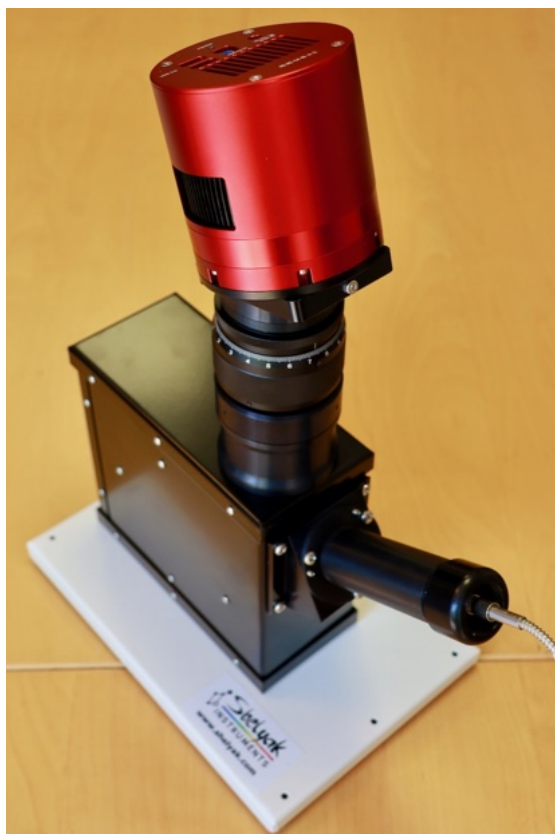


eShel III
PF0091 (manual) & PF0092 (motorized)
User Manual



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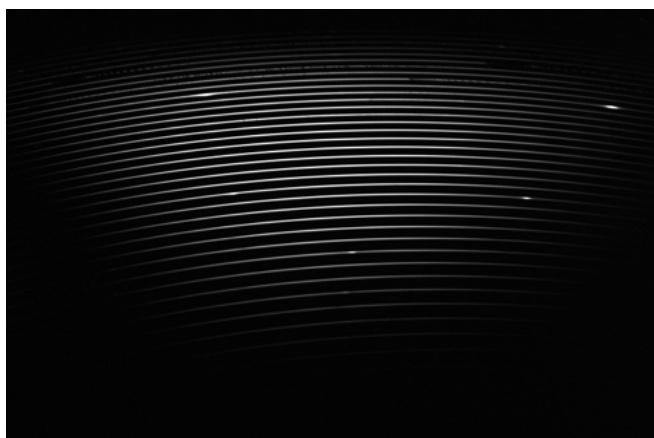


Figure 1.1: The 2D image out of the eShel III (spectrum of chi Oph). Each order (horizontal line) is a portion of the spectrum.

1.1 Versions History

Version	Date	Description
A.01	29/07/2026	Initial revision

1.2 The Whole eShel III System

Welcome to the eShel III system. This instrument has been designed and improved over time to make high-quality astronomical spectroscopic observations.

An Echelle spectroscope is a special optical device that uses a diffraction grating at high orders. The resulting image is a set of lines, each of them showing part of the source spectrum. There is a small overlap between orders, to avoid missing any detail. This Echelle spectrum can be read like the lines of a book.

The eShel III is a fiber fed instrument. This means that the light is collected at the back of a telescope, and sent towards the spectroscope through a fiber optics.

The eShel III spectroscope is part of the whole eShel III system, which includes several elements:

- eShel III (the spectroscope itself)
- The FIGU (for Fiber Injection and Guiding Unit). This is a device put at the back of the telescope, to collect the light from the star you want to observe.

- The Calibration module, that generates Flat and Calibration light, necessary to properly process the data and correct the star signal from any instrumental effect.
- The fiber optics (one for the target, usually a 50 μ m diameter, and the other for the calibration light).

1.3 The Demetra software

The spectroscope itself will produce a 2D image, with all the orders (see fig. 1.1). You'll need to process this data to get a useful spectrum, usually shown as a 1D profile.

For many years, we have been developing the Demetra software to make the whole process easy, from image acquisition to data reduction and graph production (as well as standard FIT files). Of course you can use any other software, because the eShel III is a purely optical device. You can process the images the way you want.

Demetra is free and available at the Shelyak Instruments website¹.

1.4 Two versions

We know that each observer has their own setup and working conditions. In particular, we know that some people work close to their instrument, while others work remotely (sometimes at very long distance). To cover all these cases, we propose the eShel III with two different configurations: the manual one and the motorized one.

- The manual version is enough if you're working close to your instrument, and you can correct the focusing with temperature and time (eShel III is a very stable instrument indeed).
- The motorized version is for observers working remotely – close to the instrument or at the other side of the world. With this configuration, you can remotely control the focusing of the instrument.

In both cases, the optics are exactly the same, and so is the image quality. It is only the focusing solution that differs (the way the CMOS sensor position is controlled relative to the optics).

1. <https://www.shelyak.com>

1.5 What is new with eShel III

The eShel instrument already has a long life, with a few evolutions over time. The eShel III is the latest update, which improves the optical quality of the spectrum image produced.

The difference between the eShel III and the previous generations is the objective lens. For the first time in the eShel history, we have fully internally designed optics – and we now have a fully optimized solution for our application.

The previous generations used off-the-shelf photo lenses. It happens that most fixed-focal-length photo lenses are being discontinued – most people prefer to use zoom lenses instead, which makes sense for traditional photography.

Designing our own optics was challenging for Shelyak at the beginning... but over time, we have learned and understood all the advantages of a purpose-designed solution. For instance, we can apply an Anti-Reflective (AR) coating matching our needs, which significantly increases the sensitivity in the UV and IR domains. And we can define the best dimensions of the optics (focal length and aperture) to match the sensor we use. The input lens diameter means we now have almost no vignetting at the Objective lens input (this results in better throughput, especially at extreme orders and at the order ends). We can also take advantage of our specific configuration to optimize the design (see next section).

As a result, the eShel III improves the optical performance of the instrument: more orders (thus a larger wavelength domain), higher throughput (thus a better Signal to Noise Ratio – SNR – for a given exposure time and a given target). The eShel III is for sure the best eShel instrument we've ever produced!

Note: Since the only change of the eShel III is the objective lens, you can upgrade your eShel if you have an old version!²

1.6 A very Special Optics

As you can see on all the images of the eShel III instrument, we have given an angle to the camera versus the objective lens axis. This angle is very unusual in optics, and is directly linked to our special application (Echelle spectroscopy).

If you're designing a photo lens, you must get the best optical quality in the whole field of view, and the whole color range (visible range for our eyes). This places a strong constraint on the design of the optics.

In our case, we want to extend the 'color range' (the wavelength domain) even further, but we can take advantage of one property of an Echelle spectrum: the blue (or even near-UV) light is on one side of the sensor (bottom of the image), and the red one (or even near-IR) is on the other side (top of the image). There is no more need to correct for chromatic aberration across the whole image! It is by taking this parameter into account that we found

that giving an angle to the sensor would help – a lot – to improve the image quality.

². Refer to the dedicated document to make the upgrade at Shelyak website <https://www.shelyak.com>

The eShel III at a glance

2.1 Out of the box

Your eShel III comes with the following elements:

- eShel III spectroscope
- The base plate (with screws)
- A tool set

You'll have to add a Science camera. Our recommendation is to use a Zwo ASI2600MM-Pro unit. This is a high-end CMOS camera, with the proper sensor and pixel size.

2.2 Optical Architecture

It is important to understand how the eShel III image (2D image, see 1.1) is built. This is purely optics. The figure 2.1 describes the light path. Let's detail each step.

- The light input is the fiber output. Whatever light enters the fiber will be spread out by the eShel III. This means that you don't need a telescope to start playing with the eShel III. Any light coming in can be used for first tests: Sun (or sky, or clouds) light, any artificial light, a flame, a calibration light, and so on.
- The light coming out of the fiber is sent to the collimator lens. This makes a parallel (collimated) beam.
- This collimated beam is sent to the Echelle grating, which spreads out the light at high resolution. Since the Echelle grating works at high orders, all the orders are still mixed at this stage (but each order is really spread out).
- Then the light is sent to a secondary disperser – usually called the cross-disperser – to split the orders in the other axis. In the eShel III the cross-disperser is a prism.
- Now, the beam is spread-out in two directions: the main (X) direction by the Echelle grating, and the second (Y) direction by the prism. For a given wavelength, the beam is still parallel, but from one wavelength to the other, the beam direction differs.

- The whole beam is then sent to the Objective Lens (the new eShel III element) to focus all the beams to the sensor, making the 2D image (see fig. 1.1).
- The image is produced on the sensor (CMOS camera).

2.3 Main Elements

The figures 2.2 and 2.3 show the main elements of the instrument:

- Fiber connector (spectroscope input)
- Objective lens
- Science camera
- Screws (headless) to tune the Echelle grating angle (X direction in the image)
- Screws to tune the grating angle (Y direction in the image)
- Screw to fine tune the spectrum in the image (Y direction)
- Minimal camera specification : pixel size, chip size

2.4 What you will need

To start working with the eShel III, you will need some external elements :

- A fiber optics (diameter 50µm).
- A light source. It can be the light in the room you're working in; sunlight (even on a cloudy day) is a very good start.
- A calibration light source, to fine tune the focus of the instrument. A flat light source is also required for completing a full observation. The eShel calibration module includes both calibration and flat lamps. And it can be remotely controlled. See Shelyak Website¹.

1. <https://www.shelyak.com/produit/pf0012-etalonage-eshel/?lang=en>

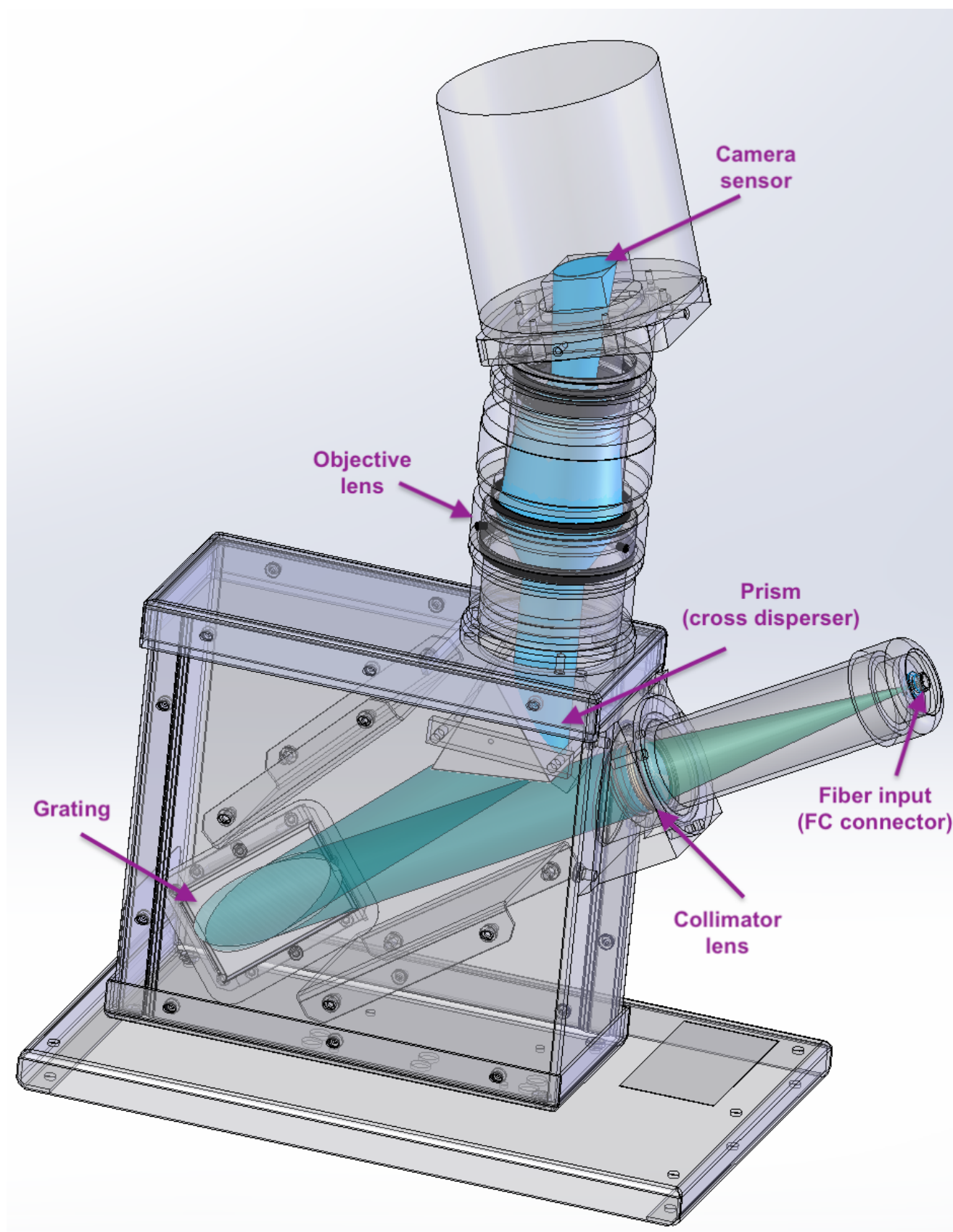


Figure 2.1: Optical architecture of the eShel III

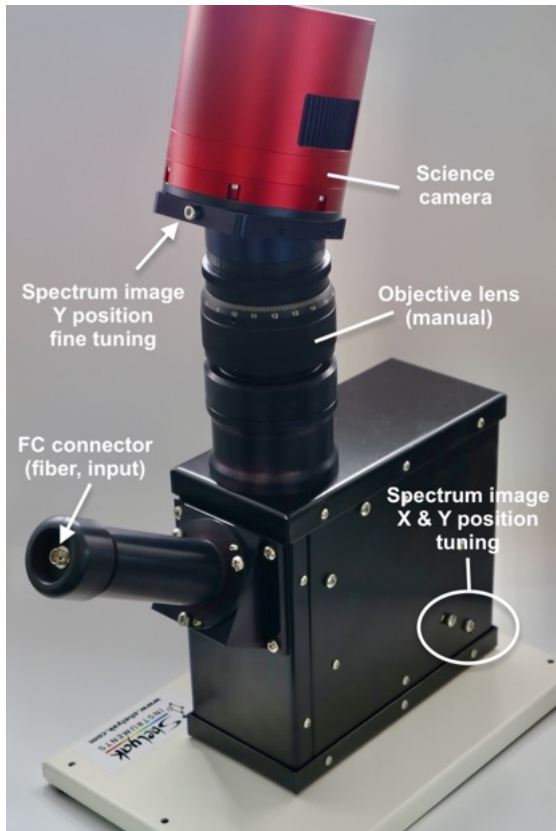


Figure 2.2: The eShel III main elements

- An image acquisition software and a data reduction software. Demetra software can do both (and it is free!). Demetra can be downloaded from Shelyak's website².
- Of course, to observe a star spectrum, you'll need a telescope (even a small one) and a FIGU (Fiber Injection and Guiding Unit). See for instance <https://www.shelyak.com/produit/pf0008-bonnette-f-6-50μm/?lang=en>.

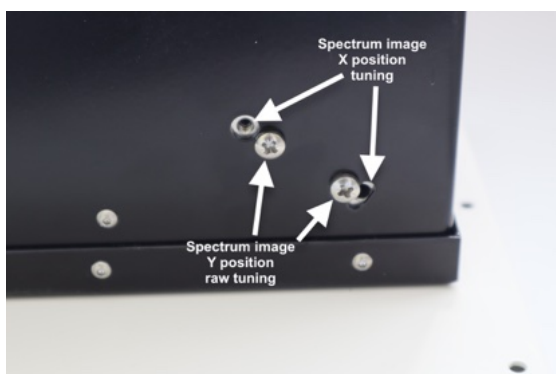


Figure 2.3: Details on the tuning of the spectrum position in the image

2. <https://www.shelyak.com/software/demetra/?lang=en>

3

Installation of the eShel III

It is now time to install the eShel III spectroscope, and take your first spectra. Let's go step by step.

3.1 The Base Plate

The base plate is attached to the eShel spectroscope thanks to four knurled screws. These are M3x10mm screws. The purpose of the plate is to provide high stability for the instrument. See the figures 3.1, 3.2 and 3.3.



Figure 3.1: The base plate, before assembling. The green circles show the holes to put the screws in.



Figure 3.2: Attaching the Base plate to the eShel III. Green circles show the positions of the screws.

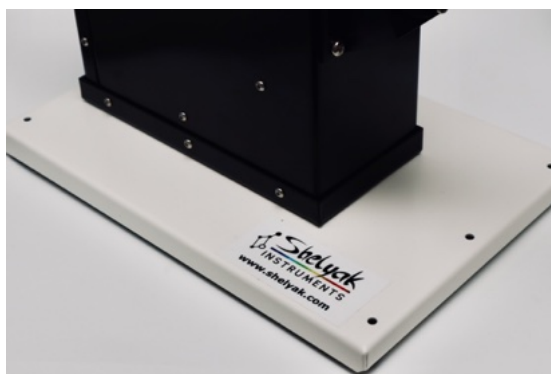


Figure 3.3: After assembling

3.2 Camera Setup

You must attach the camera plate to the camera itself with 4 screws (M2.5x6mm screws, see fig. 3.4). Make sure the orientation complies with fig. 3.5.

Then, mount the camera to the slanted dovetail. Slide the camera until the top screw blocks it. Tighten the three headless screws around the camera plate to firmly attach the camera (see fig. 3.6). Note that during the tuning step, you may have to release at least one screw to allow the camera plate to slide along the dovetail.

The camera vertical plane must be parallel to the eShel III side panels. To do this alignment, you must release the 3 headless screws below the focuser (see fig. 3.7), and rotate gently the lens (see fig. 3.8).

3.3 Connecting the Fiber

Connect the fiber to the FC connector (see fig. 3.9 and 3.10). The index of the FC connector must be properly inserted in the matching slot.

Remove the cap from the fiber at the other end, and point the fiber towards some ambient light (sunlight / cloud light is best). Put a diffuser in front of the fiber (few mm away). It can be a piece of white paper or a semi-transparent paper – the idea is to illuminate the fiber with a diffused and homogeneous light.



Figure 3.4: Attaching the camera plate



Figure 3.6: Mounting the camera to the eShel III lens



Figure 3.7: The screws to release before rotating the lens

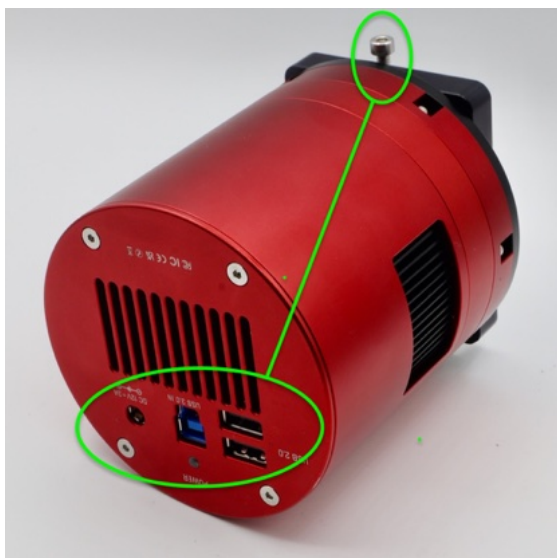


Figure 3.5: Check the orientation of the camera plate



Figure 3.8: Rotate the lens to make sure the camera sensor is parallel to the eShel III chassis



Figure 3.9: Connect the Fiber to the eShel III

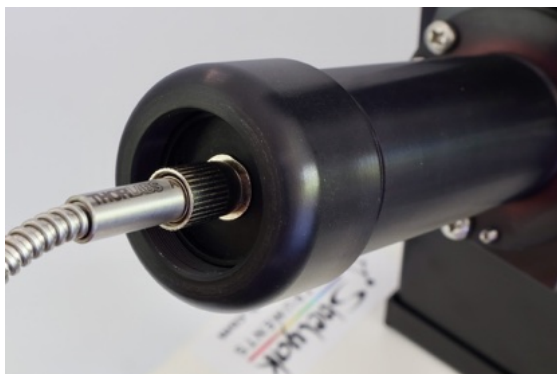


Figure 3.10: Check the index is properly inserted, and tighten the locking ring

When connecting the Fiber to the eShel III, make sure that the index of the FC connector is properly set in the FC socket. If the index is out of the slot, then the fiber will be out of the socket by few millimeters and this will directly affect the image quality.

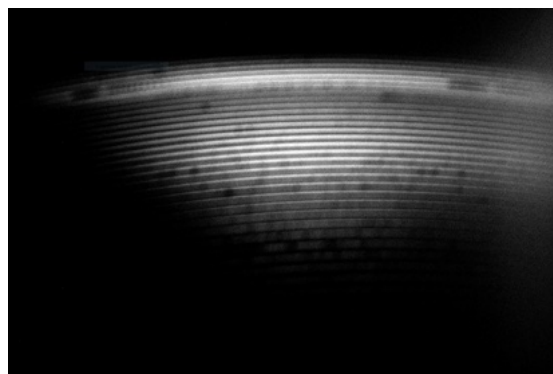


Figure 3.11: A first image

3.4 Your First Spectrum Image

You can now connect the camera to your computer and run the acquisition software. Take an image of, say 1 second exposure. Adapt the exposure time with the signal level in your image (make sure it is not saturated). You should have something like in fig. 3.11. The image is probably fuzzy, but see already different orders and some absorption lines – we'll tune the instrument in the next chapter.

4.1 Focusing the spectrum image

At this stage, we've a first spectrum image (see fig. 3.11, previous chapter). The first tuning step is to make this image sharp, using the focuser. It will be different for manual and motorized version.

Note: You can use the Sun light to roughly focus the image, but the best is to use a calibration light source, like the ThAr lamp in the calibration module. In this case, each emission line makes a spot, and each spot is an image of the fiber.

4.1.1 Manual Version

Focusing the eShel III is quick and easy with the manual focuser. Simply rotate the focusing ring (see fig. 4.1), while taking continuous images (short time, for instance 1s). When the spectrum orders are as sharp as possible, you're done. With the Sun spectrum, you should see many (many!) features in the spectrum.



Figure 4.1: Rotate the ring to focus the image.

4.1.2 Motorized Version

The electric focuser requires some power supply (12V), and can be controlled remotely. This can be done via the USB connection (using the dedicated PLAY application from PrimaLuceLab) or with your phone / tablet, using the internal WiFi access point. For more advanced configurations, you can also use ASCOM (under Windows) or INDI (under Linux) drivers. Detailed information about the focuser control can be found on the PrimaLuceLab website¹.

Once you've understood how to move the focuser, change the position while taking continuous images (short time, for instance 1s). When the spectrum orders are as sharp as possible, you're done. With the Sun spectrum, you should see many (many!) features in the spectrum.

After focusing, you should have a sharp image. The fig. 4.2 shows a Sun spectrum image and the fig. 4.3 shows a Thorium-Aron (calibration) spectrum image.

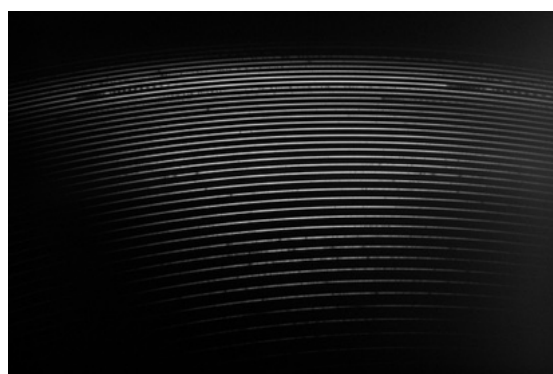


Figure 4.2: Sun spectrum image properly focused

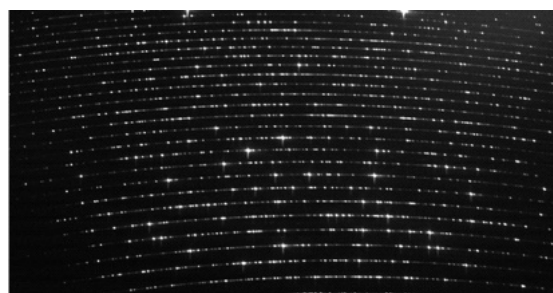


Figure 4.3: ThAr spectrum image properly focused

1. <https://www.primalucelab.com/info/downloads.html>

How far to go with focusing?

The focal length (FL) length of the eShel III Collimator lens is 125mm, and the FL for the Objective lens is 122mm. Then there is almost no internal focal reducer ($122/125 \approx 1$) and the spot images must have a size close to the fiber diameter – 50 μm . With the 3.76 μm pixels of the CMOS sensor (IMX 571, ASI 2600MM-Pro), spot images must have a FWHM of $50 / 3.76 = 13$ pixels. In real life you can get around 10 pixels almost anywhere in the image. See fig. 4.4

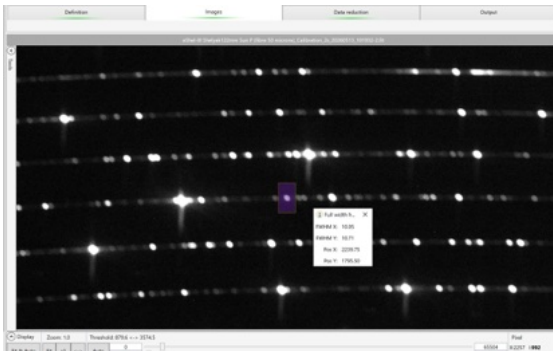


Figure 4.4: Zoom on a calibration spot, and FWHM (Demetra software)

4.2 Grating Orientation (X direction)

If the spectrum is not properly centered horizontally in the image, you must adjust the Echelle grating angle (in the fig. 4.5, we've exaggerated the case). This can be done using the headless screws on the side of the eShel III (see fig. 4.6). You must start by releasing one screw before tightening the other one.

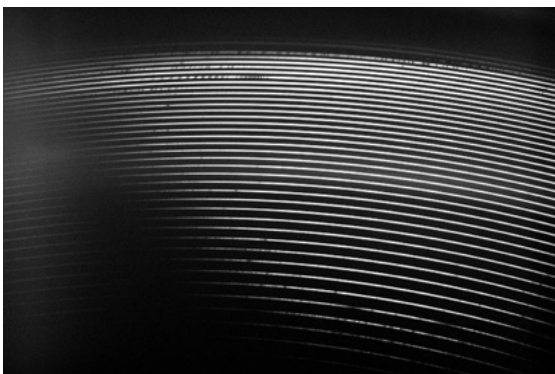


Figure 4.5: The spectrum is not centered horizontally.



Figure 4.6: Release and tighten headless screws to center the spectrum in the image.

The two screws push against the grating holder (not against the grating itself!). Remember to release one screw first, and then tighten the other one. This is to avoid putting too much stress on the grating holder – and possibly damaging it.

4.3 Vertical position of the spectrum

The spectrum occupies almost the full height of the image. Therefore the vertical position of the spectrum must be precisely tuned, to avoid losing any order in the image. The first method is to rotate the grating. This is a coarse adjustment, which is already made during the manufacturing process.

To rotate the grating angle, release the two screws at the bottom of the eShel III (see fig. 4.7). Then, slide the bottom screw in the oblong hole. The tuning is very sensitive. When you're OK with the spectrum position, tighten back the screws.

Before changing the grating angle, make sure that the camera knurled screw is in medium position (with margin in both directions).

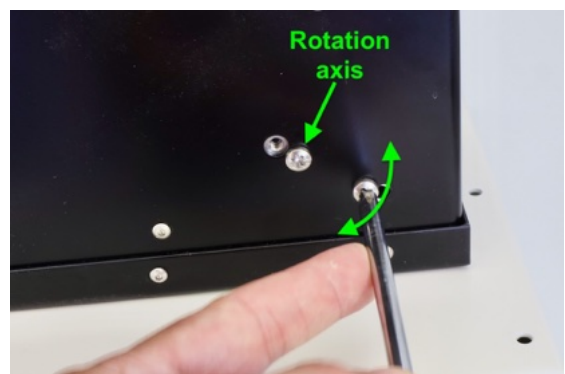


Figure 4.7: Raw tuning of the vertical position of the spectrum.



Figure 4.8: Release the dovetail screws, to allow the movement of the camera



Figure 4.9: Release the dovetail screws, to allow the movement of the camera

The second one is a fine tuning, sliding the camera itself (along the dovetail) ; it is much more precise, but with a limited range. Release the dovetail screws, as shown in fig. 4.8, and turn the stopper screw as shown in fig. 4.9. When the position is correct (top orders close to the top edge of the image), tighten back the headless screws (fig. 4.8).

4.4 Objective lens orientation

As you can see, the camera has a significant angle relative to the horizontal plane. This is needed to properly manage the chromatism in the image. However, this angle has a side effect on the image: if the camera's vertical plane is not parallel to the eShel III's main (vertical) plane, it will create a focus gap between the right and left ends of the orders. This can result in good image quality in the middle of the image (center of the orders), but poor quality at the ends.

To avoid this effect, you must ensure that the camera is well aligned with the eShel III. The rotation of the camera can be done after releasing the three screws at the top of the focuser. See fig. 4.10. When you're OK, tighten back the screws.

If necessary, refine the focusing after this operation.

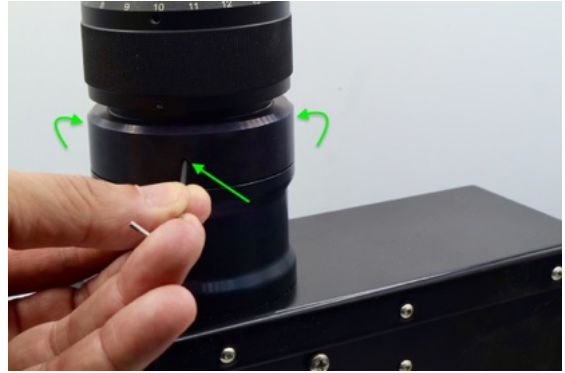


Figure 4.10: The screws to release before rotating the lens

4.5 The 'Anamorphose'

In the above chapter about focusing the image (4.1), we said that the spots in the calibration image are an image of the fiber. This needs to be clarified: the fiber is perfectly round, but the spots are elongated, more or less depending on the order and the position within the order. This elongation is called anamorphism, and comes from the optics itself. In short, this is due to the internal angle between the input and output angles of the beam on the Echelle grating.

This is not a defect – this is just optics (see fig. 4.11).

This effect can be partially corrected during the data processing. For instance in Demetra we can give a slant correction for each order. By doing it, we'll improve a little bit the resolution of the final spectrum.



Figure 4.11: Anamorphose in the optical simulation of eShel III

Your eShel III spectroscope is now ready for high quality observations! Please share your results with us - this is always very motivating to see how our instruments are used!

5

Appendix Technical Specifications

Here are the main technical specifications for the eShel
III spectroscope:

- Dimensions: refer to the drawings fig. 5.1 (manual version) and fig. 5.2 for the motorized version (next pages).
- Weight: 3.7 kg for the manual version and 4.0 kg for the motorized version (with ASI2600MM-Pro camera).
- Fiber optics: 50μm, FC/PC connector
- Orders from 22 (central wavelength 1000 nm) to 62 (central wavelength 355 nm).
- Resolution Power: $R=10.000$.
Note: $R = \lambda/\Delta\lambda$

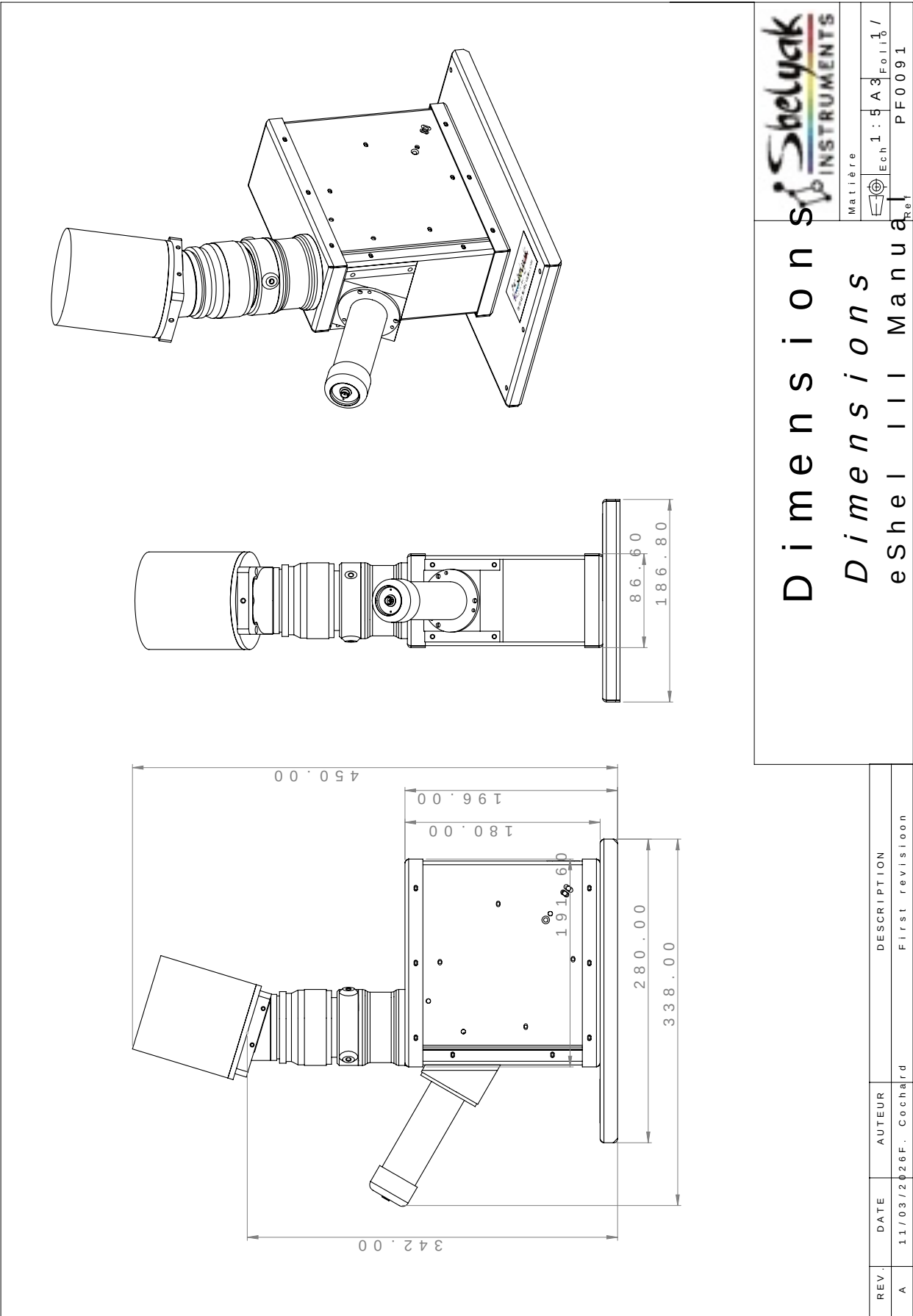


Figure 5.1: Dimensions of the eShel III - manual version

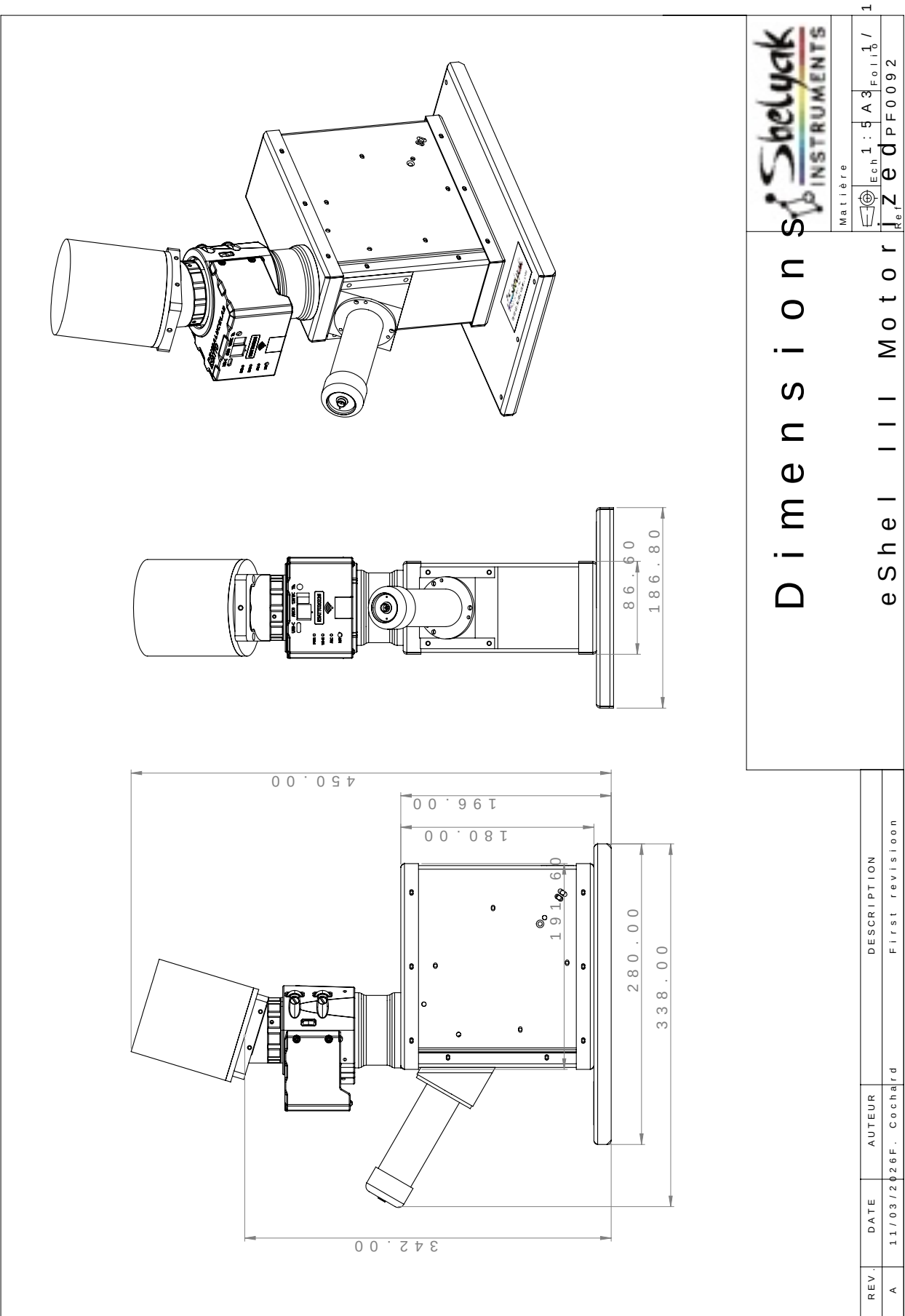


Figure 5.2: Dimensions of the eShel III - motorized version

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Appendix Physical Orders

The orders numbering come from the physical dimensions of the Echelle grating. For instance, we can say for sure that the H_α line is in the order #34. In some cases, it can be useful to know the theoretical central wavelength for each order of the eShel III. We give this data in the below table.

Note: the min and max values are given for an order overlap of 20%. Real values will be higher than these, especially in the blue orders (bottom part of the images) where the orders are shorter.

Orders 20 to 42 are given in table 6.1 (page 17) and orders 43 to 65 are given in table 6.2 (page 18).

Note : in real conditions, only orders 22 to 62 can be used.

Order	Min λ	Central λ	Max λ	Comment
#20	10655,9 nm	11216,8 nm	11777,6 nm	Not accessible with eShel III
#21	10173,9 nm	10682,6 nm	11191,3 nm	Not accessible with eShel III
#22	9733,6 nm	10197,1 nm	10660,6 nm	
#23	9329,6 nm	9753,7 nm	10177,8 nm	
#24	8957,8 nm	9347,3 nm	9736,8 nm	
#25	8614,5 nm	8973,4 nm	9332,4 nm	
#26	8296,4 nm	8628,3 nm	8960,1 nm	
#27	8001,0 nm	8308,7 nm	8616,5 nm	
#28	7725,8 nm	8012,0 nm	8298,1 nm	
#29	7469,0 nm	7735,7 nm	8002,5 nm	
#30	7228,6 nm	7477,9 nm	7727,1 nm	
#31	7003,2 nm	7236,6 nm	7470,1 nm	
#32	6791,4 nm	7010,5 nm	7229,6 nm	
#33	6592,0 nm	6798,0 nm	7004,0 nm	
#34	6404,0 nm	6598,1 nm	6792,2 nm	$H\alpha$ line
#35	6226,5 nm	6409,6 nm	6592,7 nm	
#36	6058,4 nm	6231,5 nm	6404,6 nm	
#37	5899,3 nm	6063,1 nm	6227,0 nm	
#38	5748,2 nm	5903,6 nm	6058,9 nm	Sodium (Na) doublet
#39	5604,7 nm	5752,2 nm	5899,7 nm	
#40	5468,2 nm	5608,4 nm	5748,6 nm	
#41	5338,1 nm	5471,6 nm	5605,1 nm	
#42	5214,1 nm	5341,3 nm	5468,5 nm	

Figure 6.1: Wavelength domain for orders #20 to #42

Order	Min λ	Central λ	Max λ	Comment
#43	5095,8 nm	5217,1 nm	5338,4 nm	<i>Hβ</i> line
#44	4982,7 nm	5098,5 nm	5214,4 nm	
#45	4874,5 nm	4985,2 nm	5096,0 nm	
#46	4770,8 nm	4876,9 nm	4982,9 nm	
#47	4671,5 nm	4773,1 nm	4874,7 nm	
#48	4576,3 nm	4673,7 nm	4771,0 nm	
#49	4484,8 nm	4578,3 nm	4671,7 nm	
#50	4397,0 nm	4486,7 nm	4576,4 nm	
#51	4312,5 nm	4398,7 nm	4485,0 nm	
#52	4231,2 nm	4314,1 nm	4397,1 nm	
#53	4152,9 nm	4232,7 nm	4312,6 nm	
#54	4077,4 nm	4154,4 nm	4231,3 nm	
#55	4004,7 nm	4078,8 nm	4153,0 nm	
#56	3934,5 nm	4006,0 nm	4077,5 nm	Calcium (Ca) H&K doublet
#57	3866,7 nm	3935,7 nm	4004,8 nm	
#58	3801,2 nm	3867,9 nm	3934,5 nm	
#59	3737,9 nm	3802,3 nm	3866,7 nm	
#60	3676,6 nm	3738,9 nm	3801,2 nm	
#61	3617,3 nm	3677,6 nm	3737,9 nm	
#62	3560,0 nm	3618,3 nm	3676,7 nm	Not accessible with eShel III
#63	3504,4 nm	3560,9 nm	3617,4 nm	
#64	3450,5 nm	3505,2 nm	3560,0 nm	
#65	3398,2 nm	3451,3 nm	3504,4 nm	Not accessible with eShel III

Figure 6.2: Wavelength domain for orders #43 to #65

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Appendix Focusing The Collimator Lens

The collimator lens is precisely focused during the manufacturing process, but it may happen that you have to do this focus by yourself. We describe here the process to make this focusing.

To make this adjustment, you will need (see fig. 7.1) :

- An optical fiber of 50 μm diameter.
- A tool to unscrew the base of the female connector of the optical fiber (Thorlabs tools for example).
- A holder to orient the fiber towards a source of intense light.

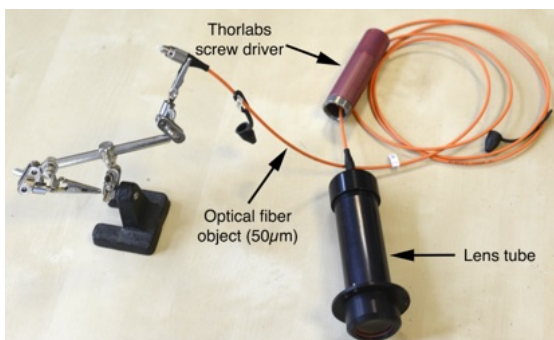


Figure 7.1: The toolset required for focusing the collimator lens.

First, disassemble the tube holding the connector of the optical fiber from the spectrograph (fig. 7.2 and 7.3).

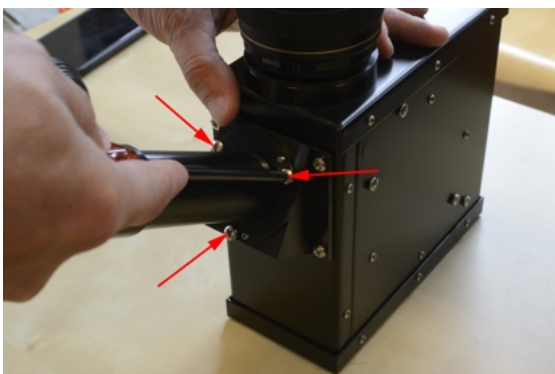


Figure 7.2: Remove the 3 indicated screws using a Phillips screwdriver.



Figure 7.3: Collimator tube

To focus the collimator lens, you will need to use a DSLR camera (with live view function) or a CCD camera equipped with a lens (roughly 135-200mm focal length), focused at infinity (you can adjust the focus to infinity by pointing at any pattern far away, such as a tree, a building, a mountain...).

If you use a DSLR camera, don't forget to put the camera in manual control for the focus.

Put the eShel tube in front of the camera lens and fix it rigidly. Don't touch the focus of the camera (it must be set to infinity). See fig. 7.4.



Figure 7.4: Collimator tube

You must see the light of the optical fiber on your screen (fig. 7.5).

The goal is to get the fiber image as sharp as possible by screwing the holder of the optical fiber connector in

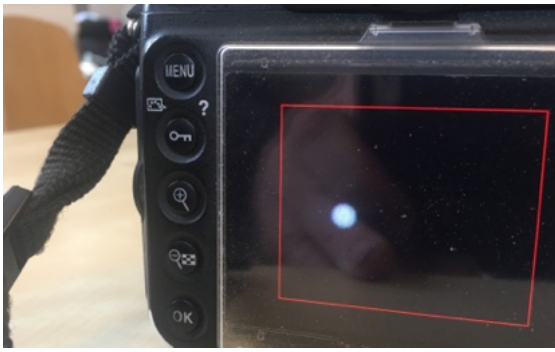


Figure 7.5: Collimator tube

or out (use the Thorlabs tool to release and tighten the fiber connector plate).

At the end, the spot (fiber image) must be perfectly sharp, like in fig. 7.6.

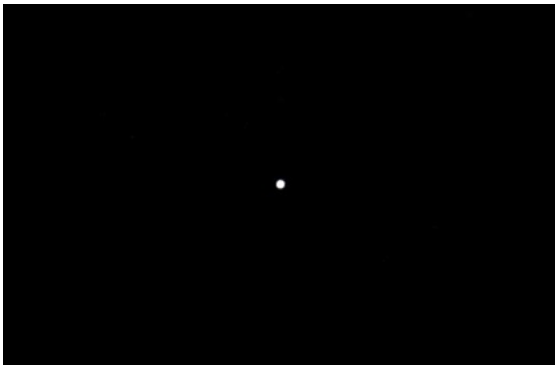


Figure 7.6: The spot (fiber image) is focused

When you have achieved the best focus, tighten the fiber base with the Thorlabs tool, then attach the tube to the eShel spectrograph by screwing in the 3 Phillips screws.

The collimator focus is done.