Experimentally searched low-cost alternatives for UV and high-intensity optical filters

Dr Tamal Sarkar* and Arindam Mukherjee,
High Energy & Cosmic Ray Research Centre,
North Bengal University, Siliguri, WB, 734013
*E-Mail: tsarkar@nbu.ac.in**

Abstract: Here, we attempted experimental verifications of the alternative band-pass filters to suit targeted wavelength bands, namely, optical and UV regions, with due attention to their hazardous aspects to both eye and imaging systems. For this purpose, some standard optical filters and welding glass shields are initially selected for observing high-intensity optical sources, full moons, and welding arc flames. We performed the experimental study of the standard filters' transmitted spectrum and intensity cut-off using a single slit, wavelength splitter (grating), and optical sensors (Web camera and Digital Lux Meter). In the next phase, we compared the various semi-transparent materials like cellophane papers, polymers, and thin metal oxide spray coating and their combinations with many standard filters to explore efficient, cost-effective alternative filters for each type of targeted source. Their experimental results determine which materials are useful as an alternative filter for Welding Shields, Moon Filters, and Deep Sky Observation.

Key Words: Optical Filter, Transmission Spectroscopy, Diffraction grating

INTRODUCTION

Optical filters are commonly used in front of telescopes to selectively transmit one portion of the spectrum or reduce the intensity of the incoming radiation (Sarkar & Mukherjee, 2023). Their purpose may be different on a case-to-case basis. Sometimes, we use them to save the human eye from damage. In some cases, it may help in good vision of a source by filtering out the unwanted or harmful lights entering the eyepiece. It is positioned or fitted in front of the objective of the optical system to filter out a part of the radiation and selectively transmit the other portion. Depending on the purpose, we have different filters. We use filters in microscopy, spectroscopy, chemical analysis, and machine vision. In the present work, we have selected a narrow field to study the filters available for watching the Moon, high-intensity optical sources and wielding arc. For this purpose, we reviewed a few of the filters mentioned below for our work.

(1) **Lunar Filter:** The most straightforward astronomical filters are the lunar/moon filters. A lunar observing filter helps to reduce glare when observing the Moon visually with a telescope. Precise scientific measurements show the Moon reflects, on average, about 12% of the sunlight that falls upon it (Brian, 2021). If one ever looked at a thickening gibbous moon through even a moderately-sized telescope, it can appear uncomfortably bright to the dark-adapted eye. Moon filters are useful for scopes of as little as 80mm aperture, and they are essential for 100mm scopes or larger. Moon Filters can be subdivided into the following categories: (i) ***Neutral density (ND) filter,*** the simplest filter for lunar observation, reduce the brightness at all visible wavelengths equally (Brian, 2021). Considering attenuation of visible wavelength to a power of ten such filters such filters are commonly designated as ND9 , ND6, ND3, etc., which transmit 12.5%, 25%, and half of the incident light respectively. These three levels of attenuation are the most common for lunar neutral density filters. (ii)***Half transmission filters*** are useful for small telescopes of aperture < 4 inches (HIGH POINT SCIENTIFIC TEAM, 2021) or for observing a crescent moon with larger telescopes. They're also

useful for attenuating the brightness of planets such as Venus and Jupiter when using larger telescopes. *(iii)* ***Variable polarizing filter:*** For observers looking for more flexibility in a single component, variable polarizing filters offer a solution (Brian, 2021). Variable polarizing filters consist of two linear polarizers that can be rotated with respect to each other. The first polarizer reduces the un-polarized part of the incident light by a certain percentage (say about 50%, which for all practical purpose vary depending upon its construction) while the second filter transmits the residual un-polarized light in proportion to the angle between the two polarizers, All wavelengths of visual light have the same transmission through a variable polarizer, at least in principle. Some *variable polarizers* are constructed so that the polarizers are integrated together into a single unit, and the unit is threaded onto the barrel of an eyepiece. The polarizers are rotated to achieve the desired level of transmission before threading it onto the eyepiece. *Other variable polarizers* consist of two separable polarizing filters, one threaded onto the telescope side and the other threaded onto the eyepiece barrel. To negotiate with the light transmission, the eyepiece in the diagonal is rotated by a suitable amount. Variable polarizers are not quite as easy to use as compared to ND filters. However, they are flexible and relatively affordable as compared to ND filters. (iv) ***Color Filters:*** Experienced lunar visual observers often recommend a simple color filter for enhancing the contrast of subtle features when observing the Moon, primarily when used together with a neutral density filter to reduce glare. Many observers already have a #56 or #58 green filter in their planetary observing toolkit. The Celestron and GSO, among other vendors, also offer specialized moon filters that include green light transmission and transmission reduction of up to 80% in a single filter. These affordable filters come in 1.25" cells that thread directly to an eyepiece or diagonal (v) ***Moon and Sky-go Filters***: Another option for lunar observation: Moon and Skyglow filters from Baader Planetarium and Opto long. These filters incorporate *neodymium*, a rare earth element, into their glass substrates to pass and block select wavelengths of visible light. These filters are not primarily intended for lunar work but rather for visual observation of planets such as Mars and Jupiter and for observation of deep-sky objects in light-polluted sky. However, some observers report these filters do enhance the visual appearance of some lunar features. The combination of two different color filters also may help to reveal some unique aspects of the stellar features as it helps to allow a particular waveband to observe/image with selective blocking of other bands, which hinders the particular features from being prominent to our eyes or imaging system.

(2) **Welding Shield**: The purpose of using a welding shield, in general, is to protect the welder's eye and face from UV radiation, high-intensity optical radiation, and heat that are being produced at the site of work. There are different types of welding shields available in the market, viz., Full-face welding Helmets, UV/IR solar-powered auto-darkening Welding Helmets, and some eye-protecting goggles. We have observed that for welding shields, there are industrial specifications for both the mechanical strength (viz., Class F, S, B, T, etc.) and optical standard (EN 166, EN175, EN 379; EN 397, etc.) (3M, 2008).

(3) **Deep-Sky Filters:** These filters improve the views of various deep-sky objects. Generally, these objects are not individual (Like et al.: Open and globular Nebulae, Bright Nebulae, Dark Nebulae, and Planetary Nebulae Galaxies) and are visually faint if seen by the naked eye and are seen using good telescopes with filters. They are classified into three classes (a) Broad-Band “Light Pollution” Filters: These filters cut out the yellow and orange parts of the spectrum (Rajkhowa, 2014) and do not alter the other colours/Wavelengths, i.e., the light pollution (ANAGNOSTOPOULOS, 2022) is a notched example is Orion Sky glow and Lumicon Deep-sky (b) Narrow-band “Nebula” filters: These are mainly used for viewing many emission nebulae (Knisely, 2013). The wavelengths between H-beta and the OIII lines pass through; any other part of the spectrum is blocked. Examples are Orion Ultra Block and Lumicon UHC. (c) Line

Filters: These filters allow only one or two spectral lines from some specific elements of the nebulae like OIII lines or the H-beta Lines, example Lumicon OIII or Lumicon H-beta

Objective of the work:

This work's main objective is to search for a low-cost alternative for the filters for the target sources as proposed above without compromising the hazardous aspects of the radiation to both the eye and imaging system. Further, the project may also help develop the filter material, which will help to protect the human eye from UV and high-intensity luminous sources.

In many places, the armature astronomers are using Optical filters and glasses to view Solar eclipse, Sun Spot, and Moon without testing as the testing facilities are unavailable. In recent years, in Universities, many students and scholars have also been interested in seeing events like solar eclipse, sunspots, and the Moon. In this connection, we want to provide testing facilities and provide experimentally tested filters for safe viewing of the different solar as well as lunar events. Moreover, it will also open a scope for the workers involved in welding to test the performance of their welding shields (Sarkar & Mukherjee, 2023).

- To study the filtration power of the commercial radiation filters available on the market for viewing the Moon, we will develop an experimentation facility to study lunar filters.

- To study the filtration power of the commercial radiation filters available in the market for Gas Welding machines, we will try to develop an experimental facility to study filters used for welding shields.

- To develop alternative and economic filters for Welding and Lunar viewing/ imaging: We will develop a process for making optical filters at the Lab using different materials and test their efficacy. Based on their filtration power, we will suggest the specification.

Experimental Design and Data Collection:

Figure 1,2 and 3 (Sarkar & Mukherjee, 2023) depicts the overall methodology of the work. The present work is done following these three motives.

(i) development of an optical system to test the filtration capacity of the filters used for witnessing and imaging the sun, full Moon, welding flame, etc. (Figure 1 and Figure 2)

(ii) To develop new optical filters using a combination of the different semi-transparent materials and film available in the market and

(iii) To test some of the filters using the system designed in the Lab.

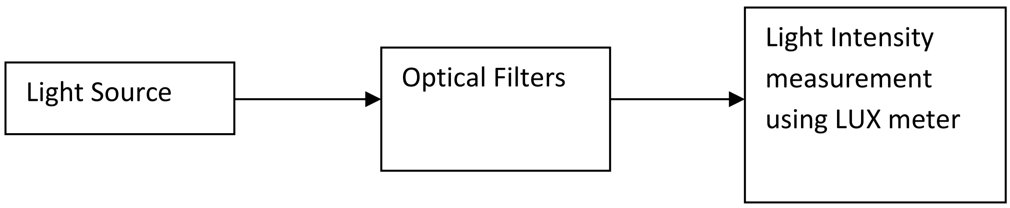


Figure 1: Experimental setup to measure intensity reduction

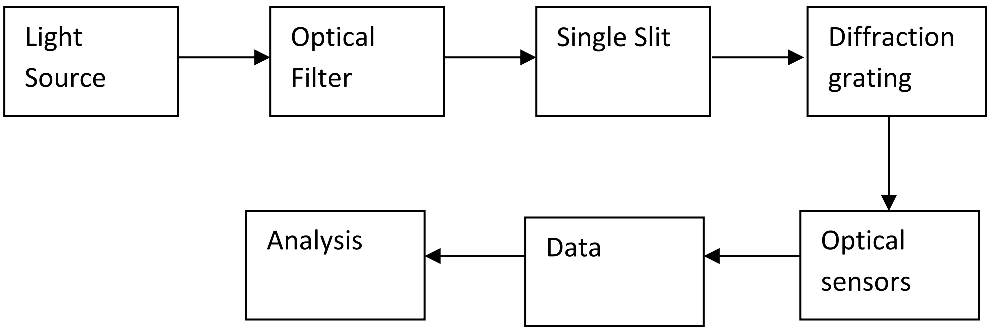


Figure 2: Experimental setup to diffraction spectrum

Method

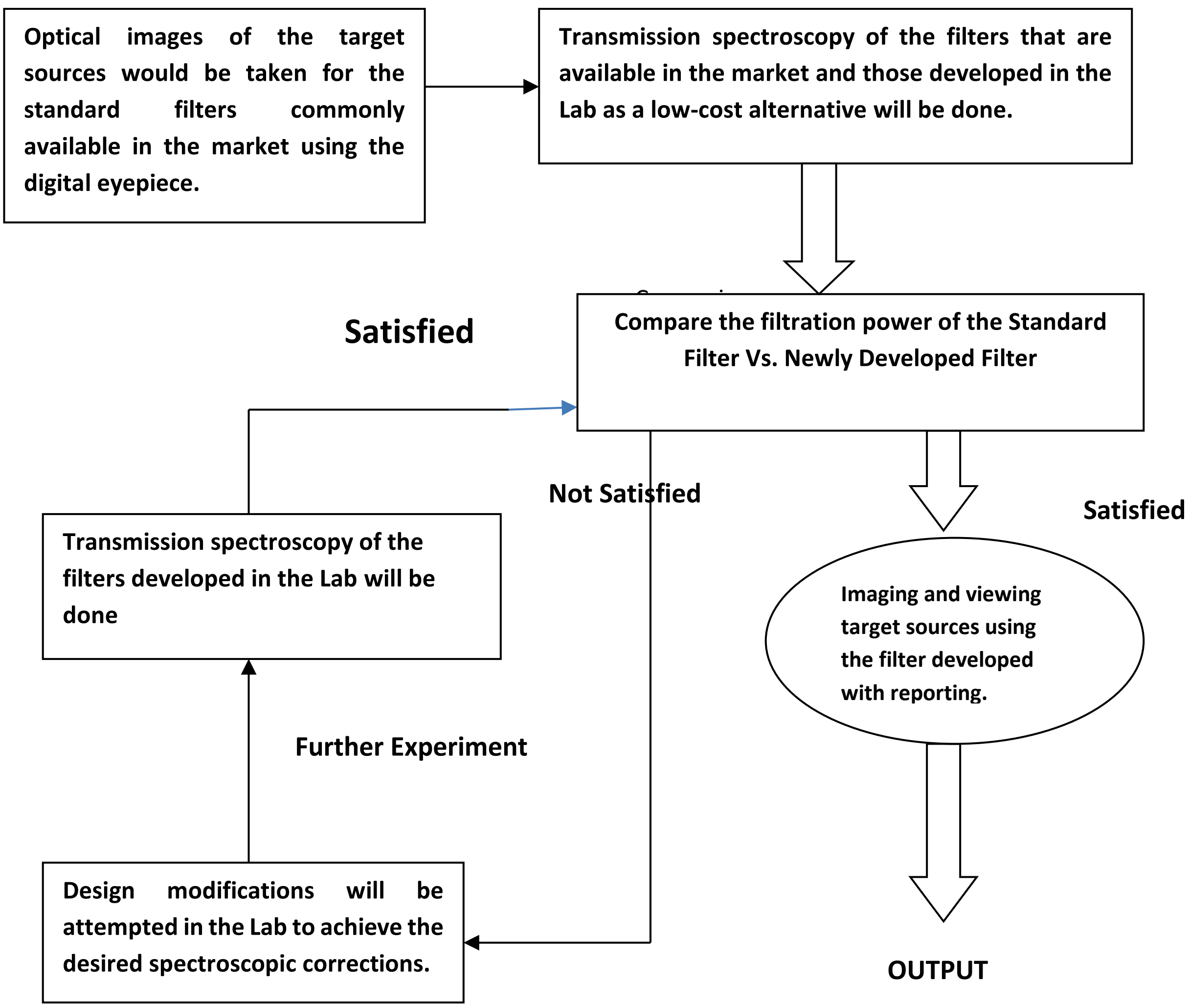


Figure 3: Block diagram of the methodology used for the work

Experimental result and discussion:

Illuminance studies using LUX meter:

We have used the HTC Lux meter (LX-101A) to measure intensity reduction, as described in Figure 1. Without any filter, the illuminance is 3550 Lux. For each measurement, we have waited till there is no fluctuation in illuminance in the Lux meter. In some samples, we observed that we have to wait a lot to get the constant value in Lux meter; the same is mentioned as slow.

Table 1;

S.No.	Sample code	illuminance in Lux	Reduction in intensity	Saturation Time
1	Gl_Gr	638	18*	Slow
2	PP_SDBlaF	10	0.28**	Fast
3	PP_SLBlaF	944	26.59	Fast
4	PP_SBluF	334	9.41	Fast
5	PP_SSlivF	12	0.34	Fast
6	PP_SGoldF	41	1.15	Fast
7	PP_SCuF	605	17.04	Fast
8	PP_SSold_Sp	1102	31.04	Slow
9	PP_DLBlaF	291	8.2	Fast
10	PP_DBluF	47	1.32	Fast
11	GG_SolarF	0.5	0.01	Fast
12	PP_DMBlaTap	19	0.54	Fast
13	PP_SSilFoil	55	1.55	Fast
14	PP_DDBlaTap	0.8	0.02	Fast
15	PP_SDBlaTap	37	1.04	Fast
16	Gl_Gr_SBlaTap	10	0.28	Fast
17	Gl_Gr_DBlaTap	0.2	0.01	Fast
18	Gl_Weld	0.2	0.01	Fast
19	B2_Gl	177	4.99	Fast
20	B2_Fibre	553	15.58	Slow
21	Celstron_Moon	82	2.31	Fast
22	Celestron_filter_80A	1506	42.42	slow
23	Celestron Filter 25	6.7	0.19	Fast

*Ri = Reduction in intensity= 638/3550*100= 17.97=18

**Ri= 10/3550*100 = 0.28

- Slow means more than four minutes
- Fast less than four minutes

S.No.	Sample code	illuminance in Lux	Reduction in intensity (R_i)	Image Clarity*	Spectrum Study
1	Gl_Gr	638	18	Clear, visible	Yes
2	PP_SDBlaF	10	0.28	clear/faint	Yes
3	PP_SLBlaF	944	26.59	Clear & Very bright	No
4	PP_SBluF	334	9.41	Clear, visible	Yes
5	PP_SSlivF	12	0.34	clear/faint	Yes
6	PP_SGoldF	41	1.15	Clear, visible	Yes
7	PP_SCuF	605	17.04	Clear, visible	Yes
8	PP_SGold_Sp	1102	31.04	poor	No
9	PP_DLBlaF	291	8.2	Clear, visible	Yes
10	PP_DBluF	47	1.32	Clear, visible	Yes
11	GG_SolarF	0.5	0.01	Clear /faint	Yes
12	PP_DMBlaTap	19	0.54	Clear, visible	Yes
13	PP_SSilFoil	55	1.55	poor	No
14	PP_DDBlaTap	0.8	0.02	Faint	Yes
15	PP_SDBlaTap	37	1.04	Clear, visible	Yes
16	Gl_Gr_SBlaTap	10	0.28	faint/Clear	Yes
17	Gl_Gr_DBlaTap	0.2	0.01	Very faint	Yes
18	Gl_Weld	0.2	0.01	Very Faint	Yes
19	B2_Gl	177	4.99	Clear, visible	Yes
20	B2_Fibre	553	15.58	Clear, visible	Yes
21	Celestron Moon	82	2.31	Clear, visible	Yes
22	Celestron_filter_80A	1506	42.42	Clear, visible	Yes
23	Celestron Filter 25	6.7	0.19	Clear and faint	Yes

After it, we have seen CFL bulb -20 Watt (for low absorption filters) or UV Basking heat light bulb -75 Watt (for high absorption filters for S. No. 2,5,11,14,16, 17,18) using each of the filters mentioned above and based on the clarity of the image and reduction in illuminance, we choose the following source for diffraction spectrum studies (Likith, et al., 2021) and group them in four categories based on reduction in the intensity of light.

Group -1 (R_i<0.5**)** : PP_SDBlaF , PP_SSlivF, GG_SolarF, PP_DDBlaTap, Gl_Gr_SBlaTap, Gl_Gr_DBlaTap, Gl_Weld, Celestron Filter 25

Group-2 (10<R_i**<50):** Gl_Gr, PP_SLBlaF, PP_SBluF, PP_SCuF, B2_Fibre, Celestron_filter_80A

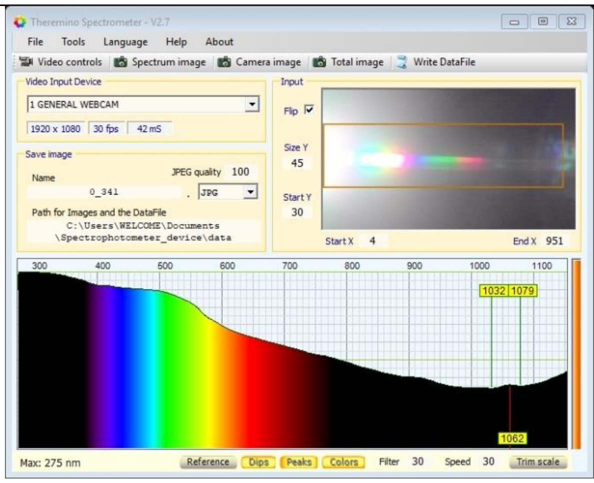
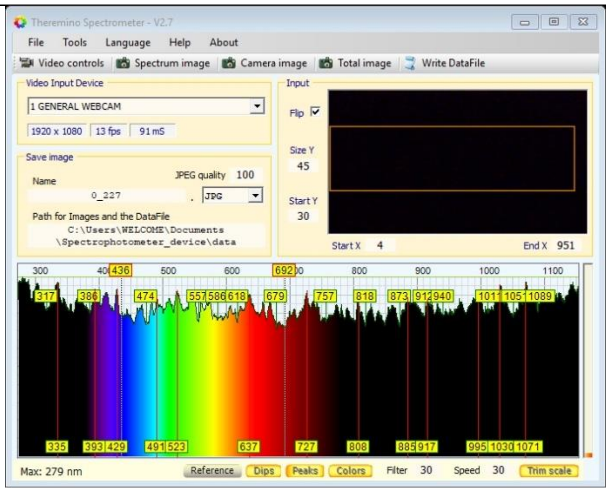
Group 3 (4.0 < R_i**<10.0):** PP_SBluF, PP_DLBlaF, B2_Gl

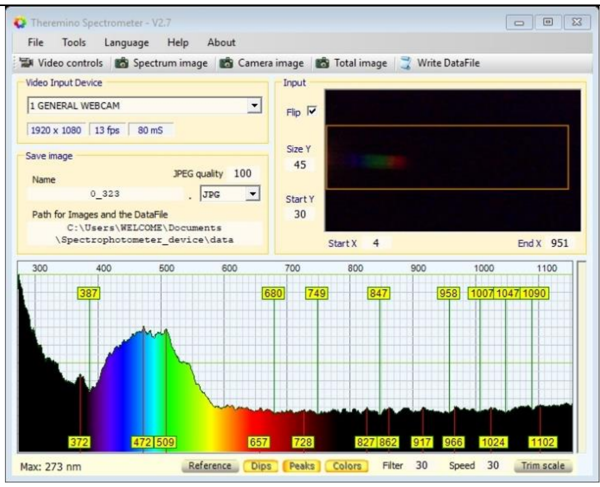
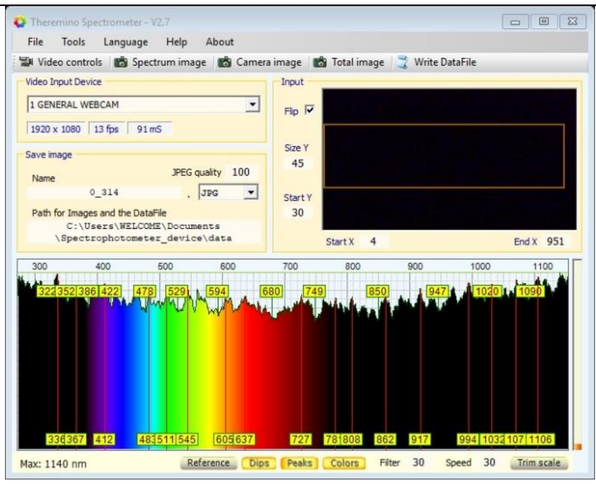
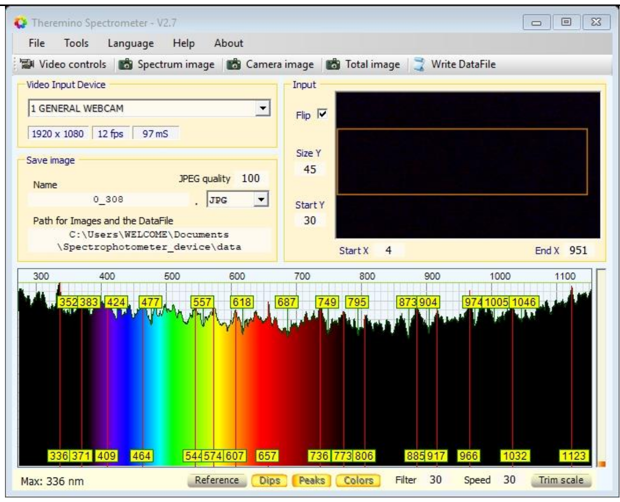
Group 4 (0.5 <R_i<4.0**):** PP_SGoldF, PP_DBluF, PP_SDBlaTap, Celestron Moon

Diffraction Spectrum study using spectrometer:

For this purpose of the same, we have designed a modified version of the spectrometer described by Theremino Spectrometer Construction (Theremino et al., 2014) in which we have used a webcam of 1080P, Hilger & Watts diffraction grating having 15000 L.P.I and the Single Slit. We have used a CFL bulb and UV Basking heat light bulb -75 watt as the source. The block diagram of the experimental setup to the diffraction spectrum is shown in Figure 2. We have used the Theremino spectrometer for spectrum analyzer (Theremino Spectrometer Construction, 2014).
Further studies: Using the spectrometer developed by us, we will study the various liquid solutions and semi-transparent materials as well as different sources of light.

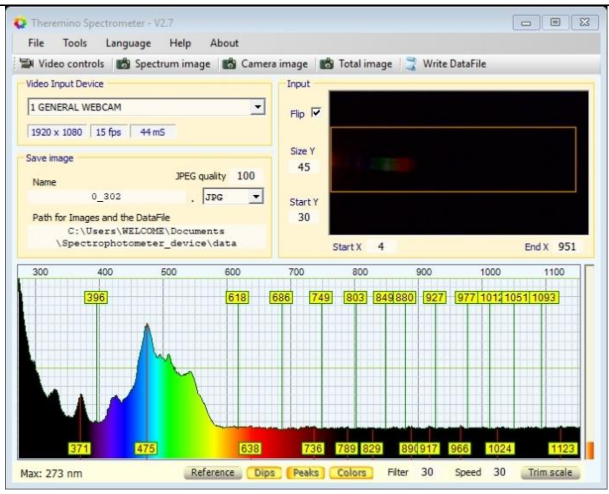
(a) Suitable material for radiation shields for welding:

Studied using the UV Basking heat light -75 Watt (Group-1 materials are used)	
Sample: No Filter used Diffraction spectrum of the UV Basking heat light, when used as a source	
Sample: **PP_SDBlaF** The studies indicate that the filter with code PP_SDBlaF is suitable for use as a radiation shield for welding	

Sample: **PP_SSlivF** The studies indicate that the filter with code **PP_SSlivF** is unsuitable for welding as a radiation shield.	
Sample: **GG_SolarF** The studies indicate that the filter with code **GG_SolarF** is suitable for welding as a radiation shield.	
Sample: **PP_DDBlaTap** The studies indicate that the filter with code **PP_DDBlaTap** is suitable for welding as a radiation shield.	

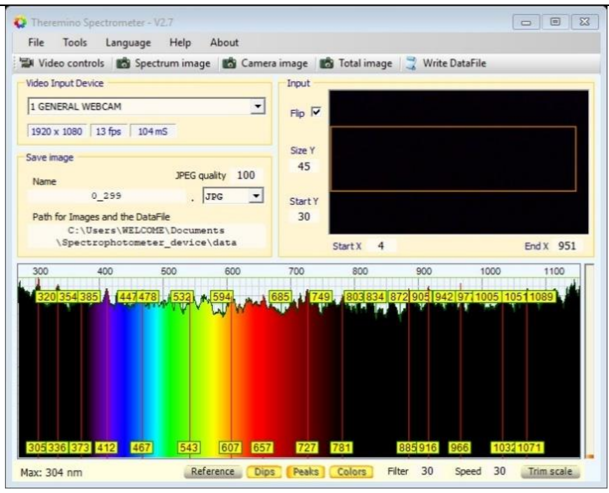
Sample: **Gl_Gr_SBlaTap**

The studies indicate that the filter with code Gl_**Gr_SBlaTap** is unsuitable for welding as a radiation shield.



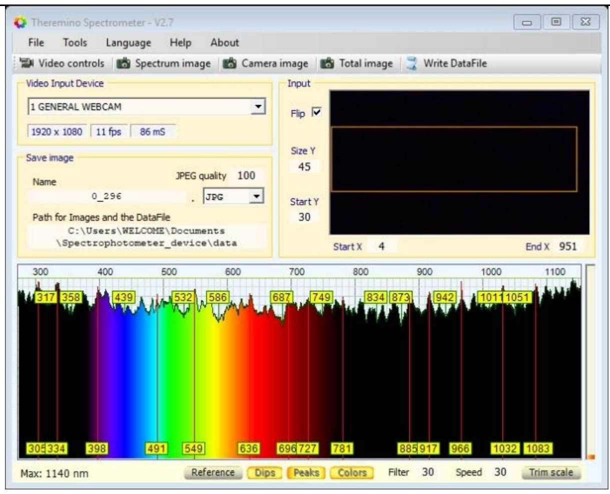
Sample: **Gl_Gr_DBlaTap**

The studies indicate that the filter with code **Gl_Gr_DBlaTap** is suitable for welding as a radiation shield.



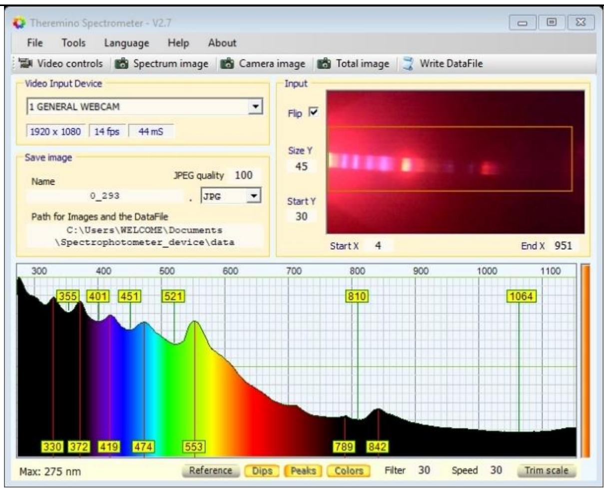
Sample: **Gl_Weld**

The studies indicate that the filter with code **Gl_Weld** is suitable for radiation shields for welding.



Sample: **Celestron Filter 25**

The studies indicate that the filter with code **Celestron Filter 25** is unsuitable for welding as a radiation shield.

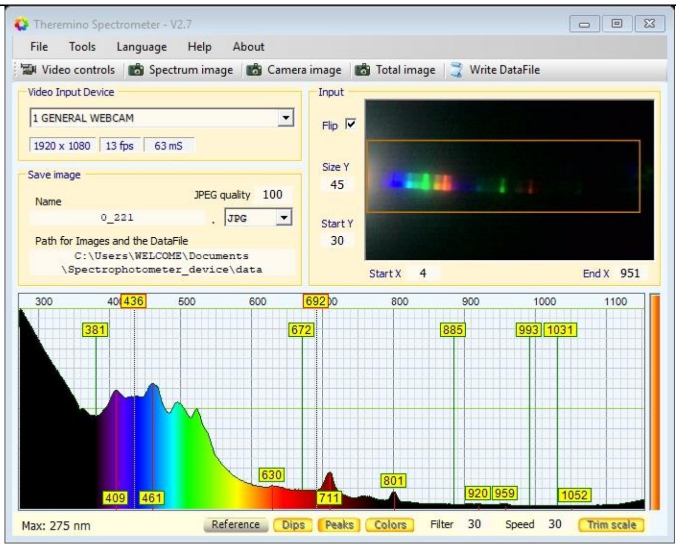


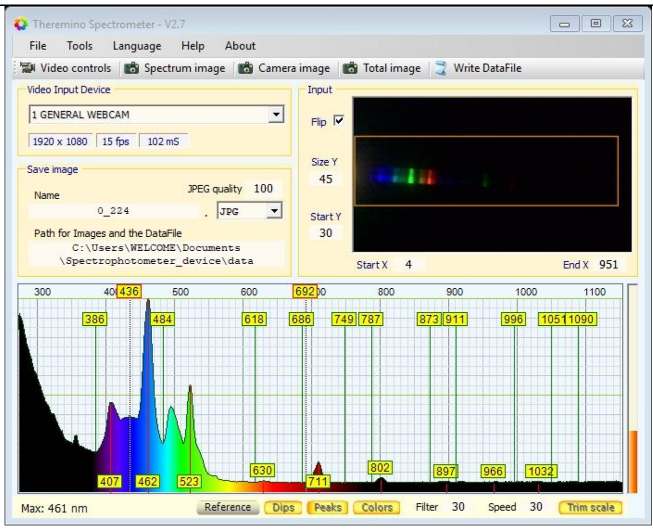
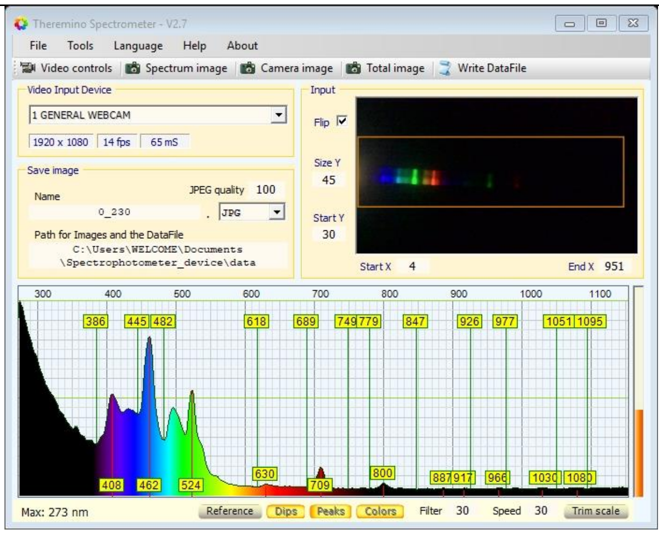
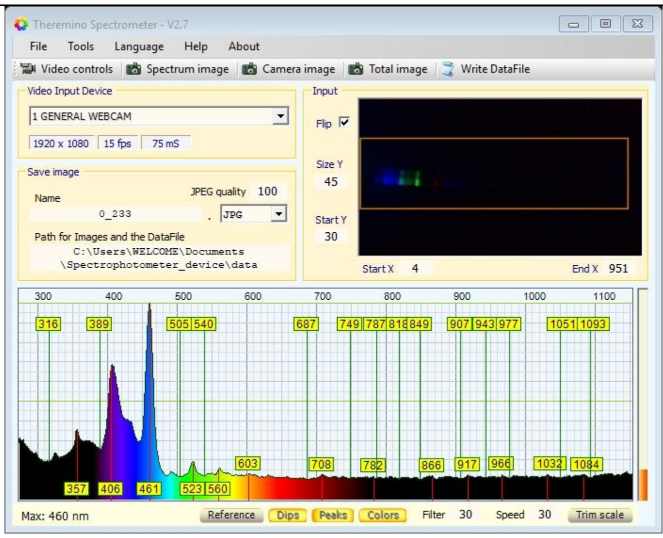
(b) Deep Sky Filters

Studied using Compact Fluorescent Lamp (CFL) Spiral - 20W
(Group-2 materials are used)

Sample: No Filter used

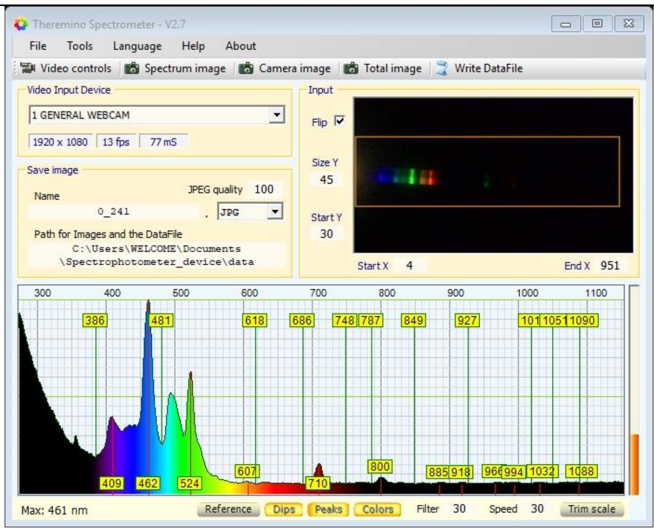
The Diffraction Spectrum of the Compact Fluorescent Lamp (CFL) Spiral - 20W light, when used as a source



sample : **Gl_Gr** The studies indicate that the filter with code **Gl_gr** is unsuitable for Deep Sky Filters.	
Sample: **PP_SLBlaF** The studies indicate that the filter with code PP_SLBlaF is unsuitable for Deep Sky Filters.	
Sample: **PP_SBluF** The studies indicate that the filter with code **PP_SBluF** suits the Deep Sky Filter.	

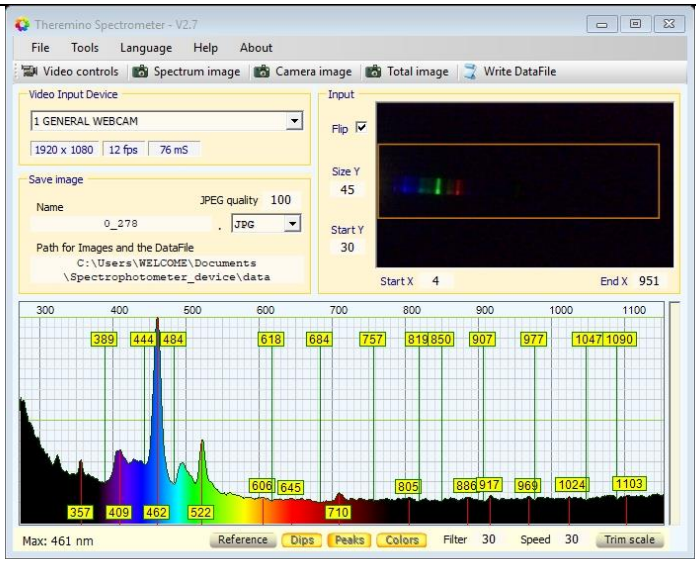
Sample: **PP_SCuF**

The studies indicate that the filter with code **PP_SCuF** is unsuitable for Deep Sky Filters.



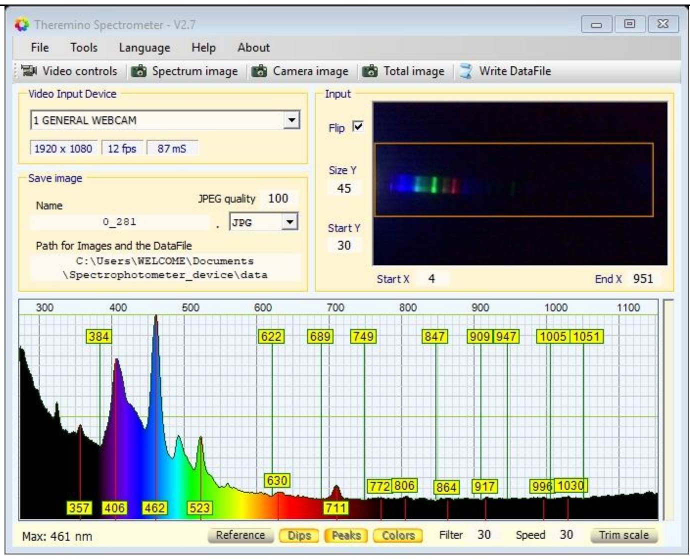
Sample: **B2_fibre**

The studies indicate that the filter with code **B2_fibre** is suitable for Deep Sky Filters.



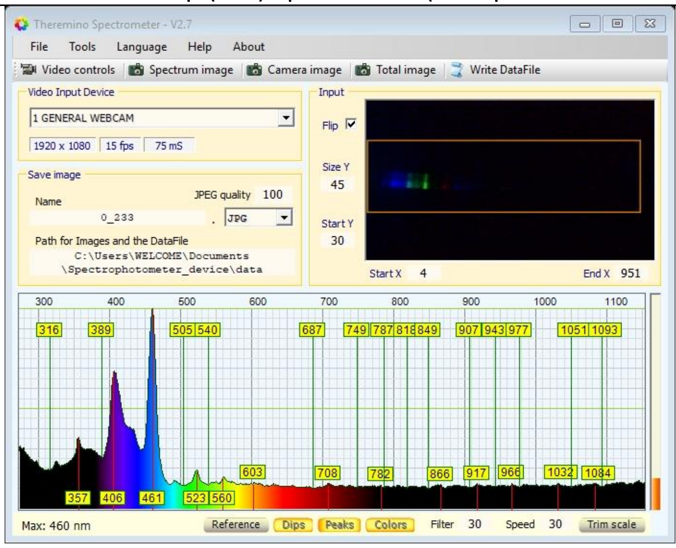
Sample: **Celestron_filter_80A**

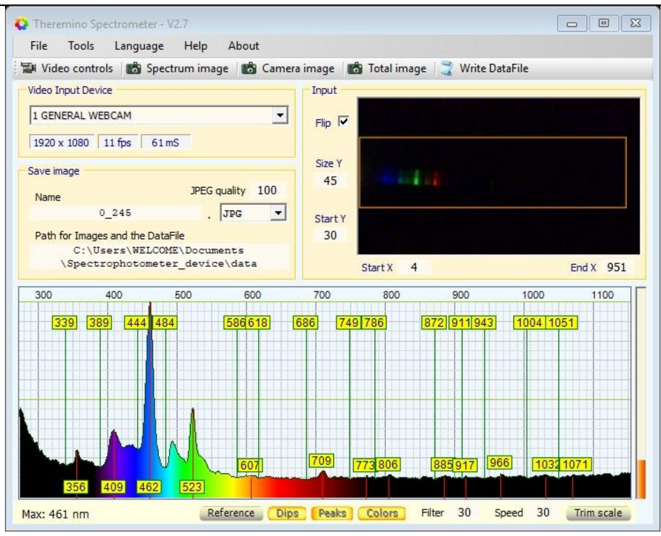
The studies indicate that the filter with code **Celestron_filter_80A** is suitable for Deep Sky Filters.

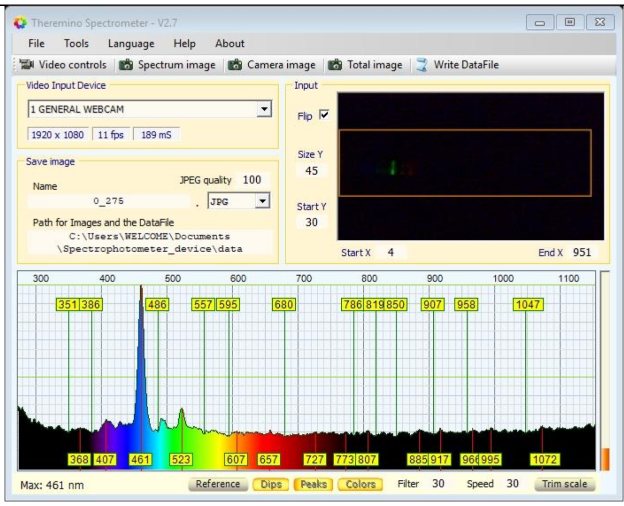


(a) Sun protective filters for Windows and Sun glasses

<table>
<tr><th colspan="2">Studied using Compact Fluorescent Lamp (CFL) Spiral - 20W (Group-c materials are used)</th></tr>
<tr><td>Sample: PP_SBluF

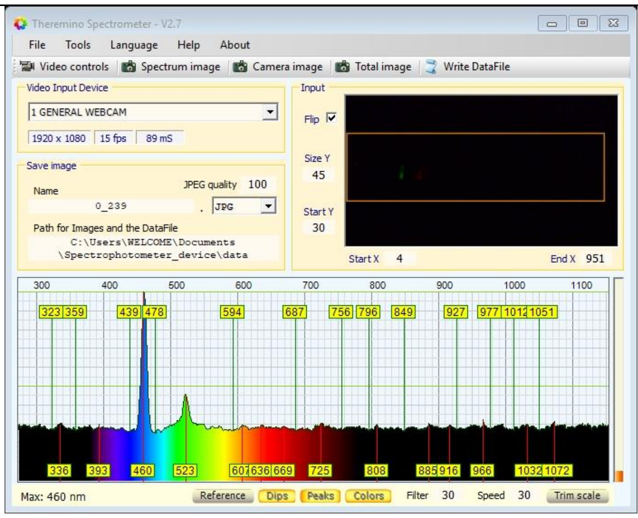
Suitable for Sun protective filters for Windows and glasses</td><td>
</td></tr>
<tr><td>Sample: PP_DLBlaF

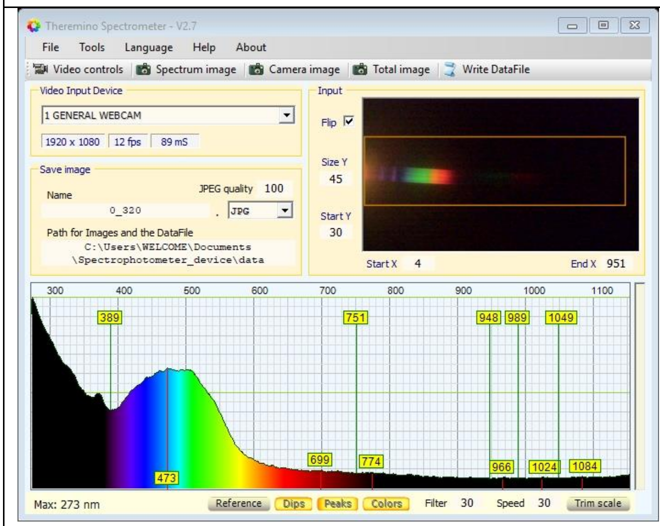
Suitable for Sun protective filters for Windows and glasses</td><td>
</td></tr>
<tr><td>Sample: B2_ Gl

Suitable for Sun protective filters for Windows and glasses</td><td>
</td></tr>
</table>

(b) Lunar Filters

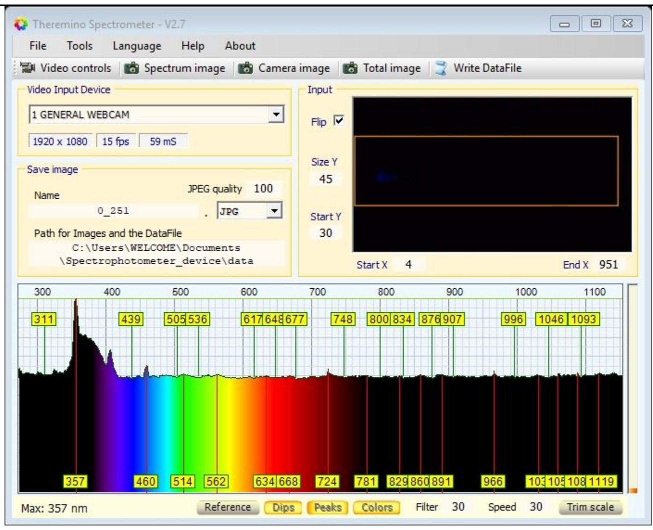
<table>
<tr><td colspan="2">Studied using Compact Fluorescent Lamp (CFL) Spiral -20 W & UV Basking heat Light - 75W (Group-D materials are used)</td></tr>
<tr><td rowspan="2">Sample: PP_SGoldF

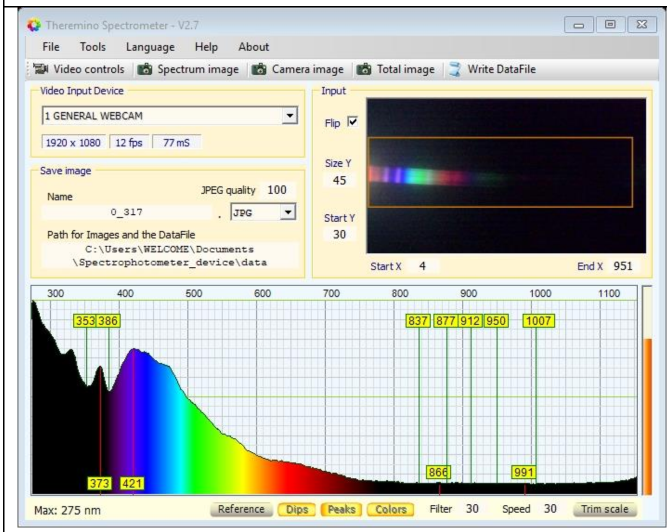
Suitable for Lunar Filter</td><td>

Compact Fluorescent Lamp (CFL) Spiral -20 W</td></tr>
<tr><td>

UV Basking heat Light - 75W</td></tr>
</table>

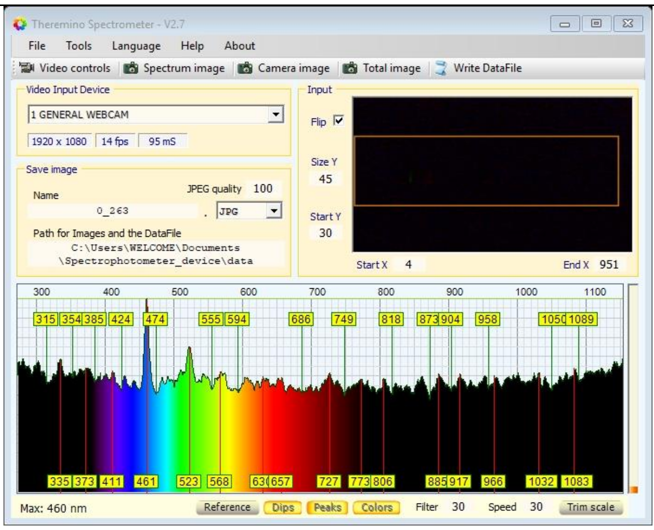
<table>
<tr>
<td rowspan="2">Sample: PP_DBluF

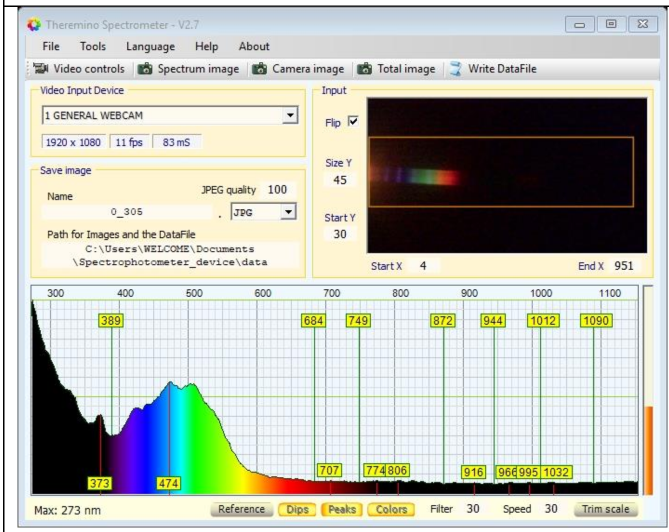
Not suitable for Lunar Filter</td>
<td>

Compact Fluorescent Lamp (CFL) Spiral -20 W</td>
</tr>
<tr>
<td>

UV Basking heat Light - 75W</td>
</tr>
</table>

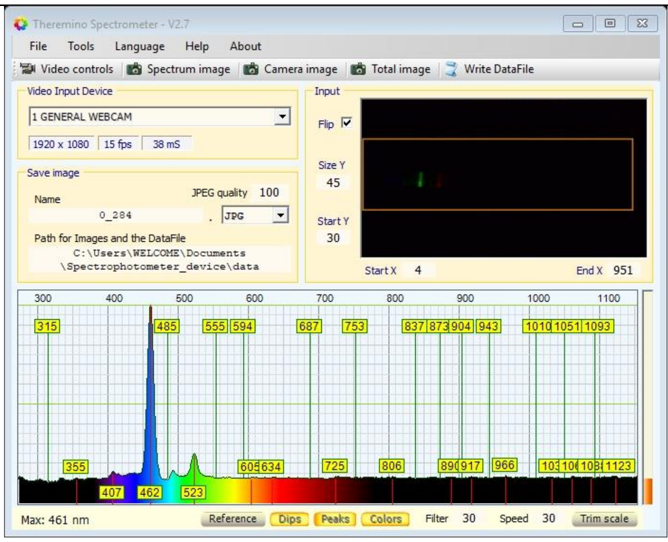
<table>
<tr>
<td rowspan="2">Sample: PP_SDBlaTap

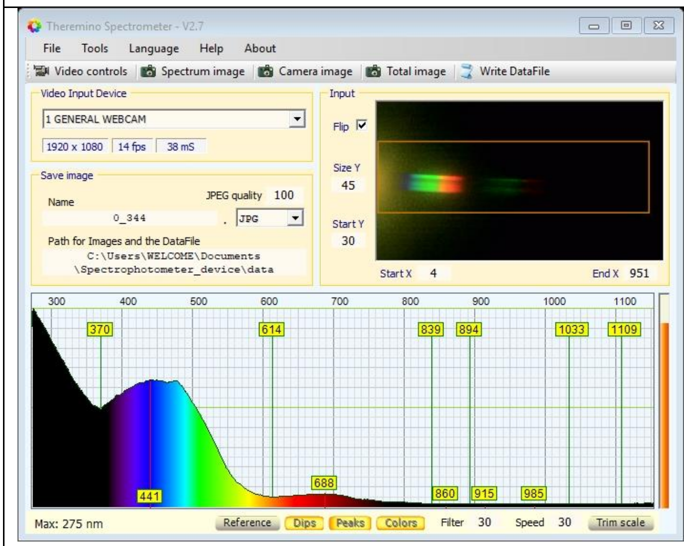
Suitable for Lunar Filter</td>
<td>

Compact Fluorescent Lamp (CFL) Spiral -20 W</td>
</tr>
<tr>
<td>

UV Basking heat Light - 75W</td>
</tr>
</table>

<table>
<tr>
<td rowspan="2">Sample: Celestron Moon Filter

Suitable for Lunar Filter</td>
<td>

Compact Fluorescent Lamp (CFL) Spiral -20 W</td>
</tr>
<tr>
<td>

UV Basking heat Light - 75W</td>
</tr>
</table>

Further studies: Using the spectrometer developed us, we will study the various liquid solutions and semi-transparent materials as well as different sources of light.

Acknowledgment: Both authors are indebted to the University of North Bengal for financial support to carry out this work.

References:

3M. (2008, 11 11). *Eye and faceprotection for weilding.* Retrieved 09 09, 2022, from multimedia.3m.com: https://multimedia.3m.com/mws/media/552213O/eye-and-face-protection-for-welding.pdf

ANAGNOSTOPOULOS, C. A. (2022, 09 22). *Light Pollution Filters: A Photographer's Guide*. Retrieved 09 08, 2022, from petapixel.com: https://petapixel.com/light-pollution-filter/

Brian, V. (2021, 05 29). *A Guide to Lunar Observing Filters*. Retrieved 09 09, 2022, from agenaastro.com: https://agenaastro.com/articles/guides/visual-and-imaging-filters/a-guide-to-lunar-observing-filters

HIGH POINT SCIENTIFIC TEAM. (2021, 01 19). *BEST TELESCOPE FILTER GUIDE.* Retrieved 09 09, 2022, from www.highpointscientific.com: https://www.highpointscientific.com/astronomy-hub/post/best-telescopes-and-accessories/best-telescope-filter-guide

Knisely, D. W. (2013, 10 30). *Useful Filters For Viewing Deep-Sky Objects*. Retrieved 09 09, 2022, from www.prairieastronomyclub.org: https://www.prairieastronomyclub.org/useful-filters-for-viewing-deep-sky-objects/

Likith, G., Jayram, N., Yaswanth, B., Sreekanth, D., Deny, J., Karuthapandi, M., & Vishwa, S. (2021). Designing of low-cost spectrometer for sensor application. *Journal of Optics*, 489–494. doi:10.1007/s12596-021-00707-w

Rajkhowa, R. (2014). Light Pollution and Impact of Light. *International Journal of Science and Research*, 861-867.

Sarkar, T., & Mukherjee, A. (2023). Optical System for Testing High - Intensity Optical. *International Journal of Science and Research (IJSR)*, 2091-2094.

Theremino Spectrometer Construction. (2014, 09 1). Retrieved 09 1, 2022, from Theremino: https://www.theremino.com/wp-content/uploads/files/Theremino_Spectrometer_Construction_ENG.pdf