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Development of a Solar Spectrum Monitor based on Diffraction Grating

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Abstract: *The sun is one of the second largest G2-type stars in the Milky Way of the universe. It is getting old, since its birth about 4.5 billion years ago. The origin of the solar spectrum and its constituent colors are the fusion reactions, thermal radiation and fundamental interactions of particles-antiparticles. Hydrogen is the main fuel of this fusion reaction from where the Earth has been receiving enormous energy continuously. As we are worried about the Global Warming, Earthquake, volcanic eruption, Tornado and other related issues of natural causalities those are directly influencedby the solar radiation and motion of the Earth. Hence my foremost interest is the monitoring of solar radiation spectrum that is a Global issue and the discovering of a special domain of research in this area of science. Development of a diffraction grating detector system and how it will be an excellent and inexpensive tool for studying the chromaticity of solar spectrum are reportedhere.*
Keywords: *Chromaticity, Diffraction, Grating, LED, Light, Radiation*

I. Introduction

The origin of solar spectrum is a blackbody radiation where fusion reaction is occurring spontaneously. The sun consists of mostly Hydrogen (~ 90%) and rests are heavier atoms e.g., Helium, Lithium, Carbon, Nitrogen, Oxygen etc. In the beta decay process particles and antiparticles are created and those recombine to form exotic atoms (e.g., Positronium). Not only the thermal radiation but also theγ-rays energies of transitions of ordinary atoms play crucial role of avisible solar spectrum. On the other hand annihilation γ-rays of exotic atoms may contribute a part of the visible spectrum after many interactions with surrounding materialsin a long journey from the core to the outer photosphere. By studying the chromatic nature of the solar spectrum [**1**] it is conceivable to infer the condition of solar atmosphere, inherent properties of solar core and nuclear reactions, constituent elements, even to discover new atoms [**2**] and particles. The study of rotational and orbital motions of the Earth about the Sun can help us to predict the natural disasters [**3**]. In the following sections development of a diffraction grating detector, experimental procedure and results will be discussed.

II. Solar Spectrum Monitor development

In order to study the chromaticity of solar spectrum a Solar Spectrum Monitor (SSM) was developed byusing colored (Blue, White and Red) epoxy glasses[**1**]. The colored signal were guided through optical fibers and collected by photodiodes. The corresponding current of each colored signals were measured by the micrometer in every hour in a day. Instead of those epoxy glasses colored LEDs wereintroduced for the first time in order to develop a SSM for studies the exotic atoms in the celestial bodies. The efficiencies of LEDs are better than epoxy glasses which are responded according to the intensity and color of the incident radiation. Study of the chromaticity of solar spectrum is one of the primary interestsand hence a diffraction grating is introduced in this system. Colored light sources, N-slits grating,convex lens, mirror, equipment holders and prism are arranged on an optical bench of 1.50 m long. A traveling microscope is used in order to focus the color fringes and measure the respective angles of the fringes after diffraction of the solar spectrum.Both vertical and horizontal movements of the microscope can be noted by the respective scales attached with it, whose Varner constant is 0.001 cm.

III. Theory (N-slit diffraction)

A light source, a diffraction grating (15000 lines/inch)and a screen/detector are required in order to observe diffraction pattern. The arrangement of this system is depicted in **Fig. 1.** When monochromatic light is passing through the slits, diffraction occurs and corresponding dark and bright fringes are produced due to interference & diffraction of light [**4**]. We can derive the grating equation after solving the following equation of the spectral field,

$$E = A\frac{Sin\beta}{\beta}Cos(\omega t-\beta)+\ A\frac{Sin\beta}{\beta}Cos(\omega t-\beta-\varphi_1)+\ \dots,\ +A\frac{Sin\beta}{\beta}Cos(\omega t-\beta-(N-1)\varphi_1) \qquad (1)$$

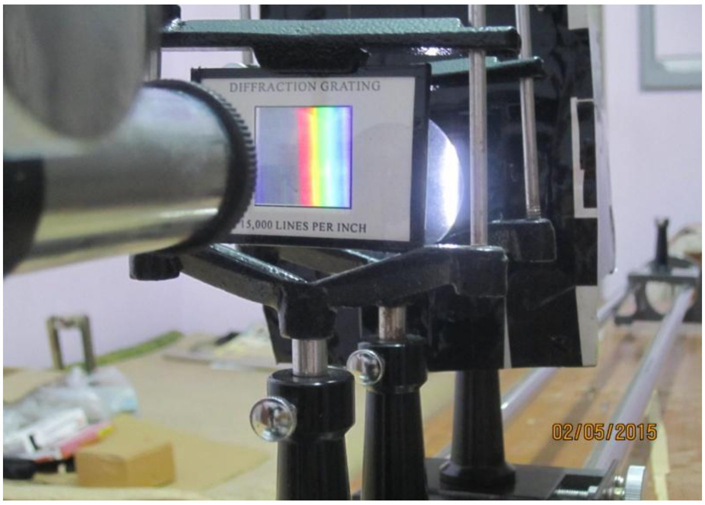

Fig. 1: Experimental set-up

Where, $A = na$ is the amplitude due to *n*number of diffracted waves and $\beta = \frac{\pi b Sin\theta}{\lambda}$ is the phase difference between two coherent waves.And resultant intensity of the diffraction due to single slit is given by

$$I_1 = I_o \frac{Sin^2\beta}{\beta^2}, \quad (2)$$

Where$I_o = A^2$and for *N*-number of slits intensity is given by

$$I_P = I_1 \left(\frac{SinN\gamma}{Sin\gamma}\right)^2, \quad (3)$$

Where, $\gamma = \frac{\varphi_1}{2} = \frac{\pi d Sin\theta}{\lambda}$ is the phase difference due to multiple slits and *d* (= *a+b; a→ slit width and b→ distance between two slits*) is called grating element. The 2nd term of Eq. (3) represents the interference pattern due to *N*equally spaced point sources. When *N* is very large, we can have high intense maxima i.e., $\gamma = m\pi$,

Hence,$dSin\theta = m\lambda$, (4)

Where, *m = 0, 1, 2, 3*, …, …, are the order of diffraction.Equation (4) is called the diffraction grating equation. When $m \neq 0$, the angle of diffraction are different for different wavelengths. Therefore, various spectral components are appeared at different position and by measuring the angles of diffraction, wavelengths of solar spectrum can be precisely measured and intensity (**Eq. (3)**) of different colors.

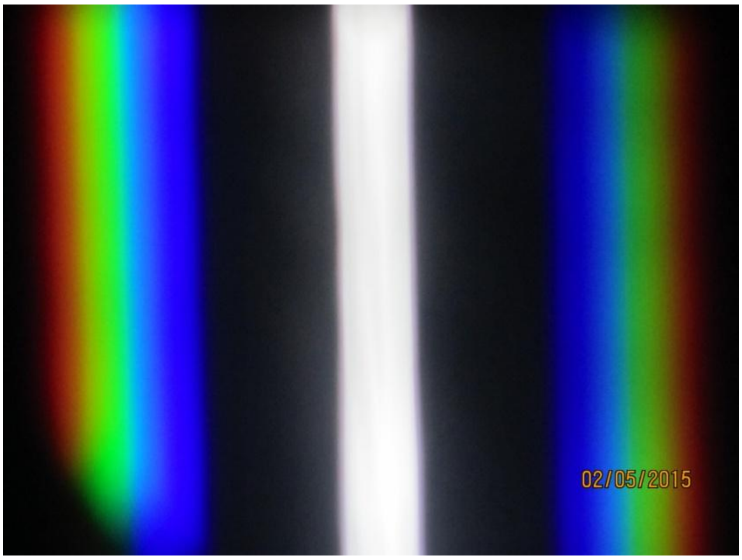

Fig. 2: colored fringes of ordinary light

IV. Experimental Results & Discussions

The pattern of diffracted color spectrum of ordinary light which is obtained from this experiment isshownin **Fig.2.**Theoretical and experimental results are depicted in **Fig. 3.** It shows that angle of diffraction of higher frequency colored light is lower than the lower frequency colored light. At First the first order diffraction pattern are determined by using the known color (wavelength, λ) light and measured the corresponding diffraction angle (θ). In order to compare the experimental results with theoretical one an extensive simulation is performed. Using Eq. (4) we determined different angles of diffraction for various colors (λ)considering the Lyman, Balmer, Paschen and Brackett series of H, Ps and He atoms which are shown in **Fig. 3**(blue spots).Experimental colored LEDs light (Red, Blue, Green and White) are shown on the same spectrum(black spots).

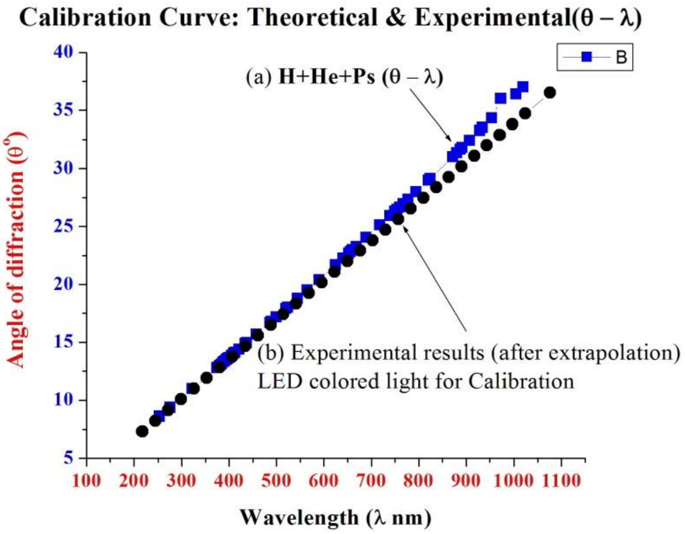

Fig.3 Theoretical spectra with experimental results

The spectrometer shows excellent agreement between theoretical and experimental results.In order to study the solar spectrum, light from the sun is to be exposed on the experimental device from outside of the room and that arrangement is in progress.

V. Conclusion

The diffraction grating detector is developed and calibration of this system is done by using different colored LEDs. The measurement of wavelengths of solar spectrum is in progress.

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