Building a sub-nanometre resolution grating monochromator

Choong Zheng Yang [1]

[1]Hwa Chong Institution (College), 661 Bukit Timah Road, Singapore 269734

Introduction

Grating spectrometry is an experimental technique first used in 1860 in the discovery of Rubidium and Caesium [1], and has since found common application in various fields for its ability to characterise and identify light sources.

We present a grating monochromator calibrated to the HeNe laser spectral peak at 632.8 nm, and offer suggestions for future investigation.

The grating equation is given as such [2]:

$$sin\theta_m = sin\theta_i + m\frac{\lambda}{d} \tag{1}$$

where θ_i and θ_m are the angles between the incident and diffracted beams from the grating normal, and m the diffraction order. With the HeNe spectral peak at 632.8 nm, $\theta_m \approx 22.3°$ at normal incidence. The resolution limit of the diffraction grating is given by [2]:

$$\frac{\lambda}{\Delta\lambda} = mN \tag{2}$$

where N is the number of lines illuminated on the grating. For a beam diameter of $\approx$ 1 cm, the grating resolution is on the order of 0.1 nm for single mode beams, and 2 nm for multi-mode beams.

Experiment

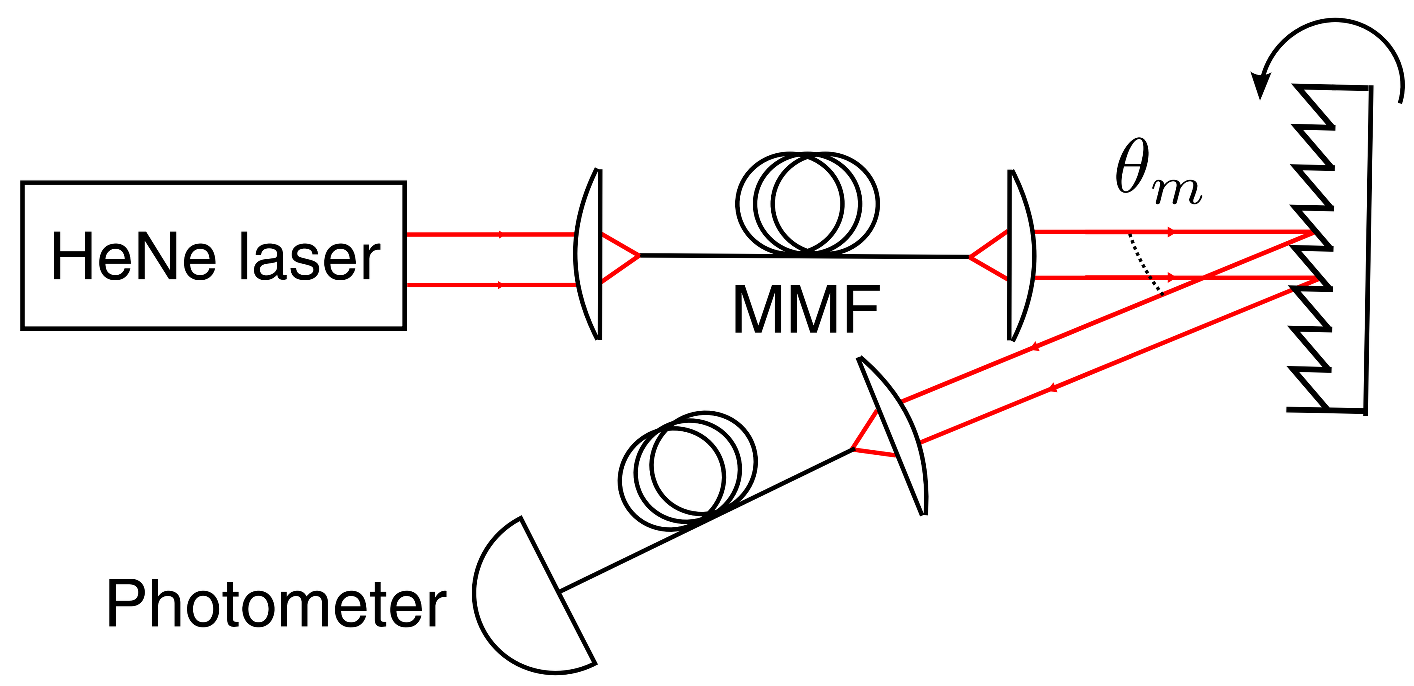

Figure 1: Schematic of the grating monochromator. The HeNe laser is coupled into a multi-mode fibre, which is then collimated, and incident on a blazed reflective grating (500 nm blaze 600 lines/mm) mounted on a motorised rotational stage; the first diffraction order is collected is incident on a photometer.

Results and Discussion

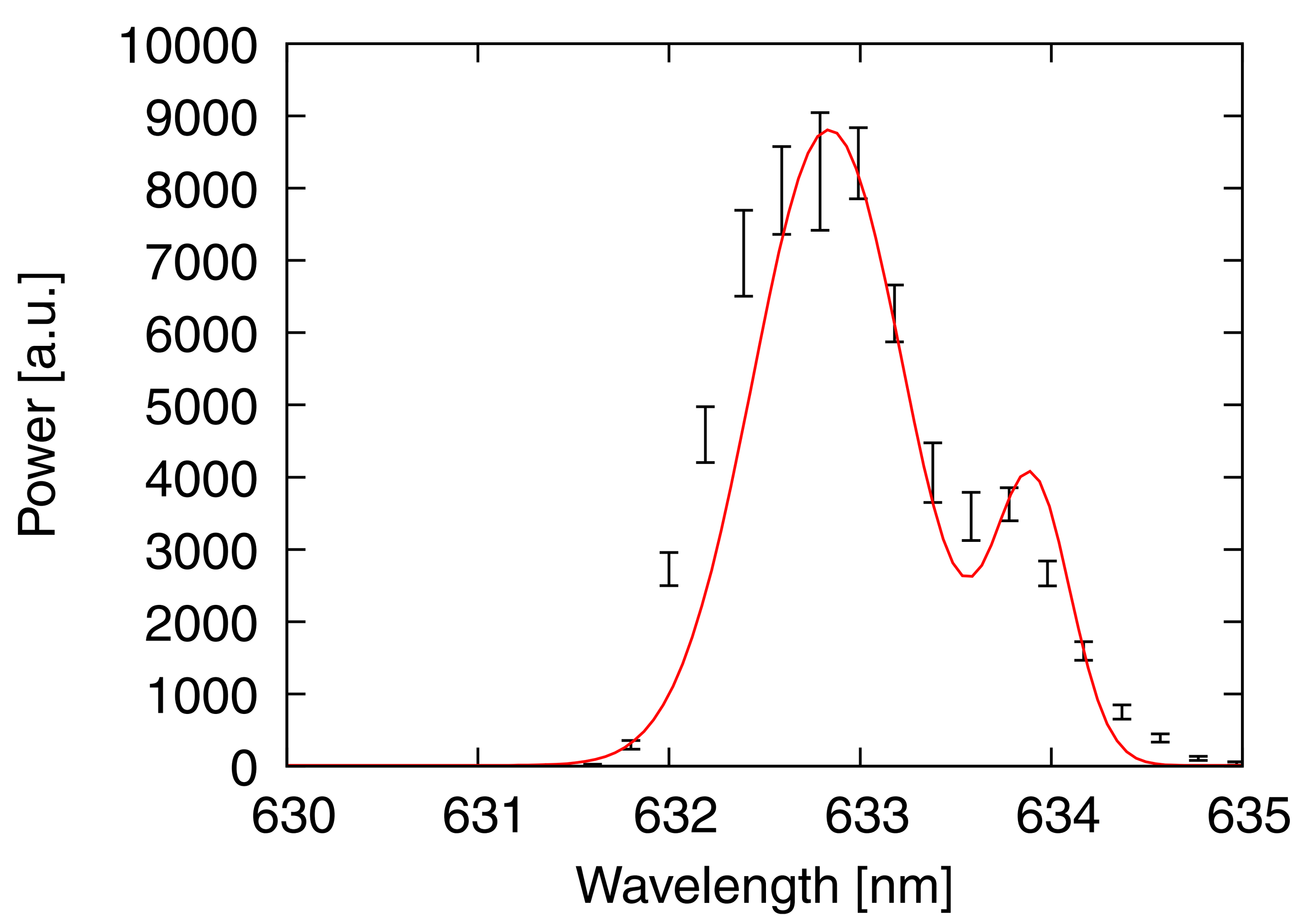

Figure 2: The HeNe spectrum measured with an OceanOptics2000 spectrometer. Fitted to a bi-Gaussian distribution, $\chi^2/doF \approx 12$, peaks at 632.8 $\pm$ 0.1 nm and 633.9 $\pm$ 0.2 nm, with a FWHM of 0.9$\pm$ 0.1 nm.

Using an OceanOptics spectrometer (USB2000, VIS-NIR), we measure the spectrum of the HeNe laser, suggesting two peaks at 632.8 $\pm$ 0.1 nm and 633.9 $\pm$ 0.1 nm, with a full-width at half maximum (FWHM) of 2.1 $\pm$ 0.1 nm.

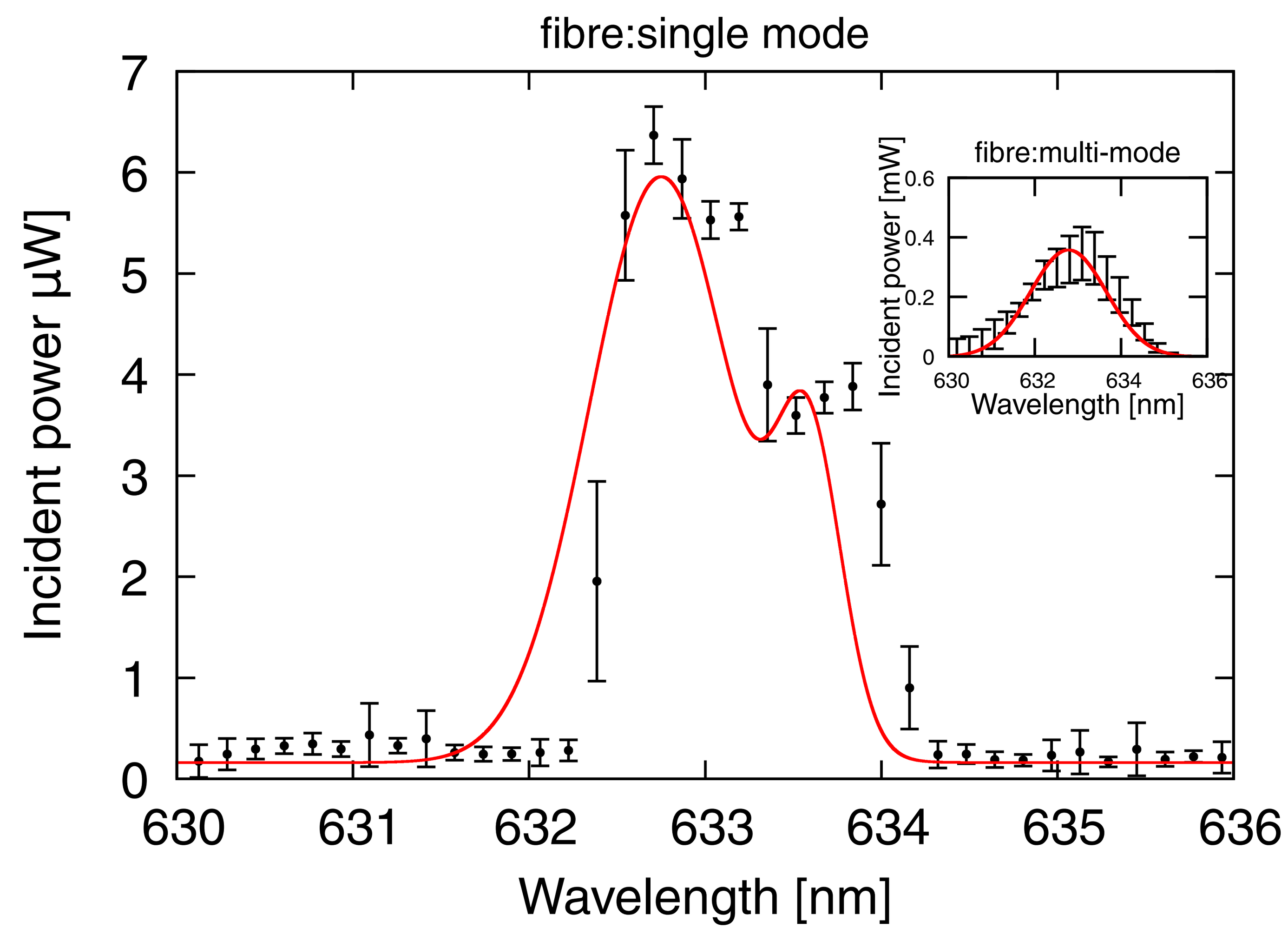

Figure 3: Fitted to a Gaussian, $\chi^2/doF \approx 8$. Using a single mode fibre, μ = 632.8 $\pm$ 0.1, σ = 0.41 $\pm$ 0.04 implying a FWHM of 0.97 nm. With the multi-mode fibre (inset), $\chi^2/doF \approx 0.7$, σ = 0.88 $\pm$ 0.05 nm

The spectrum measured with the monochromator is fitted with a FWHM of 2.1 $\pm$ 0.1 nm, in accordance with the theoretical prediction of 2 nm using a multi-mode fibre. The similar result with the OceanOptics measurement suggests that the laser linewidth is near 1.0 nm.

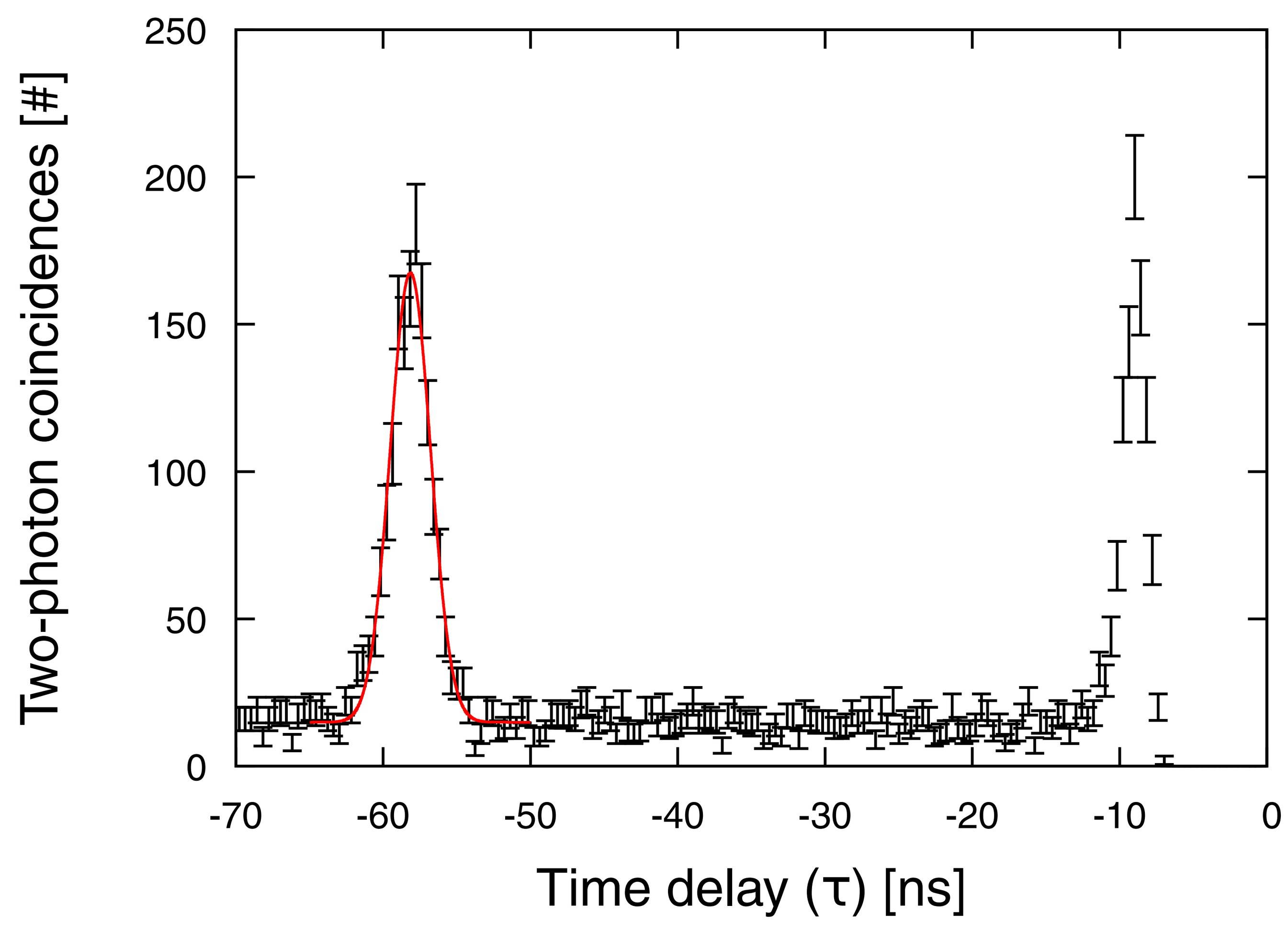

Figure 4: Coincidence counts obtained from a pair of Silicon Avalanche Photodiodes (APDs), showing a fully resolved peak at -58 ns, and a partially resolved peak near -9 ns. The resolved peak is fitted to a Gaussian, $\chi^2/doF \approx 1.4$, with a signal-to-noise ratio of 10.2 $\pm$ 0.5.

Having demonstrated the monochromator, we measure the correlation signal from avalanche flash breakdown. We hope to extend this technical capability to perform a technique called photon correlation spectroscopy to characterise the spectrum of other light sources.

Acknowledgements

We thank Dr. Tan Peng Kian from the Centre of Quantum Technologies, and Dr. Erkan Polatdemir from Hwa Chong Institution for their mentorship and guidance.

References

[1] Kirchhoff, G. and Bunsen, R. (1860). Chemische analyse durch spectralbeobatchtungen. *Annalen der Physik*, 186(**6**):161-189
[2] Popov, E. G. L. E. (1997), *Diffraction gratings and applications.* Optical engineering (Marcel Dekker, Inc.), v. 58. M. Dekker.