# Beam Expander

The most common type of beam expander is derived from the Galilean telescope which usually has one negative input lens and one positive output lens, as shown in Figure 1. The input lens presents a virtual beam focus at the output. For low expansion ratios (1.3-20×), the Galilean telescope is most often employed due to its simplicity, small package size, and low cost.

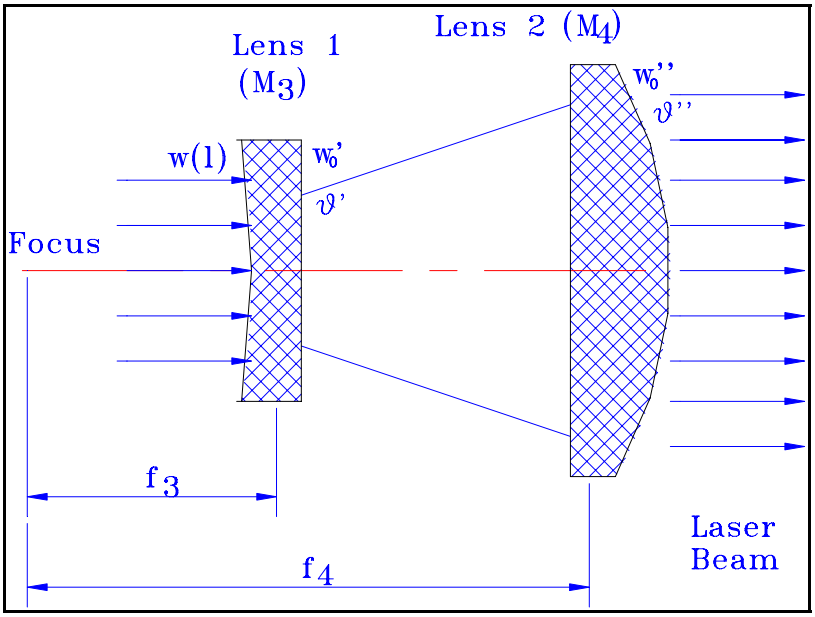


Figure 1: *Diagram of a beam expander*

As shown in Figure 1, the lens $M_3$ focuses the laser beam onto the front focus plane and the new beam waist $\omega'_0$ and divergence angle $\theta'$ can be represented as

$$\omega_0{}' = \frac{f_3\lambda}{\pi\omega(l)} \tag{1}$$

and

$$\theta' = \frac{2\lambda}{\pi\omega'_0} \tag{2}$$

$$\omega(l) = \omega_0\sqrt{1+\left(\frac{l\lambda}{\pi\omega_0^2}\right)^2} \tag{3}$$

where $\omega(l)$ is the radius of the beam entering the lens $M_3$, $l$ is the distance between the lens $M_3$ and the beam waist $\omega_0$ from the laser generator, and $f_3$ is the focal length of the lens $M_3$.

Since $\omega_0'$ lies on the back focus plane of the lens $M_4$ with a longer focal length, $f_4$, the Gaussian beam with a beam waist $\omega'_0$ will be collimated by the beam expander. The collimation ratio of the beam expander for a Gaussian beam is as follows

$$T = \frac{\theta}{\theta''} = T_1\sqrt{1+\left(\frac{l\lambda}{\pi\omega_0^2}\right)^2} \quad (4)$$

where $T_1 = f_4/f_3$. The beam waist $\omega''_0$ and divergence angle $\theta''$ after the beam expander are

$$\omega_0'' = \frac{\lambda}{\pi\omega_0'} f_4 \quad (5)$$

and

$$\theta'' = \frac{\theta}{T} \quad (6)$$

Substituting Equation (1) into Equation (5), the following expression can be obtained

$$\omega_0'' = T_1\omega(l) \quad (7)$$

From Equations (4)-(7), it is concluded that the beam expansion ratio and the collimation ratio for a Gaussian beam depend not only on the specifications of the beam expander, but also on the laser beam parameters as well as the positions of the optical lenses.

The function of a beam expander is to reduce the divergence angle of laser beams and thus make the focused beam diameter smaller.