The Ronchi Test

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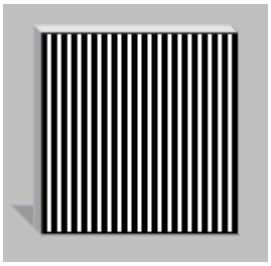
The Ronchi test is named after is inventor, Vasco Ronchi. The test is performed at the Radius of Curvature (ROC), and is qualitative, that is it does not give us any numbers to help us define the surface profile of the mirror under test. The key requirement of the test is a grating or ruling as it is called, which consists of a series of parallel lines on a transparent surface such as glass or plastic. The cheaper versions are usually black ink lines printed on a clear plastic sheet, such rulings are perfectly useable. The number of lines on the ruling can vary, the minimum being 80 lines per inch (lpi) up to several hundred lpi. An 80 lpi grating is fine, but a ruling with 100 or 120 lpi will be more advantageous in the test to be described.



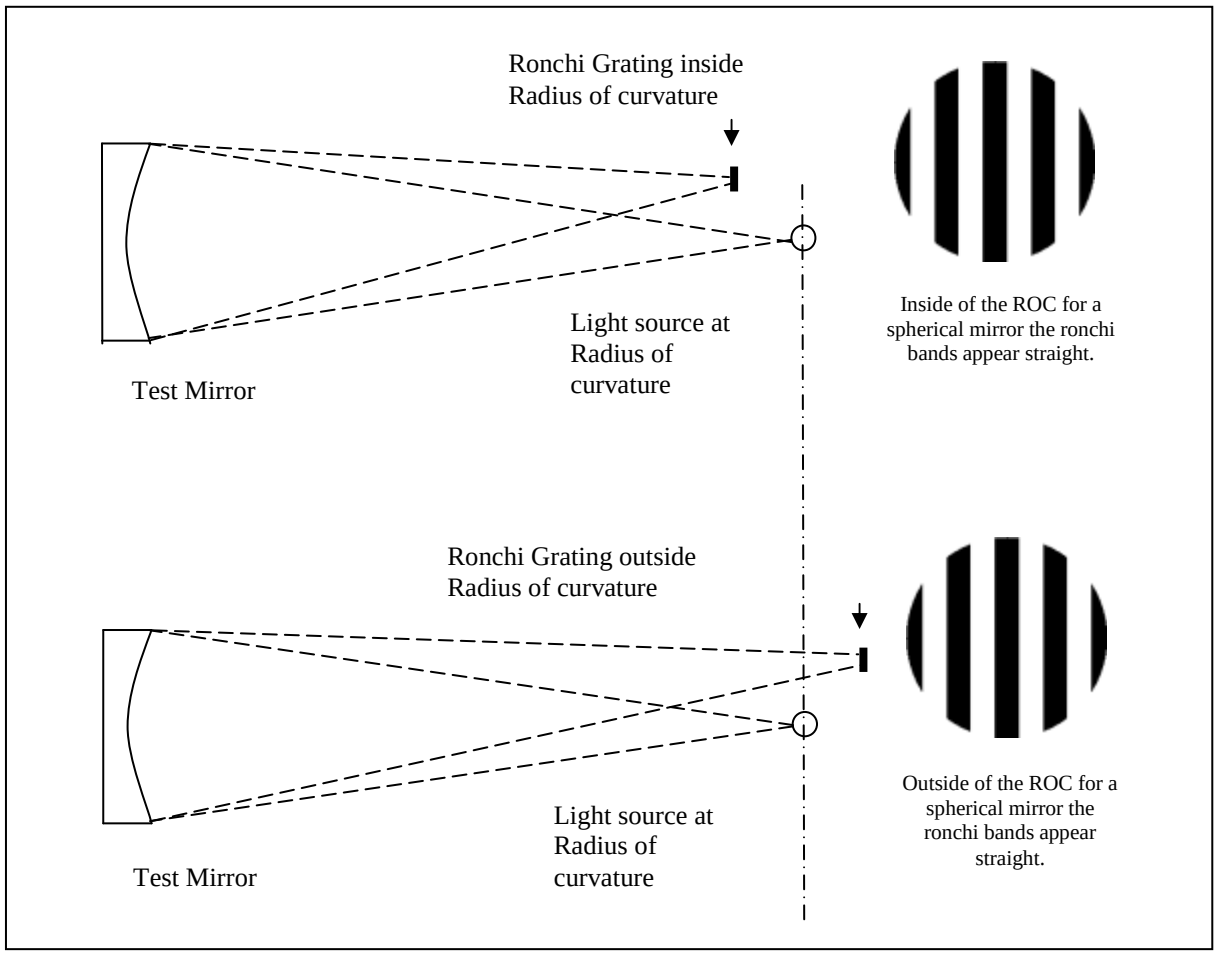
A Ronchi grating.

The test apparatus is setup at the ROC and the reflection of the light source is viewed through the Ronchi grating. The appearance of the lines, or bands as they are often called, gives us valuable information about the surface of the mirror under test. The patterns we view through the Ronchi grating are like the contour lines on a map, they can tell us about high and low areas however, we must take care when interpreting a pattern. A smooth spherical mirror shows straight Ronchi bands either side of the radius of curvature. As seen with the ronchi ruling the surface appears flat, when in reality it is convex, this is due to the fact that like the Foucault test, the Ronchi test is looking at slopes on the mirror surface as a result of this the Ronchi patterns seen give us an *apparent* surface profile, not a real one.

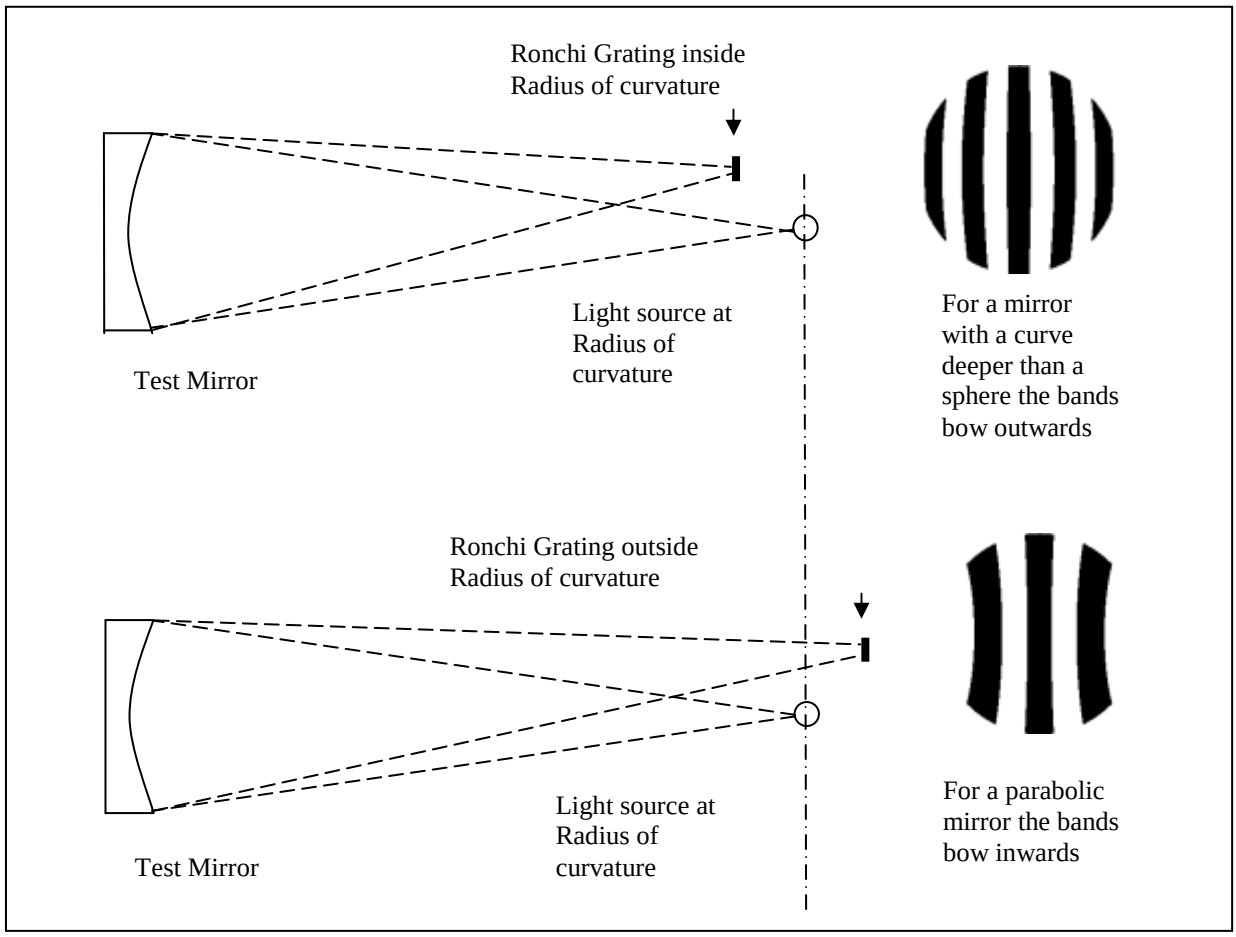
If we start with the ruling inside of the ROC, we observe a number of bands; they may appear straight or curved. As the grating is drawn back away from the mirror the number of bands appears to reduce

and those remaining broaden. As we pass through the ROC the number of bands appears to increase again and they appear thinner.

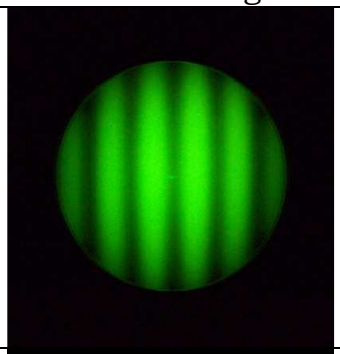
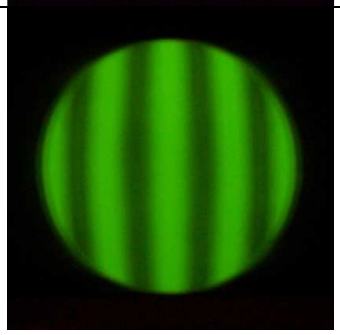
What do the bands tell us about the surface of the mirror? If the bands appear straight inside the ROC and remain the same through the ROC and beyond it, the mirror is spherical. This is shown in the diagram below.



If the lines appear bowed outwards inside the ROC and bowed inwards outside of the ROC the mirror has a curve deeper that a sphere. It may be elliptical, parabolic or hyperbolic. As stated the Ronchi test is not quantitative, observing the curved bands does not enable us to say which conic section fits the mirrors surface.

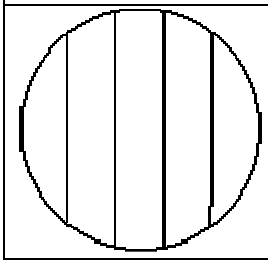
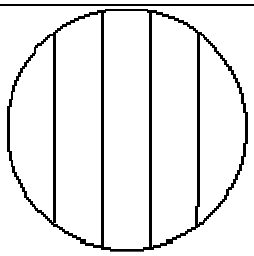
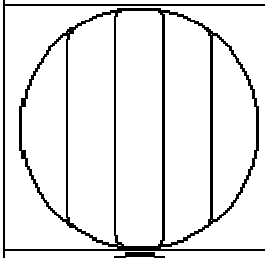
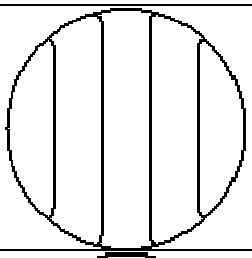
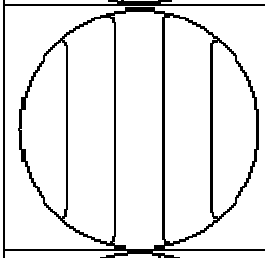
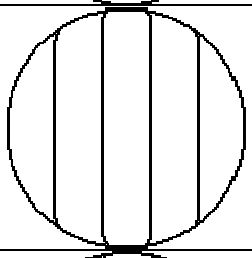
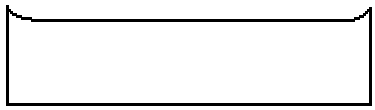
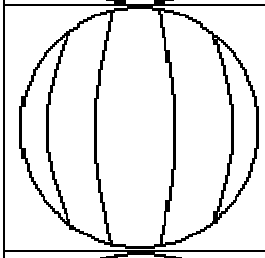
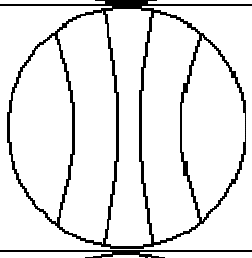
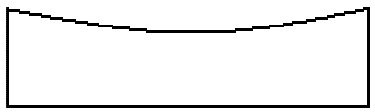
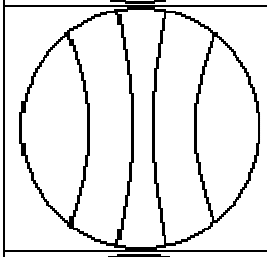
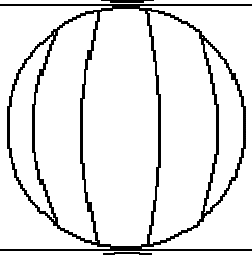
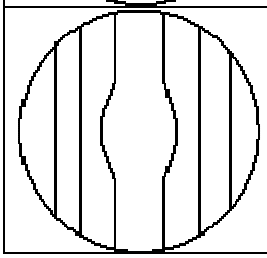
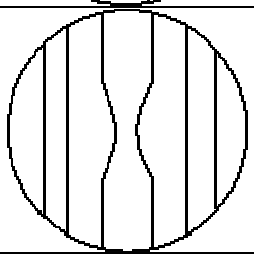
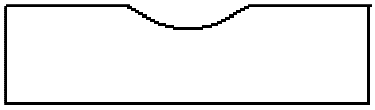


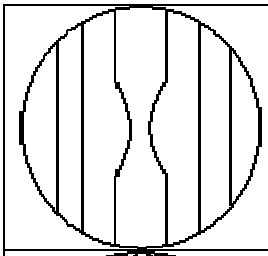
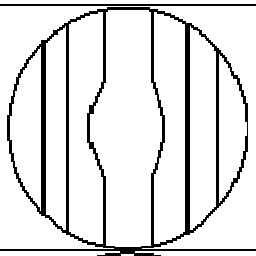
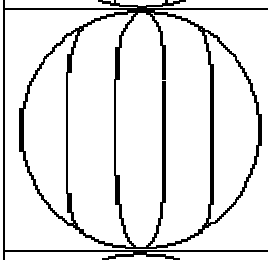
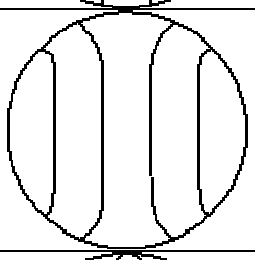
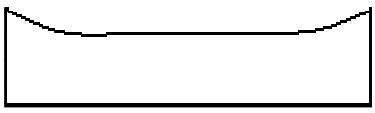
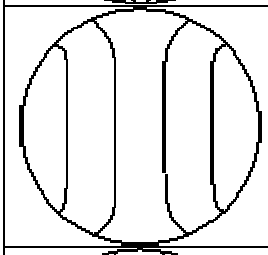
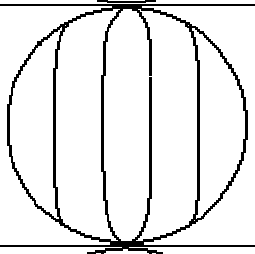
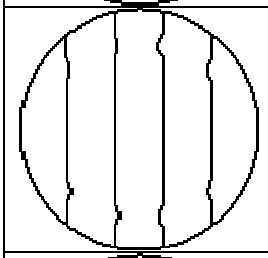
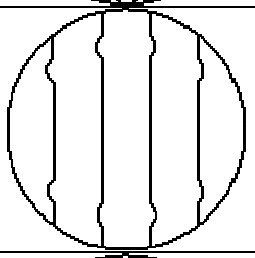
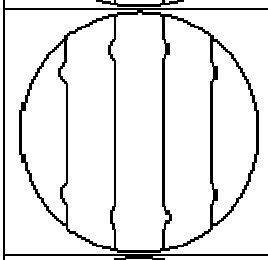
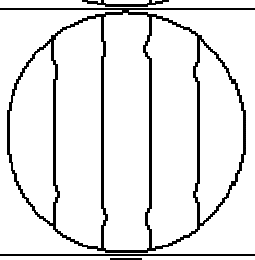
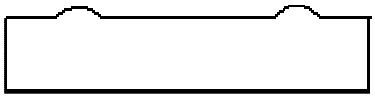
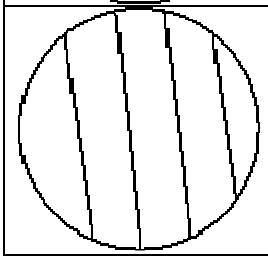
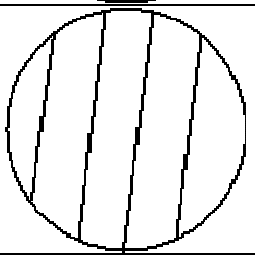
The ronchi band patterns can differ from being straight or curved depending upon the figure of the mirror being tested. The following table shows some real mirrors under the ronchi test together with an interpretation of what the images tell us about the mirrors

Ronchi Image	Interpretation
	Straight bands indicate a spherical mirror; the bands remain straight at the radius of curvature (ROC) and both inside and outside of it.
	Viewed from just inside the ROC bands bowing outwards indicates a curve that is deeper than a sphere. Smooth bands like this indicate a regular figure. Viewed from outside of the ROC bands that bow outwards indicate a curve that is shallower than a sphere.
	Viewed from inside of the ROC bands that turn off sharply at the edge of the mirror indicates a turned down edge. The bands tend to bow in slightly towards the centre indicating a that the curve in the middle of the mirror is less than a sphere.
	Viewed from just inside of the ROC the bands turn off at the edge indicating a turned down edge, although not at serious as the previous mirror. The bands towards the centre bow outwards indicating a curve that is deeper than a sphere.
	Viewed from outside the ROC the bands bow outwards indicating a curve deeper than a sphere. Notice that near the middle the bands bow very slightly outwards indicating that the curve here is not as deep as on the rest of the surface.

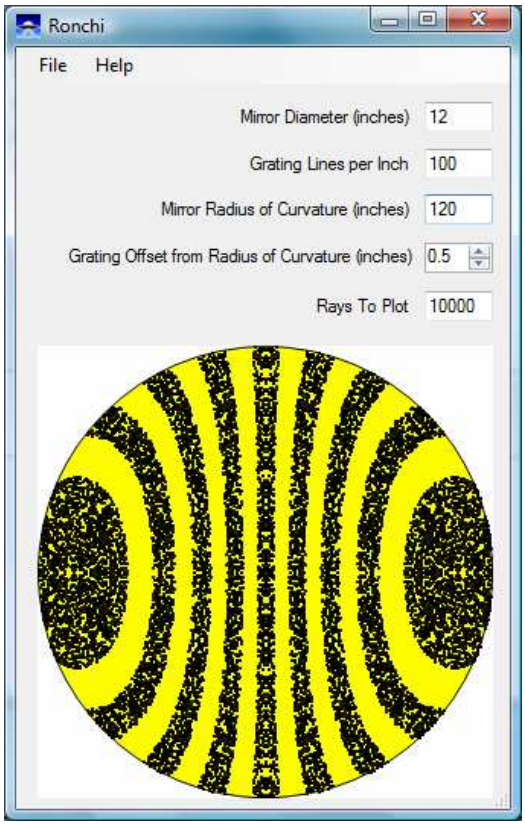
The different colours in the images are due to different coloured light sources being used. This has no effect on the interpretation of the images.

The Apparent Surface Profiles of Mirrors Tested at the Radius of Curvature with a Ronchi grating.

Inside ROC	Outside ROC	Apparent Surface Profile
		 Spherical
		 Turned down edge
		 Turned up edge
		 Over corrected sphere
		 Under corrected sphere
		 Depressed centre

		 Raised centre
		 Extended turned edge
		 Extended turned up edge
		 Depressed ring zone
		 Raised ring zone
		Astigmatism, the mirrors surface is not a figure of revolution.

The well respected American telescope maker Mel Bartels has written a computer programme to simulate the appearance of the Ronchi bands for any specified mirror. The software may be downloaded from: http://www.bbastrodesigns.com/ronchi.html, this software will be invaluable when it comes to assessing a mirror. Upon running the software the user is presented with a window like this:

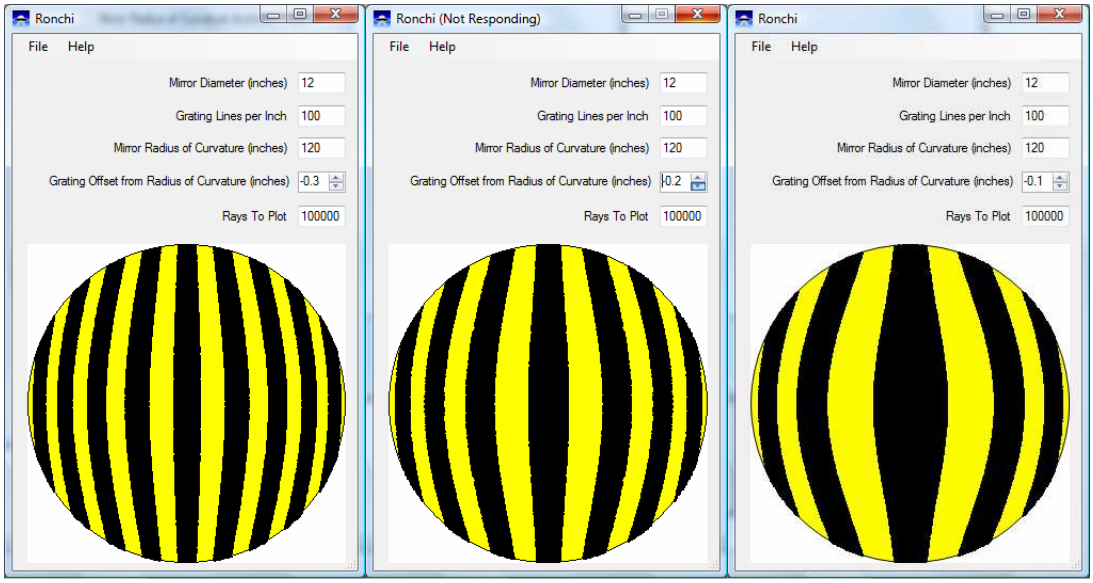


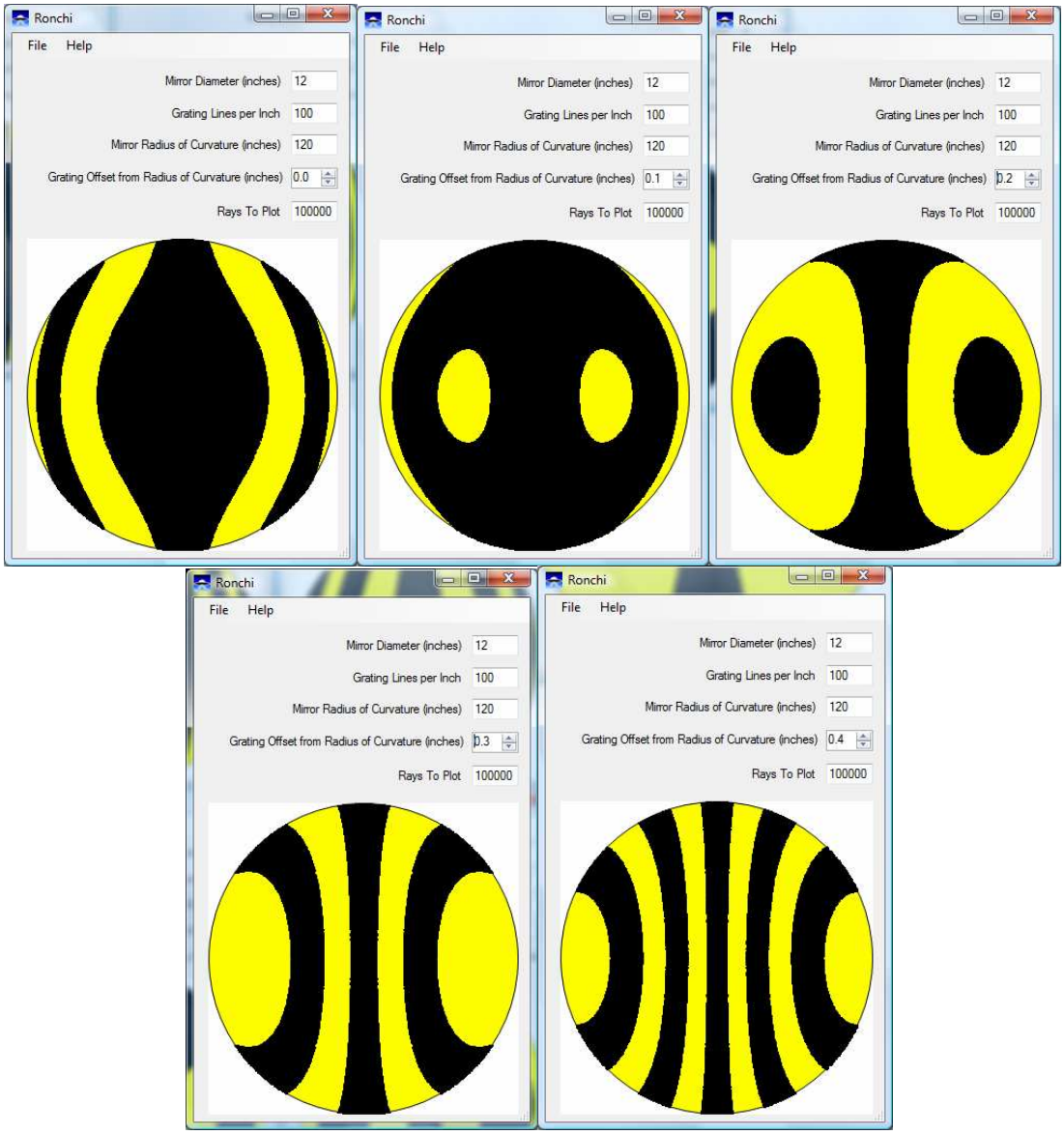
The user is invited to enter the following data; the mirror diameter in inches, the grating lines per inch, the radius of curvature of the mirror, the grating offset from the radius of curvature and the rays to plot. Please note that the software does not offer the user a choice of units, it accepts only imperial units so conversions may have to be made. Note that the software will cycle through various ronchi grating offsets, showing the appearance of the bands unless the user interrupts the process by entering data in any of the boxes. It is important to realise that the grating offset may be a negative or positive value. It is a negative value when the grating is located inside the radius of curvature, in other words the grating is closer to the mirror than the radius of curvature. The 'Rays to plot' box has a default value of 10000; this simply defines the number of points displayed in the image of the bands. Decreasing this value will allow the image to be drawn more quickly but will reduce the resolution of the resulting image. The default value works well.

The Matching Ronchi test.

It will be realised that the images produced by this software can be used to make an accurate assessment of the figure of a telescope mirror. The assumption is made that the figure is a smooth one; if the figure is not smooth any irregularities will be shown in the ronchi bands. Instead of appearing as regular curves as shown in the computer generated images they will have irregularities. If a mirror does not show smooth regular bands further work will be required before resorting to the matching ronchi test.

In order to perform the test we will need to know the radius of curvature of the test mirror quite accurately. We also need to generate, using Bartels ronchi software, a series of images at various offsets for a mirror of the diameter to be tested. We will need to know the number of lines per inch for the grating to be used. It may be useful to print these out to have at hand during the test process. Suitable offsets might be from -0.3 inches to 0.4 inches, but there are no hard and fast rules. A suitable series of images for a 12inch diameter mirror with a focal length of 60 inches and a 100lpi grating will look like this:





When performing the test the observed image, as seen through the test apparatus, is made to match the generated image at zero offset, in other words the image as seen at the radius of curvature. The grating is then moved either towards or away from the mirror by exactly 0.1 inch. The bands observed with the test apparatus are now compared to the computer generated image at that offset. The process is repeated at each offset either side of the radius of curvature to see if the images match. If the observed bands are less curved than the computer generated ones then the mirror is under corrected which means that the curve needs to be made deeper. If the observed bands appear to be more curved than the computer generated ones then the curve is over corrected, or too deep. If the curvature and number of bands observed matches the computer generated images at all positions then the mirror is good. It should be said that performing this test, like all methods of testing optical surfaces, does require patience and practise but it can be done. With experience this test is

capable of producing a mirror that will meet the Rayleigh criterion. One important point to be remembered is that Bartels' software has been developed for use with test apparatus that uses a moving light source, this means that as the ronchi grating is moved towards and away from the test mirror the light source moves with the grating.