Module 1: The Gaussian beam

Course 2 of *Optical Engineering*: Optical efficiency and resolution

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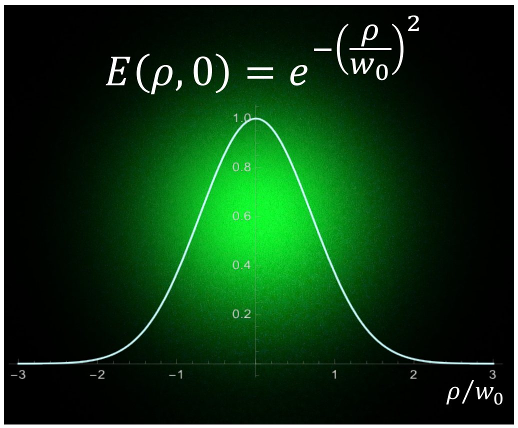
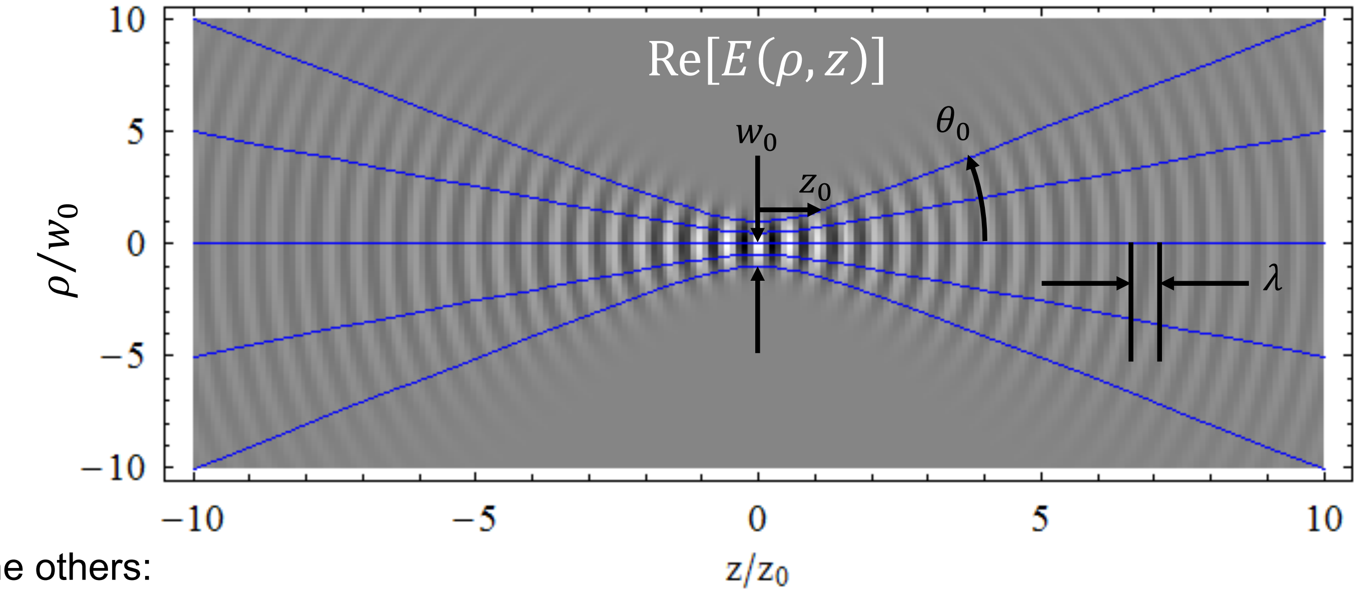
The Gaussian beam (in pictures)



https://en.wikipedia.org/wiki/Gaussian_beam



Any one quantity determines all the others:

$$\boxed{w_0 = \sqrt{\frac{\lambda}{\pi} z_0} = \frac{\lambda}{\pi}\frac{1}{\theta_0}} \qquad \boxed{\theta_0 = \frac{\lambda}{\pi}\frac{1}{w_0} = \sqrt{\frac{\lambda}{\pi}\frac{1}{z_0}}} \qquad \boxed{z_0 = \frac{\lambda}{\pi}\theta_0^{-2} = \frac{\pi}{\lambda} w_0^2 = \frac{w_0}{\theta_0}} \qquad \lambda \equiv \frac{\lambda_0}{n}$$

Saleh & Teich chapter 3

The Gaussian beam (in math)

Solution of scalar paraxial wave equation (Helmholtz equation)

$$E(\vec{r}) = A_0 \frac{w_0}{w(z)} e^{-\frac{\rho^2}{w^2(z)} - jkz - jk\frac{\rho^2}{2R(z)} + j\zeta(z)}$$

Beam radius

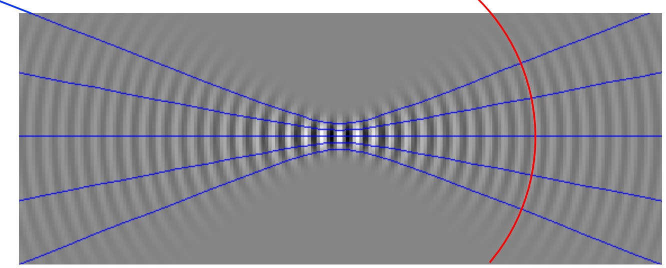
$$w(z) = w_0 \sqrt{1 + \left(\frac{z}{z_0}\right)^2}$$

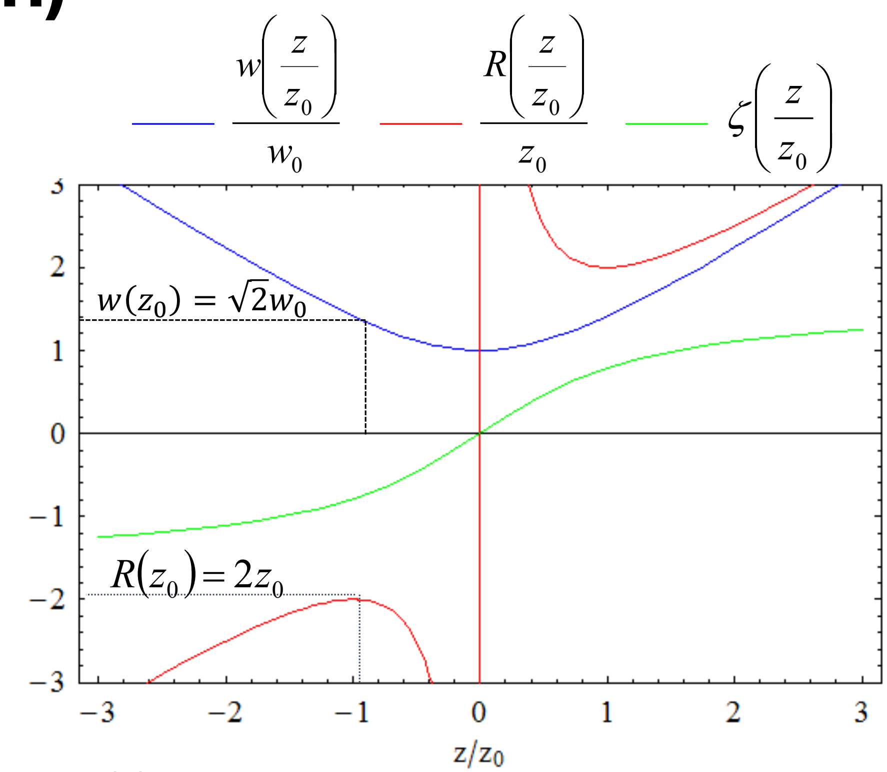
Radius of curvature

$$R(z) = z\left[1 + \left(\frac{z_0}{z}\right)^2\right]$$

Gouy phase

$$\zeta(z) = \tan^{-1}\left(\frac{z}{z_0}\right)$$



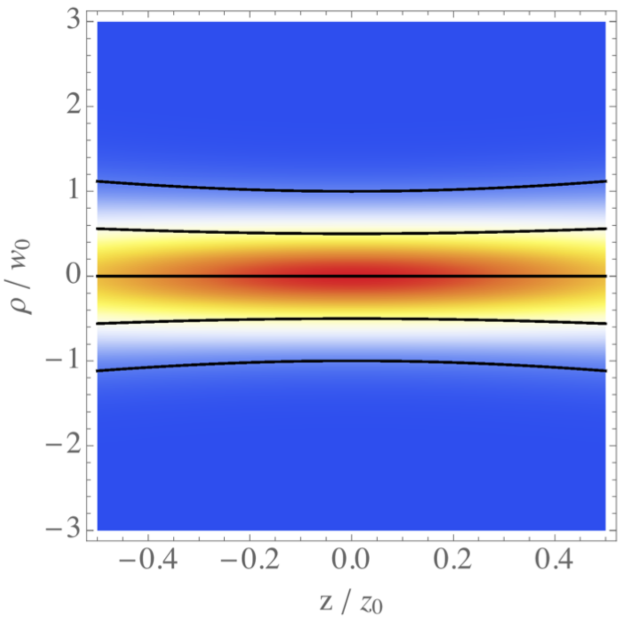


Note that R(z) does not obey ray tracing sign convention. Unfortunately there's no particularly good way to fix this.

Gaussian beam intensity

The intensity of the Gaussian beam is found via $|E|^2$ to be $$I(\vec{r}) = \frac{1}{\pi/2}\frac{1}{w^2(z)}e^{-2\frac{\rho^2}{w^2(z)}}$$

“Collimated beam”



Focusing beam