$A\Sigma K H \Sigma H$ 1 : (Reflected and Transmitted Powers)

(α) The refractive index of fused silica is calculated using the Sellmeier formula

$$n^2(\lambda) = 1 + \sum_{i=1}^{3} \frac{B_i \lambda^2}{\lambda^2 - C_i}$$

where the freespace wavelength is expressed in microns.

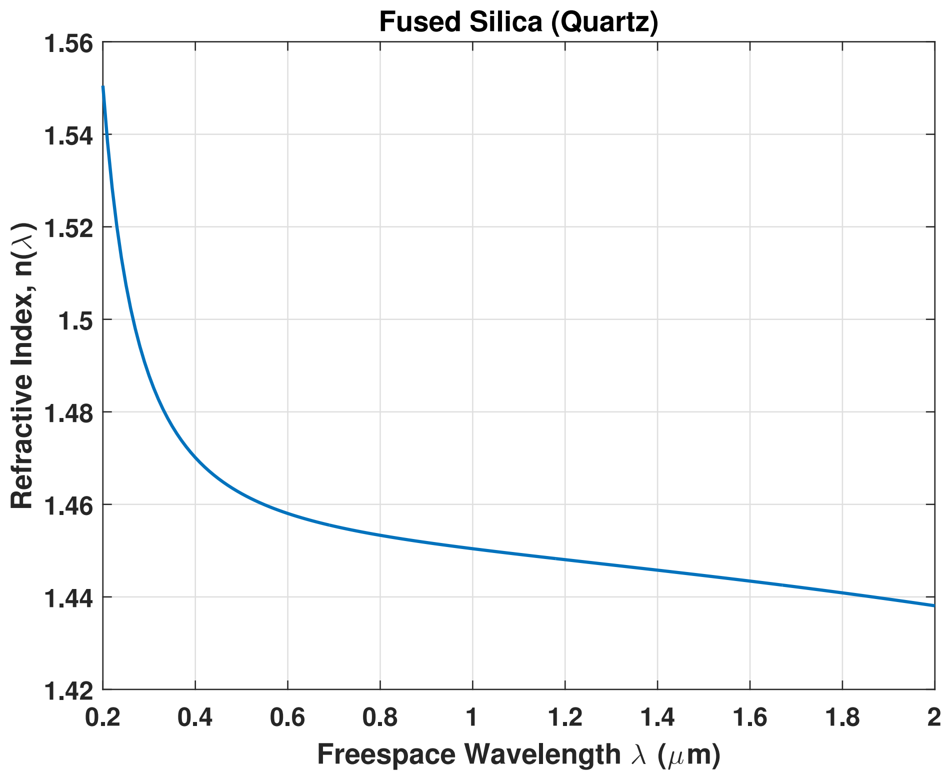
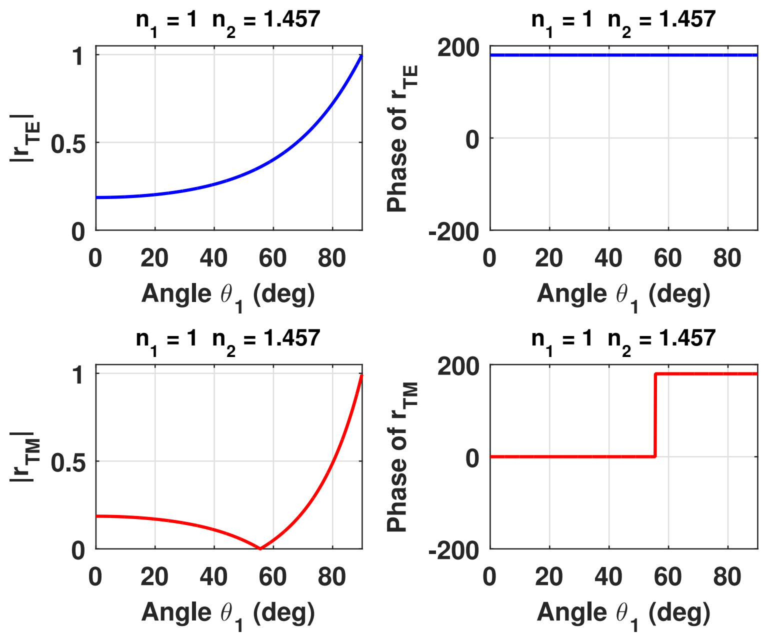
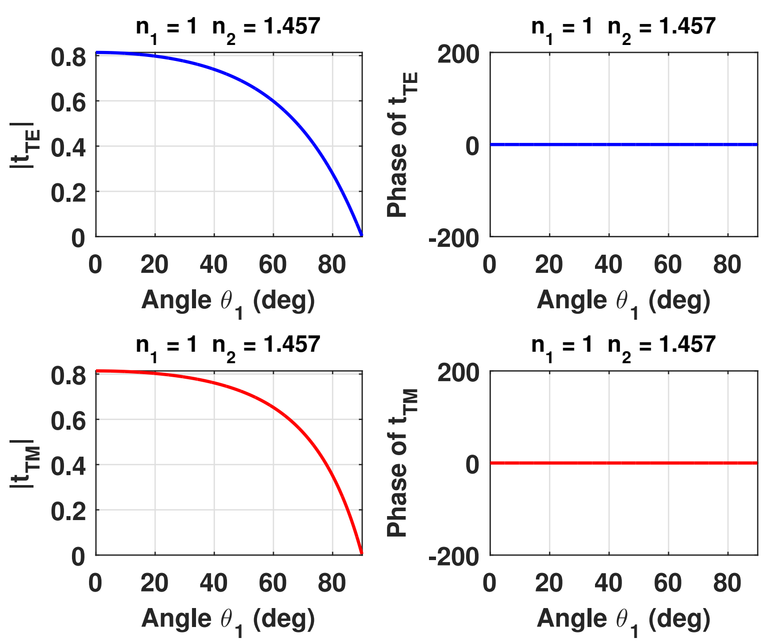


Figure 1: Fused silica (quartz) refractive index dependece on freespace wavelength.



(a)



(b)

Figure 2: (a) Reflection coefficients (TE and TM) as functions of the angle of incidence for $\lambda_0 = 0.633\,\mu$m. (b) Transmission coefficients (TE and TM) as functions of the angle of incidence for $\lambda_0 = 0.633\,\mu$m.

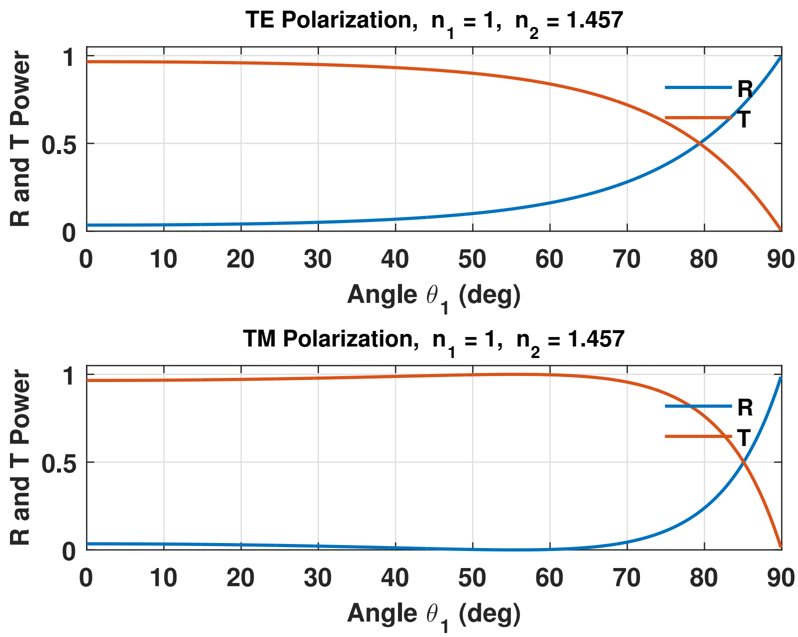
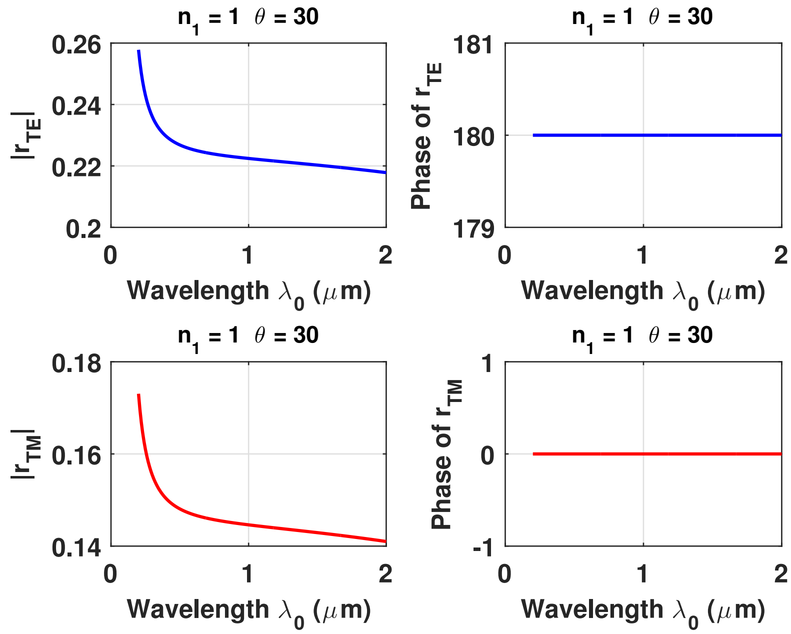
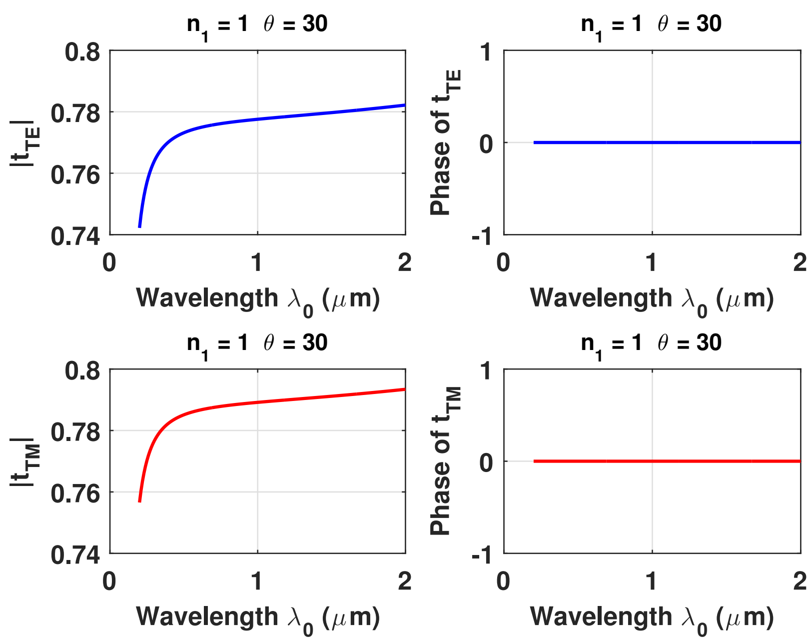


Figure 3: Reflected and transmitted powers (TE and TM) as functions of the angle of incidence for $\lambda_0 = 0.633\,\mu$m.

(β)



(a)



(b)

Figure 4: (a) Reflection coefficients (TE and TM) as functions of the freespace wavelength for $\theta = 30\,\text{deg}$. (b) Transmission coefficients (TE and TM) as functions of the freespace wavelength for $\theta = 30\,\text{deg}$.

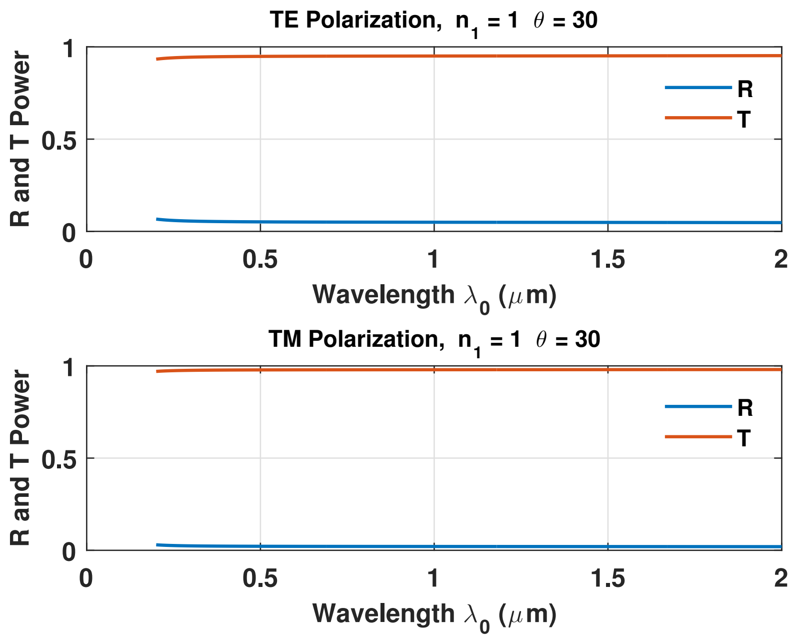
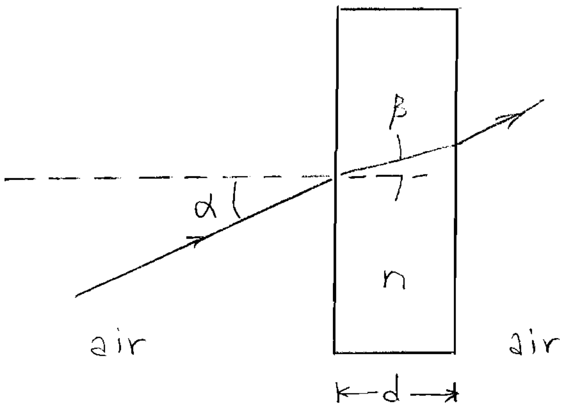


Figure 5: Reflected and transmitted powers (TE and TM) as functions of the freespace wavelength for $\theta = 30\,\text{deg}$.

ΑΣΚΗΣΗ 2: (Interference Filter)



For maximum transmission

$$2dn\cos\beta = m\lambda_o \qquad (1)$$

Filter is designed for λ_s ($\alpha = \beta = 0°$)

$$2dn = m\lambda_s \qquad (2)$$

From (1) ∧ (2) we get:

$$m\lambda_s\cos\beta = m\lambda_o \sim \lambda_o = \lambda_s\cos\beta = \lambda_o\sqrt{1-\sin^2\beta} \Rightarrow$$

$$\Rightarrow \lambda_o = \lambda_s\sqrt{1-\frac{\sin^2\alpha}{n^2}} \qquad (3)$$

The angular tuning rate is defined as $\frac{d\lambda_o}{d\alpha}$.

Therefore $$\frac{d\lambda_o}{d\alpha} = \lambda_s\frac{1/2}{(1-\sin^2\alpha/n^2)^{1/2}}(-2\sin\alpha\cos\alpha)\frac{1}{n^2} \Rightarrow$$

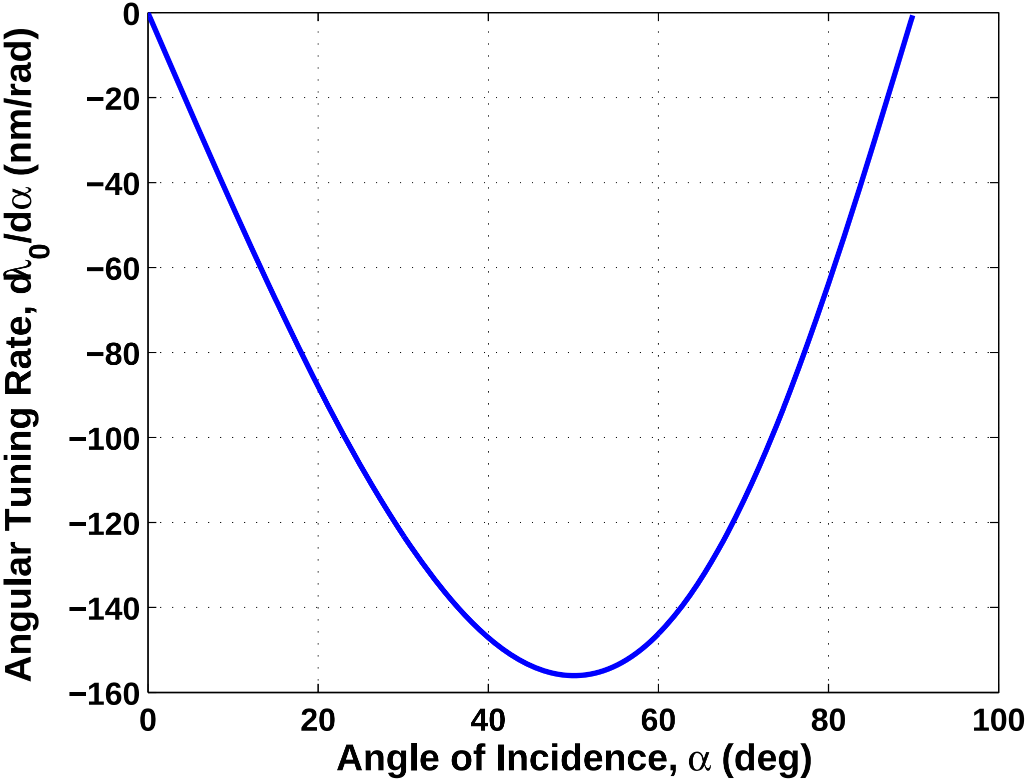
$$\frac{d\lambda_o}{d\alpha} = -\frac{\lambda_s\sin\alpha\cos\alpha}{n[n^2-\sin^2\alpha]^{1/2}} \qquad (4)$$

For $\lambda_s = 520\,nm$ $\lambda_o = 514.5\,nm$ and $n = 1.4$

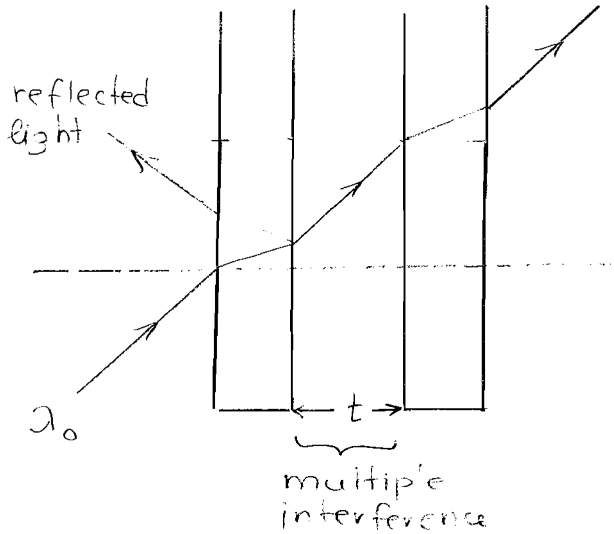
From (3) $\sim$ $\sin\alpha = n\left[1-\left(\frac{\lambda_o}{\lambda_s}\right)^2\right]^{1/2}$, $\alpha_o = 11.71725°$

$$\left.\frac{d\lambda_o}{d\alpha}\right|_{\alpha_o} = -\frac{520nm\ \sin(\alpha_o)\cos(\alpha_o)}{1.4\ [1.4^2-\sin^2\alpha_o]^{1/2}} = -53.32\ nm/rad$$

or $-0.9306\,(nm/°)$


Angular Tuning Rate, $d\lambda_0/d\alpha$ (nm/rad)
0
−20
−40
−60
−80
−100
−120
−140
−160
0
20
40
60
80
100
Angle of Incidence, α (deg)

ΑΣΚΗΣΗ 3: (Fabry-Perot Filter)



We have multiple interference only between the surfaces separated by t. All other surfaces are considered slightly non parallel so the multiple interference from all other surfaces are neglected.

Resonance Conditions:

The dark lines in the reflected light correspond to minima in reflection or maxima on transmission.

$$2tn\cos\theta_t = m\lambda_0 \Rightarrow \lambda_0 = \frac{2tn\cos\theta_t}{m}$$

$\theta_t = 45°$, $t = 0{,}001\,cm = 10^{-3}\,10^{-2}\,m = 10^{-5}\,m = 10^{4}\,nm$

For $400\,nm < \lambda_0 < 700\,nm \sim$

$$400\,nm < \frac{2 \cdot 10^4 \sqrt{2}/2\,nm}{m} < 700\,nm \sim$$

$$400 < \frac{14142.135}{m} < 700 \sim$$

$$20.2 = \frac{14142.135}{700} < m < \frac{14142.135}{400} = 35.35$$

Therefore, the integer values of m are :

21, 22, ... , 35.

As a result the dark lines are: $\lambda_0 = \frac{2tn\cos\theta_t}{m}$

$m = 21 \rightsquigarrow \lambda_0 = 673.435\ nm$

$m = 22 \rightsquigarrow \lambda_0 = 642.824\ nm$

$m = 23 \rightsquigarrow \lambda_0 = 614.876\ nm$

$m = 24 \rightsquigarrow \lambda_0 = 589.256\ nm$

$m = 25 \rightsquigarrow \lambda_0 = 565.685\ nm$

$m = 26 \rightsquigarrow \lambda_0 = 543.928\ nm$

$m = 27 \rightsquigarrow \lambda_0 = 523.783\ nm$

$m = 28 \rightsquigarrow \lambda_0 = 505.076\ nm$

$m = 29 \rightsquigarrow \lambda_0 = 487.660\ nm$

$m = 30 \rightsquigarrow \lambda_0 = 471.405\ nm$

$m = 31 \rightsquigarrow \lambda_0 = 456.198\ nm$

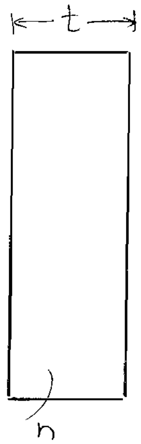
$m = 32 \rightsquigarrow \lambda_0 = 441.942\ nm$

$m = 33 \rightsquigarrow \lambda_0 = 428.550\ nm$

$m = 34 \rightsquigarrow \lambda_0 = 415.945\ nm$

$m = 35 \rightsquigarrow \lambda_0 = 404.061\ nm$

ΑΣΚΗΣΗ 4: (Fabry-Perot Filter)



$n = 4.5$, $t = 2cm$

$R = |r|^2 = 90\%$

$1\ cm = 10^{-2} m = 10^{7}\ nm$

$\lambda_0 \simeq 546\ nm$

(α) Maximum transmission: $2tn\cos\theta_t = m\lambda_0$

Maximum m occurs for $\theta_t = 0^\circ \Rightarrow m\lambda_0 = 2tn \rightsquigarrow$

$$m = \left[\frac{2tn}{\lambda_0}\right] = \left[\frac{2 \cdot 2 \cdot 10^7 nm\ 4.5}{546 nm}\right] = \left[329670.33\right]$$

$$= 329670$$

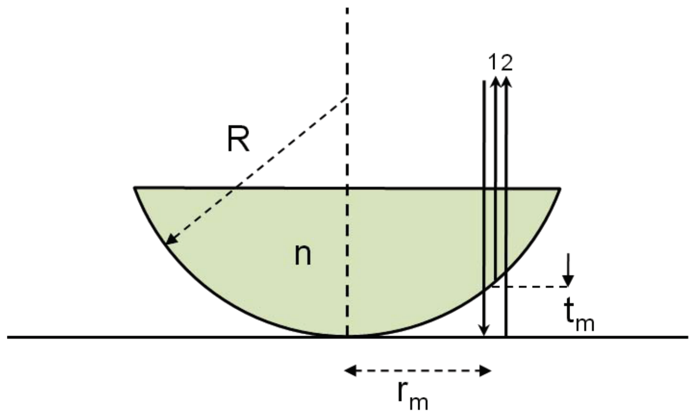
(β) $\dfrac{T_{max}}{T_{min}} = \dfrac{1}{1/(1+F)} = 1 + F$

$F = \dfrac{4r^2}{(1-r^2)^2} = 360$

$\rightsquigarrow \dfrac{T_{max}}{T_{min}} = 361$

(c) $\mathcal{R} \simeq \frac{\pi}{2} m \sqrt{F} = \frac{\pi}{2}\ 329670\ \sqrt{360} = 9.825 \cdot 10^6$

$A\Sigma KH\Sigma H$ 5 : (Newton's Rings)



The interference rings are formed from interference between waves that reflect at the inner surface of the spherical interface (like ray 1 shown in the figure) and at the optically flat bottom surface (like ray 2 shown in the figure). In order to get constructive interference the following condition should be satisfied:

$$2n_{air}t_m + \Delta_{refl} = m\lambda_0,$$

where $\Delta_{refl} = \lambda_0/2$ since ray 1 experiences an internal reflection while ray 2 experiences an external reflection. Therefore, the constructive interference condition becomes

$$2n_{air}t_m = (2m+1)\frac{\lambda_0}{2}, \qquad m = 0, 1, \cdots.$$

The tenth bright ring corresponds to $m = 9$. For $n_{air} = 1$ then $2t_9 = 19(\lambda_0/2)$. The relation bewteen t_m and r_m is given by

$$r_m^2 + (R - t_m)^2 = R^2 \Longrightarrow r_m = \sqrt{2Rt_m - t_m^2},$$

Then for $\lambda_0 = 546.1\,\text{nm}$ the value of $t_9 = (19/2)(\lambda_0/2) = 2593.975\,nm = 2.593975 \times 10^{-6}\,m$ and $r_9 = 7.89/2 = 3.945\,\text{mm}$ solving for R the previous equation it can be found that

$$R = \frac{r_m^2 + t_m^2}{2t_m} = \frac{r_9^2 + t_9^2}{2t_9} = \frac{3.945^2 \times 10^{-6} + 2.593975^2 \times 10^{-12}}{2 \times 2.593975 \times 10^{-6}}\,m = 2.9998\,m \simeq 3\,m.$$

The focal distance can be found from the equation

$$\frac{1}{f} = (n-1)\Big(\frac{1}{R_1} - \frac{1}{R_2}\Big) = (1.5-1)\Big(\frac{1}{\infty} - \frac{1}{-3\,m}\Big) \Rightarrow f \simeq 6\,m$$