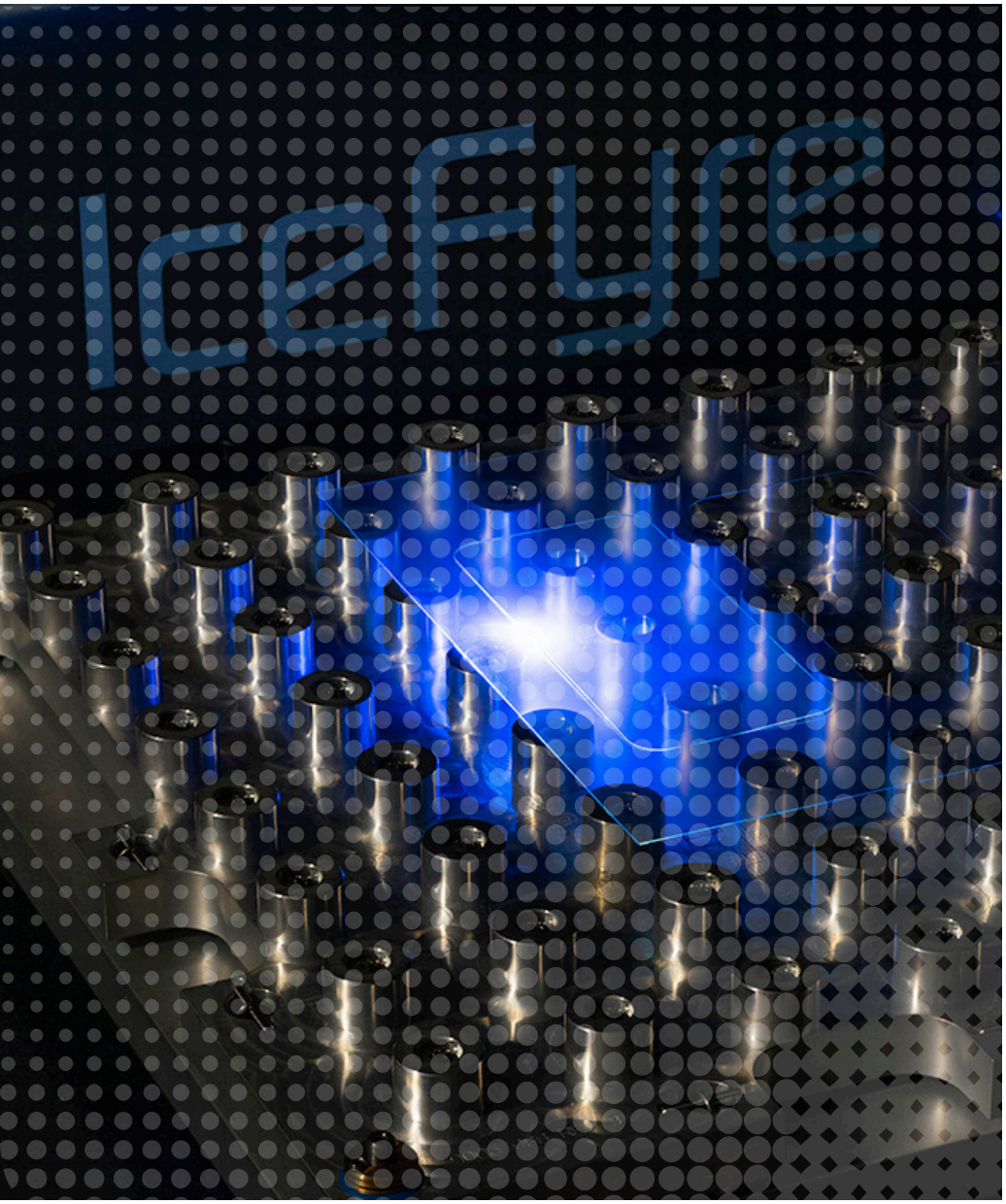
TRANSFORMING OLED PANEL PROCESSING



UBIQUITOUS DIGITAL DISPLAYS OF ALL SHAPES AND SIZES

A massive digital transformation of practically every aspect of our lives is underway. Perhaps the most visible evidence of this transformation is the sight of digital displays of all shapes and sizes in our TVs, public signage, automobile interiors, mobile phones, wearable devices, AR/VR systems and so many other facets of society.

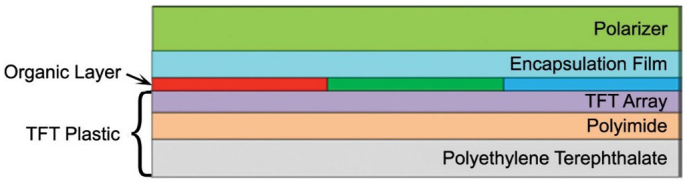
Organic Light Emitting Diode (OLED) is a leading technology for digital displays. Compared to conventional LCD displays, OLED displays offer the following advantages:

- higher contrast
- higher dynamic range
- less power consumption
- broader viewing angles
- faster refresh rate
- thinner, lighter, more flexible form factors

With these features, OLED displays are enabling the rapid digital transformation of society.

OLED Panel Processing Challenges

OLED displays are comprised of multiple layers of polymer materials—including polyimide (PI) and polyethylene terephthalate (PET)—and organic material films, with each layer varying in thickness. The displays can be rigid type, where the OLED stack is on a glass substrate, flexible type with the OLED stack on a polymer substrate, or foldable type. Therefore, the first challenge is to be able to selectively process specific materials and thicknesses.



Schematic representation of a flexible OLED structure

As displays become smaller, thinner, lighter and more foldable, processes such as cutting and drilling will require very high precision and accuracy, often on the order of microns. Moreover, advanced designs could also necessitate more flexible or complicated cutting and drilling patterns.

This leads to one conclusion: *Lasers provide the best and only solution for OLED panel processing*.

Yet not all lasers are the same. Some lasers may be able to cut and drill very quickly but produce a larger heat-affected zone (HAZ) and more thermal damage to the surrounding structure

than desired. This can result in more material being wasted, lower manufacturing yields and increased costs. HAZ can also cause an OLED polymer structure to become brittle, thereby increasing reliability risk. Moreover, poor quality cuts or drills could potentially lead to delamination.

Another factor is that certain lasers work well with some materials but not as well with others. As OLED displays are comprised of numerous materials having widely varying thermal, optical, and mechanical properties, selecting the optimal laser for both high-speed and high-quality machining is a critical task.

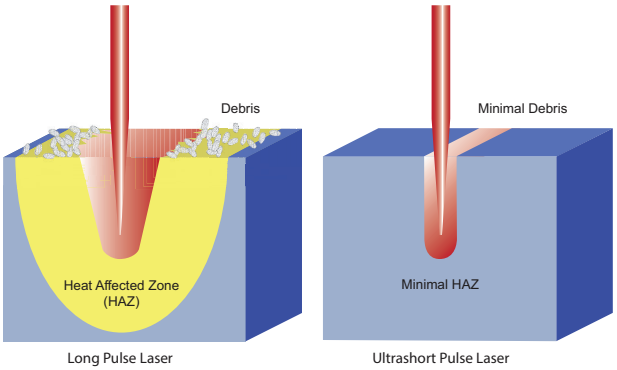
The MKS Advantage for OLED Panel Processing

MKS has a deep understanding of the challenges faced in designing and building OLED panels of all shapes and sizes. We've turned this knowledge into unique product features that provide an advantage when used in OLED panel processing. Some of these features are described here.

Ultrashort Pulse Lasers

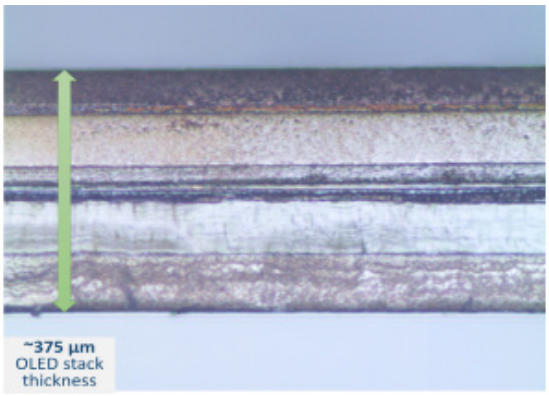
One of the challenges for laser materials processing—including cutting, drilling, repair, laser-lift-off (LLO) and scribing—is removing only the desired material, usually through localized heating, while at the same time minimizing the extent of the HAZ to any of the remaining material. Delivering laser irradiation with near-perfect beam quality precisely to the target region is a necessary step to achieving this desired result. Ultrashort pulse widths of picoseconds (ps) or even femtoseconds (fs) can be advantageous to achieving higher-quality results. Ultrashort pulses yield intense peak powers that result in nonlinear absorption at the sample for instantaneous material vaporization. Consequently, very minimal heat is transfered into the material for a negligible HAZ, which is necessary to avoid delamination. The result is a fast, high-precision, high-quality operation which leads to higher throughput and fewer part failures.

To cut film, lasers in the ps pulse width regime at UV and green wavelengths, such as the Spectra-Physics® IceFyre® Picosecond laser, may be suitable. But to achieve even higher quality results, lasers with fs pulse widths, like the Spectra-Physics IceFyre UV Femtosecond laser, can deliver extraordinary performance. And in addition to the benefits of ultrashort pulse durations, the short wavelength of UV lasers allows the pulses to be more readily absorbed by the diverse materials in an OLED stack and, with smaller focus spot sizes, enables cleaner, narrower cut widths. The low divergence of

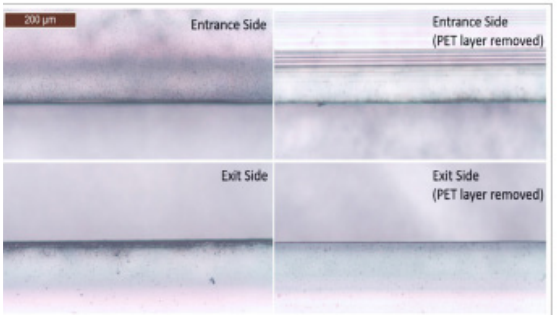


The impact of laser pulse width on machining quality for a long pulse ms laser (left) versus an ultrashort pulse laser (right).

focused UV beams is also helpful for cutting thicker OLED stacks without the need for extra passes to widen the cutting kerf. Engineers at MKS industrial applications lab have demonstrated the use of a fs laser for clean cutting of ~375-µm-thick, 6-in non-rigid OLED displays for mobile phones with a UV fs laser with an effective speed of ~133 mm/s and HAZ of just 5-10 µm.



Microscope images of a ~375-µm-thick OLED film stack cut with a Spectra-Physics IceFyre UV Femtosecond laser in multi-pass mode, resulting in a net (effective) cutting speed of ~133 mm/s and HAZ of 5-10 µm.



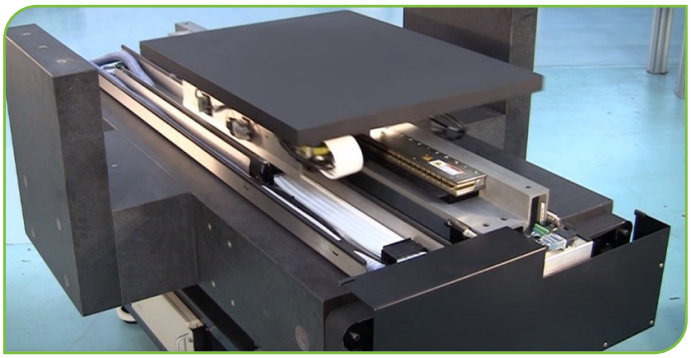
Cross-section microscope image of a ~375-µm-thick OLED film stack cut with a Spectra-Physics IceFyre UV femtosecond laser in multi-pass mode.

Other OLED panel processing applications that fs lasers excel at include repair and fine metal mask (FMM) drilling. Additionally, ps lasers can also be used for laser-lift-off (LLO), cutting glass (IR wavelengths only) and scribing/dicing thin silicon die wafers for the emerging area of µ-OLED panels.

High-Precision, High-Speed Industrial Grade Positioners

The target for a laser materials process—for instance, a sheet of OLED film stack to be cut into smaller pieces—will often have to be positioned for the laser to perform its operation. The positioning requirements for OLED panel processing can be extremely challenging. Accuracy in two dimensions is typically on the order of microns, as is the repeatability to ensure consistent results. To meet throughput demands, the required speed can be up to 1 meter/sec.

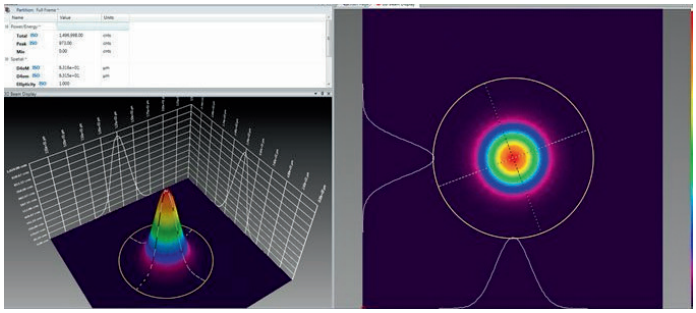
These performance requirements must be achievable in a demanding production environment. Thus, only high performing motorized positioners designed for continuous usage in industrial environments, like the Newport® HybrYX® air bearing positioners, should be considered.



Newport HybrYX G5 air bearing positioners are designed for high-performance positioning of large substrates including flat panel displays

Beam Analysis

Even with the advantages that lasers have over traditional tools, laser systems can still degrade over time. Some causes of degradation include thermal effects on a laser system's internal components, vibrations or shock and debris near the processing site. These issues could affect laser performance in a number of ways. First, output power may be reduced, causing the laser to be less efficient. Another problem that may be caused is a change in the focus or other profile of the beam, which may lead to a cut or drill to be off target, too deep, low quality or possibly damaging to another part of the material.



Beam profiling graphical user interface

Therefore, to ensure the highest quality of manufacturing OLED panels and to minimize the possibility of production down-time, it is crucial to monitor the laser beam frequently with appropriate instruments—like Ophir® power sensors, power meters and beam profilers—that can operate at the laser's wavelength while handling its maximum output power level.

MKS Products for OLED Panel Processing

MKS offers many products that are broadly utilized in OLED panel processing. For more information, please visit www.newport.com or call +1 877-835-9620.
Also, visit www.spectra-physics.com

Femtosecond UV and IR Lasers

The Spectra-Physics IceFyre fs laser family is an extraordinary leap forward in 24/7 industrial micromachining, delivering industry-leading performance, versatility, reliability and cost of ownership. They are ideal for high throughput, highest quality cutting of film for OLED panel processing. They can also be used for repair, and the UV version offers the best solution for FMM drilling. Based on Spectra-Physics' *It's in the Box*™ design, the laser and controller are integrated into a single, easy-to-install package.

- Up to >50 W (UV) and >200 W (IR) power
- Typical pulse widths <500 fs

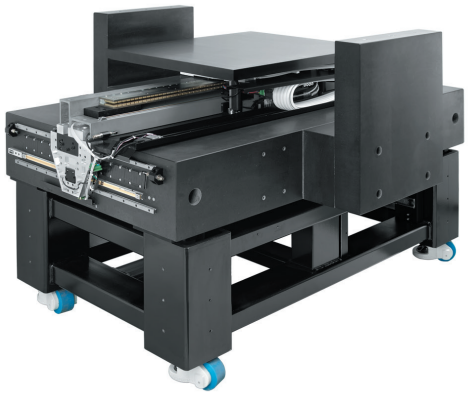
- Single shot to 3 MHz (UV) and 50 MHz (IR) repetition rate range
- Proprietary *TimeShift*™ technology for unprecedented pulse control

Picosecond UV, Green and IR Lasers

Sectra-Physics' IceFyre ps lasers set a new standard for ps micromachining. The UV and green versions enable premium quality film cutting and, for µ-OLED panels, thin silicon die wafer scribing/dicing. Additionally, the IceFyre ps UV laser is the best solution for LLO. And when cutting glass is required as part of the OLED panel manufacturing process, the IR version of the IceFyre ps laser provides unmatched performance. Like the IceFyre fs laser, the IceFyre ps laser is also based on Spectra-Physics' *It's in the Box*™ design, with the laser and controller integrated into a single, compact package for 24/7 industrial reliability.

- Up to >50 W power
- Typical pulse widths as small as 10 or 13 ps
- Single shot to 10 MHz repetition rate range
- Proprietary *TimeShift*™ technology for unprecedented pulse control

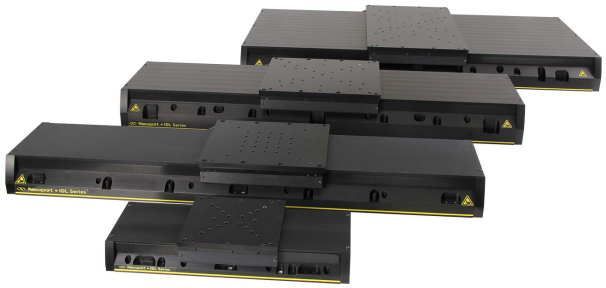
Air Bearing Positioning System



The Newport HybrYX is a high-throughput positioning system that can be customized for OLED panel processing. It combines the precision of a single plane air bearing carriage with the cost-effectiveness of mechanical bearings. The G5 version of this system features a larger carriage with higher air bearing load capacity for larger payloads. HybrYX delivers outstanding price-to-performance value for demanding, high duty cycle industrial OEM applications, including scanning applications requiring ultra-low velocity ripple and dynamic following error.

- 450 mm (X) and 1.4 m (Y) travel range
- 300 mm/sec (X) and 600 mm/sec (Y) speed
- 392 N max load capacity
- Micron level accuracy
- 0.1% speed stability

Industrial Grade Linear Positioners



For more traditional positioners, the Newport IDL-LM series are industrial-grade positioners with an ironless linear motor and recirculating ball bearings that offer the highest speed and load capacity of all linear motor stages. With an accuracy on the order of microns and sub-micron repeatability, these positioners are ideal for OLED panel processing. To further add to their design for production environments, all IDL-LM positioners feature a hard top cover, wear-resistant, flexible side bands, air purge and directed debris path.

- 100 mm to 1.2 m travel range
- 2 m/sec speed
- 450 to 2,000 N max load capacity
- Micron level accuracy and sub-micron repeatability
- Designed for the most rigorous demands of precision industrial laser microprocessing

Laser Thermal Power Sensors

MKS offers a comprehensive portfolio of Ophir laser thermal power sensors, several of which are capable of measuring the optical output power of short- and ultrashort-pulsed lasers such as IceFyre. These sensors have a very high damage threshold to withstand the high optical peak power delivered by each pulse. Ophir sensors and meters meet the ISO/IEC 17025 standard for calibrated devices.

- Spectral ranges from UV to mid-IR
- Power ranges up to a few hundred Watts
- Apertures from 16 to 30 mm diameter
- Response times of a few seconds or less
- Not water cooled

Virtual Power Meters

A sensor's output will have to be processed through a power meter. Another option is to use a PC as a laser measurement station. This can be accomplished by connecting the sensor to the Ophir Juno+ virtual power meter, which then connects to a PC via USB. This cost-effective approach also allows multiple power meters to be run on a single PC. To control and monitor a sensor remotely through the "cloud," the Ophir EA-1 Ethernet adapter allows that, as Telnet, HTTP and UDP protocols are supported. MKS user-friendly application software is included with features including extensive graphic displays of data, advanced measurement processing and data logging for future review.

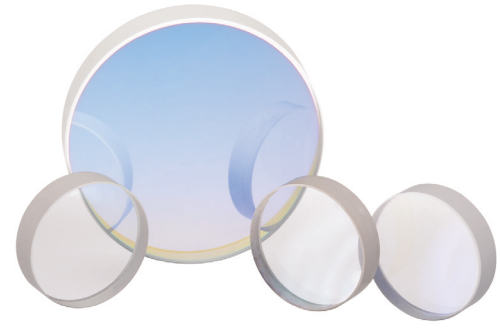
- Connect sensor to a PC via USB
- Connect sensor to the "cloud" – Telnet, HTTP and UDP supported
- Data logging
- User-friendly application software with extensive features included

Beam Profiling Cameras

An effective way to analyze beam profile is with a camera-based system. Ophir beam profiling cameras allow real-time viewing and measuring of a laser's structure in high resolution. Camera-based systems can also measure cross-sectional intensity of the laser and provide a complete 2-dimensional view of the laser mode.

- Spectral ranges from UV to mid-IR
- High-resolution, real-time viewing
- Highest accuracy measurements
- User-friendly application software with extensive analytical features included

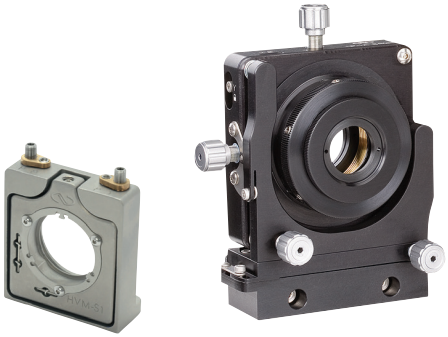
High-Energy Laser Optics



Dozens of Newport standard catalog optics are designed to operate with high-energy lasers such as those used in OLED panel processing. Mirrors, lenses, beamsplitter cubes and waveplates are readily available in various sizes and shapes whose substrate materials and coatings are optimized for UV, green and IR wavelengths. These high-performing optics are able to withstand laser fluences in the Joules and sometimes tens of Joules of pulsed energy per square centimeter to enable many solutions for OLED panel processing.

- Mirrors, lenses, beamsplitter cubes, waveplates
- Optimized for UV, Green and IR wavelengths
- Extensive ultrafast optics selection
- LIDT (Laser Induced Damage Threshold) of Joules and tens of Joules per cm^2
- Various sizes and shapes

Opto-Mechanical Components



Whenever optics are part of a laser system, they will have to be precisely positioned and steadily held over long periods of time. MKS offers the most comprehensive line of opto-mechanical components in the industry. Hundreds of optical mounts and positioners at various levels of performance and cost are readily available.

- Mirror mounts, lens positioners and other optical mounts
- Linear and rotary positioners
- Post and pedestal assemblies
- Stainless steel and aluminum

WHY MKS?

CRITICAL TECHNOLOGIES

World-class technology and development capabilities for leading-edge processes

PROVEN PARTNER

Recognized leader delivering innovative, reliable solutions for our customers' most complex problems

OPERATIONAL EXCELLENCE

Consistent execution across all aspects of our business

COMPREHENSIVE PORTFOLIO

Largest breadth of product and service solutions for the markets we serve

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Newport is a brand within the MKS Instruments Light & Motion division. The Newport product portfolio consists of a full range of solutions including precision motion control, optical tables and vibration isolation systems, photonic instruments, optics and opto-mechanical components. Our innovative Newport solutions leverage core expertise in vibration isolation and sub-micron positioning systems and opto-mechanical and photonics subsystems, to enhance our customers' capabilities and productivity in the semiconductor, industrial technologies, life and health sciences, research and defense markets.

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