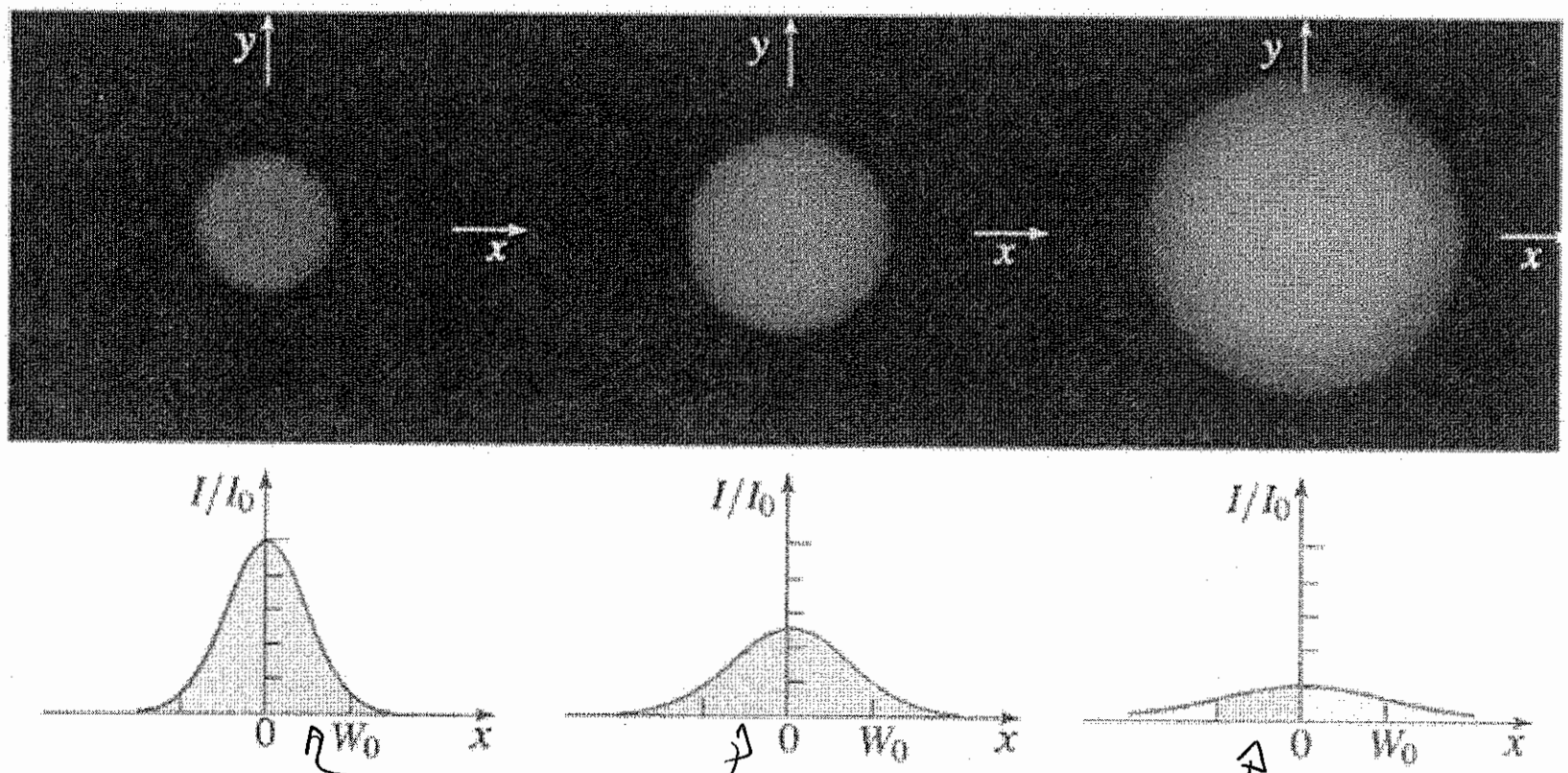


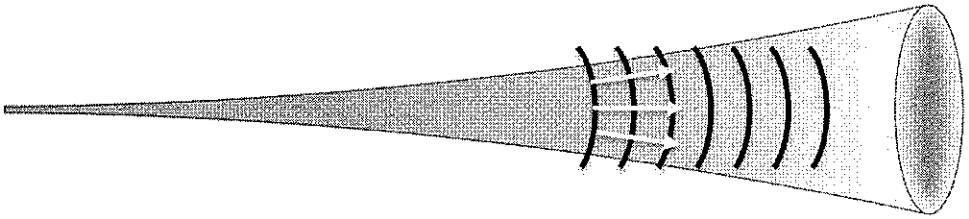
Figure 3.1-1 The normalized beam intensity I/I_0 as a function of the radial distance ρ at different axial distances: $(a)\ z = 0$; $(b)\ z = z_0$; $(c)\ z = 2z_0$.

Image from B. Saleh and M Teich, Fundamentals of Photonics, 2nd Edition. (2007) Wiley and Sons

1-This is a figure from the pre-reading. Give a physical argument why the beam's intensity must decrease as z gets larger. The power of the beam must be conserved which is the area under the curves. If the width gets bigger, the peak intensity must drop

Bonus: Given the beam width has this function dependence $W(z) = W_o\sqrt{1 + z^2/z_o^2}$ and amplitude dependence $\frac{W_o}{W(z)}$ determine the function dependence of I(x=o,y=0,z)

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$$E(x,y,z) = \frac{A}{z} e^{ik(\frac{x^2+y^2}{2z})}$$

1-Last Thursday we decided a paraboloidal wave had phase fronts that matched the behaviour of this laser beam. But still doesn't have finite transverse amplitude and it has a singularity at z=0....but it is a starting point.

2-Begin with paraboloidal wave, shift $z \rightarrow z - iz_o$ and identify in resulting expression the longitudinal amplitude/ phase components and transverse (radial) amplitude/phase components

see next page

Bonus -Sketch intensity at $z = 0$ and $z = z_o$ what is happening to the wave? The output beam of a laser is usually specified in terms of a particular z_o Why would this quantity be useful differentiating between two different lasers

Begin with paraboloidal wave, shift $z \rightarrow z - iz_o$ and identify in resulting expression the longitudinal amplitude/phase components and transverse (radial) amplitude/phase components

$$E(x,y,z) = \frac{A}{z} e^{ik\left(\frac{x^2+y^2}{2z}\right)} \Rightarrow E(x,y,z) = \frac{A}{z - iz_o} e^{ik\left(\frac{x^2+y^2}{2(z-iz_o)}\right)}$$

$$\Downarrow$$

$$E(x,y,z) = \frac{A}{z^2 + z_o^2}(z + iz_o) e^{ik\left(\frac{x^2+y^2}{2(z^2+z_o^2)}\right)(z+iz_o)}$$

$$\Downarrow$$

$$E(x,y,z) = \frac{A}{z^2 + z_o^2}(z + iz_o) e^{ik\left(\frac{x^2+y^2}{2(z+z_o^2/z)}\right)} e^{-k\left(\frac{x^2+y^2}{2(z^2/z_o+z_o)}\right)}$$

$$\Downarrow$$

$$U(x,y,z) = \frac{A\,\frac{i}{z_o}}{\sqrt{(z^2 + z_o^2)}} e^{i\tan^{-1}(z/z_o)} e^{ik\left(\frac{x^2+y^2}{2z(1+z_o^2/z^2)}\right)} e^{-\left(\frac{x^2+y^2}{(z^2/z_o^2+1)\lambda z_o/\pi}\right)} e^{ikz}$$

Longitudinal amp | Longitudinal phase | Radial phase | Radial amp

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$$U(x,y,z) = \frac{A\,\frac{i}{z_o}}{\sqrt{(z^2+z_o^2)}} e^{i\tan^{-1}(z/z_o)} e^{ik\left(\frac{x^2+y^2}{2z(1+z_o^2/z^2)}\right)} e^{-\left(\frac{x^2+y^2}{(z^2/z_o^2+1)\lambda z_o/\pi}\right)} e^{ikz}$$

Longitudinal amp

Longitudinal phase

Radial phase

Radial amp

Radius of curvature of transverse phase $R(z) = z(1+z_o^2/z^2)$

Transverse width of amplitude $W(z) = W_o\sqrt{1+z^2/z_o^2}$

$W_o = \sqrt{\lambda z_o/\pi}$

Standard Form:

$$U(x,y,z) = A_o \frac{W_o}{W(z)} e^{i\tan^{-1}(z/z_o)} e^{ik\left(\frac{x^2+y^2}{2R(z)}\right)} e^{-\left(\frac{x^2+y^2}{W(z)}\right)} e^{ikz}$$

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$$U(x,y,z) = A_o \frac{W_o}{W(z)} e^{i\tan^{-1}(z/z_o)} e^{ik\left(\frac{x^2+y^2}{2R(z)}\right)} e^{-\left(\frac{x^2+y^2}{W(z)}\right)} e^{ikz}$$

$$R(z) = z(1 + z_o^2/z^2) \qquad W(z) = W_o\sqrt{1 + z^2/z_o^2}$$

$$W_o = \sqrt{\lambda z_o/\pi}$$

4-Sketch the waist W(z) and wavefronts as a function of z

see text figs 3.1-6, 3.1-7

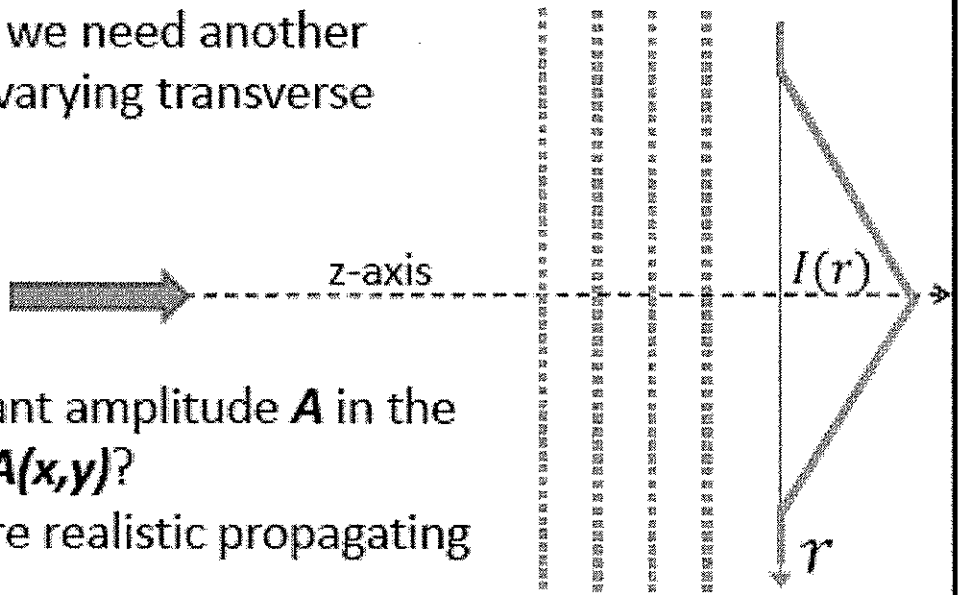
5-How many independent parameters are necessary to fully characterize a Gaussian Beam?

A_o (or the power)
z_o (or w_o)
λ

as well see in 2 pages we ~~are~~ also need to know the location of the minimum waist

6-The arctan term causes a z-dependent phase shift in z relative to both a plane wave and a paraboloidal wave. Draw the three wavefronts and discuss the implications

If we want to have a propagating wave solution that is more realistic than the plane wave solution $U(r) = Ae^{ikz}$, we need another solution with finite optical power (varying transverse amplitude).



Could we simply replace the constant amplitude ***A*** in the plane wave solution by a function ***A(x,y)***?
If so, which function leads to a more realistic propagating wave solution?

(A) Semi circular

(B) Triangle

(C) Gaussian

(D) All three can be used

(E) None of the above

Make sure you know why!!

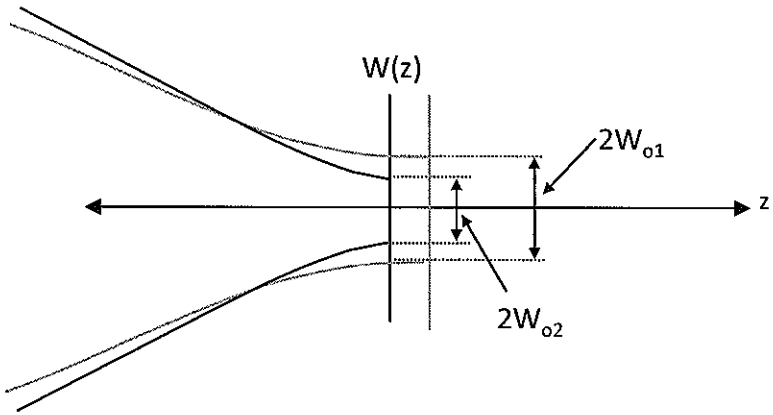
but not z

We found a Gaussian beam has three independent parameters. Instead of being given A_o and z_o what if the beam radius ~~W~~ $w(z)$ and Power are given. Is this enough to uniquely characterize a beam?

(A) No

(B) Yes

(C) Dunno



W(z) isn't enough. Many different beams could have this radius
So what other piece of info would be needed?

=> location of the minimum waist is needed.