

PRODUCT TUTORIAL

2-AXIS VS. 3-AXIS

Laser system designers have a broad range of beam positioning architectures available to them to solve various applications. This paper explores the design, benefits, consequences, and use of the 3-axis scan head technology as compared to 2-axis scan head architecture.

In a typical two axis laser scanning system, a collimated beam is reflected by the X and Y axis scanning mirrors before entering the focusing lens. The lens focuses the beam on the work surface. Rotation of the X and Y mirrors causes movement of the focused spot within a flat field. The size of the spot and the size of the field are determined by the lens (and other factors). F-theta lenses are intended for this purpose. This configuration is known as a pre-objective scanning system because the laser strikes the scanning mirrors before the focusing (objective) lens.

(See Figure 1)

The architecture works well as long as the laser beam's diameter and field size are relatively small. For example, applications using beam diameters less than 20mm and field size less than 300mm are well suited to Z-axis pre-objective scanning.

As the field size requirements grow, larger scan mirrors and laser beam diameters are needed to maintain a numerical aperture (NA) consistent with a small focused spot. F-theta scan lenses for these large laser beams would be big, costly, and impractical. For this reason, a 3-axis scanning solution should be considered.

In a 3-axis scanning system, the XY mirrors are placed after the final focusing lens, hence they are referred to as a post-objective scanning system. Since the laser beam does not move on the objective lens, the lens does not need to be very large; however, this arrangement does not create a flat field. To achieve a flat field, a third axis (Z-axis) of motion is introduced in the form of a linear lens translator.

The typical laser system uses a telescope to expand the laser beam to a diameter consistent with the required NA. The distance between the telescope input lens(s) and objective lens(s) determines the focus distance of the system. By mounting the input lens(s) on a linear lens translator (the third axis), we gain dynamic control over the focus distance. **(See figure 2)**

By coordinating the motion of the linear lens translator with the rotation of the X and Y scanning mirrors, we achieve a focused laser spot throughout a flat field.

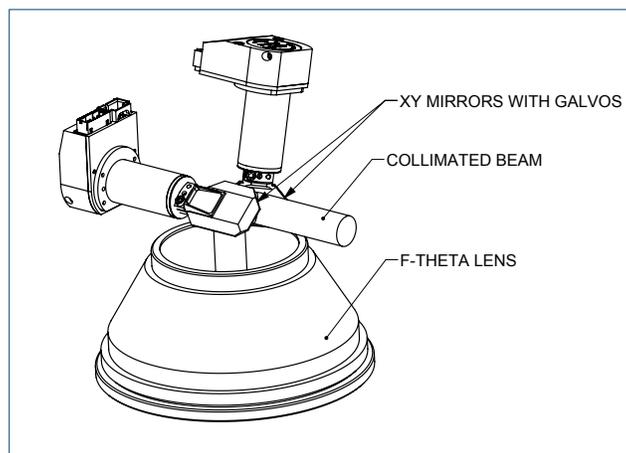


Figure 1

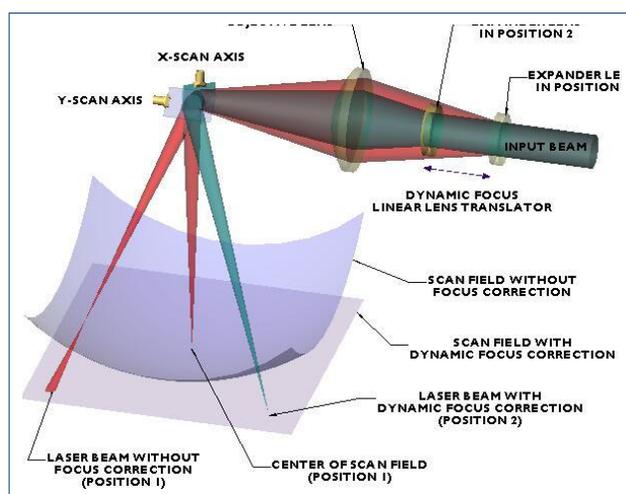


Figure 2

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Controls

In order to perform laser application tasks, the XY scanning system needs to be connected to a controller which is also operating the laser. This controller provides real time synchronization of scanners and laser, and is linked to a software or firmware which provides a stream of data to the hardware. User data (in the form of graphics, text, barcodes, etc.) is broken down to create individual commands for each axis and the laser. The controller is also required to compensate for geometric distortions inherent in the lens and the XY mirror arrangement. This is accomplished by the use of a lookup table. User coordinates are adjusted using the information in this table to achieve an undistorted image in the working field.

In most cases, the user data is presented in a 2-dimensional format. This works well with the pre-objective systems since the data or graphics can be processed into X and Y channels of data for positioning each mirror. In the 3-axis post-objective system, we require information to drive the Z-axis mechanism. Here we can take advantage of the lookup table to create a third coordinate for the Z-axis. For each XY coordinate, we calculate a Z ordinate which will be used to focus the laser beam at the desired Z-axis position. These ordinates are calculated based on prior knowledge of the optical configuration. During the laser scanning process, these values are used to create a signal for the Z-axis mechanism.

Changing Field Sizes

Using this architecture, multiple lookup tables can be tabulated to operate the optical system at various focus distances. A static adjustment of the lens spacing determines the distance from the scan mechanism to the working field. The dynamic action of the Z axis provides continuous real time focusing to maintain a flat field.

In order to operate the system at a particular distance, the operator need only select the appropriate table and set the static adjustment to the corresponding distance. **The system will focus correctly only when the information in the lookup table agrees with the physical set up of the hardware.** Discrepancies will result in focus errors at the work plane.

This type of optical system has no telecentric compensation. The rotation angle of the mirror determines the beam's angle to the flat field. One consequence is that the field size increases with the distance from the scan mirrors. This attribute makes 3-axis scanning systems more flexible than 2-axis systems, as working fields for different size objects can be realized without changing lenses or hardware.

Customarily, optics are designed to produce a constant beam diameter at the X scan mirror. Therefore, the numerical aperture (NA) of the system is determined by the diameter of the beam on the X mirror and the distance to the flat field. Since the focused spot diameter is determined by the NA, spot size and field size scale proportionally. For example, if the field size is doubled, the spot size will also double.

3D

Up to this point, we have limited to our discussion to 2-dimensional scanning. The 3-axis method is used to focus the laser spot in a 2-dimensional field. Notably, the optics and controls enable focusing of the beam in a 3-dimensional volume. Three-dimensional information can be embedded in the lookup table such that the Z-axis ordinates represent a predefined contoured surface. Alternately, the rendering software could be used to send 3-dimensional data directly to each axis enabling random access to any point within the addressable space.



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Hybrid Systems

In some cases, it is desirable to use the 3-axis system in conjunction with an f-theta lens. In this case, the f-theta lens is the primary focusing optic and works in the conventional way. The Z-axis is used to change the collimation of the beam entering the lens, producing a z-axis offset of the working field. Hybrid systems find utility in addressing work pieces of various thicknesses or in layer-based processing.

Conclusion

Pre-objective, 2-axis scanning systems effectively meet the requirements of many laser applications. Post-objective, 3-axis scanning systems are often used in applications requiring large field sizes and small spot sizes. They also provide the flexibility to realize various spot sizes and field sizes with only minor adjustments. Hybrid systems provide value in some special cases. Application requirements will determine which type of scanning system provides the most effective solution.

Nutfield Technology has been designing and manufacturing the most advanced galvanometer-based optical scanners, scan heads, laser scan kits, control electronics and software products available since 1997. Contact Nutfield Technology today for solutions.

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