



Laser Scanning Lenses

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Scanning Lens Theory

Overview

Off axis deflection through a focusing lens system will, in general form aberrated images in a curved plane as opposed to a more desirable flat surface. A flat field scanning lens is a specialized lens system in which the focal plane of a deflected laser beam is a flat surface. The most common uses of flat field scanning lenses are: Laser Machining, Pattern Generation, Laser Writing, Engraving and Marking. Additional subclasses of scanning lenses are F-theta lenses and Telecentric lenses.

F-theta Lenses

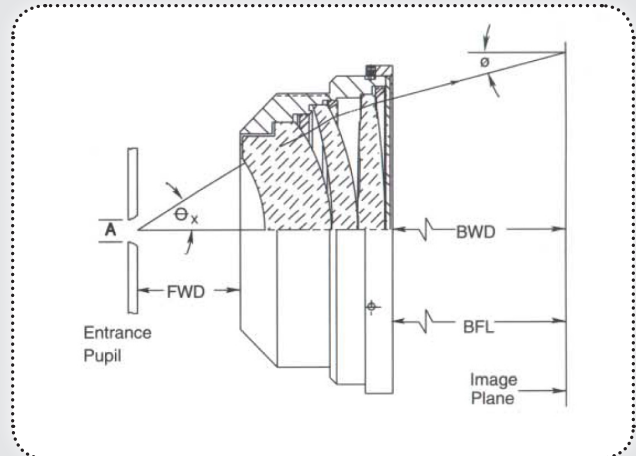
In the absence of distortion, the position of the focused spot is dependent on the product of the Focal Length (F) and the tangent of the deflection angle (θ). When the lens is designed with built-in barrel distortion, the position of the focused spot can then be made dependent on the product of F and q, thereby simplifying positioning algorithms. Lenses designed in this way are called F-theta lenses.

Telecentric Lenses

A significant feature of scanning lenses is the angle (θ) at which the focused beam strikes the work surface. In a typical lens, the beam will be normal to the surface only when the input beam is propagating along the lens axis. As the laser beam is deflecting off the axis, the angle moves off normal. This affects both the spot size, which becomes elongated, and the wall angle for cutting and drilling applications. At the cost of complexity and expense, the design of the lens can be such that the beam will strike normal to the work surface over the entire scanning field. This type of lens is defined as Telecentric. Telecentric lenses are almost always larger and more expensive than standard scanning lenses.

Deflection Angle

Figure 1 is a diagram of the standard parameters used for describing and specifying scanning lenses. The angle between the input laser beam and the lens system axis is called the deflection angle. Theta (θ) is the maximum deflection angle allowed before the laser beam experiences vignetting through the lens system or before the diffraction limited point is exceeded.



Entrance Pupil

The entrance pupil defines the origin of the laser deflection as well as the acceptable beam diameter and mirror size combination. If a single mirror system is used, the mirror is placed at the entrance pupil position and the maximum usable beam diameter is equal to the entrance pupil diameter (A). If a two mirror system is used for deflection in both the x and y directions, then the mirrors are placed on either side of the entrance pupil position and as close to each other as possible. Moving the origin of the beam deflection off of the pupil position and away from the lens system effectively reduces the allowable beam diameter and deflection angle. The maximum laser beam diameter for a two axis deflection system which has been displaced a distance L from the entrance pupil is given by:

$$A' = A [1 - (2L/A) \tan \theta]$$

where θ is half the maximum deflection, and L is the offset distance of the mirror. If the mirror is placed closer to the lens system L is a negative number and the effective aperture increases.

Front Working Distance

The Front Working Distance (FWD) is the distance from the entrance pupil to the lens housing. In a two axis system the physical working distance is less than the actual working distance since the entrance pupil position is between the two positioning mirrors.

Scanning Lens Theory

Scan Field Diameter

The scan field diameter determines many of the overall lens specifications. Once a scan field diameter is determined, it is along with the focal length defines the deflection angle required, since the focus position is proportional to the product of $F \times \theta$.

Back Working Distance

The distance from the work surface to the output side of the lens housing is the Back Working Distance (BWD). Depending on lens complexity and the degree of telecentricity, the back working distance can usually be specified and controlled during lens design.

Output Scan Angle

The angle between the normal to the image plane, or work surface, and the paraxial ray of the output beam is the output scan angle (ϕ). This angle is always zero for telecentric lenses. In general ϕ varies with the position of the focused spot across the work surface.

Spot Size

The spot size will be most affected by the input laser beam diameter, divergence of the laser source, and the effective focal length of the lens system. For a diffraction limited lens coupled with a Gaussian source, the $1/e^2$ spot size can be expressed as:

$$S = 1.27\lambda \times EFL/A$$

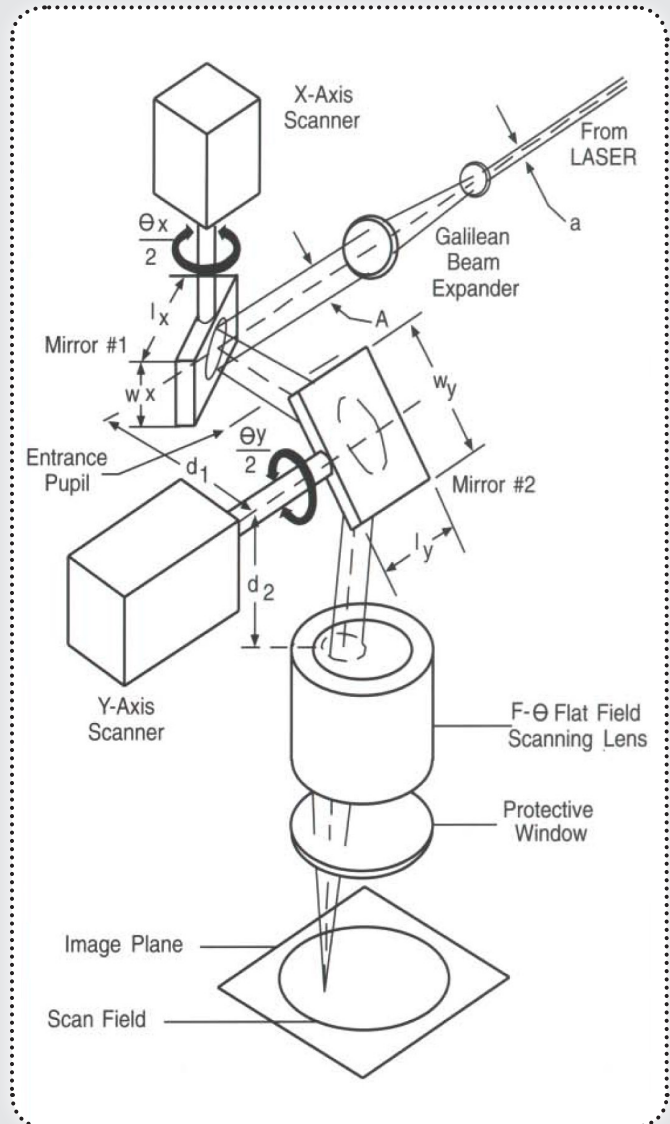
This equation is true for lens apertures which are 1.8 times larger than the $1/e^2$ beam diameter. In such instances less than 0.1% of the beam intensity is truncated by the lens aperture. For a "tophat" intensity beam incident over the entire lens aperture the spot size will be approximated by the following:

$$S = 2.44 \lambda \times EFL/A$$

The previous equations predict the spot size on the axis of the scanning lens system. For non-telecentric designs, the spot size off axis will be elongated proportionally to the output scan angle (ϕ) and is given by:

$$S_e = S / \cos \phi$$

For lens systems where ϕ is less than 10 degrees, the elongation is generally less than 2%.



Confocal Microscopy Laser Scanning Lenses

By using a Special Optics Telecentric F-Theta Laser Scan lens in place of a conventional microscope objective, Confocal Laser Scanning Microscopes can provide an image area more than 100 times that of a standard microscope. Our Telecentric F-Theta laser scan lenses are optimized for Confocal Microscopy and are ideal for focusing the incoming laser beam to a spot on the microscope slide.

Custom designed lens orders are welcomed. We design and construct countless specialty lenses for our customers everyday. Call, email or submit a custom lens request using our online form. We'd be happy to help design something to fit your exact specifications.



Applications

- Genomic and Proteomic Analysis
- Tissue Imaging
- Biotechnology

Features

- Diffraction Limited
- Precision Manufacture and Assembly

Confocal Microscopy Laser Scanning Lenses

Model	Wavelength Range (nm)	Focal Length (mm)	Field Size (mm)	Max. Input* Aperture (mm)	FWD (mm)	BWD (mm)	Scan Angle (degrees)	Lateral Color (microns)	1/e ² Spot Size (microns)
55-S28-3T	530 - 590	28.6	3	28.6	16	2.8	+/- 3	< 1	0.5
55-S30-15T	488 - 600	30.0	13	9.0	14	12.5	+/- 13	< 5	3
55-S80-25T	450 - 650	80.3	25	8.0	16	53.0	+/- 9	< 3	6
55-S172-36T	500 - 1100	172	36	20.0	49	86.0	+/- 6	< 8	10

* Single Axis Scanning
T denotes Telecentric
Model 55-S28-3 transmits 50% @ 365 nm

IR Laser Scanning Lenses

Special Optics IR F-Theta Laser Scanning Lenses are typically used with Nd:YAG lasers in laser marking, laser engraving, and laser cutting systems. All our designs are Diffraction Limited and provide a flat field at the plane of interest. Standard features include Diffraction Limited performance, air-spaced design for high damage threshold, and anti-reflection coatings on all surfaces.

In addition to the lenses listed, Special Optics regularly designs custom laser optical systems for a large variety of OEM applications and performance levels. Call us at 973.366.7289 or email us at sales@specialoptics.com to speak with one of our leading optical designers.

Features

- Diffraction Limited
- Precision Manufacture and Assembly
- Telecentric Models Available
- Germanium and ZnSe



IR Laser Scanning Lenses

Model (T denotes Telecentric)	Wavelength (microns)	Scan Field (mm)	EFL (mm)	Max Input Beam*	BWD (mm)	Deflection (degrees)	FWD (mm)	1/e2Spot Size** (microns)
55-S77-54	10.6	54	77.2	9.5	90	20.0	26.0	172
55-S102-100	10.6	100	102.0	16	120	28.5	22.0	135
55-S275-200	10.6	198	277.8	15	295	20.0	48.0	395
55-S100-100	10.6	100	100.0	21	113	28.5	30.0	101
55-S150-150	10.6	150	150.0	21	171	28.5	26.3	151
55-S125-100	10.6	100	125.0	16	150	23.0	26.2	166
55-S96-75	10.6	75	96.0	14	97	22.0	24.0	145
55-S117-75	10.6	75	117.0	17	117	18.0	42.0	146
55-S120-108	10.6	108	120.0	14	122	25.0	23.4	181
55-S149-129	10.6	129	149.0	17	153	25.0	46.3	187
55-S90-42T-λ	9.3 or 10.6	42	90.0	34	92	14.0	41.0	56
55-S101-70T-λ	9.3 or 10.6	70	101.0	33	92	22.0	44.2	64
55-S129-82T-λ	9.3 or 10.6	84	129.0	24	136	19.0	48.2	115
55-S58-40T-λ	9.3 or 10.6	40	58.0	39	34	21.2	39	31

Please replace λ in model number with working wavelength when ordering.

* Single Axis Scanning

** Spot Size = 2 λ F#

Telecentric UV Laser Scanning Lenses

Special Optics telecentric F-Theta UV scanning lenses offer greater depth of field and smaller spot sizes when marking objects for laser material processing. Telecentric scanning lenses, by the very nature of their design, maintain a near normal incidence angle of the beam to the work piece. This ensures that position errors and image distortions are minimized over the entire scan range. With the shorter wavelength, a smaller spot size is achievable.

Having a greater depth of field and smaller spot size are important for precision laser micro-machining processes where there is a need to produce fine spot sizes so as to control the width of a laser mark, scribe or drilled hole while maintaining precise placement over a relatively large field. The ability to accomplish this is sometimes affected by just minimal warping of a wafer or solar panel.

Special Optics Telecentric UV scanning lenses include focal lengths of 34mm, 50mm, and 100mm and are available for 266nm or 355nm wavelengths. The scan fields range from 9mm, 20mm, 45mm, and 55mm. Our telecentric UV scanning lenses were developed to accommodate large input beam diameters ranging from 17mm to 10mm. Thanks to the larger input beam design and shorter UV wavelength, the spot sizes achieved are 1.0 microns, 2.5 microns, and 5 microns respectively. All Special Optics lens designs are diffraction limited and deviation of the telecentricity is less than 0.9%.

Features

- Diffraction Limited
- Precision Manufacture and Assembly
- Air-Spaced Design
- Achromatic Designs Available

Telecentric UV Laser Scanning Lenses

Model	Wavelength (microns)	Scan Field (mm)	EFL (mm)	Max Input Beam*(mm)	BWD (mm)	Deflection (degrees)	FWD (mm)	Spot Size (microns)
55-S34-9UV- λ	266 or 355	9	34	17	10	7	17	1.0
55-S50-20UV- λ	266 or 355	20	50	10	15	12	23	2.5
55-S100-45UV- λ	355	45	100	10	150	16	28	5.0
55-S100-55UV- λ	266 or 355	55	100	10	135	16	28	5.0

Please replace λ in model number with working wavelength when ordering.