Live-Feed-over-LAN Camera Spectrometer (LoLAN-CaS) Documentation

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1 Overview

The Live-Feed-over-LAN Camera Spectrometer (LoLAN-CaS) is an implementation of a spectrometer which can use any Android-based phone camera. On the hardware end, the camera broadcasts through a local area network (LAN) using a pre-set IP address. On the software end, the feed can be retrieved, processed, and displayed in real-time through any Python interpreter on a device connected on the same network. The spectrometer program depends on the following Python libraries:

- Numpy
- Matplotlib
- Scipy
- OpenCV
- Peakutils
- URLlib

The current features are as follows:

- Calibration information can be set within the program itself.
- Live feed of camera and corresponding intensity profile of a selected line scan region can be displayed in real-time on a computer with the required dependencies installed.
- Scale of relative intensity profile can be set by the initial camera exposure settings but is always normalized.

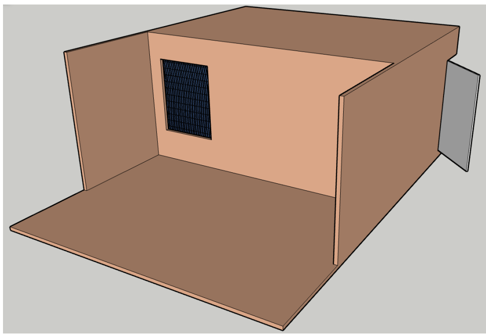
2 Setup

A spectrometer is composed of a light source, an optical system, and a detector. The emission source could be any visible light; the detector is a cellular phone; and the optical system was constructed out of office supplies.

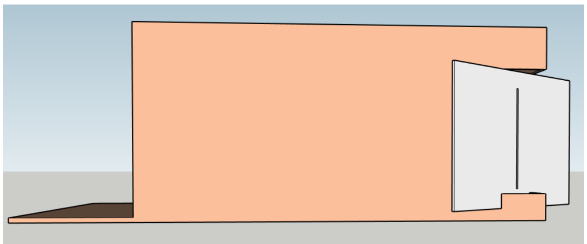
The construction of the optical system is fairly straight forward. A dark chamber was constructed by folding the cardboard box into a $10 \times 15 \times 8$ cm rectangular prism. The dimensions used are dependent on the average size of a smartphone; to hold the phone, extensions were attached to the rectangular prism as shown in Fig. 1a. A rectangular hole was cut on the rectangular prism on the side of the phone holder; the hole was strategically placed on the location where the camera is positioned to which the diffraction grating is attached. On the far right corner from the diffraction grating, a portion of the prism is cut for the placement of the slit (Fig. 1b); the slit was constructed by cutting a 6×10 cm rectangular piece of folder and slicing through the center, whose width is kept constant at approximately 1 mm.

3 Operation

The optical system is positioned in front of the light source such that the slit is directly facing the light source; the slit width dictates the resolution of the entering light with enough intensity to be able to measure the spectral lines [1]. The narrower the slit is, the more specific and discrete the spectral lines will be, but of course, the trade-off is its intensity.



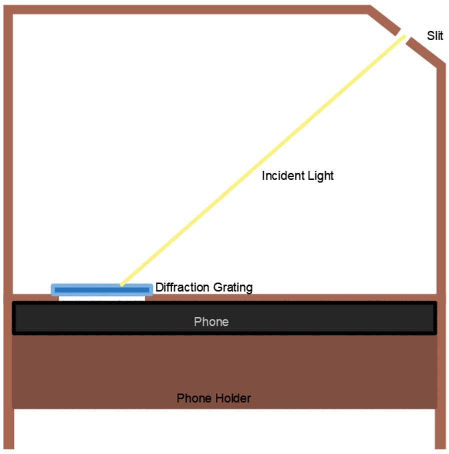
(a) Side view of the setup.

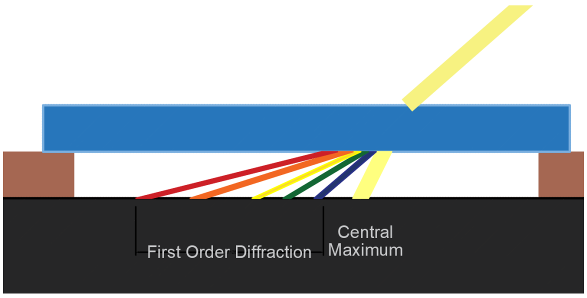


(b) Tilted view of the setup.

Figure 1: 3D design of LoLAN-CaS hardware using Sketchup

Since the diffraction grating used is a re-purposed CD, the first-order diffraction can be viewed at a certain viewing-angle, hence, we positioned the slit at the counterpart-corner from the grating. This optical system is restricted to the viewing the first-order diffraction only. An incoherent light source shall pass through the slit to make it relatively more coherent as shown in Fig. 2a. It then strikes the diffraction grating at a fixed angle and the grating splits the light into its spectral components as shown in Fig. 2b. This diffraction shall then be captured by the camera and displayed on the phone (Fig. 3).





(a) Top view of incident light striking the diffraction gratihttps://www.overleaf.com/5859638841gqscjvrwxtsp?fbclid=IwAR06 $_hYtOmB3PpTIKA7N26iqjJfWP1ng763XoPG$ $T_DPWSvuVuOcl3Yng$

(b) Zoomed in view as incident light is split into its spectral components

Figure 2: Ray tracing of diffraction of an incident light

After the calibration process, we used an Android app "IPWebcam" where the camera feed is broadcasting in full resolution (1080p) through a local network. A computer or laptop connected on the same network can send an `HTTP GET` request to the phone's local IP and port to initiate the data stream. The image is then converted to grayscale and the calibration curve is used to convert the pixel location values to wavelength.

4 Program

4.1 `Spectrometer.__init__(calibrationLocation, calibrationWavelengths, lowerPix, upperPix, lowerBound, upperBound)`

Instantiates the `Spectrometer` object and takes the calibration arguments.

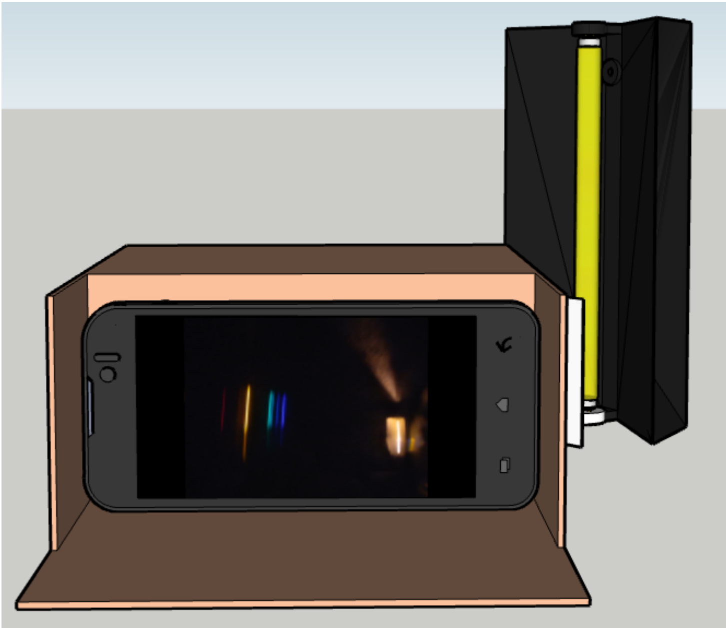


Figure 3: Spectrometer schematic diagram

Table 1: Program initialization.

Parameters	`calibrationLocation : array_like`
	Pixel locations of the peaks of the calibration image.
	`calibrationWavelengths : array_like`
	Corresponding wavelengths of `calibrationLocation`.
	`lowerPix : int`
	Specifies pixel location of `lowerBound` (optional).
	`upperPix : int`
	Specifies pixel location of `lowerBound` (optional).
	`lowerBound : float`
	Specifies wavelength lower bound.
	`upperBound : float`
	Specifies wavelength upper bound.

4.2 `Spectrometer.plotCalibration()`

Plots the calibration curve and corresponding pixel-to-wavelength equation using linear regression.

4.3 `Spectrometer.LineScan_snapshot(image_name, peaks, window_length, polyorder)`

Table 2: `LineScan_snapshot` arguments.

Parameters	`image_name : str`
	File name of locally-stored image.
	`peaks : bool`
	Sets whether peak points should be indicated on intensity profile.
	`window_length : int`
	Specifies window length of Savitsky-Golay filter.
	`polyorder : int`
	Specifies polynomial order of Savitsky-Golay filter.

4.4 `Spectrometer.LineScan_live(URL, show_peaks, window_length, polyorder)`

Table 3: `LineScan_live` arguments.

Parameters	`URL : str`
	IP address of capturing device (Android-based phone camera only).
	`show_peaks : bool`
	Sets whether peak points should be indicated on intensity profile.
	`window_length : int`
	Specifies window length of Savitzky-Golay filter.
	`polyorder : int`
	Specifies polynomial order of Savitzky-Golay filter.

5 Demonstration

For the calibration process, an image was taken through the spectrometer setup with a helium gas discharge as the light source. Gas discharge lamps have a discrete emission and the choice of these kind of sources for calibration shall be explained later. The calibration image is uploaded on the computer and using MS Paint, the image was resized to a 1920x1080 pixels image. The choice of the resizing resolution is due to the maximum live-feed video resolution of computer program. Manual line scan was then taken at a chosen y-value (between 0-1080) of an image, preferably on the apparent center of the spectral lines where radial distortion is the least. The y-value used in our calibration process was 604 pix. The calibration image contains six bright points along the line scan, and their x-value pixel locations were taken. Using the literature wavelength values, six ordered pairs corresponding to the six discrete emission spectra of helium was plotted [2]. Figure 4 shows the calibration curve obtained from a helium gas discharge lamp. By linear regression, the calibration curve for our spectrometer is given by $\mathbf{wavelength = 0.68(pixel\_location)}$ **- 855.76**.

We used the calibration curve equation to obtain pixel location x-values corresponding to the 350 nm-750 nm range. Hence, we are able to set the portion of the image where the line scan shall actively be taken. That is, at 604 y-pixel, and the x-pixel range corresponding to 350 nm to 750 nm. The spectrum of the light source is simply the intensity profile of the line scan.

LoLAN-Cas was programmed to have an output where the live-feed is shown on the left-hand plot and its corresponding spectrum on the right-hand side. The portion taken from the line scan is shown as an inset on the right-hand figure. The wavelength values are also shown for each peak. Since it is a live-feed video, the output was also real-time spectrum. But for the interests of showing in this documentation on how our live-program output looks like, we employed the same process on pre-captured images of diffraction. The results for various light sources should look like what's displayed on Figures 5-8 where it shows the emission spectra of various light sources.

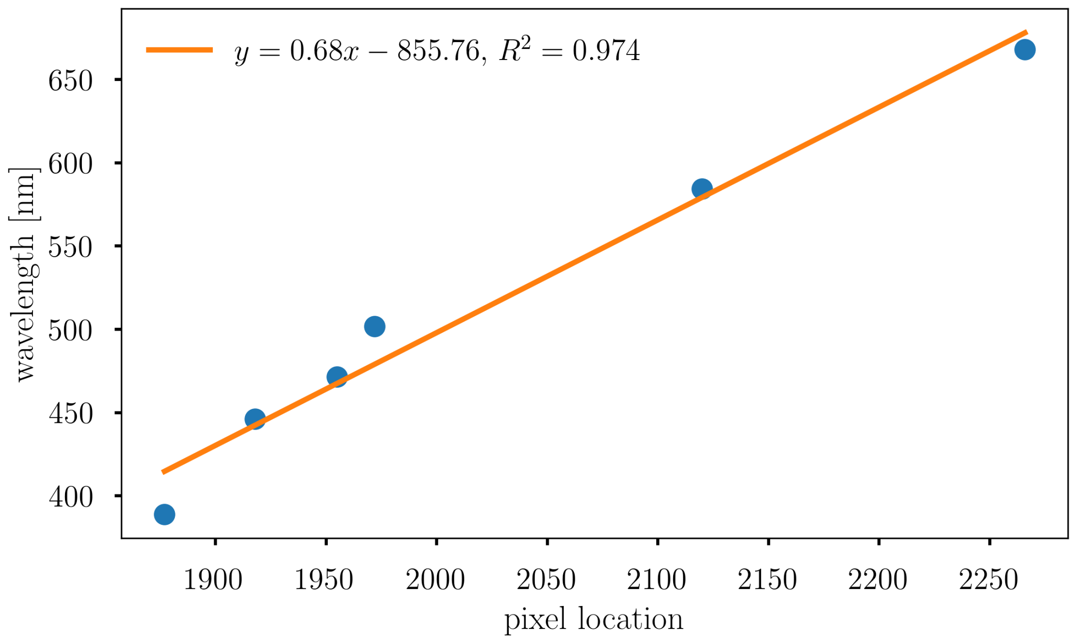


Figure 4: Calibration curve obtained using a helium vapor lamp.

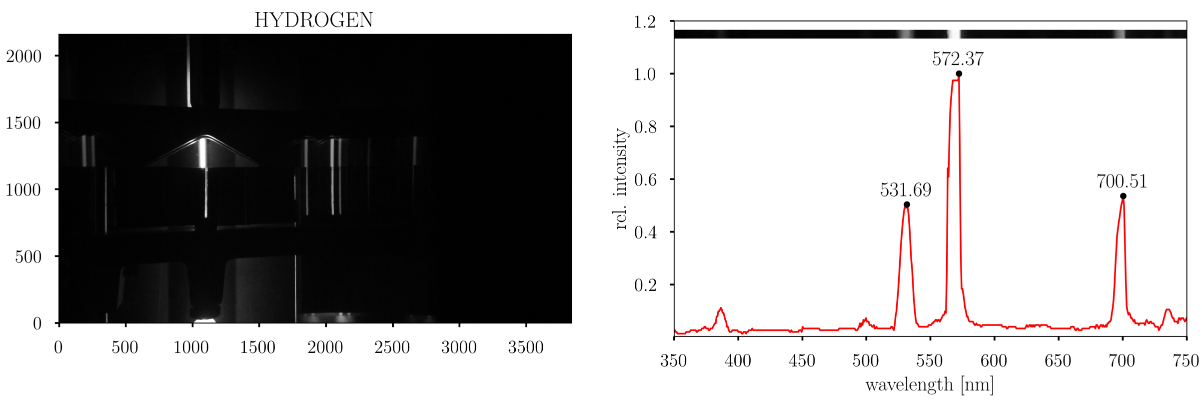


Figure 5: Emission spectrum of hydrogen.

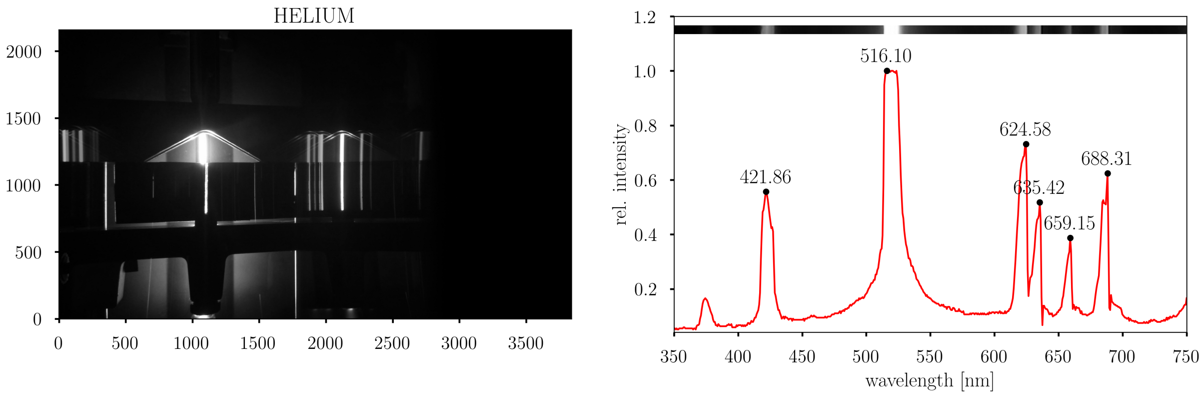


Figure 6: Emission spectrum of helium.

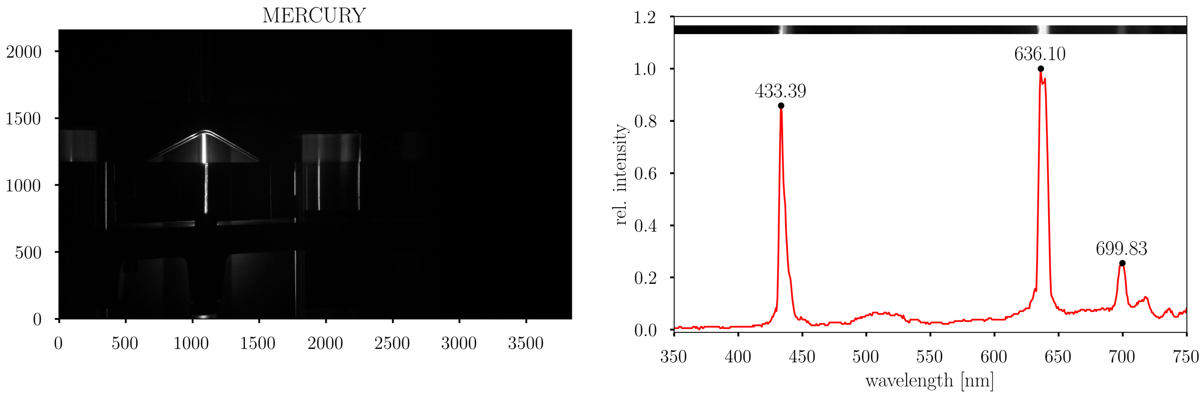


Figure 7: Emission spectrum of mercury.

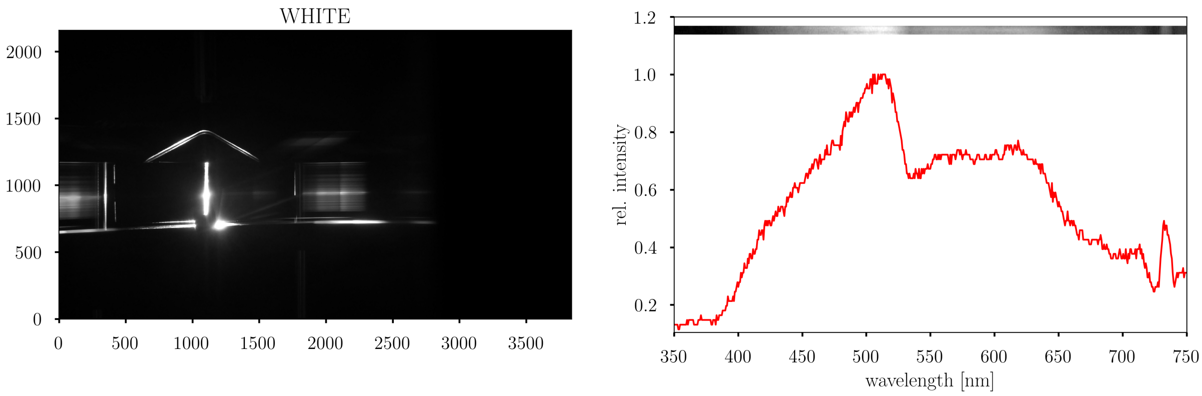


Figure 8: Emission spectrum of a white LED flashlight.

References

[1] Stellarnet inc: What is a spectrometer slit? (2017), accessed May 18, 2019, https://www.stellarnet.us/what-is-a-spectrometer?

[2] A. Kramida, Yu. Ralchenko, J. Reader, and and NIST ASD Team, NIST Atomic Spectra Database (ver. 5.6.1), [Online]. Available: https://physics.nist.gov/asd [2019, May 18]. National Institute of Standards and Technology, Gaithersburg, MD. (2018).

Appendix

Source code:
https://colab.research.google.com/drive/1VMUdZ9GGeLgUW5F7rmk0VZNeu9xxkdcU.