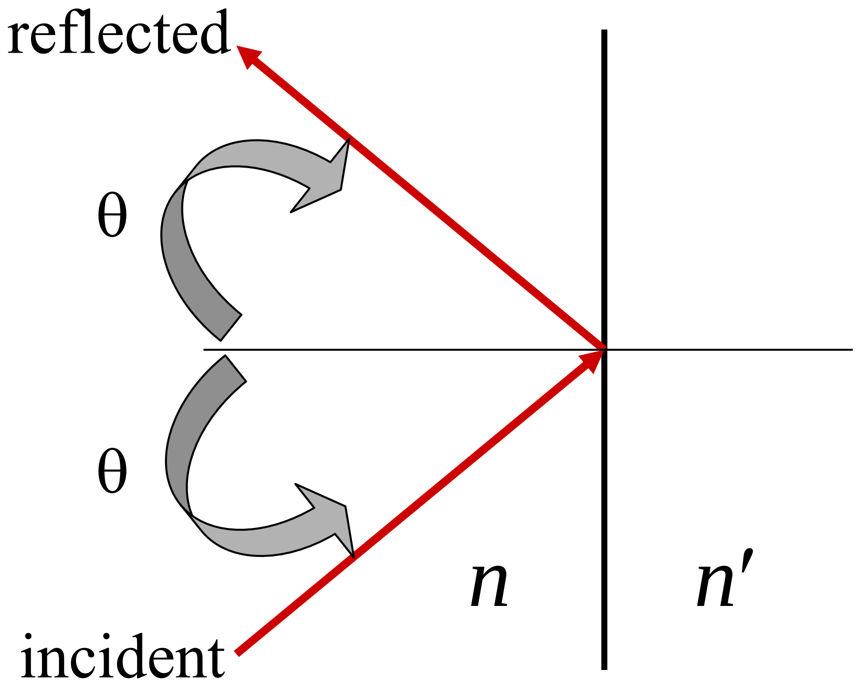
Prisms, fibers, and reflective lenses

- Total internal reflection
- Prisms
- Dispersion
- Optical fibers and other waveguides
- Reflection from paraboloidal mirrors

Total Internal Reflection (TIR)



E.g. interface from glass to air

$n=1.5,\ n'=1$

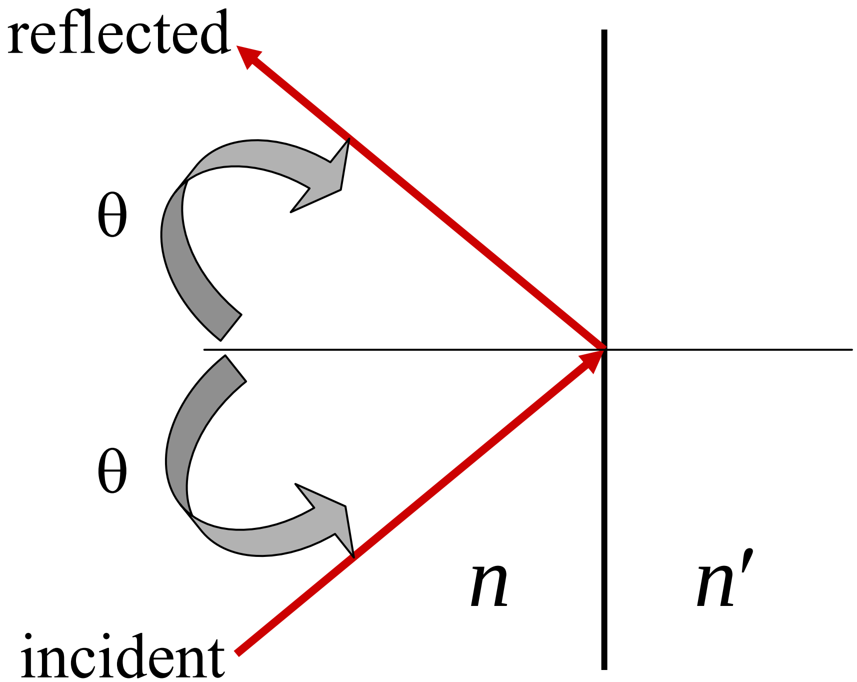
$\frac{n}{n'}\sin\theta > 1$ if

$$\theta > \theta_{crit} = \sin^{-1}\frac{n'}{n} = 41.8^\circ$$

$$n\sin\theta = n'\sin\theta' \Rightarrow \sin\theta' = \frac{n}{n'}\sin\theta$$

what if $\frac{n}{n'}\sin\theta > 1$ ...?

Total Internal Reflection (TIR)



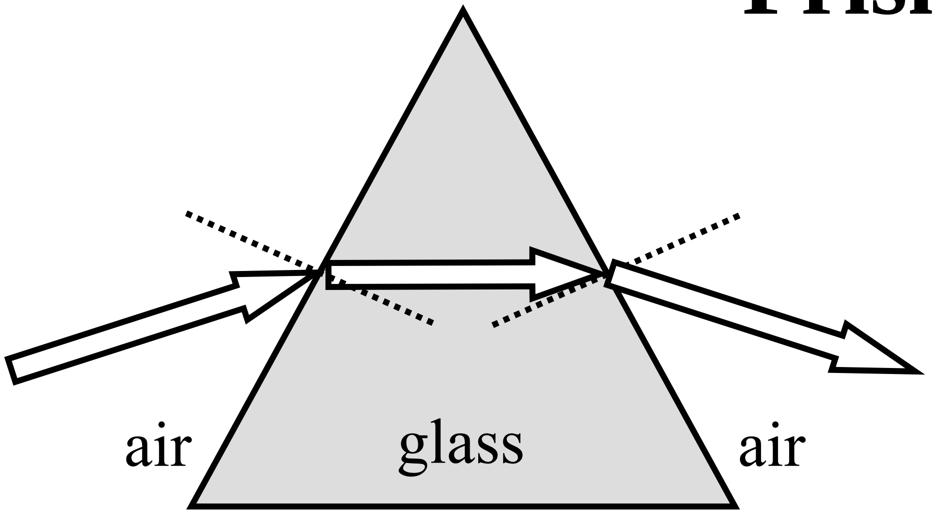
no light enters the optically less dense space

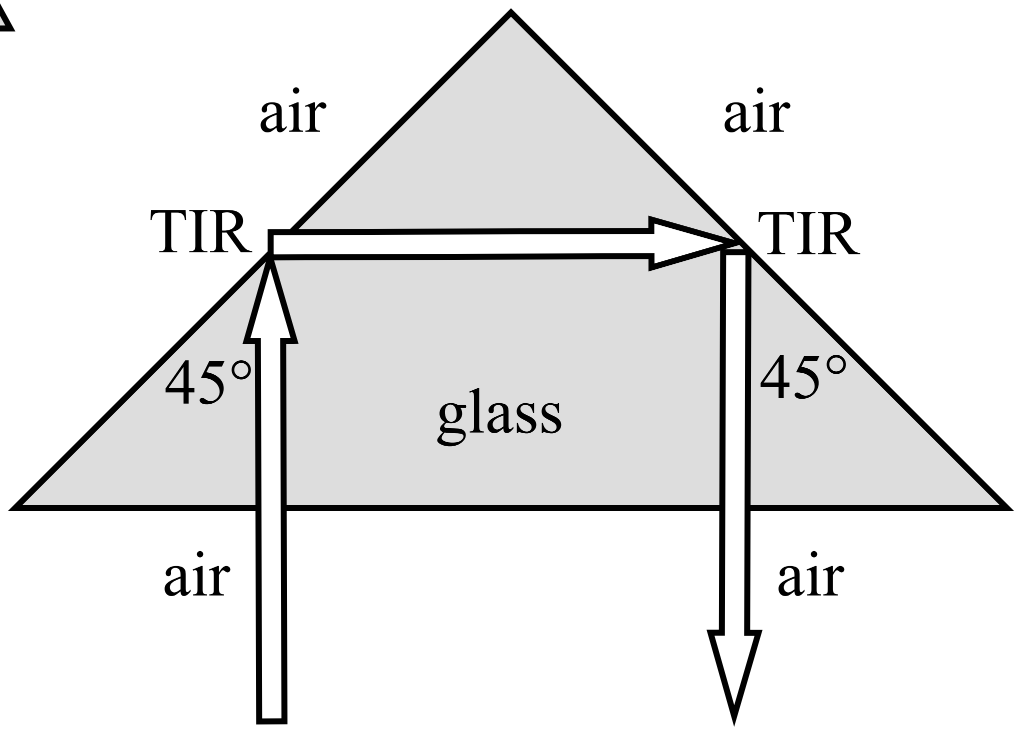
(in actuality the light field in the optically dense space is evanescent, i.e. exponentially decaying)

θ' becomes imaginary when $\theta > \theta_{\text{crit}}$

$\Rightarrow$ reflected beam disappears, all energy is reflected

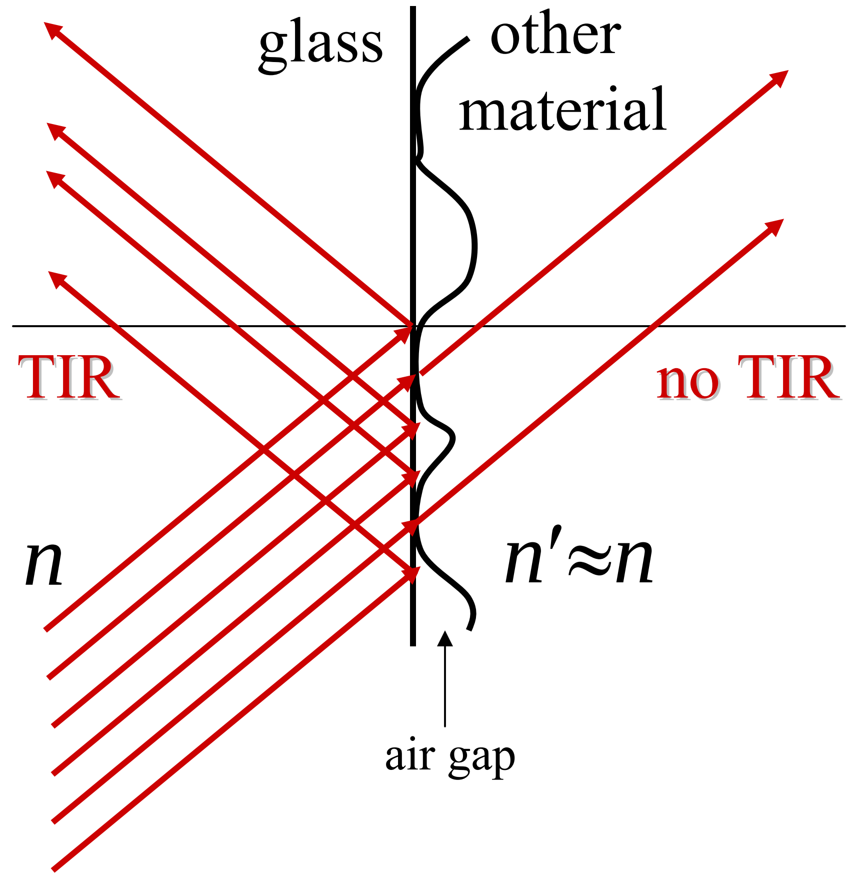
Prisms





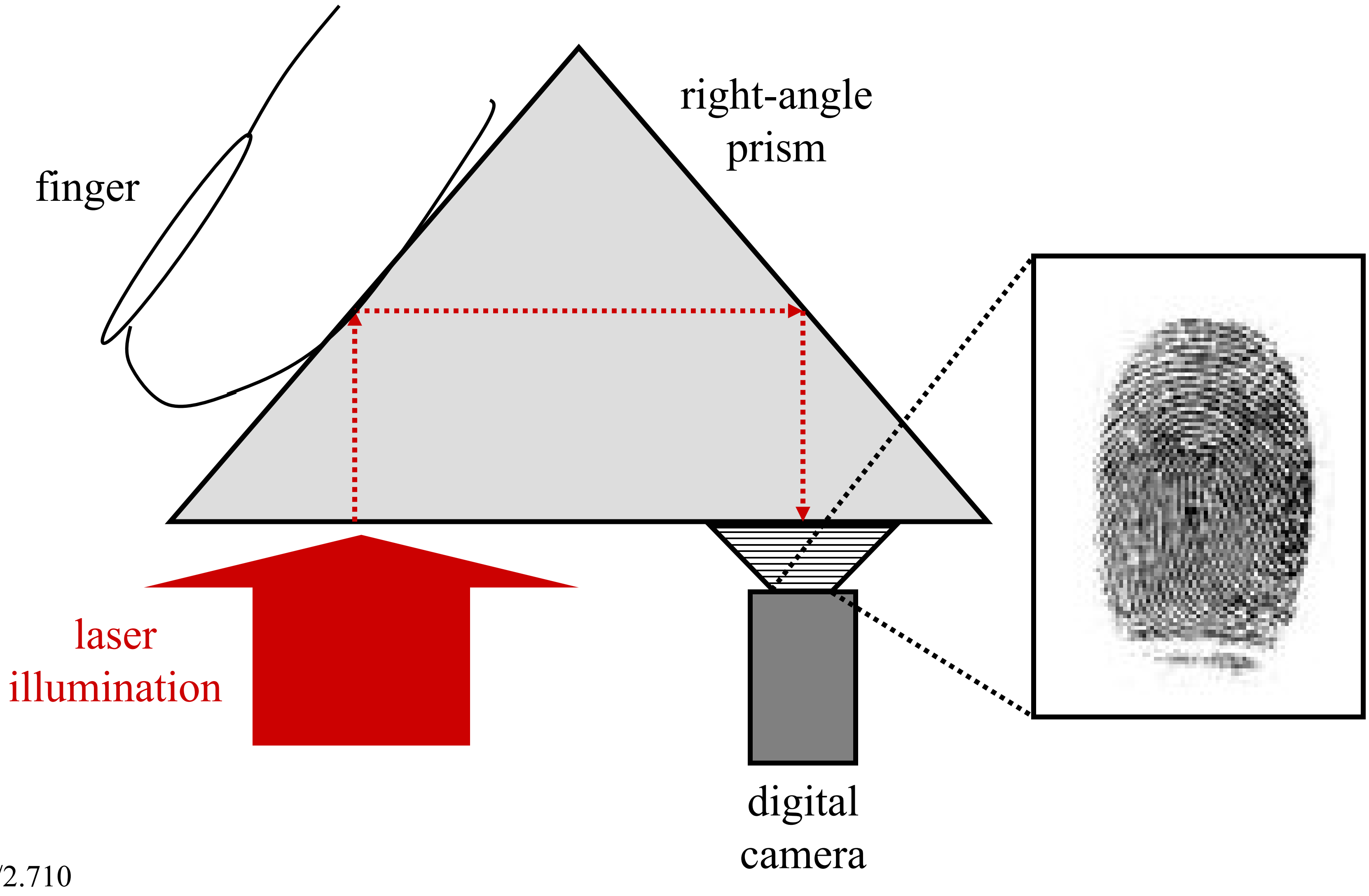
Frustrated Total Internal Reflection (FTIR)

Reflected rays are missing where index-matched surfaces touch ⇒ shadow is formed

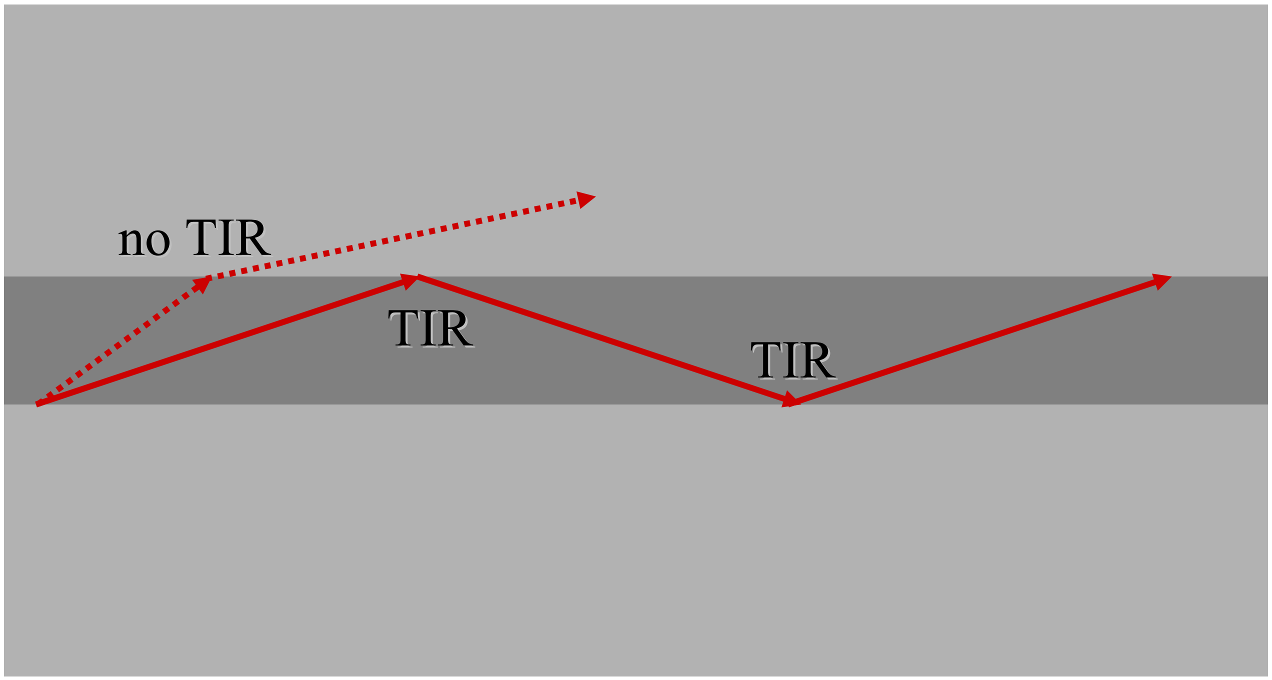


Angle of incidence exceeds critical angle

Fingerprint sensors



Optical waveguides

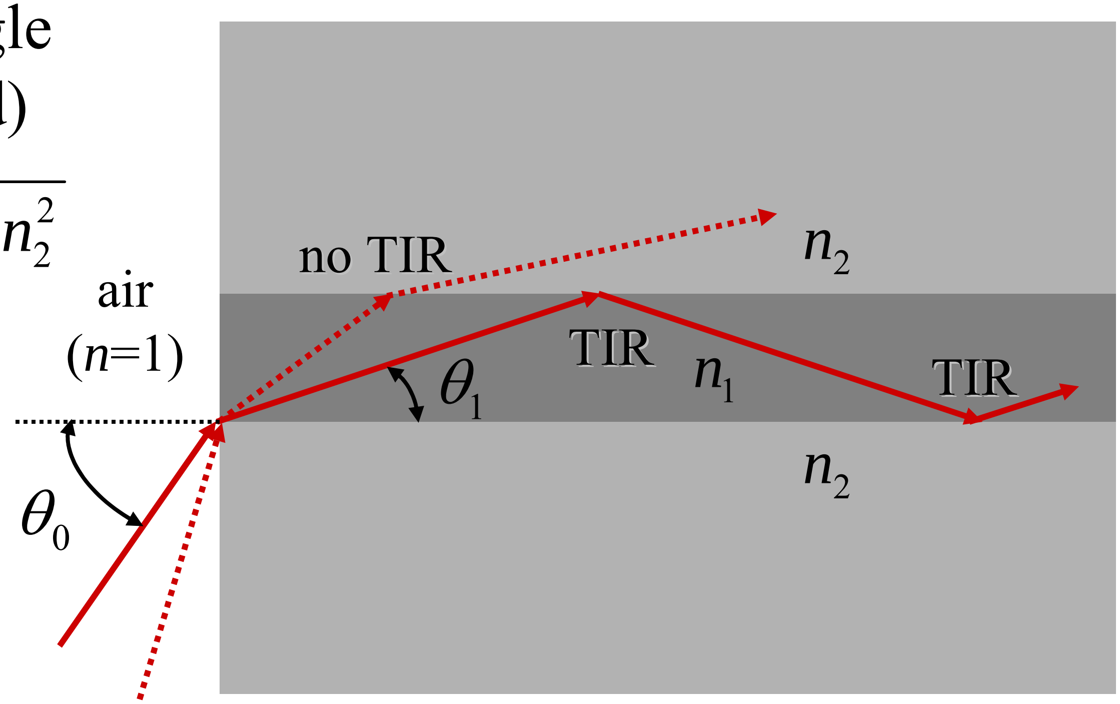


"planar" waveguide: high-index dielectric material sandwiched between lower-index dielectrics

Optical waveguides: numerical aperture (NA)

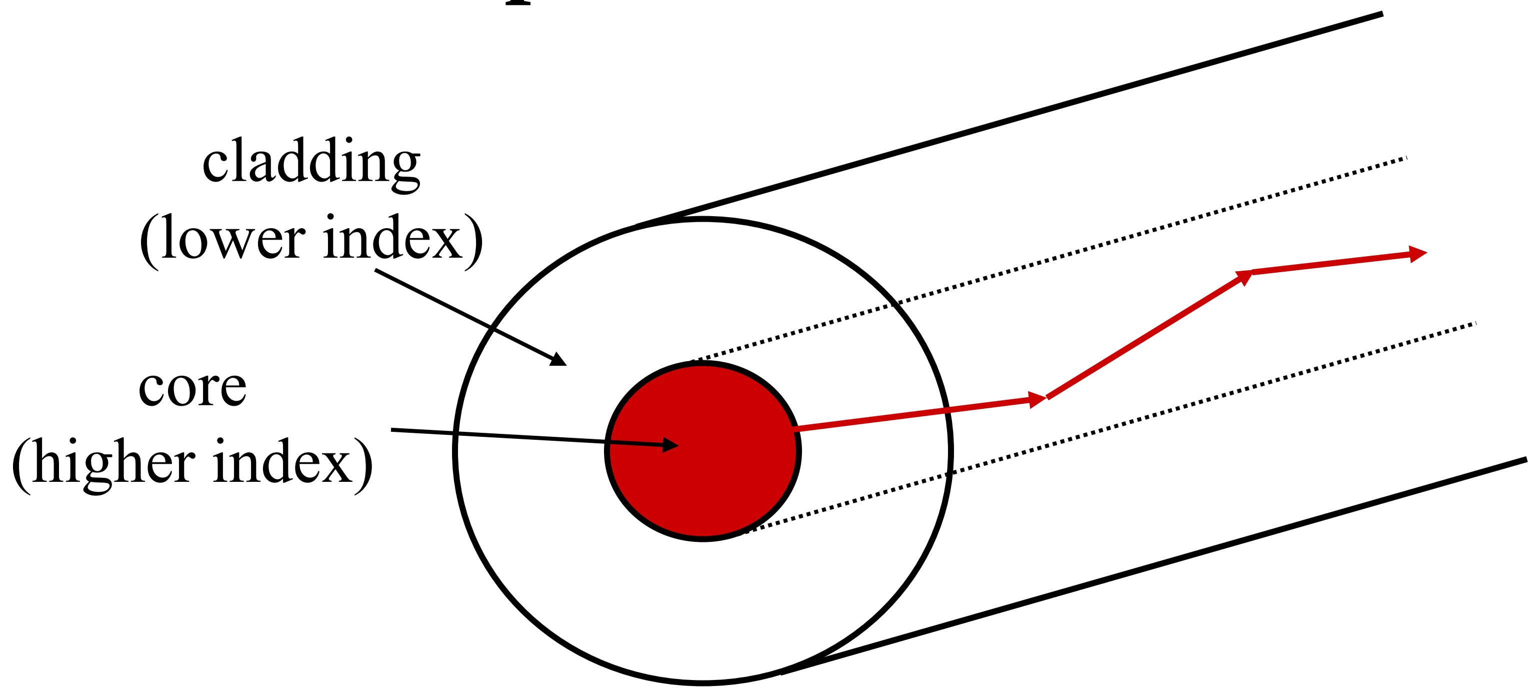
NA=sin(largest angle that is waveguided)

$$\mathrm{NA} = \sin\theta_0 \leq \sqrt{n_1^2 - n_2^2}$$



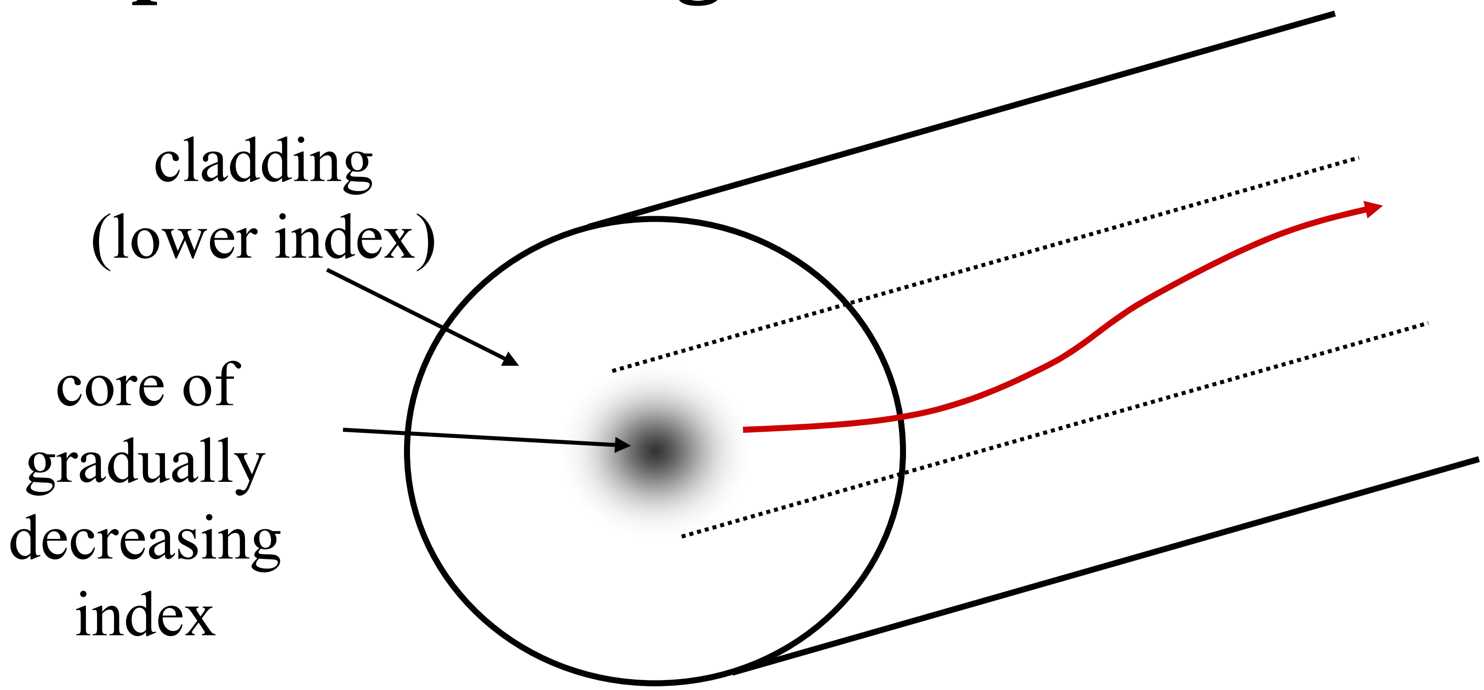
high index contrast (n_1/n_2) ⇔ high NA

Optical fibers



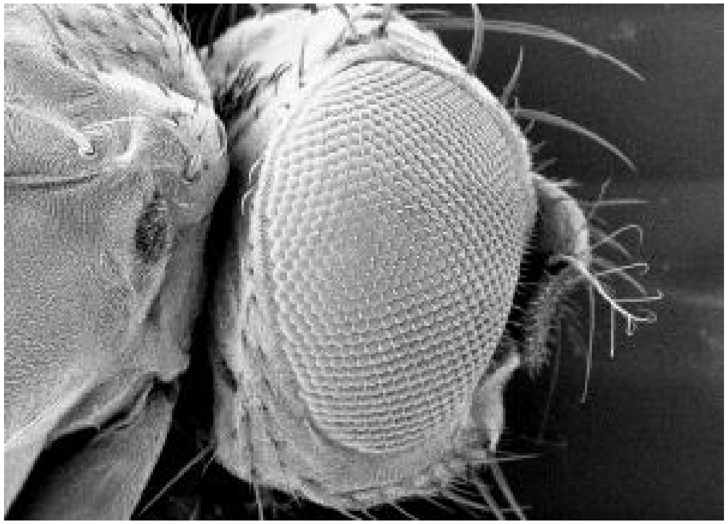
Core diameter = 8-10μm (commercial grade)
Cladding diameter = 250μm (commercial grade)
Index contrast Δn = 0.007 (*very* low NA)
attenuation = 0.25dB/km

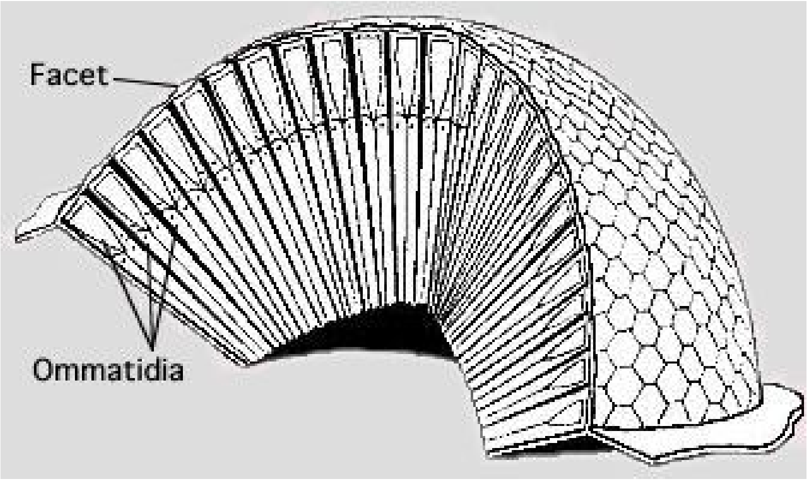
Optical fibers: gradient index

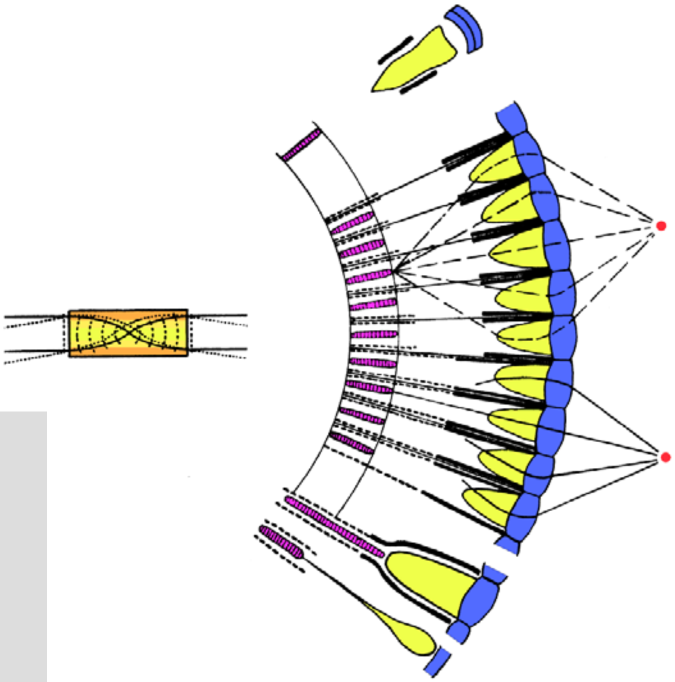


optical rays “swirl” around the axis of the core!

Gradient index waveguides in nature: insect eyes (composite eyes)

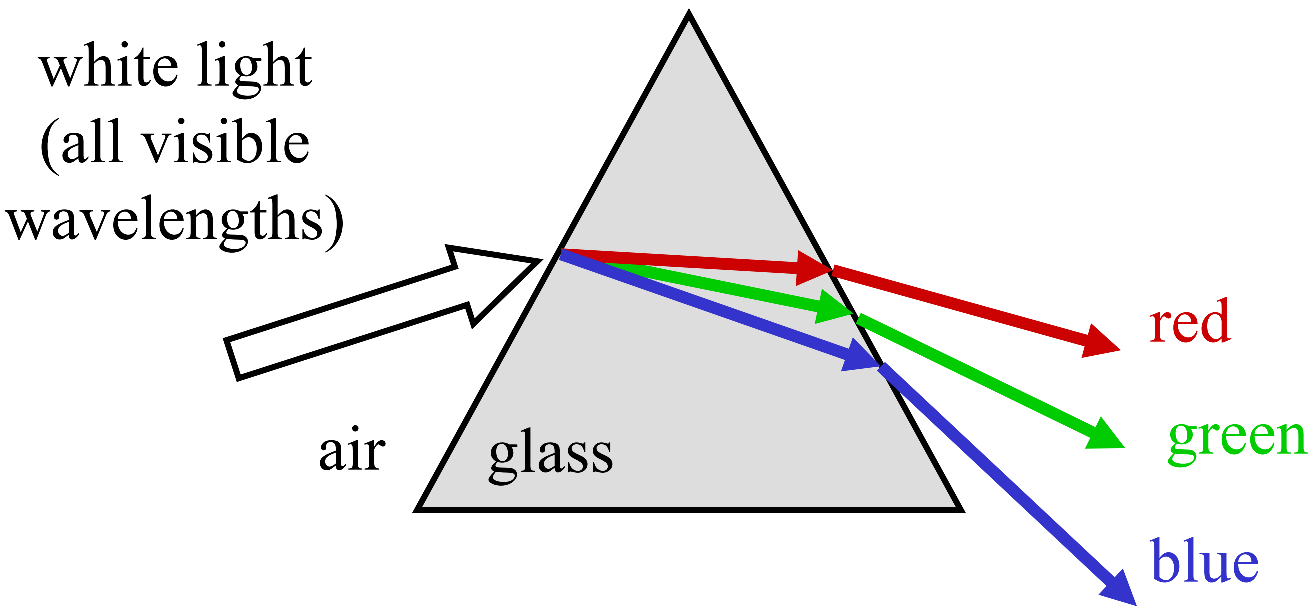






Dispersion

Refractive index *n* is function of the wavelength



Newton's prism

Dispersion measures

Reference color lines
C (H- λ=656.3nm, red), D (Na- λ=589.2nm, yellow),
F (H- λ=486.1nm, blue)

Crown glass has

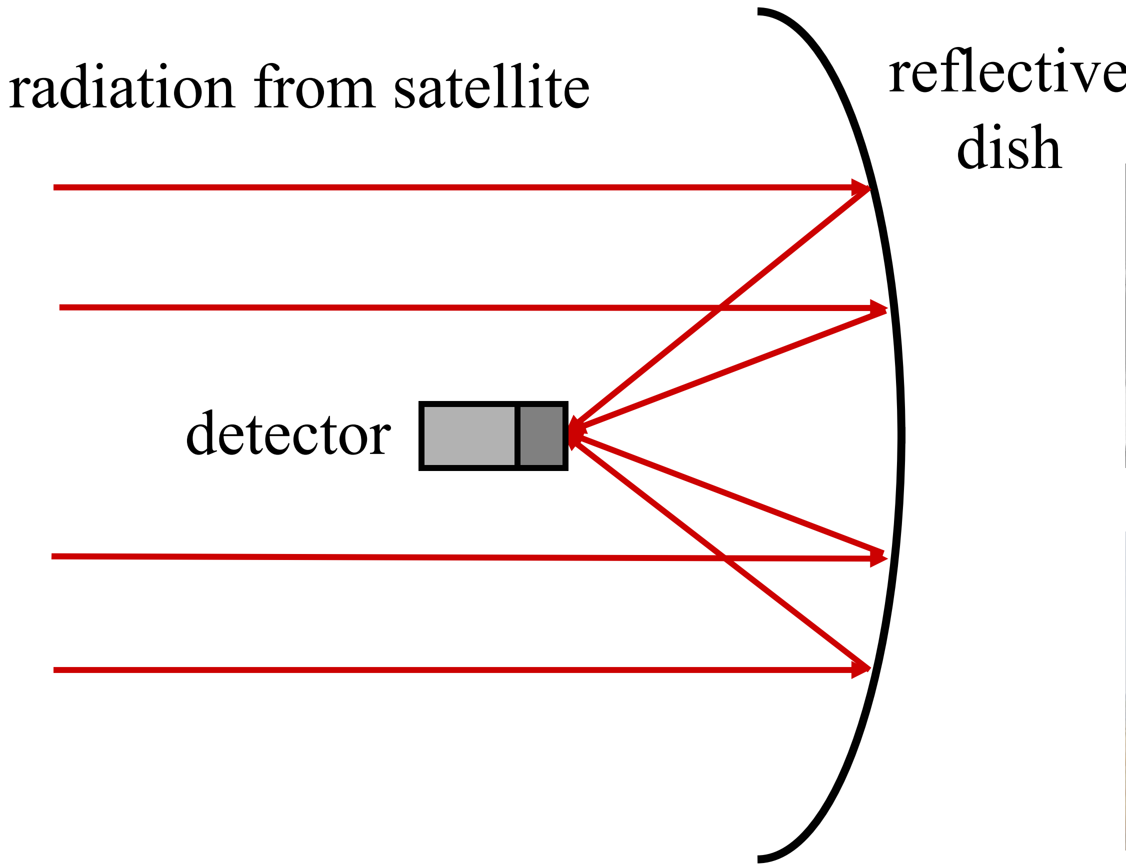
$n_F = 1.52933$ $n_D = 1.52300$ $n_C = 1.52042$

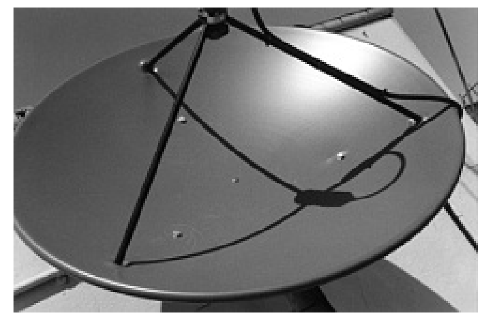
Dispersive power $V = \frac{n_F - n_C}{n_D - 1}$

Dispersive index $v = \frac{1}{V} = \frac{n_D - 1}{n_F - n_C}$

Curved reflecting surfaces

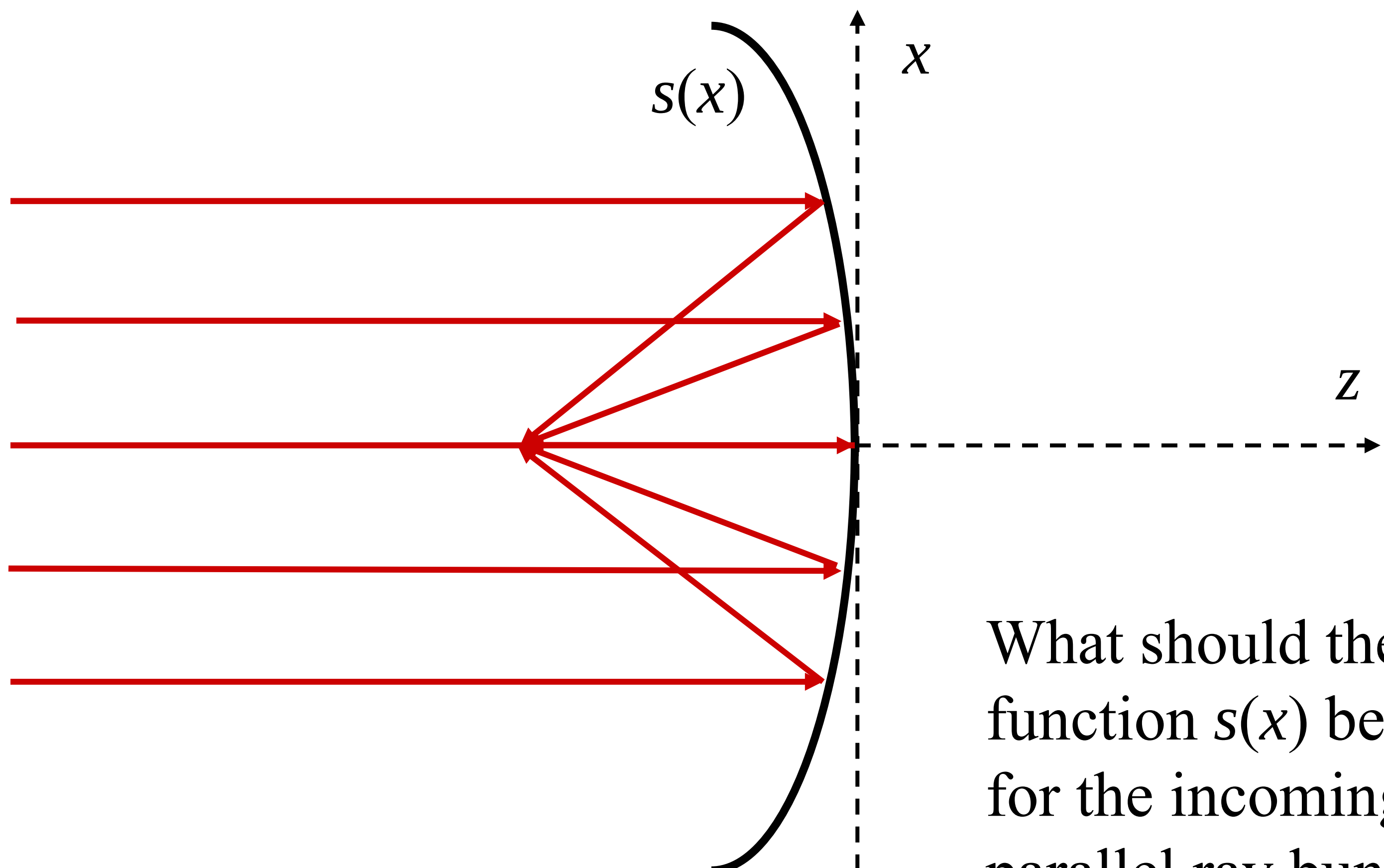
(e.g. satellite dish)





Paraboloid mirror: perfect focusing

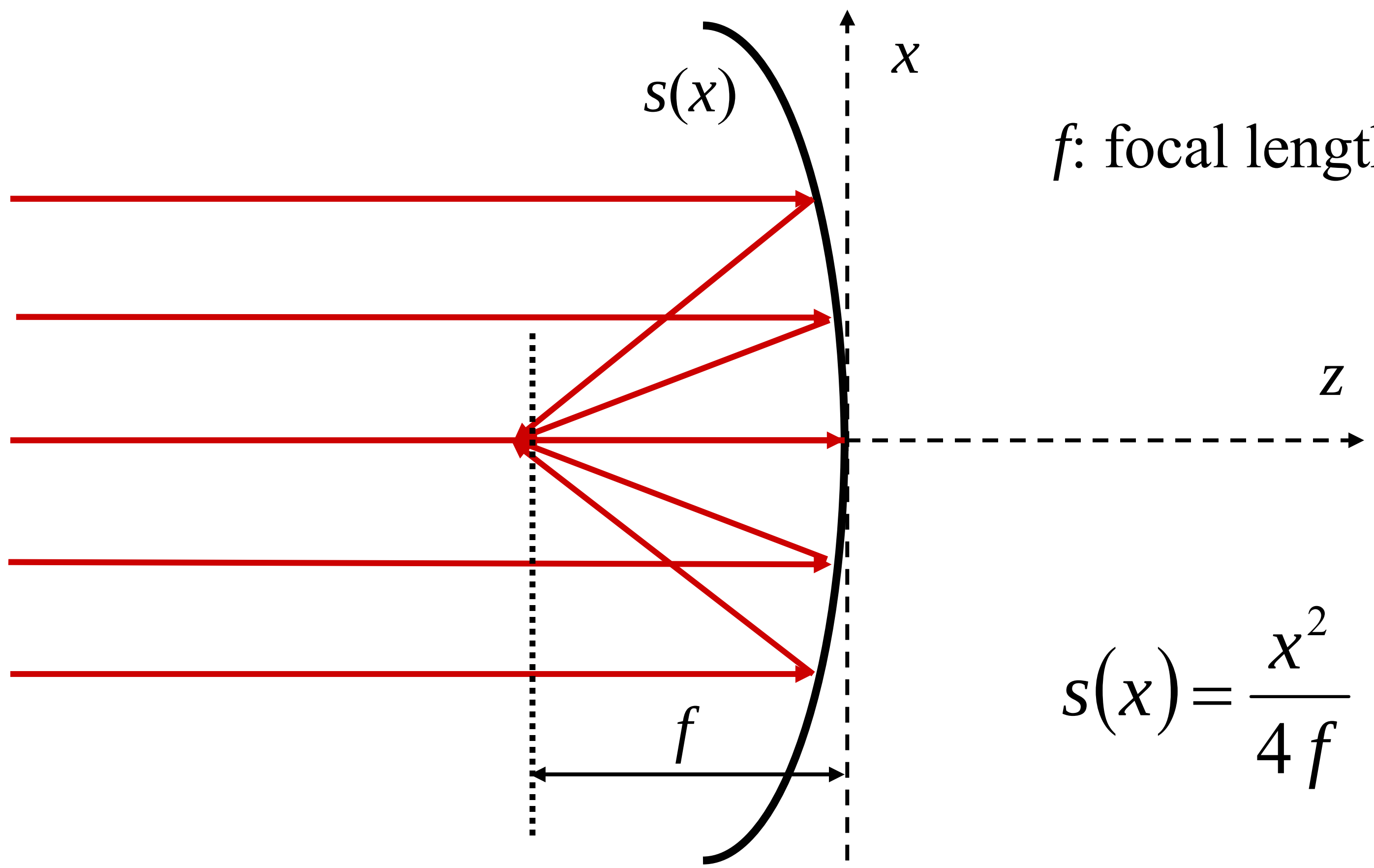
(e.g. satellite dish)



What should the shape function $s(x)$ be in order for the incoming parallel ray bundle to come to perfect focus?

Paraboloid mirror: <u>perfect</u> focusing

(e.g. satellite dish)



f: focal length

$$s(x) = \frac{x^2}{4f}$$