Wave aberration function and transverse ray aberrations

OPTI 517

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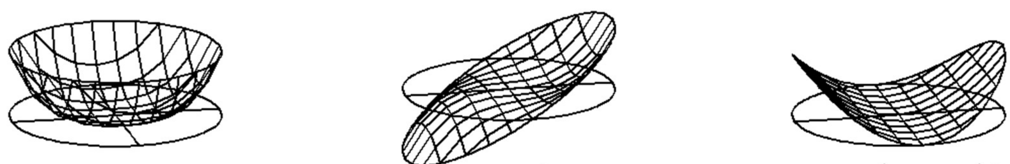
The aberration function for spherical, coma, and astigmatism aberrations is

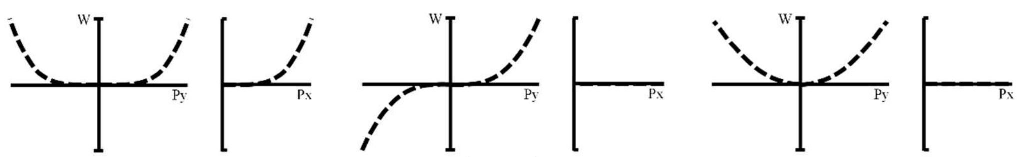
$$W\left(\vec{H},\vec{\rho}\right)=W_{040}\left(\vec{\rho}\cdot\vec{\rho}\right)^{2}+W_{131}\left(\vec{H}\cdot\vec{\rho}\right)\left(\vec{\rho}\cdot\vec{\rho}\right)+W_{222}\left(\vec{H}\cdot\vec{\rho}\right)^{2}.$$

Graphically the wavefront deformation for these aberrations is



$W_{040}\left(\vec{\rho}\cdot\vec{\rho}\right)^{2}$ $W_{131}\left(\vec{H}\cdot\vec{\rho}\right)\left(\vec{\rho}\cdot\vec{\rho}\right)$ $W_{222}\left(\vec{H}\cdot\vec{\rho}\right)^{2}$

and the wave fans are



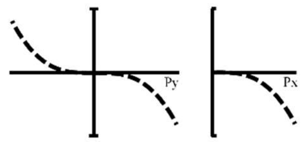
$W_{040}\left(\vec{\rho}\cdot\vec{\rho}\right)^{2}$ $W_{131}\left(\vec{H}\cdot\vec{\rho}\right)\left(\vec{\rho}\cdot\vec{\rho}\right)$ $W_{222}\left(\vec{H}\cdot\vec{\rho}\right)^{2}$

The transverse ray aberration is

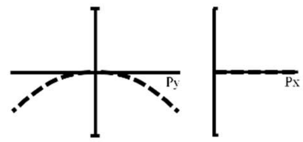
$$\vec{\varepsilon}=\bar{y}_{i}\Delta\vec{H}=-\frac{\bar{y}_{i}}{Ж}\vec{\nabla}_{\rho}W\left(\vec{H},\vec{\rho}\right)=\frac{1}{n'u'}\vec{\nabla}_{\rho}W\left(\vec{H},\vec{\rho}\right).$$

For the case of spherical aberration, coma, and astigmatism we have

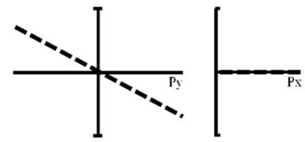
$$\begin{aligned}\vec{\varepsilon}&=\frac{1}{n'u'}\vec{\nabla}_{\rho}W\left(\vec{H},\vec{\rho}\right)=\frac{1}{n'u'}\frac{\delta}{\delta\vec{\rho}}\left(W_{040}\left(\vec{\rho}\cdot\vec{\rho}\right)^{2}+W_{131}\left(\vec{H}\cdot\vec{\rho}\right)\left(\vec{\rho}\cdot\vec{\rho}\right)+W_{222}\left(\vec{H}\cdot\vec{\rho}\right)^{2}\right)\\&=\frac{1}{n'u'}\left(4W_{040}\left(\vec{\rho}\cdot\vec{\rho}\right)\vec{\rho}+W_{131}\left(\vec{\rho}\cdot\vec{\rho}\right)\vec{H}+2W_{131}\left(\vec{H}\cdot\vec{\rho}\right)\vec{\rho}+2W_{222}\left(\vec{H}\cdot\vec{\rho}\right)\vec{H}\right)\end{aligned}.$$



$4W_{040}\left(\vec{\rho}\cdot\vec{\rho}\right)\vec{\rho}$



$W_{131}\left(\left(\vec{\rho}\cdot\vec{\rho}\right)\vec{H}+2\left(\vec{H}\cdot\vec{\rho}\right)\vec{\rho}\right)$



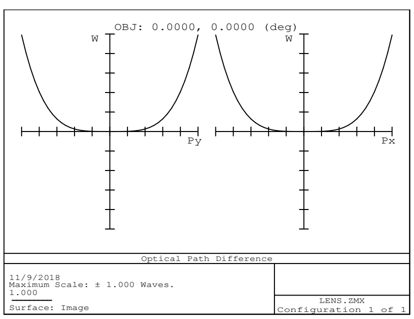
$2W_{222}\left(\vec{H}\cdot\vec{\rho}\right)\vec{H}$

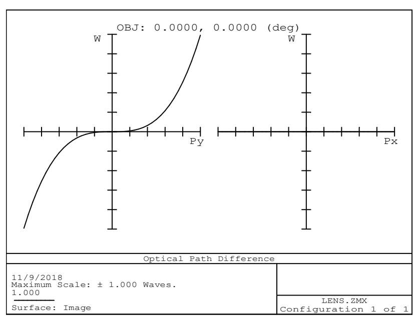
In the meridional plane $\phi=0$, at full field $H=1$, and at full aperture $\rho=1$ we have

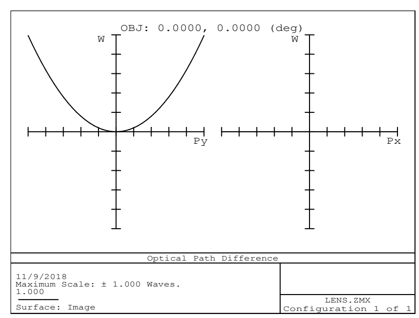
$$\varepsilon_y=\frac{1}{n'u'}\left(4W_{040}+3W_{131}+2W_{222}\right).$$

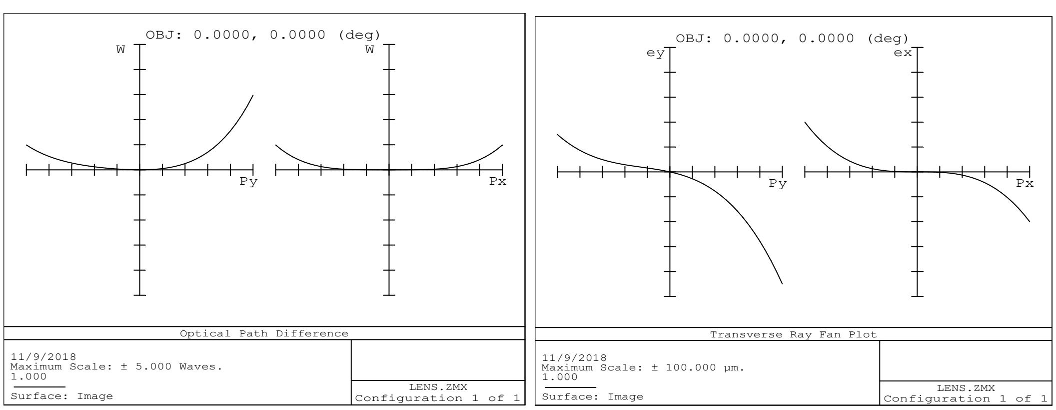
Assume the system is f/10, λ=0.0005 mm, n'=1, W_{040} =1λ, W_{131} =1λ, and W_{222} =1λ then

$$\varepsilon_y=-20\left(4+3+2\right)\lambda=-180\lambda=-0.09mm$$









Combined Wavefront deformation and transverse ray aberration

Alternatively the transverse ray aberration is

$$\varepsilon_y = \frac{1}{n'u'}\frac{\delta}{\delta\rho_y}W\left(\vec{H},\vec{\rho}\right) = \frac{1}{n'u'}\frac{\delta}{\delta\rho_y}\left(W_{040}\left(\vec{\rho}\cdot\vec{\rho}\right)^2 + W_{131}\left(\vec{H}\cdot\vec{\rho}\right)\left(\vec{\rho}\cdot\vec{\rho}\right) + W_{222}\left(\vec{H}\cdot\vec{\rho}\right)^2\right)$$
$$= \frac{1}{n'u'}\frac{\delta}{\delta\rho_y}\left(W_{040}\left(\rho_x^2+\rho_y^2\right)^2 + W_{131}\left(H_x\rho_x + H_y\rho_y\right)\left(\rho_x^2+\rho_y^2\right) + W_{222}\left(H_x\rho_x + H_y\rho_y\right)^2\right)$$
$$= \frac{1}{n'u'}\left(4W_{040}\left(\rho_x^2+\rho_y^2\right)\rho_y + W_{131}\left(\rho_x^2+\rho_y^2\right)H_y + 2W_{131}\left(H_x\rho_x + H_y\rho_y\right)\rho_y + 2W_{222}\left(H_x\rho_x + H_y\rho_y\right)H_y\right)$$

And similarly for

$$\varepsilon_x = \frac{1}{n'u'}\frac{\delta}{\delta\rho_x}W\left(\vec{H},\vec{\rho}\right).$$