Application Note:
Enhancing Laser Diode Output with Optical Lenses

Introduction

Optimizing the optical output of edge-emitting laser diodes is critical for achieving high output power and efficiency, especially with the addition of optical lenses for free space or optical fiber applications. Applications such as optical networks, data centers, LiDAR, and laser range-finding rely heavily on these light collecting methods. This application note aims to explore the different beam-shaping techniques with various optical lenses, including Fast-Axis Collimating (FAC) lens, Matched lens, aspherical lens, and ball lens. Methods for enhancing coupling efficiency from a laser diode to an optical fiber will also be discussed.

Beam Shape Optimization

Edge-emitting laser diodes typically emit an elliptical beam due to their asymmetric waveguide structure, resulting in different divergence characteristics along the two orthogonal directions, the fast and slow axes. The fast axis refers to the vertical direction to the semiconductor junction (the y-axis). The slow axis runs parallel to the semiconductor junction (the x-axis).

1. Typical Laser Diode Output:

Due to the emission aperture being very small in the fast axis direction (on the order of a few microns), the laser light spreads out more rapidly, resulting in a divergence angle of 30° typical. The slow axis, however, is expected to have a lower divergence angle usually around 10° due to the emission aperture of the laser being much larger than the fast axis. Figure 1 depicts the shape of the laser beam with the axis directions without the assistance of a lens.

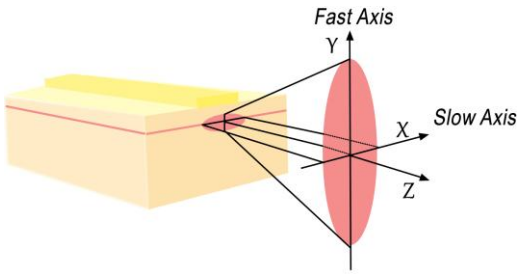

Figure 1: An edge-emitting laser output with an elliptical beam shape

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2. Lenses for Optimizing Beam Shape

The inherent asymmetry of the elliptical output beam poses challenges for controlling the direction of the laser light when integrating into larger systems. Depending on the application, achieving certain beam shapes requires the use of various lenses. See table 1 below.

Table 1: Lens Descriptions & Applications Overview

Lens Type	Function	Impact on Beam	Applications
FAC Lens (Fast-Axis Collimating Lens)	Collimates fast-axis divergence	Reduces high angular spread, making the beam more controllable	Essential for applications where precise beam directionality is crucial, such as in laser pointers, LiDAR systems, and other fiber-optic coupling systems.
SAC Lens (Slow-Axis Collimating Lens)	Collimates slow-axis divergence	Ensure even beam expansion along the slow axis	Typically used in combination with FAC lenses to ensure that both axes are collimated, improving beam quality for fiber coupling or free-space laser delivery.
Matched/GRIN Lens	Converts elliptical beam to symmetrical	Improves beam shape for easier optical design	Crucial for fiber or free space applications, where a symmetrical beam is required for efficient power transfer.
Ball Lens	Focuses or collimates light from a laser diode	Used in fiber coupling and focusing applications due to its compact size	often used in systems where space is limited, such as in handheld devices, or where spherical focusing is advantageous for fiber alignment. Commonly used in LiDAR and optical sensors.
Aspherical Lens	Reduces optical aberrations and enhances focusing	Provides high-precision beam shaping with minimal distortion	Ideal for obtaining highly accurate, well-collimated beam, in high-end optical systems applications where reducing spherical aberrations is critical.

SemiNex Micro-Lens Options

To accommodate the diverse optical system requirements of our customers, SemiNex offers a range of micro-lens options for its laser diodes. They are designed to optimize beam shapes and enhance system integration with minimal dimensions.

1. Available Lensing Options:

Matched Lens

These lenses are precisely selected and aligned to the laser emitter, providing symmetrical divergence angle in both fast and slow axes. This is especially beneficial for applications requiring a symmetrical beam profile for efficient fiber coupling or free-space beam delivery.

Optimizing beam shaping involves converting this elliptical beam into a more uniform, controlled output, transforming it from a 1:3 aspect ratio to a 1:1 ratio using Matched lenses. This process ensures improved focusing and energy distribution, benefiting applications requiring high-precision beam delivery. See figure 2 for a visual of the effects of a matched lens on a SemiNex TO9 lensed with a Matched lens.

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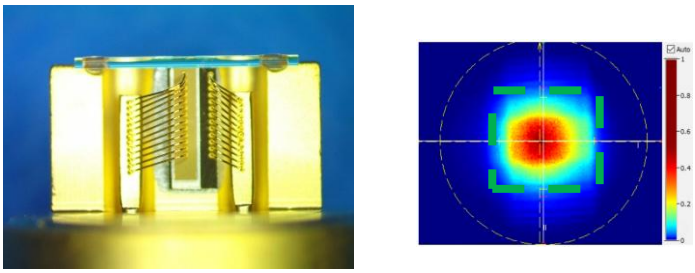

Figure 2: Far Field with Match GRIN Lens

Fast-Axis Collimating (FAC) Lens

Specifically designed to collimate the high divergence of the fast axis, FAC lenses reduce beam spread, creating a collimated beam that improves beam control and power concentration. FAC lenses mounted onto standard SemiNex products can be seen in Figure 3.

Figure 3: FAC lens Mounting Example

Both options can be integrated directly into various SemiNex submount assemblies (listed below) for customer use.

2. Ordering Guide

When ordering SemiNex laser diodes or modules, customers can specify their lensing preferences using the suffix options following the 3-digit part number. For more details, refer to the web links below and individual data sheet.

B-Mount

Suffix	Lensing Option	Description
B-aaa-108	Matched Lens	Lens GRIN, f=171um, 2.8mm Lg, fast axis divergence: 10°, slow axis divergence: 10° FWHM
B-aaa-118	FAC Lens	Lens Collimated <10mrad, FAC, f=274um, 5.0mm Lg, fast axis divergence: 0.6°, slow axis divergence: 10° FWHM
B-aaa-134	Matched Lens	Lens, GRIN, f=274um, 5.0mm Lg, fast axis divergence: 10°, slow axis divergence: 10° FWHM
B-aaa-141	FAC Lens	Lens Collimated, WD: 150um, FAC, f=590um, 2.8mm Lg, Fast Axis: 0.3° FWHM, Slow Axis: 10° FWHM

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C-Mount

Suffix	Lensing Option	Description
C-aaa-118	FAC Lens	Lens Collimated <10mrad, f=274µm, 5mm Lg, fast axis divergence: 0.6°, slow axis divergence: 10° FWHM
C-aaa-134	Matched Lens	Lens Matched f=274µm, 5.0mm Lg, fast axis divergence: 10°, slow axis divergence: 10° FWHM
C-aaa-141	FAC Lens	Lens Collimated, WD: 150um, FAC, f=590µm, 2.8mm Lg, Fast Axis: 0.3° FWHM, Slow Axis: 10° FWHM
C-aaa-186	FAC Lens	Lens Collimated 5mrad, FAC, f=590µm, 5.0mm Lg, WD=150µm, Fast Axis: 0.3° FWHM, Slow Axis: 10° FWHM

TO9

Suffix	Lensing Option	Description
TO9-aaa-115	FAC Lens	Lens Collimated <5mrad, f=590µm, 5mm lg, Fast Axis: 0.3° FWHM, Slow Axis: 10° FWHM
TO9-aaa-140	Matched Lens	Lens GRIN, Matched f=171µm, 5.0 lg, fast axis divergence: 12°, slow axis divergence: 12° FWHM
TO9-aaa-181	FAC Lens	Lens Collimated 5mrad, FAC, f=1.2mm, 5.0mm lg, Fast Axis: 0.3° FWHM, Slow Axis: 10° FWHM

TO56

Suffix	Lensing Option	Description
TO56-aaa-116	FAC Lens	Lens FAC f=590µm, 2.8mm Lg, Fast Axis: 30° FWHM, Slow Axis: 10° FWHM
TO56-aaa-126	Matched Lens	Lens Matched f=171µm, 2.8mm Lg, fast axis divergence: 14°, slow axis divergence: 14° FWHM
TO56x-aaa-184	FAC Lens	Lens FAC f=1.2mm, fast axis divergence: 0.3°, slow axis divergence: 10° FWHM
TO56s-aaa-126	Matched Lens	Lens Matched f=171µm, 2.8mm lg, fast axis divergence: 12°, slow axis divergence: 12° FWHM

Laser Engine

Suffix	Lensing Option	Description
LEQ-aaa-172	FAC Lens	LEQ Lens Collimated FAC, f=7.7mm, with fan, fast axis divergence: 10°, slow axis divergence: 2° FWHM
LEQ-aaa-178	Matched Lens	LEQ lens SA Matched , f=1.36mm, with fan, fast axis divergence: 28°, slow axis divergence: 28° FWHM

SemiNex provides various micro-lenses options on its standard laser diode packages. For further questions or inquiries, please contact us directly at info@seminex.com.

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