User Manual and Notes on the

RAPID IMAGING PLANETARY SPECTROGRAPH

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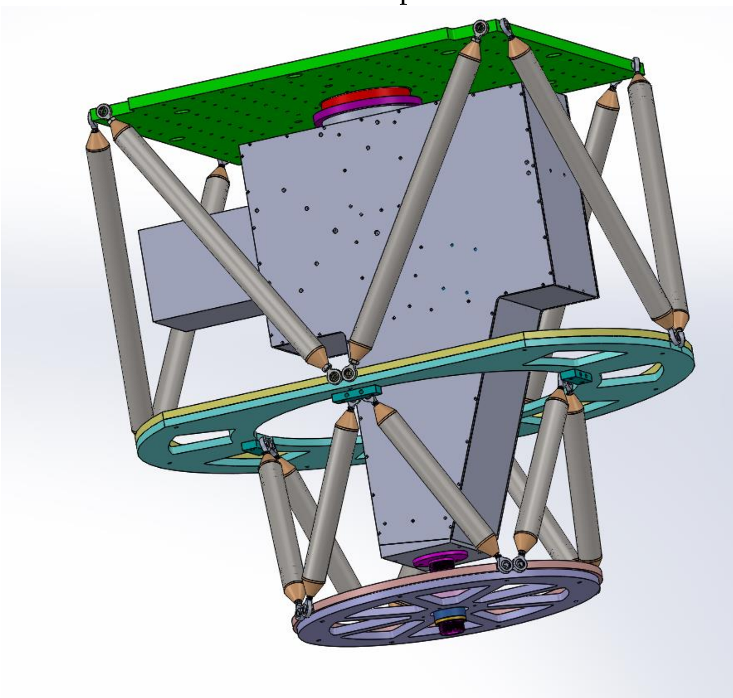


Table of Contents

I. User's Guide

Introduction and Capabilities

RIPS is designed for concurrent imaging and long-slit high resolution spectroscopy on the same detector at the same time. It was designed to utilize "lucky imaging" techniques to overcome atmospheric seeing, thereby placing the precise location of bright line emissions around resolved Solar System objects.

Resolving Power:	R~97,000 for a 2.45 pixel FWHM.
Dispersion:	24.6 mÅ/pixel or 1.25 km/s/pixel at 5900Å
Detector:	Andor iXon 1024 x 1024 EMCCD
Plate scale:	0.106 arcsec/pixel (on the f/17.5 Perkins 72")

I.1. Motors

Stepper motors connect between the RIPS microUSB port and the RIPS computer. This connection <u>must</u> go to the orange USB port on the RIPS computer which is powered on all the time. Otherwise changing filters will interrupt communication with the stepper motor phidget controller.

Set motor velocity to maximum, and motor acceleration to minimum in all cases.

Controller Serial Number 428174
Motor #0 = slit width
Motor #1 = grating
Motor #2 = spec focus
Motor #3 = slit viewer focus

Controller Serial Number 280531
Motor #2 = Slit Position Angle (Rotiserizer)

I.2. Exposure Times & Acquisition Modes

Saving one image as an unsigned 16 bit integer resets the default for auto-save, otherwise auto-saved format might be 32bit.

Common hotkeys in Andor Solis:
- Ctrl+Q = acquisition setup
- F5 = take image
- F3 = start video mode
- Esc = Abort

I.2.1. Exposure Times

I.2.2. Acquisition Modes

OptAcquire modes that seem usable for fast kinetics:

(All have vertical bleeds and left vertical structure. *Time lapse* mode makes vertical bleeds worse. *Highest Dynamic Range* is SLOW but has very little vertical bleed)

Dynamic Range and Speed [EM Amplifier] OptAquire is free from most cross-hatch structure
Fastest Frame Rate [EM Amplifier] OptAquire is free from most cross-hatch structure.

I.3. Switching Wavelength Modes: Spectral Channel

Changing wavelength modes involves (1) rotating the spectral filter wheel, (2) changing the grating position motor #1 (3) changing the spectral focus motor #2.

I.3.1. Rotating the Spectral Filter Wheel

Order sorting wheel is Serial Number 293.

Spectral Wheel Position	Filter
1	OPEN
2	Na I (Omega)
3	S II (Custom Sci 2)
4	K I (Omega)
5	Dark

I.3.2. Changing the Grating Position (Motor #1)

Stepper Motor #1 controls the echelle grating angle. **Negative numbers shift the spectra to right in the Andor Solis viewer.** Like the other motors, there is no way to find a home position, so everything is referenced to sodium 5893Å.

Line	Order #	Steps on Motor #1
Na I	97th order	Default home
K I		Na 97th + 4000 steps
S II		Na 97th – 1143 steps
O I 6300Å		Na 97th + 1400 steps
Na I	98th order	Na 97th + 6100 steps
Na I	96th order	Na 97th – 5700 steps

Hysteresis correction: if the grating motor reverses direction, a correction for slop/hysteresis is needed somewhere **between 70 and 80 steps** to correct for this. Na: ~93 steps/Å and 1 grating motor step = 0.436 pixels

I.3.3. Changing the Spectral Focus (Motor #2)

When changing Spectral Wheel positions the focus motor #2 must be changed accordingly, per the settings below. The optimal focus to get a minimal linewidth differs from the focus to get spatially sharp definition along the slit. Design-wise a cylindrical lens with ~7m focal length may bring spatial and spectral into mutual alignment. We're exploring this possibility. Be sure to use controller #428174.

Spectral Wheel Position	Filter	Focus motor #2 location SPECTRAL	Focus motor #2 location SPATIAL
2	Na	0 (reference point)	+3000
3	SII	+4000	+8000
4	K	+6000	+10000
(2” filter only)	O	+500 to +1000	+5000

I.3.4. Troubleshooting

If the filter controllers spit garbled error messages about ‘*Magnet weak*’ then *configure* and *recalibrate*.

I.4. Slit width (Motor #0)

Setting the slit width motor #0 to a large negative value, say -500, closes it as far as it can go roughly 15µm. Once the motor is here reset this as zero. Increasing the slitwidth by ~125 steps does not degrade the linewidth or spectral resolution, but benefits from letting more light into the spectral channel.

When changing direction, the slit mechanism has some backlash to be overcome (somewhere around 25 steps). At its minimum 15µm (“closed”) setting the slit is unresolved by the CCD. So increasing the slit does not change the image size.

Steps	Mean Counts (incandescent) Bias of 525 DN	Linewidth (Neon Tube)
0	6432	~2.45 pixels
25	6485	~2.45 pixels
50	6743	~2.45 pixels
75	7405	~2.45 pixels
100	8042	~2.45 pixels
125	8493	~2.7 pixels
150	9090	~2.8 pixels
175	9890	~3.0 pixels
200	10358	~3.1 pixels

I.5. I.3. Switching Wavelength Modes: Imaging Channel

When loading filters into RIPS, make sure the shiny side faces away from the detector

I.5.1. Imaging Channel Filter Wheel

Imaging Channel / Slit Viewer Wheel is Serial Number 295.

Imaging Wheel Position	Filter
1	OPEN
2	SII+ ND1 sandwich
3	ND3
4	ND3 + ND1 sandwich
5	DARK

Imaging Wheel 1" Filter	Imaging Drop-In 2" filter	Imaging Focus Motor setting
	Na D2 4Å + ND1 sandwich	0
Open (1)		+4000
SII+ ND1 sandwich (2)		-1500
ND3 (3)		0
ND3 + ND1 sandwich (4)		2200
	O 6300 18Å	?
	K	?

I.6. Filter Options

When loading filters into RIPS, make sure the shiny side faces away from the detector

I.6.1. Available Filters of 1" size

Line	Center Wavelength	Bandpass	Identifier	Notes
Na I	5893Å	30Å	Omega Optical 216908 3057656	3 total available; 1st one tested (2 Mar 2018) seems to be fairly wide, but shorter on the red side
K I	7700Å	30Å	Omega Optical	Transmission curve plotted in the section below.
S II	6724Å	45Å	Custom Scientific 10525-1	Worse of the two SII 1"
S II	6724Å	45Å	Custom Scientific 10525-2	Better of the two SII 1"

I.6.2. Available Filters of 2" size

Line	Center Wavelength	Bandpass	Identifier	Notes
Na I	5889Å	4Å	/ 0.4 nm	For Io and Mercury, this should be sandwiched with ND1. Narrowest Na. R. Killen has a 1.5Å on order
Na I	5893Å	18Å		
K I	7700Å	14Å	2394 BARR	
O I 6300	6303Å	Probably ~20Å	630.3NB2 139604	

I.7. Calibrations

Since wavelength is not repeatable with grating angle movements or flexure, wavelength calibration should ideally be taken temporally adjacent to any change in either. Sky flats and a solar spectrum can be used in as a wavelength reference: https://diglib.nso.edu/flux

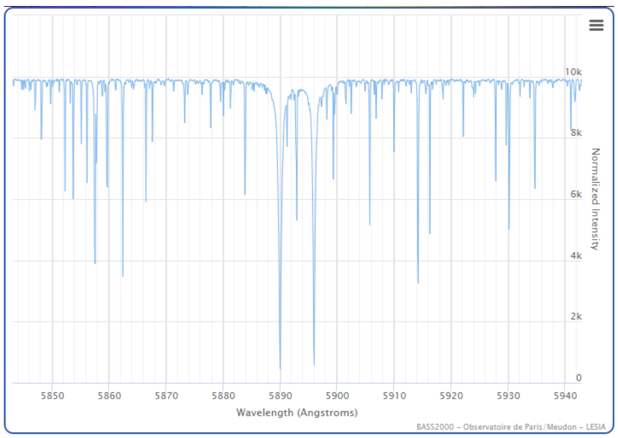
I.7.1. Spectral Lamp Lines in Range

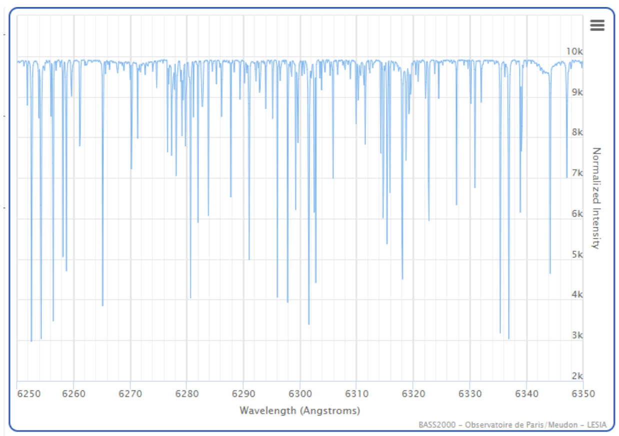
A Thorium-Argon lamp is best for calibration, and a line list is available from ESO here:
http://www.eso.org/sci/facilities/paranal/instruments/uves/tools/tharatlas/thar_uves.dat
If unavailable the following lines may be useful:

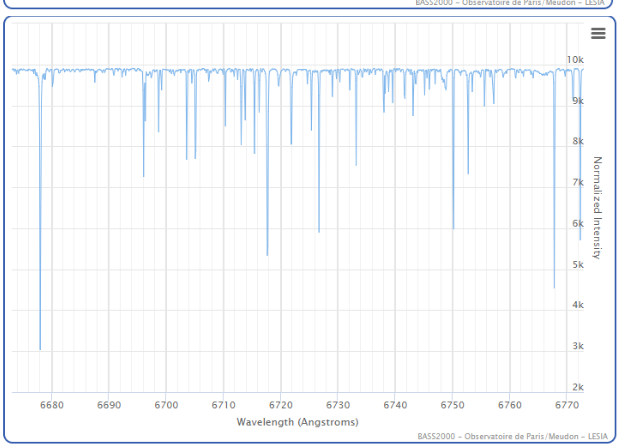
Line	Calibration Arc Lamps	Notes
Na I	Neon: 5881.895Å, 5913.633Å	(Bright)
	Argon: 5882.624Å, 5888.584Å, 5912.085Å	(Faint)
	Krypton: 5870.916Å	(Bright)
	Helium: 5875.621Å	(Bright)
K I	Argon: 7685.246Å 7694.540Å	(Faint)
	Krypton: 7723.761Å, 7724.207Å	(Bright)
S II	Neon: 6717.043Å	(Bright)
O I 6300 Å	Neon: 6293.744Å, 6304.789Å	(Bright)

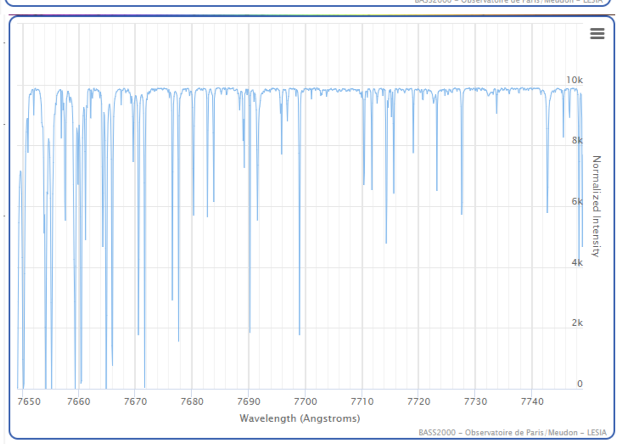
I.7.2. Solar Spectrum References

Via Bass2000 at 0.1Å resolution:









I.8. Filter Curves

Filter transmission curves from the manufacturers:

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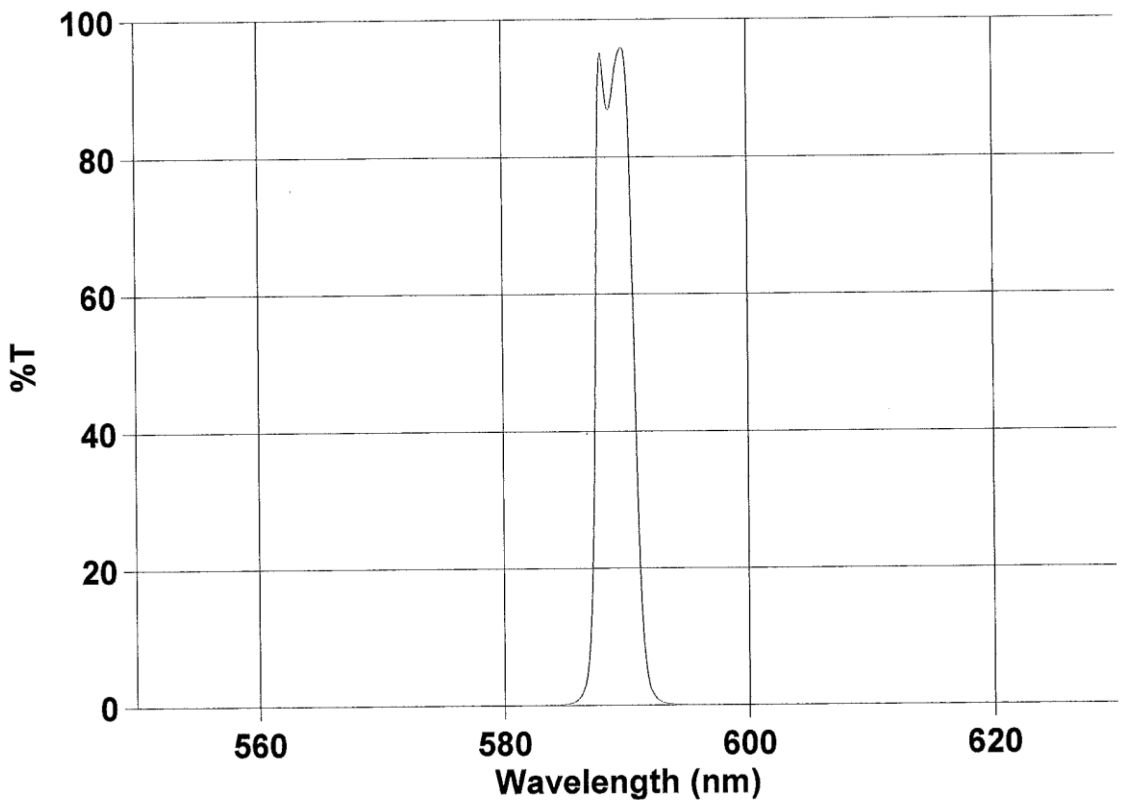
Omega Optical Inc.
Instrument Serial Number EL00123848



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Report Time : Fri 16 Feb 11:48:59 AM 2018
Batch:
Software version: 02.00(25)
Operator:
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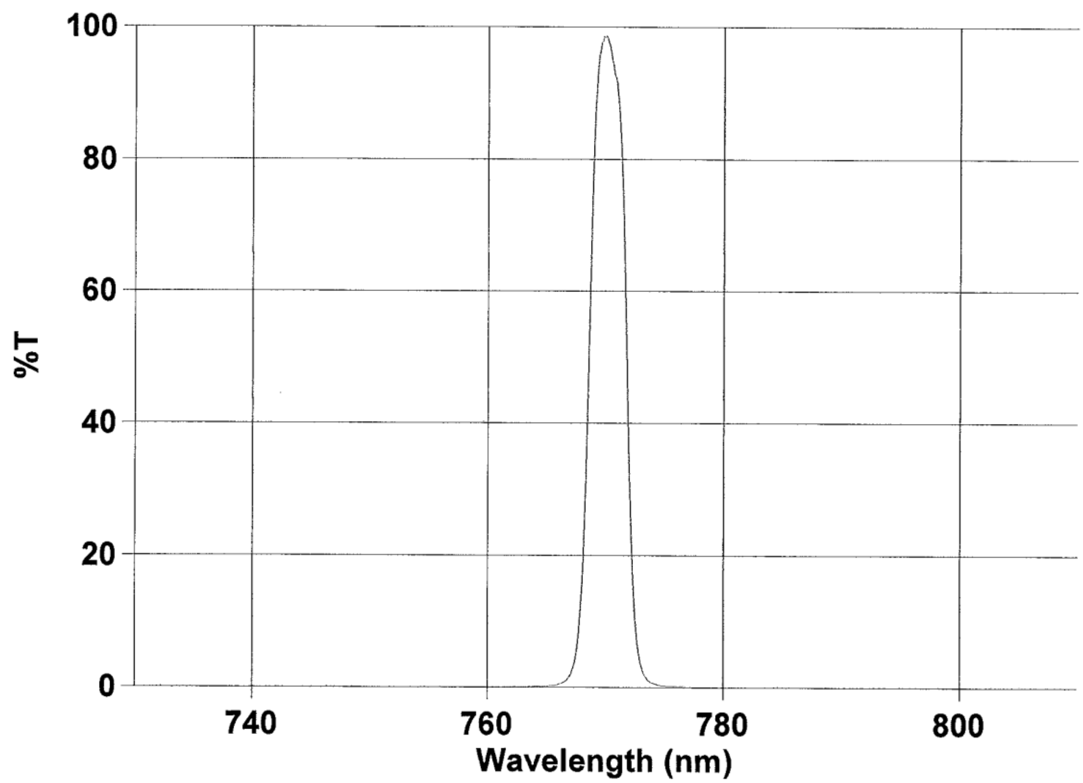
Sample Name: PN 589.3 NB 3.0; BATCH# 216908; JZ

Collection Time 2/16/2018 11:49:03 AM

2/16/2018 11:12:59 AM Page 1 of 1

Omega Optical Inc.
Instrument Serial Number EL00123848



Scan Analysis Report

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Report Time : Fri 16 Feb 11:07:30 AM 2018
Batch:
Software version: 02.00(25)
Operator:
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Sample Name: PN 770 NB 3.0; BATCH# 216912; JZ

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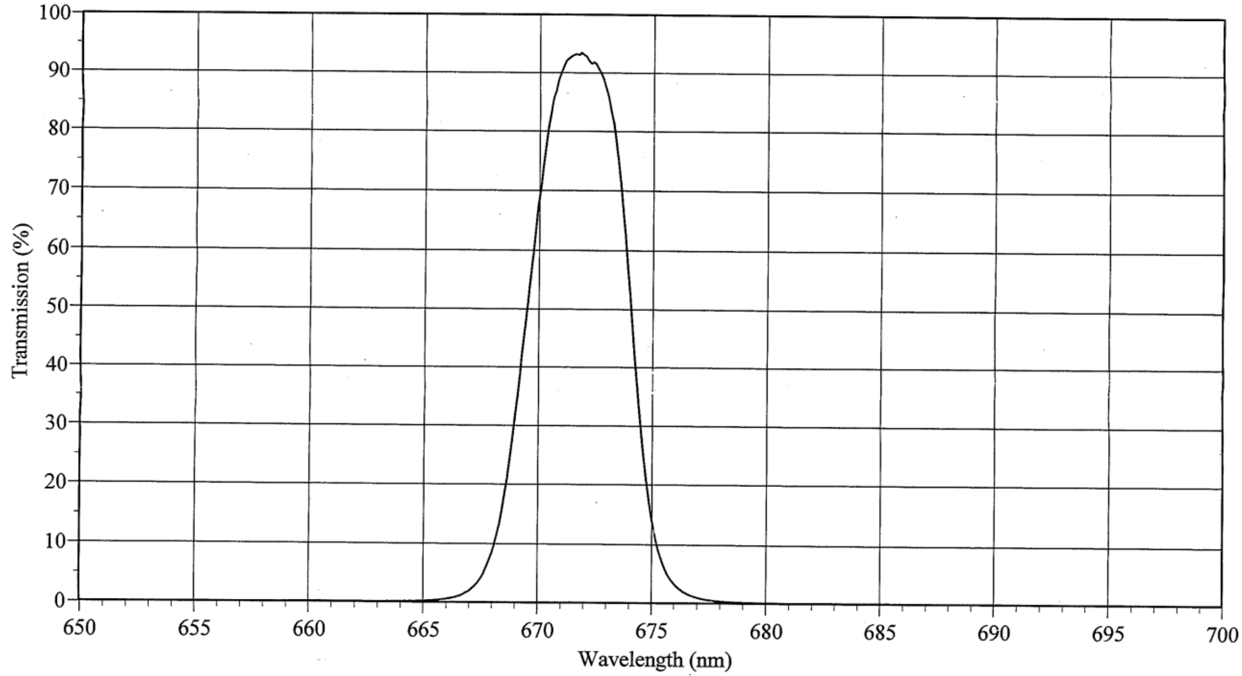
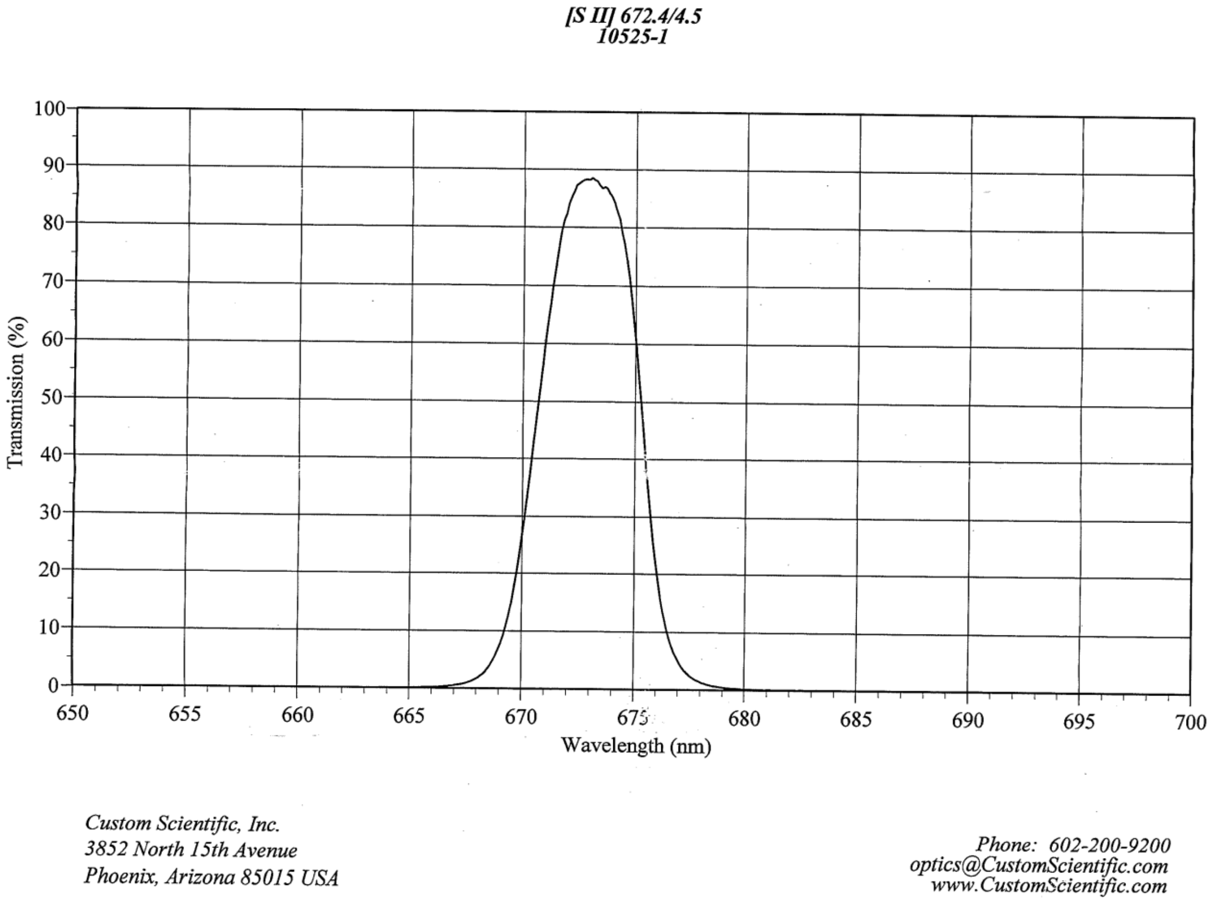
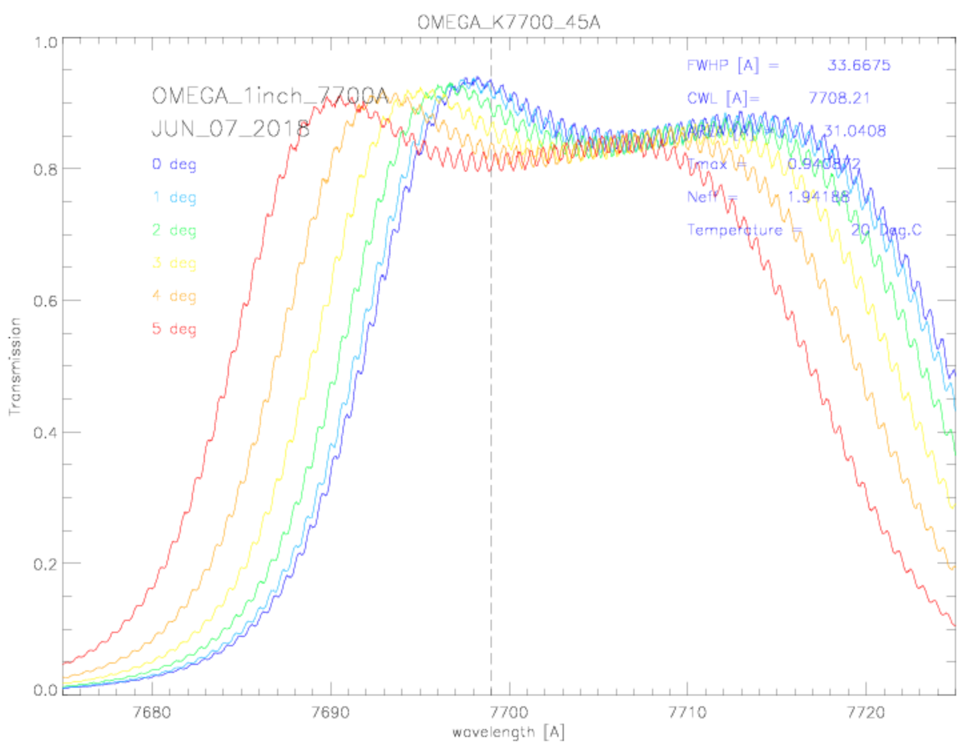
[S II] 672.4/4.5 nm
10525-2



Custom Scientific, Inc.
3852 North 15th Avenue
Phoenix, Arizona 85015 USA

Phone: 602-200-9200
optics@CustomScientific.com
www.CustomScientific.com


[S II] 672.4/4.5
10525-1
Transmission (%)
Wavelength (nm)
Custom Scientific, Inc.
3852 North 15th Avenue
Phoenix, Arizona 85015 USA
Phone: 602-200-9200
optics@CustomScientific.com
www.CustomScientific.com


OMEGA_K7700_45A
OMEGA_1inch_7700A
JUN_07_2018
0 deg
1 deg
2 deg
3 deg
4 deg
5 deg
FWHP [A] = 33.6675
CWL [A]= 7708.21
Transmission
wavelength [A]

I.9. Slit Position Angle (Controller #2, Motor #2)

The Position Angle Stepper Motor is specified with negative steps being east of north, counter clockwise on the sky.

266.7 steps/degree (e.g., 90 degrees rotation takes 24000 steps)

II. Assembly & Disassembly Notes

II.1. Assembly Procedure

OPENING THE WOODEN BOX AND PELICAN CASE WITH TRUSS PARTS

The wooden box contains the 1 plate (and 4 rings) that are held apart by the struts. The struts are located in bottom of the large (44 x 24 x 16) Pelican case. This case has stuff in both the bottom half AND the top half. Once the clips are released, to separate the top from the bottom, work your hands between the foam at the seam, and try to turn the top over holding the foam in place.

There are 16 struts: 8 short ones, 6 longer ones, and two slightly longer ones. The cage is assembled in two units: The front unit uses the 28” x 28” x 0.75” thick aluminum plate and the ~36” diameter x 0.5”(with one side cut flat) ring (this ring is bolted to another ring in the box for shipping purposes). The plate and the ring are labeled “A” and “B”. The front plate has a large bearing captured on one surface…this should face up during assembly. The edge of this plate has 8 - 5/16-18 tapped holes where one end of a strut goes. Each hole (and strut end) has a unique identifier e.g. “A1” or “A8” etc. The side of the front plate that has the cut-outs are where the longest struts go (A7 and A8 ??) (this is the side where the flat side of the first ring “B” is lined-up with). When attaching the strut ends to the front plate, use a lock washer between the strut and the plates for struts 1 – 6; **struts 7 and 8 do not use a washer**, as it would push the struts beyond the 14” radius allowed on this face. There are special 5/16 round head cap screws for all of the strut ends.

Once all of the struts are attached to the front plate, attach the other ends to ring B. At this point it will be easier if someone holds ring B(I believe that the ring has an arrow on its edge that should point away from the front plate) above the front plate while the washer and bolts are inserted (do not tighten these bolts until all of them are inserted) I have found that installing B1, B2 and then B5,B6 will hold the ring in place, then install the other bolts. Once all of the struts are installed, tighten all of the bolts. Some of the struts will still be able to rotate around its axis on the ball ends… .this is normal, the resulting truss structure is very rigid.

Assembling the second truss structure

There ae 8 short struts and two rings left (The smaller ring is composed of two 0.5” thick rings bolted together with a captured bearing on one side). Place the large ring down with the 4 black anodized blocks on the top surface. These are where one end of the short trusses attach. Again, the trusses and corresponding holes are uniquely identified (the identifiers on the truss pieces are viewed from the outside of the completed structure). Attach all of the struts to the big plate, using the washers under all tie rod ends, then, as before, hold the smaller plate over the large plate and attach the trusses (as before , attach opposite pairs first, then the others). The orientation of the smaller plate should be such that the captured bearing faces down (eventually toward the captured bearing in the front plate, and the clock angle (45 deg)is such that the flat

areas on the smaller plate are positioned between the flat areas on the large plate. I can't remember if I marked this clock angle… there are 4 possible orientations…I may have marked one as special (in any case the unique identifiers will not make any sense if it is not oriented properly).
Now we have two truss structures that eventually are bolted together, but now we have to assemble RIPS that fits between the two structures.

RIPS assembly
RIPS is in the second Pelican case. After removing the Andor CCD camera, and other stuff packed on top of RIPS, it can be lifted out and placed on a table top. In the box there is a 6" diameter flange that is to be attached to the front of the instrument with 5 - ~2.5 " long 10-32 SHCS. This flange has a cut-out in it to accommodate a 2" filter holder, if the holder is in place, remove it (It is held there by magnets). The cut-out should point up towards the top surface of RIPS, There are extra holes in this flange…be sure to pick the ones that have a matching pattern on the front face of RIPS (the other ones will not go anywhere). You should probably remove the tape that is covering the input aperture, so that it does nor stick under the flange. In the box where the struts were you will find, among other things, a large gear, another flange, tools etc. The gear will be used later. The flange should be attached to the front of RIPS using 4 short hex head 10-32 bolts with dogs (there should be an open end wrench that fits these bolts somewhere) It is this flange that will fit into the big bearing on the front plate.

Now for the other end of RIPS. When RIPS was designed, it was not anticipated that it would be mounted so that it could be rotated around its optical axis. Therefore a special end cap was made to attach to the end of the instrument that holds a ~1.5" diameter axis. This end cap needs to be attached to RIPS. The cap has a wedge angle so that when attached in the correct orientation, the axis will be perpendicular to the front surface of RIPS (there are two orientations possible). There are four 4-40 holes on the back surface of the end cap. After the cap , is in place (it fits pretty tight!) these screws are used to hold it in place while 4 - 8-32 screws through the top and bottom are installed to really hold it in place. This axis has some brass nuts and spaced rings on it. The nut and ring closest to the end cap should remain on the axis, but remove the other two brass nuts and spacer ring to be used after RIPS is Inserted into the truss (and mounted on the telescope). Take great care that the threads on this axis be not damaged… the extra bras nuts will be used to capture a large gear onto the axis after RIPS is on the telescope.

Attaching the Andor CCD camera.
The Andor camera attaches to RIPS with four 10-32 SHCS and dogs to hold it down. The camera is oriented such that the power button and other connections on the camera are facing up towards the top of RIPS. There is a faint scratch mark on RIPS and the flange on the camera flange marking the exact clock angle. Be sure to remove the body cap from the front of the camera (leave the "c" mount extension tube in place) before putting it on RIPS!

At this point, we are ready to assemble the cage around RIPS. Depending on how many people are available, there are two ways to do this. The original plan was to have a ~22" diameter hole cut into the top shelf of the service cart I had delivered from Amazon. This should allow the truss structure with the short struts to be lowered into the hole and the big disk would rest on the lip of the top shelf. Rips is then lowered into this structure . The brass nut and spacer, (which will want to fall off the axis!)will come to rest on the inner race of the bearing (which is now facing up). Rips is almost balanced about is optical axis(more on this later) but someone should hold it steady while the larger (and heavier!) truss structure is lowered onto RIPS engaging the top bearing . The length of RIPS was adjusted so that there is ~0.050" squeeze on the bearings when the two truss structures are bolted together by 8 ¼- 20 bolts. There is no retaining ring securing the flange into the large bearing.. just the squeeze of the truss.

Another way to assemble it, is to lower RIPS onto the front plate through the big 36" ring (RIPS will not fit through this ring in all orientations due to the flat portion, so one has to be careful to orient RIPS so that the CCD camera is not facing this flat area.) If the front plate is level, RIPS will sit there without support in the front bearing. Then, the smaller (and lighter!) truss can be placed on top, again, the brass nut and spacer will hold the two structures apart by ~0.050", and then they can be bolted together, loading the bearings.

Now, RIPS is upside down relative to the mounting position needed. Two people will be needed to turn it 180 deg to mount it on the telescope. The bottom (smaller round disks) should be set on 4" x 4" spacers (or the whole thing can be put into the modified service cart ….this will require three people to be safe). It is in this service cart where I envision RIPS to live when not on the telescope.

I have included two 1" diameter plugs that can be inserted through the front plate(from the rips side of the plate) to help align the holes with those in the telescope. After RIPS is on the telescope, ,there are a few more things that should be put on it to get the best balance. RIPS is not perfectly balanced about it optical axis. It needs ~5 lbs to be added to the end of the Andor CCD camera..there is a steel frame in the strut box to do this. I put two large rubber gaskets between the camera and the frame. Also, the NUC computer can be attached to RIPS using the Velcro pads . Also, that large gear will be attached to the stub of the axis on the bottom of rips and there is a motor assembly in the box as well that will be ultimately to the end of RIPS. Also, there are three brick power supplies that will be on RIPS, you could just use zip ties to hold them in place on the truss while balancing.

This is the first-cut for this procedure. I may be able to do a IKEA style itemized step by step later.

II.2. Disassembly Procedure

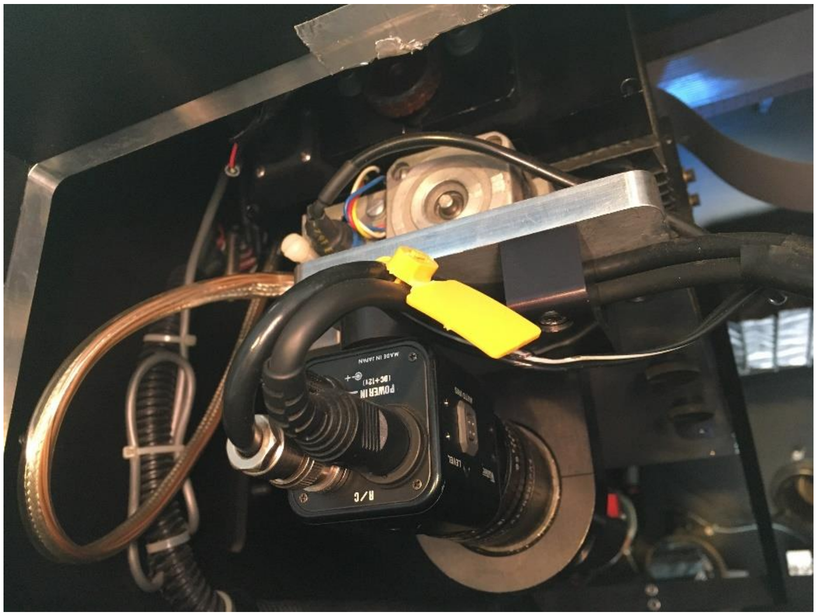
TBD

III. Data Examples

IV. Notes on different telescopes

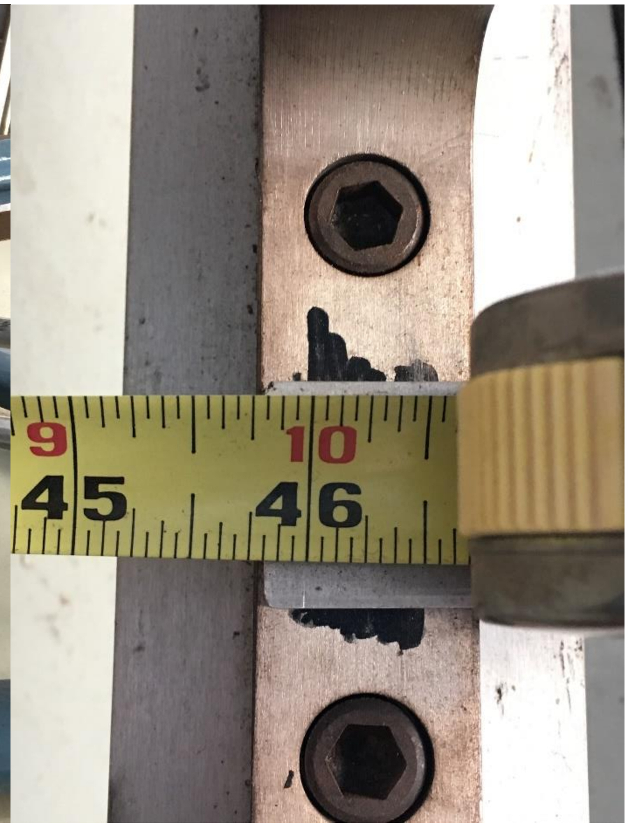
IV.1. Perkins Specific Installation Notes

Guide Camera: Compared with PRISM & MIMIR (not DeVeny), the Guide Camera needs to be moved back one position. That is, move it farther in back-focus by one set of bolt holes in the aluminum plate above the camera in the picture below:



Telescope balance: First, all six c-shaped were removed:

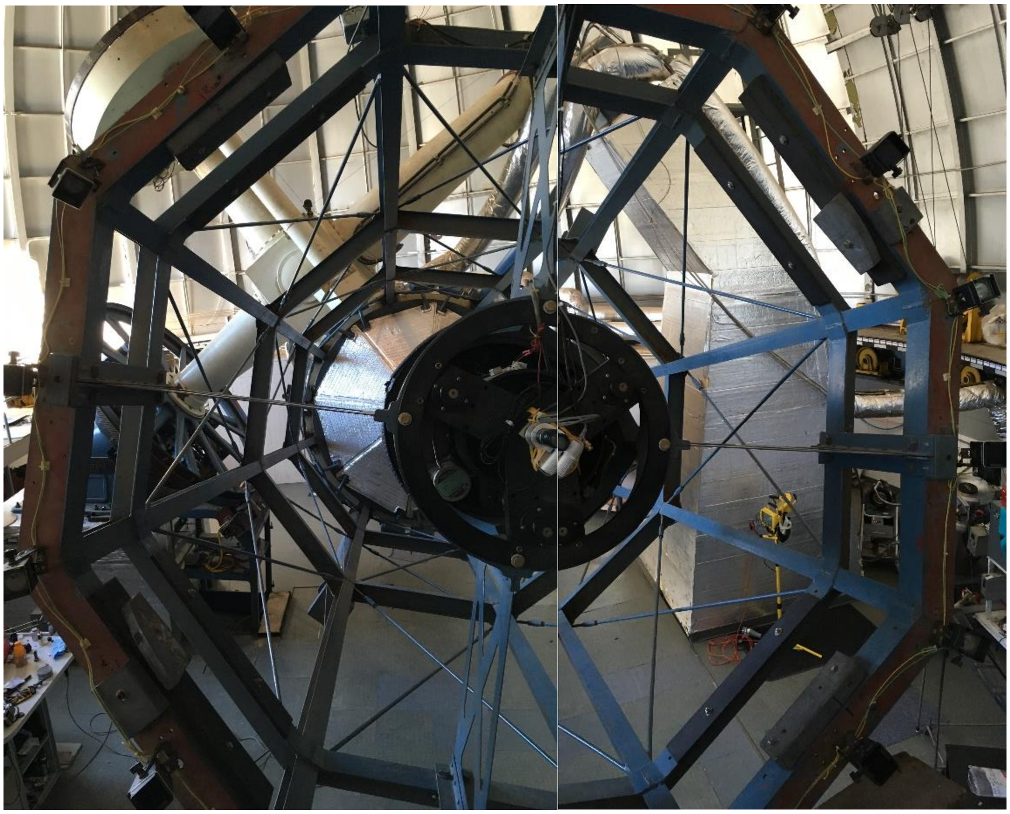
Two arc shaped weights were tied to one end of the ballast. The tape value is then 45-3/4”:



Two white balance weights C and D are set at zero, all the way to the end of their reach. A and B balance weights are set at 18.

Four numbered lead bricks were removed from the ring that contains the flat field lamps at the far end of the Perkins 72”. These ones.

To clarify, at least if it’s setup for PRISM, the ring looks like the photo below and where weights labeled 1, 2, 3 & 4 should be removed from the face.



And lastly, the balance controls when installed read:

Focus: The nominal 72” focus location seems to be about 1050A.