Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

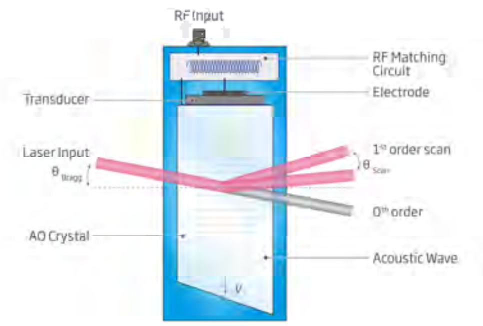
THE EVOLUTION OF ULTRAFAST, ULTRA-PRECISE BEAM STEERING TECHNIQUES FOR MICRO-MATERIAL PROCESSING

ARRON CAMPI, ACOUSTO-OPTIC PRODUCT MANAGER

High-precision steering of femtosecond laser beams with acousto-optical deflectors and a dual-axis driver delivers the fastest processing possible for micro-material and microelectronics manufacturers.

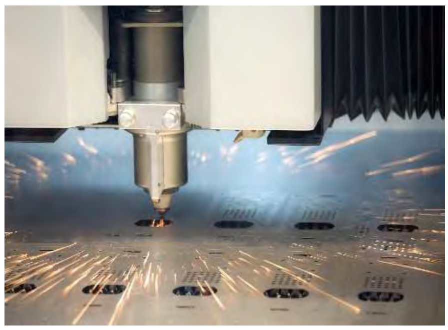
Manufacturers must consider a complex interplay of numerous factors when designing micro-material processing equipment. At the simplest level, the end game often comes down to extremely accurate positioning of lasers for cutting, drilling, scribing, or marking at the highest rate possible. For integrated circuits currently used in smartphones, tablets, wearables, and Internet of Things (IoT) devices, the beam steering accuracies required can be staggering: processing equipment must be able to drill microvias and scribe trenches less than 10 µm in size. Spot placement for laser processing of microelectronics requires accuracy in the range of only a few microns with little or no heat affected zone (HAZ). In addition, display manufacturers must accurately place and repair pixel circuitry at ever shrinking resolutions on ever larger substrates, requiring advance tooling to avoid significant increases in processing time and costs.

Historically, industrial systems used for microelectronics and micro-material processing have incorporated linear stages to move a large substrate, which may be glass, silicon, printed circuit board (PCB), or another material, under the laser beam. As the requirements for ever smaller spot sizes and more accurate placement increased along with laser pulse rates, tool makers incorporated a pair of mirrors on galvanometers (galvos) to steer the laser beam in the *x* and *y* dimensions. However, galvos are ultimately mechanically limited by the mass of the mirror and the speed of the servo. As a result, when laser pulse rates exceed 1 MHz, galvos struggle to keep up and maintain spot placement accuracy. "Random" access becomes particularly difficult due to the linear motion of the mirror.



Acousto-optic beam deflector schematic

With the introduction of ultrafast pulse lasers and pulse rates of 1 to 5 MHz in recent years, the addition of acousto-optical deflectors (AODFs) paired with galvos has enabled quicker and more accurate beam steering. An AODF uses a crystal and transducer at RF frequencies to create compression waves that act like a grating to diffract the laser beam. Varying the RF frequency of those compression waves is equivalent to changing the pitch of the grating. In micro-material processing the angle changes rapidly, redirecting the pulse in under a microsecond. However, AODFs add incremental cost to the system, and have a limited angle of deflection, 'swinging' over a much smaller arc (4 – 30 mrad). Additionally, the intrinsic advantage of speed and accuracy gained with an AODF requires a high performance RF driver and a high-speed interface to define the signal frequency, delivered laser power (amplitude), and even phase. In many applications the incremental cost and complexity provided is fully justified by the otherwise unachievable improvement in performance of the tool.



Lasers provide speed and precision in material processing

Femtosecond laser pulse repetition rates of 5 to 10 MHz are now available that can accommodate spot sizes of less than 10 µm; as they decrease in cost, production equipment vendors are increasingly incorporating these lasers into new tool designs.

The high peak pulse energy of pico- and femtosecond lasers leads to ablation at the laser's wavelength, which may be IR, Visible or UV. Ablation causes the excess material to sublimate, a neat solution that eliminates post-processing and improves depth control.

Some vendors choose ultraviolet (UV) lasers for their superior ability to reduce spot size and HAZ. For example, the Gooch & Housego 4200 series of AODFs is optimized for precision control of a UV laser beam. This product has a 210 MHz center frequency, RF bandwidth of 130 MHz, and a diffraction efficiency of 83% typical over a full 30 mrad scan angle. It is now being used by a number of OEM manufacturers for their latest micro-electronic processing tools.

G&H UV acousto-optic beam deflector

For an X-Y beam steering system a pair of AODFs are needed – one for each axis. It is important that the timing between the controllers directing each device is tightly synchronized. Recently Gooch & Housego began shipping the acousto-optical deflector (AODF) Dual Driver, which enables independent control of two AODs at once with a single driver system. The AODF Dual Driver replaces two drivers and their corresponding amplifiers with a single device consisting of two independent 15 W RF output channels and dual fast parallel interfaces that can simultaneously steer two beams with sequential or preloaded fabrication patterns. Thus, the AODF Dual Driver can accomplish twice as much as a single RF driver with reduced power consumption, footprint and cost.

The AODF Dual Driver is offered in three band ranges (20 to 150 MHz, 40 to 245 MHz, or 140 to 450 MHz). By default the driver operates in stand-alone mode controlled by the high speed parallel interface. Additionally a host PC can control the device through a USB interface and a simple command set, enabling control and optimization of different capabilities based on the specific requirements. Mux mode with phase control, for example, enables dual identical output signals dynamically shifted in phase for controlling a two element phased array AODF. Waveforms can be preloaded and played back at full speed to execute a desired ablation pattern.

G&H RF Dual Driver

The Multiple Tones configuration enables each channel to independently generate several unique tones with individually defined amplitude and phase to effectively split a single input beam into multiple beams. These pre-programmed configurations deliver versatility in a simplified system architecture with reduced BOM cost.

Acousto-optical deflector devices have been available for over thirty years. Recent advancements in laser pulse energy and rep rates above 1 MHz have created a need for precision beam control at high speed. Our AODF devices are well suited for this application. The speed and functional re-configurability of our new AODF Dual Driver is the next-generation solution for controlling AODF devices in ultra-high-performance, high-precision OEM applications, including via drilling, micro-machining systems, and optical inspection systems.

When considering the overall value of purchasing versus building your own complex beam-steering solution, the in-house expertise of a manufacturer can be a great resource. Look for a one-stop shop with technical experts who can advise you on the entire range of system components, with respect to critical details like laser type (wavelength, pulse duration, beam shape) and material properties (thermal, mechanical and optical). Building reliable and high-quality AODF beam-steering systems requires mastery of crystal polishing, coatings and transducers, as well as a focus on superior engineering and manufacturing finesse. Gooch & Housego, a global leader in its field, offers these capabilities as well as experience in researching, designing, and manufacturing of advanced photonic systems, components and instrumentation for applications in aerospace & defense, industrial, life sciences and scientific research.

For more information

Visit the AO product section of our website or
contact Aaron Campi at paloaltosales@goochandhousego.com

goochandhousego.com