ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

Optical Modelling of Spatial Heterodyne Spectrometer for Airglow Emission Measurements

Neema Maria John[1], Arun Jose[2]

PG Student [OEC], Dept. of ECE, TKM Institute of Technology, Kollam, Kerala, India[1]

Assistant Professor, Dept. of ECE, TKM Institute of Technology, Kollam, Kerala, India[2]

ABSTRACT: Spatial Heterodyne Spectroscopy (SHS) assume a critical part in ground-based aeronomy. Fizeau fringes of wavenumber dependent spatial frequency are produced by SHS, which is a form of Michelson interferometer modified with diffraction gratings instead of mirrors. Fringes produced are recorded on a position detector and Fourier transformed to recover the spectrum over a limited spectral range limited at the Littrow wavenumber of the gratings. The system combines interferometric and field-widening gains together to attain 10,000-fold sensitivity gains compared to conventional grating instruments of similar size and resolving power. Defects can largely be removed in data processing. This paper will briefly describe the developing of a grating based interference spectroscopy system, called the Spatial Heterodyne Spectrometer (SHS) on a table top for ground based measurements of faint airglow emissions 6304Å with the ultimate goal of making it in the form of a payload for satellite based studies.

KEYWORDS: Spectroscopy, Spectrometer, Spatial Heterodyne Spectroscopy, Airglow emissions.

I.INTRODUCTION

Interference spectrometers, like Fabry-Perots and Michelson, offer significant advantages over conventional grating spectrometers for the study of faint spatially extended sources [1]. The primary advantages are (1) etendue (or throughput), typically 200 times larger than grating spectrometers operating with a similar spectral resolution; (2) compact size, especially at high resolution; and (3) relative ease of attaining high resolution. In combination these advantages can provide important economies in cost, weight, and volume of the systems, which are crucial in rocket and satellite based programs [1].Consequently, for extraterrestrial studies in atmospheric research, interference spectrometers are becoming ideal tool. We have been involved in the study of the aeronomy of the mesosphere thermosphere ionosphere (MTI) region of earth atmosphere using airglow emissions (as the primary tool), which are very faint luminosity of atmosphere arising from radiative transitions between energy states of atoms/molecules.

II.LITERATURE SURVEY

In the basic spatial heterodyne spectrometer, Fizeau fringes of wavenumber-dependent spatial frequency are produced by a modified version of Michelson interferometer in which the return mirrors are replaced by conventional blazed diffraction gratings as shown in Figure 1.

For each wavelength in the wave-front entering the interferometer, two wave-fronts exit with a wavelength-dependent crossing angle between them. This produces a superposition of Fizeau fringes with wavelength dependent spatial frequencies centered near the gratings. The fringes are recorded on a position sensitive detector and its fourier transformation will recovered the spectrum. In this process, no element is mechanically scanned[2].

DOI:10.15662/IJAREEIE.2016.0504142

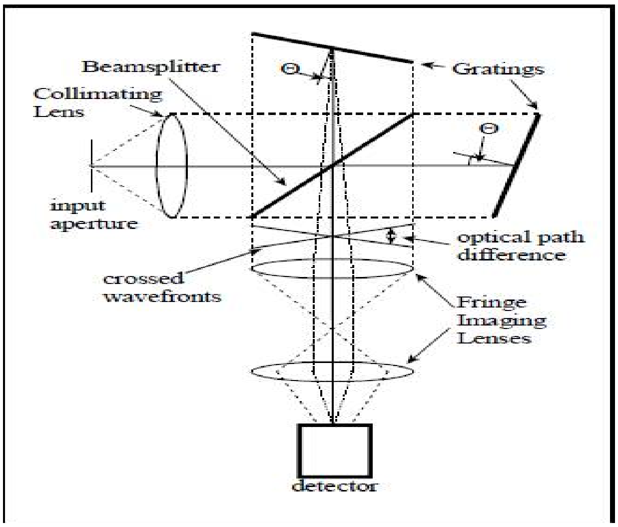


Fig 1. SHS Configuration

SHS concept can be evoked by the fact that the gratings can be tuned to place zero spatial frequency at a selected wavenumber σ_0, where σo is the Littrow wavenumber of the diffraction gratings. Now with the grating pair in the Littrow configuration, for collimated monochromatic light of wavenumber σ_0 entering into the system two coherent coinciding plane wavefronts are produced at the output. Obviously, SHS records the cosine Fourier transform of the input spectra without any scanning and heterodynes the interferogram with a frequency corresponding to the Littrow wavenumber of the grating. Fourier transform of I(x) yields the light spectra, which entered into the system, about the heterodyne wavelength. For a system tuned toσ_0, adjacent spectral elements$\sigma_0 + \delta\sigma$, $\sigma_0 + 2\delta\sigma$, $\sigma_0 + n\delta\sigma$ produce 1,2, n-cycle spatial frequencies across the detector as shown in figure 2.

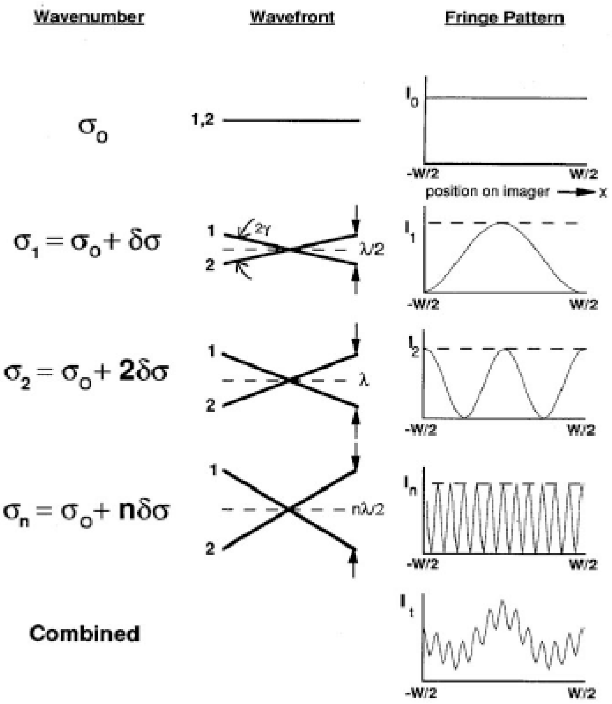


Fig 2. Fringe pattern formation

Gains associated with field widening are typically two orders of magnitude in solid angle over conventional interferometers (104 larger than diffraction grating spectrometers). The prism apex angles are chosen so that from a geometrical optics point of view the gratings appear coincident. The geometrical path difference in the system is then near zero for a wide range of input angles resulting in a field of view much like a conventional Michelson at zero path difference. Aberrations introduced by the prisms ultimately limit the field of view, but not before large gains can be achieved in many applications. At R = 50,000, angles up to ±5 deg can be used within the interferometer.

III. OBSERVATION AND RESULTS

We are currently using the SHS technique to measure the extremely faint [OI] λ 6300 A° from the ionosphere [4]. The [OI] airglow emissions are mainly found and formed in a region of about 220 Km height from the ground surface. The formation of [OI] airglow emissions mainly occurs due to the following processes like Photo-Electron impact, Photo dissociation and Dissociative Recombination[5]. Airglow emissions are potential tracer for Ionospheric temperature and wind measurements. They also helps in the study of energy flow dynamics and photochemistry within the species formed in Ionospheric region.

Initial alignments were made using coherent light source such as laser (He-Ne) and incoherent light source of Neon spectral lamp. The former was centered at 633nm and lamp was centered to be in 630.4nm wavelengths. The experimental setup is shown in figure 3.The spatial heterodyne spectrometer employs diffraction gratings with a groove density of 1200 grooves mm^{-1} and a cryogenically cooled EMCCD detector.

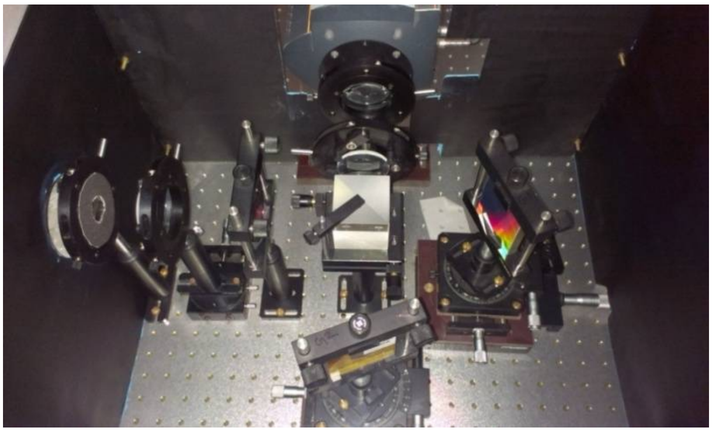
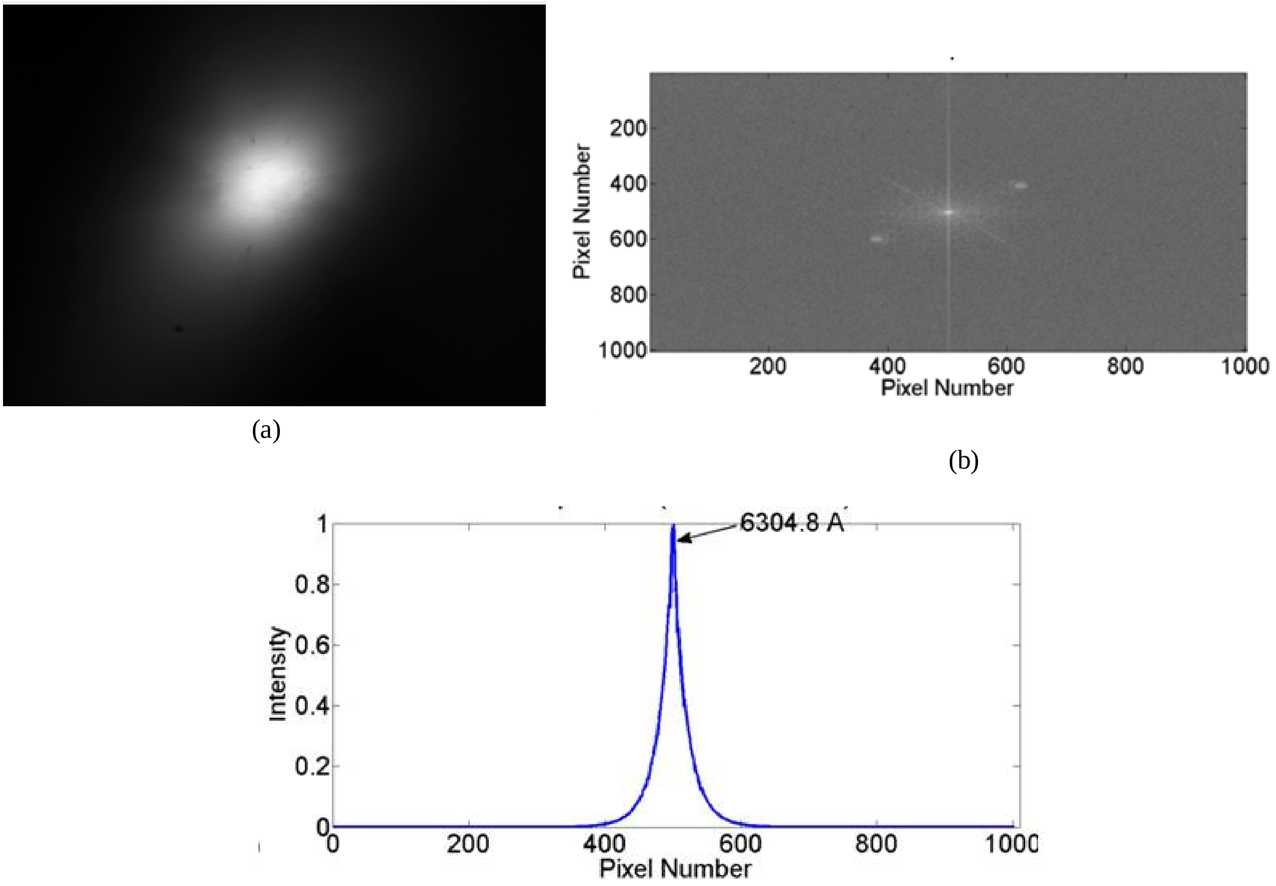


Figure 3. Experimental setup of SHS

An interference filter with a 20 ˚A pass-band, centered near λ 6304.8, FWHM 11 ˚A˚ is used as a pre-filter in order to reduce photon noise due to the sky background during tuning. The gratings are of 58 X 58 mm^2 and the ruled area is about 56 X 56 mm^2. The gratings are tuned to the Littrow angle of about ~ 22° 13´ for the Ne lamp. The blaze wavelength is set to be about 630nm. The field of view at the gratings being assumed to be 14 deg, gives a resolving power of the [OI] SHS system ~ 30,000. Beam splitters and the lens mechanism are implemented to fulfill the path of the emissions. Detectors used are mainly CCD (1392×1040 pixels, 6.45×6.45 μm^2) and EMCCD (1004 ×1002 pixels, 13×13 µm2).

A. SHS Interferograms and obtained spectrums

SHS technique was used to measure the faint [OI] λ 6304 A° emission lines of Interstellar medium [4]. Here, Littrow was set at an angle of 22°.13´. As a result, an interferogram is produced for neon lamp and is shown in figure 4 (a). Resulting power spectrum and line spectrum are also shown in figure 4 (b) and 4 (c).



(a)

(b)

(c)

Figure 4 (a) Interferogram (b) Power spectrum and (c) Filtered line spectrum obtained using neon lamp

In the analysis of the output spectrum, the central region of the interferogram was cropped (in order to avoid the edges of the grating), apodized with a Gaussian function, and a two-dimensional Fourier transform was applied. Figure 4(b) shows the resulting power spectrum. There are 481 pixels within the cropped region interferogram, out of a possible 512 pixels if the full 512 × 512 CCD array were used.

IV. CONCLUSION AND FUTURE WORKS

The advantages of SHS can make this approach the method of choice for of key helio-physics mission objectives. One example is the measurement of thermospheric wind and temperature profiles. We have recently completed construction of a compact SHS system which would be capable of observation of Night sky 6300 °A and the study of wind and temperature measurements can be done at high resolving power. As the airglow emissions are very much faint emissions, and centered towards 220km away, the delicate situations of sky is always a favorable factor. In order for the observations to be real, a clear night sky devoid of clouds, as well as the moonlight must be formed. FOV can be increased further using telescopes and field widening prism depending upon the requirements. The earlier study for the 630 nm airglow emission observation prolonged for about 3 years and 89 night observations [6].

V. ACKNOWLEDGEMENT

This work on SHS was funded by Vikram Sarabhai Space centre and carried out to realize by the help of Space Physics Laboratory, ISRO. For their help and support is gratefully acknowledged.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

REFERENCES

[1]. J.M.Harlander and F. L.Roesler,“Spatial heterodyne spectroscopy: A novel interferometric technique for ground-based and space astronomy,” in Astronomical Telescopes and Instrumentation for the 21stCentury, Proc.SPIE1235, p.622,1990.

[2]. J.M.Harlander, Spatial Heterodyne Spectroscopy, interferometric performance at any wavelength without scanning, Ph.D. Thesis, University of Wisconsin-Madison, 1991.

[3]. J.M.Harlander, R.J.Reynolds, and F.L .Roesler, “Spatial heterodyne spectroscopy for the exploration of diffuse interstellar emission lines at far-ultraviolet wavelengths,”ApJ396, p.730,1992.

[4]. J. M. Harlander, F. L.Roesler, J. Cardon, C.Englert , and R.R.Conway, “Shimmer: A spatial heterodyne spectrometer for remote sensing of earth’s middle atmosphere,” AppliedOptics41, p.1343,2002.

[5] Vladislav Yu Khomich, Anatoly I. Semenov, Nikolay N. Shefov, “ Airglow as an Indicator of Upper Atmospheric Structure and Dynamics” Devoted to the 50th anniversary of the International Geophysical Year (1957–1959), Springer.

[6] A D Tillu, “Night Airglow at Poona observed at (1955-1964) ” Department of Physics , University of Poona, received on Vol 39A,No 6.