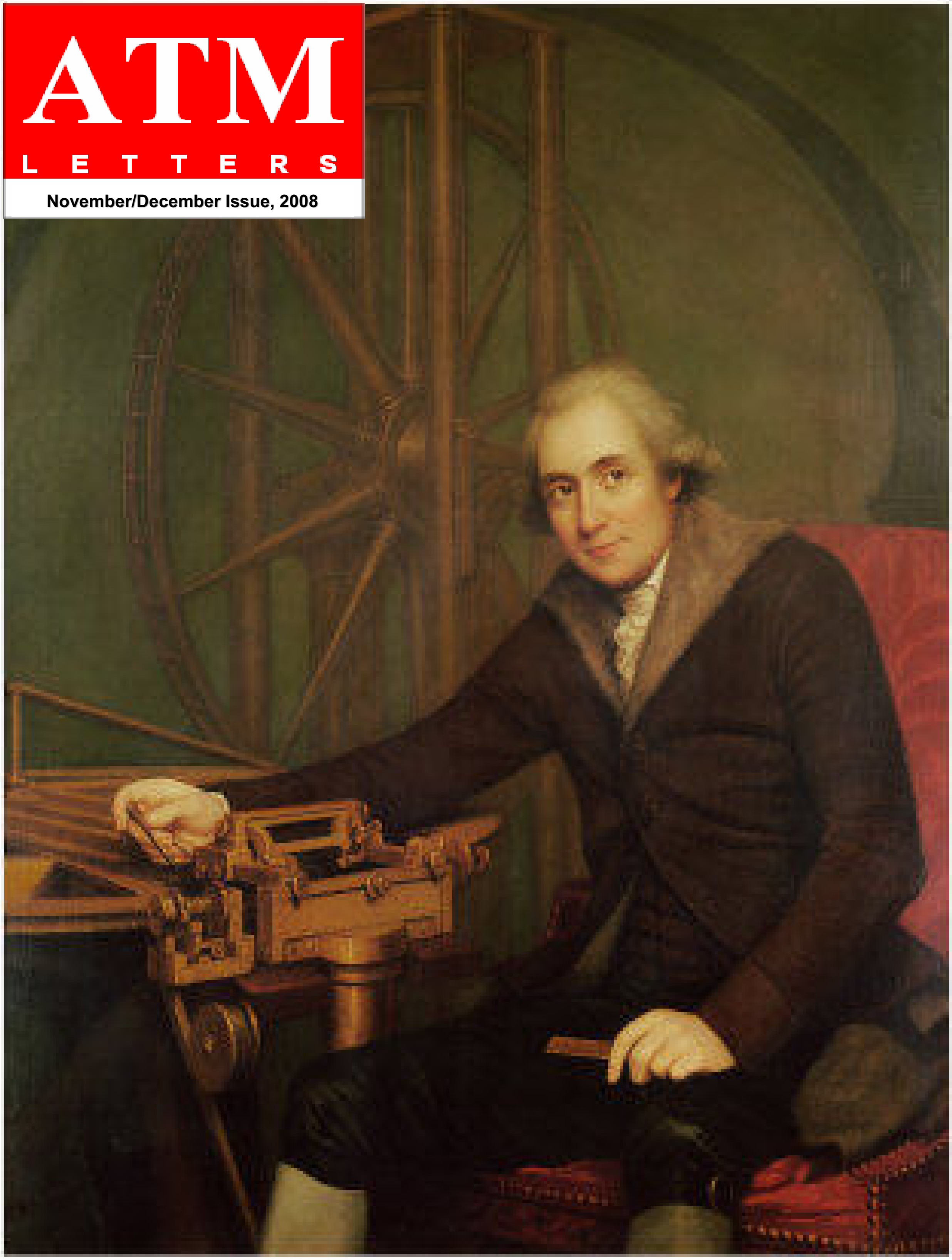
ATM LETTERS
November/December Issue, 2008



Praxis: Slit Image Test

Bibliography: Pioneers in Optics – Jesse Ramsden

Software: OpenRayTrace and Terragen

Slit Image Test by Bill Thomas

Overview

The **S**lit **I**mage (CCD or film) **T**est (**SIT**) combines the best of the **Caustic** & Lateral Wire Test (**LWT**) and avoids their difficulties:

- The Caustic requires determining the Center of Curvature (**COC**) within 0.001". A difficult task **[1 - page 223]**.
- With the *LWT* **[6]** each zone needs to be measured mechanically to better than 0.0005". A difficult task unless the room temperature is closely controlled i.e., distance from the mirror to tester changes with temperature while the readings are being taken.

SIT employees a Caustic type mask, each mask hole returning an images of the testers slit, which by the way is visible in an eyepiece. But unlike the Caustic, all the mask holes are open allowing the capture of all the *LWT* measurements with one exposure.

Film Verses CCD

For a digital SLR (lens removed), you need to know:

- CCD cell size.
- Lens mounting to CCD spacing.

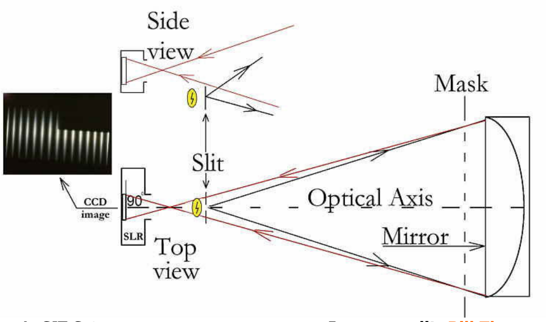
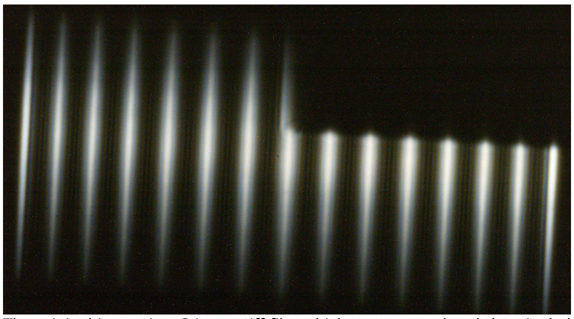


Fig. 1. SIT Setup. **Image credit:** Bill Thomas



The original image is a 24 meg tiff file, which was cropped and then jpg'ed down to 660 k. Do to the jpg compression and cropping your results will not exactly match that of the web. For example: After Photoshop Rotate Arbitrary CCW 2.97 of the jpg image, I get 165 pixels for the left outer slit, and 3202 for the right outer slit.

The difference is 3037 pixels. The web site difference (3225-188) is 3037 pixels. The web zone pixel differences are:

13.8%	467
27.6%	931
41.5%	1389
55.3%	1835
69.1%	2258
82.9%	2662
96.7%	3037

Image credit: Bill Thomas

Fortunately, this information was available on the WEB for the *Olympus E-300*, which I use **[2, 3]**. For film, all you need know is the DPI of the scanner. The slit image whether film or CCD is processed exactly the same.

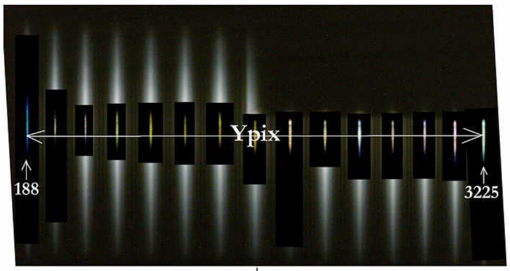
Note: The Slit or CCD or both can be in front or aft of ROC (**Fig. 1**). LWT experts recommend both in front, avoiding the confusion of which ray belongs to which hole (behind ROC the rays cross the optical axis). My setup has both aft of ROC because of the way the camera is attached to the tester. That forces both to be behind where the outer hole ray becomes the outer slit in the image. The examples are that of a 22" f/4.75 - first light May 2008.

Photoshop:

To facilitate measuring:

The image is rotated using the *Measuring Tool* and *Rotate Arbitrary*. Using *Selection* and *Levels* the width of the slits are reduced to the brightest pixels – **Fig. 4**.

The pixel coordinate (**Y**$_{\mathbf{pix}}$) of the slits are measured using the *Measuring Tool* – **Fig. 2** and **5**.



zones %	Ypix	
13.8%	1471	1938
27.6%	1239	2170
41.4%	1010	2399
55.3%	786	2621
69.1%	575	2833
82.9%	373	3035
96.7%	188	3225

Fig. 2. Image Processing. **Image credit:** Bill Thomas

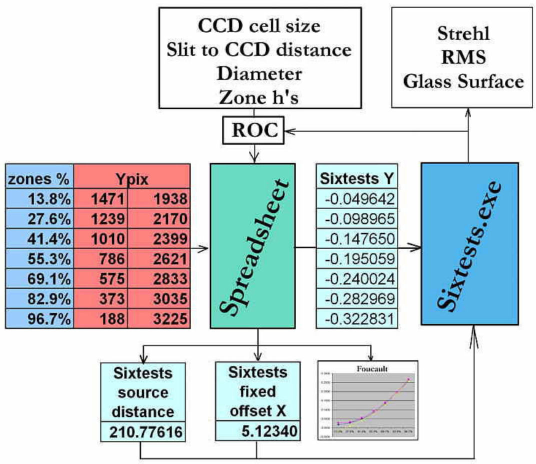


Fig. 3. Crunching The Numbers. **Image credit:** Bill Thomas

Slit Image Test by Bill Thomas

Bill Thomas and his 22" f/4.75 Dob. Image credit: Bill Thomas

Sixtests is available at:

http://home.earthlink.net/~burrjaw/atm/odyframe.htm

Spreadsheet is available at:

http://yubagold.com/tests/computations.php

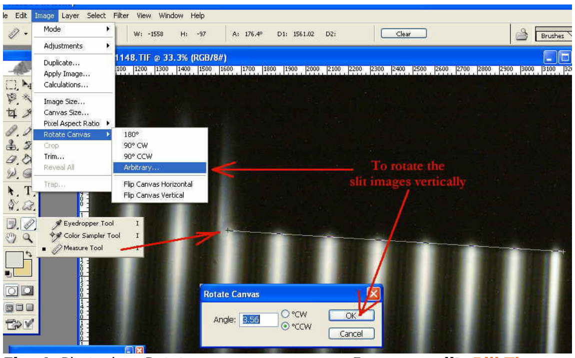


Fig. 4. Photoshop Rotate. **Image credit:** Bill Thomas

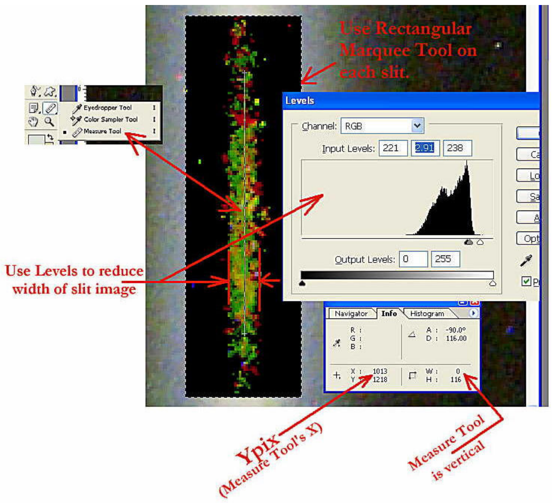


Fig. 5. Photoshop Levels and Measuring. **Image credit:** Bill Thomas

Sanity Checks:

E300 Specs:

The *E-300* was replaced with a fixture positioning film at the CCD image plane – **Fig. 6**. The processed images confirmed the *E-300's lens mount to CCD spacing*, and *cell size.*

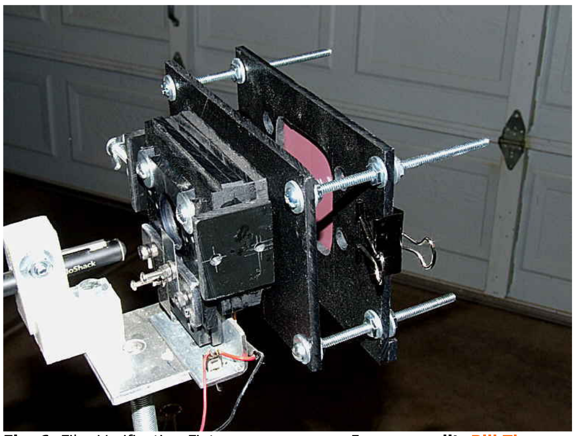


Fig. 6. Film Verification Fixture. **Image credit:** Bill Thomas

Star Tests

Two mirrors (22" f/4.7 and a 12.5" f/4.5) were figured using *SIT*, which were then star test validated.

Tester Alignment:

As is the case with the Caustic and *LWT*, the testers longitudinal axis needs to be aligned to the mirrors optical axis, and the film plane needs to be perpendicular to that axis. All of which is quite doable, and is described at:

http://yubagold.com/tests/alignment.php.

Mask Holes

The mask holes need to be accurately located. The mask material I use is *040 ABS* (0.040" thick) 5 inches wide. The 3/4" holes were cut with a plunge router, with a threaded rod controlling the positioning – **Fig. 7**. Molding glued to the bottom stiffens the mask. Cardboard is then used to covers the rest of the mirror.

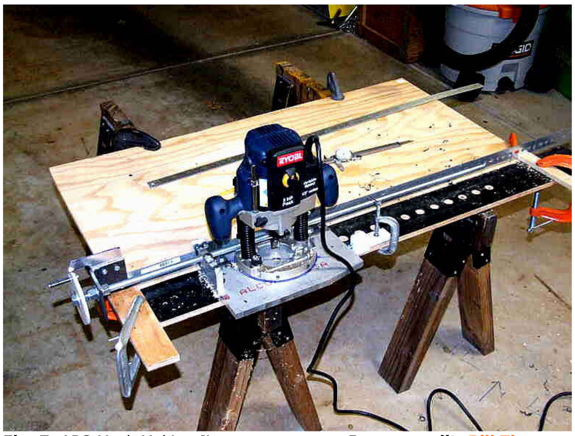


Fig. 7. ABS Mask Making Jig. **Image credit:** Bill Thomas

Note: Accuracy of the hole positions is vary important. To that end, the mask is flatbed scanned (direction of scan is most accurate). Then hole positions are adjusted to compensate for parallax i.e., rays are not at right angles to the mask. This is done in *'router mask'* of **SIT.xls**.

In the past, had local machine shop make the mask for about $90 - still scanned them.

A scanning laser which would start pulsing on detection of the edge, would eliminate the need for a mask.

Computations

In the Spreadsheet (**SIT.xls**; the examples are that of a 22" f/4.75 mirror):

Input:

CCD:

- G2 = The E-300 CCD cell size in microns (=0.00003937 inches) **[2]**
- F2 = The E-300 Lens mount to CCD spacing **[3]**

- E2 = Slit to lens mount distance – **Fig. 13** and **14**
- J2 = The E-300 CCD glass thickness **[2]**
- K2 = The E-300 CCD glass index of refraction **[2]**

FILM:

- D2 = Slit to image plane (usually zero).

H2 = Scanned DPI.

A2 = Mirror optical diameter.

B2 = ROC initially to +/- 1/8". Then refined from Sixtests results.

B4:B12 = Zone h's (linked to 'router mask'!D12:D18)

Accuracy of hole positions is refined by flatbed scanning the mask (direction of scan is most accurate), and then processed in 'router mask' B23:C30 & B33:C40. The hole positions are then adjusted, using Solver to compensate for parallax i.e., rays are not at right angles to the mask.

Solve for the h's - Cells D12:D18 of *'router mask'* **Fig. 12**.

Tools->Solver can only solve for one at a time:

- First: F12 value of 0, By Changing D12
- ....
- Last: F18 value of 0, By Changing D18

Y$_{pix}$'s As measured in Photoshop.

- D5:D11 left side.
- E5:E11 right side
- D4 = Center.

Used to check if the mask was properly centered. If any of the pixel differences, F5:F11 are greater than +/- 9, the mask needs to be re-centered and the test done again.

Solve for l (C14) – **Fig. 11 and 12**

Tools->Solver (computations are relative to the edge zone)

- Target Cell = D14, value of 0
- By Changing Cell C14

Solve for the Foucault's - Cells F18:F23.

Tools->Solver can only solve for one at a time:

- First: E18 value of 0, By Changing F18
- ....
- Last: E23 value of 0, By Changing F23

Note: Because the calculations are relative to the edge, the outer zones s' (F24) is $h^2/(2R)$ (using the outer zones h).

Spreadsheet

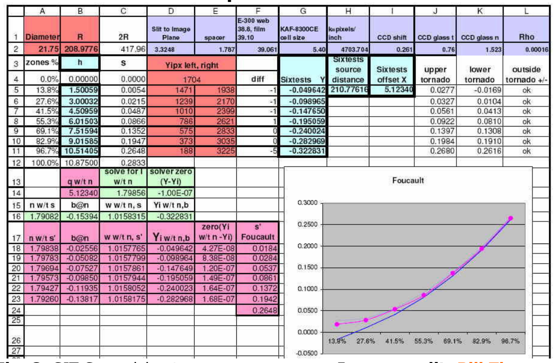


Fig. 8. SIT Spreadsheet. **Image credit:** Bill Thomas

Using Notepad type (paste) the following info from the spreadsheet to create file Sixtests_input.txt – **Fig. 9**.

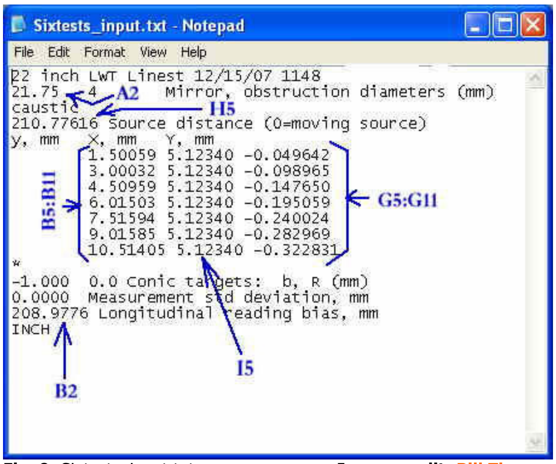


Fig. 9. Sixtests_input.txt. **Image credit:** Bill Thomas

Note: A program to replace the spreadsheet, and generate Sixtests_input.txt file is underdevelopment.

In Sixtests.exe

File->Open setup

- Navigate to file Sixtest_input.txt
- Click Open
- Click Surface getting – **Fig. 10**

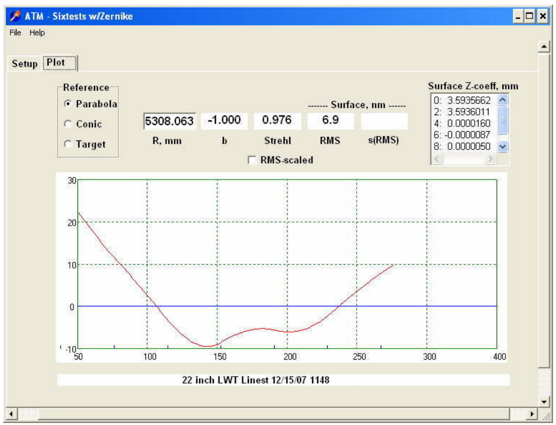


Fig. 10. Sixtests output. **Image credit:** Bill Thomas

Note: The Glass Surface Plot is invaluable when figuring. With the exception of interferometry, the rest of the tests measure the derivatives of the glass surface. Conjuring the surface from the derivatives e.g., Foucault is not intuitively obvious and is best left to programs like Sixtests.

Equations:

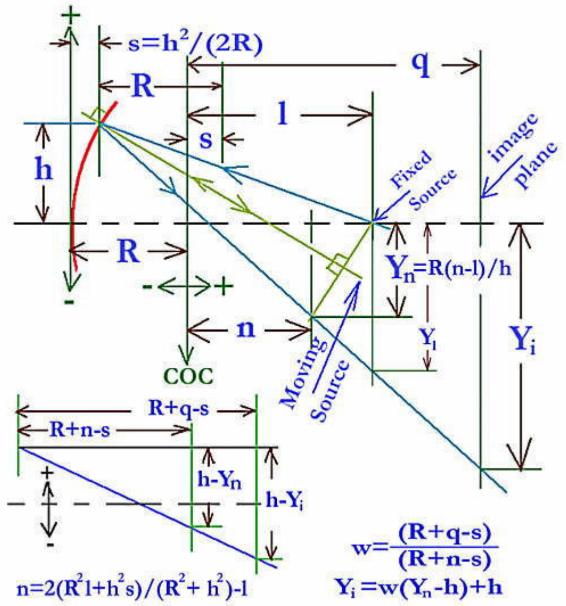


Fig. 11. Fixed Source-LWT. **Image credit:** Bill Thomas

- $\mathbf{Y_{diff}}$ is the pixel distance between slit pairs i.e., $\mathbf{Y_{pix}}$ right D5:D11 - $\mathbf{Y_{pix}}$ left E5:E11 – **Fig. 8**.
- $\mathbf{Y_i}$ = ($\mathbf{Y_{diff}}$/pixels per inch)/2 i.e., a negative value.

Foucault:

Given the $\mathbf{Y_i}$'s (G5:G10), the spreadsheet Solver tool is used to work the equation $\mathbf{Y_i}$=w($\mathbf{Y_n}$-h)+h, backwards to obtaining the s' (F18:F23) – **Fig. 8** and **11**.

Note: Because the calculations are relative to the edge, the outer zones s' (F24) is $h^2/(2R)$.

- $\mathbf{Y_l}$ = $\mathbf{Y_i}$ when q = l (**Fig. 11**).
- $\mathbf{Y_l}$ is approximately 2h(s-l)/R

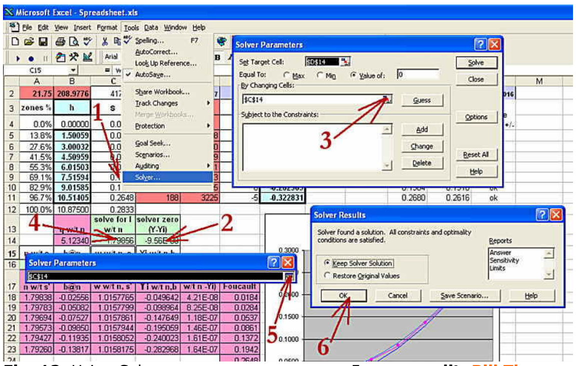


Fig. 12. Using Solver. **Image credit:** Bill Thomas

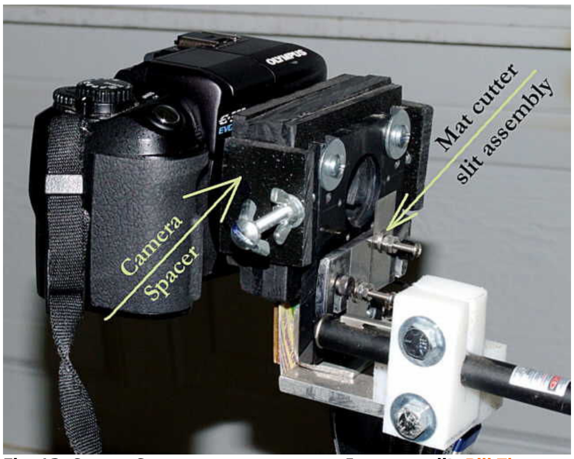


Fig. 13. Camera Spacer. **Image credit:** Bill Thomas

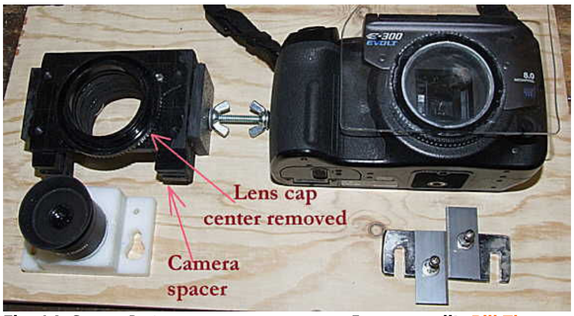


Fig. 14. Spacer Parts. **Image credit:** Bill Thomas

Alignment/Imaging

The testers longitudinal axis needs to be aligned to the mirrors optical axis, and the film plane needs to be perpendicular to that axis. The time consuming initial alignment's need be done only once. From then on, a laser pointer is used to quickly align the tester.

Initial Alignment

Longitudinal Axis to the Mirrors Optical Axis:

- Center dot the mirror.
- Mount the *mask* with the center hole over the center dot, also making sure the holes are level.
- Observe the center slit with a 10 mm eyepiece. Rotate the tester (camera tripod works well) horizontally and vertically so as to keep the center slit image fixed with respect to the upper mat cutter blade while moving the tester on the longitudinal axis – **Fig. 15**.
- In order to avoid doing this again, aim an attached laser pointer at the center of the mirror. Lock the laser pointer down. Mark where the returning beam strikes an attached card – **Fig. 16**.

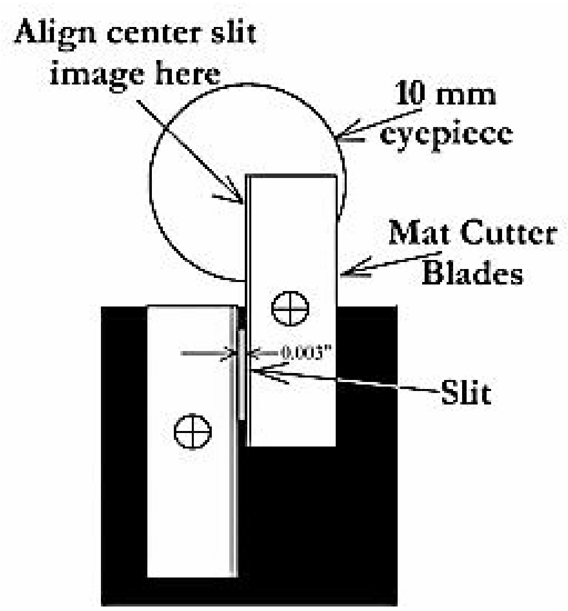


Fig. 15. Mat Cutter Slit Assembly. **Image credit:** Bill Thomas

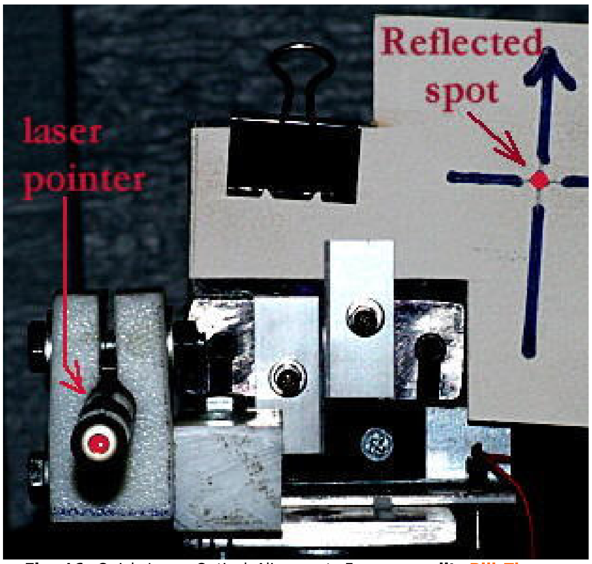


Fig. 16. Quick Laser Optical Alignment. **Image credit:** Bill Thomas

Source Plane Perpendicular to the Optical Axis:

- Remove the mask, making sure not to move the mirror or the longitudinal axis of the tester.
- Attach a plastic mirror to the *Source Plane* – **Fig. 18**. Direct a laser pointer through the hole of the plastic mirror to the center of the test mirror.

  Rotate the *Source Plane* until the third bounce strikes the test mirror's vertical centerline – **Fig. 17**. Lock the *Source Plane*.

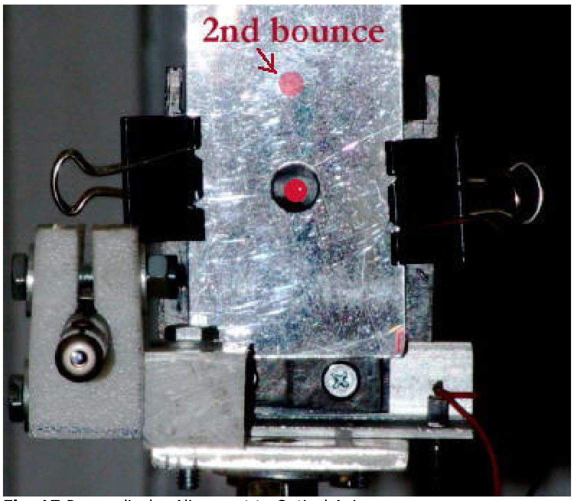


Fig. 17. Perpendicular Alignment to Optical Axis.
Image credit: Bill. Thomas

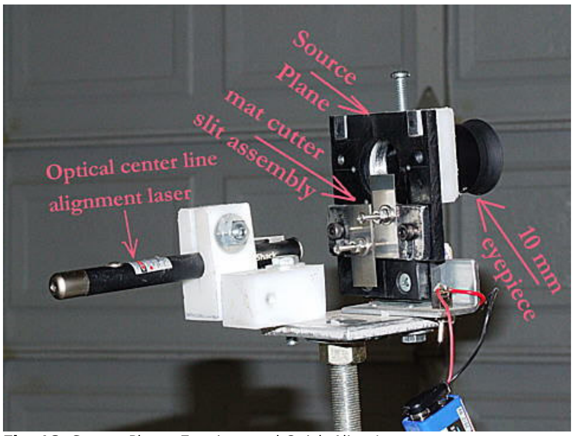


Fig. 18. Source Plane, Eyepiece and Quick Align Laser.
Image credit: Bill Thomas

Imaging:

- Center dot the mirror.
- Align the testers longitudinal axis to the mirrors optical axis:
  1. Rotate the tester so that the attached laser hits the center of the mirror – **Fig. 18**.
  2. Rotate the test mirror until the returning beam hits the attached card where previously marked – **Fig. 16**.
- Locate *COC* with the *Foucault*. It need not be precise - useful for the next step.
- Move the tester aft of *COC* by an amount where the image nearly fills the *CCD*. After a bit, you will know exactly how far aft of *COC* you need to be. Make sure the outer slit image is the edge zone image i.e., aft of *COC* the rays cross the optical axis.
- Remove the *KE*.

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- Mount the *Mat Cutter Slit Assembly* – **Fig. 13**.

- Mount the *mask* with the center hole over the center dot, also making sure the holes are level. Also, make sure not to move the mirror.

- Attach the *10 mm eyepiece* to the back of the Source Plane – **Fig. 18**.

- Move the tester laterally to align the center-slit image to the edge of the upper mat cutter blade – **Fig. 18**.

- **For CCD, E-300 setup**:
  1. Manual mode.
  2. TIFF 3264x2448.
  3. ASA 1600.
  4. Exposure delay 12 seconds.
  5. Exposure 1/20 of a second.
  6. *Remove the lens*.
  7. Attach the E-300 to the Camera Spacer – **Fig. 13**.
  8. Click - *capturing the image*.

- For Film:
  1. In the dark mount the film to the *image plane*.
  2. Expose the film. An enlarger timer works well.

□

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The author's home page is: http://www.yubagold.com

References

[1] Karine and Jean-MarcLecleire, A Manual for Amateur Telescope Making. http://www.willbell.com/tm/atmmanual/index.htm
[2] Kodak Spec KAF-8300CE
[3] E-300 Lens mount to CCD spacing http://www.markerink.org/WJM/HTML/mounts.htm
[4] Mirror Math Jim Burrows http://home.earthlink.net/~burrjaw/atm/atm_math.lwp/atm_math.htm
[5] Foucault Test by Leon Foucault 1858 http://bobmay.astronomy.net/foucault/leontop.htm
[6] Lateral Wire Test (LWT) http://hometown.aol.com/julesfran/index.html