Mini-SHG **K M Harrison June 2021**

Introduction

Based on the recent success of Christian Buil's Sol'Ex 3D printed SHG (http://www.astrosurf.com/solex/sol-ex-presentation-en.html) I looked at the opportunity of preparing a similar short focal length SHG based on "bits in the box" rather than getting involved in 3D printing.

The success of this design depends on the quality of the optics, the use of a small pixel fast frame camera, a very narrow slit gap and a high resolution reflection grating. Shelyak can supply all these optical elements for around 450 Euro. I compromised, and used available bits and pieces.

Mini-SHG

The collimator

Surplus shed can supply suitable achromatic lenses and 1.25" filter holders in similar focal lengths to the Sol'Ex (80mm, 120mm and 60mm).

I selected the 25mm diameter, 120mm focal length. (p/n #L10914) for both the collimator and the imaging lens. The 1.25" filter holders were already "in the box" (Surplus Shed # M2629D)

An adjustable slit (Surplus Shed # M1570D) adapted to fit into a 15mm T thread spacer and fitted to a 2" nosepiece was "borrowed" from the MG80 spectrograph.

An eyepiece projection body and a couple of T thread spacers allowed the assembly of the collimator.

The grating

The 30 x 30mm, 2400 l/mm grating and holder was available from earlier trials with the Spectra-L200.

This defined the optical axis at 30mm above the base.

The Imaging lens

A 1.25" nosepiece held the imaging lens and a 1.25" helical focuser (Borg # 7315) fitted with a T thread connection, together with a couple of T thread spacers connected to an ASI 178 camera.

The ASI 178 (14 bit) has 2.4micron pixel and an array 3096 x 2080 giving a 5 x 7.4mm area.

SimSpec SHG results

This shows a dispersion of 0.066 A/pixel (@Ha) and a full disk image of 5.63mm at 600 fl (typical ED80)

Based on a slit gap 10micron (!!) and a total angle of 35 degree, R= 46000

SIMSPEC SHG version V1.3, by Ken Harrison			Latest Revision:	Dec-20
Enter data in highlighted cells				

Telescope		
Diameter:	60	mm
Effective Focal Ratio:	10.0	
Focal length:	600	mm
Solar disk		
Solar disk (arcmin):	32.27	arcmin
Solar Disk size at slit focus:	5.63	mm
Plate scale:	343.8	arcsec/mm
Entrance slit scale:	0.344	arcsec/ micron
Solar disk size on CCD chip:	5.63	mm
Solar disk height:	2347	pixel
%age solar disk height coverage:	131.9	%
Seeing (ϕ) :	2	arcsec
Seeing disk (FWHM):	5.8	micron

SUMMARY		
Resolving power R	46124	
Spectral resolution	0.14	Å
Wavelength range	136	Å
Grating-Lines/ mm	2400	
Grating-Diffraction order	1	
Slit width	10	microns

Other Results		
Angle of incidence (α) :	73.17	°
Angle of diffraction (β) :	38.17	°
Anamorphic factor (r) :	0.37	
diffraction limit grating, FWHMd :	2.42	microns
Slit/ image width on CCD, FWHMt :	5.21	microns

Spectrograph		
Collimator		
Collimator-Focal length:	120	mm
Collimator-Required Focal ratio:	10.0	
Collimator-Minimum diameter:	17.6	mm
Resolution of Collimation lens-FWHMo :	1	microns
Camera		
Camera-Focal length:	120	mm
Camera-Distance to grating:	35	mm
Camera-Minimum lens diameter:	17.6	mm
Camera-Maximum focal ratio:	6.8	
Resolution of Camera lens-FWHMc :	1	microns
Collimator/Camera -Total angle (γ) :	35	°
Entrance Slit		
Slit width (w) :	10	microns
Spatial (solar surface) slit coverage:	3.44	arcsec
Slit height:	6	mm
Grating		
Grating-Lines/ mm:	2400	
Grating-Diffraction order:	1	
Grating- Minimum height (H) :	17.6	mm
Grating- Minimum width (W) :	60.9	mm
Dispersion (ρ) :	0.066	Å/ pixel
Resolving power (R) :	46124	
Spectral resolution (Δλ) :	0.14	Å
Dispersion (r) :	27.30	Å/ mm
Wavelength Range		
Reference wavelength:	6563	Å
Lambda min. (λ1) :	6495	Å
Lambda max. (λ2) :	6631	Å
Wavelength range/ full image frame:	136	Å

Camera		
Camera (Select from list)	ASI 178MM	
pixel sizel (p) :	2.4	microns
number of Y pixels(Ny) :	3096	
number of X pixels(Nx) :	2080	
Max array size (Ny):	7.4	mm
Binning, X axis (fλ) :	1	
Binning, Y axis (fy) :	1	
Sampling Factor :	2.17	
RoI setting/ frame rate		
Width of RoI:	100	pixel
wavelength range:	6.55	Å
Framerate:	120	fps
Full disk scan rate:	15	sec
Total frames:	1800	
X/Y sampling	1.30	
Spatial (best) resolution:	1.7	arcsec
Solar surface resolution:	1186	Km
Selection pixel width:	2	
Estimated (best) bandwidth:	0.13	Å

Note: if the actual grating size is smaller than the minimum, then the image will be vignetted

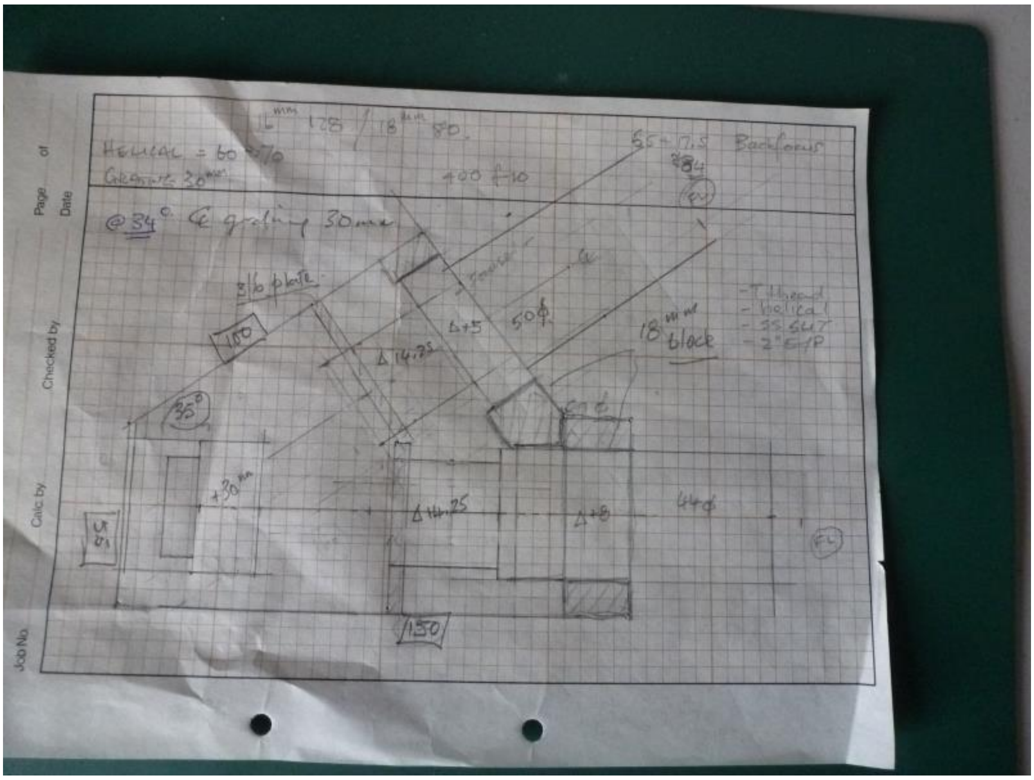
Note: collimator/ grating/ imaging lens should be sized to the solar disk size and f ratio.

Note: If the height of the sensor is < the solar disk size the coverage will be reduced.

MiniSHG: SimSpec SHG results

<u>Housing</u>

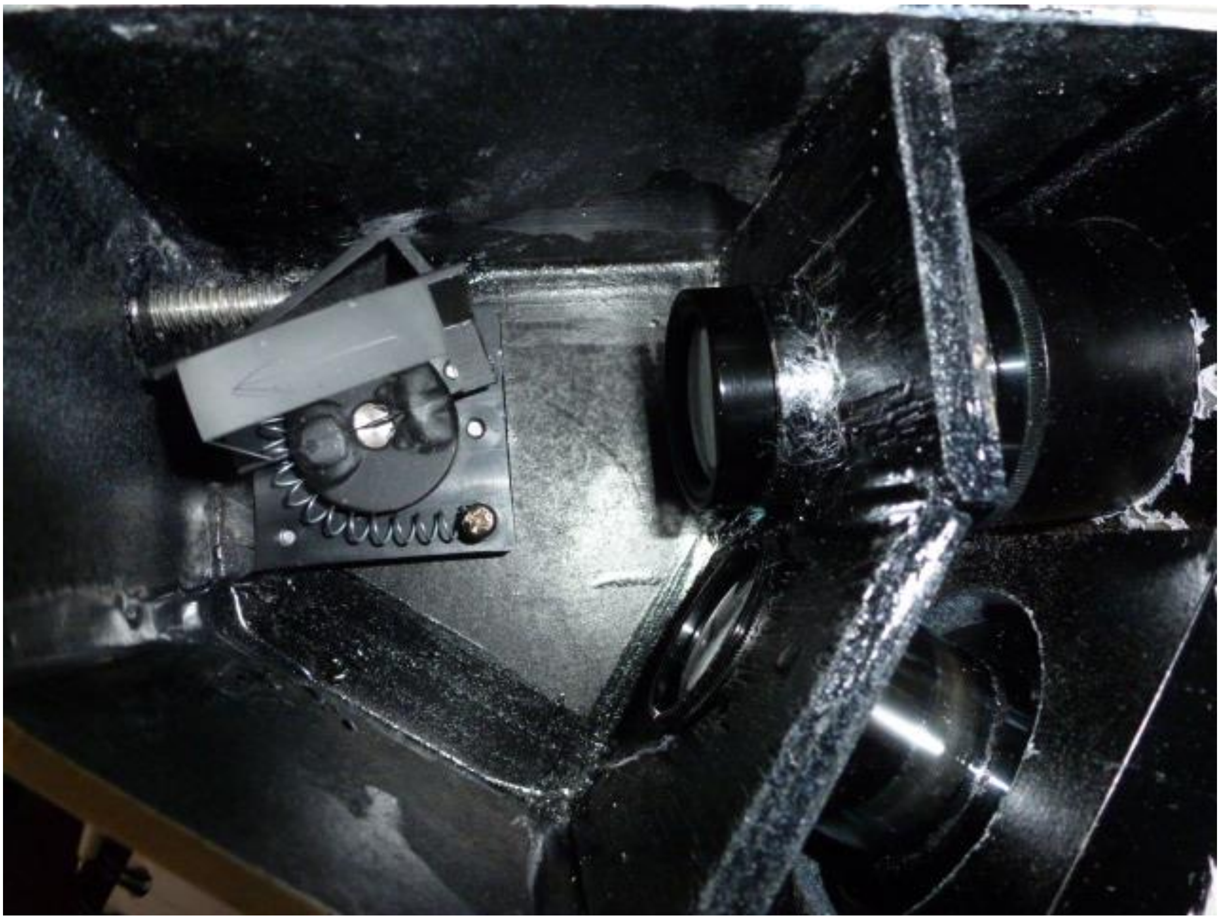
Based on minimum weight, a 3mm MDF base, walls and lid was used. 6mm ply dividers to support the 1.25" section of the collimator/ imager and 18mm wood blocks added to support the 44mm / 50 mm body sections. Overall dimensions: 150mm x 120mm x 70mm, total angle 35 degree. Total weight, including camera, 1.2Kg.



MiniSHG: Design Layout

MiniSHG: Mock-up

The collimator and imaging camera lens were adjusted using a finder to give best zero slit image.



MiniSHG: Final assembly

MiniSHG: Painted ready to go

MiniSHG: Using the ED80 stopped to 60mm and Baader ND0.9 filter.

To reach focus on the ED80, a 80mm 2” spacer was required. To reduce the energy loading on the slit, a Baader 2” 0.9ND filter was fitted at the front of the spacer.

Initial Trials

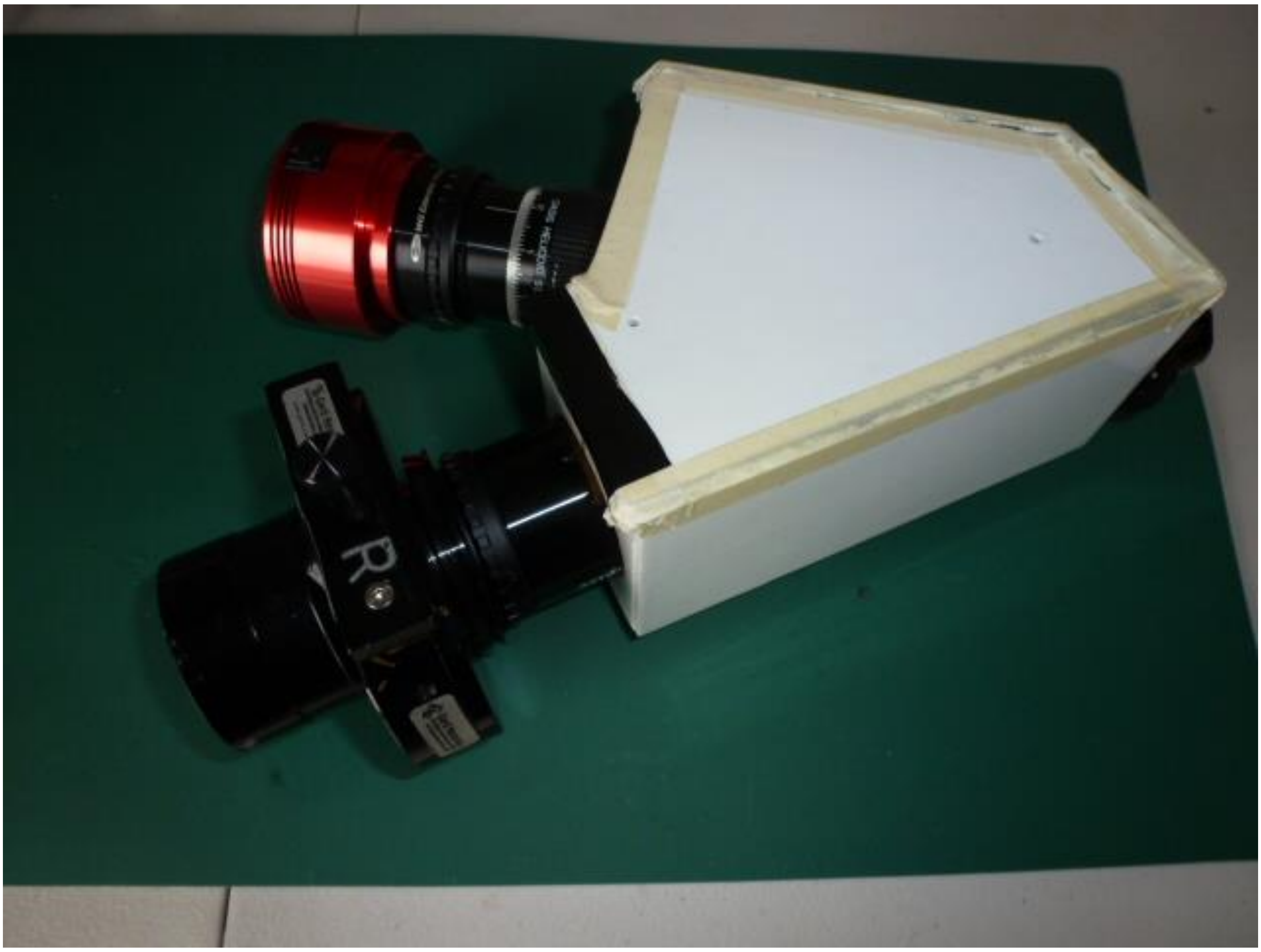
Not very successful.

Problems with the Surplus Shed slit. Uneven gap and difficult to maintain a very narrow gap.

Unable to get a good focus (telescope) which showed the “wiggles” in the absorption line.

Changed the slit to a Custom OVIO plate mounted in a Neumann filter drawer. This allowed the 20 micron slit gap to be set on the axis.

Readjusted the collimator to maintain slit focus.



MiniSHG: With Custom slit plate

20 Micron Slit Results

It was quickly seen that the quality and size of the slit gap had improved the spectrum.

After some trial and error the “best” telescope and spectrograph settings were determined. (See note below)

At this point the spectral lines were clear and contrasty. The “wiggles” of cellular movement were obvious in the absorption line.

The changes in focus were measured by a micrometer. I measured from the fixed shoulder of the focuser to the front of the adaptor. The total "telescope" focal length was 532mm plus the delta. The telescope focus change from Ha and CaK was minimal, 0.1 or 0.2mm

The helical focuser position on the imaging optics of the spectrograph was recorded. The difference was 0.75mm between the Ha and CaK spectral focus.

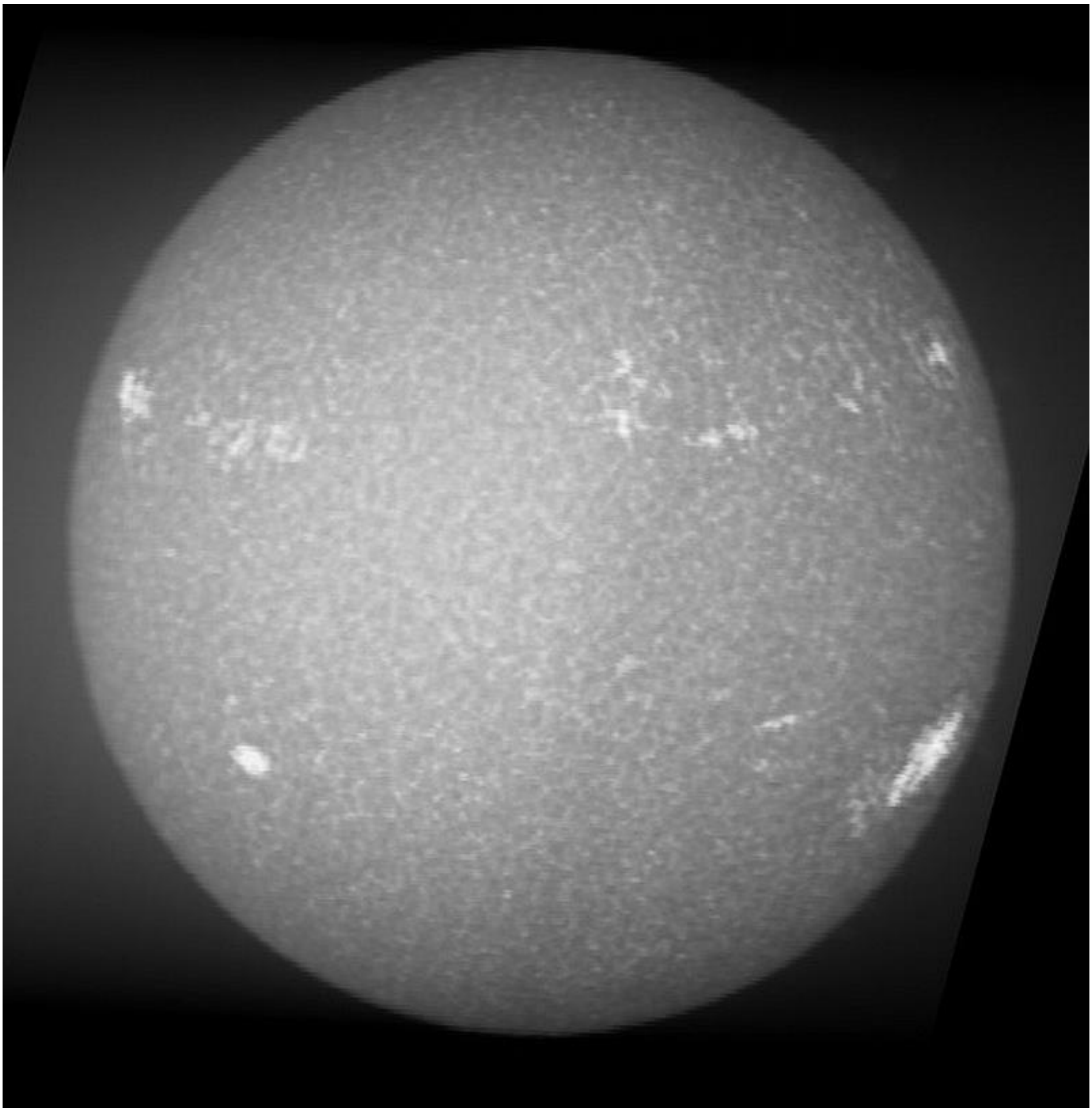
Summary

For CaK: Telescope focus- 532+28.23 to 27.8mm (+/-560mm), spectrograph 2.55mm

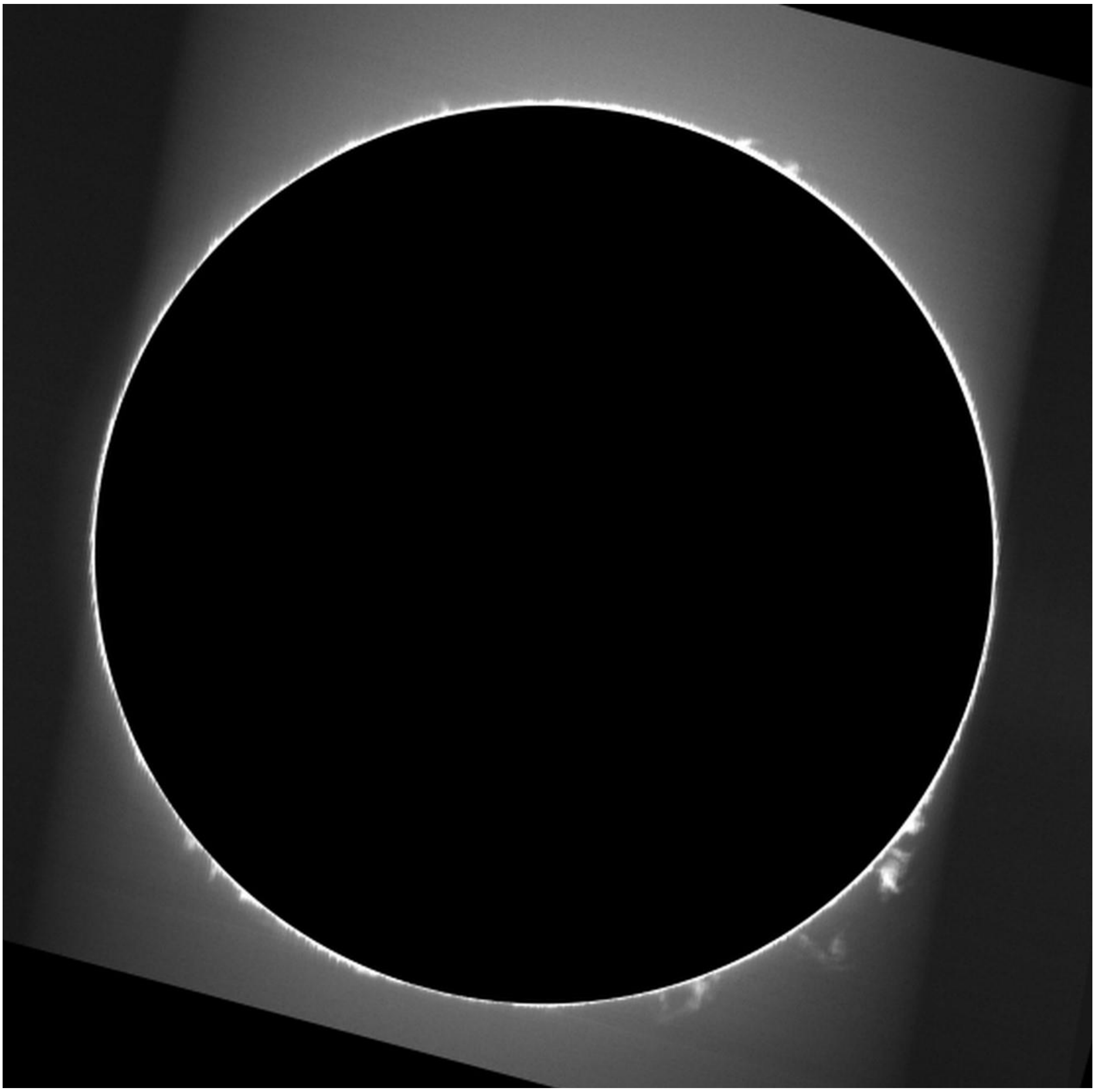
For H alpha: Telescope focus-532+28.15 to 27.8mm (+/-560mm), spectrograph 1.8mm

NOTE:

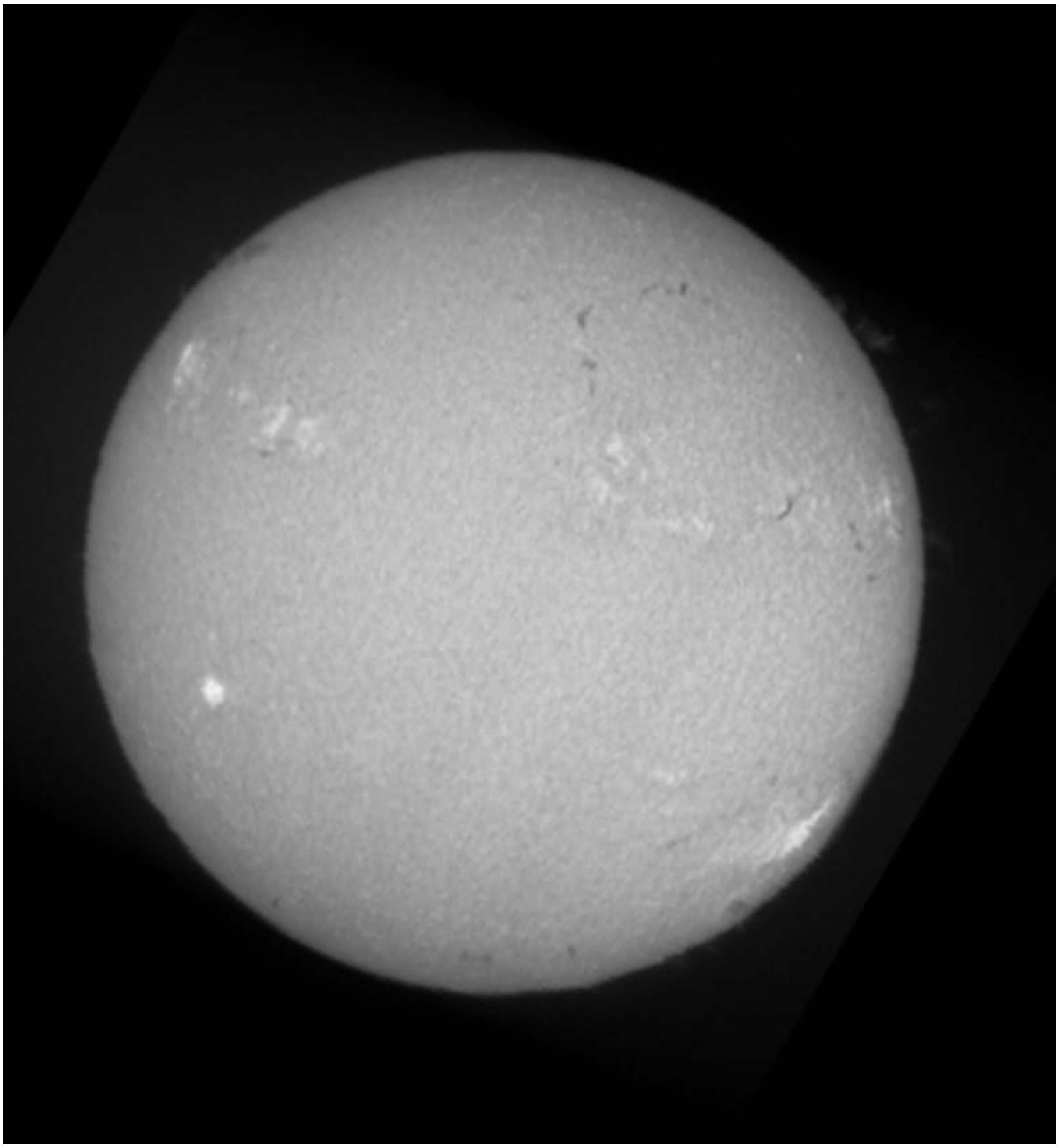
The optimum focal point – “wiggles” in the absorption line and spectral edge crisp was approximately 93% of the telescope quoted infinity focus i.e. 560mm v’s 600mm for the ED80. Fulvio Mete has already pointed this out in his eBook.



MiniSHG: CaK result. 18 sec scan (in Declination) 020921



MiniSHG: H alpha result. 18 sec scan (in Declination) 020921



MiniSHG: H alpha result. 18 sec scan (in Declination) 020921

Acquisition and processing

FireCapture V2.7

The OVIO Custom slit is 6mm long, when the SHG is used in the ED80 (600 fl) the solar diameter can vary from 5.49mm (July) to 5.68mm (Jan). The 6mm slit length is therefore ideal for this scope, allowing full disk recording.

The 20 micron slit width gives a sampling of 3.4 with the ASI 178 (2.4 micron pixel). This is due to the anamorphic factor of 0.35 resulting in a slit image of only 8 micron. A 10 micron would be a better slit gap.

SimSpecSHG shows that the solar diameter varies from 2289 to 2366 pixel through the year.

To obtain a Y/X ratio close to unity, the frames exposed during the scan should be about 2350.

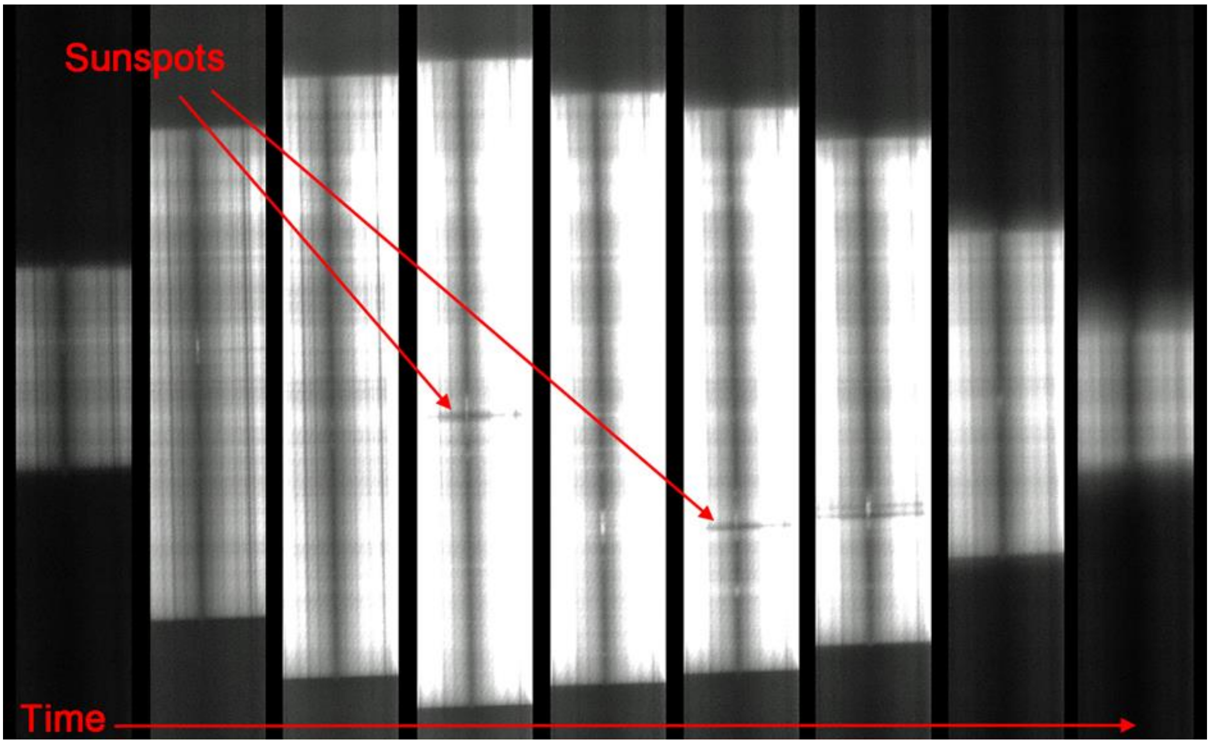
Using the SkyWatcher HEQ5 mount the fast slew settings can be used. A slew rate of x2 gives an 18 sec scan time on the solar disk. The optimum frame rate would then be 2350/18 = 130 fps.

To allow maximum frame rates an ROI should be chosen to cover the whole of the solar disk height, say 2400 pixel and wide enough to capture the target absorption line, say 150 pixel.

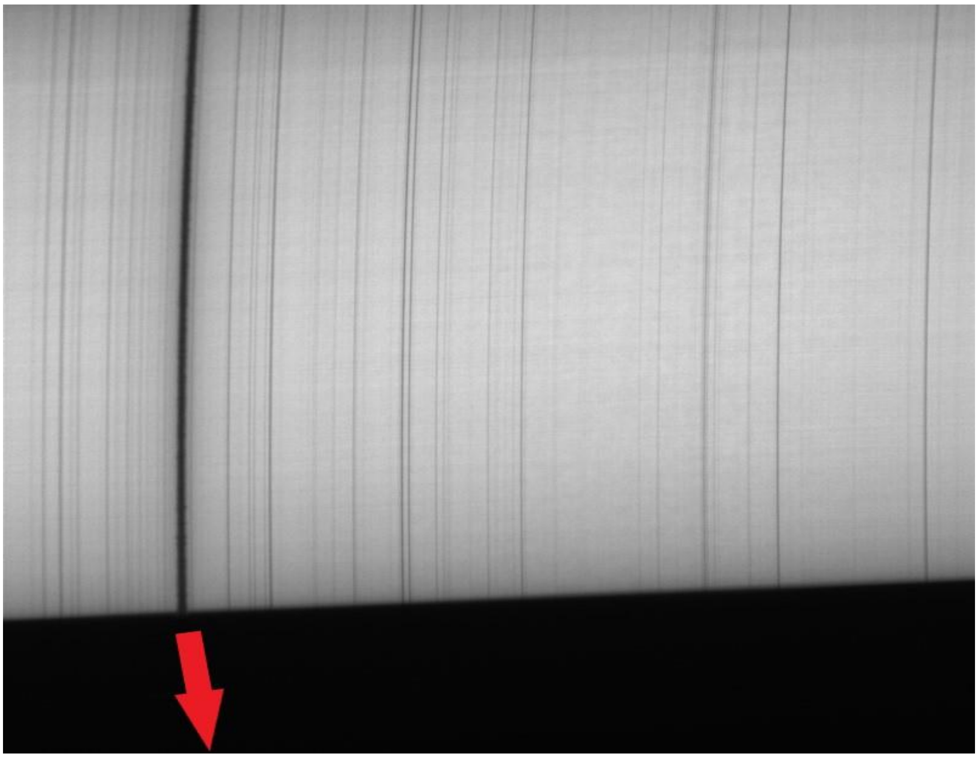
FC can then be set to record to a 16bit SER file, ROI 2400 x 150 pixel and a Frame Rate of 130

I elected to use a scan in Declination. I currently use a 60mm aperture stop on the ED80.

The telescope is set up, balanced and directed to the Sun. Movement in E –W allows the spectrum to be centred on the slit, movement in Dec takes the spectral image from the extreme limb to the maximum width at the centre of the solar disk.



At this maximum width, the exposure can be set to maximize the “wiggles” in the target line.



Wiggles inside the absorption line

By using the x2 (or x3) scan in Declination (say South, for example) the solar spectrum can be positioned at the extreme solar edge. Run the slew for a few seconds more to give some clear space above/ below the solar disk and start the scan video, at the same time press the opposite slew button (North) to bring the edge of the solar disk back into view, and the subsequent solar disk.

INTI_EN V3.2/ Matt’s AVI

The latest versions of INTI (The Smith’s INTI ENV3.2 and Matt’s Solex_ser_recon_AVI) are very fast and can produce an image in three to four seconds!

Amazing performance.

Next Step

1. Change to the Buil 2nd generation lenses. Use the 125mm focal length for both collimator and imager. Shelyak #OP0181(A), 75 euro each.
2. Change the slit plate to the Jeulin version which has a 10 micron x 6mm slit. Jeulin # 204012, 24 euro. (Oct 21) slit plate arrived. Resolution looks much better.
3. Consider adding an H alpha narrowband filter, 7nm bandwidth, as an ERF in H alpha. – Done! Very successful. Also reduces the background in the Prom image (Protus)
4. Consider adding a Baader CCD Blue filter as an ERF in CaK. Done! Not very impressive. Significant loss of light. The Astronomik UV-IR filter much better (Astronomik IR-Block).

Additional Info

I've put a copy of an excellent GIF by Pascal Berteau in my Dropbox (2Mb)

https://www.dropbox.com/s/j3bxq9mrh9...image.gif?dl=0

https://groups.io/g/astronomicalspectroscopy/message/17120

Parts List for final version MiniSHG (Aug 2021)

1.	2” to T thread nosepiece adaptor	$40
2.	10mm T thread spacers x 2	$20
3.	Jeulin custom 10micron slit plate	$40
4.	25.4mm Achromat, 125 fl x2	$150
5.	30 x 30mm 2400 l/mm grating	$250
6.	Grating support and rotation lock/ indicator	$50
7.	T thread mounted 1.25” non-rotational helical focuser	$50
8.	1.5mm Aluminium housing	$100 (Est)
9.	Mounting plates for 25.4mm lenses, x2	$40
10.	T thread mounting plates for slit/ focuser, x2	$40
11.	ASI 178 Cmos camera	$430
12.	2” Baader H alpha filter	$160 (recommended)
13.	2” Baader 0.9ND filter	$114 (Mandatory)
14.	2” Astronomik IR block filter	$150 (Mandatory)
15.	Software: Firecapture, EN_INTI	$ 0
	Total cost:	$1,500 (Approx)