# Keplerian with Relay



10X  $MP = -10$  $f_o = 200\,mm$

$f_{eye} = 20\,mm$

a) Base telescope

$L = f_o + f_{eye} = 220\,mm$

ER: Image stop through eye lens

$$\frac{1}{z'} = \frac{1}{ER} = \frac{1}{z} + \frac{1}{f_{eye}}$$

$z = -220\,mm$

$ER = 22\,mm$

b) Add Relay lens  $f_R = 30$

$MP' = MP \cdot m_R = 20$

$m_R = -2$

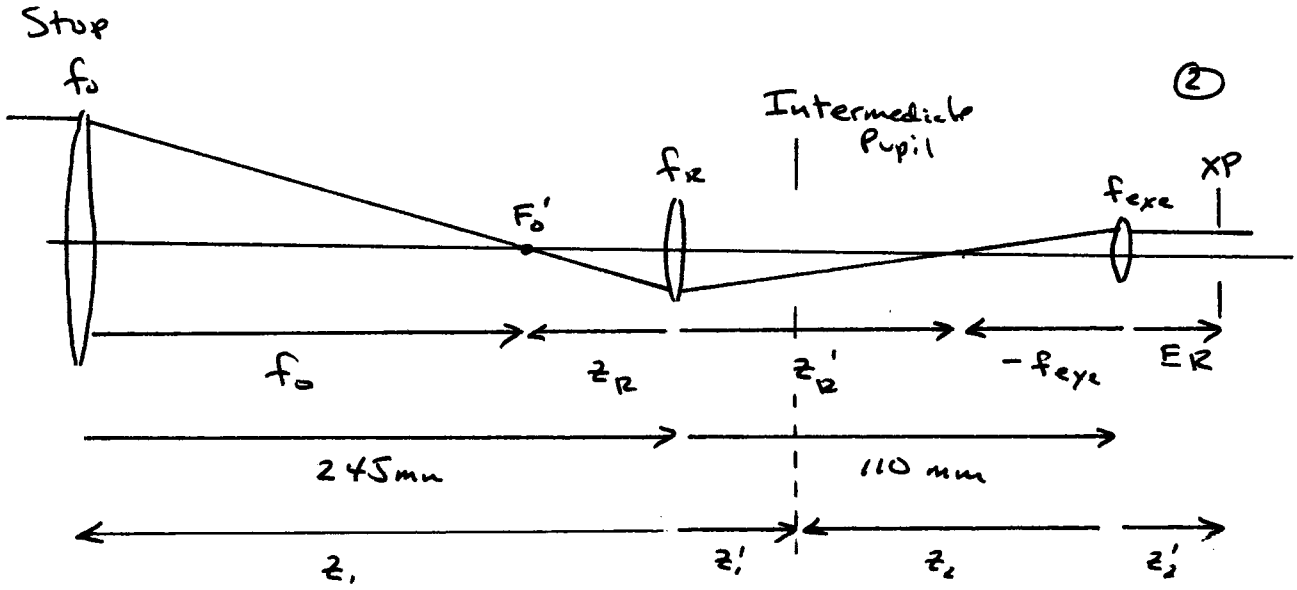
$m_R = z'_R / z_R$  $z'_R = -2 z_R$

$$\frac{1}{z'_R} = \frac{1}{z_R} + \frac{1}{f_R}$$

$$\frac{-3}{2 z_R} = \frac{1}{f_R} = \frac{1}{30}$$

$z_R = -45\,mm$

$z'_R = 90\,mm$




To determine the ER, first image the stop through the relay to an intermediate pupil. Then image this intermediate pupil through the eye lens to the XP.

$$\frac{1}{z_1'} = \frac{1}{z_1} + \frac{1}{f_R} \qquad z_1 = -245 \text{ mm}$$

$$z_1' = 34.19 \text{ mm}$$

$$z_2 = -f_{eye} - z_R' + z_1'$$

$$z_2 = -75.81 \text{ mm}$$

$$\frac{1}{z_2'} = \frac{1}{z_2} + \frac{1}{f_{eye}}$$

$$z_2' = ER = 27.17 \text{ mm}$$

c) Add a field lens at $F_o'$

Image the stop into the relay lens

$$z_f = -f_o = -200 \text{ mm}$$

$$z_f' = -z_e = 45 \text{ mm}$$

$$\frac{1}{z_f'} = \frac{1}{z_f} + \frac{1}{f_F}$$

$$\underline{f_f = 36.73 \text{ mm}}$$

Since the stop has been imaged to the relay lens, the eye relief is found by imaging the relay lens through the eye lens

$$z = -f_{eye} - z_{12}' = -110 \text{ mm}$$

$$\frac{1}{z'} = \frac{1}{ER} = \frac{1}{z} + \frac{1}{f_{eye}}$$

$$\underline{ER = 24.4 \text{ mm}}$$

d) Required Lens Diameters

$$D_{obj} = D_{STOP} = 20 \text{ mm}$$

$$FOV = \pm 1 \text{ deg}$$

$$\bar{u} = \tan(1 \text{ deg}) = .0175$$

The field lens radius must equal the first intermediate image size:

$$r_f = \bar{u} \cdot f_o$$

$$r_f = 3.49 \text{ mm}$$

$$\underline{D_f = 6.98 \text{ mm}}$$

The relay lens size is equal to the size of the stop image formed by the field lens.

$$m_f = z'_f / z_f = 45/-200$$

$$m_f = -.225$$

$$D_R = |m_f| D_{STOP}$$

$$\underline{D_R = 4.5 \text{ mm}}$$