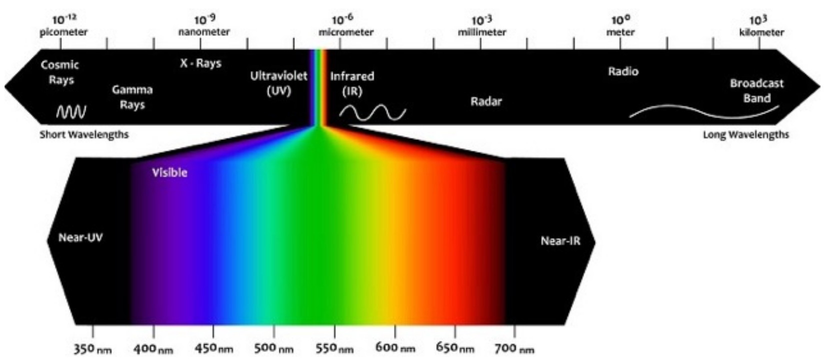
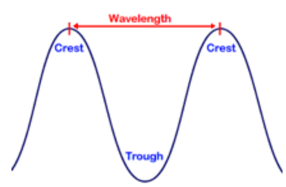
Laser Beam Measurement Vocabulary

Wavelength: In physics, the wavelength of a sinusoidal wave is the spatial period of the wave—the distance over which the wave's shape repeats,[1] and the inverse of the spatial frequency. It is usually determined by considering the distance between consecutive corresponding points of the same phase, such as crests, troughs, or zero crossings and is a characteristic of both traveling waves and standing waves, as well as other spatial wave patterns.[2][3] Wavelength is commonly designated by the Greek letter lambda (λ).





λ: The Greek symbol lambda is used to express wavelength.

Gaussian: The graph of a Gaussian is a characteristic symmetric "bell curve" shape. The parameter a, is the height of the curve's peak, b is the position of the center of the peak and c (the standard deviation, sometimes called the Gaussian RMS width) controls the width of the "bell".

Gaussian functions are widely used in statistics where they describe the normal distributions, in signal processing where they serve to define Gaussian filters, in image processing where two-dimensional Gaussians are used for Gaussian blurs, and in mathematics where they are used to solve heat equations and diffusion equations and to define the Weierstrass transform.

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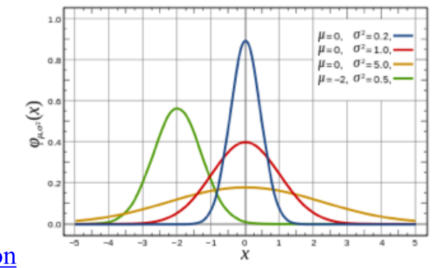
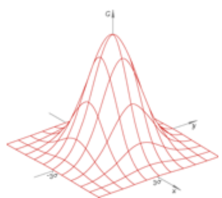
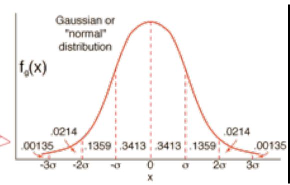
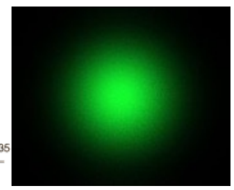


https://en.wikipedia.org/wiki/Gaussian_function

A Gaussian beam is a beam that has a normal distribution in all directions similar to the images below. The intensity is highest in the center of the beam and dissipates as it reaches the perimeter of the beam.

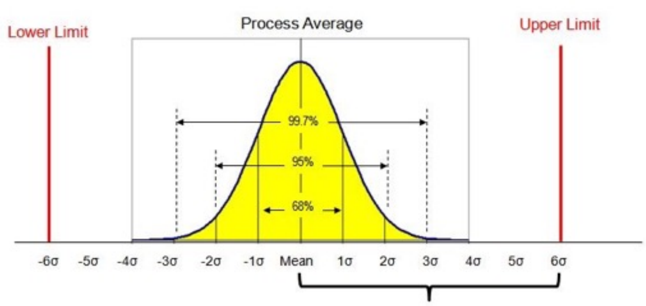






Beam Width or Beam Diameter: The measured diameter of a laser spot. There are many different ways to measure a beam. The measurement method is determined by the application.

> **D4σ (D4Sigma):** It is defined as 4 times the standard deviation of the energy distribution evaluated separately in the X and Y transverse directions over the beam intensity profile.



> **Knife Edge:** Knife Edge beam widths are computed using special algorithms that simulate knife-edge techniques. All Knife Edge Diameters are the computed average of the orthogonal beam widths.

> **Percent of Power/Energy**: BeamGage totals the pixel energy values of all pixels in descending order until it finds the pixel that causes the sum to exceed the set Clip% of the total energy value. The energy value of this pixel becomes the clip level.

Laser Caustic: The envelope of light rays reflected or refracted by a curved surface or object, such as a lens. Focusing light rays create a pattern where the beam diameter starts out large, then focuses down to a minimum beam size, and then gets larger.

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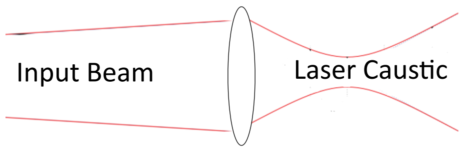
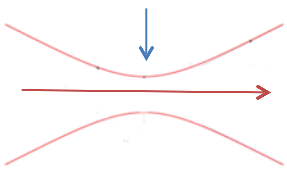


Beam Waist: The minimum spot (focus) achievable with a laser at a particular wavelength and lense. The image below shows a depiction of a side view of a laser coming to focus and diverging again. The beam waist is in the center.

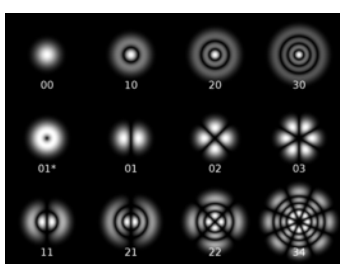


Divergence: This is what the laser does after it has reached focus. The beam size appears larger and less intense as the beam diverges. Many lasers diverge before they exit the laser head and are then focused down using optics.

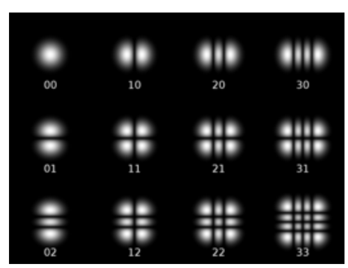
Attenuation: The gradual loss in intensity of any kind of flux through a medium. We use sunglasses to attenuate sunlight before it reaches and damages our eyes. Attenuation reduces the intensity of light

Mode Content:

- Particular pattern of waves in the electromagnetic field of radiation measured in a cross-section of a beam
- Normally designated as TEM_{xx}
- A pure Gaussian beam (called TEM_{00}) has an $M^2 = 1$

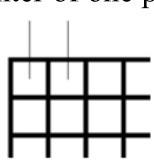


Laguerre Transverse Mode patterns



Hermite Transverse Mode patterns

Pixel Pitch: The physical distance from center of one pixel to the center of the next pixel



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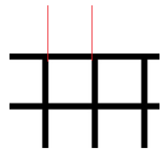
Pixel Size: The physical size of a pixel.



M2 Measurement: The M^2 factor, also called *beam quality factor* or *beam propagation factor*, is a common measure of the beam quality of a laser beam. According to ISO Standard 11146 [4], it is defined as the beam parameter product divided by λ / π, the latter being the beam parameter product for a diffraction-limited Gaussian beam with the same wavelength. In other words, the half-angle beam divergence is

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

where w_0 is the beam radius at the beam waist and λ the wavelength. A laser beam is often said to be "M^2 times diffraction-limited".

A diffraction-limited beam has an M^2 factor of 1, and is a Gaussian beam. Smaller values of M^2 are physically not possible. A Hermite–Gaussian beam, related to a TEM_{nm} resonator mode, has an M^2 factor of $(2n + 1)$ in the x direction, and $(2m + 1)$ in the y direction [1].

The M^2 factor of a laser beam limits the degree to which the beam can be focused for a given beam divergence angle, which is often limited by the numerical aperture of the focusing lens. Together with the optical power, the beam quality factor determines the brightness (more precisely, the radiance) of a laser beam.
https://www.rp-photonics.com/m2_factor.html

Rayleigh Length: The Rayleigh length (or *Rayleigh range*) of a laser beam is the distance from the beam waist (in the propagation direction) where the beam radius is increased by a factor of the square root of 2. For a circular beam, this means that the mode area is doubled at this point.

For Gaussian beams, the Rayleigh length is determined by the waist radius w_0 and the wavelength λ:

$$z_R = \frac{\pi w_0^2}{\lambda}$$

where the wavelength λ is the vacuum wavelength divided by the refractive index n of the material.

For beams with imperfect beam quality and a given waist radius, the Rayleigh length is effectively decreased by the so-called M^2 factor. This implies that such beams have a larger beam divergence for a given beam waist radius.

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Energy Density: Energy density is the amount of energy stored in a given system or region of space per unit volume or mass, though the latter is more accurately termed specific energy. https://en.wikipedia.org/wiki/Energy_density

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