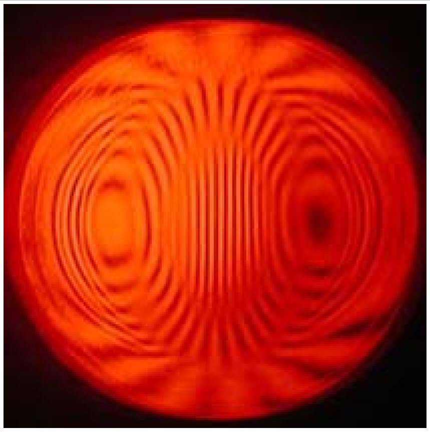
Spherometers



Ronchi image of a 12.5" mirror with over 21 waves of Turned down edge spanning the outer 4.5" of the mirror. This error could have been avoided following the steps on this page.

In this condition, a mirror cannot be used for astronomical observations.

A Spherometer is used to measure the radius of curvature on a surface. When grinding a telescope mirror, this information can tell you the focal length of the mirror, and can show you any zones that exist on the mirror during the grinding process. These zones can then be ground out in a few minutes.

If you wait untill the mirror has been polished out, you may end up with a figure like the one shown at left. This 12.5" mirror has 21 waves of error from the center of the mirror to the edge. This error would have shown .0015 to .0020" or more variation on a 3" diameter spherometer. On this particular mirror, after 50 - 60 hours of polishing, the error was reduced to 7 waves of error. Then by going back to 220 grit, this mirror was finished and properly parabolized to within 1/4 wave accuracy in only 10 hours.

Note: This error was created by an extra long "W" stroke during roughing out with 60 grit silicon carbide. When testing with a foucalt tester, the tester had to be moved almost four inches to find the neutral zone between center and edge.

Base of my 3" spherometer. Notice the circular grooves made with a circle cutter, the three feet, the pin of the indicator in the center, and the thumb set screw to keep the indicator from sliding out of the hole slowly during use.

This base has holes drilled at 1", 2", and 3" diameter. In use, I have found that the 3" circle is the only size I ever use. These other sizes turned out to be a learning experience, but ended up being a

This is the base to one of my spherometers. I prefer to use a three legged base that is less than half the diameter of the mirror. This allows the testing of zones across the mirror in addition to measuring the radius of curvature.

To build a simple but accurate spherometer base ...

1. Find or cut out a circle of wood, plastic, or metal.
2. Mark the exact center of the base.
3. Using a circle cutter, cut a shallow groove at the desired radius. You do not need three sizes like this base.
4. Make three marks around this circle evenly spaced. The straight line distance between each point will be the same when all three points are accurately space. Use a protractor, calipers, ruler, or two marks on the edge of a piece of paper to compare the spacing between the three marks.
5. Drill and tap three holes centered on the circular groove for a #6 socket cap screw, or an appropriate size for your feet.
6. For the three feet, I have used #6 socket head cap screws. In the hex head recess, epoxy small spherical ball bearings. Once set, the ball bearings make great feet for the spherometer.
7. In the exact center, drill a 3/8" hole. You may need to measure the stem of your dial indicator to verify it's size. With my two Mitutoyo indicators, they fit perfectly in a 3/8" hole.
8. If the stem has a little play in the hole, drill and tap a hole going

waste of time to create. The base of my other spherometer only has a 3" circle.

through the edge of the disk to put a thumb screw that can be used to snug against the stem of the dial indicator.

This Spherometer uses a dial indicator. Having a needle on the face makes it easy to see slight surface variations while sliding the indicator across the surface of the mirror.

This is my most accurate spherometer. The dial indicator is made by Mitutoyo, has 1.0 mm of travel with a resolution of only 1um, or 1/1000 mm. This indicator can only be used after fine grinding with 220 or 320 grit, otherwise, the texture on the glass can cause a deflection of the needle in excess of 1/4 rotation.

To use a dial indicator ...

1. Set the indicator on the center of the mirror and notice the position of the needle. The actual measurement is not important. What is important is to notice the movement of the needle across the surface of the mirror.
2. Slide the indicator slowly towards the edge of the mirror.
3. NOTE: This indicator turns counter clockwise when the indicator is lifted off the surface of the mirror, so if your indicator turns the opposite direction when lifted, the following information needs to be reversed as well.
4. If the needle rotates counter clock wise, then the edge of the mirror is turned up.
5. If the needle rotates clockwise, then the surface of the mirror is turned down.
6. If the needle does not move at all, then the mirror is spherical.
7. If there are inconsistent zones in the mirror, then the needle will move up and down as the spherometer is slid across the glass. To determine if the zone is a depression, or a hill, watch the needle.
8. If the needle turns CCW then CW, the zone is a depression.
9. If the needle turns CW then CCW, the zone is a hill.
10. Repeat these steps across the mirror in several places.
11. To test if the mirror is astigmatic (Potato Chip shaped), slide the spherometer around the mirror in a circle. If the indicator moves considerably, then the mirror needs to be ground more to remove the astigmatism.
12. Our goal when grinding our 8" mirrors is to have the surface within 3um at the end of 220 grit, 2um at the end of 320 grit, and 1um by the end of 25 and 12 micron. Each small tick mark on the indicator is 1um, the large printed numbers are actually 10um. If needed, continue grinding untill the surface is within these tolerances. This will eliminate any bad zones in the mirror before you start polishing and save many hours of work later.

This is the most convenient indicator I use since the indicator can show a direct digital reading of the surface deviation. The number on the indicator is looked up on a chart to give a measurement of the focal length within 1/4" or so depending on the focal length. This indicator was a gift from a machinist friend who I helped build a 12" F8 dobsonian telescope for. (Thank-You Rick).

This spherometer uses a digital dial indicator donated by a friend to help me teach others how to build telescopes. Thanks to this donation, my total cost to build this indicator was less than $5.

To use this indicator ...

1. Make certain the indicator is measuring inches not mm. Press the in / mm button to switch to inches if needed.
2. Zero the indicator (See the next section below)
3. Place the indicator on the center of the mirror.
4. Look up the reading on the printed chart to determine your focal length and / or radius of curvature on the glass.
5. Using the method listed above, test the surface of the mirror.
6. If the numbers get larger, the edge is turned up, or the indicator has gone over a depression.
7. If the numbers get smaller, the edge is turned down, or the indicator has gone over a hill.
8. Our goal when grinding our 8" mirrors is to have the surface within .0005" at the end of 80 grit. If needed, continue grinding with 80 grit untill the surface is within .0005". By using a 1/4 to 1/3 center over center stroke, errors on the mirror can be corrected in a few minutes saving many hours of work later.

Using a military surplus mirror to zero both of my spherometers.

To accurately use a spherometer, it needs to be zeroed. My dial indicator only needs to be zeroed if it will be used to measure radius of curvature. However since I use this indicator to only show surface accuracy across the mirror, not curvature, zeroing is not critical. The digital indicator must be zeroed before testing the mirror. This way, the number on the display can be looked up directly from the chart. From experience, this indicator measures the radius of curvature extremely accurate. The radius of curvature on the example 8" F4.0 mirror was within 1/64" of the calculated value using the spherometer.

The mirror I use to zero the indicators is a surplus military mirror that is flat to somewhere around 1/20 wave.

To calculate the radius of curvature, several spreadsheets are available on the internet. The formula is R = (D^2 + 4*S^2)/8*S where R is the radius of curvature (twice the focal length), D is the diameter where the feet are mounted at, and S is the sagitta or the measurement on the dial indicator. For a more detailed explanation see the Spherometer section on AtroTel.

To zero the spherometers ...

1. Place the spherometer on the surface of the mirror.
2. With the digital indicator, turn it on if needed, then press the zero button.
3. With the dial indicator, loosen the thumb screw. Carefully slide the indicator untill the small needle is pointing close to the 1.0 mark. Loosen the set screw and rotate the black ring untill the number "0" is directly under the needle. You may have to do this several times since your hand pressure is enough to cause the needle to move.
4. Once zeroed, test the surface on the mirror.

5. Once the test is completed, turn off the digital indicator to save battery life.