LightMachinery

Technical Note – Calibration lamps with differing plasma conditions.

December 2022

As part of our process for calibrating spectrometers, LightMachinery purchases a variety calibration lamps from several different manufacturers. These calibration lamps generally contain a noble gas (argon, neon, helium) and a metal such as mercury, sodium, or iron. An electric current generates a discharge in the lamp, and the excited gas plasma emits narrowband emission lines at known wavelengths [1].

We recently noticed an interesting difference in the plasma emission from two lamps containing Argon supplied by two different manufacturers. The spectra of the two lamps were taken with an HN-8995-1 spectrometer. This etalon-based cross-dispersion spectrometer has a resolution of 2 pm in the 800 nm wavelength range, and it is this high resolution that allows us to see the differences in the plasma emission from the two lamps.

In Figure 1 below, we show a typical spectrum taken in the 840 to 870 nm region.

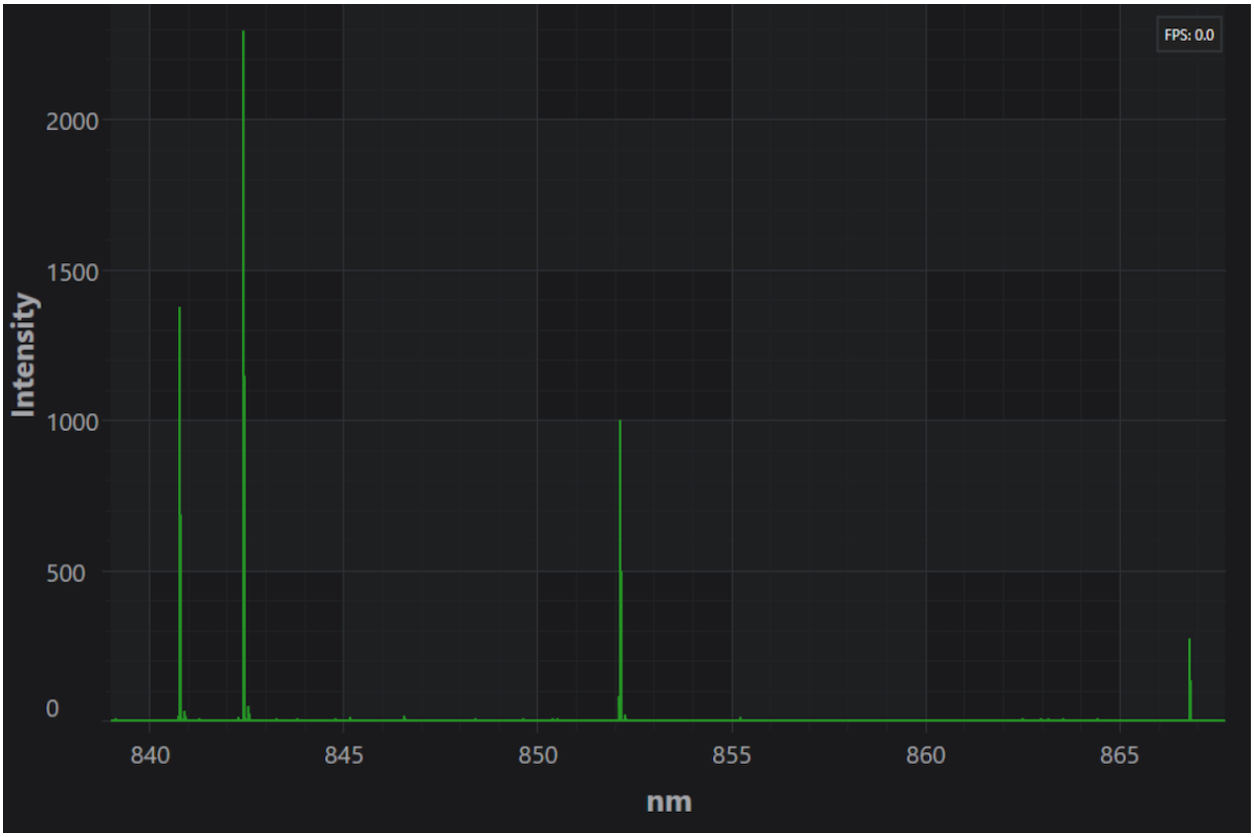

Figure 1 – Typical spectrum of an Argon calibration lamp in the 850 nm region. Note the four narrow emission lines.

A quick comparison of the spectra of the two lamps showed that the *relative* peak intensities of the four lines varied from lamp to lamp, but closer examination determined that much of this peak intensity variation resulted from a variation in the **widths** of the emission lines. In the Table below, the measured FWHM of the four lines are compared for the lamps from Manufacturers A and B

Wavelength in nm	FWHM in pm Manufacturer A	FWHM in pm Manufacturer B	Ratio A/B
840.821	14.32	5.01	2.86
842.469	6.01	4.36	1.38
852.144	14.57	4.67	3.12
866.794	4.95	4.24	1.17

Table 1 – Comparison of the line-widths of the four Argon emission lines seen in Figure 1.

Note the significant variation in the ratio of the linewidths of the emission lines. This variation can be seen in Figure 2 below.

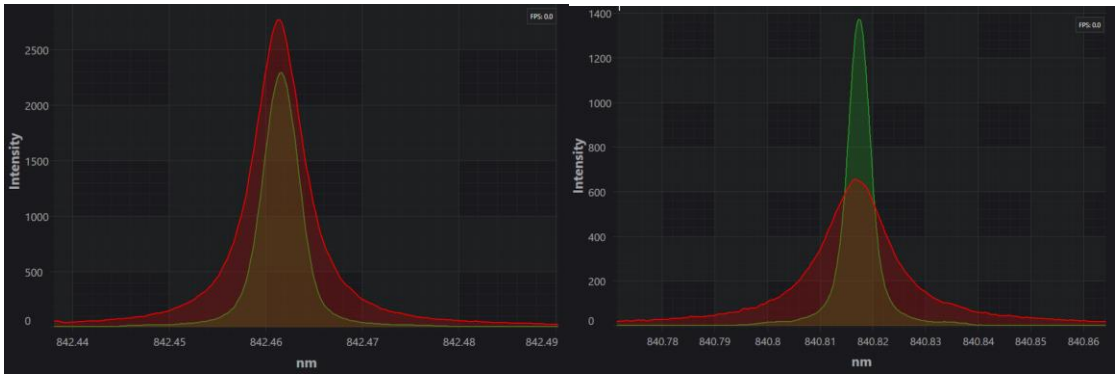

Figure 2 – Comparison of the emission lines from Lamp A (red) and Lamp B (green) at wavelengths of 842.5 nm and 840.5 nm. The exposure times for the two lamps were chosen to emphasize the linewidth differences.

The spectra shown in Figure 2 clearly show that at 840.5 nm the line-width of the emission line from Lamp A is ~3 times wider than the line from Lamp B. However, for the nearby emission line at 842.5 nm the linewidths only differ by a factor of 1.3.

It is interesting to consider the differences in plasma conditions in the two lamps that would lead to such large variations in relative linewidths. Differences in gas temperature might lead to differences in Doppler broadening but cannot account for the strong wavelength dependence of the relative linewidths. Differences in gas pressure will lead to minor differences in linewidths when pressure-induced van der Waals interactions are considered, but again not on the scale of the differences shown in Table 1. It is only when *resonant* pressure broadening is

considered that we find our explanation. Resonant broadening is *highly* dependent on the receiving level of the energy transition responsible for the emission line of the calibration lamp. If the pressure in the lamp A is higher than in lamp B, we would expect the 840.821 nm and 852.144 nm line-widths to be significantly broader in emission from lamp A relative to lamp B, as these transitions fall on energy levels most affected by resonant broadening. The effect of resonant broadening is less for the 842.469 nm transition, and least significant for the 866.794 nm line (which has a metastable receiving level). Note that the ratio A/B shown in Table 1 agrees very well with this explanation [2].

We also looked briefly at the *integrated* intensities of the four lines shown in Figure 1. We found that the relative areas under the line-shape of the four lines were similar from lamp to lamp (varying by at most 30%), confirming that most of the variation in relative peak intensities is caused by the x3 variation in linewidths.

It is worth noting that the ability of etalon-based cross-dispersion spectrometers [3] to record a spectrum spanning 30 nm with a resolution of 2 pm enabled us to discover these linewidth anomalies. Figure 3 shows a portion of the raw sensor images to directly illustrate the differences between Lamp A and Lamp B.

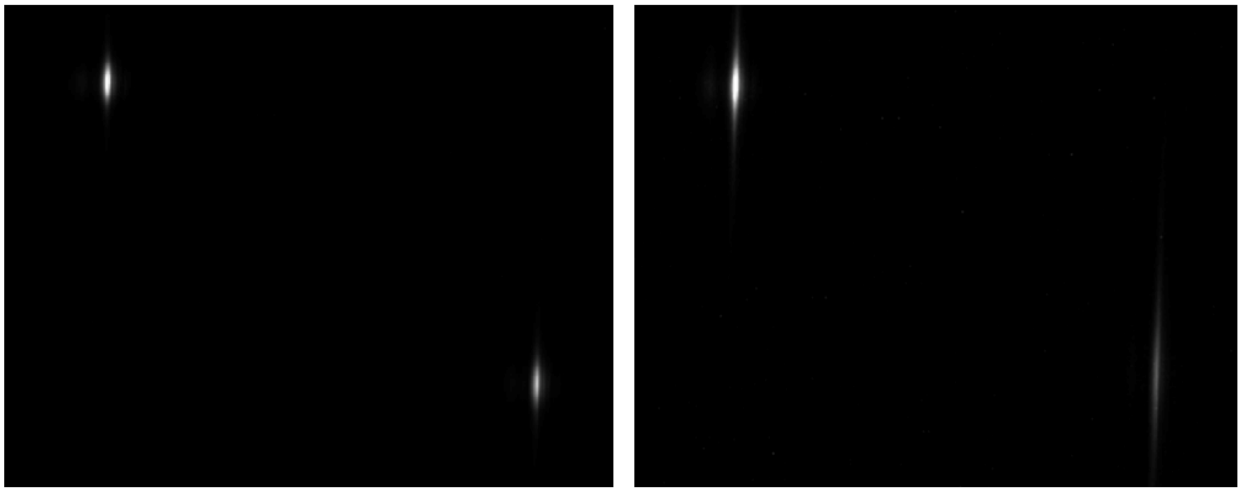

Figure 4 – A portion of the image on the sensor when recording spectra from Lamp B (left) and Lamp A (right). In each image the two “blobs” are the cross-dispersed spectra from the emission lines at 842.5 (left blob) and 840.8 (right blob) nm. The long faint blob on the far right corresponds to the wide line-width of the 840.8 nm emission line from Lamp A.

Footnotes

[1] – NIST provide very useful tables of the line positions of all the strong emission lines at https://physics.nist.gov/PhysRefData/Handbook/element_name.htm

[2] – Thanks to Professor Luc Stafford of the University of Montreal for his explanation of resonant pressure broadening in Argon lamps.

[3] – More details of the operating principles of these spectrometers can be found at https://lightmachinery.com/media/1857/hyperfine-principles-of-operation.pdf