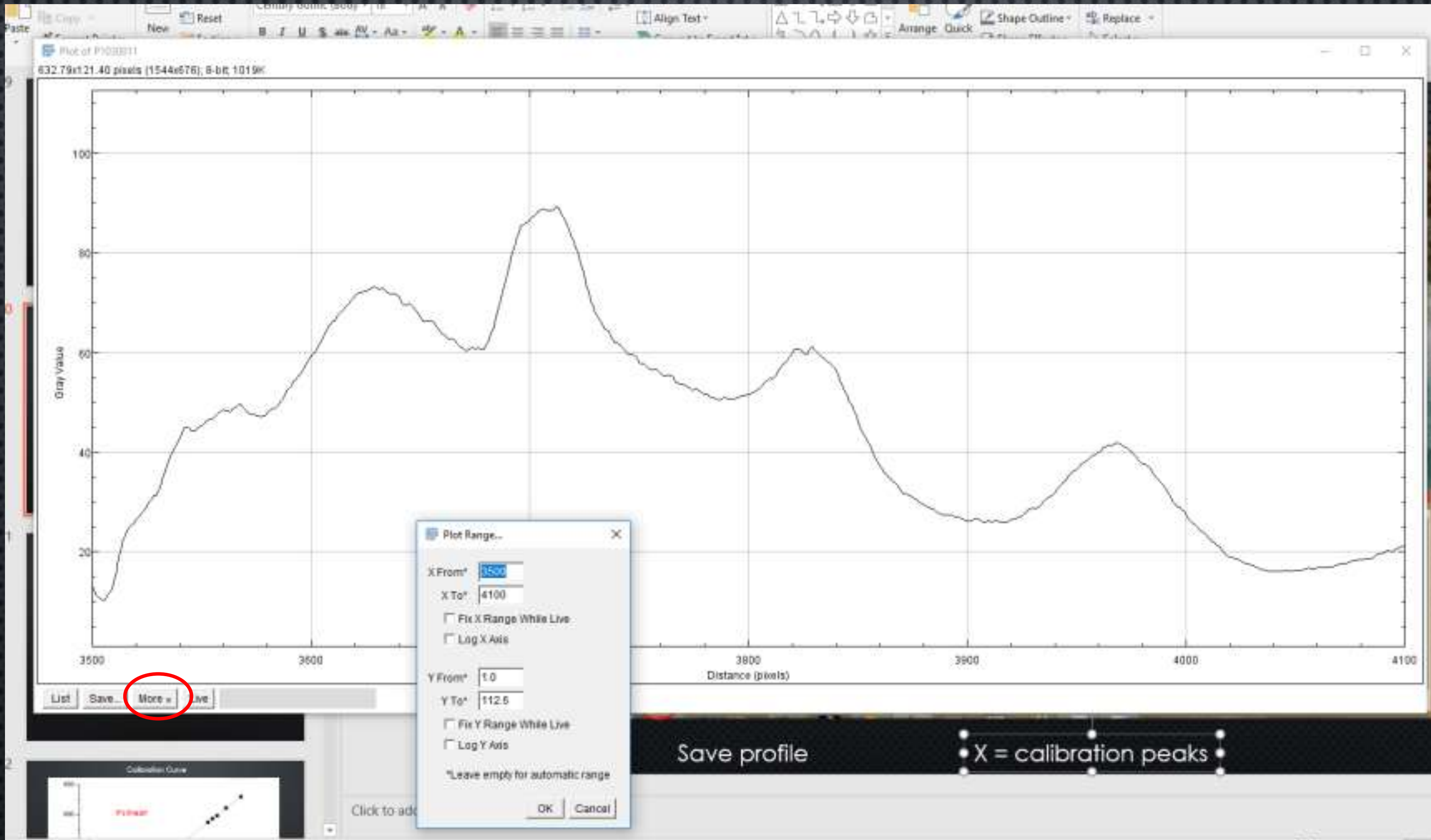
https://imagej.nih.gov/ij/download.html
https://imagej.net/Fiji/Downloads

Open images in Image-J. Crop. With Box-tool/ Analyze/Plot Profile



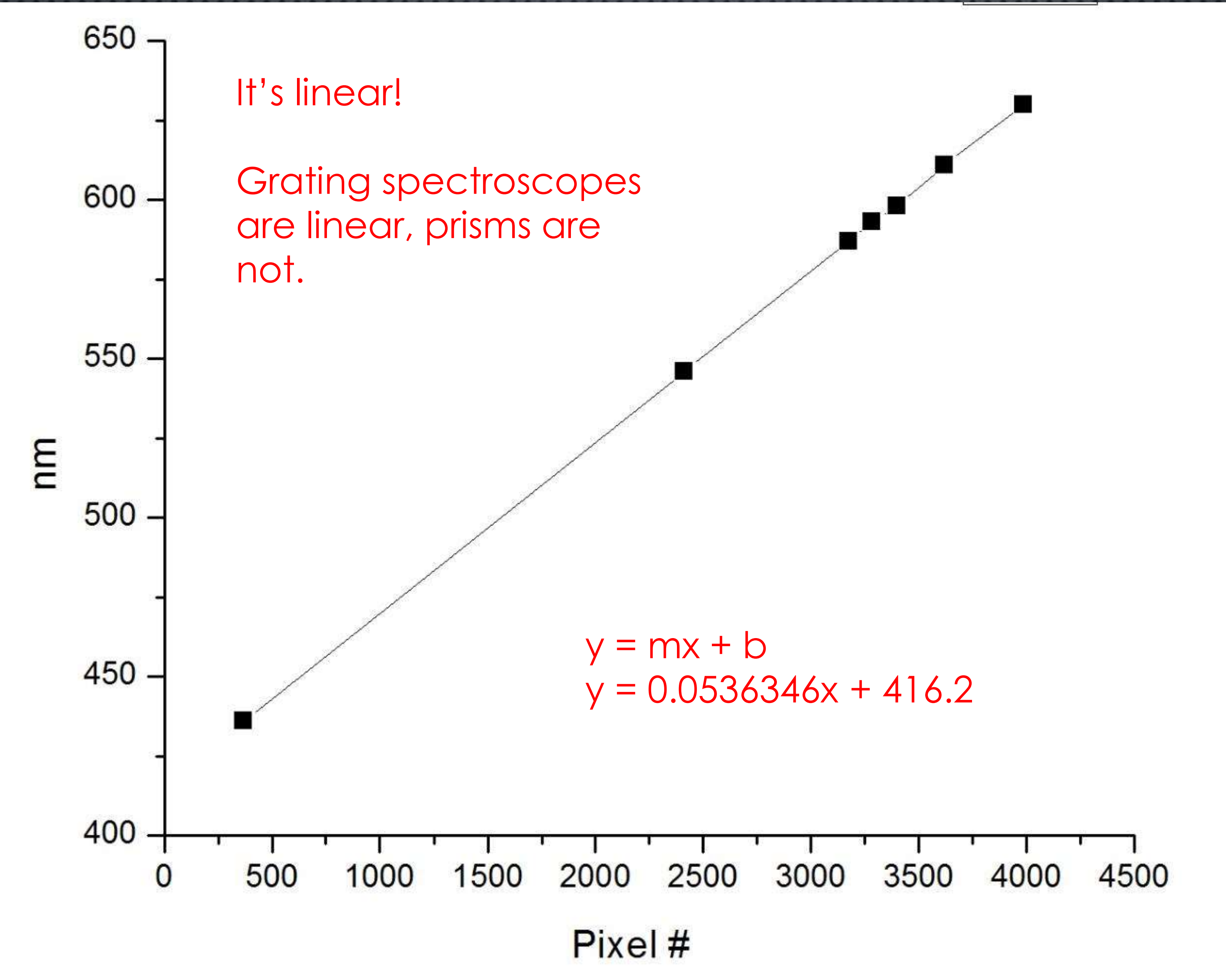
Save profile X = calibration peaks

Pixel #1 is the left most in the box not the image. Make sure the left edge of the box = the left edge of the image!

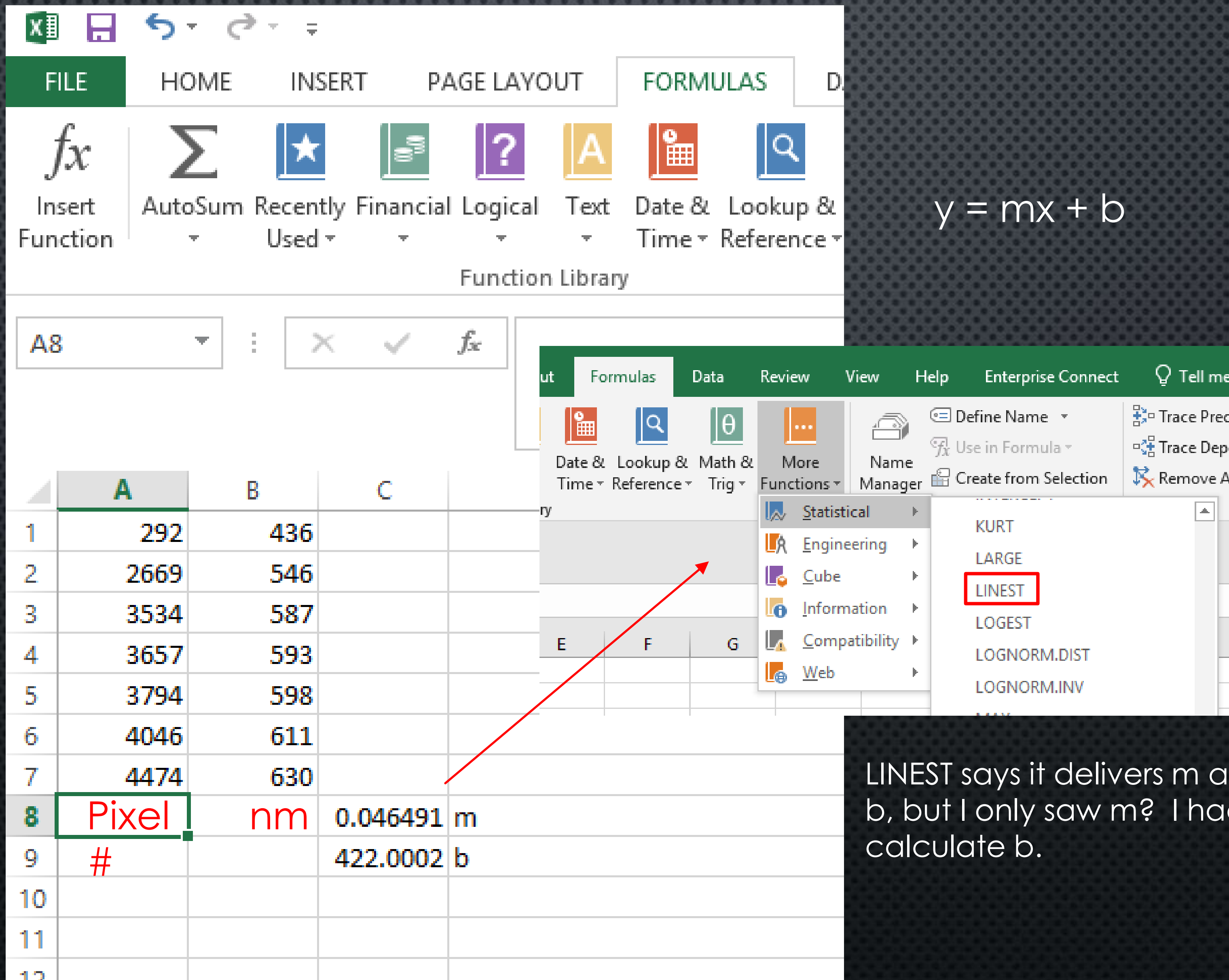


More/Set range: zooms in. Cursor reads out x-position to manually find peak locations

Calibration Curve



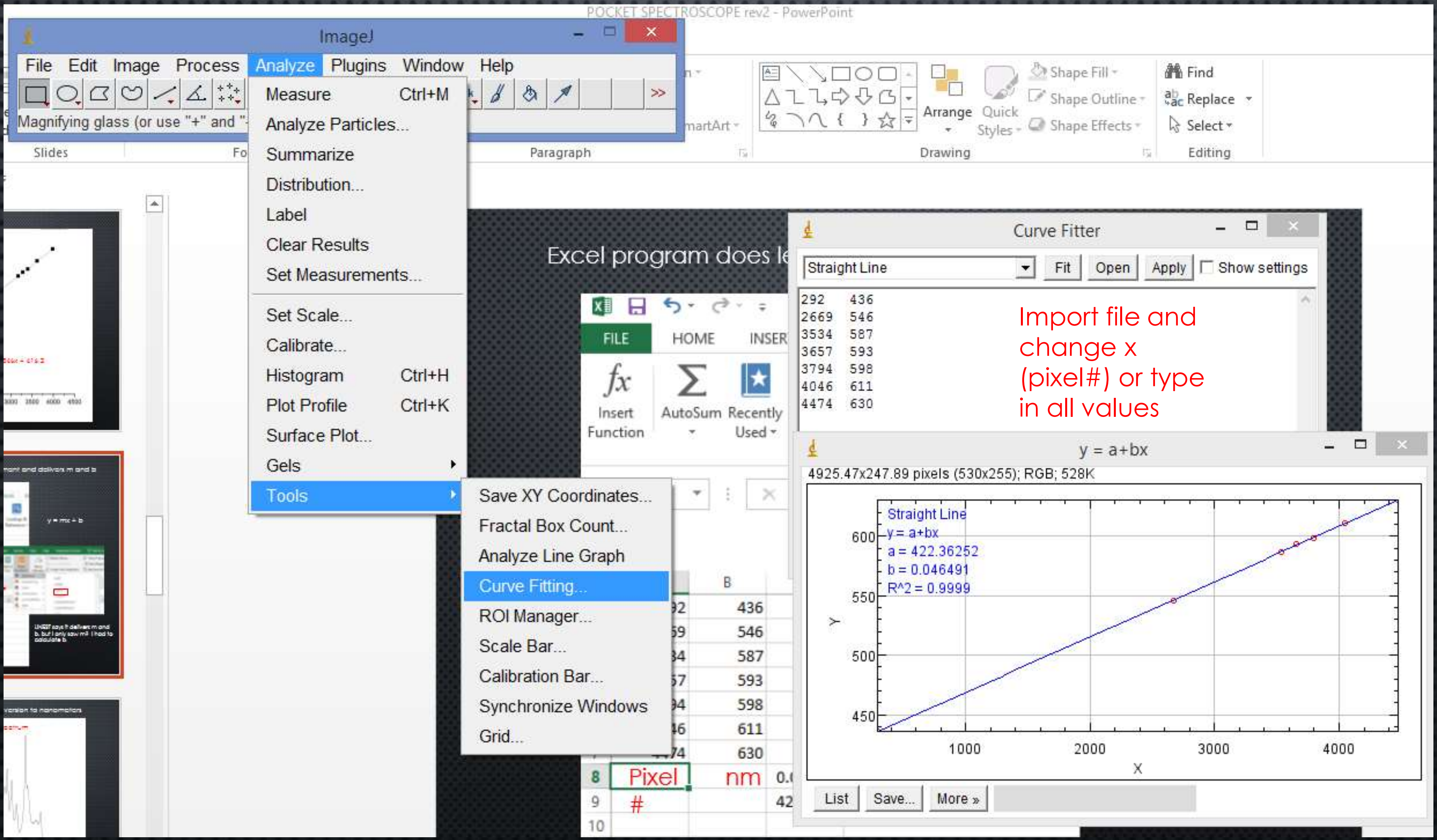
Excel program does least squares refinement and delivers m and b



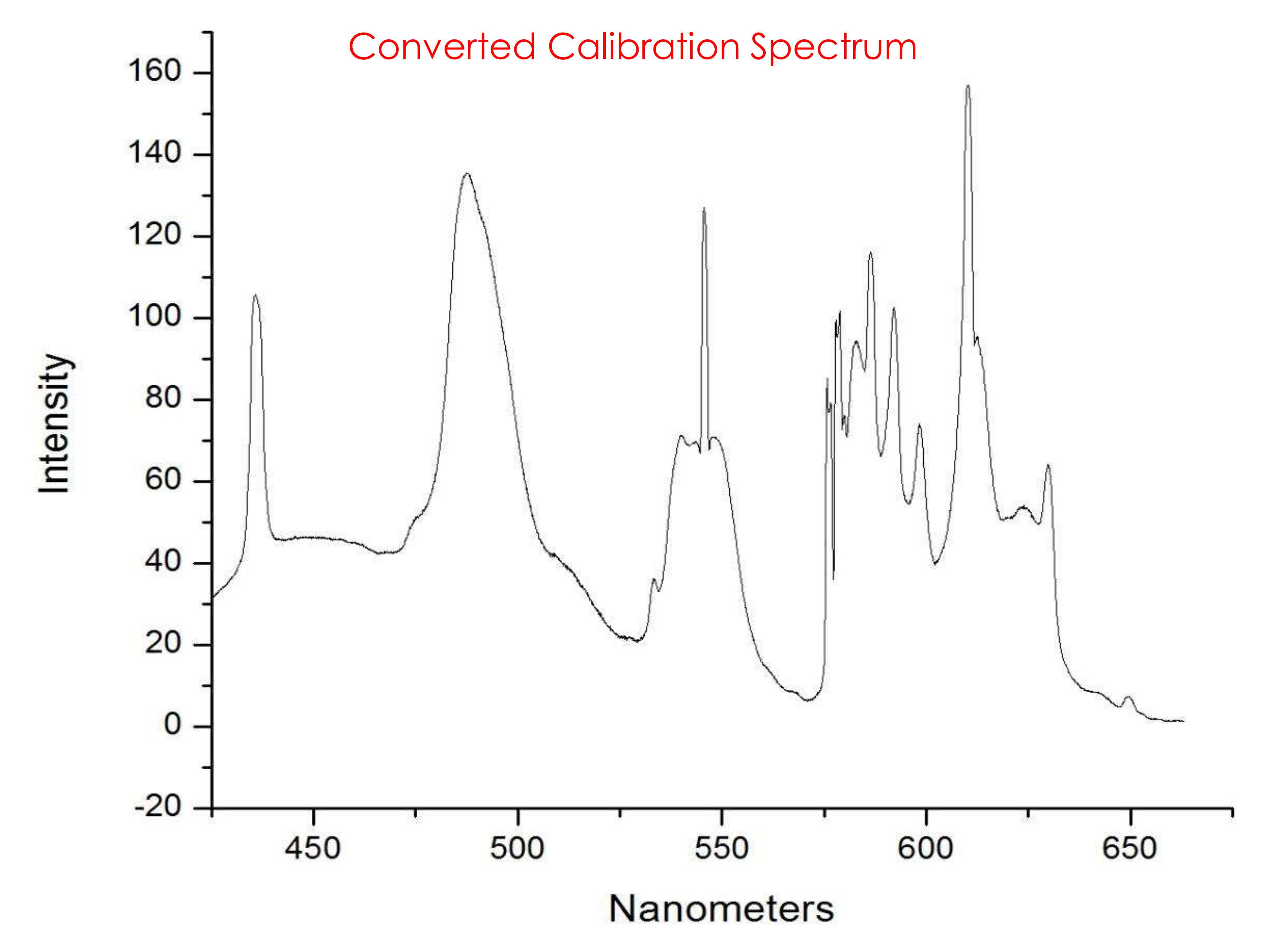
$y = mx + b$

LINEST says it delivers m and b, but I only saw m? I had to calculate b.

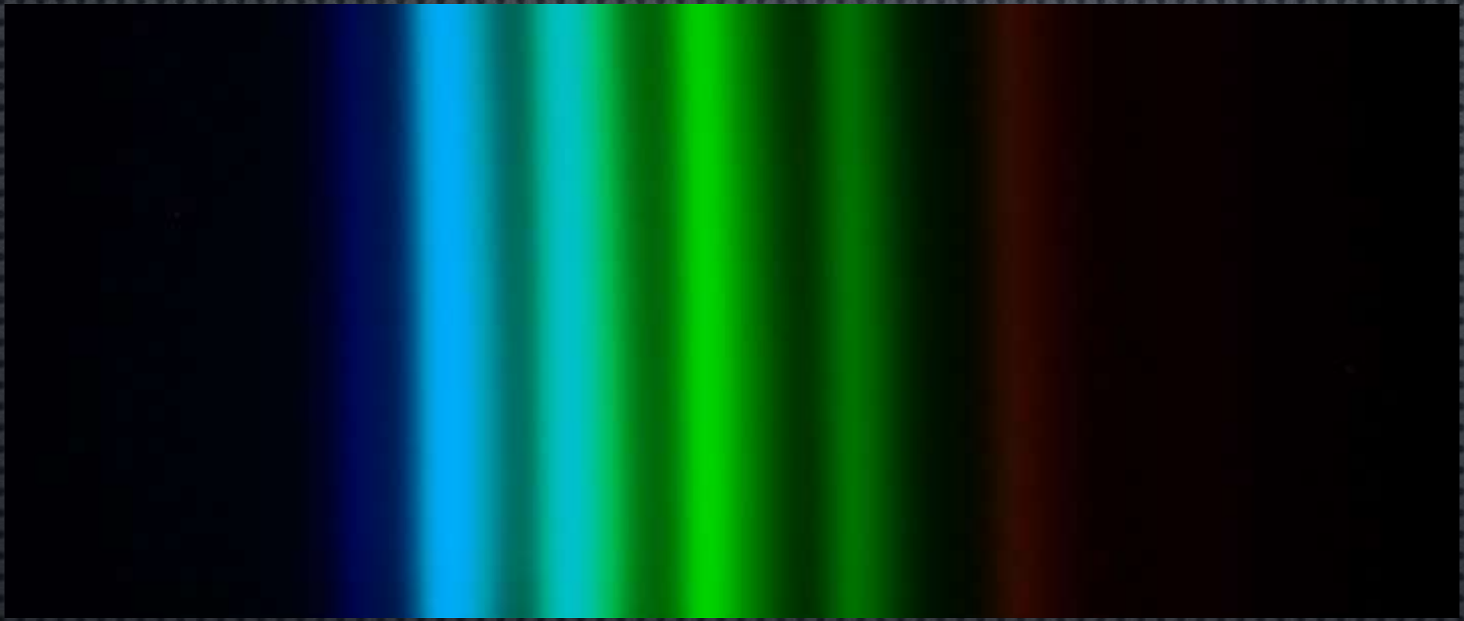
Image-J also does curve fitting (least square straight line) and returns m(b) and b(a)



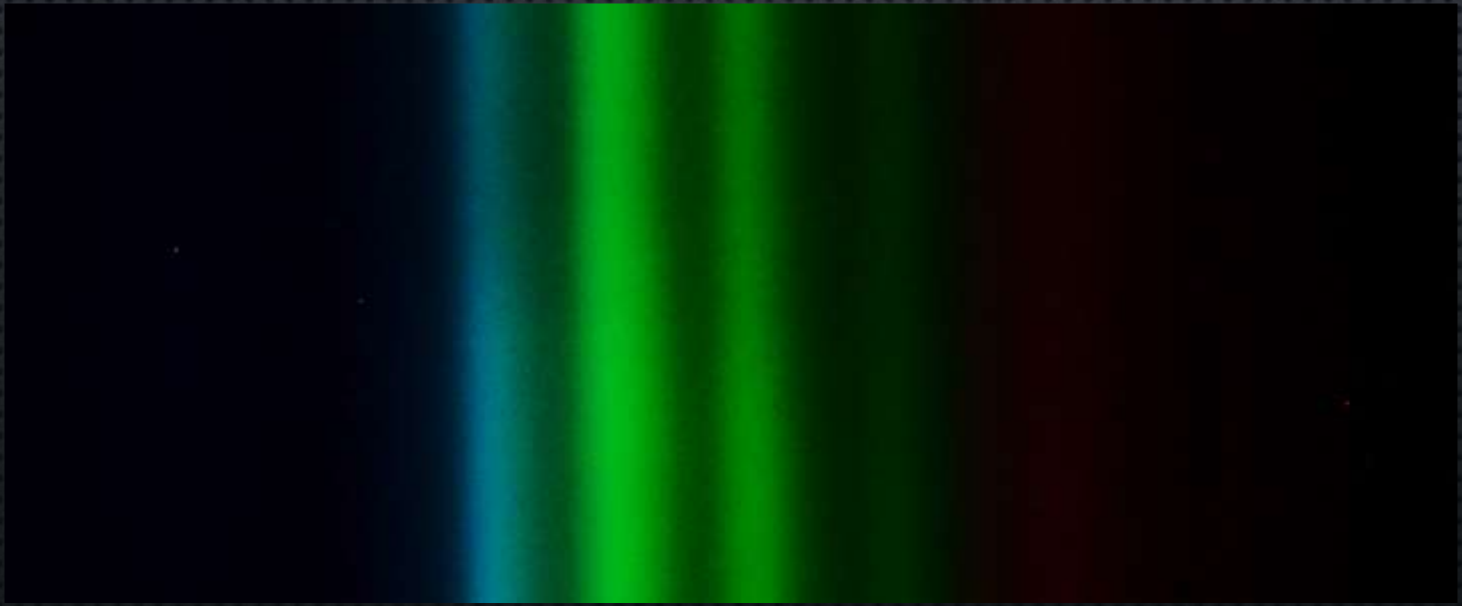
Use Excel program to apply calibration – conversion to nanometers



Possibly use for field discrimination? WiFi transfer to cell phone.



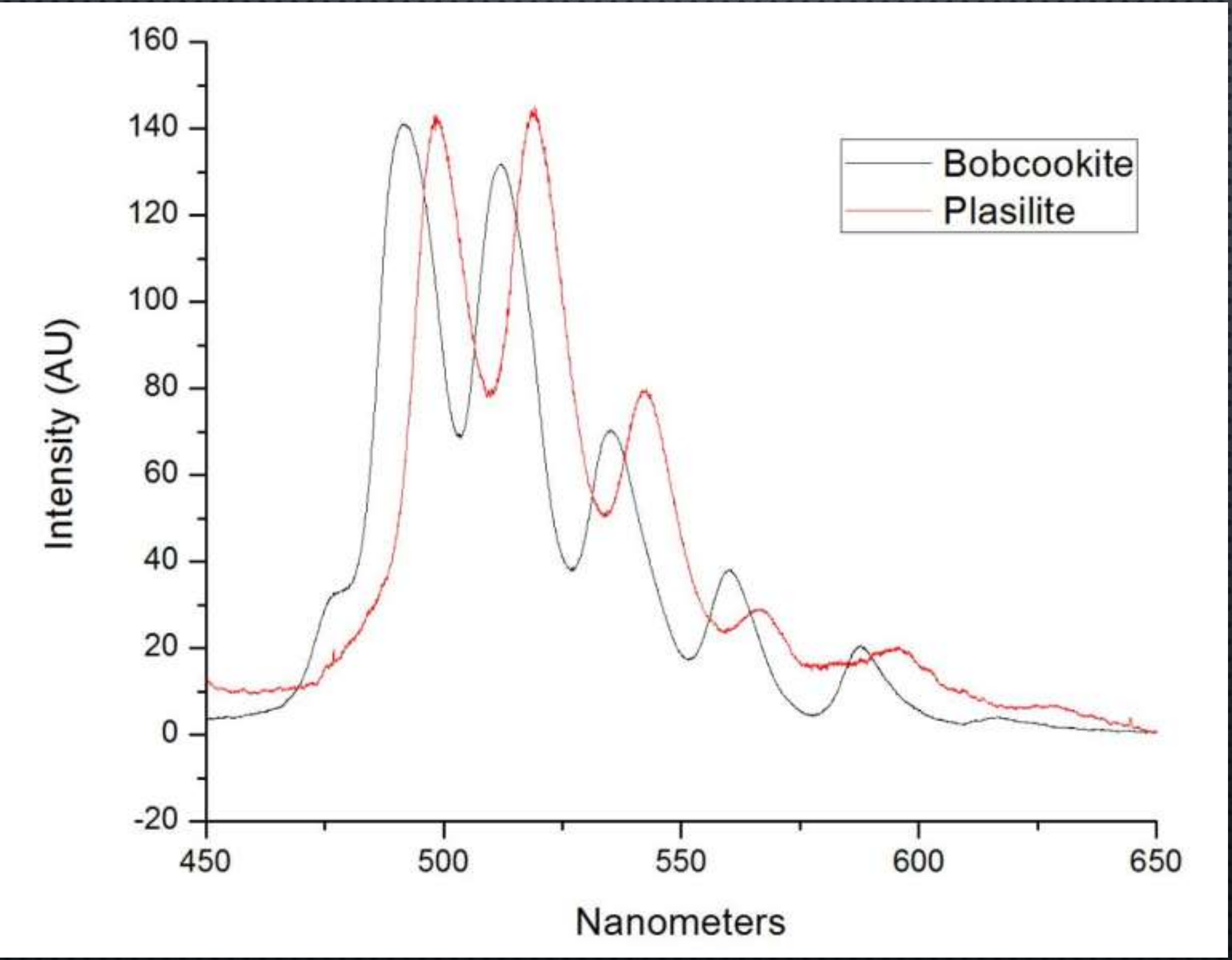
Bobcookite



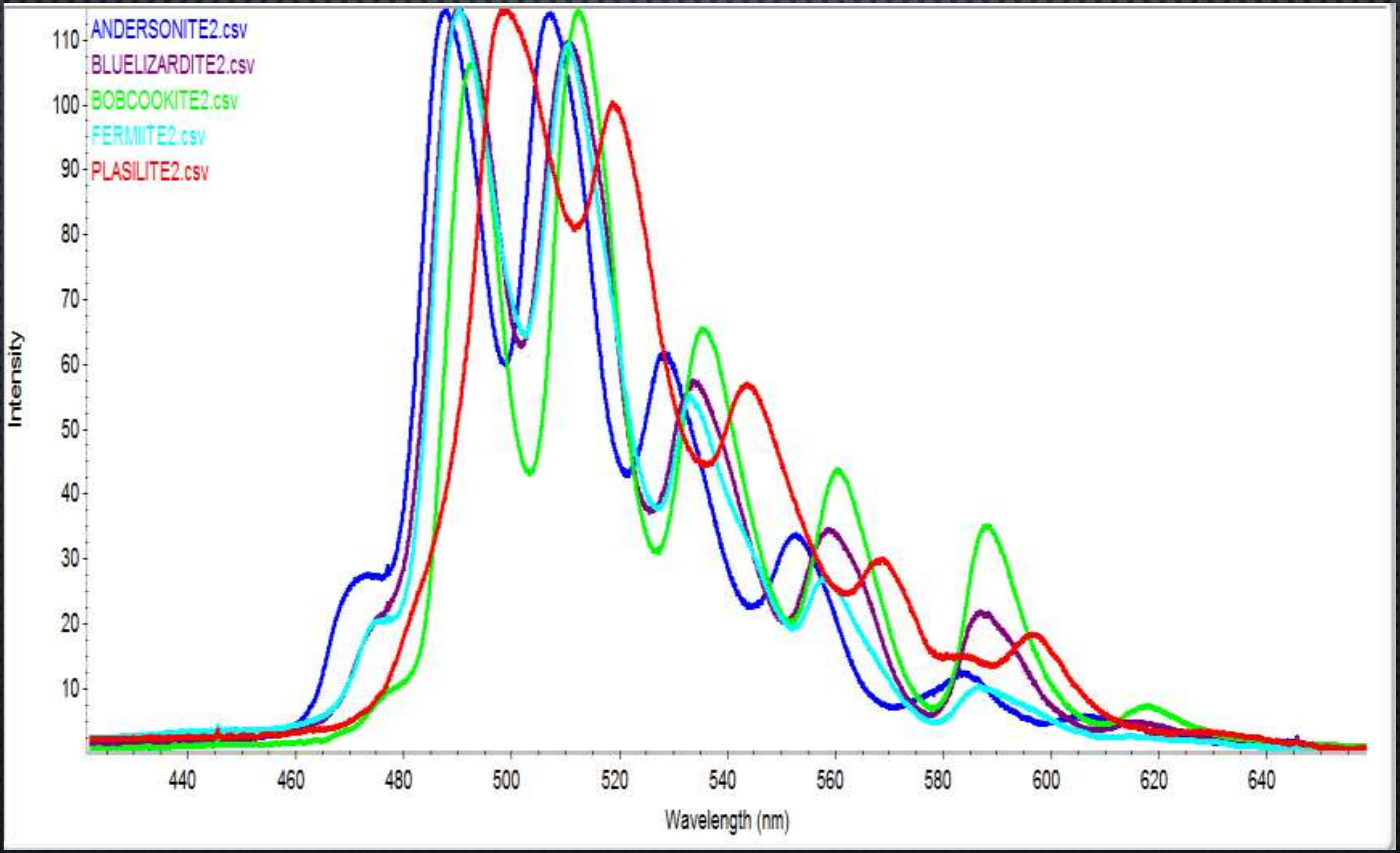
Plasilite

Natrozippeite

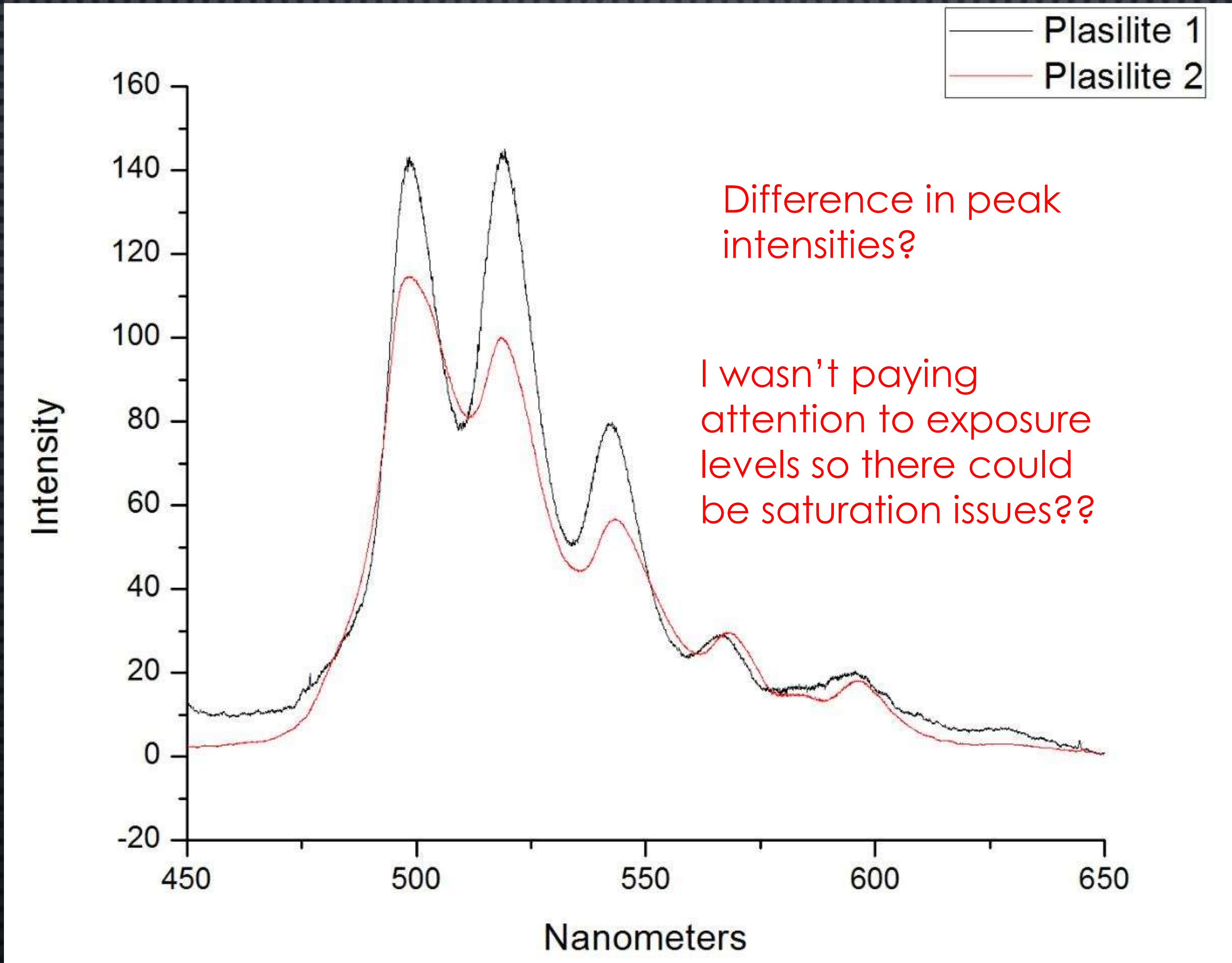
7 nm peak shift



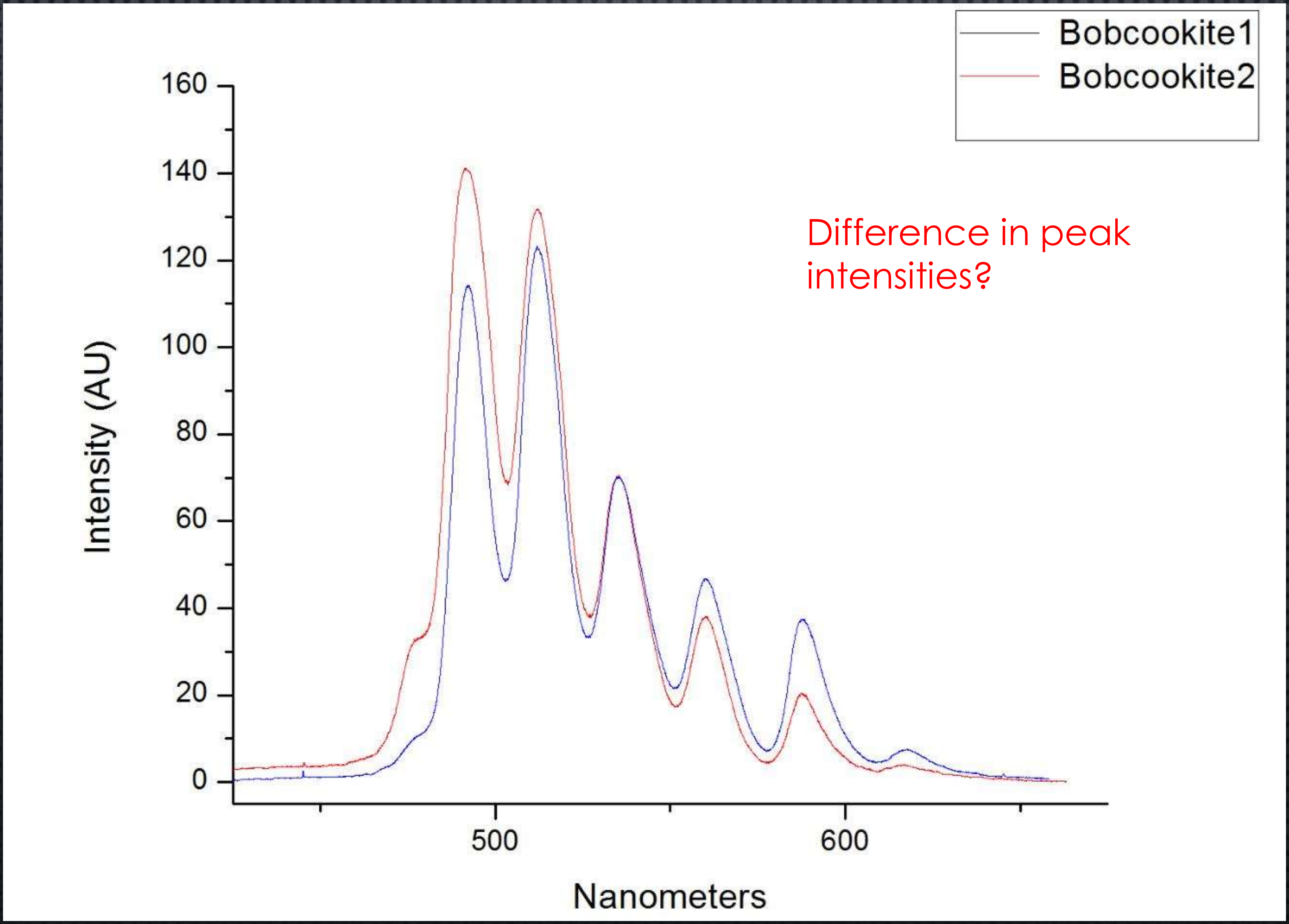
Subtle differences between common species
12 nm shift between andersonite and plasite



Plasilte: Two specimens – two calibrations

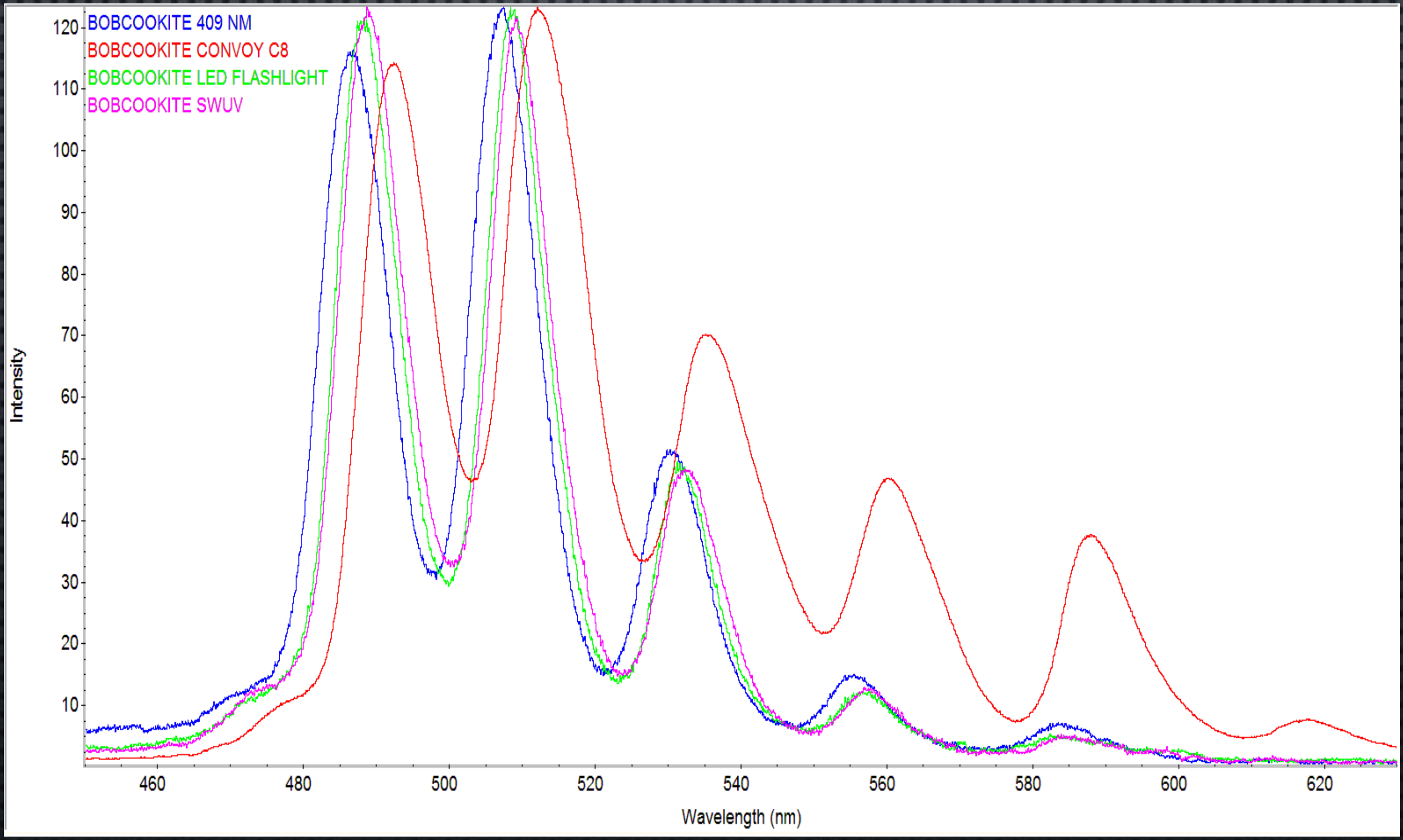


Bobcookite: Two specimens – two calibrations

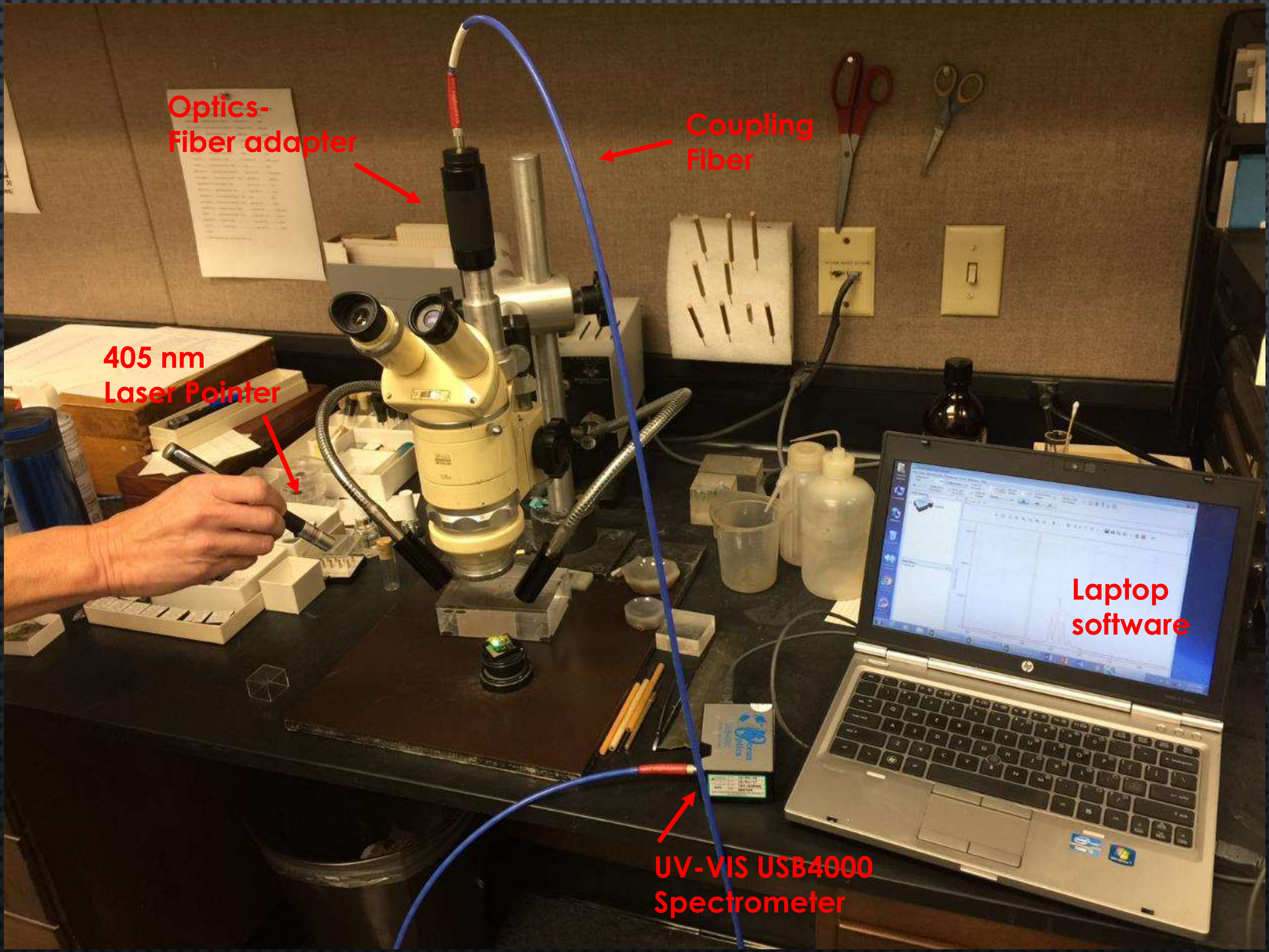


Difference in peak intensities?

Subtle peak shifts depending on excitation wavelength?



Comparison with Ocean Optics USB4000 Spectrometer



For macro samples (without microscope. i.e. bare fiber) LED flashlight was adequate http://oceanoptics.com/product/usb2000uv-vis/

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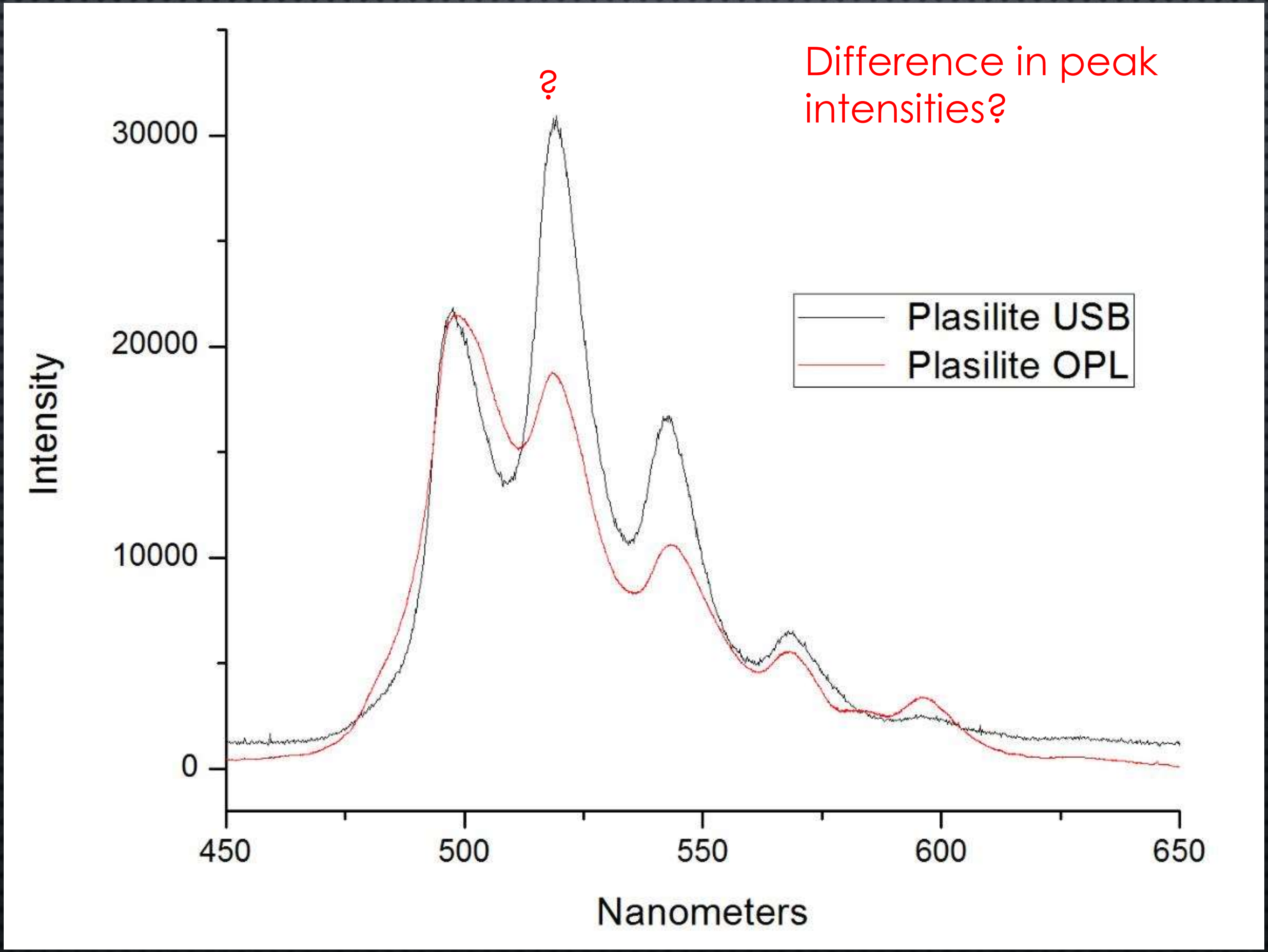
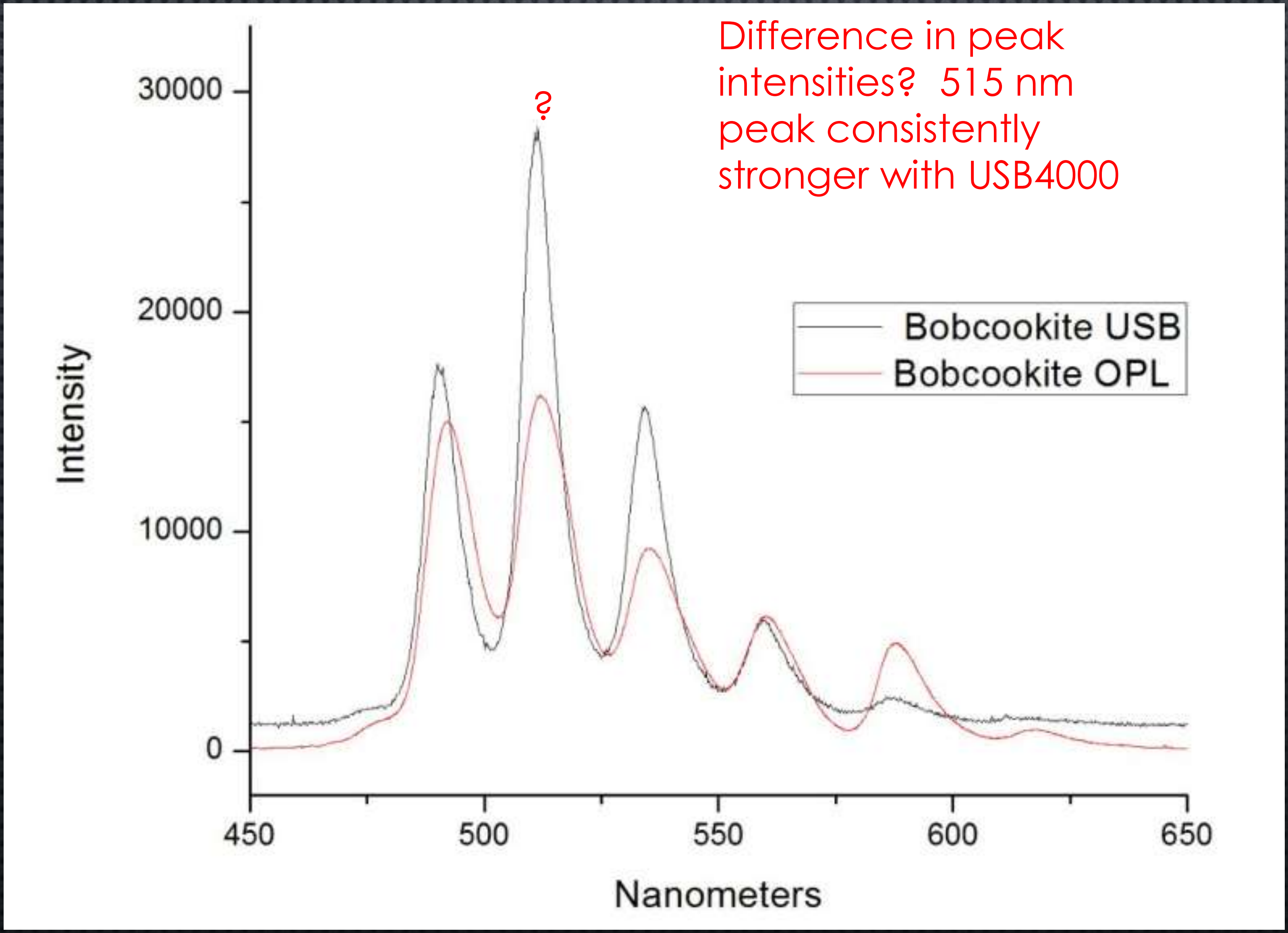
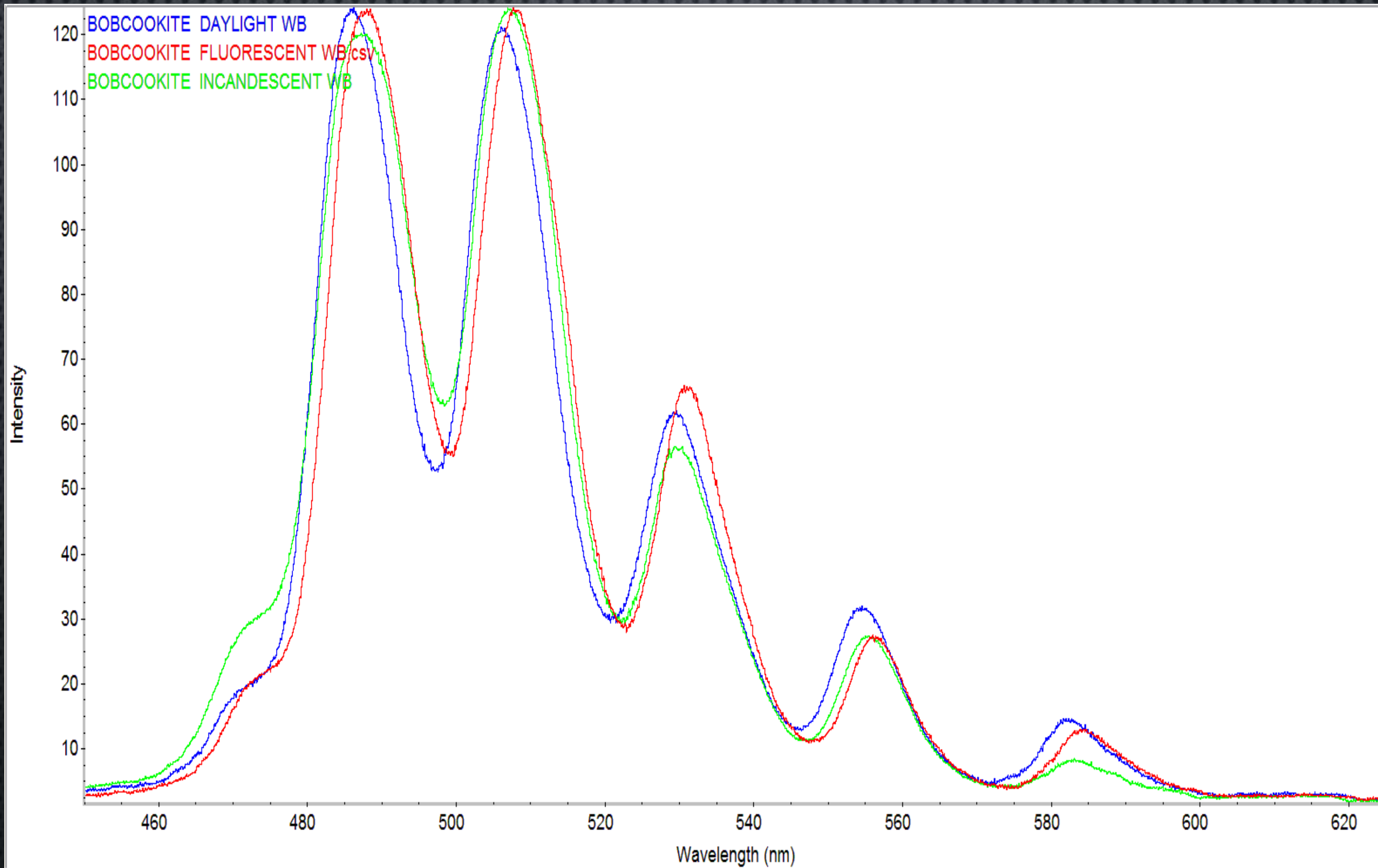
Ocean Optics USB4000 with LED Flashlight Comparison with OPL Pocket Spectroscope with Convoy C8



Ocean Optics USB4000 with LED Flashlight Comparison with OPL Pocket Spectroscope with Convoy C8



Convoy C8 as a Function of Camera White Balance



Radiochim. Acta **88**, 757–762 (2000)

Spectroscopic properties of uranium(VI) minerals studied by time-resolved laser-induced fluorescence spectroscopy (TRLFS)

By G. Geipel[1,*], G. Bernhard[1], M. Rutsch[1], V. Brendler[1] and H. Nitsche[1,2]

[1] Forschungszentrum Rossendorf, Institute of Radiochemistry, P.O. Box 510 119, D-01314 Dresden, Germany
[2] University of California at Berkeley and Lawrence Berkeley National Laboratory, The Glenn T. Seaborg Center, MS 70A-1150, Berkeley, CA 94720, USA

266 nm excitation

Mineral	fluorescence emission bands/nm					
				Phosphates		
Chernikovite						
Saleeite	489.0	501.1	522.1	545.7	570.9	600.9
Autunite	488.6	504.0	524.2	548.0	573.9	602.4
Metaautunite	491.3	501.8	522.9	546.9	572.2	591.7
Uranocircite	488.1	503.5	523.9	547.0	572.1	599.7
Metauranocircite	488.9	502.5	523.7	547.4	573.4	602.6
Sabugalite	491.4	506.4	527.7	550.8	575.9	604.8
Threadgoldite	489.7	501.4	522.1	545.6	571.2	601.3
Ranunculite	491.4	501.2	521.9	545.5	570.5	600.3
Phuralumite	496.9	500.6	520.3	542.9	568.7	599.9
				Arsenates		
Troegerite	485.5	502.2	524.4	547.4	572.7	604.8
Novacekite	486.3	502.6	523.1	546.8	572.8	601.7
Metanovaceckite	492.1	504.3	526.7	549.7	575.5	608.2
Uranospinite	488.2	502.2	523.6	547.2	573.0	600.7
Metauranospinite	489.9	502.7	526.8	549.2	574.5	604.3
Heinrichite	495.0	505.8	528.4	551.4	577.7	604.6
Metaheinrichite	492.4	505.7	527.9	551.4	576.9	606.1

Conclusions

The fluorescence data of minerals can be used as fingerprints to determine secondary mineral coatings on rock materials, and can support the interpretation of spectra of unknown ternary and quaternary solution species. These data are also useful to identify uranyl(VI) species sorbed on mineral and rock surfaces and on certain bacteria.

By comparing the fluorescence data of several mineral series, we were able to study the influence of secondary metal ions, anions and the bound water molecules on the fluorescence properties of the uranyl group. Information on the axial U–O bond length is derived from the band spacing of the fluorescence emission maxima. The vibrational ground state transition frequency is equal to the IR band of the symmetric stretching vibration ν_1 of the UO_2^{2+} ion. We found an empirical correlation between the vibrational frequency of the ground state and the fluorescence lifetime.

Proof of Concept:
Can spectroscope be used on a microscope to examine small crystals?

- Leitz Ortholux 2 microscope with 4X objective
- Spectroscope and camera in trinocular port – no transfer optics – same adapter as on macrostand – i.e. loose fit !
- 409 nm laser pointer (Convoy doesn't have enough output!)
- "macro" bobcookite and micro plasilite (0.1 mm? cluster of crystals?)

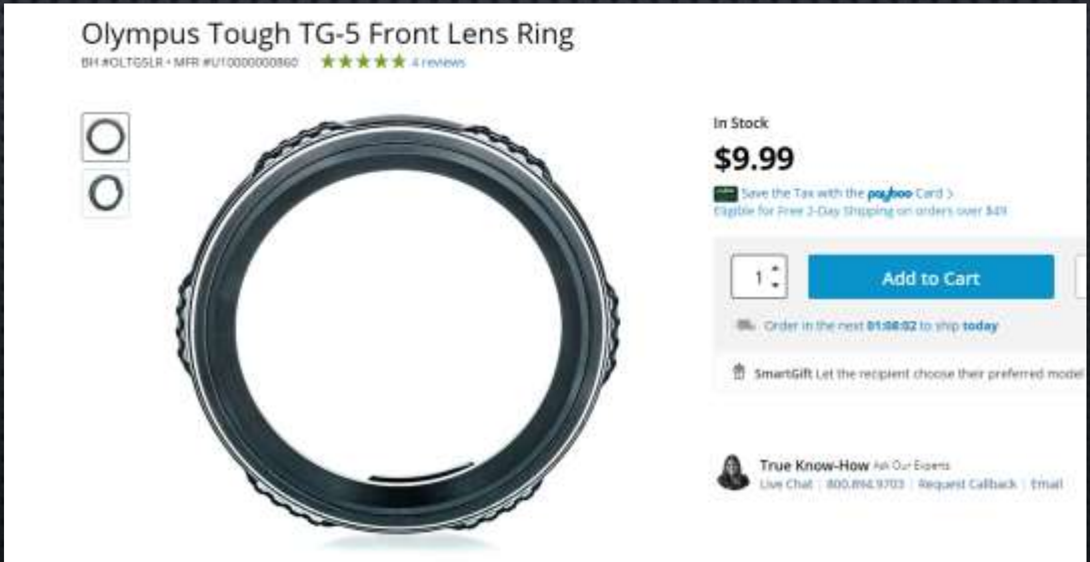
Leitz microscope with 4X objective

Very hard to hand hold laser pointer in FOV !!

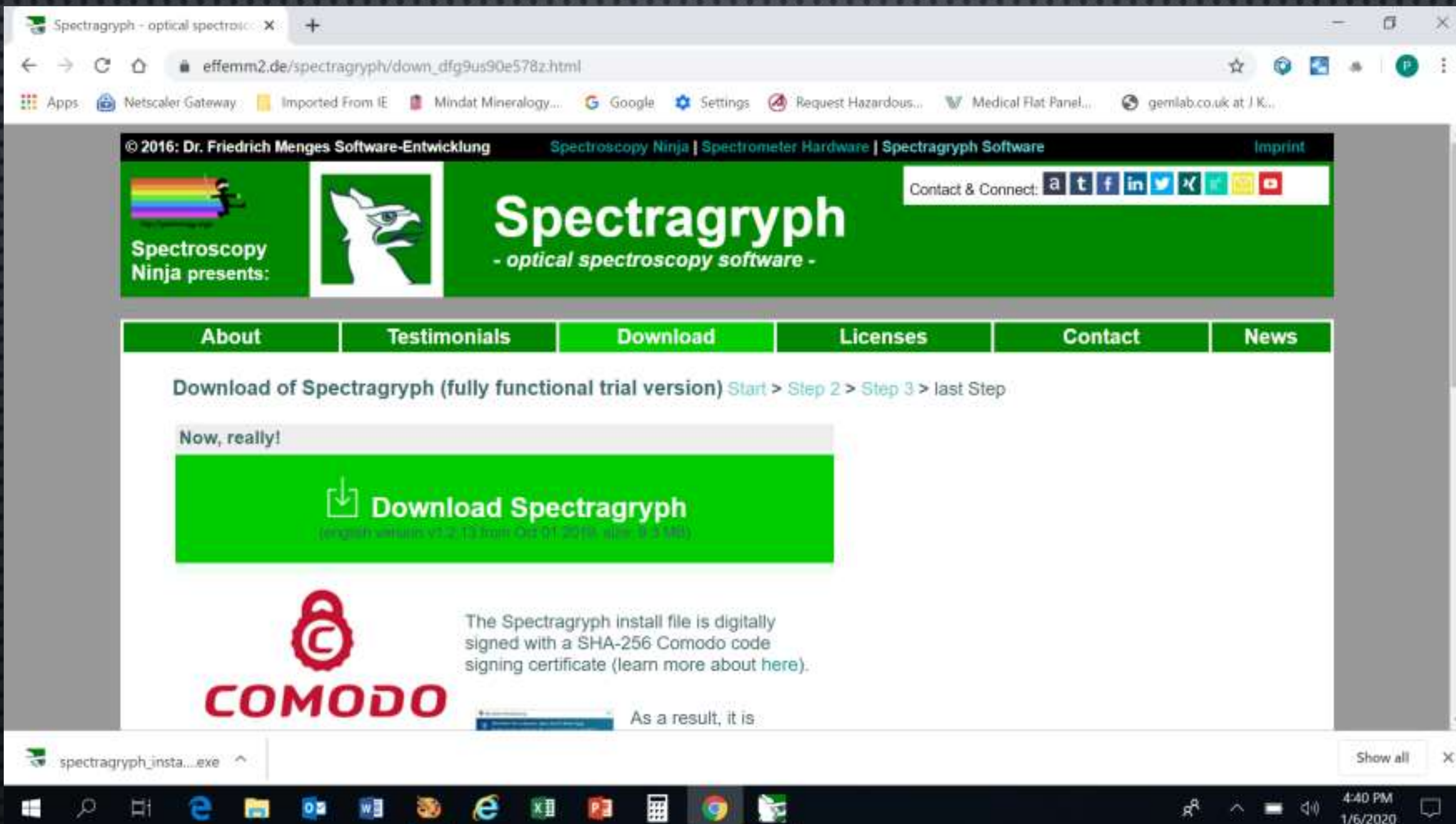
Comments

I have a TG-3 (also a TG-5 at work). The TG-5 has many more features including ability to store RAW images (may have greater dynamic range). Image-J will not open Olympus RAW. TG-5 may have more control over shutter speeds allowing for longer exposures for weakly fluorescing samples (or shorter exposures for strong emitters).

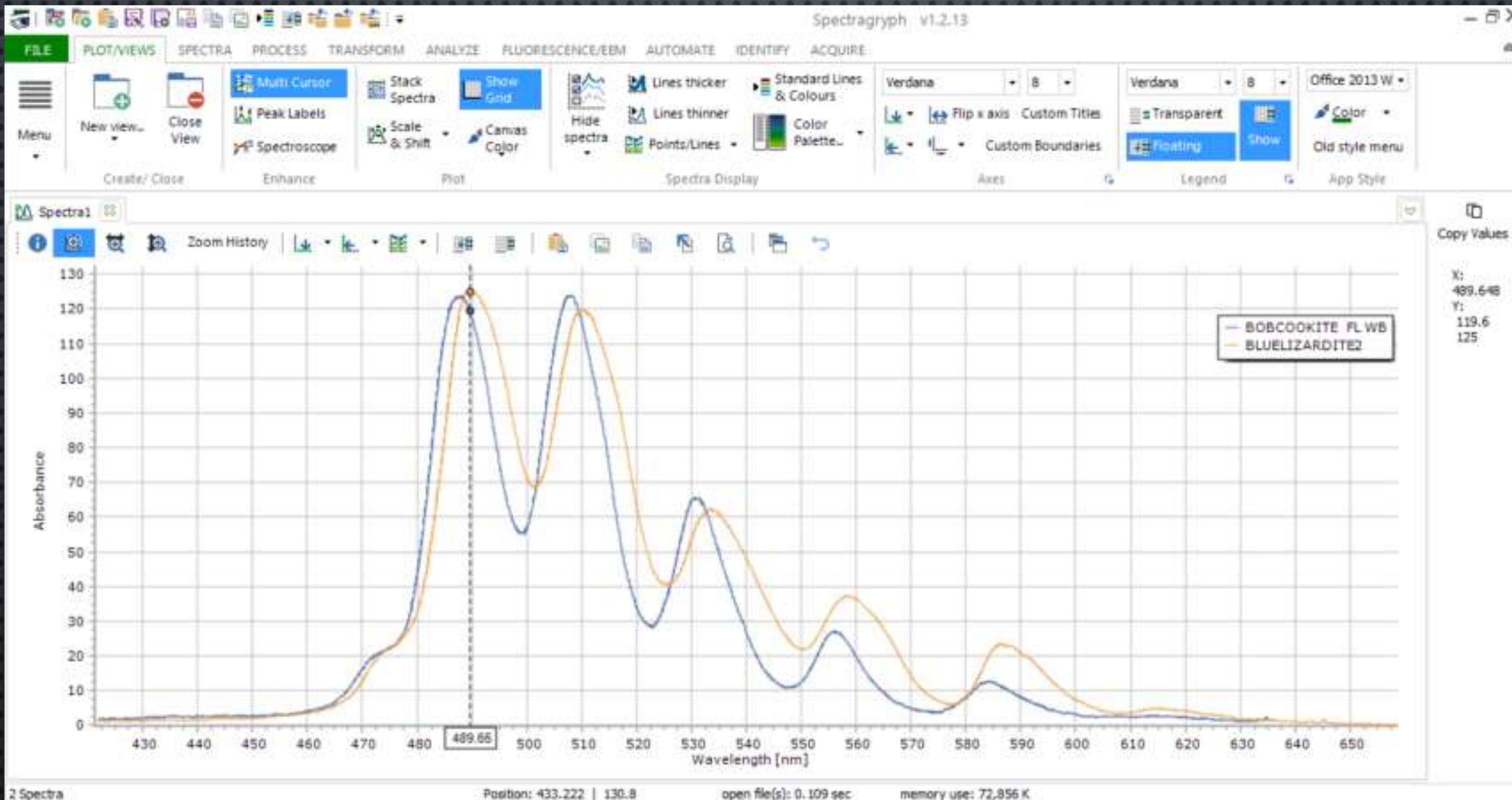
It may be possible to couple the spectroscope/camera to a microscope with different adapter? Order a separate bayonet ring from B&H? There is also a bayonet to 40.5 mm thread adapter ($19.95).



Spectragryph free(?) spectroscopy software. Very comprehensive package!!



Spectragryph free spectroscopy software



These spectra were calibrated .csv files but it looks like it will also do the wavelength calibration from the CFL spectrum and also create databases!

Spectrum: BOBCOOKITE FL WB

wavelength [nm]	absorbance	FWHM [nm]
488.272	123.75	15.4075
507.544	124	15.3093
530.514	65.781	11.2272
555.902	27.356	10.9612
584.228	12.716	8.48067