Çankaya University – ECE Department – ECE 474 (Final)

Student Name : Date : 27.05.2010
Student Number : Open book exam

Questions

1. (70 Points) An input plane Gaussian beam with $\alpha_s = 1$ cm, $\lambda = 1.55\ \mu$m is given. For this beam, we alternatively set a) $F_s \to \infty$, b) $F_s = 1$ km, c) $F_s = -1$ km. Answer the followings ;

A) Describe the type of a beam for settings in a), b), c) above.
B) For each case of a), b), c), calculate α_r (beam size) and F_r (wavefront radius of curvature) at z = 1.5 km.
C) For each case of a), b), c), calculate α_B (beam waist), α_f (beam size at focus), z_B (distance to beam waist) and z_{R1}, z_{R2} or z_R (Rayleigh range), identifying near and far field regions.
D) Plot the variations of α_r (beam size) and F_r (wavefront radius of curvature) along z axis.

Solution : A) a) is a collimated beam, b) convergent beam, c) divergent beam
B) a) For collimated beam, from Notes on free space propagation for ECE 474_Nisan 2012, using (G24) we get

$$\alpha_r =_{F_s \to \infty} \left(\frac{k^2\alpha_s^4 F_s^2 - 2k^2\alpha_s^4 F_s z + 4F_s^2 z^2 + k^2\alpha_s^4 z^2}{k^2\alpha_s^2 F_s^2} \right)^{1/2} = \left(\frac{k^2\alpha_s^4 + 4z^2}{k^2\alpha_s^2} \right)^{1/2} = 7.47 \text{ cm}$$

Then using (G28) of the same notes we get

$$F_r =_{F_s \to \infty} \left(-\frac{k^2\alpha_s^4 F_s^2 - 2k^2\alpha_s^4 F_s z + 4F_s^2 z^2 + k^2\alpha_s^4 z^2}{4F_s^2 z - k^2\alpha_s^4 F_s + k^2\alpha_s^4 z} \right) = -\frac{k^2\alpha_s^4 + 4z^2}{4z} = -1527.2 \text{ m}$$

b) For convergent beam, using the above and inserting $F_s = 1$ km we get

$$\alpha_r = \left(\frac{k^2\alpha_s^4 F_s^2 - 2k^2\alpha_s^4 F_s z + 4F_s^2 z^2 + k^2\alpha_s^4 z^2}{k^2\alpha_s^2 F_s^2} \right)^{1/2} = 7.42 \text{ cm}$$

$$F_r = -\frac{k^2\alpha_s^4 F_s^2 - 2k^2\alpha_s^4 F_s z + 4F_s^2 z^2 + k^2\alpha_s^4 z^2}{4F_s^2 z - k^2\alpha_s^4 F_s + k^2\alpha_s^4 z} = -1486.3 \text{ m}$$

c) For divergent beam, using the above and inserting $F_s = -1$ km we get

$$\alpha_r = \left(\frac{k^2\alpha_s^4 F_s^2 - 2k^2\alpha_s^4 F_s z + 4F_s^2 z^2 + k^2\alpha_s^4 z^2}{k^2\alpha_s^2 F_s^2} \right)^{1/2} = 7.81 \text{ cm}$$

$$F_r = -\frac{k^2\alpha_s^4 F_s^2 - 2k^2\alpha_s^4 F_s z + 4F_s^2 z^2 + k^2\alpha_s^4 z^2}{4F_s^2 z - k^2\alpha_s^4 F_s + k^2\alpha_s^4 z} = -1563.9 \text{ m}$$

C) From the same notes, a) For collimated beam we have $\alpha_B = \alpha_s$, $z_B = 0$,

$z_R = 0.5k\alpha_s^2 = 202.68$ m.

b) For convergent beam, $\alpha_B = \left(\frac{4\alpha_s^2 F_s^2}{4F_s^2 + k^2\alpha_s^4} \right)^{1/2} = 0.98$ cm $z_B = \frac{k^2\alpha_s^4 F_s}{4F_s^2 + k^2\alpha_s^4} = 39.46$ m

$z_{R_1} = \frac{k^2\alpha_s^4 F_s - 2k\alpha_s^2 F_s^2}{4F_s^2 + k^2\alpha_s^4} = -155.226$ m , $z_{R_2} = \frac{k^2\alpha_s^4 F_s + 2k\alpha_s^2 F_s^2}{4F_s^2 + k^2\alpha_s^4} = 234.145$ m

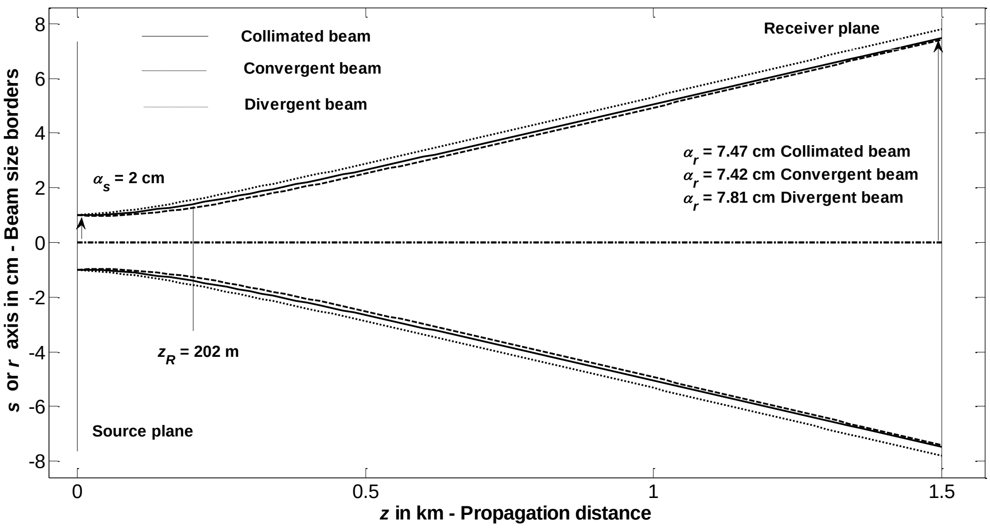
Up to $z_R = 0.5k\alpha_s^2 = 202.68$ m is near field, from z_R onwards it is far field. $\alpha_f == \frac{2F_s}{k\alpha_s} = 4.93$ cm

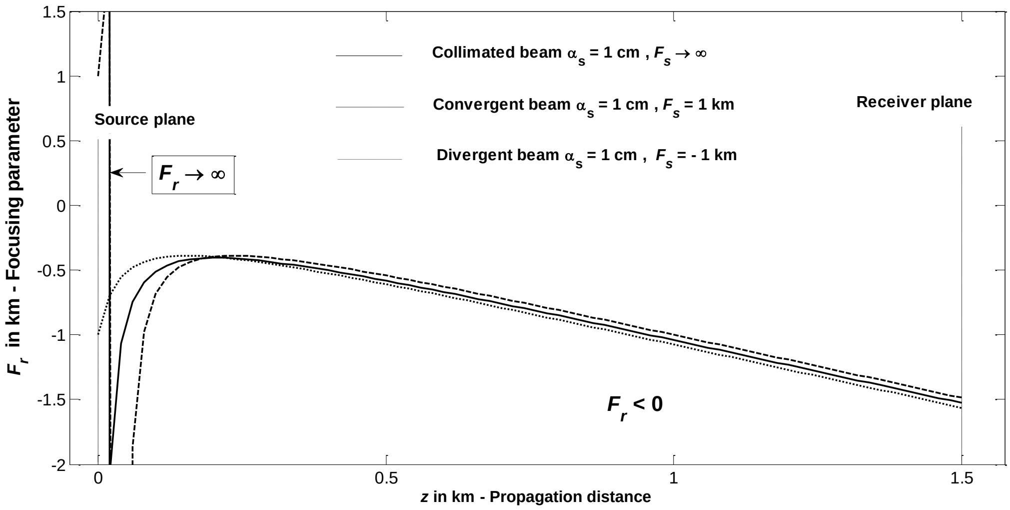
c) For divergent beam, we have $\alpha_B = \left(\frac{4\alpha_s^2 F_s^2}{4F_s^2 + k^2\alpha_s^4} \right)^{1/2} = 0.98$ cm, but this is not meaningful

since for a divergent beam, α_B is positioned to the left (behind) of the source plane, thus

$z_B = \frac{k^2\alpha_s^4 F_s}{4F_s^2 + k^2\alpha_s^4} = -39.46$ m

D) For three beam types, below we give the graphs of α_r and F_r along z axis which are obtained from Beamsize.m and Focusingpram.m





Collimated beam α_s = 1 cm , F_s → ∞
Convergent beam α_s = 1 cm , F_s = 1 km
Divergent beam α_s = 1 cm , F_s = - 1 km
Source plane
Receiver plane
F_r → ∞
F_r < 0
F_r in km - Focusing parameter
z in km - Propagation distance
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.5
1
1.5

2. (30 Points) Answer the following questions as **True** or **False.** For the **False** ones give the correct answer or the reason. For the **True** ones justify your answer

a) APD is more efficient than PIN photodiode : True, since in APD, there is the current multiplication factor of M. This multiplication factor multiplies only the signal and has no effect on noise. This way, it is a true gain.

b) A laser resonator produces at its output many frequencies determined by the separation between the laser mirrors : True. In laser resonator, frequency or wavelength spacing is inversely proportional to separation distance between mirrors.

c) Dispersion causes a signal to propagate slower inside the fibre : Not exactly, dispersion is basically due to finite time difference between slow and fast propagating modes (rays).

d) The efficiency of a photodiode is measured by the number of photons falling on its receiving surface : True, but efficiency is quantitatively measured by dividing the number of electron-hole pairs generated by number of photons falling onto the surface of the photodiode.

e) A Gaussian beam becomes larger in beam size as it propagates along propagation axis : This is true for all beam types if we extend propagation distance towards infinity. But for convergent beam, prior to beam waist location, the beam size initially becomes smaller (than source size), then it starts to expand.