Use of a lock-in amplifier with AC lamps in spectroscopy

4
1
2
2
2
2
2
15
= 8

Abstract

When working with AC lamps in Spectroscopy, the use of a lock-in amplifier can greatly decrease the amount of noise generated by the fluctuations in current. For this project we examined the D-lines of Sodium (588.995 nm and 589.592 nm) and the 313 lines of Mercury (313.155 nm and 313.184 nm). In our experiment, a normalized signal without the lock-in amplifier created a signal with up to ±2 V deviation from the signal for Sodium and approximately ±0.5 V for Mercury.

Introduction

Trying to obtain the spectrum from an AC lamp presents a number of challenges. The most notable is the rapid change in light intensity due to the cycling of current. In the United States, a standard wall socket produces a current with a complete cycle of approximately 60 Hz. Because the cycle includes both a "forward" and "back" component, changes to the current in the lamp actually happen at a rate of 120 Hz. The effect of this is a sharp sinusoidal pattern in the output of the monochromator and photomultiplier tube.

not really in uncertainty ↓ beats

During a slow scan of a portion of the spectrum, this leads to uncertainties in the wave, making some calculations (e.g. the full width at half maximum or FWHM) prone to error. During a broader scan this can prevent lines from being detected if the examination of a wavelength of interest occurs at a node point of the power wave.

The first of these problems can be mitigated by making use of a properly configured lock-in amplifier. The lock-in amplifier uses narrow band filters and a Fourier Transforms to isolate signal from noise with the help of a reference signal. The lock-in amplifier multiplies the input signal by the reference signal and then performs a Fourier Transform. When the signal is averaged over a period of time longer than the frequency of the reference signal, any part of the signal that is not exactly at the same frequency as the reference signal will average to zero. Parts of the signal that are exactly at the same frequency as the reference signal will be output as a DC signal with strength equal to the original amplitude multiplied by the cosign of the phase difference.

Equations

With signal amplitude V_s, signal angular frequency of ω_s, and reference angular frequency of ω_r, multiplying the signal by the reference gives us:

$$
\begin{aligned}
V_{out,1} &= V_s * \cos(\omega_r t)\cos(\omega_s t + \varphi) \\
&= \frac{1}{2}V_s * \cos[(\omega_r + \omega_s)t + \varphi] + \frac{1}{2}V_s \\
&\qquad * \cos[(\omega_r - \omega_s)t + \varphi] \\
V_{out,2} &= V_s * \sin(\omega_r t)\cos(\omega_s t + \varphi) \\
&= \frac{1}{2}V_s * \sin[(\omega_r + \omega_s)t + \varphi] + \frac{1}{2}V_s \\
&\qquad * \sin[(\omega_r - \omega_s)t + \varphi]
\end{aligned}
$$

Both signals are passed through a narrow band pass filter and the output has a magnitude equal to:

$$V_{final} = V_s * \sqrt{(V_{out,1})^2 + \left(V_{out,2}\right)^2}$$

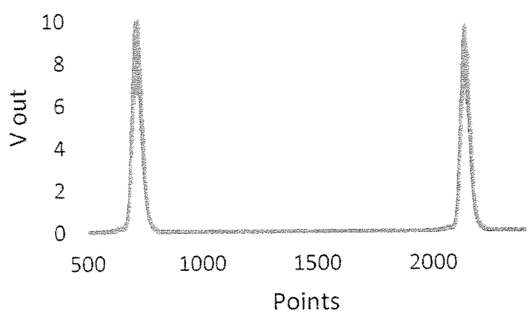
Model

All measurements were taken twice: once with the standard configuration of instruments to analyze the spectra of a lamp; once with the Standford Research SR530 lock-in amplifier details

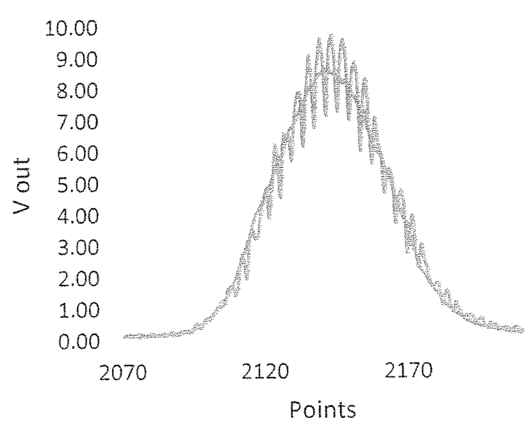
wired between the electrometer and the computer. The lock-in amplifier was set to use a reference at twice the frequency provided ("2f" setting), a sensitivity of 50 mV, a time constant of 10 ms, and a post of 0.1 s. The scan of the Sodium D-lines was done at 0.5 nm/min with a sampling rate of 20 points/second. The scan of the 313 lines of Mercury was done at 0.1 nm/min with a sampling rate of 20 points/second.

Data

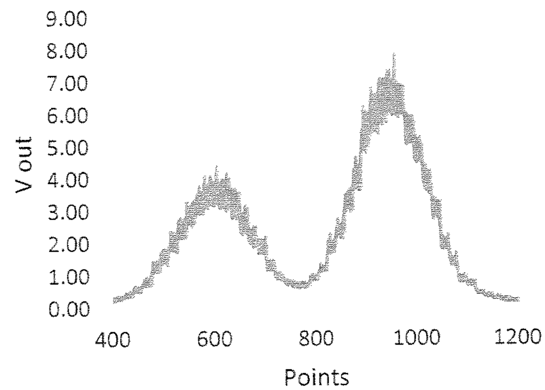
Sodium D-Lines (588.995 and 589.592 nm)



Sodium 589.592 nm



Mercury 313 lines



Analysis

It is difficult to determine where changes to the lock-in amplifier configuration would allow for better results. The scan of the 313 lines of Mercury shows odd behavior in the curve but it is present both with and without the lock-in. Further analysis would be needed to determine the source of that behavior, however, that is not within the scope of this research assignment.

? not really. it is expected

Conclusion

Use of the lock-in amplifier with an AC light source allows for much greater resolution and analysis of the spectrum. Careful calibration is needed, however, to get the best results.

References

SR 530 Manual: http://www.thinksrs.com/downloads/PDFs/Manuals/SR530m.pdf