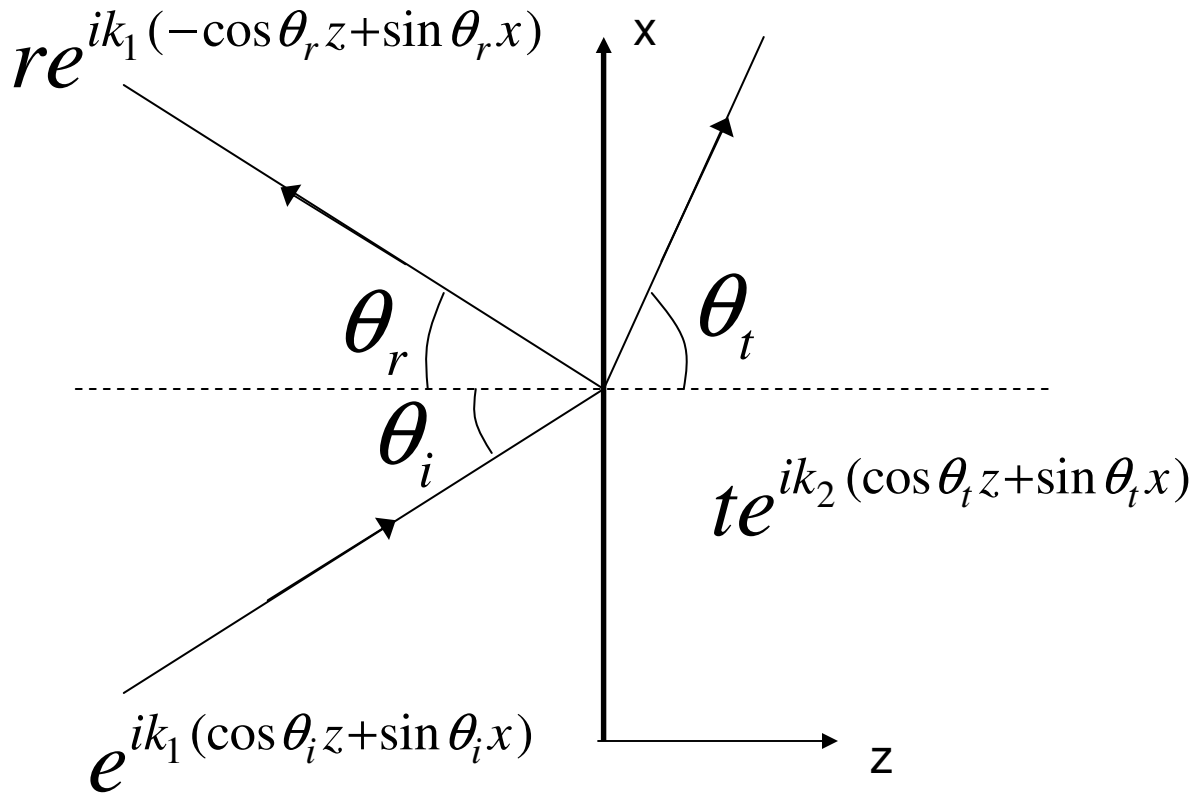


BCs, e.g. $E_{||}^1 = E_{||}^2$:

$$\cos\theta_i\, e^{ik_1(\cos\theta_i z+\sin\theta_i x)}\Big|_{z=0} + r\cos\theta_r e^{ik_1(-\cos\theta_r z+\sin\theta_r x)}\Big|_{z=0} = t\cos\theta_t e^{ik_2(\cos\theta_t z+\sin\theta_t x)}\Big|_{z=0}$$

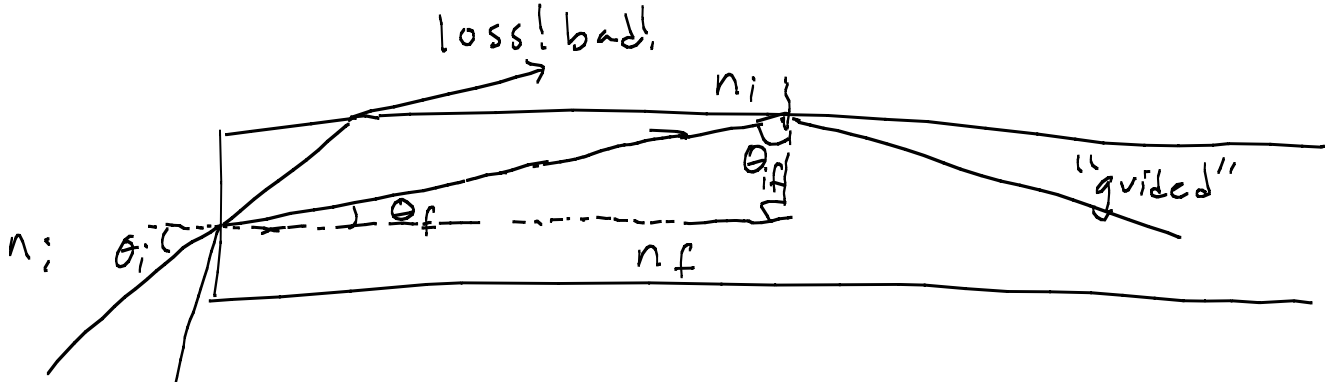
This is only true for all *x* if:

$$k_1\sin\theta_i = k_1\sin\theta_r = k_2\sin\theta_t \qquad \frac{\omega}{k_1} = \frac{c}{n_1}$$

$$k_1 = \frac{n_1\omega}{c}$$

$$\theta_i = \theta_r \qquad n_1\sin\theta_i = n_2\sin\theta_t$$

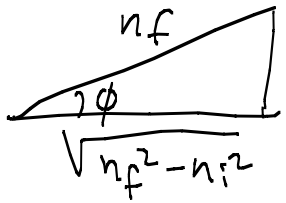
TIR application: fiber optics



top surface: $n_f \sin\theta_{if}^c = n_i \sin\frac{\pi}{2} \rightarrow \theta_{if} > \theta_{if}^c = \sin^{-1}\frac{n_i}{n_f}$
(sides of fiber)

$$\sin\theta_f = \cos\theta_{if}$$

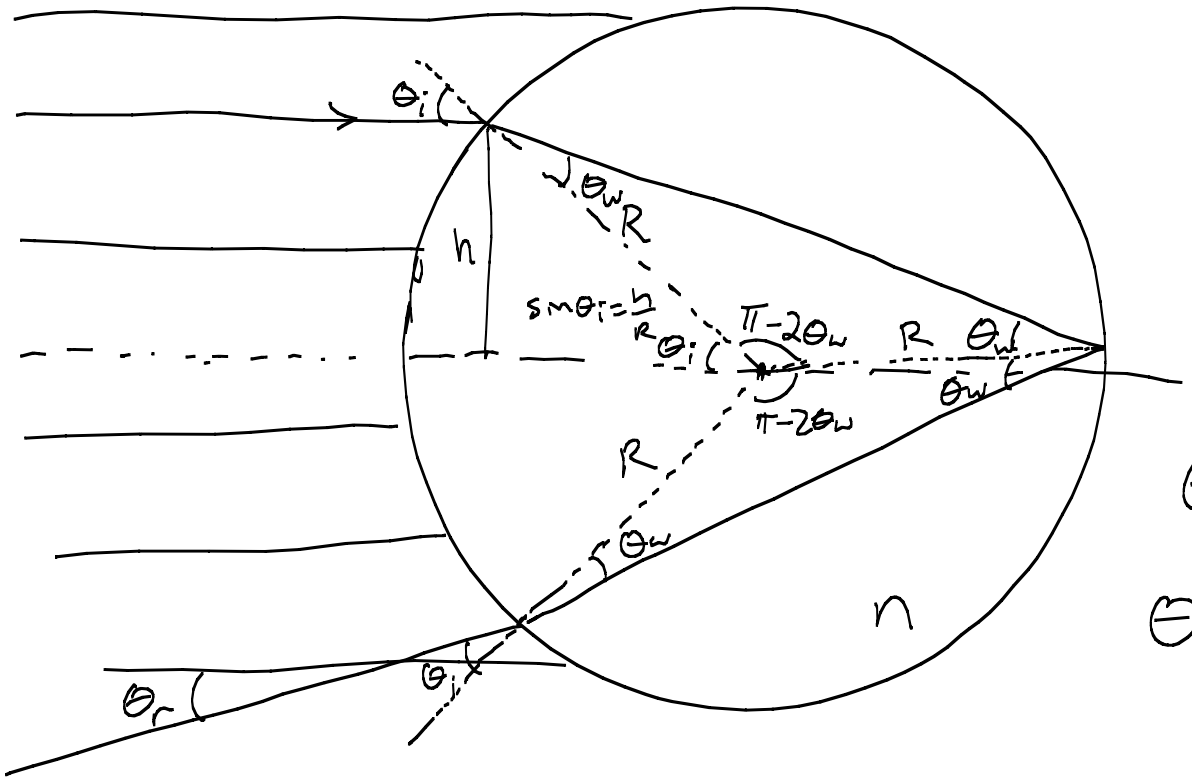
Input interface: $n_i \sin\theta_i^c = n_f \sin\theta_f^c = n_f \cos\theta_{if}^c = n_f \cos\left(\sin^{-1}\frac{n_i}{n_f}\right)$



$$n_i \sin\theta_i^c = n_f \frac{\sqrt{n_f^2 - n_i^2}}{n_f}$$

$$\theta_i < \theta_i^c = \sin^{-1}\frac{\sqrt{n_f^2 - n_i^2}}{n_i} = \sin^{-1}\sqrt{\left(\frac{n_f}{n_i}\right)^2 - 1}$$

Refraction and Reflection in a sphere



$$\sin\theta_i = n \sin\theta_w$$

$$\theta_w = \sin^{-1}\frac{\sin\theta_i}{n}$$

$$\theta_{tot} = 2(\pi - 2\theta_w) + 2\theta_i$$

$$\theta_r = 2\pi - \theta_{tot} = 4\theta_w - 2\theta_i$$

$$= 4\sin^{-1}\left(\frac{\sin\theta_i}{n}\right) - 2\theta_i$$

$$\theta_i = \sin^{-1}\frac{h}{R}$$

Caustics

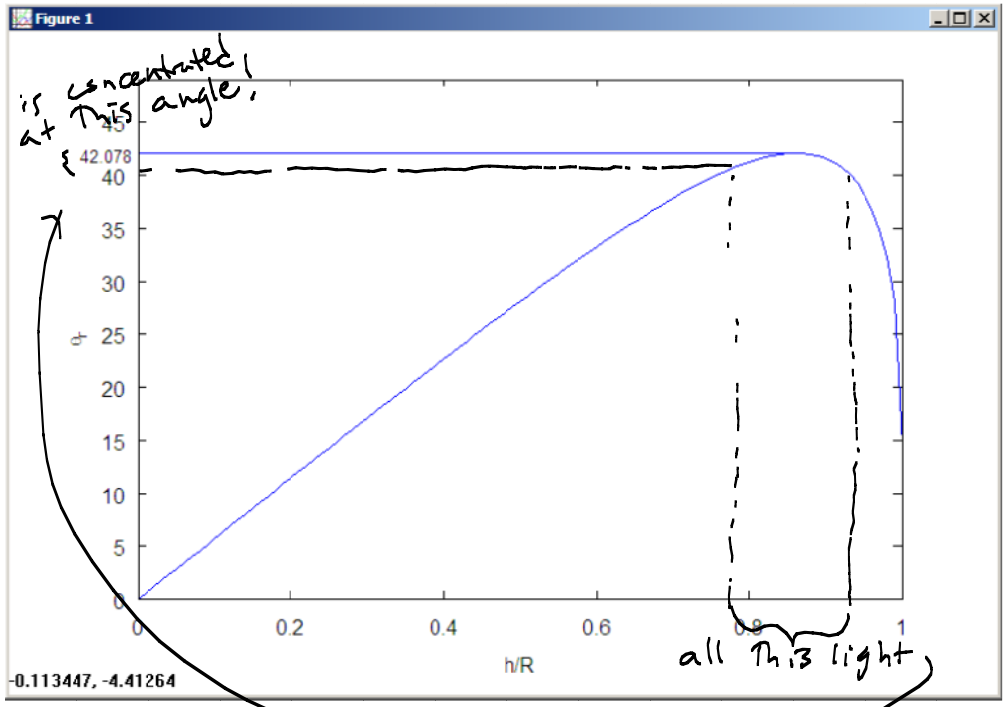


Figure 1
is concentrated at this angle!
42.078
45
40
35
30
25
20
15
10
5
0
θ_r
0
0.2
0.4
0.6
0.8
1
h/R
all this light
-0.113447, -4.41264

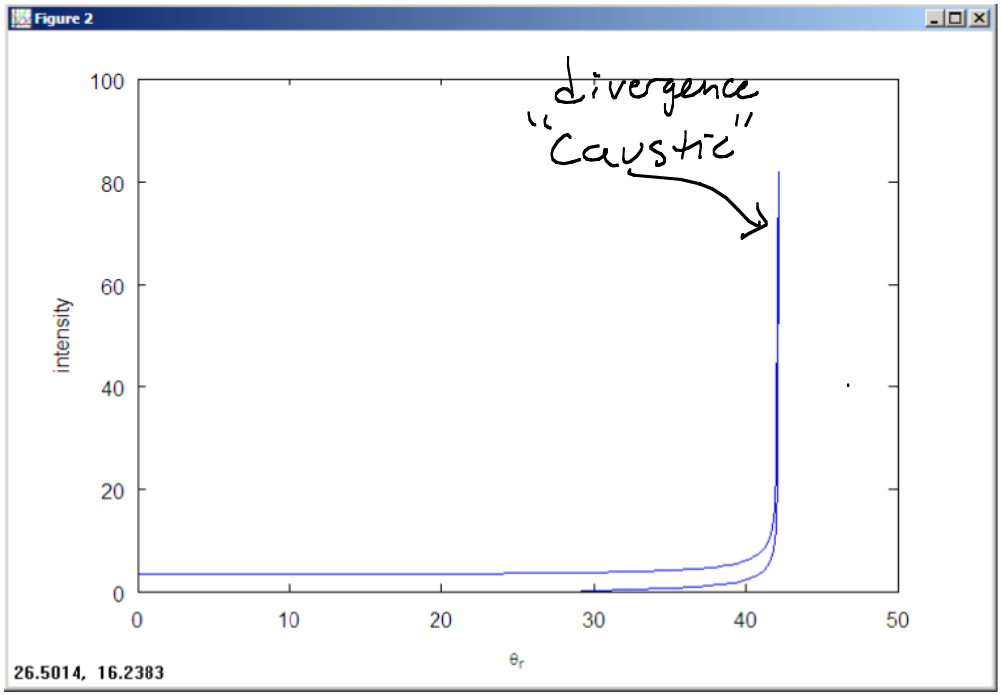
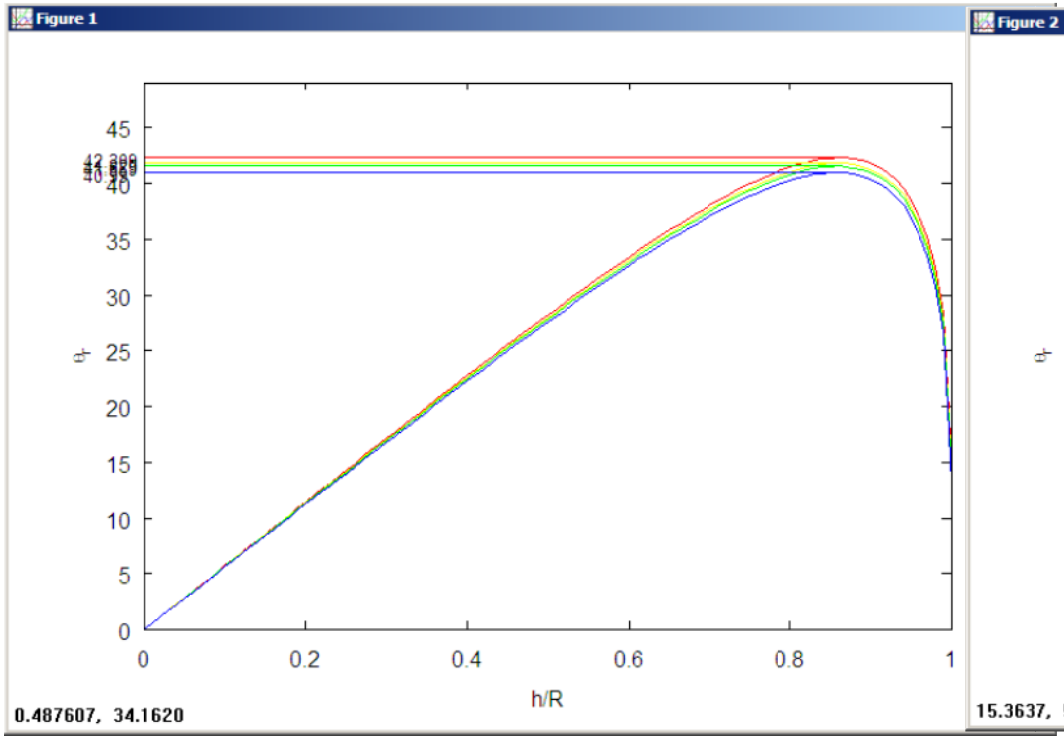
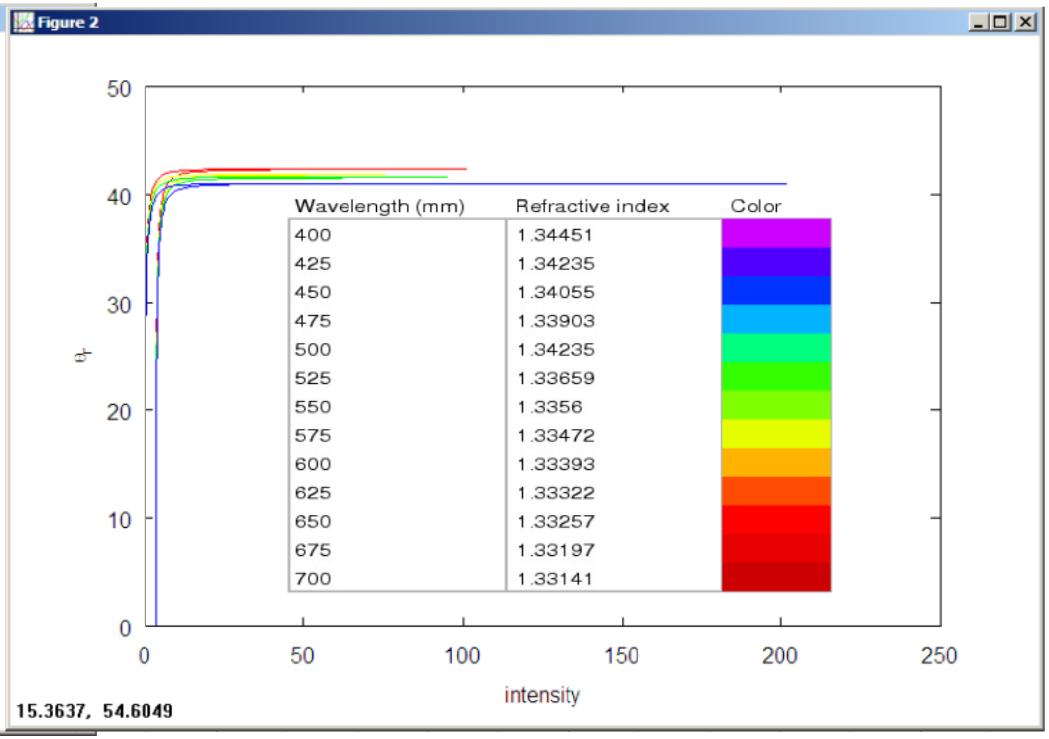


Figure 2
divergence
"Caustic"
100
80
60
40
20
0
intensity
0
10
20
30
40
50
θ_r
26.5014, 16.2383

Rainbows





Second rainbow from 2 internal reflections → colors reversed!

primary rainbow