Introduction to Geometrical Optics - a 2D ray tracing Excel model for spherical mirrors - Part 7

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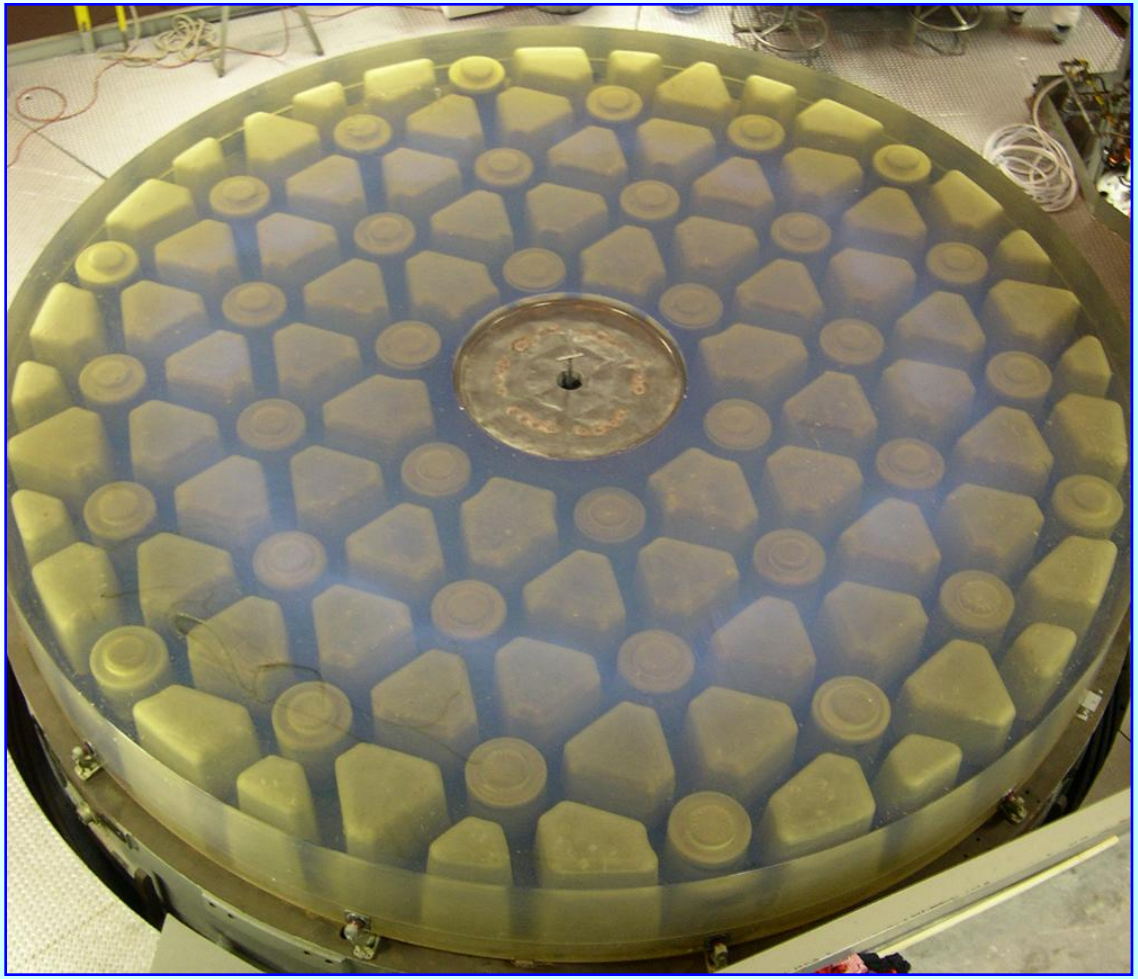
- In the previous section we derived the formulas for a simpler and cleaner way of calculating the terminal point of the reflected ray. We also used the same principle to derive the terminal point of the virtual reflected ray.

- In this section of the tutorial, a new Reflect_7() custom VBA function is written which will supersede the old Reflect() function together with the Chart_Reflect() function.

- This new user defined function will return three pairs of x-y coordinates for the incidence point, and the terminal points of both the real reflected ray and virtual reflected rays.



The 5 meter Mount Palomar - Hale telescope mirror with the aluminum reflective coating stripped off. You can observe the honeycomb like structure which allows for significant mass and thermal inertia reduction. For many years this was the largest telescope mirror in the world.

Writing the code new custom function Reflect_7():

- Most of the code of this new function is taken from the old "Reflect()" function.
- The new function has a new input argument called Max_scale which is the PT parameter that we mentioned in the previous section

- The variables x, and y where renamed xi and yi (from the word "incident")
- The function returns eight values which are the Cartesian coordinates of four points: the light source, the incident point, the terminal point of the reflected ray and the terminal point of the virtual ray.
- Just like the previous functions, this function returns an array and just like in the previous cases there is a special procedure of typing in this function in the worksheet.

```
Function Reflect_7(xL, yL, xM, yM, alpha_incident, R, Max_scale)
    Dim a, b, c As Double
    a = 1 / Cos(alpha_incident) ^ 2
    b = 2 * (Tan(alpha_incident) * (yL - yM - xL * Tan(alpha_incident)) - xM - R)
    c = (xM + R) ^ 2 + (yL - yM - xL * Tan(alpha_incident)) ^ 2 - R ^ 2
    xi = (-b - Sgn(R) * Sqr(b ^ 2 - 4 * a * c)) / (2 * a)
    yi = Tan(alpha_incident) * xi + yL - xL * Tan(alpha_incident)
    ar = alpha_incident + 2 * Application.Asin((yi - yM) / R)
    xr = xi - Max_scale * Cos(ar)
    yr = yi + Max_scale * Sin(ar)
    xv = xi + Max_scale * Cos(ar)
    yv = yi - Max_scale * Sin(ar)
    Reflect_7 = Array(xL, yL, xi, yi, xr, yr, xv, yv)
End Function
```

Create a new worksheet:

- Copy the last worksheet (Tutorial_5) and rename the new worksheet Tutorial_7.
- Create a new cell with the value of the variable "Max_scale"
- A23: "Max_scale" (a label),
- B23: "=x_scale_max + y_scale_max - x_scale_min - y_scale_min"
- Name cell B32 "Max_scale"

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	A	B
21	y_scale_max	3
22	y_scale_min	-3
23	Max_scale	16
24		

How to use the new function to calculate the incident and the reflected rays:

- Range E41:M41 contains labels. E42: "=0", E46: "=E42+1".
- F42: "=Reflect_7(xL,yL,xM,yM,alpha_min+E42*delta_alpha,Radius,Max_scale)" then select F42:M42 and holding F2 - down hit Ctrl+Shift+Enter
- F43: "=H42", G43: "=I42" - represent the coordinates of the incident point
- F44: "=J42", G44: "=K42" - represent the coordinates of the terminal point of the real reflected ray
- Copy range F42:M44 into range F46:M48
- Copy range E46:M49 into range E50:M141

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	E	F	G	H	I	J	K	L	M
39									
40									
41	Ray_index	x	y	xi	yi	xr	yr	xv	yv
42	0	-5	0	2.401924	-1.5	-2.68664	-16.6693	7.490488	13.66926
43		2.401924	-1.5						
44		-2.68664	-16.6693						
45									
46	1	-5	0	2.324826	-1.35773	-4.60878	-15.7773	9.258428	13.06188
47		2.324826	-1.35773						
48		-4.60878	-15.7773						
49									
50	2	-5	0	2.259678	-1.22092	-6.31918	-14.7266	10.83854	12.28475
51		2.259678	-1.22092						

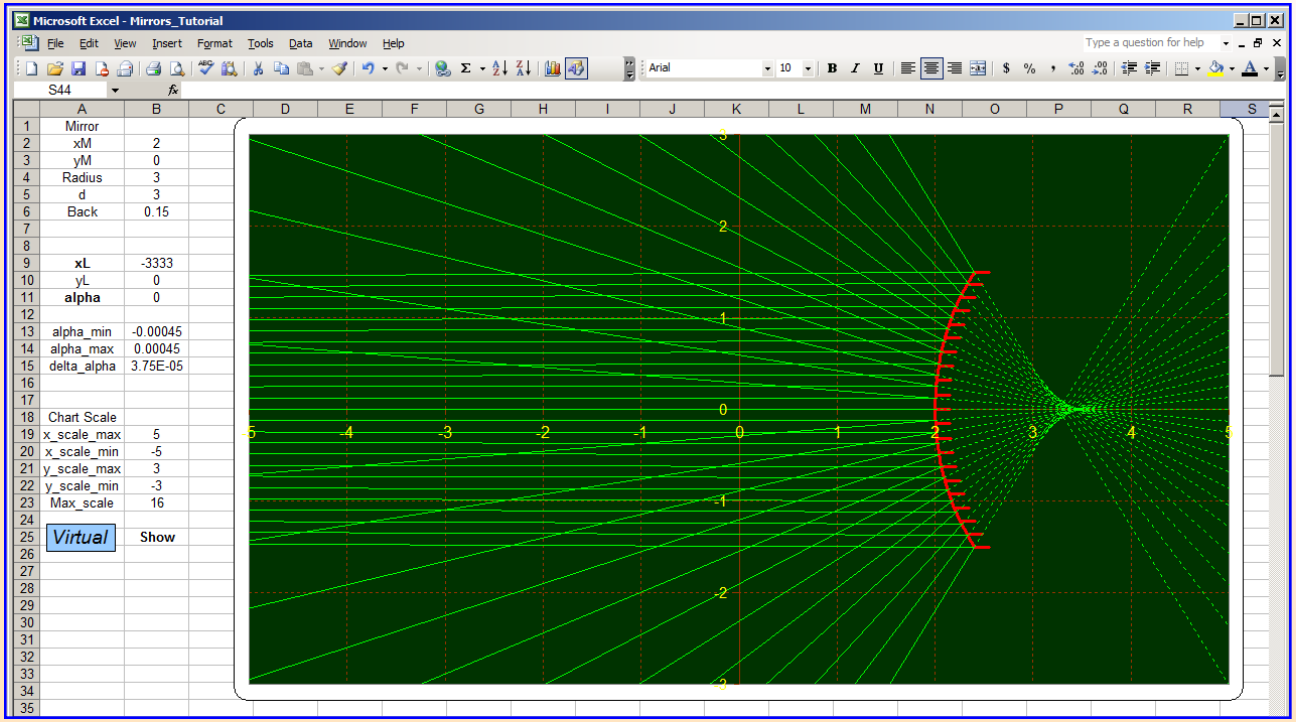
Calculate the virtual rays:

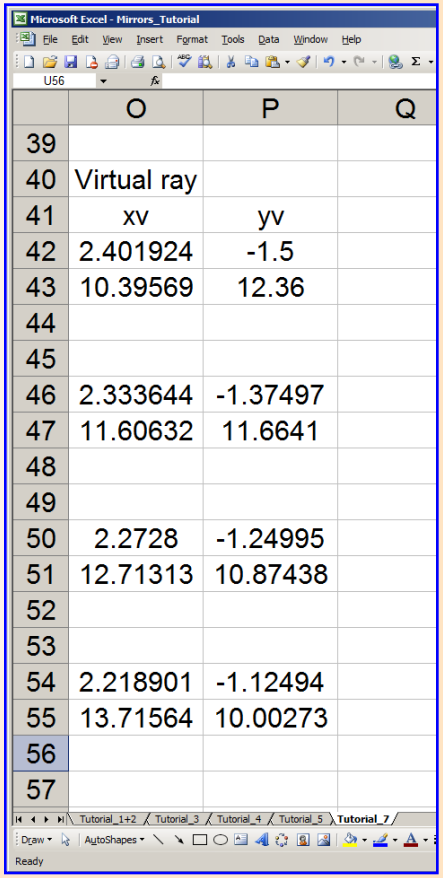
- First, we would like to have the option of turning these rays on and off (making them visible or invisible).
- For this we will use a button and a "switch cell".

- Create a text box with the label "Virtual" and assign to it the macro shown to the right:
- Whenever the button is clicked, this macro will toggle the value in cell [B25] between "Show" and "Hide"
- We will use this cell to conditionally move the virtual ray curves in and out of sight (in or out of the visible charting area)

```
Sub Virtual()
    If [B25] = "Show" Then
    [B25] = "Hide"
    Else
    [B25] = "Show"
    End If
End Sub
```

- We will generate the virtual ray data in range O42:P139.
- Range O40:P41 contains labels.
- O42: "=H42", P42: "=IF(B$25="Show", I42, 7777)"
- O43: "=L42", P43: "=IF(B$25="Show", M42, 7777)"
- Copy range O42:P45 into range O46:P141 and the table is complete
- After that make sure to add range O42:P139 as a new series on the chart (named "Virtual"). Use a dotted line as a pattern and a color you like.





	O	P	Q
39			
40	Virtual ray		
41	xv	yv	
42	2.401924	-1.5	
43	10.39569	12.36	
44			
45			
46	2.333644	-1.37497	
47	11.60632	11.6641	
48			
49			
50	2.2728	-1.24995	
51	12.71313	10.87438	
52			
53			
54	2.218901	-1.12494	
55	13.71564	10.00273	
56			
57			

to be continued...