App Note: DLS-01

Optimization of Fiber Coupling with Edge-Emitting Light Source

1. Introduction

1.1 In most applications, the optical output from a semiconductor light emitting device, such as a laser diode and SLED, is to be coupled into an optical fiber. The key attribute required of this optical assembly is a high coupling efficiency with minimal back-reflection from the fiber tip back to the light emitting chip.

1.2 Most edge-emitting light sources are designed based on a ridge waveguide structure, which gives a slightly elliptical mode profile with far-field beam divergence in the order of 25 to 35°. The beam divergence in the vertical/perpendicular direction is normally larger than the beam divergence in the horizontal/parallel direction.

1.3 The optical fiber typically used is the standard single-mode fiber, and for the SMF-28e fiber, the core diameter is 8.2µm with a circular optical mode profile and mode field diameter of 9.2µm at 1310nm and 10.4µm at 1550nm.

1.4 In order to get good coupling efficiency, the optical mode of the fiber has to be matched with the optical mode and beam divergence of the light emitting from the light source chip.

2. Lensed Fiber Tips

2.1 In order to get good coupling with the light source chip, the fiber tip to couple the incoming light is normally tapered and lensed. There are a number of such available lensed tips, such as spherical, wedge/cylindrical and biconic types as shown in Figure 1[1].

2.2 The spherical type is designed for single mode laser diodes and SLEDs, with slightly elliptical mode profile. The cylindrical type is catered to high power laser diodes, which have a multimode output and highly elliptical optical mode. The biconic lensed tip is for matching optical mode profiles that are in-between that of the spherical and cylindrical types.

[1].Adamant Namiki Precision Jewel: https://www.ad-na.com/en/product/optical/device/lensed-fiber.html

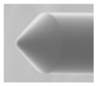
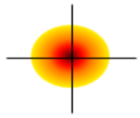
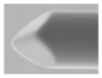
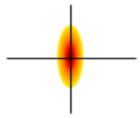
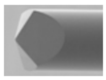
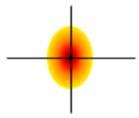
Fiber Tip Configration	Beam pattern	Aprlication
Spherical Lensed Fiber (SLF) 		- 1310nm, 1550nm LD Coupling → LD Module - OWG, Si-wire waveguides - Out put to PD - Microscopic region Lighting
Cylindrical Lensed Fiber (CLF) 		- 980nm LD Coupling → Amp LD Module → High Power LD Module (Fiber Laser, Medical) - Visible Light etc. - OWG, Functional waveguides
Biconic Lensed Fiber 		- 1480nm LD Coupling → Amp LD Module - Visible Light etc. - OWG, Functional waveguides

Figure 1: Types of lensed fiber tip (ref: Adamant Namiki)

3. Optimization of Coupling Efficiency

3.1 The achievable coupling efficiency at best optical alignment is determined by the lens radius of the fiber tip and separation between the light emission point and the fiber tip.

3.2 Figure 2 shows the coupling efficiency of a spherical lensed fiber at various chip-fiber separations and lens radii. This is for the case of a 1550nm laser diode with beam divergence of 20° × 20°. It can be observed that for a specific lens radius R, there is an optimal chip-fiber separation to get the best coupling.

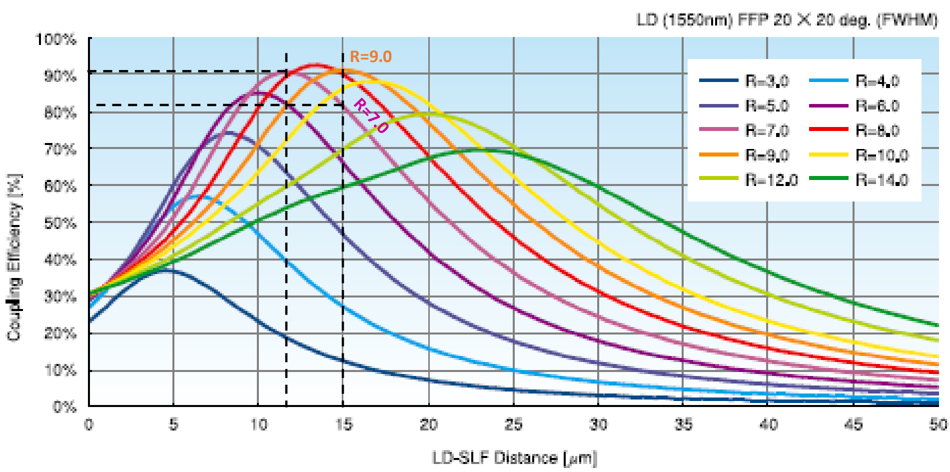


Figure 2: Variation of spherical lens fiber's coupling efficiency with lens radius[2]

[2] https://www.ad-na.com/en/product/optical/device/pdf/LensedFiber.pdf

3.3 Figure 3 shows the best achievable coupling efficiency with the spherical lensed fiber at various beam divergence angles for 1550nm light. It can be observed for beam divergence of 30° by 35°, a coupling efficiency of 0.9~0.95 can be achievable at the best alignment and optimal chip-fiber separation. This is a slight drop of 5.3% from coupling efficiency decrease from 0.95 to 0.9 with beam divergence changed from 20° ╳ 20° to 30° ╳ 35°.

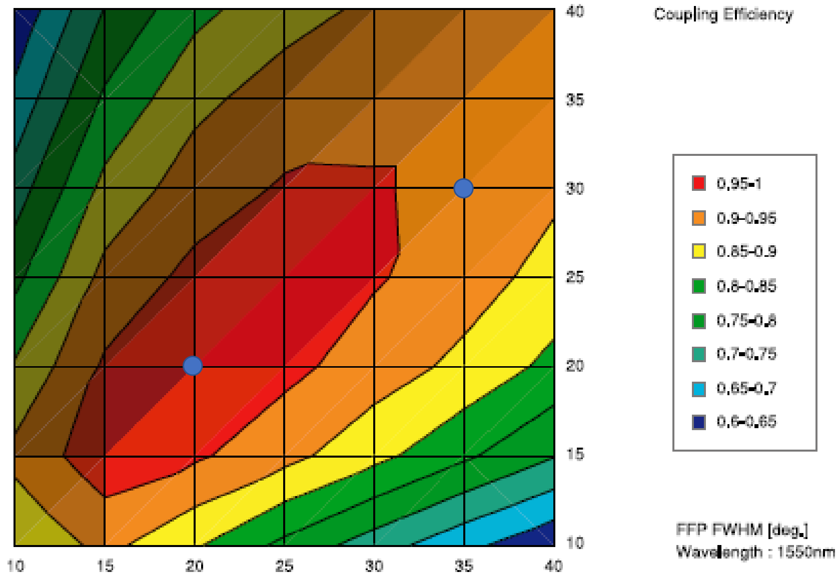


Figure 3: Variation of spherical lens fiber's coupling efficiency with beam divergence[2]

3.4 Examining the case for a fiber tip with 7µm lens radius tip that is separated from the light source chip by 15µm in Figure 2, the best achievable coupling efficiency for input light with 20° ╳ 20° beam divergence is 0.82, but this is lower than 0.90 that is the case at optimal separation of 11.5µm between the chip and fiber. The achievable coupling efficiency at 30° ╳ 35° beam divergence will be even lower.

3.5 For a chip to fiber tip separation of 15µm, it can be observed that the best lens radius is 9µm, giving coupling efficiency of 0.90 for input beam with divergence of 20° ╳ 20°. If the beam divergence is 30° ╳ 35°, it can be estimated that the best achievable coupling efficiency at perfect alignment becomes 0.90 x 0.947 = 0.85.

3.6 In summary, the best coupling efficiency can be obtained by mode matching the output beam divergence from the light source chip with that of the lensed fiber tip. For a chip to fiber tip separation of 15µm, the optimal lens radius for the lensed tip is around 9µm. A detailed relationship of coupling efficiency with the optimal lens radius and chip-fiber separation at the specific beam divergence can be determined by optical simulation or by experimental characterization.

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