May/June 2002
A Penton Publication
md News
Medical Design

# Laser Machining for Medical Applications

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**High-performance laser machining centers benefit from advances in motion control and positioning technology.**

Medical advances in the last decade have produced numerous surgical tools, drug delivery equipment, diagnostic devices, and surgically implantable devices. This proliferation created a major challenge to the high-volume producers of such ultra-precise devices.

Traditional production facilities have relied on CNC-controlled conventional machines (mills, lathes, grinders, automated welders) and CNC EDM machines. These machines can produce consistent high quality parts, but typically are not optimized for production of medical components.

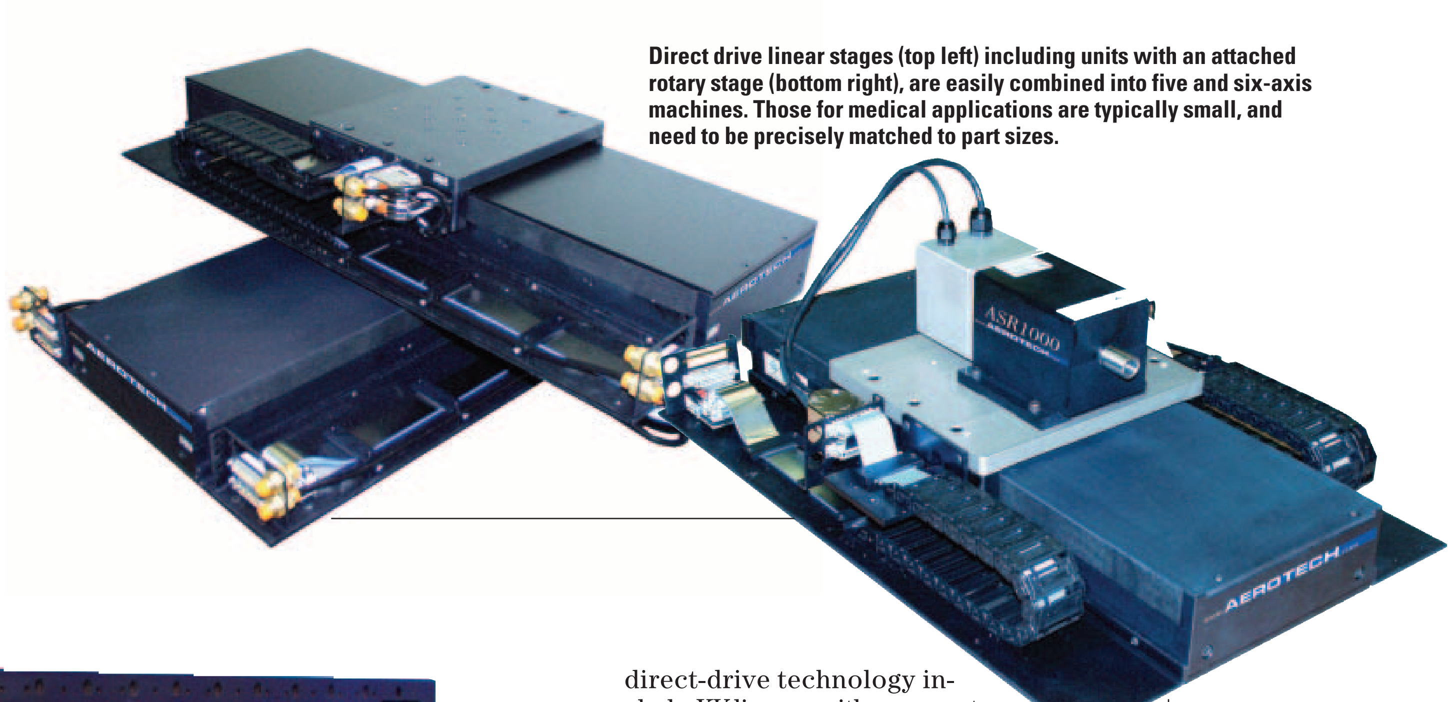
Nd:YAG and excimer lasers are the energy sources of choice for production of most medical components. They process stainless steels, titanium, Nitinol, polyamides, and ceramics. Processing operations include cutting, welding, and surface treatment.

Lasers offer the possibility of even higher levels of precision, part quality, consistency, and throughput. However, this can only happen when lasers are used in conjunction with high-accuracy and high-repeatability motion control equipment.

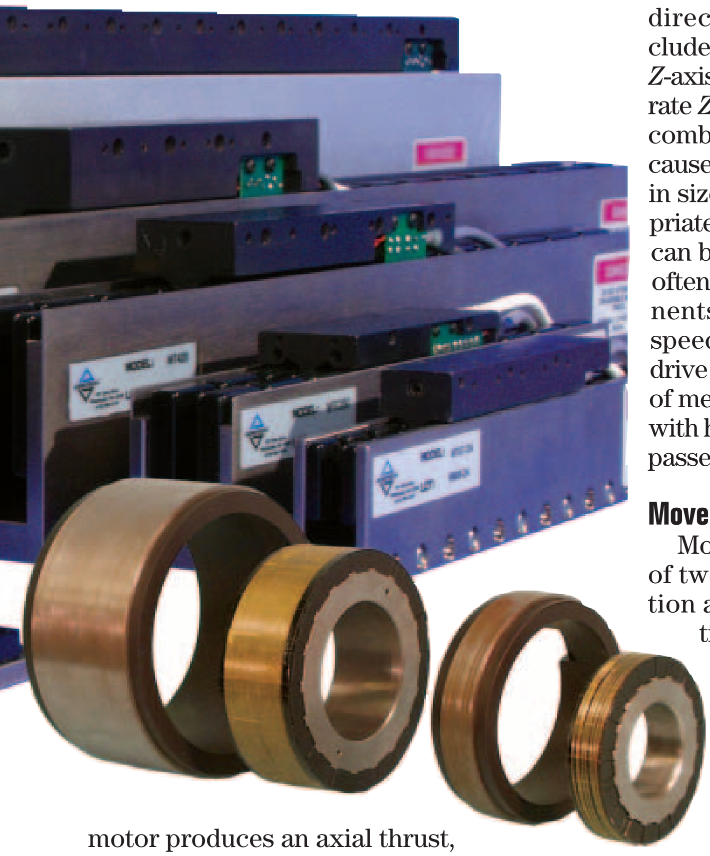
Brushless linear motors come in a wide variety of displacements and force ratings, while brushless torque motors host numerous rotational torque ratings. Because these motors use direct drive, they have virtually no friction and provide an extremely stiff mechanical system.

## Advances in Positioning and Motion Control

A significant advance in precision motion control is brushless direct-drive motors. They include both linear motors and direct-drive rotary motors. In operation, a series of motor coils interacts with a high-flux magnetic field array to produce the desired motion. The linear




**Direct drive linear stages (top left) including units with an attached rotary stage (bottom right), are easily combined into five and six-axis machines. Those for medical applications are typically small, and need to be precisely matched to part sizes.**



motor produces an axial thrust, while the rotary motor provides torque.

One critical consideration is that these motor elements are incorporated into the body of the linear stage or rotary stage, eliminating mechanically complicated drive mechanisms. This arrangement provides a stiff electromechanical system. Because these devices have no contacting elements, they have no inherent friction. This lets a direct drive produce extremely precise steps on the nanometer or sub-arc-second level, and provide exceptionally fine velocity regulation.

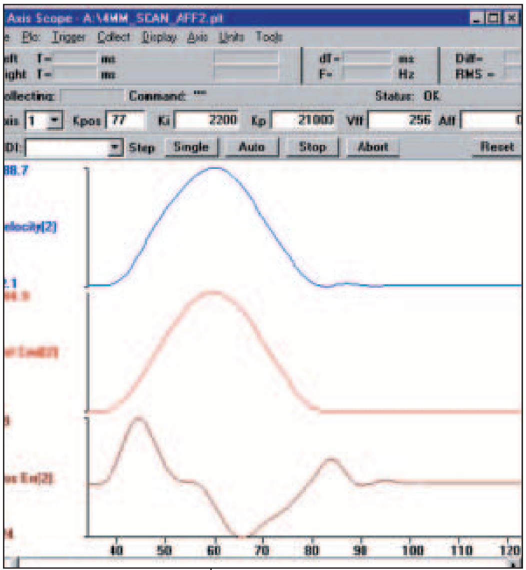
Examples of linear and rotary stages using direct-drive technology include *XY* linears with a separate *Z*-axis, and *X*-Theta axes with a separate *Z* for beam focus. Axes can be easily combined into five and six-axis machines. Because most medical devices are relatively small in size and weight, the staging must be appropriately matched in proportion to part size. This can be contrasted with machine tools that are often used in the production of medical components. The combination of high processing speed via appropriate laser selection, direct-drive motion technology, and optimized sizing of mechanics provides an automation platform with high accuracy and repeatability and unsurpassed part production.

## Move Profiles

Move profiles for part manipulation consist of two general categories: point-to-point motion and multi-axis contouring. For applications requiring point-to-point moves, high acceleration and high servosystem bandwidth are required. Direct-drive stages can reach servosystem crossover frequencies in the 50 to 150 Hz range, depending on payload and travel requirements.

Contouring applications require high-velocity regulation and high-servosystem bandwidth. Frequently, the contouring involves small circles and arcs with a further requirement for high acceleration. An example circular profile using an *XY* stage set with a 75-lb payload contours at a feedrate of 250 mm/sec. Contouring feedrates of 10 to 25 in/min are typical for *X*-Theta systems articulating small parts. At these rates, laser-processing considerations are usually limiting.

Motion controllers that operate these systems have full CNC capability and G-code programming capability. Most part geometries




**Point-to-point motion and multi-axis contouring moves require high acceleration and bandwidth capability. Move and settle plots such as these can be used to calibrate and monitor positioning accuracy.**

are complex and are generated in 2D or 3D CAD models. CAD/CAM software converts these geometries into G-code parts programs. Two additional controller features are necessary for successful system design and operation: multi-block look-ahead, and laser power control and synchronization.

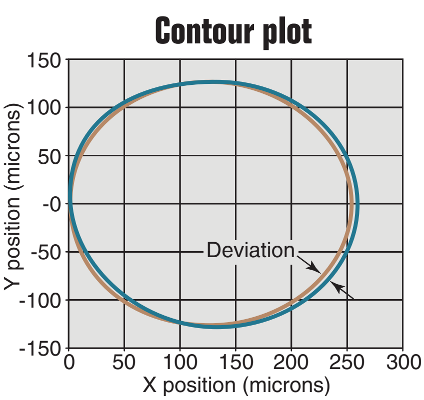
Multi-block look-ahead is the process of examining future blocks of CNC program lines, while executing a contoured move, for information on the next contoured moves. The controller can then take appropriate action in anticipation of these moves. For example, the controller can decelerate motion over blocks of program lines while executing linear moves, to the velocity required for a small radius circular move. After completing the circular move, motion at the previous velocity automatically resumes.

Most motion controllers are capable only of single block look-ahead. Multi-block look-ahead greatly simplifies parts programming by establishing attainable feedrates and accelerations for all moves. An operator does not need to predetermine a feedrate for each line of code.

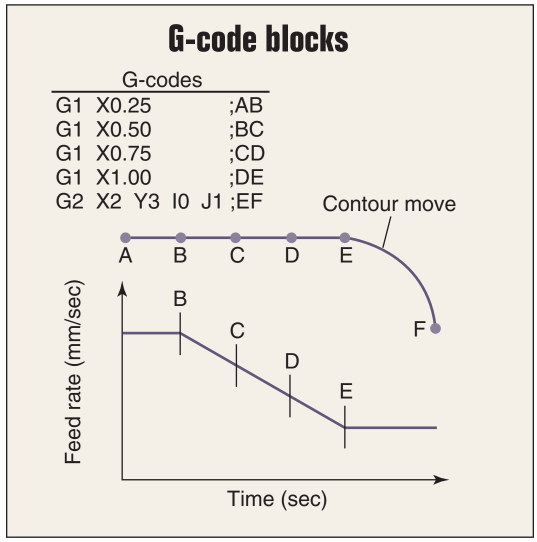
## Controlling Laser Power

Why control laser power? It ensures proper power is provided for the required process. For example, cut kerf and weld width depend on speed and laser power. There are many ways to control laser power, and they can be easily accomplished by linking the laser power control to the axes of motion. This can be referred to as Position Synchronized Output (PSO).

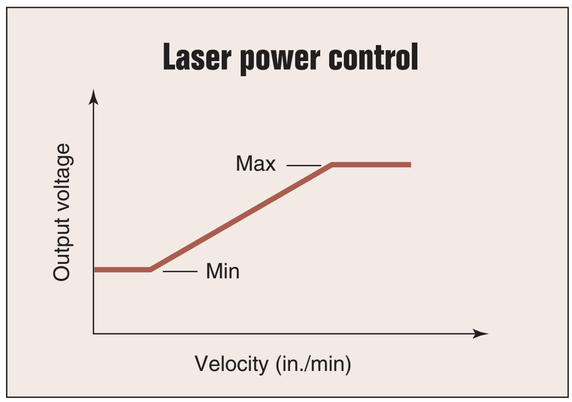
The PSO provides on-the-fly synchronization of a laser's pulse and power outputs with the motions of a positioning system controlled by an appropriately equipped controller. This means that the outputs of the PSO are precisely linked to the axis motion/servocontrol card.




**Plots of circular motion that show micron deviations from an absolute circle realistically determine the system's contouring accuracy.**




**CNC program lines are contained in blocks of G code for describing contouring moves. The controller can look ahead one or more blocks to adjust the acceleration and velocity and ensure the most accurate move for a stage.**




**Laser power output is linked to the axes of motion to control the cut kerf and weld width. This technique is called Position Synchronized Output, PSO.**

Several output modes are possible with the PSO. These include fixed pulse, ramped pulse, array-based, bit mapping, multiple pulse-at-position, and others.

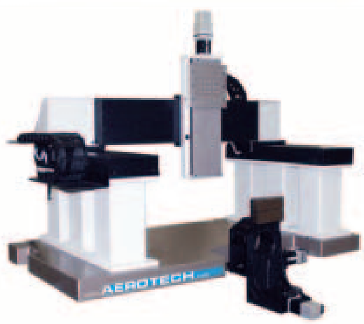
Using advanced, high-speed, digital signal processing technology, the PSO can acquire and analyze the positions of up to four axes at a maximum input frequency of 5 MHz. The PSO can also vector-process two or three axes to provide laser control that is precisely synchronized with two or three-dimensional contoured motions. All of this is done in hardware and therefore is faster than background tasking such as polling, and does not impact motion, such as block processing. This is an extremely versatile and powerful tool for laser process applications. ■

# Why Do The World's Leading Medical Device Manufacturers Use Aerotech Motion Systems?


- **Exceptional ability to maintain tight tolerances on small features.**
- **Adaptive velocity control to minimize acceleration in small diameter arcs and circles.**
- **Integrated high-speed laser control based on position or velocity feedback.**
- **High-speed, high acceleration linear and rotary direct-drive stages.**
- **Component to highly integrated system level solutions.**
- **Suitable for metallic, ceramic, and composite material processing.**
- **Completely sealed stages to protect bearings and linear encoder from contamination.**
- **Field-proven in hundreds of applications worldwide in continuous 24/7 operation.**

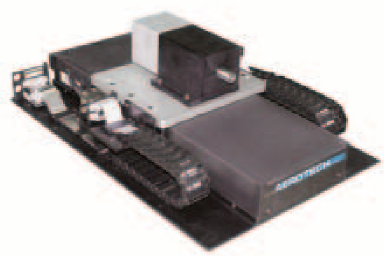
**Clean room compatible, FDA compliant systems**

*Two-axis aspheric and spherical CNC lathe for IOL/contact lens fabrication*



*5-axis precision laser cutting & welding station*


*Low profile, ultra-smooth velocity, direct-drive rotary actuator with 50 mm clear aperture*



*High throughput cylindrical laser cutting system*

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