Assignment 6

OPTI 502 Optical Design and Instrumentation I

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October 12, 2025

Exercise 1

a) We trace the chief ray denoted as CR, and a potential marginal ray MR with unitary height at the stop.

		Object space	EP		L_1		Stop		L_2		XP	Image space
	$C/R/f$				250				400			
	t			$z_{EP}=-62.5$		50		70		$z_{XP}=-84.8$		
	n	1	1	1	1	1	1	1	1	1	1	1
	$-\phi$				-0.004				-0.0025			
	t/n			$\tau_{EP}=-62.5$		50		70		$\tau_{XP}=-84.8$		
	y		0		-5		0		7		0	
CR	nu			0.08		0.1		0.1		0.0825		
	u			0.08		0.1		0.1		0.0825		
	y		$R_{EP}=1.25$		1		1		1		$R_{XP}=1.21$	
MR	nu			0.004		0		0		-0.0025		
	u					0		0				

Table 1: Raytrace, with CR=Chief ray, MR=Marginal ray.

Due to the diameter of the stop is $R_{stop} = 10\ mm$, we scale the potential marginal ray to give the true marginal ray and therefore obtain the radius of the pupils:

$$\begin{array}{l} R_{EP} = (10)(1.25) = 12.5\ mm \\ R_{XP} = (10)(1.21) = 12.1\ mm \end{array} \Longrightarrow \begin{array}{l} D_{EP} = 2R_{EP} = 25.0\ mm \\ D_{XP} = 2R_{XP} = 24.2\ mm \end{array}$$

b) For Gaussian imagery, we see the stop as the object for the front group and rear group. For the EP, we have a backward propagation that is maganed with the flip of the sign in the refrractive indices.

$$\frac{-1}{z_{EP}} = \frac{-1}{Z_{\text{stop}}} + \frac{1}{250} \longrightarrow z_{EP} = 62.5\ mm.$$

This entrance pupil is to the right of the lens L_1. The magnification is:

$$m_{EP} = \frac{z_{EP}}{z_{\text{stop}}} = \frac{R_{EP}}{R_{\text{stop}}} = -1.25.$$

The diameter of the entrance pupil is therefore:

$$D_{EP} = 2R_{EP} = 2[|m_{EP}|R_{\text{stop}}] = 25\ mm.$$

For the rear group, we have analogously:

$$\frac{1}{z_{XP}} = \frac{1}{Z_{\text{stop}}} + \frac{1}{400} \longrightarrow z_{XP} = -84.848\ mm.$$

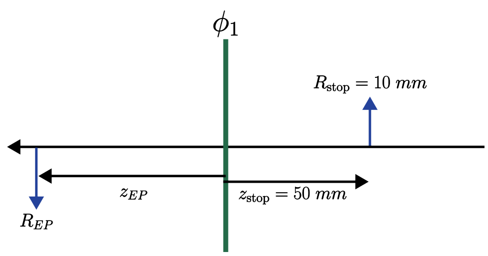
The exit pupil is then to the left of the lens L_2. The magnification in this case is

$$m_{XP} = \frac{z_{XP}}{z_{\text{stop}}} = \frac{R_{XP}}{R_{\text{stop}}} = 1.21.$$

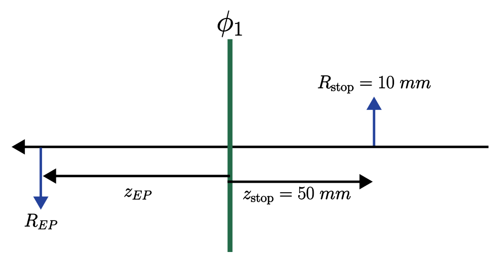
The diameter of the exit pupil is:

$$D_{XP} = 2R_{XP} = 2[|m_{XP}|R_{\text{stop}}] = 24.2\ mm.$$

The illustration of each case is illustrated in the figure 1.



(a) EP for front group



(b) XP for rear group

Figure 1: With Gaussian imagery, the computation of the pupils is based on the stop as the object of two optical systems.

Using either method, the result is the same and is shown in figure 2

Exercise 2

a) The raytrace needs of three rays, the chief ray, the marginal ray, and a forward parallel ray. The following table shown those. We need to notice that the propagation through the pupils and stop require to **copy** the ray angle as there is no refraction. It is equivalent to just sum the partial distance and do one raytrace from one surface to the next one.

The optical power is the ratio $\omega = -\omega_k/y_1$:

$$\phi = -\frac{\omega_k}{y_1} = 0.0184 \longrightarrow f_E = \frac{1}{\phi} = 54.35\ mm.$$

The back focal distance can be obtained as the **sum** of the distance $XPF' = z'$ and $L3XP = z_{XP}$:

$$BFD = z_{XP} + z' = 38.978 - 17.647 = 21.33\ mm.$$

The true marginal ray is obtained scaling the potential marginal ray traced by 5. Therefore, the diameters are:

$$D_{EP} = 2(5R_{EP}) = 16.39\ mm, \quad D_{XP} = 2(5R_{XP}) = 11.76\ mm.$$

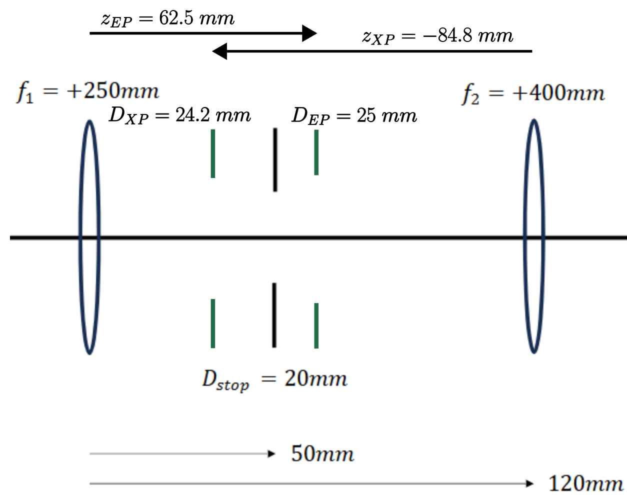


Figure 2: Illustration of the stop and pupil in the optical system.

		EP		1		2		Stop		3		XP		
	$C/R/f$			50		-100		$-$		100				
	t		$z_{EP} = -47.541$		15		20		14		$z_{XP} = -17.647$		$z' = 38.978$	
	n	1	1	1	1.5	1	1	1	1	1	1	1		
	$-\phi$			-0.01		-0.005				-0.01				
	τ		$\tau_{EP} = -47.541$		10		20		15		$\tau_{XP} = -17.647$		$\tau_{z'} = 38.978$	
	y	0		-2.9		-2		0		1.5		0		
CR	nu		0.061		0.09		0.1		0.1		0.085			
	u		0.061		0.06		0.1		0.1		0.085			
	y	$R_{EP} = 1.639$		0.95		1		1		1	$R_{XP} = 1.176$			
MR	nu		0.0145		0.005		0		0		-0.01			
	u		0.0145		0.003		0		0		-0.01			
	y	1		1		0.9		0.61		0.3925		0.7172		0
FR	nu		0		-0.01		-0.0145	$\longrightarrow$	-0.0145		-0.0184	$\longrightarrow$	-0.0184	
	u		0		-0.006		-0.0145		-0.0145		-0.0184		-0.0184	

b) In this case, the F-number gives us the information of the entrance pupil:

$$f/\# = \frac{f_E}{D_{EP}} \longrightarrow D_{EP}^{\text{new}} = 10.87\ mm.$$

With this value, we can obtain the scale we need to apply to the exit pupil and the stop diameters:

$$m = \frac{D_{EP}^{\text{new}}}{D_{EP}^{\text{old}}} = \frac{10.87}{16.39} = 0.663.$$

Therefore,

$$D_{\text{stop}}^{\text{new}} = mD_{\text{stop}}^{\text{old}} = 6.63\ mm, \quad \text{and} \quad D_{XP}^{\text{new}} = mD_{XP}^{\text{old}} = 7.79\ mm.$$