University of technology
Laser and optoelectronics eng. Dept.

LASER APPLICATION COURSE
4TH YEAR
LEC.3

CRITICAL ANGLE & TOTAL INTERNAL REFLECTION

- When light crosses *materials* with different refractive indices, the light beam will be partially refracted at the boundary surface, and partially reflected. However, by increased the incident angle the refractive angle increased too, until refractive of light be parallel to the boundary surface, and at this point the incident angle called the ***critical angle*** ***(represent the boundary between two different phenomenon, the refraction & reflection)***. Then if the incident angle is bigger than the critical angle, all the incident light will be reflected and this is know ***total internal reflected***, as shown as in figure (1.3)[

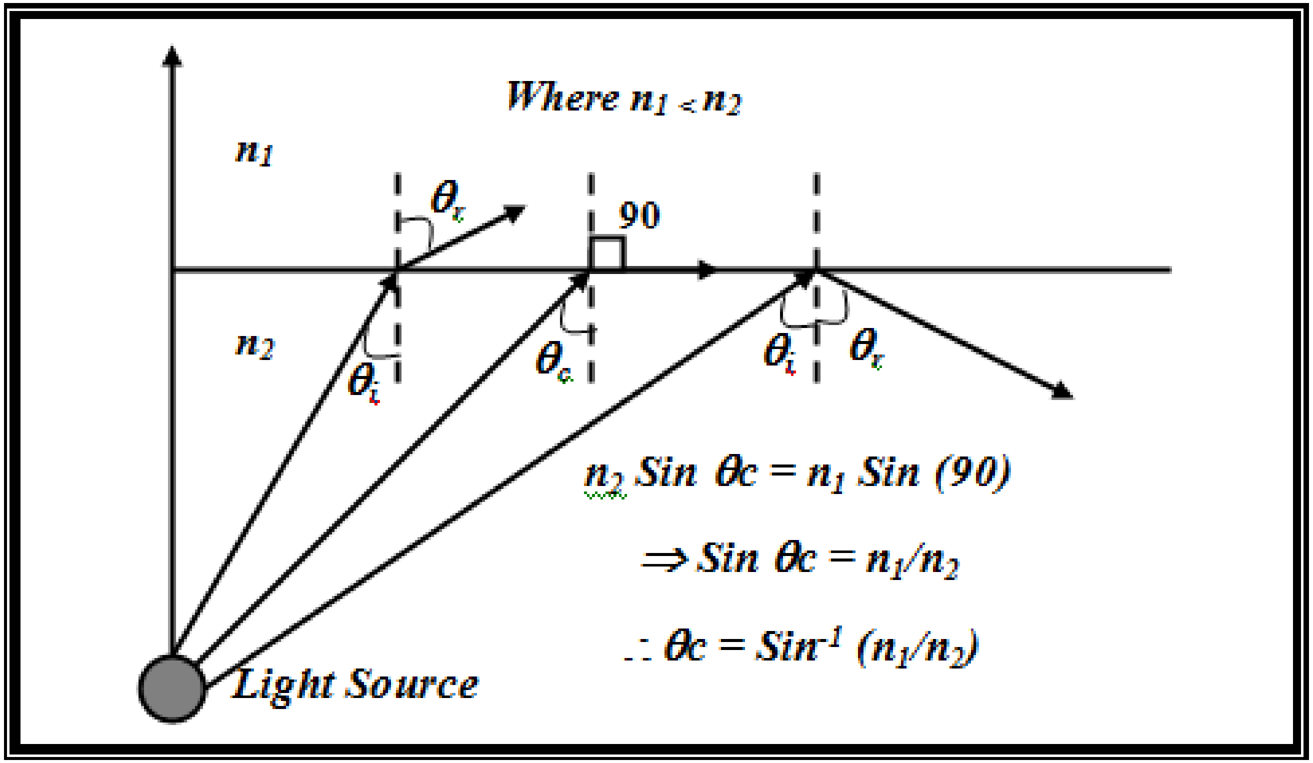

Figure (1.3) the Total Internal Reflection[5]

Beam Focusing

- A schematic diagram of the layout often used to direct the laser beam on to work piece is shown below

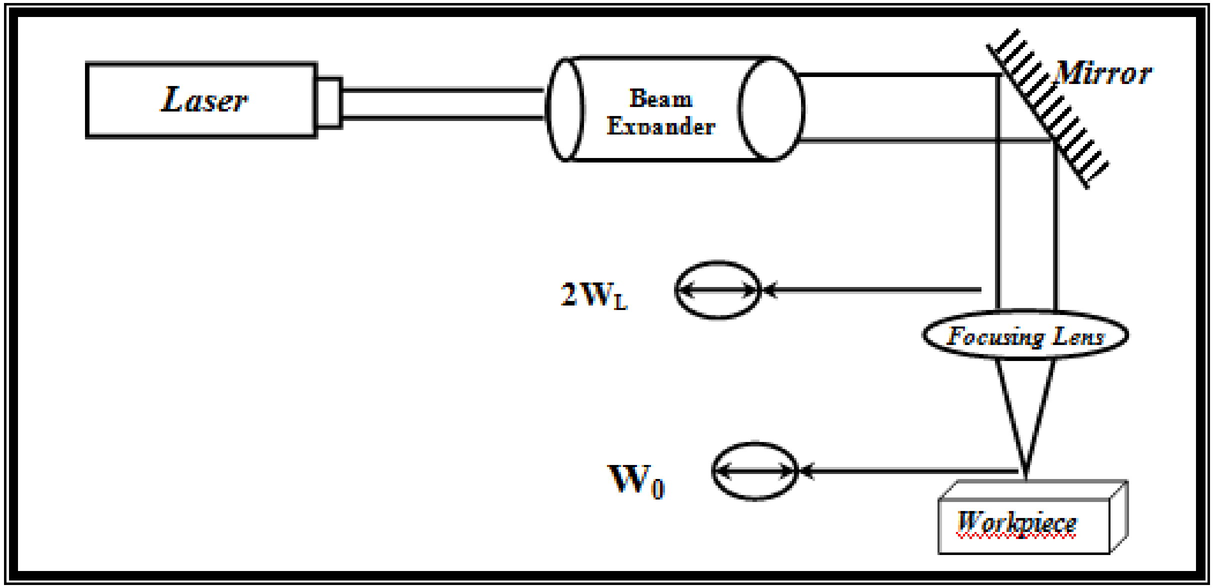

Figure (1.4) Schematic layout of a laser beam delivery[4]

- Basically the beam is passed through a beam expander and then focused to a small spot on the workpiece using lens.
- ***The reason for incorporating a beam expander into the optical system is that enables a smaller final spot to be obtained.*** The focused spot size ( ) is given by[4]:

$$w_o = \frac{\lambda f}{\pi w_L} \quad \text{..(1.8)}$$

Where:

- ***: Focus Spot Size (mm).***
- ***f: The Focal Length of the Lens (mm).***
- ***: Wavelength (µm).***
- ***: The Beam Radius at the Final Focusing Lens (mm).***
- Another aspect of interest is the so-called ***Depth of Focus (Z)*** of the beam, ***which is the distance we can move the workpiece a way from the minimum beam radius and still have an acceptably small spot.***

$$Z = \frac{\pi w_o^{2}}{\lambda}\left[\left(\frac{w(z)}{w_o}\right)^{2} - 1\right]^{\frac{1}{2}}$$

Example-2[4]:

It is required to focus the output of an Nd:YAG laser (λ=1.06μm) down to a spot of (50μm) radius. Given that the beam has a radius at the final focusing lens of 1mm). ***Calculate the focal length of the lens required, what will be the resulting depth of focus (Z)? Take*** $\frac{w(z)}{w_o} = 1.1$.

Solution:

$$w_o = \frac{\lambda f}{\pi w_L} \Rightarrow f = \frac{w_o \pi w_L}{\lambda} = \frac{1\times10^{-3}\times\pi\times50\times10^{-6}}{1.06\times10^{-6}} = 148mm$$

$$Z = \frac{\pi w_o^{2}}{\lambda}\left[\left(\frac{w(z)}{w_o}\right)^{2} - 1\right]^{\frac{1}{2}} = \frac{\pi(50\times10^{-6})^{2}}{1.06\times10^{-6}}\left[(1.1)^{2} - 1\right]^{\frac{1}{2}} = 3.39\text{mm}$$

Example-3[4]:

If the spot radius for ***He-Ne*** laser (***12.5 cm***), & focal length lens is (***1.5 cm***) ***Calculate the focused spot size at (λ=632.8 nm).***

Solution: $w_o = \frac{\lambda f}{\pi w_L} = \frac{(632.8\times10^{-9})(1.5\times10^{-2})}{\pi(12.5\times10^{-2})} = 24nm$

Optical Processes

- When a laser beam hits matter, ***4 processes*** can take place[1]:
- ***1. Reflection*** - according to the law of reflection: The reflected angle is equal to the incidence angle.
- ***2. Scattering***- laser energy is scattered to all directions.
- ***3. Transmission***- laser beam pass through the material.
- ***4. Absorption***- laser beam is absorbed by the material.
- *Only the last process (**Absorption**) can transfer energy to the material & causing a rise in temperature or chemical reaction.*

ENERGY BALANCE APPROXIMATION

- Simple energy balance approximations frequently provide reasonable ball-park for many applications. For that reason, some discussion of this approach is presented here. In the figure (1.5) a schematic representation of laser beam focused onto the surface of a workpiece. If it is assumed that the material is heated to a depth (Z) with cross section area (πa^2), then the energy (U) required to bring the material to temperature (T) is given by[2]:

$$U = (CT + L_m + L_V)\rho\pi a^2 Z \quad \text{...(1.10)}$$

- Where (T) is used for temperature to avoid confusion with time(t) & represents the change in temperature of the part. It has been assumed in equation (1.7) that (&C) are independent of temperature & are the same for liquid & solid.

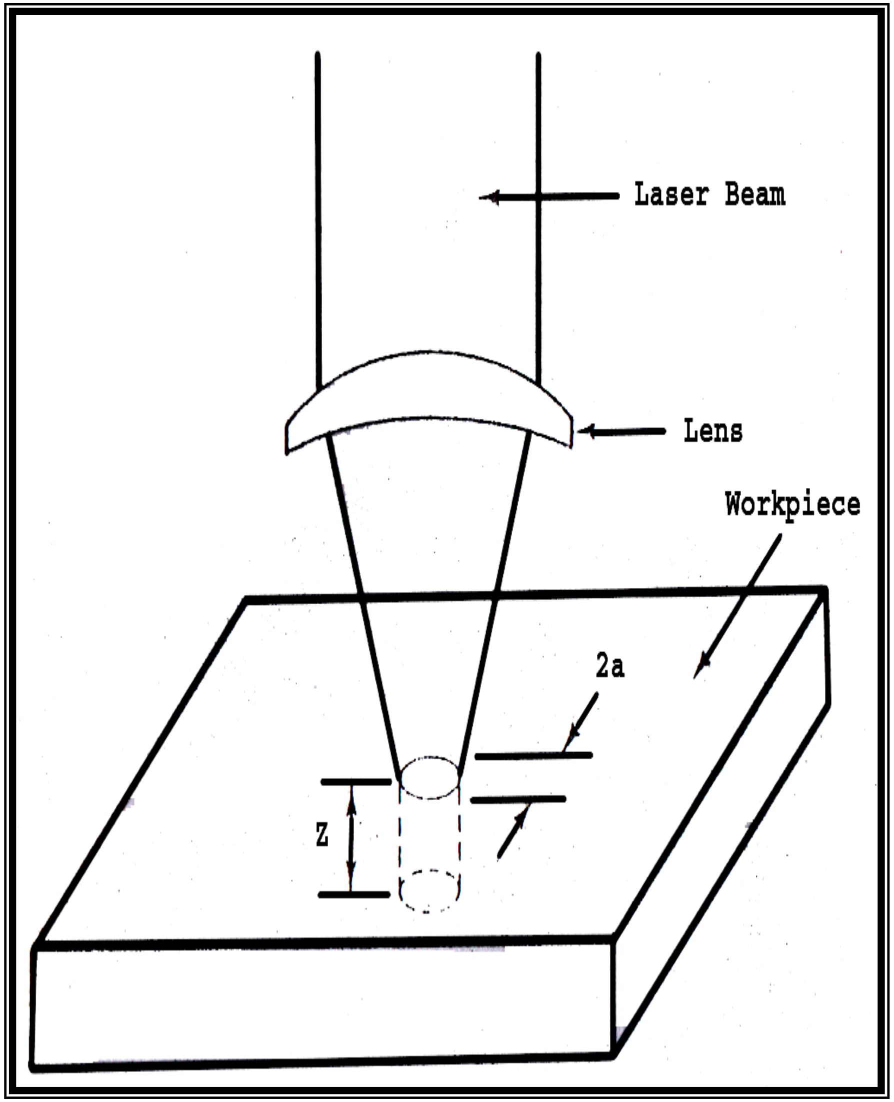

Figure (1.5) Laser beam focused on a workpiece[2]