Lesson 6

Optics

Refraction index

- Speed of light is a function of the media.
- In vacuum it's *c=~300,000km/s.*
- In other media than vacuum it's a function of the material.
- The refraction index is defined as a measure of the change in the speed of light.

$$n(\lambda) = \frac{c}{v(\lambda)}$$

Table 5.1. *Indices of refraction. Both the index and dispersion are given at the wavelength of the Fraunhofer D line. Data after Pedrotti et. al. (2006) and the Schott Glass (2009) website**

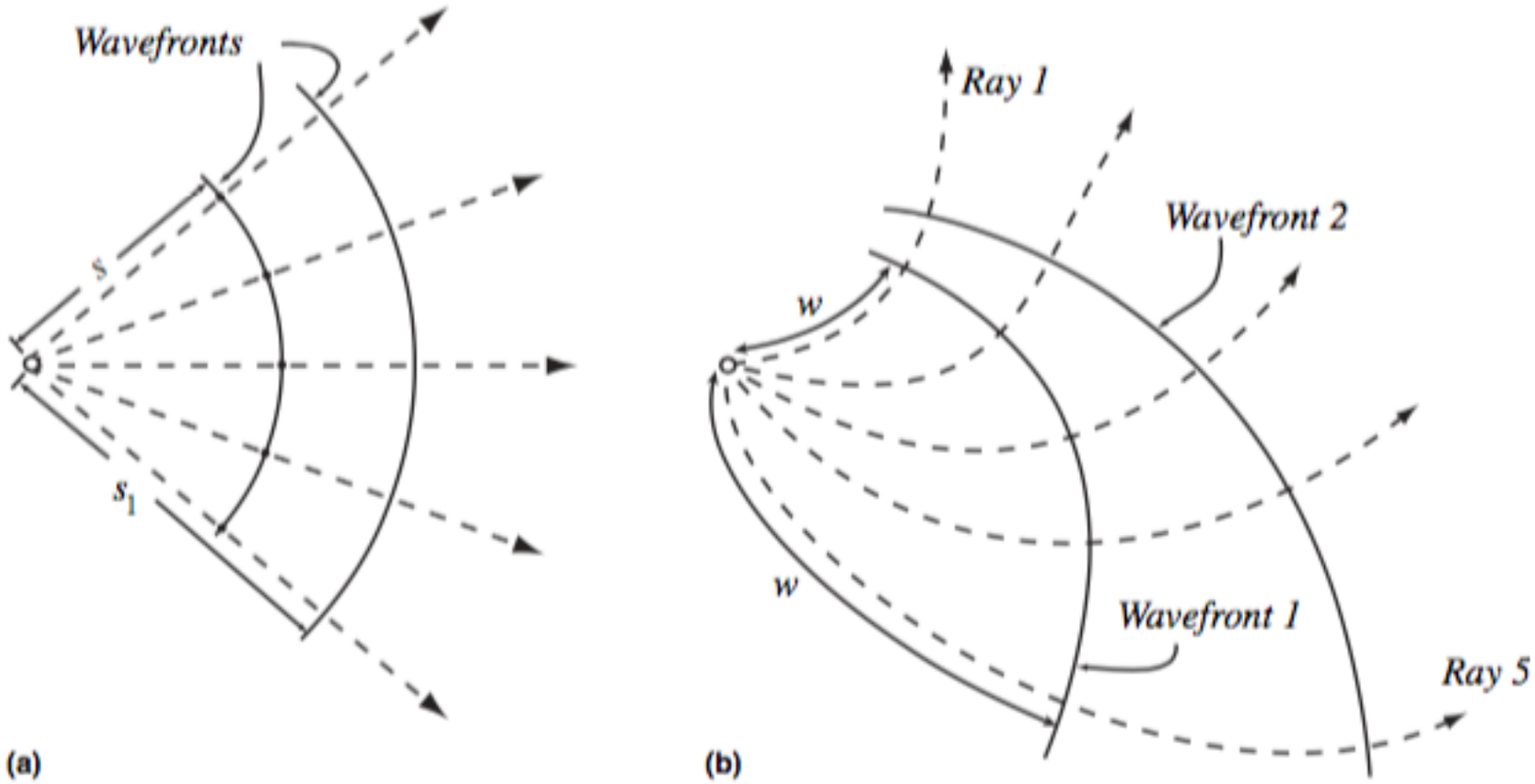
Material	n ($\lambda = 588$ nm)	$dn/d\lambda$ (μm^{-1})	ν_D
Air (STP)	1.00029	2×10^{-5}	85
Water	1.33	0.017	114
Calcium fluoride	1.435	0.027	95
Fused quartz	1.458	0.040	68
Borosilicate crown glass (BK7)	1.517	0.047	64
Flint glass (F2)	1.620	0.100	36
Dense flint glass (SF4)	1.756	0.161	28
Diamond	2.42	0.250	33

* http://www.us.schott.com/optics_devices/english/download/kataloge.html

Dispersion

- Dispersion is the result of the refraction index being a function of λ.
- D=dn/dλ
- Abbe # $$\nu_D = \frac{(n(\lambda 588) - 1)}{(n(\lambda 486) - n(\lambda 656))}$$
- All the points (in a homogeneous medium) at a distance s=ct/n determine the wavefront.

Wavefront

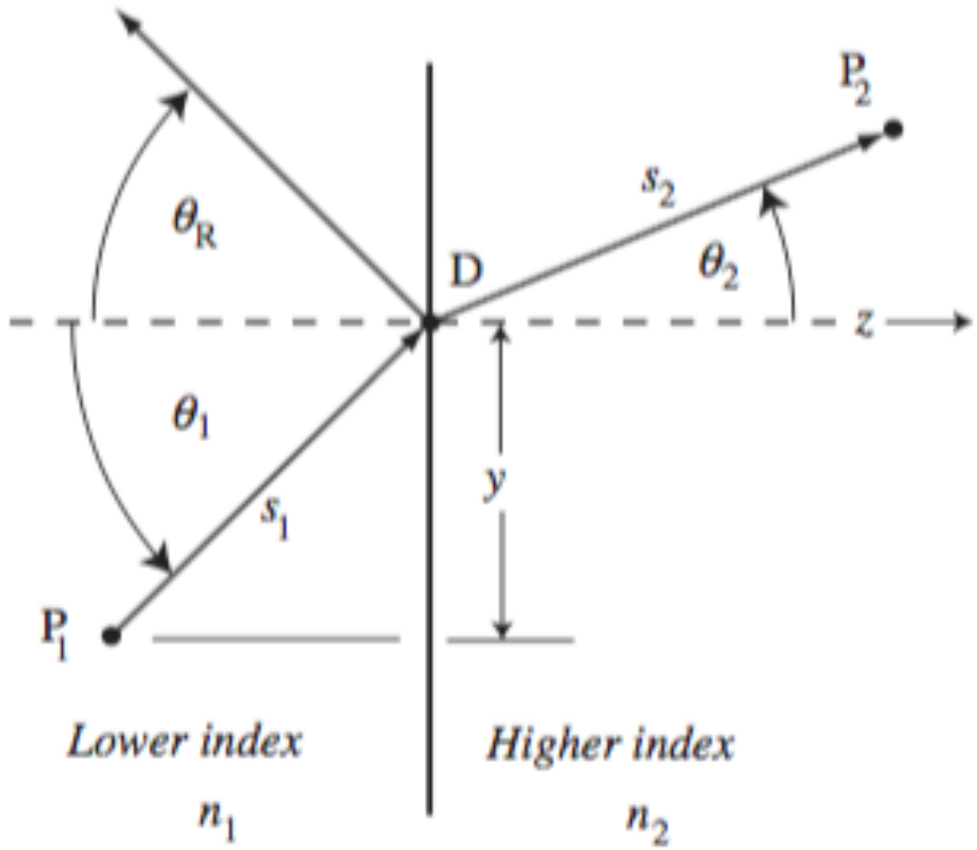


- Everywhere on the wavefront the optical path length and travel time from the source are constants.

$$t = \int \frac{ds}{v} = \frac{1}{c} \int nds = \frac{w}{c}$$

- $w = \int nds$ is the optical path length.

Fermat's principle and Snell's law

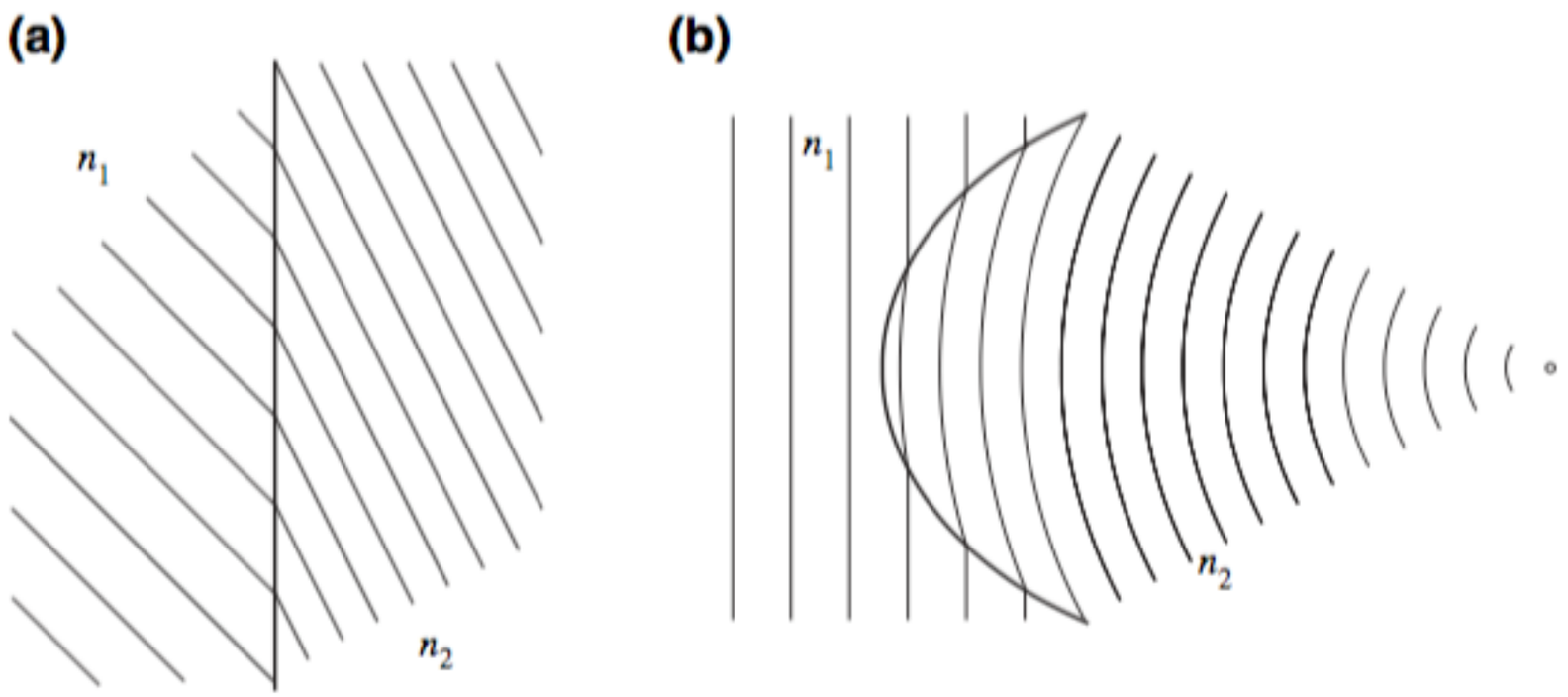


$$\theta_1 = -\theta_R \qquad\qquad n_1 \sin\theta_1 = n_2 \sin\theta_2$$

- Total internal reflection

$$\theta_C = \sin^{-1}\left(\frac{n_1}{n_2}\right)$$

Wavefronts



Reflection and refraction coefficients

- The reflectance, R, is the fraction of the power of the incident wave that is reflected. At normal incidence (h1 = 0) for all cases (TE, TM, external, or internal):

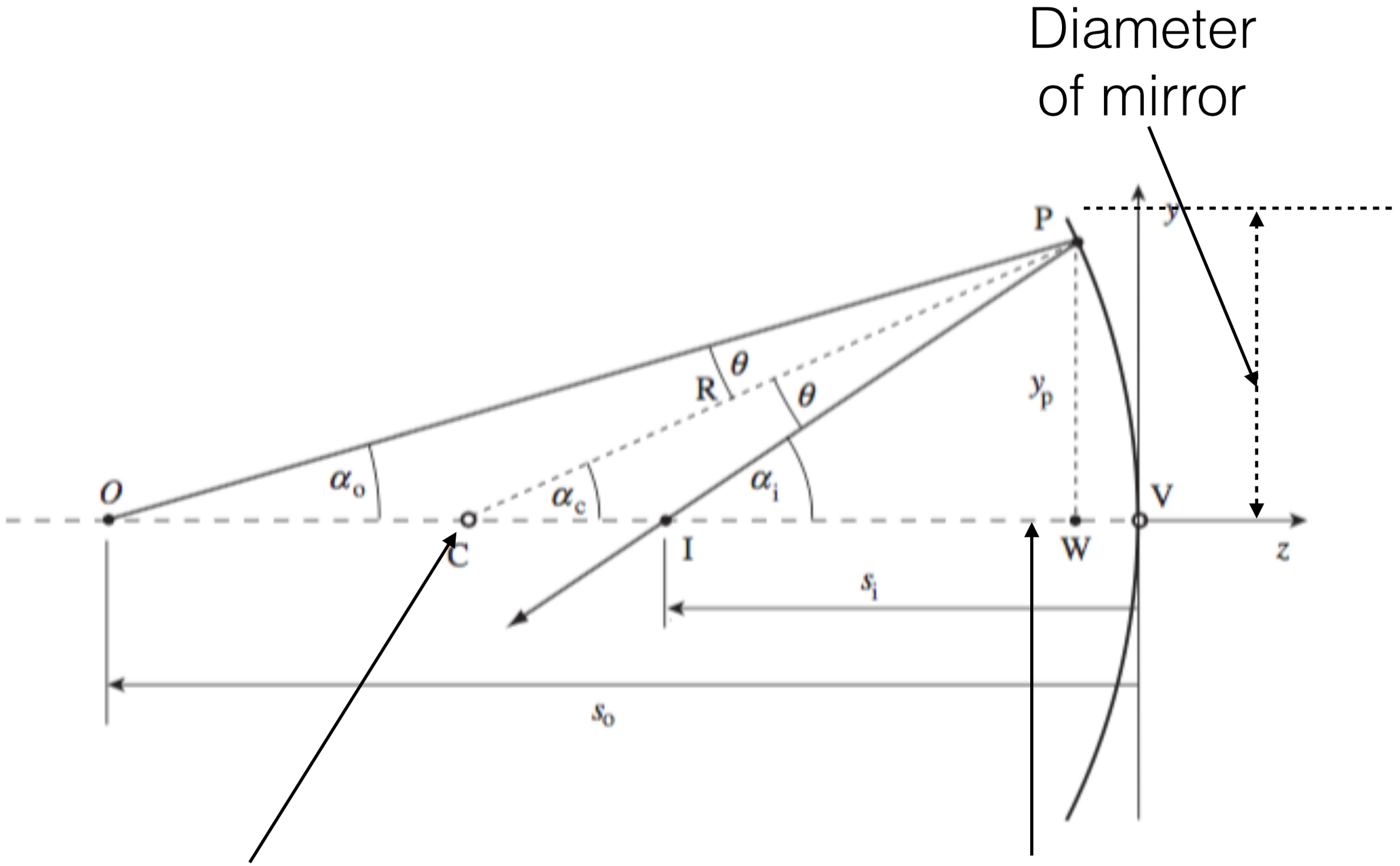
$$R = \left(\frac{n_1 - n_2}{n_1 + n_2} \right)^2$$

- For TE and TM polarizations, the reflectance *R ->1:0* as Θ_1 *-> 90°,* and light rays Θ_1 close to 90° will be mostly reflected. For the internal case, R = 1.0 (a perfect mirror) for all angles greater than the critical angle.

- For all other values of Θ_1, R is smaller for the TM polarization than for the TE polarization. Initially unpolarized light will become partially polarized after reflection from a dielectric surface.

- At Brewster's angle, $\Theta_p = tan^{-1}(n1/n2)$, and *R=0* for the TM polarization, and only one polarization is reflected.

Mirror


Diameter
of mirror
P
y
R
θ
θ
y_p
O
α_o
α_c
α_i
C
I
W
V
z
s_i
s_o
Center of curvature
Axis of symmetry

$$\alpha_o \approx \tan(\alpha_o) \approx \frac{y_p}{s_o}$$

$$\alpha_c \approx \tan(\alpha_c) \approx \frac{y_p}{R}$$

$$\alpha_i \approx \tan(\alpha_i) \approx \frac{y_p}{s_i}$$

- If we consider OPC and CPI we have.

$$\theta = \alpha_c - \alpha_o = \alpha_i - \alpha_c$$

$$2\alpha_c = \alpha_o + \alpha_i$$

- and we have the paraxial equation for mirrors:

$$\frac{2}{R} = \frac{1}{s_o} + \frac{1}{s_i}$$

R/2=f focal length
P=-1/f is the power
DIOPTER = 1/m

- and we have the paraxial equation for mirrors:

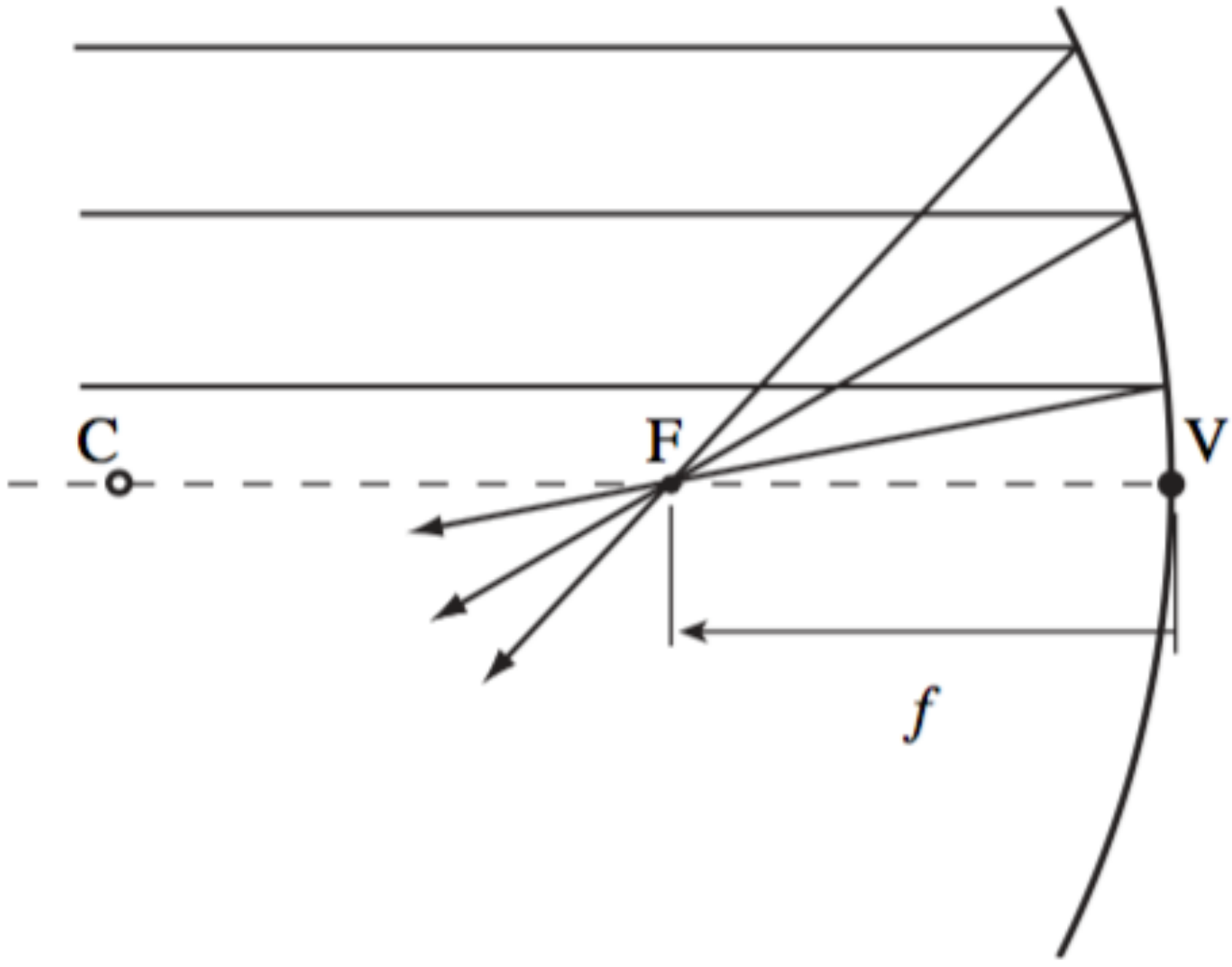
$$\frac{2}{R} = \frac{1}{s_o} + \frac{1}{s_i}$$

R/2=f focal length

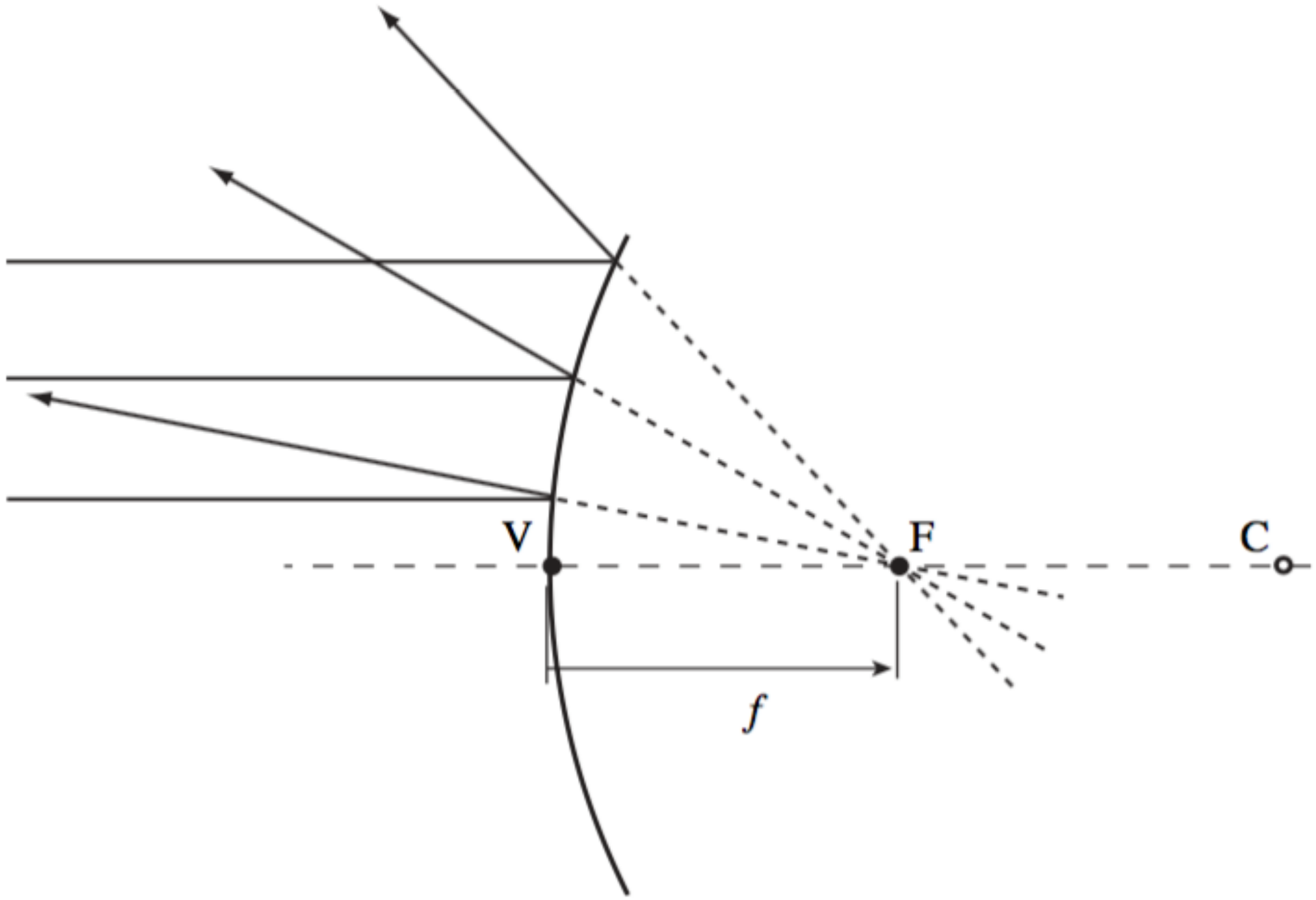
P=-1/f is the power

DIOPTER = 1/m

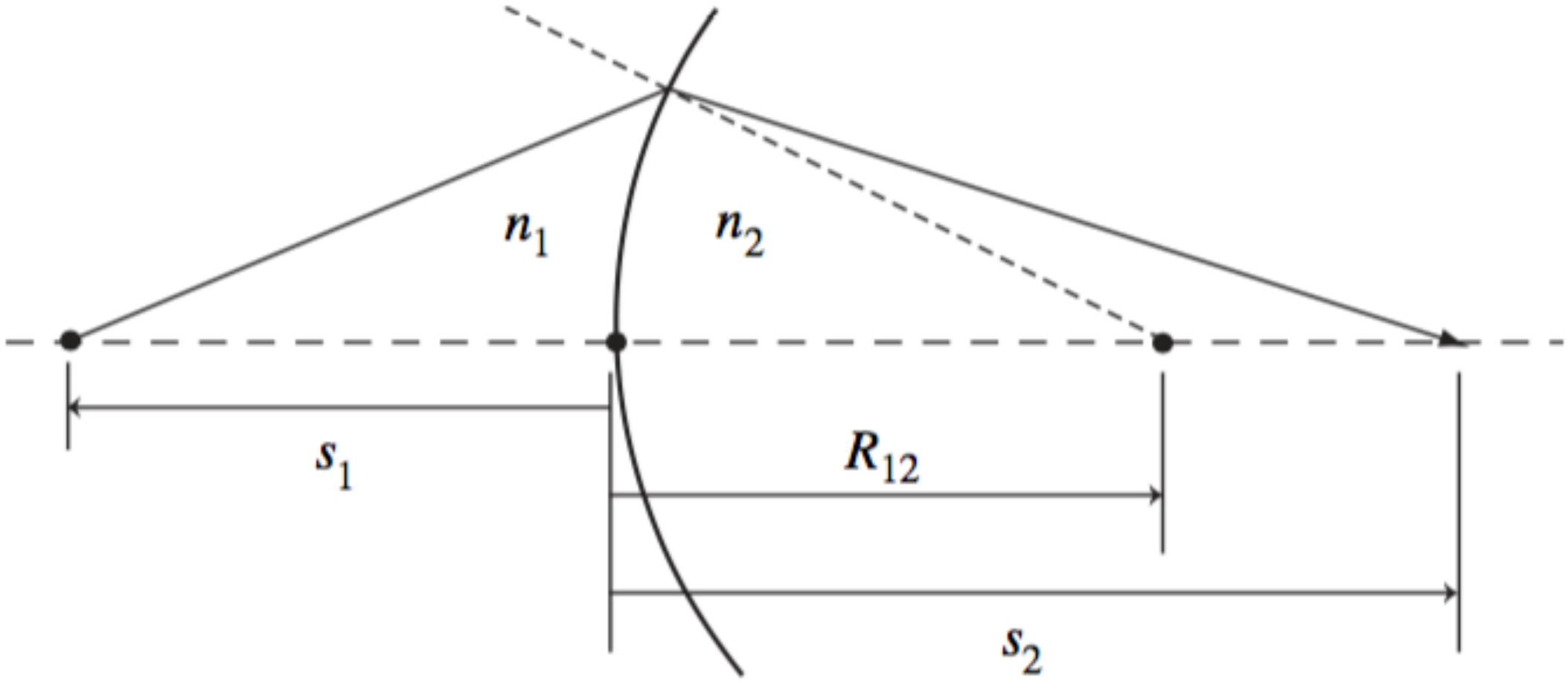
- If s_o ->∞ then s_i is equal to the focal length.
- Parallel rays focus on a point.



The light-gathering power of a mirror will be directly proportional to its surface area, which is proportional to the square of its aperture (diameter).

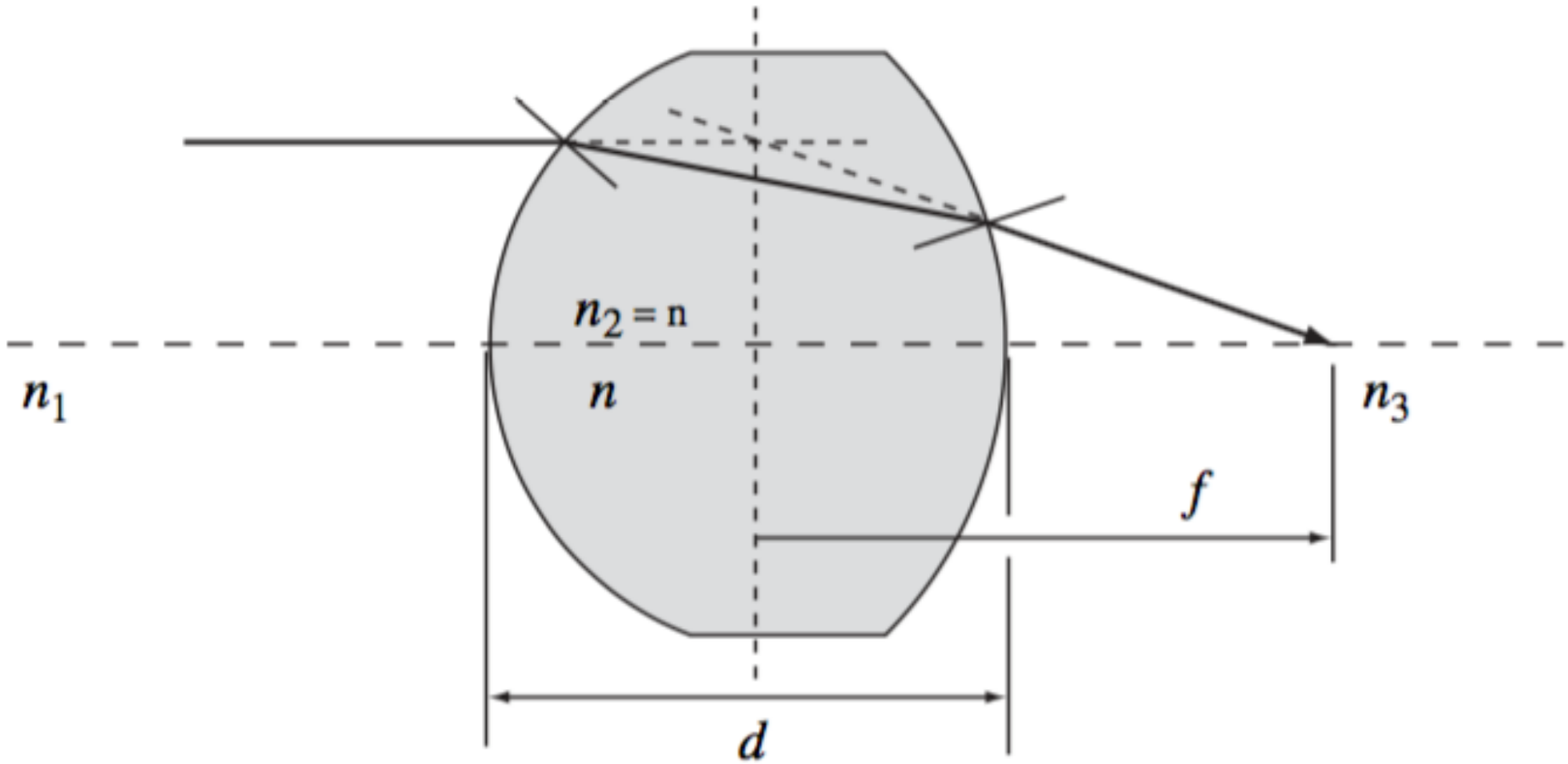

V
F
C
f

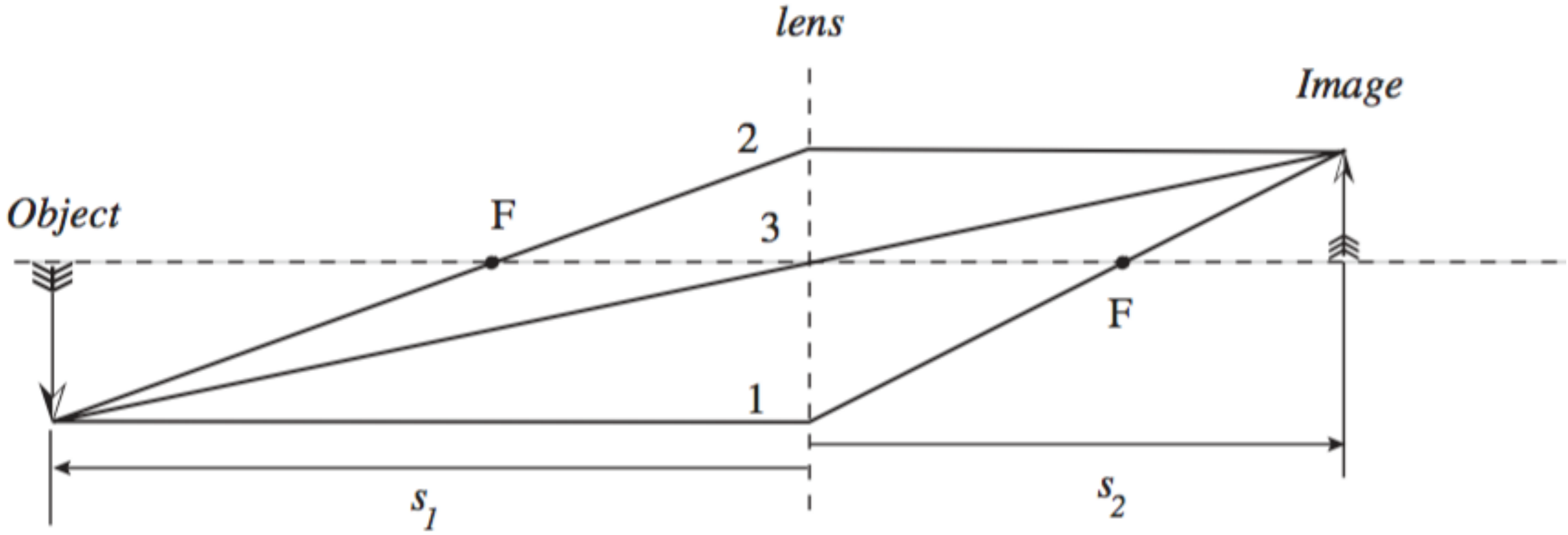
Refraction from a spherical surface

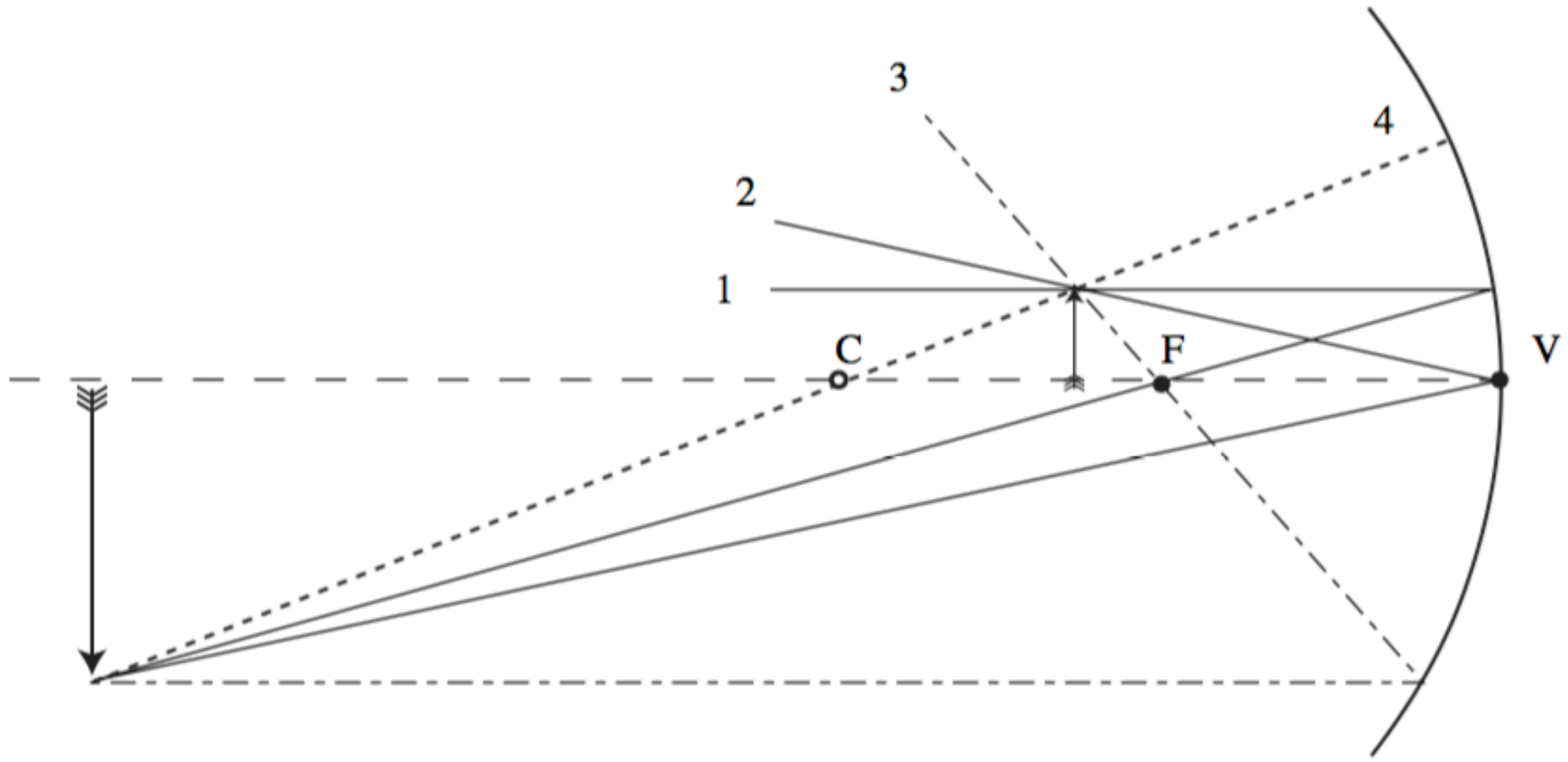


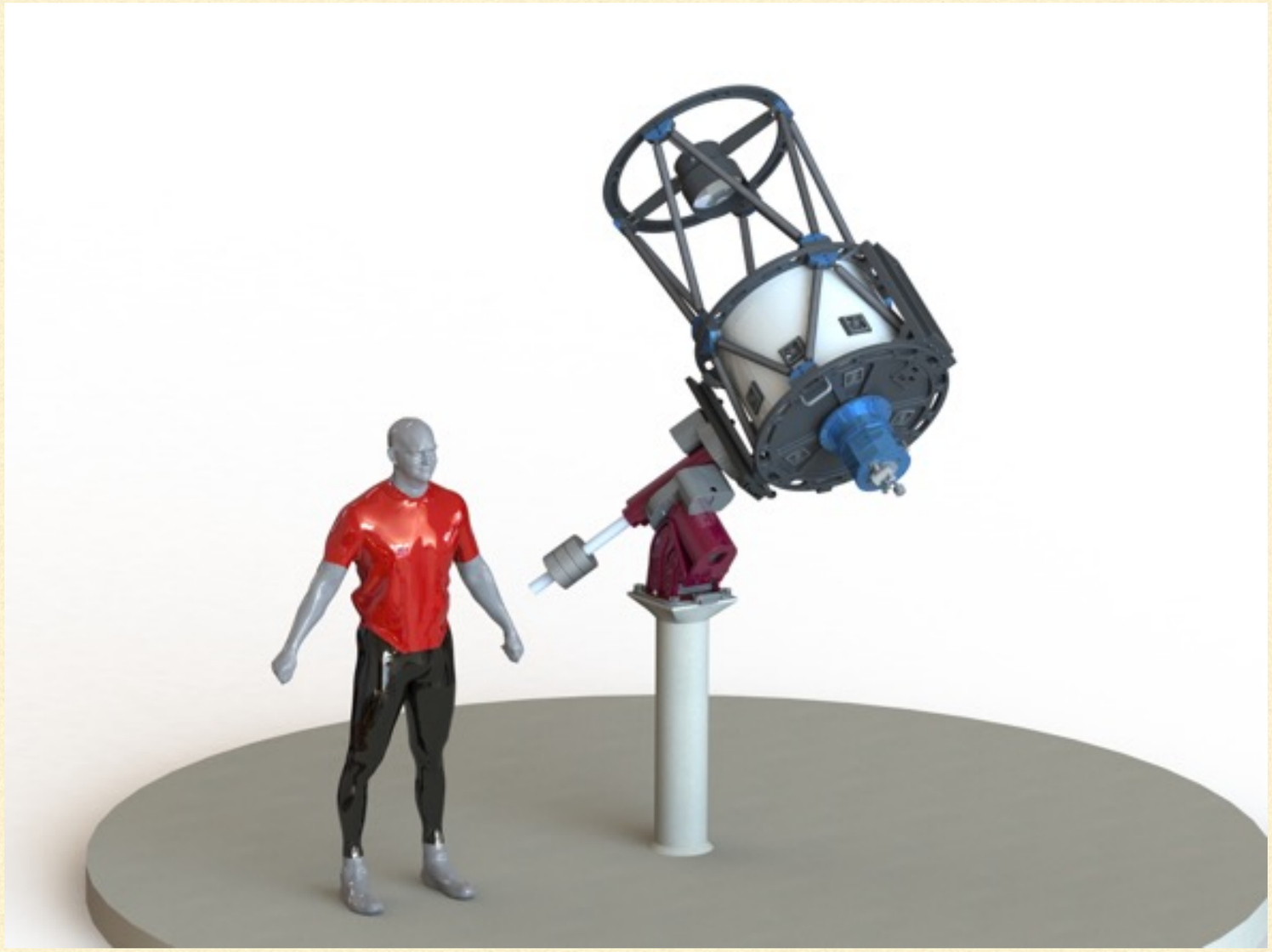
$$\frac{n_2}{s_2} - \frac{n_1}{s_1} = \frac{(n_2 - n_1)}{R_{12}} \qquad f_2 = \frac{n_2 R_{12}}{(n_2 - n_1)} \qquad \frac{n_2}{s_2} - \frac{n_1}{s_1} = \frac{n_2}{f_2} = -\frac{n_1}{f_1} = P_{12}$$

S2 is the focal length when s1 is infinity.
P12 is called the power of the surface.

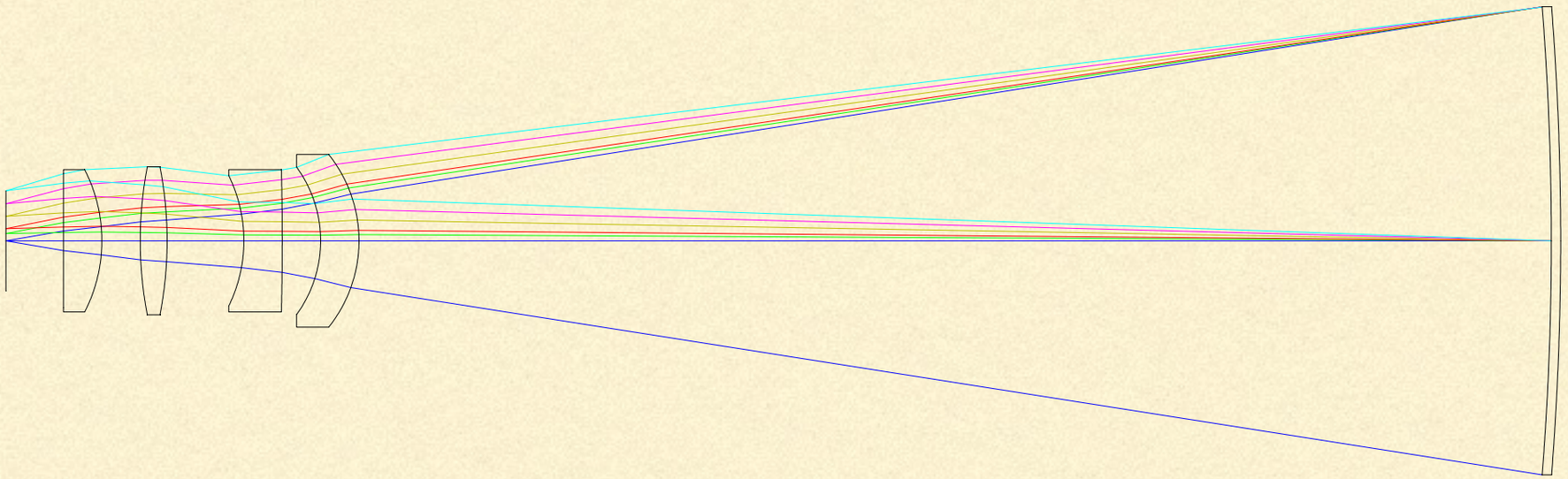

$n_2 = \mathrm{n}$
n_1
n
n_3
f
d


lens
Image
2
Object
F
3
F
1
s_1
s_2


3
4
2
1
C
F
V



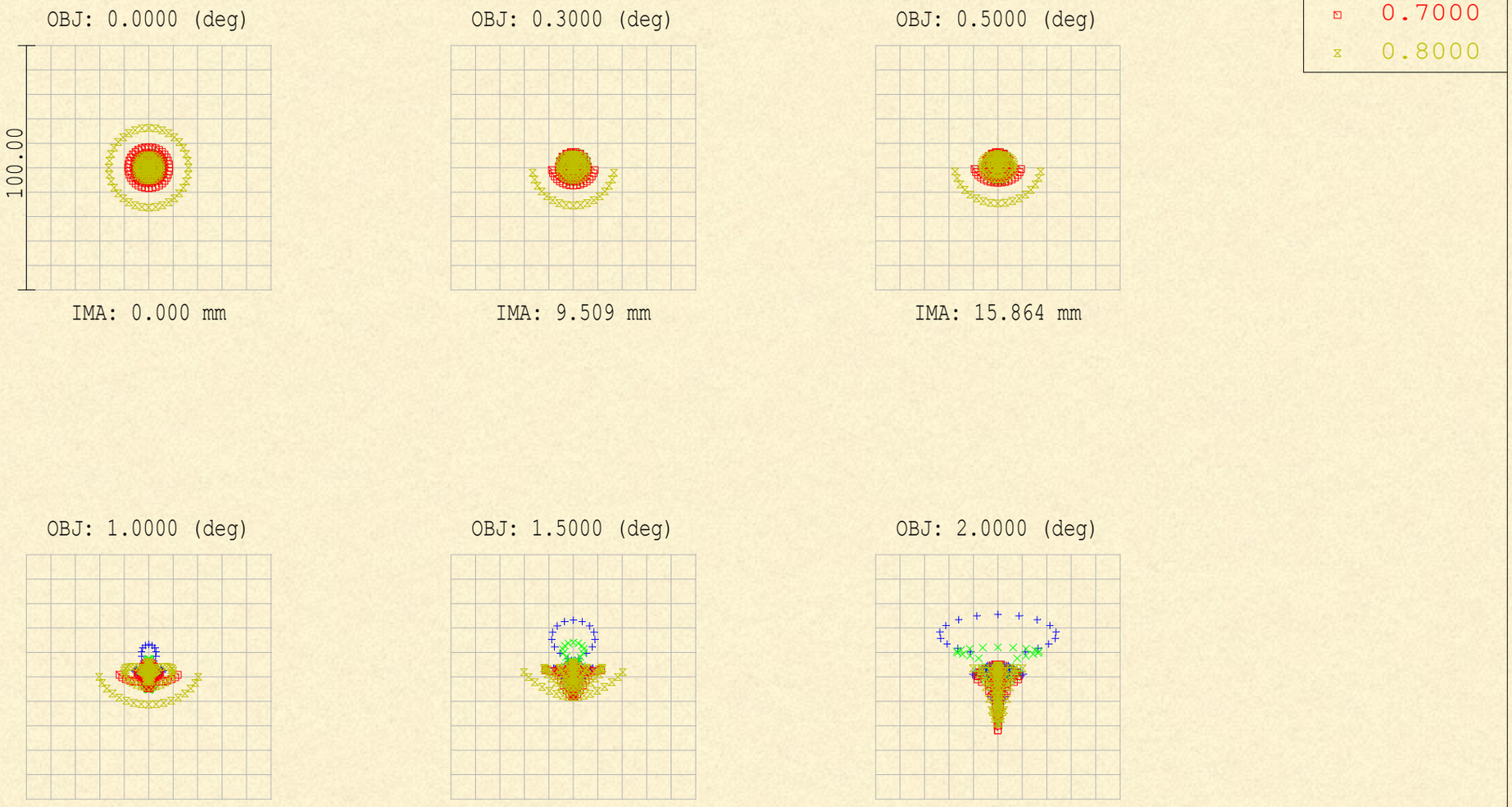
TOROS TELESCOPE



Layout

4 LENS PRIME FOCUS CORRECTOR
11/18/2013
Total Axial Length: 2013.46175 mm

GLOPT_010.zmx
Configuration 1 of 1



Surface: IMA

Spot Diagram

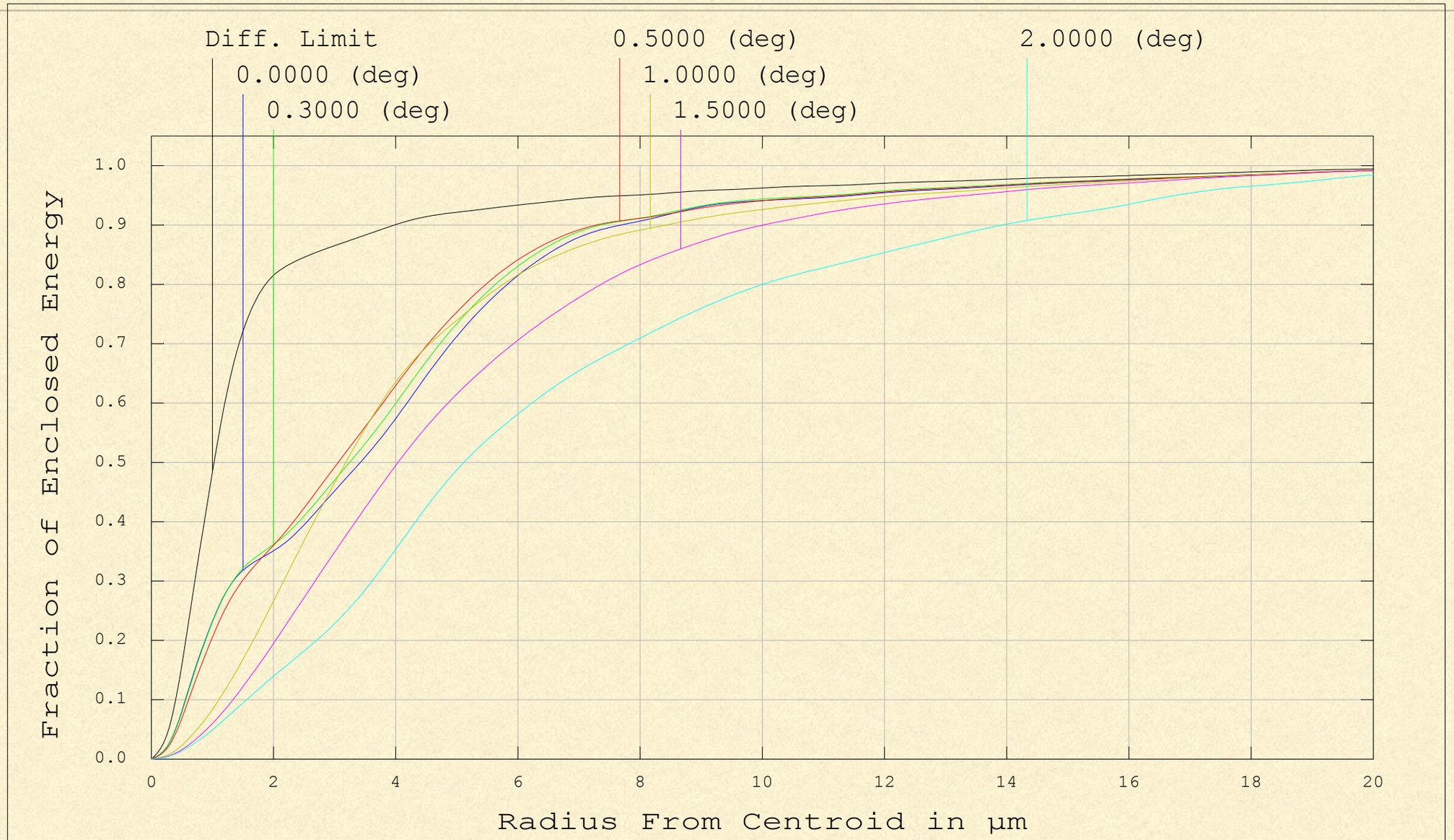
4 LENS PRIME FOCUS CORRECTOR
11/18/2013 Units are µm.

Field	:	1	2	3	4	5	6
RMS radius	:	5.924	4.998	4.967	5.490	6.660	9.235
GEO radius	:	16.311	16.749	17.558	20.254	23.243	30.011

Scale bar : 100 Reference : Chief Ray

GLOPT_010.zmx
Configuration 1 of 1

DIAGRAMA DE ‘SPOT’



FFT Diffraction Encircled Energy

4 LENS PRIME FOCUS CORRECTOR
11/18/2013
Wavelength: Polychromatic
Surface: Image

GLOPT_010.zmx
Configuration 1 of 1

ENERGIA CONCENTRADA POR CIRCULO

- Telescope Planewave, 24”, aprox 610 mm.
- principal focal corrector of 4 elements to achieve A precision of 9 microns over the entire field (1 corrector lens of 200 mm CaFl).
- CCD 10Kx10K, 9 microns p pixel, plate scale.
- focal length 1815 mm.
- plate scale 1arcs p/pixel.
- FOV 3° x 3°
- Capable of detecting mag 22/23 with 15 min exposure.