Apparatus Competition

2019 AAPT Summer Meeting

Provo, UT

Apparatus Title: Something NEW from Something OLD - A tool for the Optics Lab

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Abstract (50-75 words): Many departments have old, but still useful equipment that may seem obsolete. In an effort to make use of an old student spectrometer, a new data acquisition scheme using an Arduino UNO and a low cost light sensor has allowed for re-purposing the old instrument, making for a "semi-automated" light scattering experiment.

Construction of Apparatus: See attached

Use of Apparatus: See attached

[Your description of the apparatus should explain how to construct and use the apparatus along with the educational value or use of the apparatus. Figures, pictures, sample lab write-ups, etc. may be included as appropriate. This description (made anonymous) will be available to the judges of the apparatus. This description will also be posted on the apparatus competition web page.]

Something NEW from Something OLD

A tool for the Optics Lab

Toni Sauncy, Texas Lutheran University

Construction of the Apparatus

An old (circa 1960's era) student spectroscope was used to construct a more useful tool that allows for light intensity vs. angle measurements for scattering experiments. The detector can also be used on an optical rail for performing Malus Law experiments.

Starting Point – Obsolete equipment

The old student spectroscope arms were emptied and replaced with a light source coupling on one arm, and a fiber optic sensor on the other. (Figure 1)

Figure 1: Old student Spectroscope, 1960's era (BEFORE)

Something New – Fiber optic input

The fiber optic cable (~ 0.5 m long) is inserted through #4 Rubber stoppers that fit snuggly in the movable arm of the spectroscope.(Figure 2)

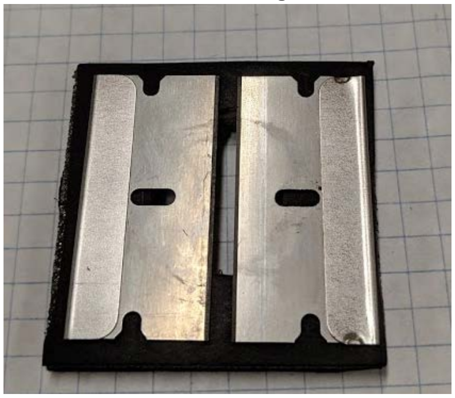
(a) (b)

Figure 2: Movable arm of spectroscope outfitted with two #4 Stoppers and a fiber optic cable. (a) entrance (b) fiber exit - going to breadboard with light sensor

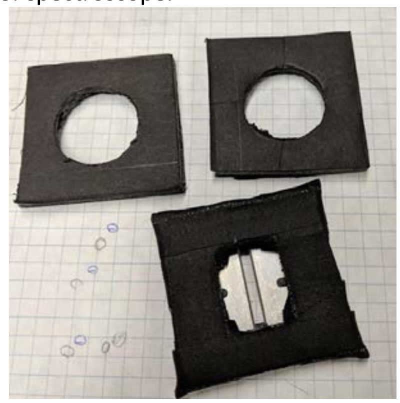
Something new and cheap – homemade slit

The fixed arm of the spectroscope was outfitted with a home built slit, made from foam core board and two single edge razor blades, affixed with gaffer's tape. Slit width is ≈3mm. Students measure the exact width with a Vernier calipers as part of the experiment. Illustrated in Figure 3.

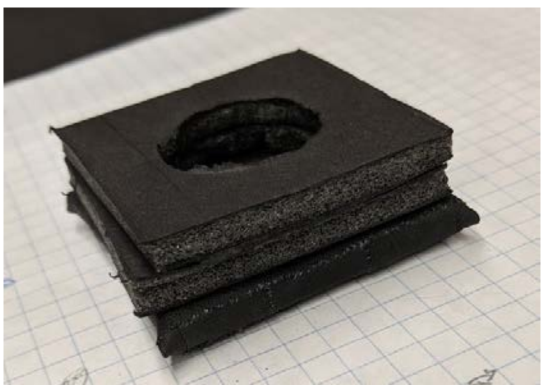
Figure 3: Construction of the slit for fixed arm of spectroscope.



Two Razor blades on foam core board



Two more pieces of foam core board with openings to fit inner tube from fixed arm of spectrscope



Layered (before taping)

Tape and inserted onto inner tube of spectroscope

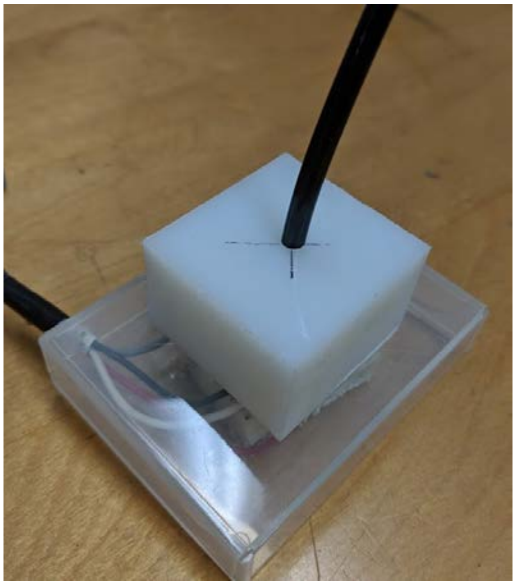
It should be noted that many of these old instruments may have variable slits attached, and if so, they could also be used. We found that the slit width was limited and decided to go with a slight larger opening for more light on the samples.

Something new – a low cost light detector

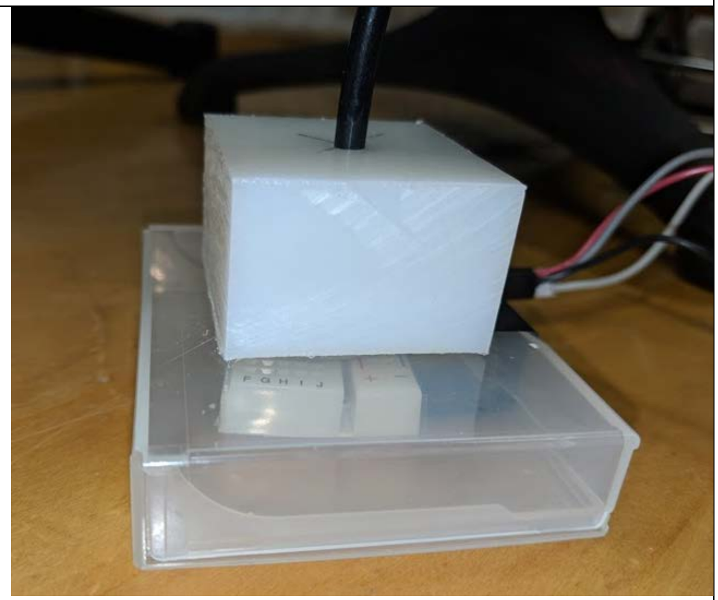
For detection, the fiber optic cable was inserted into a 1" x 2" x 2" Teflon block, with a hole of diameter matching the diameter of the fiber cable drilled in the block and aligned over the hole in the case. The block was epoxied to the case. (Figure 4)

The case contains a small piece of solderless breadboard The TSL2591 sensor contains both infrared and full spectrum diodes so that separate measurements of infrared, full-spectrum or visible light can be obtained separately.

Figure 4 – Construction of the detector



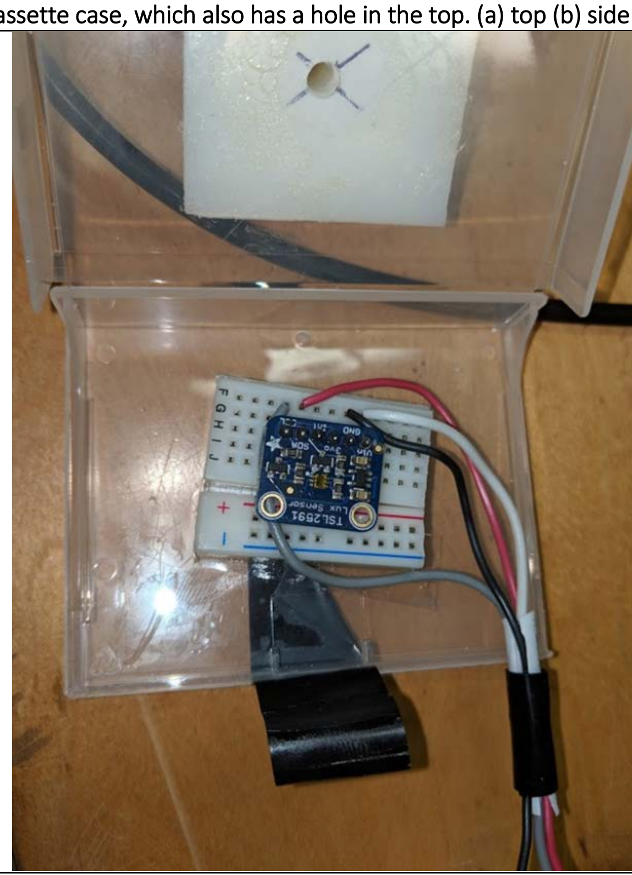
(a)



(b)

Fiber optic inserted into Teflon block. Block is epoxied to the old cassette case, which also has a hole in the top. (a) top (b) side

Adafruit breakout board detail



Finished detector, with output wires to Arduino Uno

Something new – Python code to access data from Arduino interface

A python program was developed that allows user input of angle data, followed by time acquisition of light intensity. This loops for the number of data points determined by the user. The code has built in statistical analysis for error/uncertainty in each intensity value. The data (Intensity vs. Angle) are then plotted on the computer screen, updated after each subsequent data point. The Python code features a manual user input of integration time, and input of each angular position before deploying the automated signal acquisition.

The code includes an option for subtraction of background signal, which is acquired prior to signal measurements. The acquisition routine computes average intensity for the prescribed time period, along with statistical data for the three light regimes measured by the sensor.

Data is appended for each angular position and compiled in a CSV file for analysis in Python and is graphed on screen.

Figure 5: Completed apparatus (light source coupling not shown)

Parts List

- Old spectroscope (most departments have several)
- Various Light Source (use what is on hand and/or inexpensive laser pointer)
- Small piece of scrap foam core board (or buy a full size piece ~$5)
- Two single edge razor blades
- Gaffer's tape (about 1 meter, but a full roll is ~$8(
- Arduino Uno (~$20)
- Adafruit TSL2591 High Dynamic Range Digital Light Sensor (~$8)
- Fiber Optic Cable (~$2.50 per foot)
  25 Strand Fiber Optic Lighting Cable End Glow Cable 15/64 (w / PVC Jacket)
- Solderless breadboard (cut into small pieces about 2"x2") $5.00
- Miscellaneous housing (small plastic box – what ever you have on hand)

Use of the Apparatus and Educational value

Advantages

The major advantage in this project was in repurposing an otherwise obsolete piece of well-constructed equipment. The ability to precisely determine angle (and for students to practice using Vernier measurements) was a plus. The older apparatus provides precise determination of relative angular position due to the Vernier scale on the rotating arm. The 180 degree position was determined by monitoring intensity while adjusting the rotating arm without a sample. The relative angular position is noted. Angular position is then measured relative to this position. The TSL2591 sensor and simple fiber cable provided adequate sensitivity, even for relatively low intensity light sources (LED flashlight). The angular position was systematically changed by increments as small as 1degree. The Python code was launched manually after each angular change, with typical integration time of 10-30s per position.

The apparatus is used in a variety of light scattering experiments and can be couple with either a broad band white light source or a laser depending on the experiment. The detector can also be used on a rail, with the stopper inserted into a one-inch PVC pipe and mounted in a lens holder.

Drawbacks

One drawback is the limitation of the angular position of the rotating arm. Several different spectroscope scattering systems were constructed. Most limited the angular range to approximately 45 – 315 degrees (relative to light source arm)

Though the apparatus provides accurate measurement of angular position, the acquisition is tedious and time consuming when compared with reading a number from the analogue photometer in the old Pasco kit, primarily due to the manual repositioning and integration time required between each data point.

Low cost: Each setup was constructed for well under $100, making it possible to have multiple setups for a low overall cost. The apparatus is used in both the Applied Optics course and the Advanced lab course for different experiments.

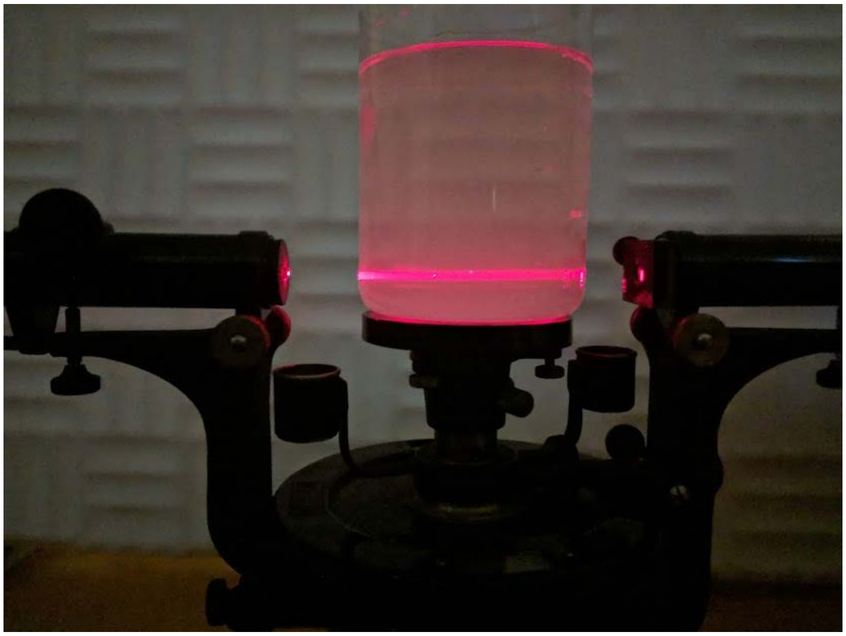


Figure 6: Light Scattering experiment (HeNe Laser in water/milk solution)

Experimental Goals

Experimental goals were to ascertain wavelength dependence of the scattering, as well as explore the effect of scattering particle size and polarization effects on scattering behavior.

Scattering media included milk-water solution, cream-water solution, Silver Nitrate aqueous solution, and Polystyrene spheres in water. Distilled water was used for normalization prior to measurements in all scattering media

Light sources included white light (LED Flashlight), red, green, blue (filtered) light, and red and green laser pointers.

An extension of the Python code to create polar plots of relative intensity as a function of angular position was used to analyze data for a variety of scattering media and light sources. An example of the data acquired from scattering experiments is shown in Figure 7.

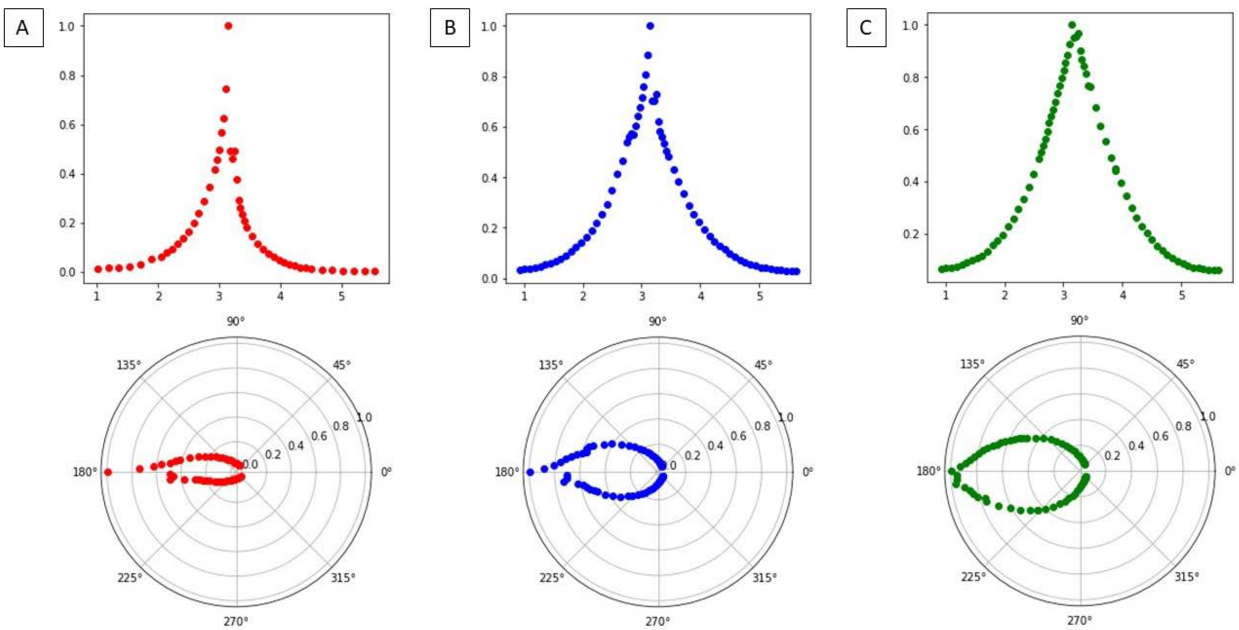


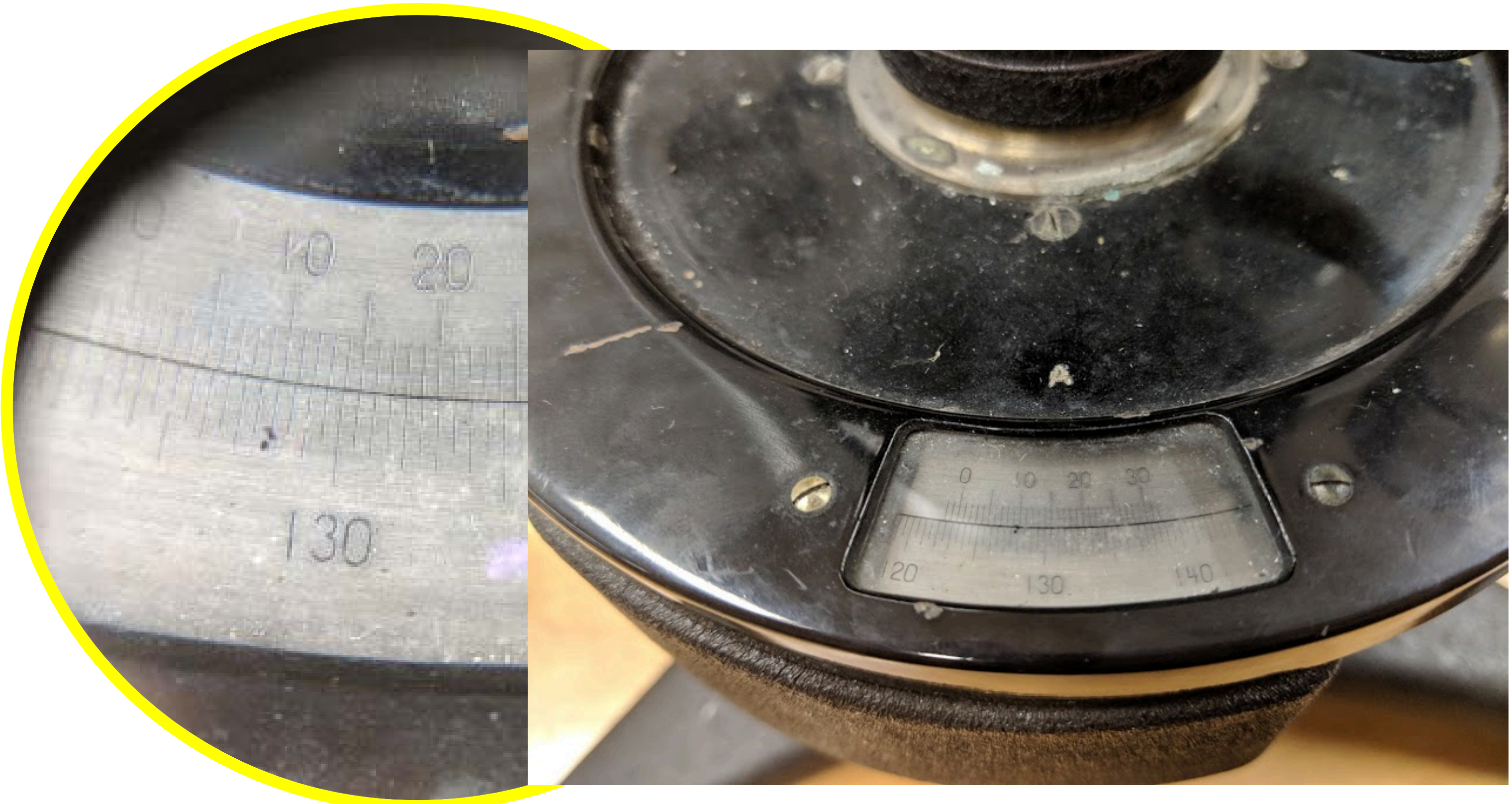
Figure 7: Data analysis from scattering experiments

Resources (abbreviated list)

A study of electric dipole radiation via scattering of polarized laser light Natthi L. Sharma, Ernest R. Behringer, and Rene C. Crombez, Am. J. Phys. 71 (12), December 2003

Nondipole Optical Scattering from Liquids and Nanoparticles, Natthi L. Sharma, PRL 98, 217402 (2007)

Mie scattering from cellular structures, Steven L. Jacques, Scott A. Prahl, Oregon Graduate Institute 1998 (https://omlc.org/classroom/ece532/class3/mie_softtissues.html)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