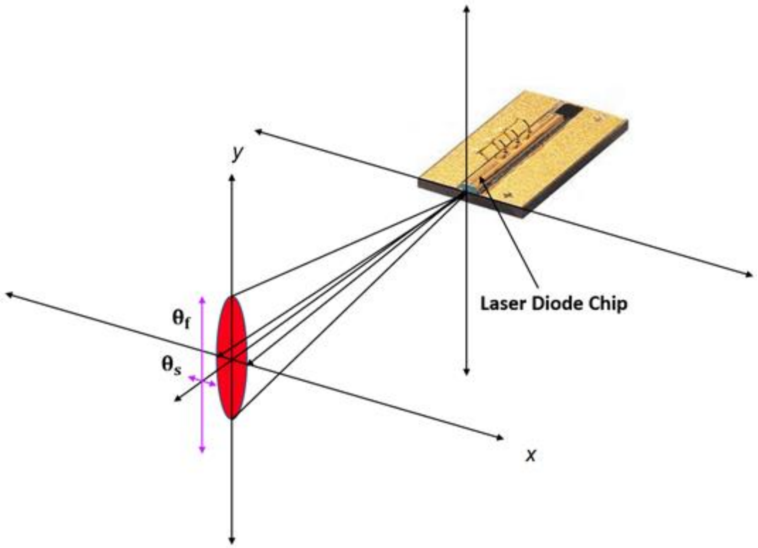
Lecture 18

Diode Lasers and Fiber Coupling



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- Diode Lasers
  - FAC / SAC Design
  - Fiber Coupling

Introduction

Coherent light generated by lasers has properties different from light generated by other sources which we usually deal with in more conventional optical systems.

Most laser beams can be approximately described by Gaussian optics. Gaussian optics is a type of wave optics and is very different from geometric optics.

Thereare many companies that provide laser source for the end users.
See: some laser resources

In this chapter we will investigate modelling coherent light generated by lasers.

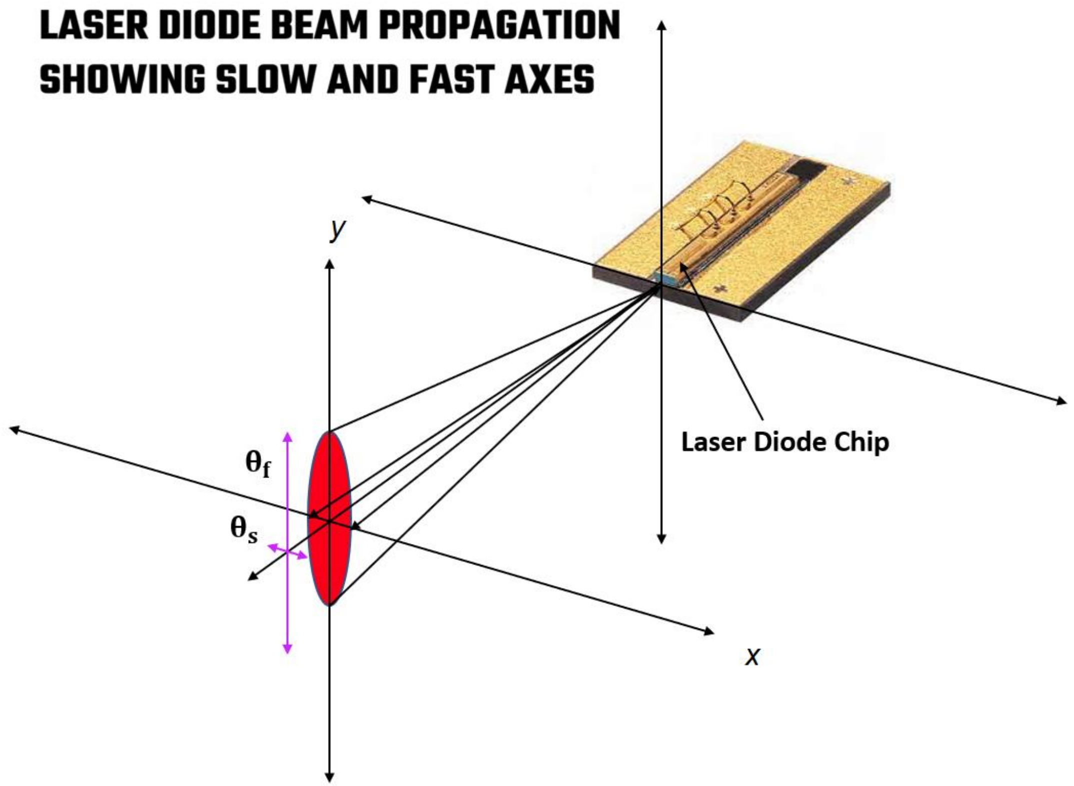
Defining Diode Laser Source

Consider a diode laser given right:

This is the product

OPD000082 FL-COC11-10-808

laser from focuslight



Optical Data[2]	Unit	Value
Centroid Wavelength	nm	808
Wavelength Tolerance	nm	± 3
Emitter Width	µm	200
Output Power[3]	W	10
Spectral Width FWHM	nm	≤ 3
Spectral Width 90% Energy	nm	≤ 5
Fast Axis Divergence (FWHM)	°	~ 30
Slow Axis Divergence (FWHM)	°	8
Polarization Mode	-	TE
Wavelength Temp. Coefficient	nm / °C	~ 0.28
Electrical Data [2]		
Operation Current	A	≤ 11.8
Threshold Current	A	≤ 1.8
Operating Voltage	V	≤ 2.2
Slope Efficiency	W / A	≥ 1
Power Conversion Efficiency	%	≥ 44
Thermal Data		
Operating Temperature	°C	15 ~ 30
Storage Temperature [4]	°C	-40 ~ 55
Recommended Heatsink Capacity	W	≥ 20

Defining Diode Laser Source

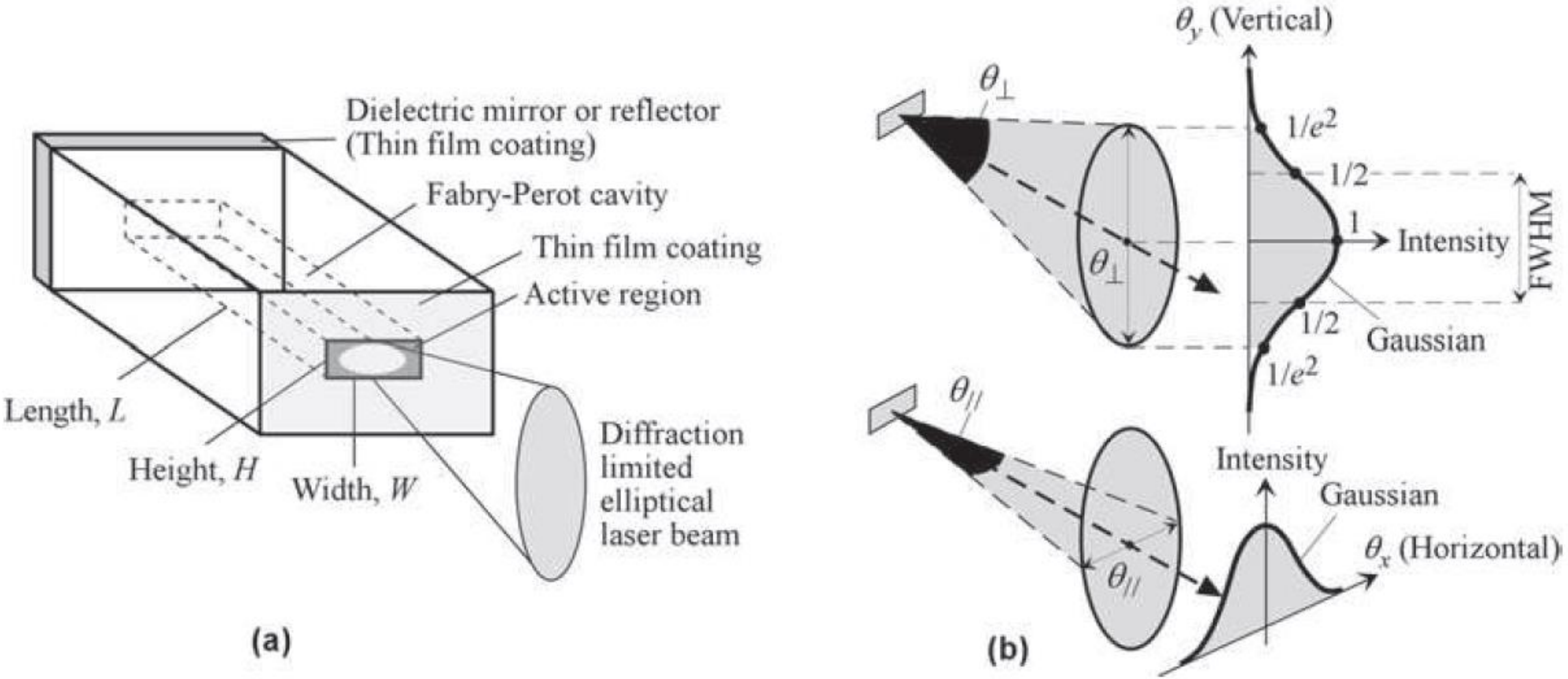


FIGURE 4.42 (a) The laser cavity definitions and the output laser beam characteristics. (b) Laser diode output beam astigmatism. The beam is elliptical, and is characterized by two angles, $\theta_{\perp}$ and $\theta_{//}$.

Example 1

Implement the laser diode given right in Zemax. Place **Source Diode** at z = 0. Also, include a rectangular detector of suitable size at z = 100 mm. Investigate far field beam shape of the laser.

Wavelength = 808 nm

X-divergence = 8 * 0.849 = 6.792^o (Slow Axis)

Y-divergence = 30 * 0.849 = 25.47^o (Fast Axis)

X-SuperGauss = Y-SuperGauss = 1

X-width = 200/2 = 100 µm = 0.1 mm

Y-width = 2/2 = 1 µm = 0.001 mm

X-sigma = 1 mm

Y-sigma = 1 mm

X-sigma Hx = X-sigma Hy = 1 mm

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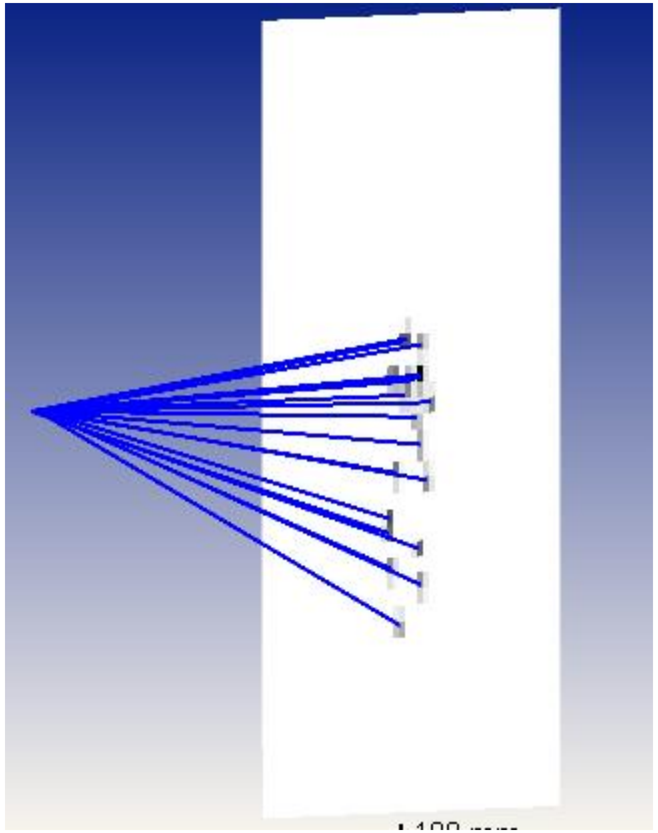
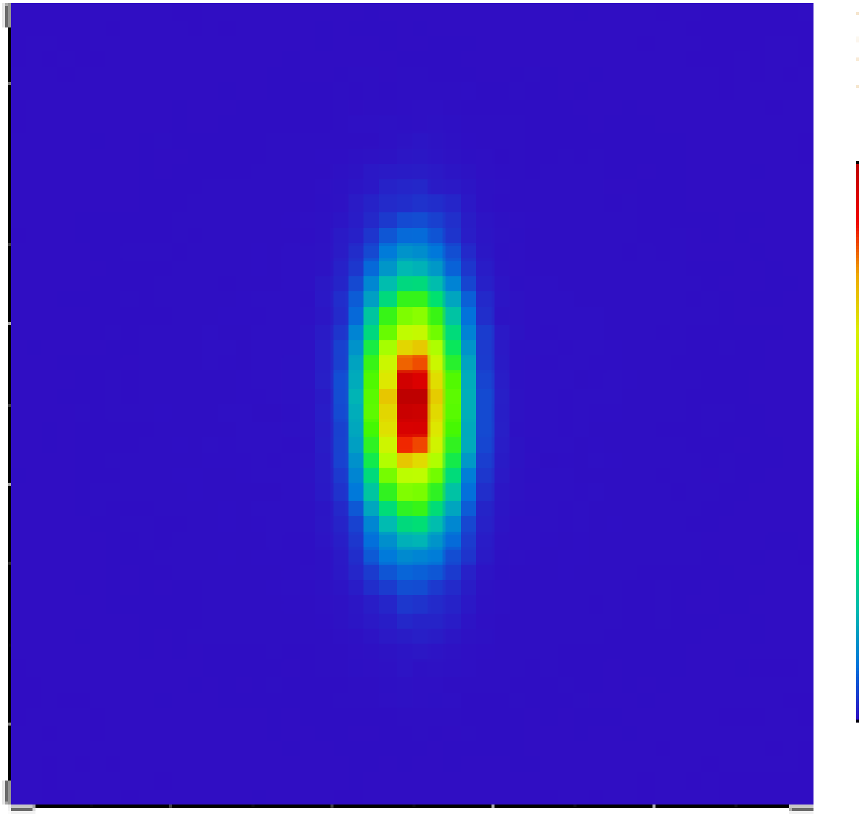
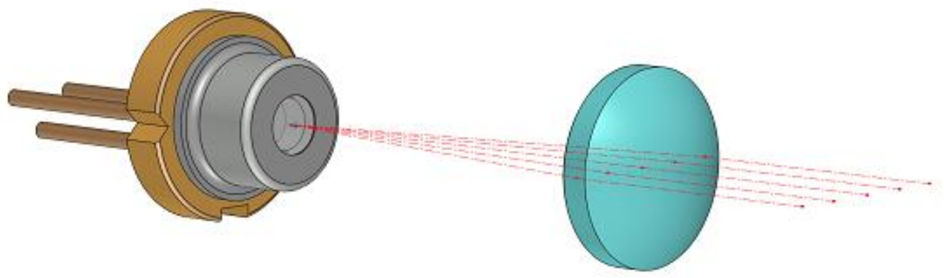




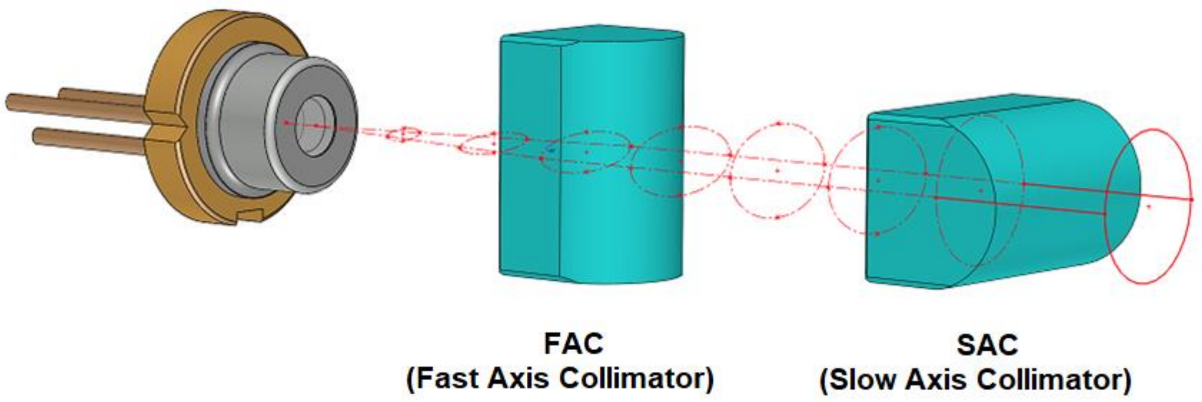
Laser Beam Collimation

A collimator is a device which narrows a beam of particles or waves.

If beam circular it can be collimated by a aspherical lens.

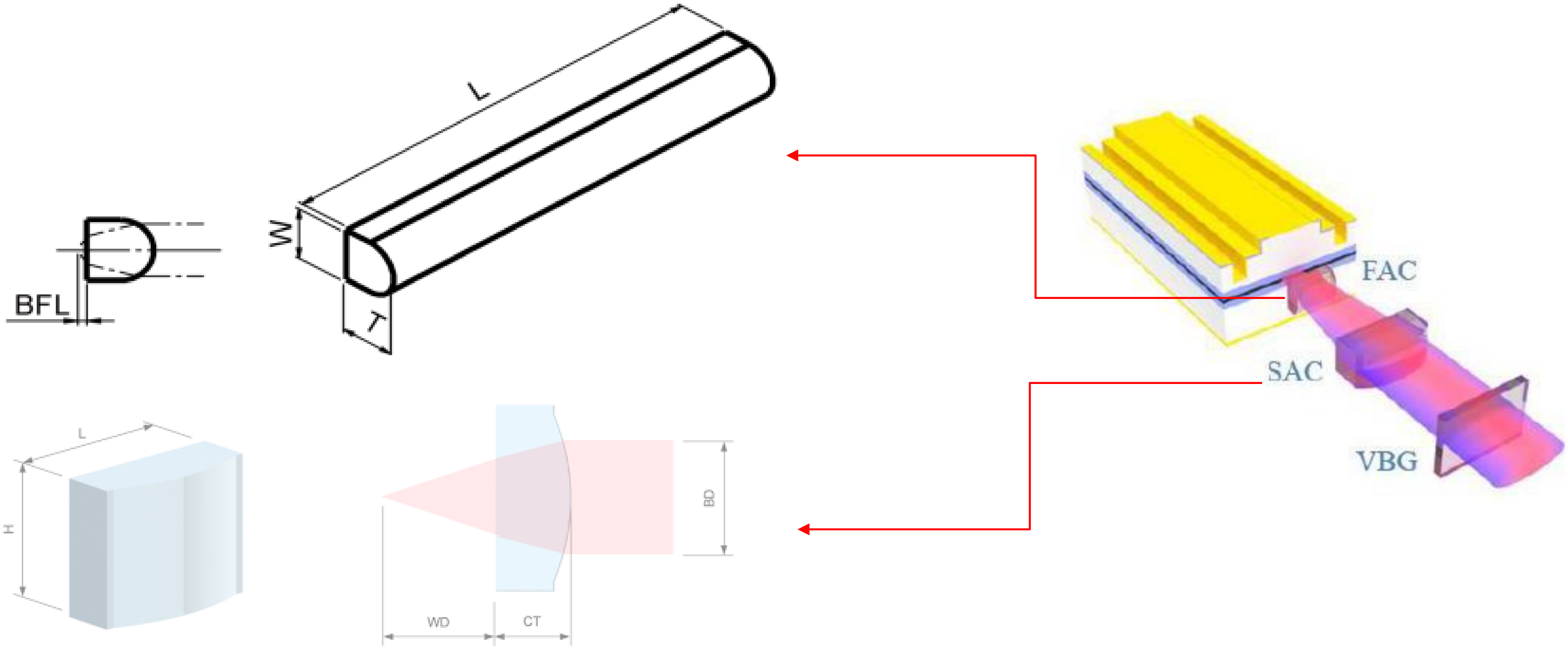


Diode lasers can be collimated by a pair of cylindrical lenses.

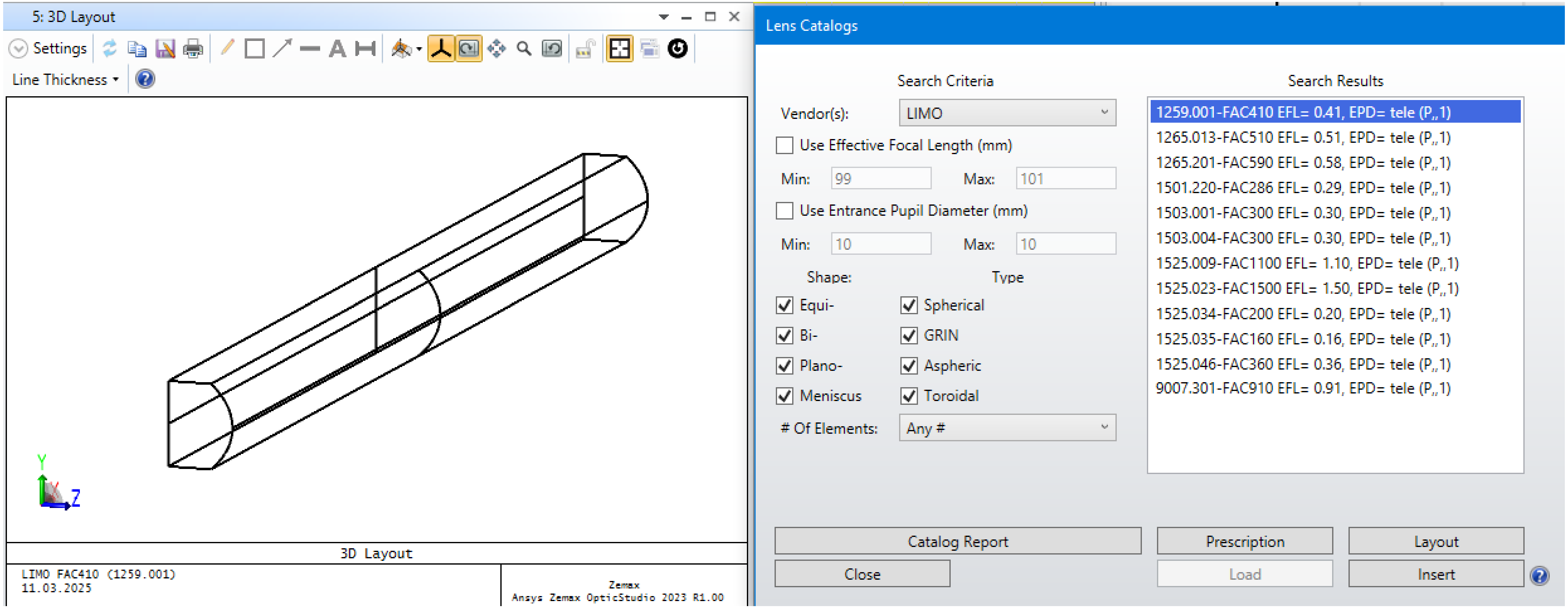


FAC / SAC Design

Note that in general the cylindrical lenses can be modelled by **Toroidal Lens** object as NSC.



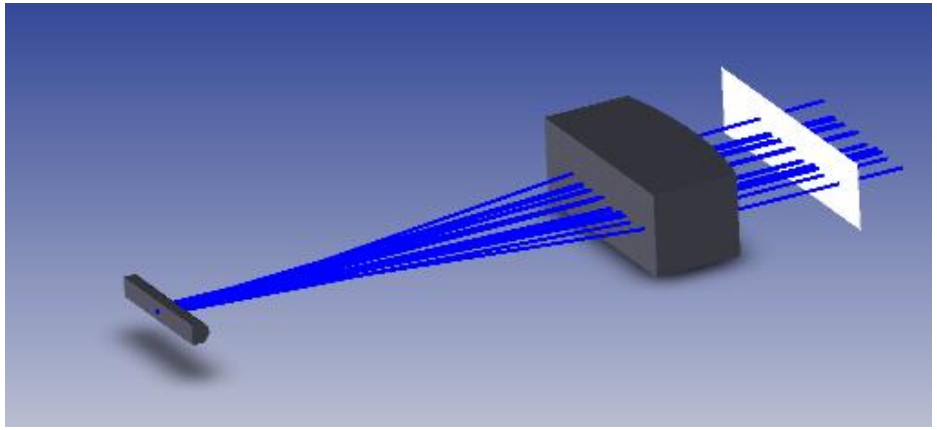
I will mention about FAC lenses in Lens Catalog. Vendor **LIMO**.



Plano convex FAC Design Parameters:

Inputs: W, T, L, λ, Glass, BFL, Fast axis divergenge

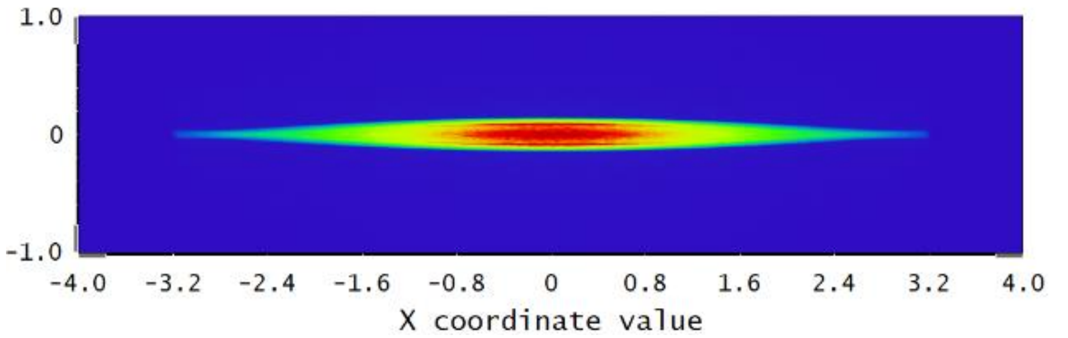
Outputs for convex side: R, k, A4, A6, A8



Plano convex SAC Design Parameters:

Inputs: W, T, L, λ, Glass, BFL, Slow axis Divergenge

Outputs for convex side: R, k, A4, A6, A8



where

R = Radius of curvature

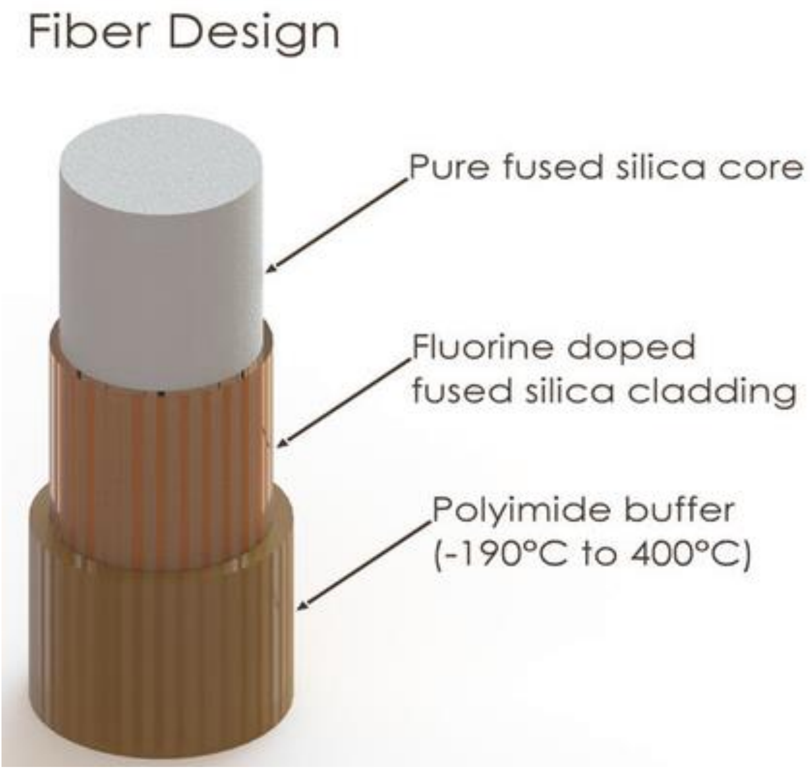
k = conic constant

A4, A6, A8 = aspheric constants

Glass = SILICA, S-TIH53, S-NPH3, N-BK7, H-K9L, D-PK3, D-K59

Optical Fiber

An optical fiber, is a flexible glass or plastic fiber that can transmit light.

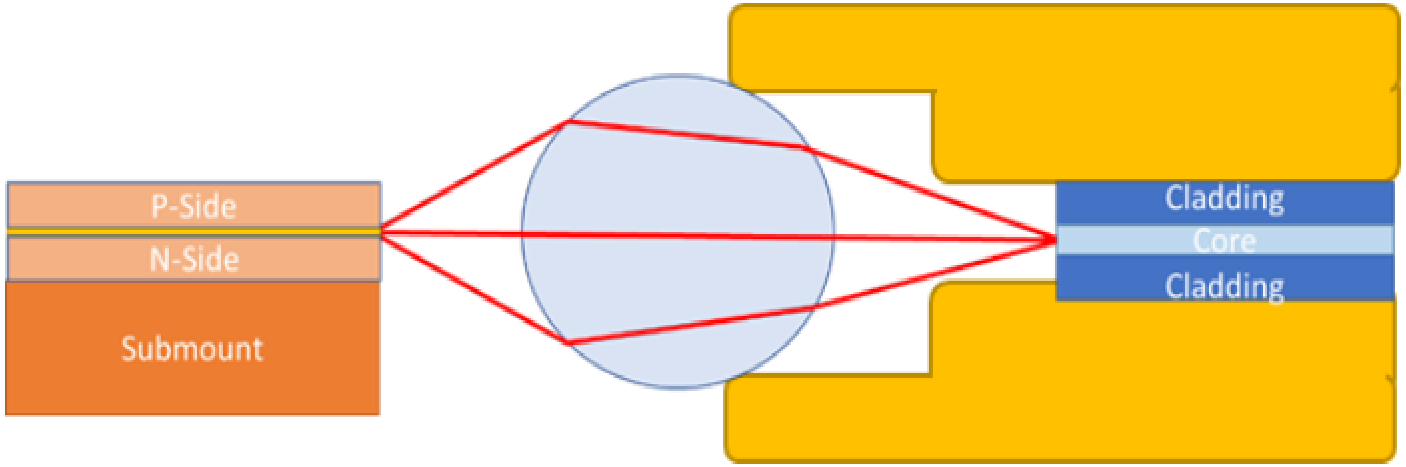


Example:
0.22 NA Silica Core, Glass Clad Multimode Optical Fiber, Step Index, fiber cables:
https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=6838

Fiber Coupling

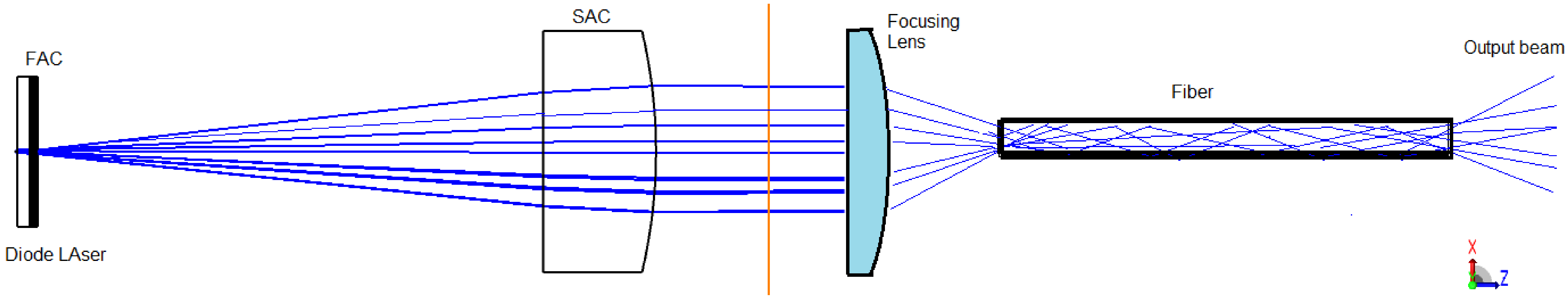
Fiber-coupled diode lasers have become commonplace since the telecom boom of the 1990s. Fiber optics are widely used in laser technology because of their ability to trap light and guide it from one location to another without experiencing significant loses.

The most straightforward approach is to utilize two ball lenses, one to collimate the laser diode and then one to refocus it into the fiber.



Diode Laser & Fiber Coupling

If we introduce both FAC and SAC, a converging lens (or lens group) is required to focus laser beam into the fiber core.



30W 915 nm Uncooled Multimode Laser Diode Module

Some Key Points for Diode Laser and Fiber Coupling

Definitions & Equations:

$$BPP = w_0\theta = M^2\frac{\lambda}{\pi}$$

$$BPP_f = w_{0f}\theta_f$$

$$BPP_s = w_{0s}\theta_s$$

$$BPP_{tot}^2 = BPP_f^2 + BPP_s^2$$

$$M^2 = \frac{\pi w_0\theta}{\lambda}$$

$$B = \frac{P}{\pi^2 Q^2} = \frac{P}{\pi^2 \times BPP_{tot}^2}$$

$$Q = \frac{w_0}{2\theta}$$

BPP = Beam Parameter Product

P = Optical power of the beam

For effective coupling:

$$BPP_{tot} < \left(\frac{D_{fiber}}{2} \times NA_{fiber}\right)$$

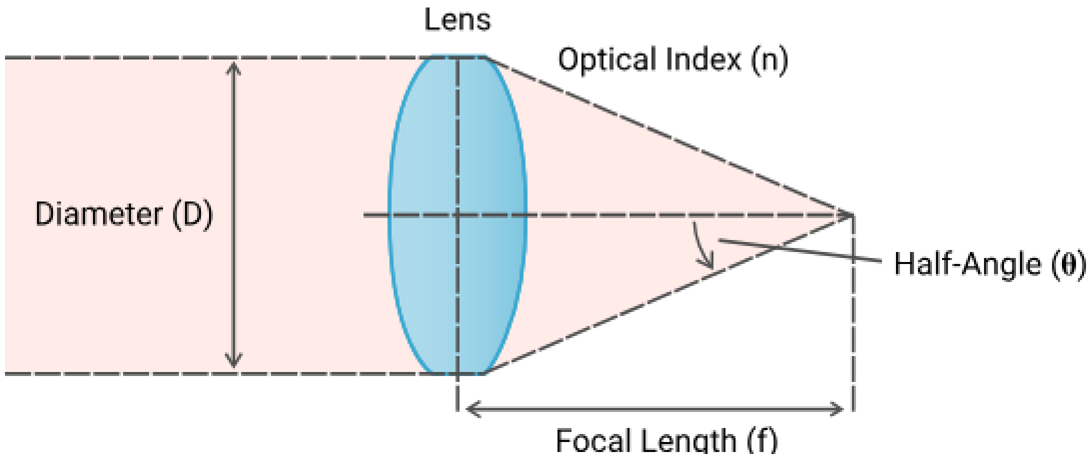
Image space NA of the focusing lens:

$$NA_{lens} = n_0\sin(\theta)$$

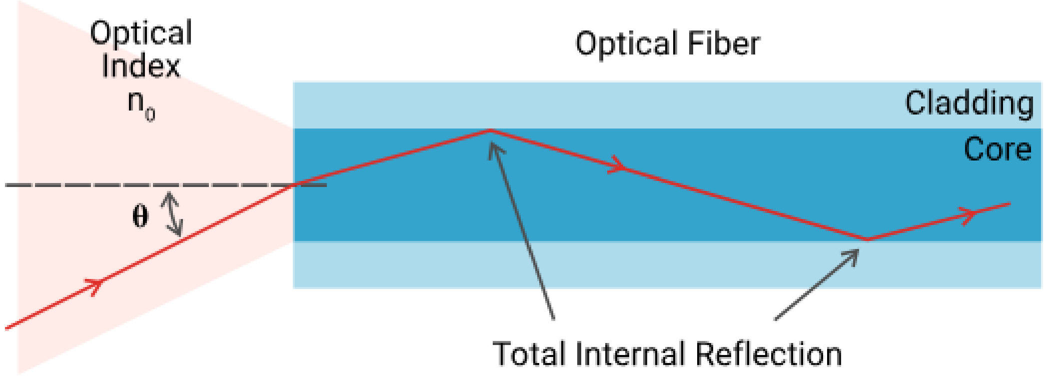
D_{fiber} = Diameter of the fiber core

n_0 = Refractive index of the medium surrounding the optical system

BPP quantifies the quality of a laser beam, and how well it can be focused to a small spot.
A Gaussian beam has the lowest possible value of ***BPP = λ / π***



$$NA_{lens} = n_0 \sin(\theta)$$



$$NA_{fiber} = n_0 \sin(\theta_{\max})$$

θ_{max} is the half-angle of the cone of acceptance

Example 2

Consider a diode laser and fiber core data are given as follows:

$$\theta_{\perp} = \theta_f = 29° = 0.5061 \text{ mrad}$$
$$\theta_{\parallel} = \theta_s = 9° = 0.1571 \text{ mrad}$$
$$w_{of} = 0.5\ \mu m = 0.0005 \text{ mm}$$
$$w_{os} = 95\ \mu m = 0.0950 \text{ mm}$$
$$\lambda = 980 \text{ nm}$$

$$D_{fiber} = 500\ \mu m = 0.5 \text{ mm}$$
$$NA_{fiber} = 0.1 \text{ rad} = 100 \text{ mrad}$$

Then,

$$BPP_f = 0.253 \text{ mm. mrad}$$
$$BPP_s = 14.92 \text{ mm. mrad}$$
$$BPP_{tot} \approx 15 \text{ mm. mrad}$$

$$\frac{D_{fiber}}{2} \times NA_{fiber} = 25 \text{ mm. mrad}$$

Diffraction limited BPP:

$$BPP = \frac{\lambda}{\pi} = 0.3119 \text{ mm. mrad}$$

Therefore, an effective fiber coupling can be achieved since $BPP_{tot} < 25$ mm. mrad

Example 3: Diode Laser/FAC/SAC/Fiber Coupling

* **Soruce:** Single emitter provided by Ermaksan Company (see course page)
* **Collimators:** We'll design FAC/SAC lenses. *Material: SILICA, S-TIH53, S-NPH3, N-BK7, H-K9L, D-PK3, D-K59*
* **Focusing Lens(es):** Can be aspheric.
* **Fiber:** Core diameter = 300 µm and NA = 0.22. *Material: core = SILICA, cladding = F_SILICA*

In the design procedure, We will use both Sequentail mode and Nonsequential mode.
Details are going to be given during the lesson.