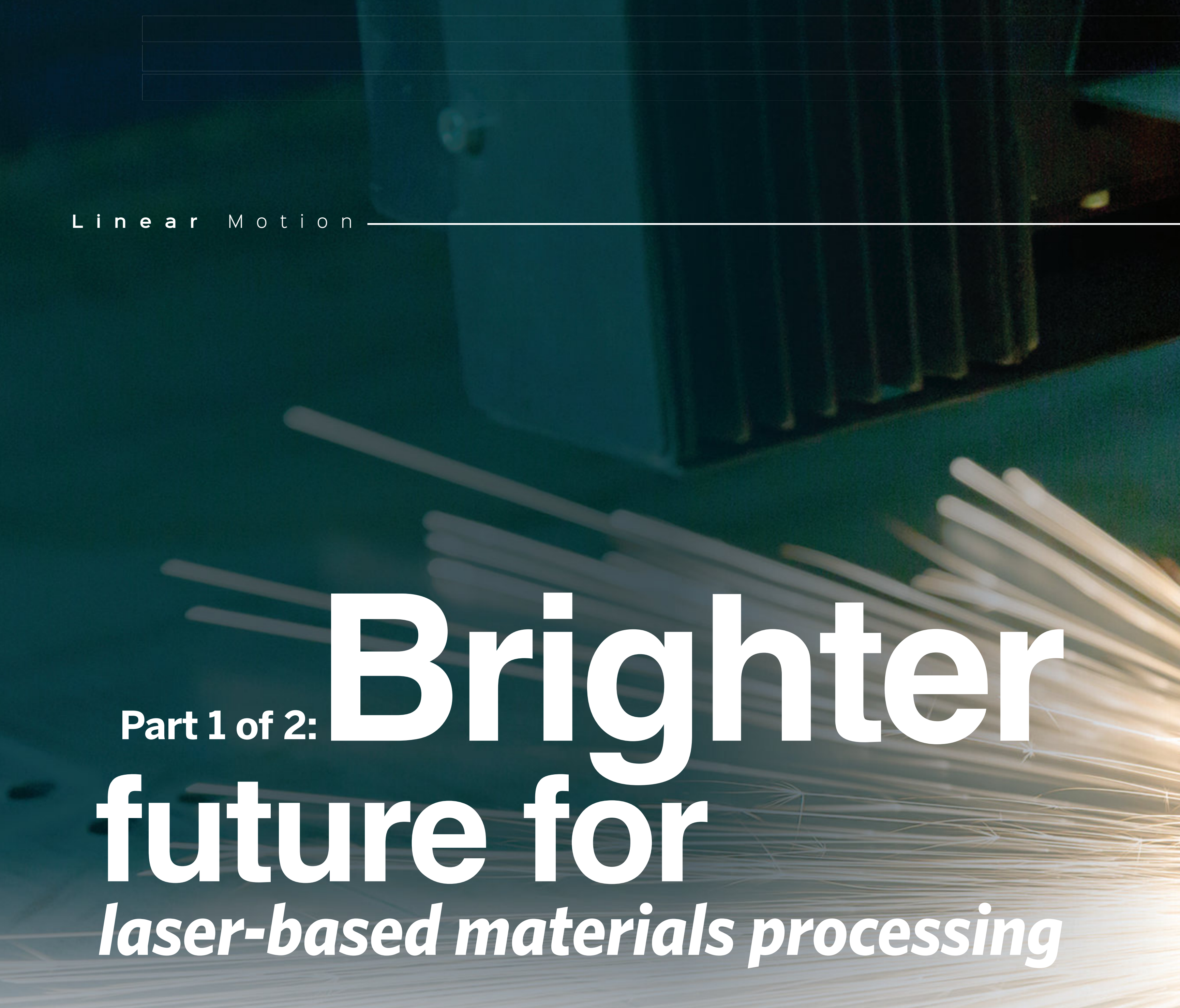

Part 1 of 2: Brighter future for *laser-based materials processing*

New modular controllers offer flexible solutions for linking a laser to multi-axis positioning, making it easier for system integrators to design and build advanced systems for a new age of laser applications.

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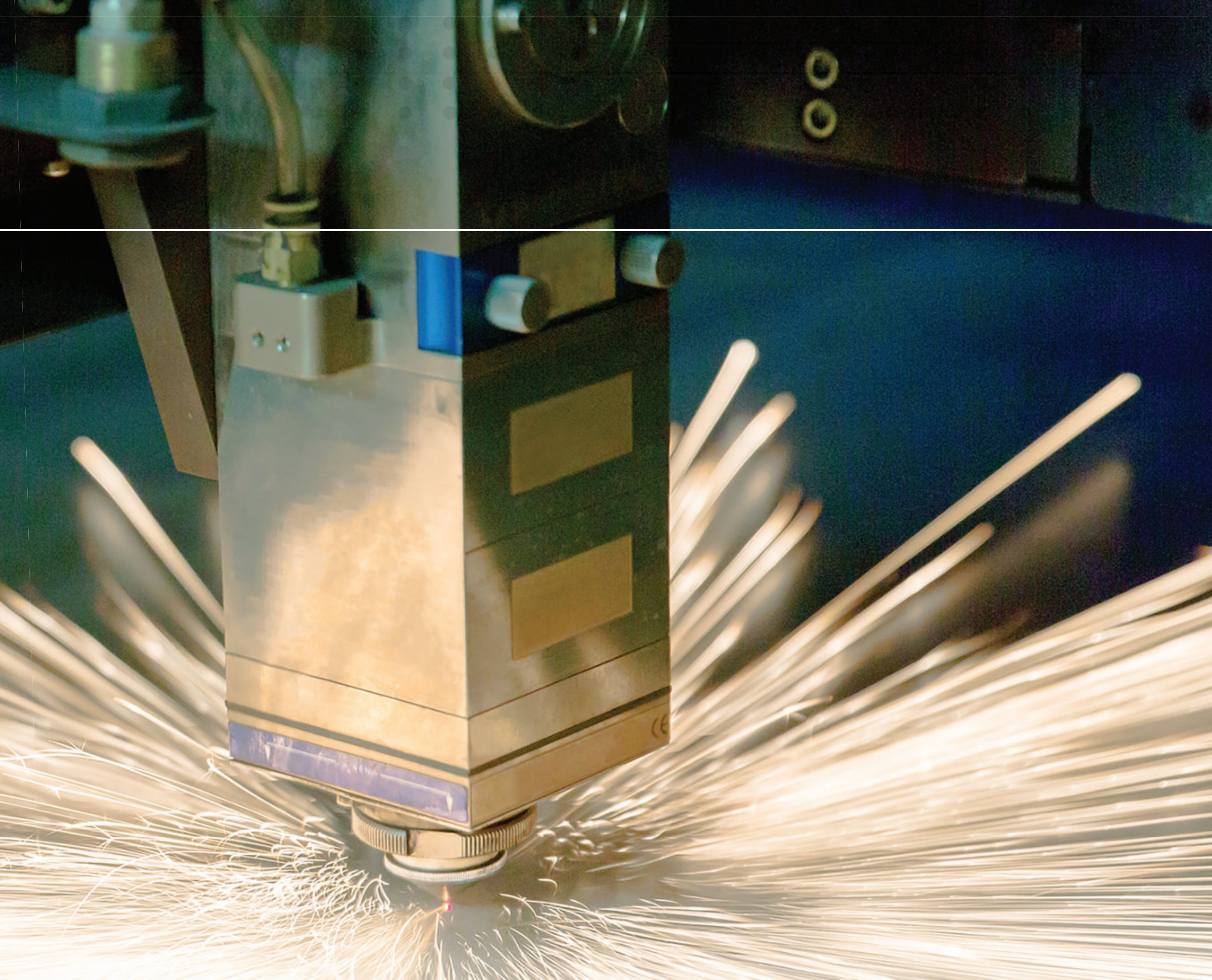
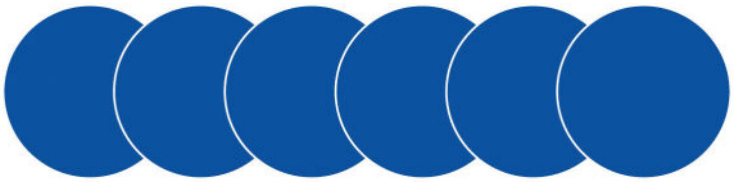


Lasers have been used for welding and cutting applications in materials processing for years. However, laser technology has frequently been considered a specialist area, requiring complex control systems for accurate positioning, as well as significant investment and expertise. Recently, the cost of lasers has decreased, opening them up to new applications; even the latest extremely fast ultrashort pulse lasers are now feasible options for machine builders who would typically have used less risky laser setups.

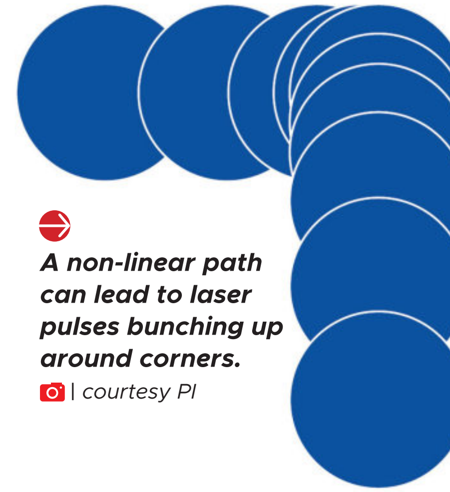
The commoditization of lasers means that system integrators must do more to gain and maintain an advantage, and that positioning and control – as integral parts of any laser system – are important elements of this. The newer technologies work in a slightly different way, so it makes sense that positioning and control also need to be different. The basic ability to fire the laser in the right place has become more challenging, and a simpler approach is even more important than ever, especially for those who are completely new to the technology.

Novel solutions are now available that take a uniquely modular approach to laser control, making it far easier and faster for system integrators to design and build systems in the first place, whether or not they have previous experience of lasers. The use of industrial control networks such as EtherCAT makes this modular solution even more flexible, as other items – such as sensors, or non-motion devices – can be easily incorporated.



Laser pulse placement during a constant speed profile. *| courtesy PI*

An example of a non-uniform laser pulse delivery. *| courtesy PI*



A non-linear path can lead to laser pulses bunching up around corners. *| courtesy PI*

Why choose laser processing?

There are many significant advantages to using lasers instead of traditional machining processes, not least is their capacity for much higher throughputs. Lasers are not susceptible to the same wear and tear that can lead to breakdown disruption and costs in mechanical components, and are often efficient at processing materials that are otherwise notoriously difficult to deal with. The fine beams of lasers also give a level of detail and accuracy that is near impossible to create using other methods, which is ideal for applications such as those generating high aspect ratio holes or other features requiring similar high precision.

High intensity short pulse lasers, in particular, are incredibly precise. The low thermal energy deposition around the beam of these lasers means there is negligible damage to the surrounding areas. Lasers can even process below the surface of a material, depending on where the beam focuses, examples of which can be commonly found in microelectronics devices, such as light-emitting diodes and flexible displays.

Striking the right balance of speed, power and precision

Whatever the application, fast shuttering and accurate firing of laser pulses is essential to ensure consistent, high-quality processing. Precise placement and energy control are crucial here and can be achieved by linking the automation and motion system directly to the laser output. It's extremely important to be able to make sure that the laser is focused on the right place, for the right amount of time, and delivering the right level of power in order to prevent damage to the material or the production of inaccurate parts.

One option is to link laser power to pulse rate and modulation. If the power is fixed, then the motion system will need to run at a constant speed to ensure that the correct level is delivered across the surface. This suits some operations, such as raster scans where the laser is fired following motion in one direction, or during the constant velocity phase between acceleration and deceleration phases. However, cutting and welding applications may also need the laser pulses to overlap at a consistent ratio, even when the motion path speed is not constant, and laser pulses occur at a fixed frequency. This could result in a non-uniform pulse delivery, where too much energy to a particular area could create HAZ (heat affected zones), and too little could cause weak regions or breaks in the cut or weld path.

The problem of HAZ occurs even more frequently with multi-axis systems, simply because of the nonlinear path of corners or arcs. The best analogy is that of a sports car driving around a racing track – when it gets to a corner, it must slow down, otherwise it wouldn't be able to follow the racing line and would probably run off the track; the same is true for an XY table. However, if the motion path slows down too much but the laser pulsing rate remains constant, too much power is delivered into the corners as the laser pulses bunch up. Some G-code capable CNC machines have look-ahead capabilities to address this, allowing the motion controller to look for changes in speed that exceed predetermined limits.

Linking laser control to speed and position

One of the simplest methods of controlling laser power is to link it to the velocity of the motion path. This can be simply achieved by linking an analog output in the controller to that of the vector speed of the motion path, and linking this to the laser power. The analog output is connected to the power input connection on the laser, for example, a 0-10 Vdc range.

Typically, the motion controller will let users define a scaling factor so that the maximum output is relative to the maximum power of the laser required for the process – a lower limit may also be set. It's important to remember that if the motion is badly tuned, jerks may result in bad processing. Poor placement accuracy could also create a bad quality part. This is a simple but effective process, for example, in welding.

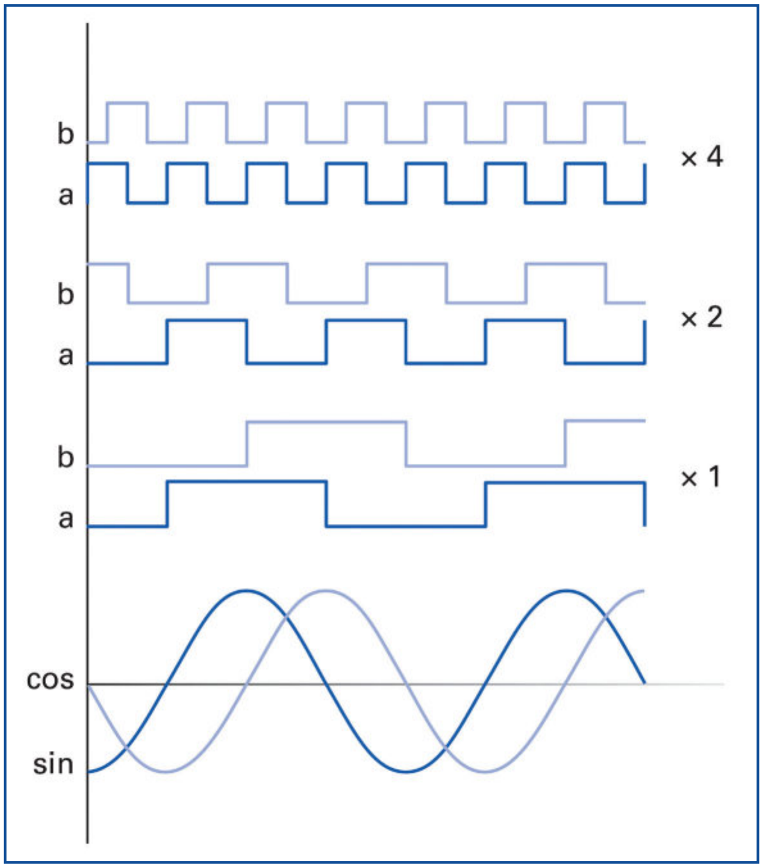
Another approach is to precisely control the laser by pulse placement along the motion path, regardless of the vector velocity. It's also possible to combine these two methods to control scaling of the power output, which overcomes undesired features of the laser electronics or optic path.

There are several technologies available in the industry that can generate such accurate, high-speed, position-based events linked to electronic outputs; for example, laser pulses. Although subtly different from each other, they essentially do the same thing for motion in a single axis. Some are better suited to galvo-technology, others are more aimed at motorized positioners. New developments such as modular controllers from Physik Instrumente's ACS Motion Control, Position Event Generation (PEG) is emerging as a solution for linking a laser to multi-axis positioning.

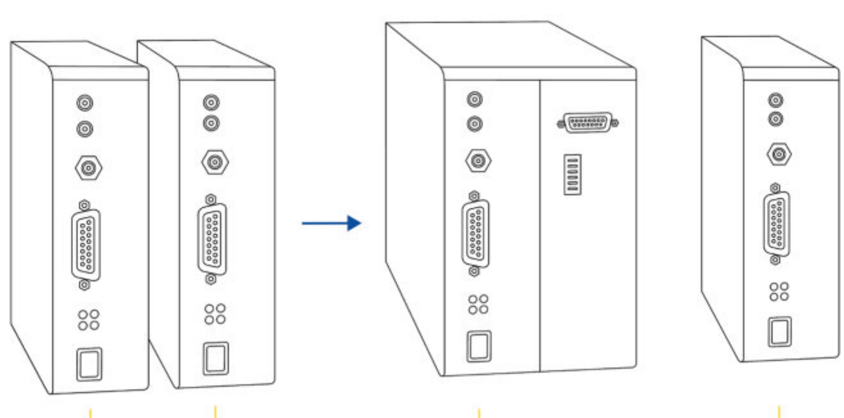
Challenges of controlling multiple axes

Paths that create three-dimensional trajectories can be created from three or more axes. Examples are simple dual-vector tracking – generated from two axes and widely used for linear XY table contouring, including circles or arcs and straight lines – a linear theta combination for processing tubing, or any combination of linear and rotary stages, for example, producing helical motion for drilling. Until recently, controlling the motion path for lasers across multiple axes has come with certain limitations relating to performance, speed, practicalities, and, not least, higher complexity and costs.

Many of the drives available for precision motion and laser processing have to be predefined, depending



Sine wave encoder subdivision (encoder multiplication). | *courtesy PI*



Because laser processing adds hardware requirements to a system, designers may need to replace the original drive with a larger, more complex one.
| *courtesy PI*

on the feedback device used on the stages or the table used in the motion system. Positional feedback means a device that is capable of reading the stage's position, but also allows the controller to calculate the speed of such a device. Some motion stages do not use any feedback; they rely on the principle that the commanded motion request equals the actual response. Typically, feedback systems are either incremental or absolute – incremental encoders require a reference point or known position when the system starts up, often a homing switch. In comparison, an absolute encoder system has the positional data built into the feedback measurement scale. This positional data is available at startup and therefore removes the step of physically moving the system to a reference device.

There are two types of incremental encoders; square wave or sinusoidal (sin/cos wave). Square wave encoders provide the system with discrete digital steps of a fixed distance. For example, a square wave encoder on a rotary motor may output 1,000 steps per revolution; if the rotary motor was driving a 1-mm pitch screw, the system resolution would be 1 mm/1,000, i.e. a 1 µm resolution. A potential problem with a square wave encoder is when it has a high-count output to obtain resolution, and the system also requires high speed. The output frequency could potentially exceed the maximum frequency input of the controller's feedback circuit, resulting in position loss.

Sine wave encoders are able to provide much higher resolution with higher stage speeds because the controller inputs the data at the fundamental frequency of the encoder, which is much lower than the square wave equivalent. The controller feedback circuit internally subdivides the sine wave into digital steps to produce the internal digital steps; this process is called multiplication.

In practice, a square wave encoder may start out as a sinusoidal encoder, and the key difference is where the digitization or multiplication takes place – at the feedback device in the case of a square wave or in the controller.

However, many laser firing controllers unfortunately cannot use sinusoidal feedback to produce an output that will trigger the laser – their electronics require digital square wave signals – and this may limit their usability to low-speed systems with high feedback resolutions or to high-speed systems with low feedback resolutions.

Multiple feedback in multi-axis systems

Laser synchronizing technologies use encoder data for single axis path motion to trigger, for example, one-to-one firing so that there is a single laser pulse with every millimeter or micron moved. When it comes to multi-axis, for example, pulsing in a circle, the same principle can be applied – data is taken from the individual encoders of each axis and fed into on-board electronics hardware, where the combined vector output is calculated. This has been the accepted norm for many years and, in theory, its accuracy comes from the fact that it is based on real-time positional information from the encoders. However, in reality, if the motion system is not adequate in performance, then this approach will produce poor results. For example, a constant speed circle on an XY table is made up of sinusoidal changes in velocity for each axis. A change in velocity means there must be an acceleration associated with the motion. Acceleration is directly proportional to following error (the difference between the commanded path and the actual path). Therefore, the path will always deviate from what was commanded, and it is the user's responsibility to ensure the error is below the threshold for the required accuracy. The path may be longer or shorter because of the deviation, which would mean the laser pulsing could be activated at incorrect positions.

Additionally, the electronic circuitry used for processing multiple feedback devices, and creating the output vector used for firing, can result in a significant delay (latency) to the output; the more encoders that are tracked, the more dramatically the speed of the output reduces, consequently the data input rate (tracking) of each feedback is reduced.

Firing hardware that requires encoder data obviously cannot be used to generate events for motors that have no feedback; for example, stepper motors. Similarly, they're not appropriate for serial communication-based absolute encoders. These encoders do not need to be homed when they start up, which can be a significant advantage with regard to safety and convenience for some advanced systems. Kinematic systems like hexapods are also challenging – the encoder data is not directly linked to the position or motion in a parallel direction, or may be a combination of data from multiple axes that requires calculation, and so does not generate direct triggering for paths in Cartesian coordinates.

There are few automation controllers on the market that can handle this level of complexity to ensure that the motion system not only has the correct motion performance, but also the ability to read in and trigger out the encoders used for these applications. With this in mind, users should consider pulsing strategies that do not rely solely on direct feedback.

New developments such as Physik Instrumente's ACS Laser Control Module (LCM) offers designers a different way to construct motion systems based on the EtherCAT industrial network. | *courtesy PI*

Whichever method is chosen, the machine builder should always consider the motion performance of the mechanics and controller. Motion systems have other system issues, such as resonances, low bandwidth, under-powered motors, or mechanical inadequacies (accuracy, roll, pitch, yaw, flatness, straightness, and stacking areas) that need to be appropriately matched to the system requirements so that the work piece or the laser head is in the right place when firing occurs.

The drawbacks of repurposing drive systems

Laser processing puts additional hardware requirements onto an automation system and the system designer needs to be aware of the input and output needs of connecting a laser to a controller. In theory, every time a system integrator designs a new system with advanced laser control abilities, they must take the input/output capability of the master controller or the master drive unit into consideration. This is frustrating because the focus shifts from the servo performance required to the laser connection functionality. Typically, the machine builder has to literally rebuild the entire control system to take account of these additional requirements. This may involve replacing the first drive unit with a physically larger, much more complex, and more expensive drive that combines such capabilities. This can have a significant impact on cost, including time for redesigning the system, additional hardware, stock of spare parts, and larger electrical cabinets. DW

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Part 2 of the series (in the July issue of Design World) looks at the benefits of modular control for laser processing.