Measuring the Wavelength of Hg and Na Light using a Michelson Interferometer

Abstract: A Michelson interferometer has been used to determine the wavelength of the green emission line from a mercury lamp. The measured wavelength was 549.0(9)nm. Using the known wavelength of the same line, 546.074nm, the reduction lever of the interferometer was found to reduce the micrometer travel by a ratio of 5.026(8):1, rather than the quoted 5:1. Using this calibrated reduction ratio, the average wavelength of the yellow sodium doublet was determined to be 589.3(10)nm and the splitting between the lines forming the doublet was 0.5971(5)nm. These are in excellent agreement with the literature values of 589.294nm and 0.5974nm, respectively.

In a Michelson interferometer (Figure 1), monochromatic light from an extended source is divided into two equal-amplitude beams by a beam splitter. One beam travels towards a *fixed* mirror (M2) and is reflected back to the beam splitter. The other beam travels to a *moveable* mirror (M1), and is reflected back to the beam splitter. The two beams then recombine and are then detected showing interference fringes. If the effective pathlength of one of the optical path lengths is changed, then any given point on the interference patterns shifts from light to dark, or vice-versa, for each half-wavelength of path length change. Thus if N fringes shift across the field of view when M1 is translated, then the distance x moved by M1 is $N\lambda/2$.

Using a mercury lamp with a green filter to transmit only the 546.074nm green emission line, the number of localised fringes that passed the centre of the field of view when mirror M1 was translated was determined.

Fringes	Micrometer Reading (mm) (all ±0.002)	Corrected for Gearing (mm) (all ±0.0004)
0	15.735	3.1470
150	15.530	3.1060
250	15.391	3.0782
400	15.186	3.0372
500	15.049	3.0098

A plot of micrometer reading versus the number of fringes passed should be linear with a gradient $\lambda/2$. The data are shown in Figure 2a. The error bars are smaller than the symbols used to plot the points and have been omitted. A least-squares fit to the data using LINEST gave a gradient of 274.5(5)nm/fringe. The wavelength of the green emission line is therefore 549.0(9)nm. A plot of the residuals (Figure 2b) shows no systematic deviations, but suggests that the estimated uncertainty of ±0.002mm in the micrometer readings is probably an overestimate.

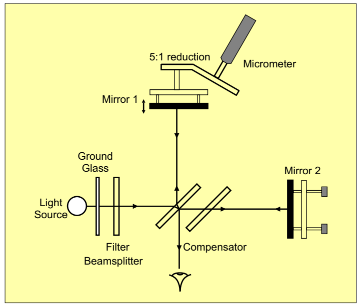

Figure 1: Schematic diagram showing the layout of the Michelson interferometer.

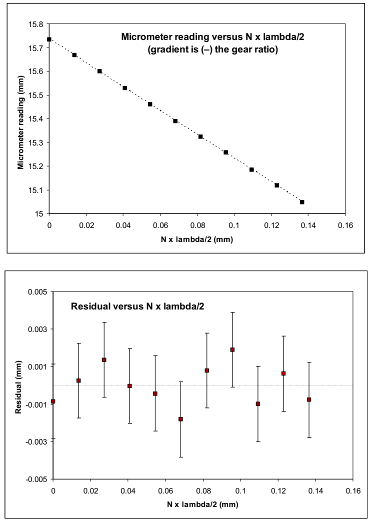

Figure 3: (Top) Micrometer reading versus N $\times\lambda/2$, with λ= 546.074nm. The dashed line through the data points is the best-fitting straight line from the least-squares fit. (Bottom) The residuals from the least-squares fit. The distribution of the points suggests that the uncertainties are probably overestimated.

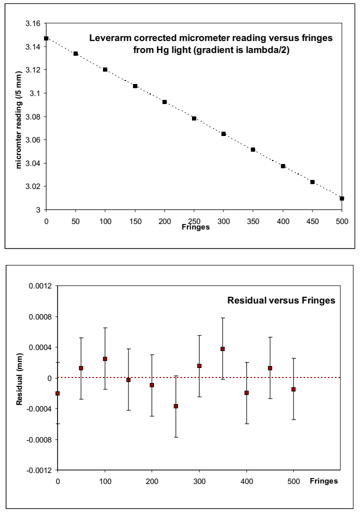

Figure 2: (Top) Gearing corrected micrometer reading versus fringe number for the green mercury emission line. The dashed line through the data points is the best-fitting straight line from the least-squares fit. (Bottom) The residuals from the least-squares fit. The distribution of the points suggests that the uncertainties are probably overestimated.

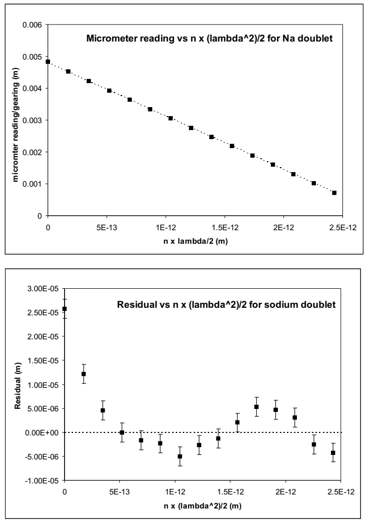

Figure 4: (Top) Micrometer reading versus $N\lambda^2/2$, with λ= 546.074nm. The dashed line through the data points is the best-fitting straight line from the least-squares fit. (Bottom) The residuals from the least-squares fit show a clear systematic deviation.

The literature value of the same line is 546.074nm, and this was used to calibrate the ratio of the reduction arm. A plot of micrometer reading versus $N\lambda/2$, where λ=546.074nm should give a straight line with a gradient equal to the gearing ratio.

The data are shown in Figure 3. The error bars are smaller than the symbols used to plot the points and have been omitted. A least-squares fit to the data using LINEST gave a gradient of 5.026(8). A plot of the residuals of the fit showed no systematic deviations, but again suggested that the estimated uncertainty of ±0.002mm in the micrometer readings is probably overestimated.

Finally, the interferometer and the calibrated lever arm ratio were used to determine both the average wavelength of the two emission lines that make up yellow sodium-doublet, and their wavelength splitting.

The average wavelength of the sodium doublet was obtained by counting fringes, as for the 549nm Hg line. From a plot of gearing-corrected micrometer reading versus fringes (using the experimentally determined gearing ratio), a least-squares fit to the data using LINEST gave a gradient of 294.6(5)nm/fringe. The average wavelength of the sodium doublet is therefore 589.2(9)nm, in excellent agreement with the literature value of 589.294nm.

Contrast Minimum (n)	$n\lambda^2/2$ (m)	Micrometer reading (mm) (all ±0.01)
0	0	24.245
1	1.73634×10^{-13}	22.715
3	5.20901×10^{-13}	19.730
4	6.94535×10^{-13}	18.260
7	1.21544×10^{-12}	13.870
8	1.38907×10^{-12}	12.415
13	2.25724×10^{-12}	5.100
14	2.43087×10^{-12}	3.630

To determine the wavelength splitting of the doublet, the distance traveled by mirror M1 between successive contrast minima in the fringe pattern was determined. The data for 14 such minima are shown above. A linear plot of the gearing corrected micrometer (using the calibrated ratio of 5.026(8)) versus $N\lambda^2/2$ is shown in Figure 4a. The error bars are again smaller than the symbols used to plot the data. A linear least-squares fit to all the data using LINEST gave a wavelength splitting of 0.5951(9)nm. However, a plot of the residuals (Figure 4b) clearly shows a systematic deviation from the straight line. Refitting the data omitting the two worst fitting data points (n=0 & 1) gave a wavelength splitting of 0.5970(6)nm, in