ATM Journal 8: Figuring Your Mirror
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Last time, we looked at how to test your mirror and determine what figure you had achieved through the polishing process. Obviously, you need to know how to test your mirror before you can start zeroing in our our goal – a perfect paraboloidal mirror. This process is named Figuring, and is the most challenging task you face in mirror making. Or is it? Let's have a quick look at what we're trying to achieve, how it's measured, and whether we need to bother attempting to parabolize at all.

It's common to gage optical quality through the use of peak-to-valley wavefront error. A wavefront is a line traced from the crest or trough of a light wave perpendicular to the direction of motion. When the wavefront encounters a theoretically perfect paraboloidal surface it is reflected in a converging wavefront to a minimum spot size or “diffraction disk.” An optical surface that diverges from a perfect paraboloid (i.e. one which has some measure of spherical abberation) will introduce errors which will cause the diffraction disk to get larger and less intense, which reduces the resolving capability of the system. But just how much error can we tolerate?

J. W. Strutt (Lord Rayleigh) stated that if total wavefront error exceeds ¼ wavelength of yellow/green light (550nm) then optics begin to noticeably degrade. I note that this ¼ wavelength number has been variously expressed as 1/8 wavelength surface, +-1/6 wave surface, 1/27-wave RMS on the surface, etc. These various measures, as well as the term “Diffraction Limited”, all mean that an optical system meets or exceeds Rayleigh's ¼ wave criterion. So, we now have a minimum level of optical quality we need to meet or exceed. [1]

Figuring is generally iterations of figure, cool down, and testing. The same pitch lap tool is used, mirror on top or bottom as you prefer. Because the act of making figuring strokes imparts a measure of heat to the mirror, it is imperative that the mirror be allowed to cool down for at least an hour before attempting testing. Is is also important to creep up on the correct figure through multiple sessions to avoid overshooting a paraboloid. Although it is simple to return the mirror to a sphere using the same stroke as polishing, it's painful to obliterate an attempted figure – be patient, test often, and keep meticulous notes on what you're seeing at the testing stand.

On the assumption that your mirror ends up being a spherical surface following polishing, you can use several methods of creating a paraboloidal figure on the surface. First, if you have a fairly short focus mirror, you can commence the process of deepening the centre of the mirror into a paraboloid by using the same Chordal stroke we used when we were hogging out our mirror, except using CeO and a pitch lap rather than rough grit and a tile tool. It should be noted that this technique tends to produce a rougher surface so you should use it sparingly and follow it with more gentle strokes.

One of the gentler approaches to creating a smoothly transitioned mirror from edge to centre is Long Strokes. With a well pressed lap, ensure that you have good contact on the mirror. Apply CeO more liberally than usual, and start using “W” strokes such as those used in polishing, but extend the strokes to as much as ¾ of the mirror diameter. This will cause the centre of the mirror to deepen with a gradual slope. Continue these strokes slowly and carefully for 30 seconds at a time, then cold press the lap for two minutes to ensure continued good contact on the mirror. After a total of three minutes of polishing time, cool the mirror and test to see the progress. You can adjust the steepness of the curve in the mirror by shortening and lengthening your strokes – shorter will tend towards a sphere, longer a paraboloid. Continue iterating through figure, cool, test until you reach the desired figure.

1 For more information on how mirrors are graded see Suiter's “Star Testing Astronomical Telescopes” Willmann-Bell, Inc. 2001

Should you discover your newly polished mirror is a different shape than desired ie a hyperboloid or an oblate spheroid, all is not lost. You can bring the mirror back to a sphere quite easily using variations of the stroke you used to get the mirror there in the first place. For example, hyperboloidal figures (which are essentially overshooting the paraboloid) are generally the result of using strokes that are too long while polishing – a few minutes of polishing using shorter “W” strokes will take the mirror back towards spherical. As always, figure, cool and test as you go and see how the mirror changes each session. For an oblate spheroid where the centre is not deep enough for the edges, lengthen your “W” strokes.

I should note here that you should be using a program such as TEX to reduce your data taken during testing. Another excellent program for test analysis is SIXTESTS, located at:

http://home.earthlink.net/~burrjaw/atm/atm_math.lwp/atm_math.htm

This software extends the concept of the Rayleigh Criterion and introduces the Root Mean Square (RMS) error and the Strehl Ratio. RMS is a measure of the deviation of the figure of your mirror from a statistically perfect paraboloid, while Strehl Ratio is the ratio of the light intensity at the peak of the diffraction pattern of an aberrated image to that at the peak of an aberration free image. The Sixtests program provides more detail on how well your mirror fits this perfect paraboloid.

Next time, we'll finish of the mirror making process by looking at ways to fix problems with your mirror during parabolizing. As always, questions or comments are welcome at gtulloch@shaw.ca.

What do the transit of Venus and the Royal Astronomical Society of Canada General Assembly have in common?

They are both happening this year in St. John’s, Newfoundland and Labrador.

Mark your calendar as the St. John’s Centre of the Royal Astronomical Society of Canada invites you to where the rising Sun makes its first appearance in North America and where we will celebrate not only the RASC General Assembly but the historical rare occurrence of witnessing two Transits of Venus from our coast.

The 1761 transit of Venus was the reason for the first scientific expedition originating from “America” to help define the Astronomical Unit. Come raise a glass to John Winthrop, who probably celebrated this event at one of over 80 pubs that existed in St. John’s before the Americans won their independence. You will find that George Street still carries on this pub tradition.

Travel the many walking paths that could lead to Winthrop’s Venus Hill or relive the last battle with France during the Seven Years’ War. Look out from Signal Hill as humpback whales beach or a 10,000 year old iceberg passes by. Travel to St. John’s and experience the City of Legends, and take a memory home that will last forever.

From July 1st to July 5th amateur astronomers from across the country and the world will gather in St. John’s, Newfoundland and Labrador to attend the RASC General Assembly. In addition to poster and paper sessions there will be many interesting events planned for the General Assembly topping it off with the Helen Sawyer Hogg public lecture presented by Dr. Sara Schechner of Harvard University on “Harvard’s Own John Winthrop and his Transit of Venus Expedition”.

For the latest program updates and registration visit the National website often.