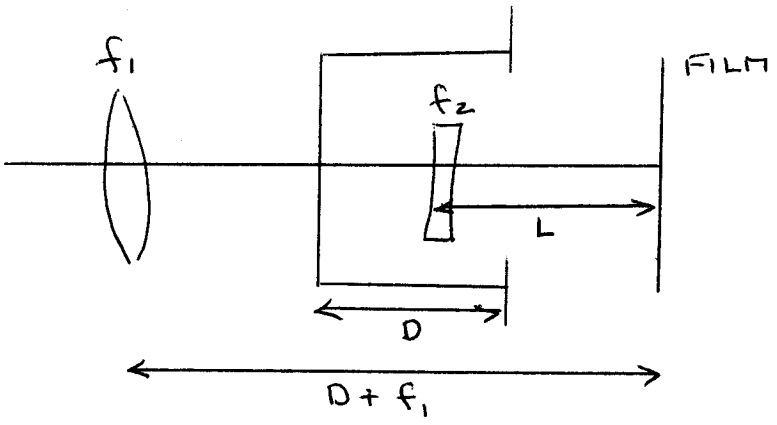
Teleconverter - original image plane at F_1'



$f = N f_1$

$$\phi = \frac{\phi_1}{N} = \phi_1 + \phi_2 - \phi_1 \phi_2 t$$

$$t = D + f_1 - L$$

$$\phi = \frac{\phi_1}{N} = \phi_1 + \phi_2 - \phi_1 \phi_2 \left(D - L + \frac{1}{\phi_1}\right)$$

$$\frac{\phi_1}{N} = \phi_1 + \cancel{\phi_2} - \phi_1 \phi_2 (D - L) - \cancel{\phi_2}$$

$$\frac{1}{N} = 1 - \phi_2 (D - L)$$

$$\frac{\frac{1}{N} - 1}{L - D} = \phi_2$$

To get the correct new focal length

$$\boxed{f_2 = \frac{L - D}{\frac{1}{N} - 1}}$$

$$d' = \delta' = -\frac{\phi_1}{\phi} t = -\frac{\phi_1}{\phi_1 N} (D + f_1 - L)$$

$$d' = \delta' = -N(D + f_1 - L) = -N f_1 - N(D - L)$$

to match the image plane $f = Nf_1 = L - \delta'$

$$d' = \delta' = -Nf_1 + L = -Nf_1 - N(D-L)$$

$$L = -N(D-L)$$

$$\boxed{L = \frac{ND}{N-1}}$$ Relationship between L and D

$$f_2 = \frac{L-D}{1/N - 1} \qquad (L-D) = L/N$$

$$f_2 = \frac{L/N}{1/N - 1} = \frac{L}{1-N}$$

$$\boxed{f_2 = \frac{L}{1-N}}$$

Other expressions are possible (f_2 in terms of D, for example)

Example 3X teleconverter with D = 50 mm

$$L = \frac{3 \cdot 50\,mm}{2} = 75\,mm$$

$$f_2 = \frac{75\,mm}{-2} = -37.5\,mm$$

Since the entrance pupil dia remains constant, and the focal length increases by NX,

$$\boxed{f/\#_{New} = N \; f/\#}$$