

## Ronar-Smith® F-Theta Scan Lenses

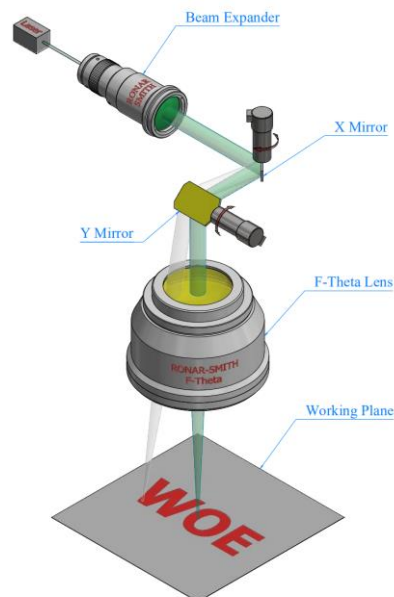
Ronar-Smith® F-Theta Scan Lenses are meticulously designed and crafted for a broad range of laser applications. With over a decade of expertise in optical grade and coating production, Ronar-Smith® scan lenses yield some of the world's finest optical performance in the market. We also provide customisation services for customers based on their requirements.

Our F-Theta scan lenses are optimised for laser-material processes, specifically for engraving, cutting, welding and bonding. The scan lenses are available in working wavelength telecentric (TSL-Q and TSL series) and non-telecentric (SL-Q and SL series) configuration. For vision system that requires an additional wavelength, we provide achromatic scan lens in telecentric (TSLA series) and non-telecentric (SLA series) configuration.

### Working Principles

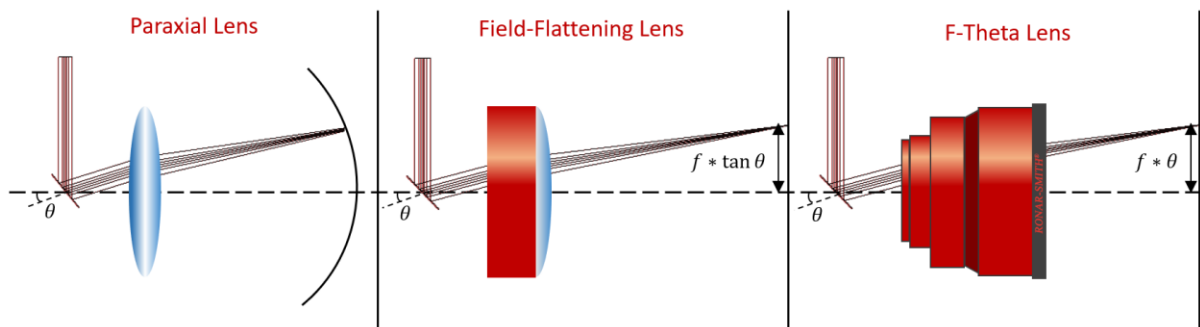
#### F-Theta Scan Lens

For most applications in laser-material processes, a planar imaging field is necessary for quality output. Traditional optics such as paraxial lens focuses only on its spherical plane, resulting in distortions such as spherical aberration while imaging on a planar surface.



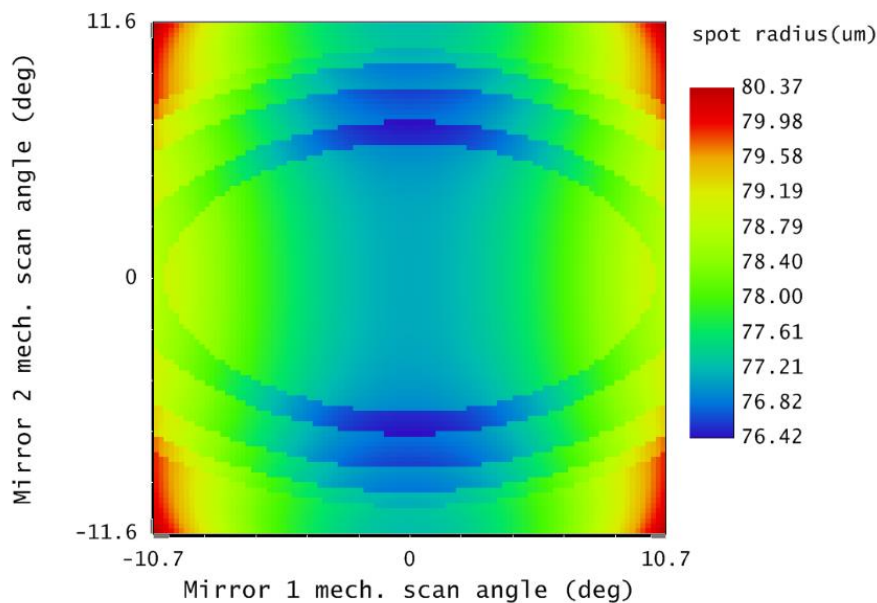
Field-flattening lens resolve the challenges of a spherical-field-orientated optics by creating a flat focal field, but at the cost of inducing a nonlinear behaviour. The displacement term between the effective focal length ( $f$ ) and the deflection angle ( $\theta$ ) prevents a uniform movement (i.e. constant scan rate) of the scanning mirror due to this nonlinearity ( $f * \tan \theta$ ). It also resulted in an angular field-of-view and causes inaccuracy between varying magnification and observed measurement by vision system. To resolve this nonlinearity, F-theta lens are designed and engineered for the beam displacement to be independent from the tangent of the deflection angle.

F-theta lens provides the linear dependence between  $f$  and  $\theta$ , creating a linear displacement that is ideal for use with scanners (XY galvanometer with mirrors) rotating at a constant angular velocity. The fixed velocity of the scanners corresponds to a constant velocity of the focal point on the flat focal field, with little to no electronic noise correction required. Complex scanners algorithm for the nonlinear compensation is eliminated, hence provide an accurate, safe and inexpensive solution to customers.



Our F-theta scan lens is designed for a wide range of applications. It is available over a broad wavelength, ranging from UV, VIS, NIR and CO<sub>2</sub> Laser. We also provide customise solutions for wavelength-specific application.

### Spot Size Diagram



F-theta scan lens are subject to spot size variations on the planar surface, and the spot size diagram plot provides more information about the typical variation as a result of the angle movements of both mirrors on the XY axis of a galvanometer. The spot size variations can also be calculated using the following equation.

$$\phi_{spot\ size} = \frac{\lambda g f * APO * g M^2}{D}$$

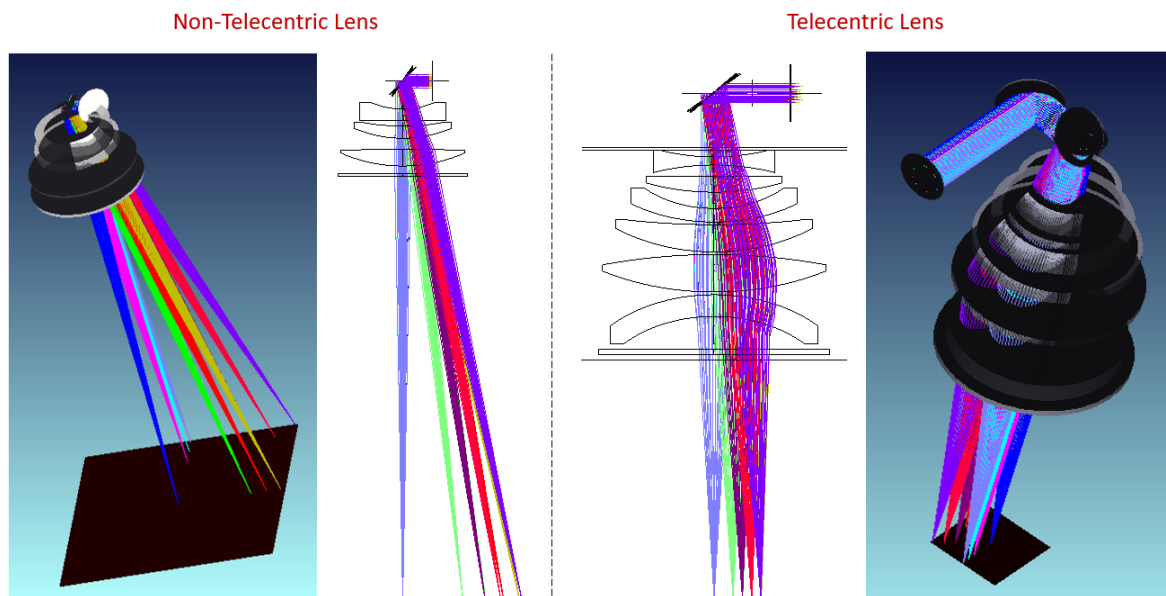
where APO is a factor relating the ratio of beam diameter D and entrance pupil.

Entrance Pupil/ Beam Diameter D	APO
2.0	1.27
1.5	1.41
1.25	1.56
1.0	1.83
0.9	1.99
0.75	2.32
0.5	2.44

### Telecentric vs Non-Telecentric Scan Lens

Ronar-Smith® F-Theta scan lenses are designed to meet the broad industrial requirements of our customers. When laser-material processes require constant field-of-view with no dependency between the lens magnification and the depth, an object-space telecentric lens is recommended. For processes that has less stringent requirements on the quality of finish at the focal plane, a non-telecentric lens is capable of delivering the job to customers satisfaction.

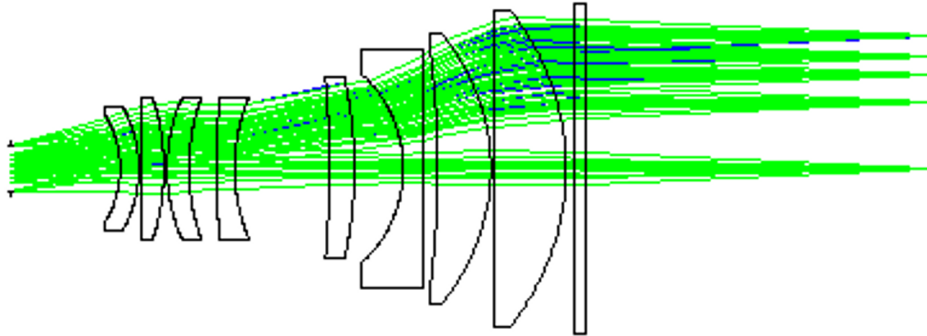
Telecentricity describes the angle of incidence of the laser beam delivered to the surface of the material during laser processing. In general, the angle of incidence for every point on the focal plane is the same, while non-telecentric lens have varying angles of incidence on different points of the same plane. The end result of telecentricity produces repeatable and homogeneous spot size distribution on the object space field, while reducing the effects of parallax error.



### Achromatic Scan Lens

Ronar-Smith® F-Theta achromatic scan lens is designed to limit spherical and chromatic aberration, and bring in two different wavelengths (working and visible wavelength) onto the same plane. This enable the transmission of wavelength-specific laser beam during laser-material processes while ensuring that the visible (feedback) and laser beam wavelength are temporally and spatially matched. Our achromatic scan lens enables machine vision in industrial processes for automation control and feedback, while ensuring the product quality is not compromised.

Achromatic Lens



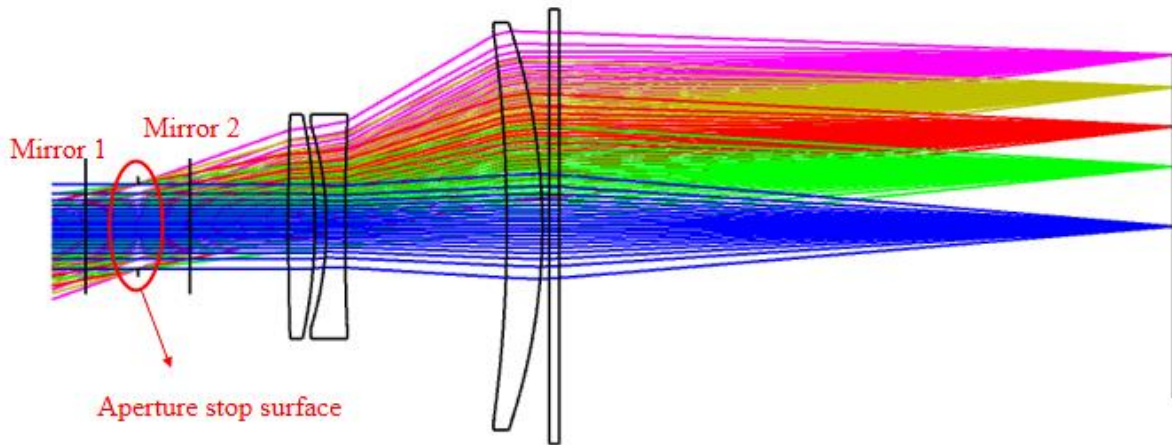
### Important Definitions:

#### Aperture stop surface

F-Theta is usually used in laser scanning systems. The working wavelength is a single wavelength and the working pieces is a plane. The F-Theta lens belongs to a large field of view and a small relative system design. Then the aperture stop diameter is equal to the laser beam diameter. In the 2D Galvo Scanner system, there is actually no optical aperture pupil

If only one mirror is used, the aperture stop is located on the mirror. If two mirrors are used, the aperture stop is located in the middle of the two mirrors, and the beam will be skewed. Usually they will use two galvanometers and focus the beam on a 2D plane.

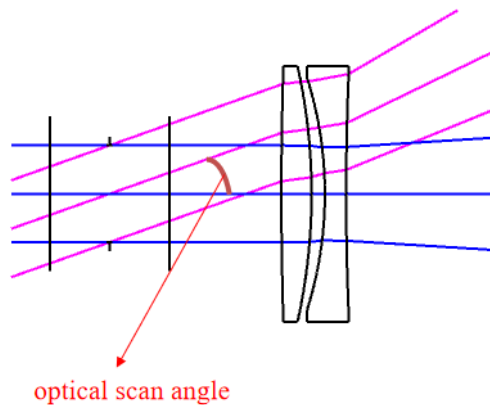
In practical applications, there is no mechanical boundary to create any kind of aperture in it. When designing, they will place the aperture in the middle of the two mirrors, as shown in the figure below.



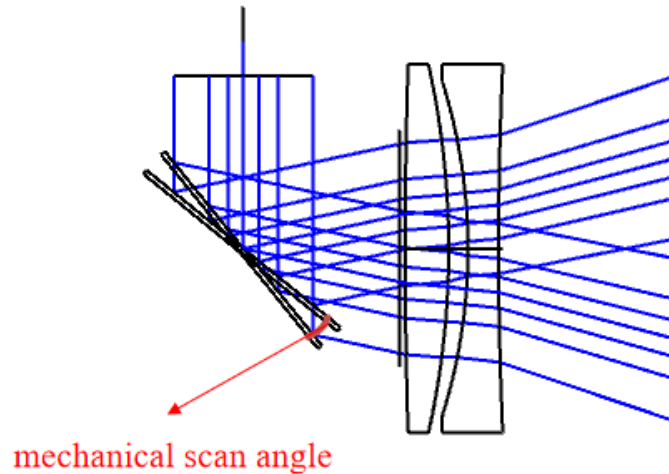
**Scan angle**

Usually F-Theta lens has two scanning angles, one scanning angle is optical scanning angle, and another is mechanical scanning angle.

The optical scanning angle is the field of view of the lens, which determines the diagonal length of the the maximum scanning field. The F-Theta lens specifications usually mention the optical scanning angle, the diagram is as follows:



The mechanical scanning angle is related to the scanning mirror. It is usually the rotation angle of the two mirrors, which controls the scanning range from two directions. In the Galvo Scanner system, the specifications on the scanner refer to the mechanical scanning angle of the mirror. The schematic diagram is as follows:



We use two mechanical scanning mirrors as Mirror X angle and Mirror Y respectively, then the relationship between them and the optical scanning angle is:

$$(\text{Mirror X angle})^2 + (\text{Mirror Y angle})^2 = (\text{optical scan angle}/2)^2$$

### **Back reflection**

Back reflection ghosting is the surface reflection from the scanning lens. The reflected focus points appear at different positions. When using a picosecond or femtosecond pulsed laser, the reflected focus point can easily damage the coating or lens material on the lens surface.

This is a challenge for the designer. In the optimization, the designer must not only consider the performance of design but also avoid the reflection focus point on lens.

