

Spot Sizes

Question

I am using the star test to evaluate an optical system. How does the minimum blur diameter due to third-order spherical aberration compare to

- the blur diameter due to astigmatism at the circle of least confusion?
- the width of blur due to third-order coma which is twice the sagittal coma?

Assume equal amounts of third-order spherical, coma, and astigmatism as the maximum wavefront aberration.

Solution

Spherical aberration

$$\Delta W = \Delta W_s \rho^4$$

$$\epsilon_y = -\frac{R}{h} \frac{\partial \Delta W}{\partial y} = -\frac{R}{h} 4 \Delta W_s = -8 \left(\frac{R}{2h} \right) \Delta W_s$$

Therefore,

$$2 \epsilon_y = 16 f^\# \Delta W_{\text{sph}}$$

The minimum blur diameter is $\frac{1}{4}$ of this or

$$\text{MinimumBlurDiameter} = 4 f^\# \Delta W_{\text{sph}}$$

■ a)

Astigmatism

$$\Delta W = \Delta W_a y^2$$

$$\epsilon_y = -\frac{R}{h} \frac{\partial \Delta W}{\partial y} = -\frac{R}{h} 2 y \Delta W_a = -4 \left(\frac{R}{2h} \right) \Delta W_a$$

$$2 \epsilon_y = 8 f^\# \Delta W_{\text{ast}}$$

Blur diameter at circle of least confusion is one-half of this or

$$\text{BlurDiameterAtCircleOfLeastConfusion} = 4 f^\# \Delta W_{\text{ast}}$$

■ b)

Coma

$$\Delta W = \Delta W_c \rho^3 \cos[\phi] = \Delta W_c (x^2 + y^2) y$$

$$\epsilon_y = -\frac{R}{h} \frac{\partial \Delta W}{\partial y} = -\frac{R}{h} \Delta W_c (x^2 + 3y^2) = -\frac{R}{h} \Delta W_c (\rho^2 + 2y^2)$$

At $y^2 = 1$

$$\epsilon_y = -2 \frac{R}{2h} \Delta W_c (3) = -6 f^\# \Delta W_{coma}$$

The sagittal coma is 1/3 of this and the diameter of the blur circle is 2/3 of this or

$$\text{DiameterOfBlurCircle} = 4 f^\# \Delta W_{coma}$$

From Volume 11 of Applied Optics and Optical Engineering page 23 we have

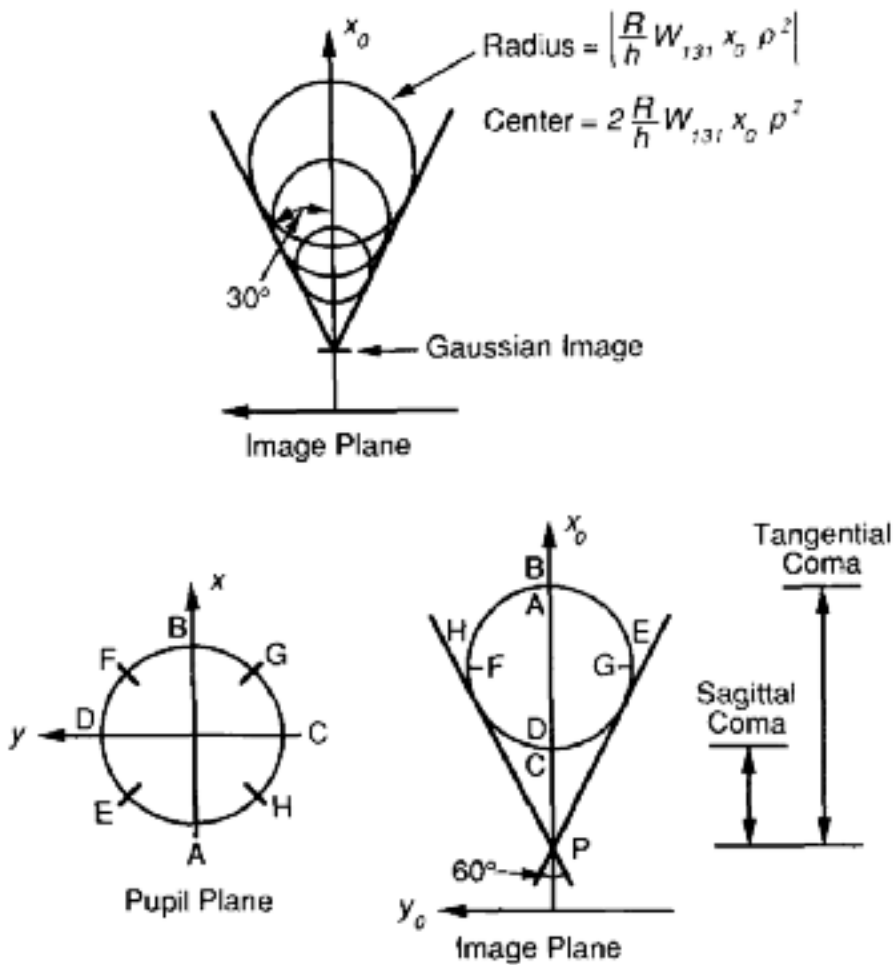


FIG. 26. Transverse ray aberration for coma.

Therefore, the minimum spot diameter for third-order spherical, the width of the coma image (2/3 the tangential coma), and the diameter of the blur for astigmatism that falls halfway between the sagittal and tangential focus are all given by

$$d = 4 f^{\#} \Delta W$$