Çankaya University – ECE Department – ECE 474 (FE) - YO

Student Name : Date : 21.08.2014
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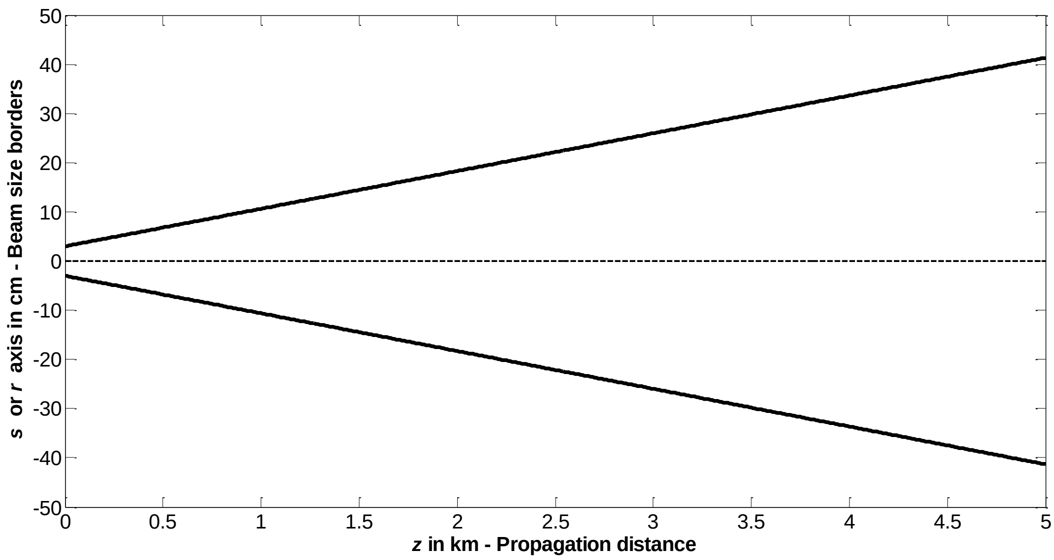
Questions

1. (70 Points) The following plots in Figs. 1.1a), 1.1b), 1.2a), 1.2b), 1.3a), 1.3b) are for the beam size α_r and radius of curvature F_r variations of three Gaussian source beams that emit light at $\lambda = 1.55\ \mu\text{m}$. By reading the numeric values from these plots, identify beam types for beam1, beam2, beam3 and evaluate the following relevant parameters,

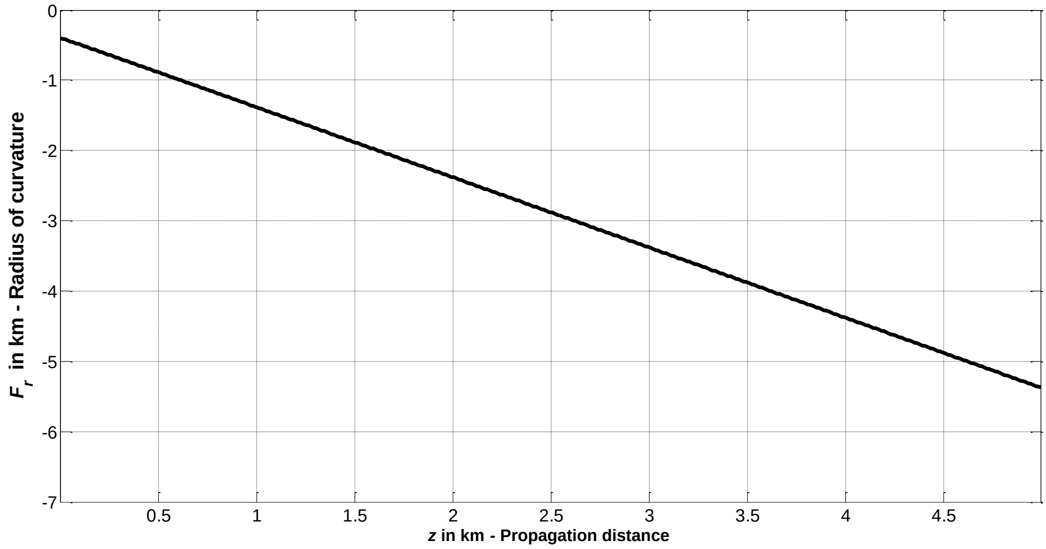
a) α_s, α_B, α_f, z_B, z_R, z_{R_1}, z_{R_2}

b) α_r and F_r at $z = 0.5$ km, 1 km, 5 km

c) The power, P and the the intensity levels at $r = 1$ cm and at $z = 0.5$ km, 1 km, 5 km.

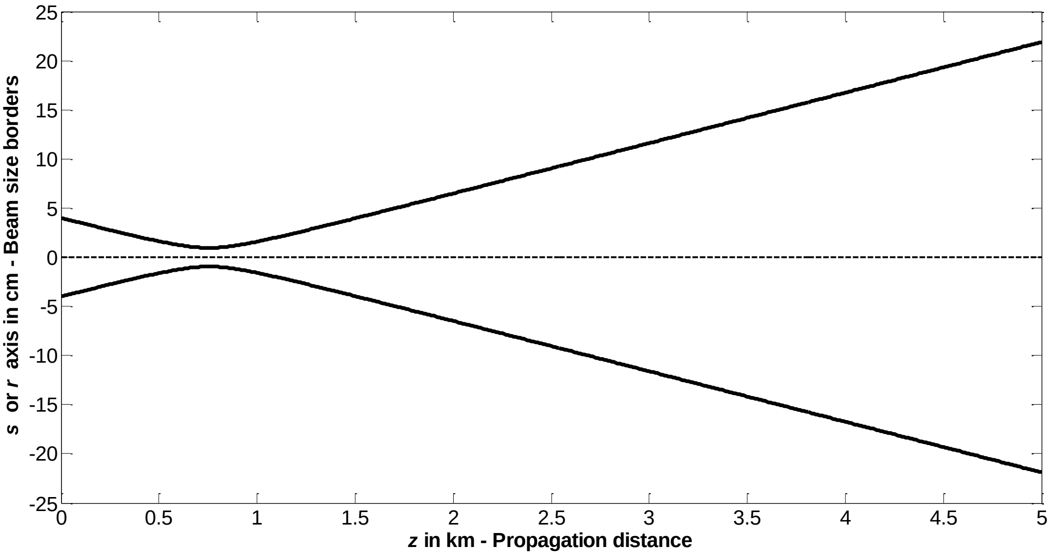


a) Beam size, α_r variation for beam1.

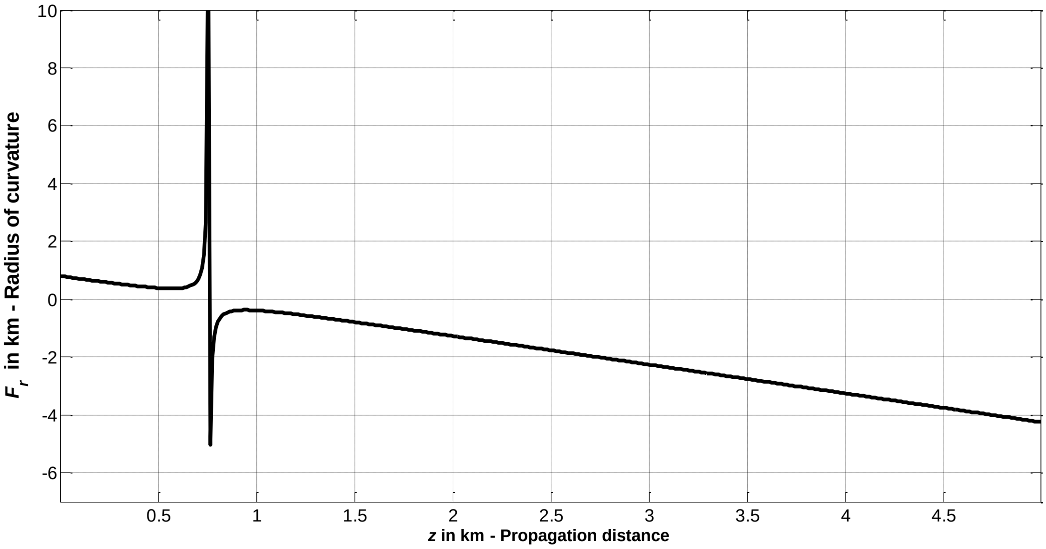


b) Radius of curvature, F_r variation for beam1.

Fig. 1.1 Beam size and radius of curvature variations for beam1.

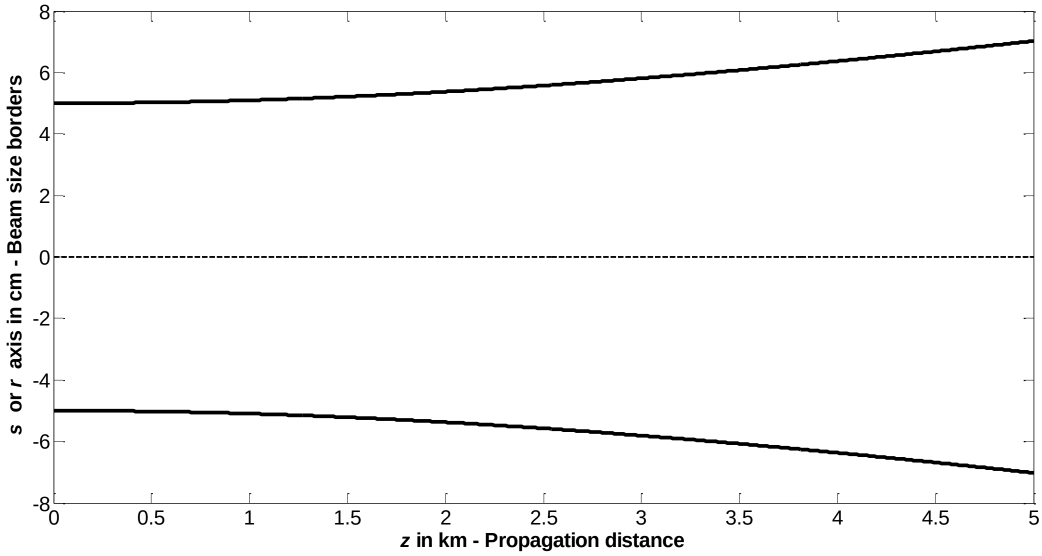


a) Beam size, α_r variation for beam2.

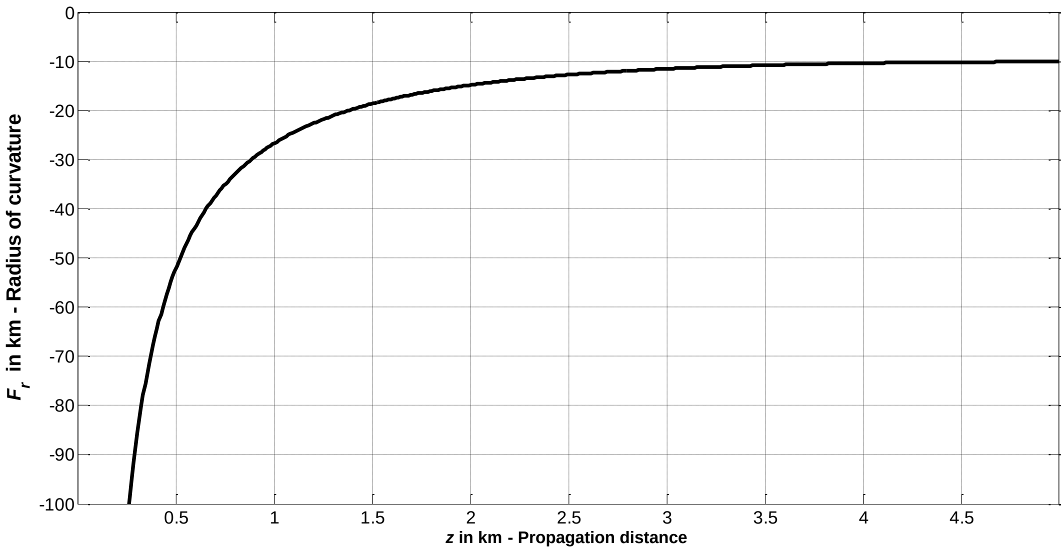


b) Radius of curvature, F_r variation for beam2.

Fig. 1.2 Beam size and radius of curvature variations for beam2.



a) Beam size, α_r variation for beam3.



b) Radius of curvature, F_r variation for beam3.

Fig. 1.3 Beam size and radius of curvature variations for beam3.

Solution : Comparing Figs. 1.1, 1.2 and 1.3 to those figures on pages 16, 17 and 18 of Notes on free space propagation for ECE 474_Nisan 2012, we find that beam1 in Fig. 1.1 is a divergent beam, beam2 in Fig. 1.2 is convergent beam, beam 3 in Fig. 1.3 is a collimated beam. From these figures, we read

$$\begin{aligned}&\text{beam1 - divergent beam : } \alpha_s = 3 \text{ cm}, F_s = -400 \text{ m}\\&\text{beam2 - convergent beam : } \alpha_s = 4 \text{ cm}, F_s = 750 \text{ m}\\&\text{beam3 - collimated beam : } \alpha_s = 5 \text{ cm}, F_s \to \infty \qquad (1.1)\end{aligned}$$

a) Now using (G30), (P6), (G29), (G31) for $\alpha_B,\ \alpha_f,\ z_B,\ z_R,\ z_{R_1},\ z_{R_2}$ as

$$\text{beam1 : } \alpha_B \to \alpha_s = 3 \text{ cm} \ ,\ \alpha_f \ ,\ z_B \ ,\ z_{R_1} \ ,\ z_{R_2} \text{ are undefined}$$

$$\text{beam2 : } \alpha_B = \left(\frac{4\alpha_s^2 F_s^2}{4F_s^2 + k^2\alpha_s^4}\right)^{1/2} = 0.9 \text{ cm} \ ,\ \alpha_f = \frac{2F_s}{k\alpha_s} = 0.93 \text{ cm} \ ,\ z_B = \frac{k^2\alpha_s^4 F_s}{4F_s^2 + k^2\alpha_s^4} = 711.9 \text{ m}$$

$$z_{R_1} = \frac{k^2\alpha_s^4 F_s - 2k\alpha_s^2 F_s^2}{4F_s^2 + k^2\alpha_s^4} = 547.3 \text{ m} \quad , \quad z_{R_2} = \frac{k^2\alpha_s^4 F_s + 2k\alpha_s^2 F_s^2}{4F_s^2 + k^2\alpha_s^4} = 876.6 \text{ m}$$

$$\text{beam3 : } \alpha_B = \alpha_s = 3 \text{ cm} \quad \alpha_f \ ,\ z_{R_1} \ ,\ z_{R_2} \text{ undefined} \ ,\ z_B = 0 \ ,\ z_R = 0.5k\alpha_s^2 = 5.067 \text{ km} \qquad (1.2)$$

b) It is possible to evaluate α_r and F_r at $z = 0.5$ km, 1 km, 5 km either from (G24) and (G28) of Notes on free space propagation for ECE 474_Nisan 2012 or by reading from Figs. 1.1 to 1.3. Hence

$$\text{beam1}: \alpha_r = \left(\frac{k^2\alpha_s^4 F_s^2 - 2k^2\alpha_s^4 F_s z + 4F_s^2 z^2 + k^2\alpha_s^4 z^2}{k^2\alpha_s^2 F_s^2} \right)^{1/2} = 6.8 \text{ cm at } z = 0.5 \text{ km}$$

$$= 10.63 \text{ cm at } z = 1 \text{ km}$$

$$= 41.33 \text{ cm at } z = 5 \text{ km}$$

$$F_r = -\frac{k^2\alpha_s^4 F_s^2 - 2k^2\alpha_s^4 F_s z + 4F_s^2 z^2 + k^2\alpha_s^4 z^2}{4F_s^2 z - k^2\alpha_s^4 F_s + k^2\alpha_s^4 z} = -0.89 \text{ km at } z = 0.5 \text{ km}$$

$$= -1.388 \text{ km at } z = 1 \text{ km}$$

$$= -5.374 \text{ km at } z = 5 \text{ km}$$

$$\text{beam2}: \alpha_r = 1.47 \text{ cm at } z = 0.5 \text{ km}$$

$$= 1.816 \text{ cm at } z = 1 \text{ km}$$

$$= 23.49 \text{ cm at } z = 5 \text{ km}$$

$$F_r = 0.3394 \text{ km at } z = 0.5 \text{ km}$$

$$= -0.3897 \text{ km at } z = 1 \text{ km}$$

$$= -4.285 \text{ km at } z = 5 \text{ km}$$

$$\text{beam3}: \alpha_r = 5.024 \text{ cm at } z = 0.5 \text{ km}$$

$$= 5.096 \text{ cm at } z = 1 \text{ km}$$

$$= 7.024 \text{ cm at } z = 5 \text{ km}$$

$$F_r = -51.75 \text{ km at } z = 0.5 \text{ km}$$

$$= -26.65 \text{ km at } z = 1 \text{ km}$$

$$= -10.14 \text{ km at } z = 5 \text{ km} \qquad (1.3)$$

c) From (G21) of of Notes on free space propagation for ECE 474_Nisan 2012, we have

$$\text{beam1}: A_c^2 \frac{\pi}{2} \alpha_s^2 = 1.4 \text{ mW} \text{ , if } A_c = 1$$

$$\text{beam2}: A_c^2 \frac{\pi}{2} \alpha_s^2 = 2.5 \text{ mW} \text{ , if } A_c = 1$$

$$\text{beam2}: A_c^2 \frac{\pi}{2} \alpha_s^2 = 3.9 \text{ mW} \text{ , if } A_c = 1 \qquad (1.4)$$

By running GaussianbeamR.m, we find the intensities as

$$\text{beam1}: I_r\left(r = 1 \text{ cm}\right) = 0.1861 \text{ at } z = 0.5 \text{ km}$$

$$= 0.07823 \text{ at } z = 1 \text{ km}$$

$$= 0.005262 \text{ at } z = 5 \text{ km}$$

$$\text{beam2}: I_r\left(r = 1 \text{ cm}\right) = 2.774 \text{ at } z = 0.5 \text{ km}$$

$$= 2.254 \text{ at } z = 1 \text{ km}$$

$$= 0.02483 \text{ at } z = 5 \text{ km}$$

$$\text{beam3}: I_r\left(r = 1 \text{ cm}\right) = 0.9123 \text{ at } z = 0.5 \text{ km}$$

$$= 0.8887 \text{ at } z = 1 \text{ km}$$

$$= 0.481 \text{ at } z = 5 \text{ km} \qquad (1.5)$$

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. Answers are to be based on references from lecture notes, answers from non-academic and internet sources are not acceptable.

a) The emission wavelength of an LED is determined by material composition : True, according to descriptions found in Examples 2.1 and 2.2 of Optical transmitters and receivers_2013_HTE.

b) In a single mode fibre, the propagation constant of TM_{01} has to be lower than k_2 : False, the nearest correct version would be "the propagation constant of HE_{11} has to be higher than k_2". Relevant details are in Examples 3.1 and 3.2 of Notes on free space propagation for ECE 474_Nisan 2012.

c) In graded index fibres, rays with $\theta_{x0} \neq \theta_{y0}$ or $x_0 \neq y_0$ are skew rays : True, as stated page 6 of Notes on Propagation in GI fibres_Feb 2013_HTE.

d) Eikonal equation describes the phase variations : True, as explained on underneath (3.1) in Notes on Propagation in GI fibres_Feb 2013_HTE.

e) Attenuation is more in multimode fibres : False, there is no difference between single and multimode fibres as regards to attenuation, there is only dispersion difference between these two fibres as explained in the notes of Attenuation and dispersion in fibres_March 2013_HTE.

f) Dispersion analysis helps to find the SNR on the receiving side of the fibre : True, as shown in Examples 4.1.1 and 4.1.2 of Attenuation and dispersion in fibres_March 2013_HTE.