Industrial Laser Review

Beam delivery basics

This piece represents the fourth in a series of educational articles

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A laser beam delivery system is designed to safely deliver the laser beam to the workpiece with precision, accuracy, and stability in an industrial environment. Process characteristics that must be considered in the design of such systems include: type of laser process, material being processed, processing speed, quantity, reliability, laser type, wavelength, average and peak power, mode, mode quality and stability, pointing stability, beam size, polarization, divergence, pulse shape, pulse frequency, duty cycle, and so on. All of these characteristics are engineered into the manufacturer's design of the beam delivery system and each beam delivery component. This article focuses on the basic use and application of the laser beam delivery components related to laser type and application.

Basic configurations

Beam delivery systems fall into two basic categories.

Transmissive beam delivery systems-This type of beam delivery is commonly referred to as "fiber delivery." It provides a flexible method to deliver a laser beam to the workpiece using a special fiber-optic cable, designed for high-power laser applications. Several configurations are available utilizing various fiber diameter and jacket designs and some incorporate wiring integral to provide feedback and communications to and from the laser. The fiber-optic cable can be used only with short-wavelength lasers such as the Nd:YAG laser. Special optics focus the laser beam into the fiber and then recollimate the beam at the fiber output. This combination of components is determined by the laser manufacturer, laser beam delivery builder, and the specific laser application.

Reflective beam delivery systems-This type of beam delivery is also commonly known as "raw beam" or "hard optic" delivery, and it can be used for all laser wavelengths. Specially designed adjustable mirror mounts are used to bend the laser light and deliver it to the workpiece.

Because reflective beam delivery systems can be used for all wavelengths, this article will focus primarily on reflective beam delivery systems and their individual components, although transmissive beam delivery systems share many common components.

Beam delivery components

Laser beam delivery systems can incorporate a wide variety of components to deliver the laser beam to the workpiece. The combination of these components is critical to the overall laser system's performance and reliability. Standard beam delivery components can be used in an "erector set" format to provide a wide variety of system configurations. These beam delivery configurations will incorporate a selection of components in the following groups.

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Figure 1. Capacitive autofocus head incorporates an internal motion axis.

Beam directing components

Laser beam directing components "direct" or "deliver" the laser beam to the workpiece. This is accomplished using laser mirrors that are fabricated using special materials with high-reflective coatings dependent on the laser wavelength and power.

Kinematic or gimbal design beam benders are used to hold the laser mirrors. Kinematic designs will actually displace the laser beam while the gimbal design will not. Beam benders must permit solid, repeatable orthogonal adjustments of $\pm$ 2 degrees. In addition, they must be designed to hold the mirror distortion-free and provide an option of internal-cooling for high-power lasers.

Beam switching units provide a method of sharing the same laser beam between two or more processing systems. They are designed to accurately and repeatedly switch or redirect the laser beam using mirrors.

Beam enhancement & positioning components

Laser beam components can enhance and condition the laser beam dependent on the specific beam enhancement component selected. Laser beam positioning components manipulate the laser beam dependent on the specific application. These enhancements and positioning components can be further explained individually by the following examples:

Circular polarizing units convert the laser beam from linear to circular polarization. They are used in some applications that require equal energy in two orthogonal axis to enhance a laser drilling or cutting application. In general terms, circular polarizing is often referred to as the comparison between cutting with a dull knife versus a sharp knife. A special quarter-wave optic and standard bending optics are used in conjunction with an "in-line" or "off-set" circular polarizing unit design. The unit assists in providing straight uniform laser drilled holes and uniform cut widths in all cutting axes.

Collimators and spatial filters enhance the laser beam using two moveable lenses or mirrors. Collimators can change the beam size and laser beam divergence of the laser for a specific laser processing application. Spatial filters provide a method of "cleaning-up" a laser beam by blocking stray energy around the beam. This method will induce a power loss due to the masking of the beam.

Autofocus units provide a method of maintaining optimum focus on an uneven or varying workpiece. "Roller-ball" units use small balls that roll on the workpiece to move the focus head. "Electronic-foot" units use a small foot and sensor system to provide feedback to a motion system to move the focus head. "Capacitive" units provide a noncontact method to maintain optimum focus. Capacitive units measure the distance between the laser nozzle tip and workpiece and provide feedback to a motion system to move the focus head. Very tight focal point positioning accuracies can be held with these units (see Figure 1).

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Figure 2. In-line design incorporates two motion axis with a capacitive height sensor.

Trepanning units provide a method to drill or cut holes larger than the focus spot size, by circularly moving the laser beam. In some applications moving the laser beam is the preferred method opposed to moving the entire part. Several optical and mechanical designs are available. These range from units based on X/Y positioning designs to rotating wedge designs for manipulating the focal point. Specific designs are based on laser power, speed, and processing application.

Optical laser wrist units provide a method to manipulate the laser beam around the workpiece, to process compound angles and large parts. Several "in-line" and off-set designs are available dependent on the specific application (see Figure 2). Usually these units are integrated into a CNC for positioning. Accuracies are design and focal length dependent.

Articulated arm units provide a flexible method to direct the laser beam when laser power and/or wavelength do not permit the use of a fiber-optic laser beam delivery. The articulated arm is designed to deliver the laser beam to the workpiece by directing the laser beam through special beam tubes by a series of bending mirrors. Rotary bearings allow the unit to translate and move the beam in any direction while maintaining optical alignment. Several designs and sizes are available for both industrial and medical applications. An important quality of the articulated arm is that it can be used for any laser wavelength and provides a constant length beam path independent of position. In addition, it also preserves the laser mode while introducing very little power loss (see Figure 3).

Beam position viewing components

Laser beam position viewing components provide a method of remotely viewing the workpiece via closed-circuit-TV to position the laser and monitor the laser process. Several designs are available with a wide variety of options dependent on the laser application.

Laser process heads

Laser process heads provide a method to focus the laser beam onto the workpiece. Transmissive optic designs are most commonly used, while reflective optic designs are used in high-power applications. Gas jets are also incorporated into this design to assist in the laser process and protect the optics. Desired designs provide a method to quickly change or inspect the focus lens. The laser process head provides movement of the focus lens and gas jet tip for laser beam alignment. Additional linear mounts provide focus adjustment. Several nozzle tip or "gas jet" designs are used dependent on the application and focal length used (see March *ILR*, p. 24).

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Figure 3. A counterweight provides ease of articulated arm movement.

Adapters, mounts, clamps, beam tubes, etc.

Several types of adapters, mounts, and clamps connect the individual beam delivery components from the laser bezel down to the workpiece. Laser beam protection tubing provide a safe method to contain the beam while sealing and keeping the optics of the delivery system clean. Telescopic beam tubes are used in conjunction with motion systems where the beam tube length needs to vary.

Conclusion

The laser beam delivery manufacturer generally acts as the liaison between the laser builder and the end user to build a system that performs according to the end user's laser processing requirements. In addition, the laser beam delivery manufacturer will be able to assist the end user with custom components, installation, training, and technical support. □