CASCADE LASER CORPORATION

Manual Beam Expander

Product Information

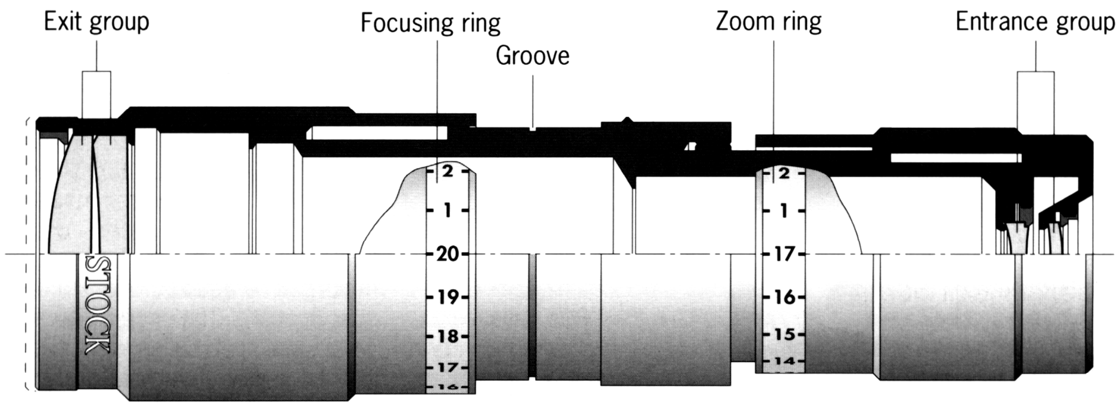

Figure 1: *Manual Beam Expander*

A beam expander is an afocal optical system comprising at least two optical elements. It serves primarily for the expansion of the cross-section of parallel beam bundles, for example of lasers. The ray divergence (= deviation from the ideal parallel form) is inversely proportional to the expansion factor so that the beam expander also reduces ray divergence. In design the beam expander corresponds to an inverted telescope (Figure 2); the expansion factor corresponds to the telescope enlarging ratio Γ'.

Two design principles: Following Galileo or Kepler

- With **Galilean principle** the beam bundle first passes through a negative element which causes divergence; in this (expanded) state it then passes a positive element which restores the parallel state. The focus points F_1' of the negative element (group) and F_2 of the positive element (group) must be at the same point. The distance between the two elements (groups) is given by the difference between the two absolute focal lengths.
- With **Kepler's principle**, however, both elements have a positive refractive power. A real focal point F_1' (=F_2) is produced and image inversion occurs. The over-all length is given by the sum of the two focal lengths.

At the focal point between both elements the bundle forms an extremely narrow “waist” so that the ray density is very high at this point. This can lead to problems with applications involving very high power (e.g. in material processing) due to the high heat development.

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Applications of beam expanders

Beam expanders are frequently used in combination with gas or solid state lasers in order to expand the exiting beam to the extent desired. In some applications, however, the reduction of the beam divergence may be more important.

With a correspondingly designed beam expander it is also possible to obtain focusing, temperature compensation and - with a modified construction - also shape changes of the beam bundle cross-section in an optical system.

One particular important application is with ***laser scanners*** which work with an HeNe laser as the beam source (Figure 3). The beam bundle of the laser is expanded by a beam expander, then deflected (e.g. by a polygon wheel or a galvo mirror) and focused on the image (scan) plane with one or more lenses. Here, the expansion is used to fill up the entrance of the focusing lens as completely as possible with the beam bundle to minimize diffraction and to obtain the best point image quality.

If ***laser diodes*** are used as beam source in the optical system, beam expanders will generally be positioned behind a collimator which will give a parallel orientation to the divergent exit bundle of the laser diode. For high quality demands, the collimator may contain correction elements, e.g. to eliminate laser diode astigmatism, to approximate an elliptical bundle cross-section to a circular shape, for temperature correction or for system coordination. However, it is also possible to integrate ***correction elements*** in the beam expander.

If beam expanders with a variable expansion factor are used in optical systems for ***laser material working*** (or engraving), a change in the bundle cross-section in front of the pupil of the focusing lens can be used to control the ***heat requirement*** to adapt this to the material to be worked.

When used in combination with ***high power lasers***, a further advantage of bundle cross-section expansion can be found in the lower ***thermal strain*** on the following optical system.

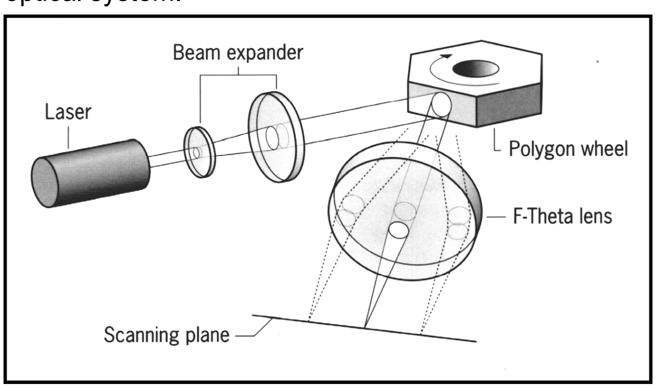

Figure 3: *Beam expander in schematic beam path of a laser scanner with an HeNe laser as the beam source. Due to the expansion of the beam bundle cross-section the entrance pupil of the F-Theta lens is optimally filled up. Due to the reduced diffraction and less beam divergence this causes, a smaller point image diameter and so a better image quality can be achieved in the scanning plane.*

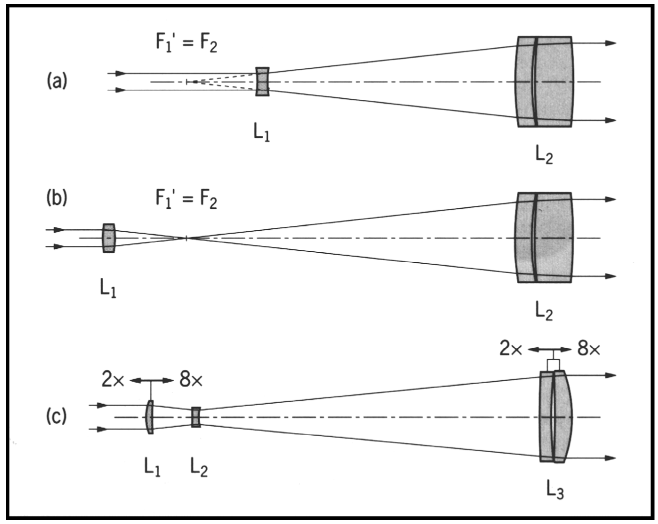

Figure 2: *Design of a beam expander according to the principle of Galileo (a) and of the Kepler telescope (b). The Galilean principle produces a shorter over-all length and is therefore more popular. Kepler's principle inverts the image and provides a real focal point F_1'-which needs to be taken into account for some applications. The vario beam expanders from Cascade Laser (c) largely correspond to the Galilean principle, but from the first to the second lens element they do have a convergent beam path as the Kepler's principle.*

Typical properties of a beam expander

If a beam expander is required to solve a particular problem, the following optical properties must be taken into account. The requirements made on these properties will determine whether a standard series beam expander can be used (See Table 1) or whether special developments may be cheaper or even absolutely necessary.

Design principle: The optical design principle (Galilean or according to Kepler) is of decisive importance, particularly for the over-all length. The type of application will determine whether image inversion and the existence of a real focal point (possible heat development!) will also play a role in the type according to Kepler.

Color correction: This will determine the wavelength and so also the type of laser the beam expander can be used for. Cascade Laser Corporation supplies standard beam expanders suitable for wavelength 532 nm (double-frequency YAG laser), 633 nm (HeNe laser) and 780 to 860 nm (laser diodes) or 1064 nm (YAG laser, material working). To increase the transmission and to reduce scattered light, the elements of these beam expanders are coated with a reflection-reducing layer of the type V coordinated to their nominal wavelength; the laser diode beam expander (780 nm to 860 nm) has a broadband coating for 630 nm to 1070 nm.

Optical quality: The beam expander also pays a role in determining the optical quality of the total system. This means that its optical quality may not be neglected. All beam expanders from Cascade Laser Corporation reach the limit of diffraction from a qualitative point of view at their nominal wavelengths.

Expansion factor: The beam expander expands the diameter of a beam bundle by a factor which corresponds to the magnification ratio Γ' of the (inverted) telescope system. By a suitable choice of the expansion factor, it is possible to obtain optimum adaptation of the bundle diameter to the entrance pupil of a following system such as an F-Theta lens. A variable expansion factor allows exact adaptation under changing application conditions. The benefit can be found in reduced diffraction and divergence, that is in a higher imaging quality. With variable beam expanders it must be remembered that the bundle cross-section can be limited by the entrance or the exit pupil depending on the expansion factor selected.

All of our standard series beam expanders allow the setting of the expansion factor to a value between 2x and 8x; for this purpose the focusing ring and the zoom ring have to be set according to a diagram supplied (Figure 5). The maximum usable entrance bundle diameter E will be 4 or 8 mm depending on the model; the maximum usable exit diameter is 31 mm.

Divergence reduction: An immediate consequence of the inverted telescope principle used in the beam expander is the reduction in beam divergence inversely proportional to the expansion factor (when the telescope is inverted, its magnification factor Γ' becomes the reciprocal reduction factor).

Image angle: Mechanical assembly tolerances can tilt the beam expander axis over the axis of the incident beam bundle. This requires an image angle other than zero. The available standard Cascade Laser Corp. beam expanders provide sufficient play (0.2°) for mechanical adaptation within the total system.

Focusing: If the distance between the two optical elements of the beam expander is adjustable, then it can be used to change the back focal distance of the

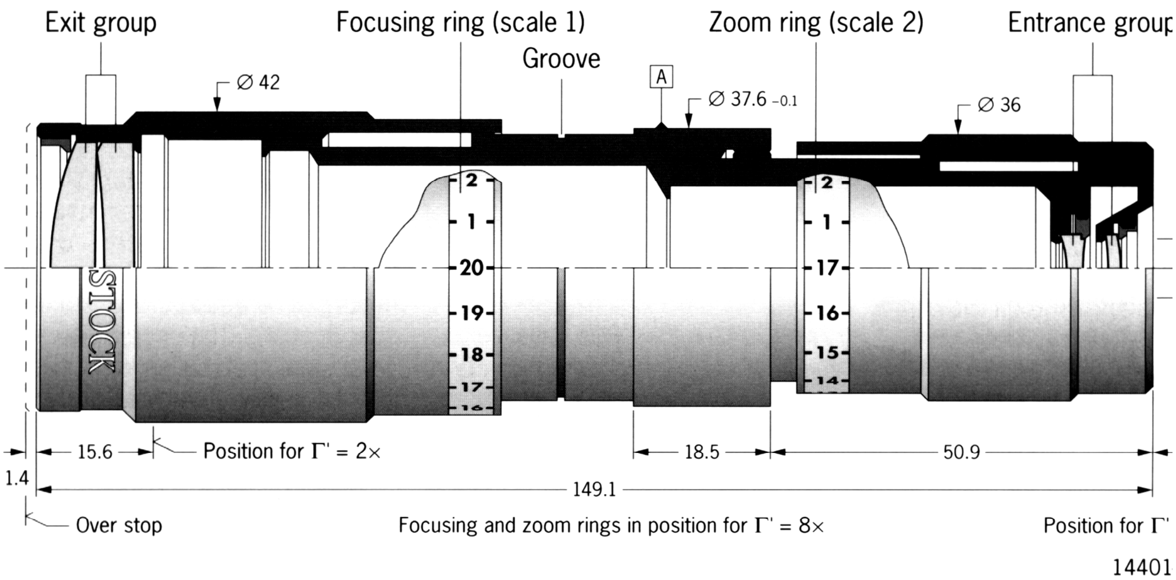

Figure 4: *Beam Expander in four-element design with variable expansion factor 2x to 8x for wavelength λ = 1064nm. The right-hand setting ring is used to change the distance between the two lenses of the entrance element and so its focal length. The left-hand ring moves the positive exit element in such a way that its real focal point F_2 on the entrance side coincides with the virtual focal point F_1' (on the exit side) of the generally negative entrance element. In addition, it can be used if required to refocus the total optical system. The beam expander should be installed in the device holder at surface [A].*

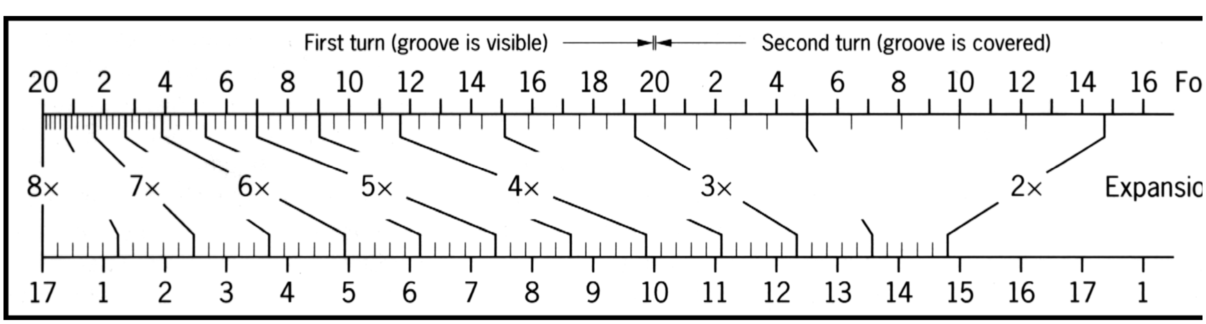

Figure 5: *Setting values for the focusing ring (1) and the zoom ring (2) to obtain expansion factors 2x to 8x for the beam expander shown above with a variable expansion factor. When the focusing ring is moved past one full turn (above 20 the scale begins from the start again), the groove is covered. The setting values of the other vario beam expanders from Cascade Laser are similar, but not identical.*

Beam Expander (Order Number)	Lens element number	Corrected for wavelength (also usable for the wavelength range)	Reflection reduced coated for the wavelength (type of coating) or for the wavelength range	Expansion factor	Maximum entrance bundle diameter	Maximum exit bundle diameter
14401-205-000-20 D)	4	532 nm	532 nm (type V)	2x ... 8x	4 mm	31 mm
14401-181-000-20 D)	4	1064 nm	1064 nm (type V)	2x ... 8x	4 mm	31 mm
14401-257-000-20	4	532 nm	532 nm (type V)	2x ... 8x	8 mm*	31 mm
14401-258-000-20	4	633 nm (780 ... 860nm)	630 nm ... 1070 nm	2x ... 8x	8 mm*	31 mm
14401-256-000-20	4	1064 nm	1064 nm (type V)	2x ... 8x	8 mm*	31 mm

Table 1: *D) = Discountinued model (on request); * For expansion factor 2x...3.9x- above: max. entrance bundle diameter = 31 mm/ expansion factor.*

total optical system. A variable afocal setting also allows a refocusing to compensate for focal length tolerances of other optical components. All of our beam expanders offer this possibility. The focus helix provides a distance over the stop of (depending on the model) at least 1.4 mm and so ensures variable afocal adjustment even at the extreme setting of the expansion factor 8x (scale value 0 to 20)

Advantages of a customized beam expander

In addition to the available standard range of beam expanders (See Table 1), Cascade Laser Corporation can also provide customized beam expanders which provide both cost benefits in larger volumes and an optimum qualitative and mechanical adaptation to the total system.

Furthermore, customized beam expanders can be substantially varied as regards of their optical properties.

Experience: Cascade Laser Corporation is able to provide you with beam expanders of the most varied types for almost all conceivable applications.

Mechanical adaptation: The mechanical design can take the installation design and customer demands such as compensation features and special movement possibilities into account.

Temperature compensation can be provided optically or mechanically and can be designed so that the effects of the customer's instrument are also compensated. Optical compensation is provided by the selection of glasses with corresponding thermal expansion coefficients and refractive indices. However, due to the low number of optical elements in the beam expander, only small back focus corrections can be obtained in this way. A much more substantial compensation can be achieved by means of mechanical temperature compensation. By selecting suitable materials for the tube of the beam expander or by a so-called "trumpet" design, the temperature behavior of a complete subassembly can be corrected.

Optical adaptation: The optical parameters such as expansion factor, entrance and exit bundle diameter or color correction (wavelength) can be adapted to individual customer requirements far beyond the band width offered by standard models. A cylinder afocal lens can, for example, shape the cross-section of the beam bundle. This allows the different-size semi-axes of a beam bundle emitted by a light pen with a laser diode to be adapted to the requirements of the following optical system if this was not possible or provided for by the collimator lens.

Cost minimization: When the total system is taken into account, the optical quality of the individual components can be adapted to customer specifications. The price/ performance ratio can be improved if for the desired quality of the total system a minimal configuration of components is used.

Contact Cascade Laser Corporation for ordering information or to request a quotation on manual beam expanders.

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