

Beginners interferometry for ATM

There are several mirror testing methods in use by ATM. Foucault knife-edge method, Ronchi grating method and Star test method are among most popular.

Interferometry is still not catching in popularity, in spite of recent developments like availability of analysis programs and powerful personal computers. Even its simplicity and unsurpassed quality of its results, which are quantitative, and represent the whole mirror surface, have not change the current attitude.

This article intention is to be encouragement and help in building and using interferometry by any ATM disregarding the level of experience.

The next picture is the Bath interferometer as (will be) build in this exercise.



Fig. 1: Bath interferometer

There is Yahoo group for interferometry with reports on, up to now, 24 different Bath interferometers built by ATMs. Essential information about this subject is available on the Wiki for interferometry:

http://starryridge.com/mediawiki-1.9.1/index.php?title=Main_Page

which is written for amateurs by amateurs.

If by chance you have items on the next picture, you are already equipped with all necessary parts required to build an interferometer.



Fig. 3

If not, here is description of pictured components and where you can get them:

- a) Wooden base plate 75 x 50 x (8 -12)mm
- b) Keychain diode laser pointer \$2, less than 1mW power,
Or similar 4mW, \$9.15, unit used in this article, available at:
www.roithner-laser.com (glass lens, focusable, power stabilized)
- c) Beam splitter cube
<http://www.surplussed.com/pages/item/l2046d.html>
Item No L2046D, \$ 19.00
- d) Flat, first surface mirror, (This component we shall refer to as a FLAT
<http://www.surplussed.com/pages/item/pm1012.html>
Item No PM1012, \$ 12.75
Or: <http://www.surplussed.com/pages/item/l3129d.html>
Item No L3129D, \$ 5.00
- e) Biconvex lens. For Example
<http://www.surplussed.com/pages/item/pl1009.html>
Item No PL1009, \$ 6.00 (Diam. 12.7 mm, FL 14 mm)
Or: <http://www.surplussed.com/pages/item/pl1098.html>
Item No PL1098, \$ 5.00 (Diam. 7.5 mm, FL 10 mm)
- f) Spherical, front surface concave mirror. It will be our mirror under test. (Referred to as a MIRROR)
<http://www.surplussed.com/pages/item/l1565.html>
Item No L1565, \$ 6.00 (Diam 60mm, ROC 1275 mm)
Or: <http://www.surplussed.com/pages/item/l3862.html>
Item No L3862, \$ 2.75 (same as L1565 but scratched)

If you already have a spherical or paraboloid mirror it can be used for this exercise.

And that's it. For about \$ 50 an interferometer can be built in few hours, learned a lot and find about your mirror more and faster than with any other test method available to ATM. Interferometer in this exercise, ready for use, will basically look like this:

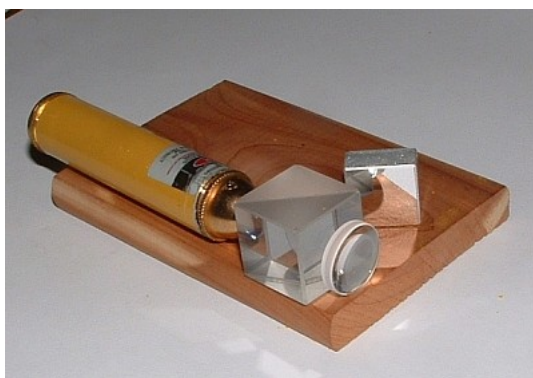


Fig. 4: With keychain laser pointer

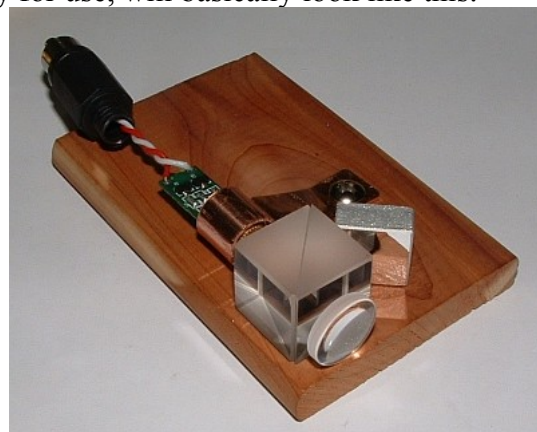


Fig. 5: With laser model used in this article

Disadvantage of a keychain laser pointer is that it is powered by small knob batteries which do not last very long in continuous use. But they can be replaced by power supply of suitable output (cca 3V, 100 mA) like one on Fig. 6, or with batteries like in Fig. 7:



Fig. 6 Power supply for longer use

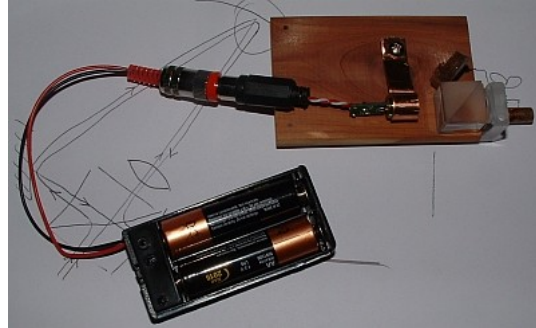


Fig. 7, I have used batteries in this article.

To put the interferometer together, first the laser is fixed to the base. I have done it like this.

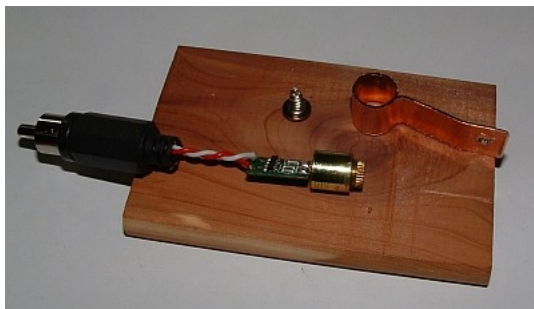


Fig. 8: Copper sheet bent to laser diameter.



Fig. 9: laser holder screwed to the base. Serves also as a heat sink, if required.



Fig. 10: laser lifted, to have a beam 7 mm above the base

Laser Beam distance from the base can be adjusted so that beam hits the splitter cube near its center. Cube is 15 mm, so I have lifted laser a bit to have a beam at 7 mm from the base. The

beam should be approximately parallel to the base, done by bending the copper holder with pliers.

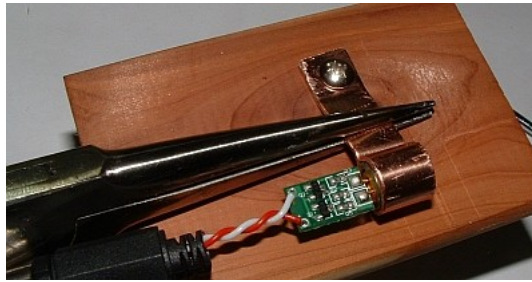


Fig. 12, A brute force adjustment method.

Next, a beam splitter is placed in front of the laser and lightly glued to the base (by a small drop of instant glue so that it can be easily removed if required) . Assembly is clamped to the table, Fig. 13 (temporarily), to prevent its accidental movement during the following adjustment steps.

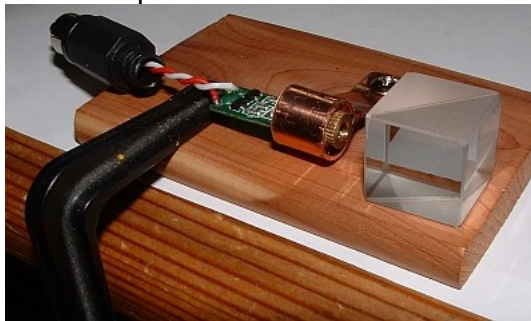


Fig. 13

The location of the splitter cube at the very corner of the baseplate is not accidental. It is essential to allow mounting of the diverging lens very close to the cube, and placing the recording camera, if used, very close to the cube output side.

In the next step the mirror under test is placed at distance of its ROC from the interferometer (splitter cube center) and positioned so that laser beam hits approximately its center. This beam is referred to as the TEST beam. Mirror is mounted on the tripod which enables adjustment of the: mirror's vertical, lateral and longitudinal position and rotation about vertical and horizontal axes (which are at right angle to the optical axis of the mirror),



Fig 14

Next component added to the interferometer is the flat front surface mirror. It is placed as close to the splitter as possible (but not touching it), and oriented at angle which will redirect the second laser beam coming from the splitter (known as REFERENCE beam) , toward the center of the mirror under test, to coincide with the test beam at the mirror's surface, (coincide means that reference beam hits the mirror under test at the same spot as the test beam.) This will be the first delicate adjustment operation because small movement of the flat strongly changes position of the beam on the mirror's face. It is not practical to glue it to the base with an instant glue because such glue will grab before adjustment was achieved. To solve the problem I have used a jig temporarily attached to the flat. The jig makes adjustment easier and is removed later.

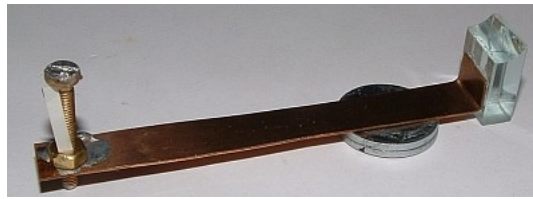
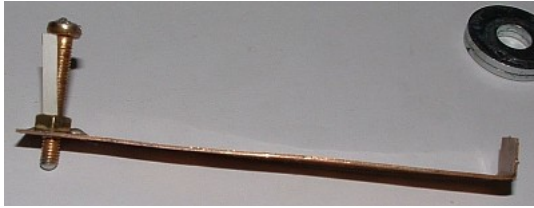


Fig. 15: The screw on the left will adjust angle (tip) of the flat and flat is glued lightly to the jig to make later separation easier. Some SLOW setting epoxy glue is added to the base of the flat mirror, which will allow enough time for adjustment before setting.

Fig. 16: Jig is before gluing slightly elevated from the base by coins

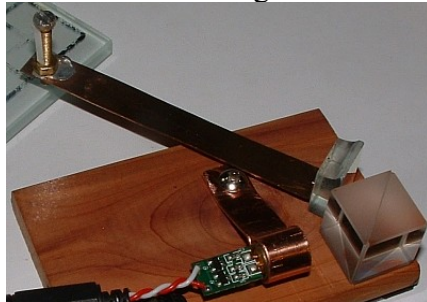


Fig. 17: Flat is positioned near the splitter cube approximately at 45 degrees.



Fig. 18: Angle of the flat is roughly adjusted to put reference beam near the test beam at the mirror under test. The spot on the right is from the test beam.



Fig. 19: By adjusting the screw of the jig the flat is tipped about horizontal axis until the reference beam spot is brought to the same elevation

as the test beam spot on the mirror.

We want to place the reference spot to coincide with the test spot.



Fig. 20 The flat is rotated about vertical axis for coincidence of two spots.

Flat mirror is now in proper position and should be left undisturbed for the time sufficient for the glue to set.



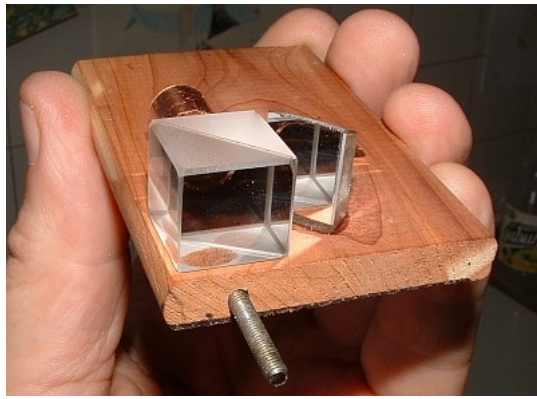
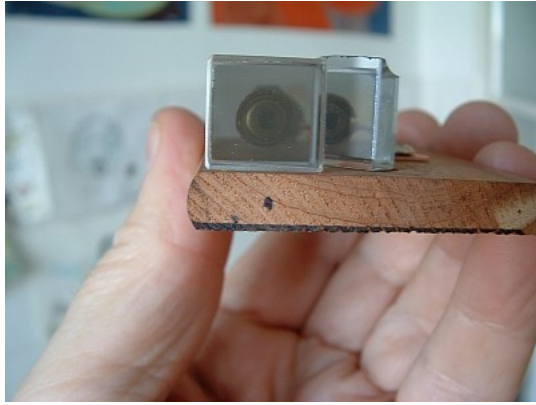
Fig. 21 The adjustment jig is separated from the flat (therefore it was glued to flat lightly),

Fourth and last component to be installed is the diverging lens. It is the only adjustable component which can be replaced by another lens if required.

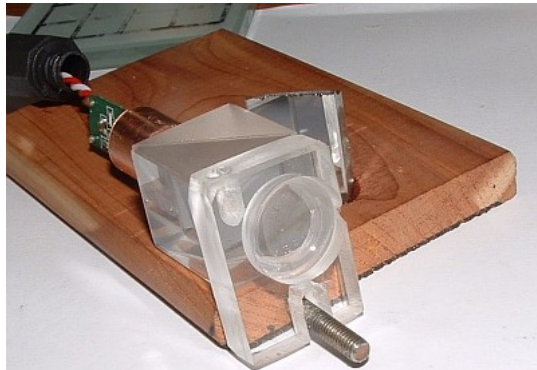
Adjustment will enable positioning of the lens in the xy plane so that laser beam goes through the lens center, is centered on the MIRROR and fully illuminates it.

This will be done by installing the lens in a holder and making the holder movable in xy plane and then locked .

For this the screw is inserted in the base plate, directly under the test beam



Figs 22: The position directly beneath the test beam is marked, drilled and screw inserted



Figs. 23: The lens is inserted in holder, with slot or hole slightly bigger than the screw, to facilitate adjustment in xy plane (up-down, left-right).

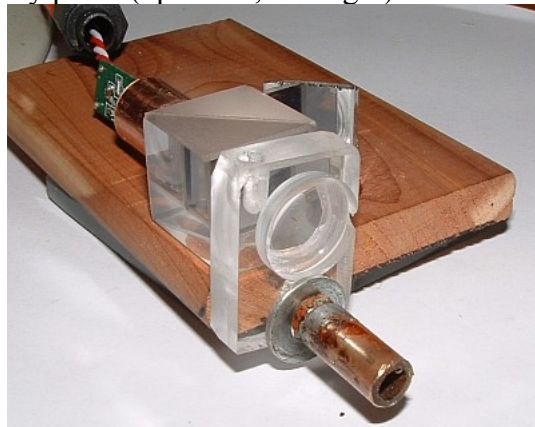


Fig 24: Washer and nut are for fixing the holder. For easier tightening of the nut it is elongated for comfortable hold.

Required adjustment amount is small. The lens holder is moved until the diverging test beam fills the mirror.

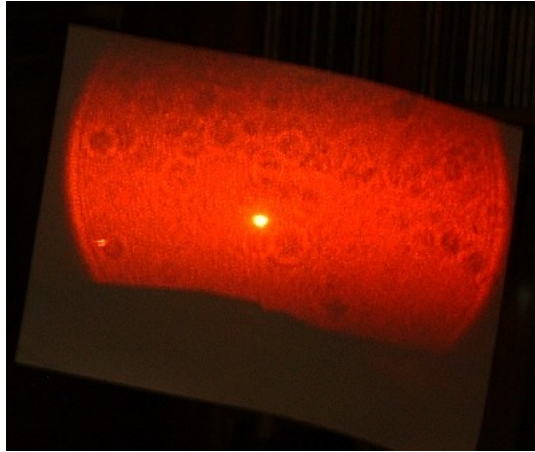


Fig 25: Paper screen is placed in front of the mirror (without displacing the mirror).

The reference beam is in the center of the mirror, expanded test beam fills the mirror and is also approximately centered on the reference spot.

When the paper screen is removed, both beams are reflected somewhere depending on the actual tip and tilt of the mirror.

Mirror is at the correct initial distance (ROC) from the interferometer. For fine adjustment of this distance we shall use the interferogram.

Next step is final adjustment of the mirror tip and tilt which will ensure common path for beams. Common path means that test and reference beams retrace each others paths to and from the mirror. Since the test beam is expanded into a cone and reference beam is collimated, the common path refers only to the central “ray” of the test beam.

One beam, for example the test beam, is blocked at the splitter by the paper thin enough for the test beam spot hitting it from behind to be visible.

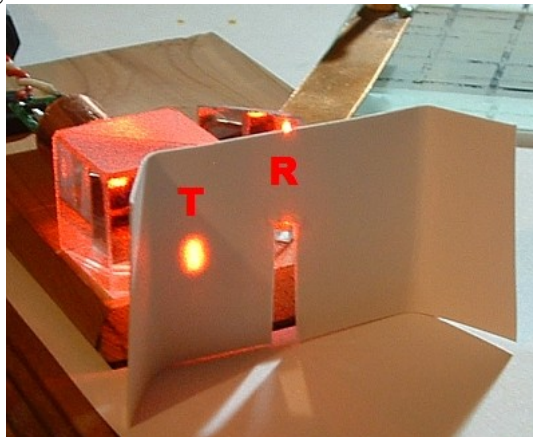


Fig 26: Test beam spot (T) seen through the paper.

The tip and tilt of the MIRROR is adjusted until reference beam reflected from the mirror hits the paper screen at the same spot as the test beam does from behind. This can be assisted by repeated interrupting of the reference beam to check how well the two spots coincide on the paper. After the coincidence is achieved, the paper mask is removed. And this is all there is to it. The interferometer is very likely adjusted enough to show fringes.

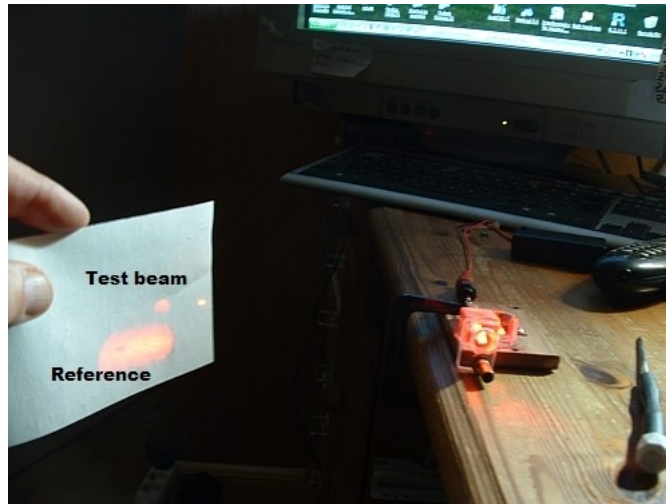


Fig. 26a: Fringes are observed by placing paper screen to intercept beams, or by observing beams through the frosted glass. Because of insufficient adjustment, test and reference beams do not overlap each other. Rightmost spot is from some reflections in the beamsplitter.

Diameter of the beams at the splitter face is very small. Screen or frosted glass has to be placed at some distance for good observing. If the diameter of the mirror is D , and Fnr its F-number, the diameter of interferogram on the screen at distance L from splitter face will be $d=0.5*L/Fnr$. Mirror used in this article has F number 10, diameter of the interferogram 20 cm from the splitter will be 1 cm.

Depending on adjustment (Fig. 26) what will be seen are two possible cases. Either the test and reference beams are separated like in Fig. 26a, or 27, or overlapped like in Fig: 28

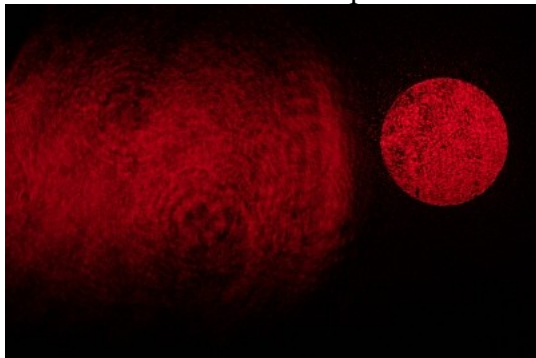


Fig. 27

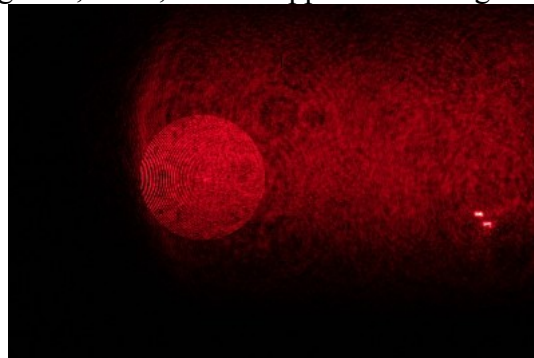


Fig. 28

If the beams are separated, no interference can be seen. If they are overlapped, interference fringes are always there but it can happen that they will not be recognized. In the Fig.28 it seems that fringes are absent. De facto they are all over and if magnifying glass is used they will be seen like this: Fig. 29

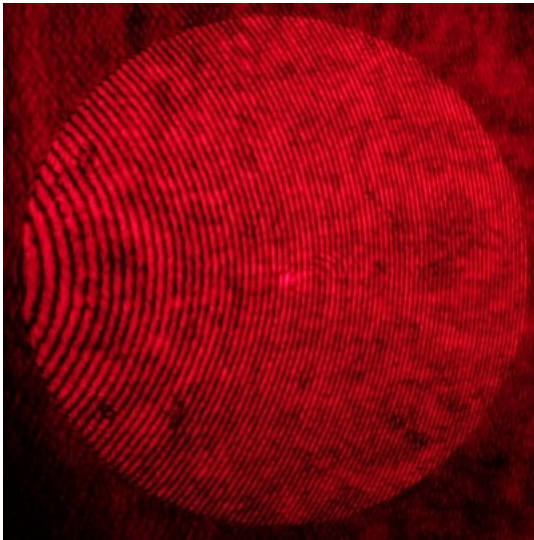


Fig. 29: Magnified part of Fig.28. Fringes at the right became more and more dense and less visible (resolved).

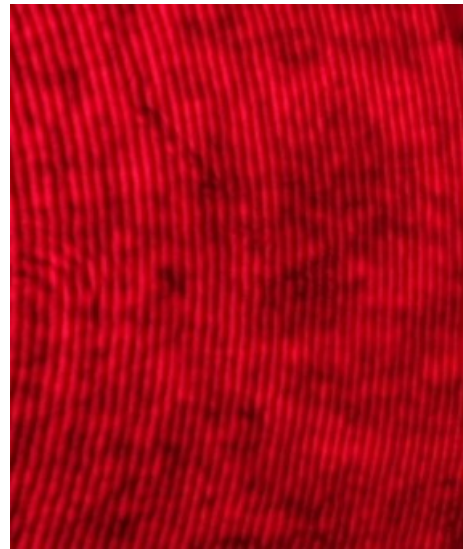


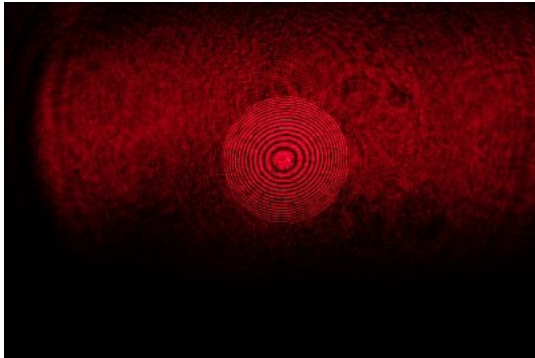
Fig. 29a: If right part is magnified even more, fringes became again visible.

If beams overlap, fringes are there. If you can't see them, the resolution of your observing tool is too low, fringes can be too narrow and dense to be resolved. In such a case fine adjustment will reduce the number of fringes and bring them in a form suitable for analysis. The fringes are not well visible mostly because the mirror to interferometer distance is too big or too small and fringes are very dense. Adjustment of distance will decrease the number of fringes.

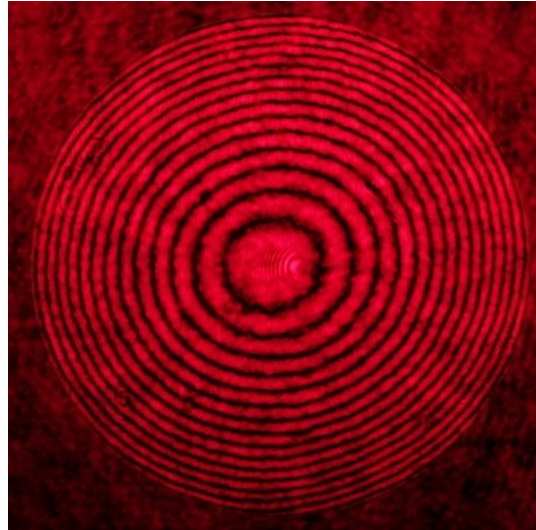
If you came that far, there is absolutely nothing that will prevent you to get fringes from the mirror under test which are good for analysis.

The two spots on the right in the Fig. 28 are parasitic reflections in the splitter, and as long as they are outside of the interferogram, are harmless.

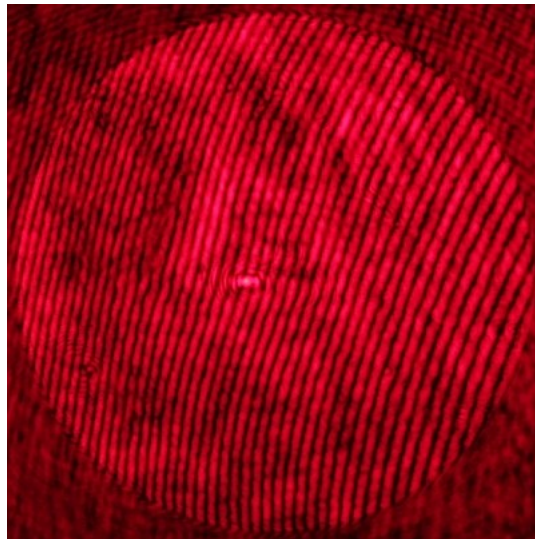
In case that beams do not overlap, small additional adjustment is required. For this interferometer is usually mounted on translational stages which move it in x, y and z direction. In our case there are no such facilities. By placing a sheet of white paper in the beams path as in Fig. 26a, and observing the beams, slight (very slight indeed) adjustments of the mirror tip and tilt will adjust the beams to be overlapped. Sliding the interferometer on the table sidewise can also help. In such a case the reference beams spot on the mirror must be kept on the mirror and close to the center.



Figs.30 well centered beams and correct distance



Observed with magnifier fringes will be like this:



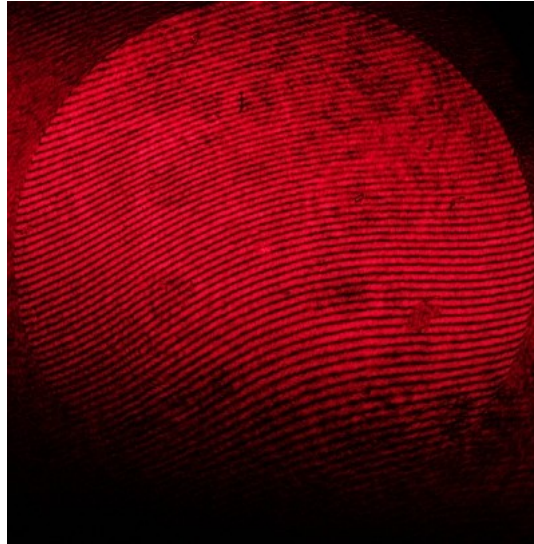
Figs. 31a; On some interferograms "bulls eye" shape can be absent and open, curved fringes observed. Magnified interferogram reveals fringe structure suitable for analysis.

Remember that this interferogram was made with our rudimentary demo Bath interferometer. But it is real Bath interferometer. Its upgrading will provide adjustment comfort via translational stages, recording facilities like digital cameras and webcams, but essential part, the interferometer, is what you have built and will remain unchanged 😊

The purpose of the article was to bring you to this point. You can play now with the interferometer, slightly move the interferometer on the table to see the effect on the interferogram. First thing to do later is to provide better control of the position of the interferometer by placing it on the xyz translational stages. The stages must not be of expensive variety with micrometer readouts. Readouts are not required and stages can be

highly improvised, but stable. The amount of travel may be small, few mm. Rough adjustments is done by moving by hand the entire interferometer or tripod with the mirror under test, just like in this exercise.

Even more, this interferometer can be used on the real mirror like this one:
(ROC=1215 mm, D= 152 mm, F/4)



Figs. 32: The small one is our \$3 SurplusShed spherical mirror used in this exercise. The bigger one was tested with the same interferometer. Interferograms is on the right

This interferogram is good example of insufficient illumination of the mirror under test. The laser beam should be wider and/or the diverging lens should have smaller focal length, in order to provide diverging cone of light covering entire surface of the mirror under test. Example of calculation for the minimal required lens focal length and laser beam width for full illumination of the mirror under test.

It is better that beam diameter at the mirror is approximately 150 % to 200 % of the mirror diameter

(D) Mirror Diameter = 151.9 mm

(Fnr) Mirror F-number = 4

(F) Lens Focal Length = 14.0 mm

(w) Laser Beam Diameter = 1.5 mm



For this case: Cone Diameter at Mirror = 130.2 mm

For full illumination $F = w \cdot \text{ROC} / D = 12.0 \text{ mm}$

Regards
Vladimir.

Regards
Vladimir

"Time to take a BATH !"
(Mel Bartels)