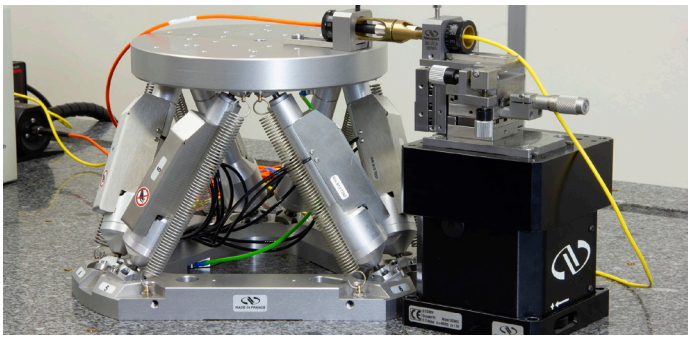
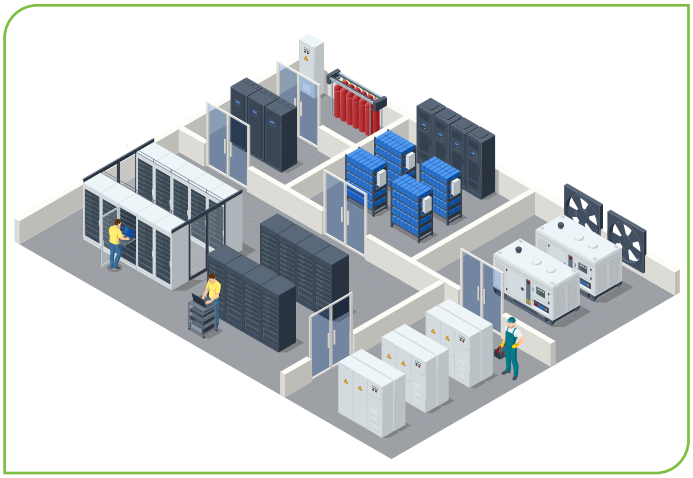
ELEVATING OPTICAL TRANSCEIVER MANUFACTURING
ENABLING THE AI REVOLUTION



ARTIFICIAL INTELLIGENCE BOOSTS DEMAND FOR OPTICAL TRANSCEIVERS

Artificial Intelligence (AI) is a technological revolution that is dramatically transforming society. But for all the promise AI brings, it also requires a massive infrastructure characterized by enormously increased data storage, continuously advancing computing capabilities, faster and expanded networking, and greater power consumption. This brochure will address a critical building block of the data centers that will support an AI-world: optical transceivers.

A data center is generally defined as a physical space, typically a building or group of buildings, which houses computing infrastructure such as servers, storage systems, routers, switches and transceivers. As its name implies, a data center stores data (and applications) but in addition, it also functions as a central point to efficiently process, access and distribute data securely. Large-facility data centers emerged with the rise of the Internet in the 1990s, mainly relying on electrical signals transmitted over copper wire. As the needs for data storage, processing and networking expanded, greater bandwidth and higher speed transmission was pursued, since copper wire can be limited in managing larger volumes of datacom. And as AI becomes more ubiquitous, the demands for bandwidth and speed will accelerate even further. Some extra factors that will multiply datacom requirements include the rollout of 5G, virtual and augmented reality, more autonomous vehicles, and the Internet of Things.



One way to surpass the limitations of copper wire, thereby expanding bandwidth and boosting speed, is by sending information over optical fiber in the form of pulses of light. Further benefits of this method include lower signal loss and no electromagnetic interference. In an optical fiber network, information managed by electronic devices must be converted to optical signals, sent over optical fiber, and then converted back to electrical signals on the receiving end for additional electronic devices to process.

Optical transceivers are the devices that convert electrical signals to optical signals, and vice versa, and serve to bridge the gap between electronic devices and fiber optic cables.

Optical Transceiver Manufacturing Challenges

Of the many tasks performed in designing and producing optical transceivers, MKS particularly excels in two critical processes. One is fiber alignment, where a transmitter (laser diode chip) and receiver (photodiode) must be aligned to ensure that maximum light is transmitted through the fiber or waveguide with minimal losses. This way, the transceiver can operate optimally. Fiber alignment can be quite a challenge, as alignment in three axes is typical, and sometimes up to six axes are necessary. Misalignment by only a few microns can result in significant injected power loss. As such, sub-micron movements and precision are standard, and motion control on the order of hundreds of nanometers is often required. In addition to such high-performance requirements, fiber alignment must be performed quickly to increase throughput and reduce processing costs. MKS has been a leader in providing motion control systems for high-throughput fiber alignment for decades.

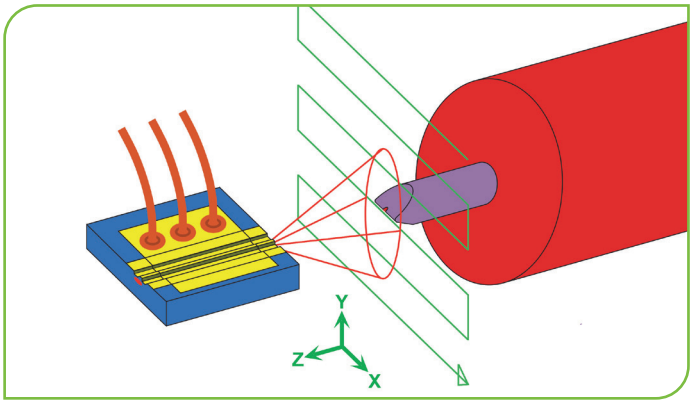
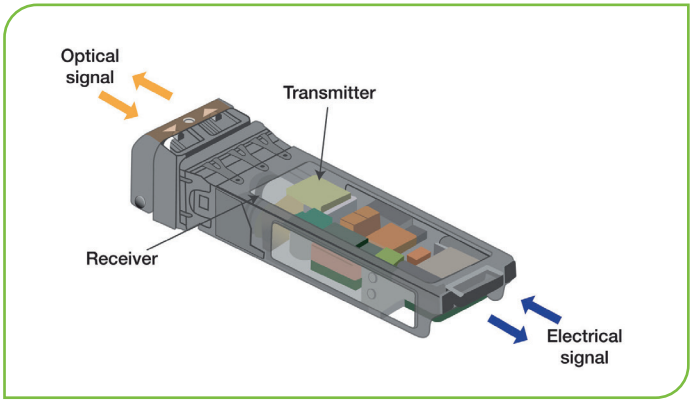
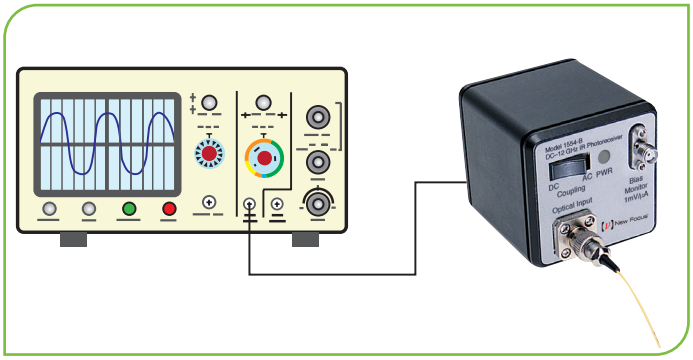


Illustration of coupling between laser diode and fiber

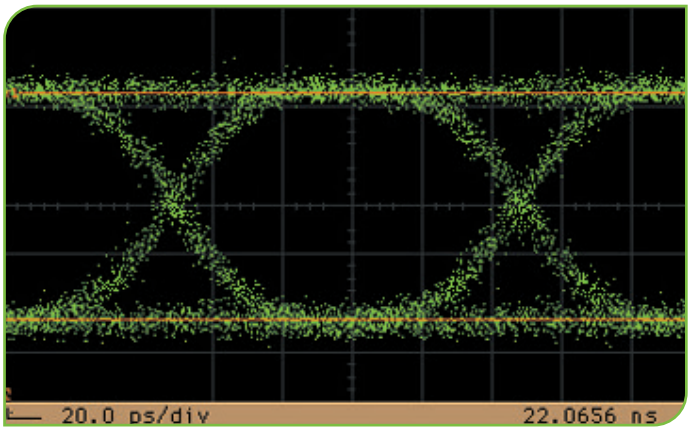
Another crucial task in optical transceiver manufacturing is testing and measurement in order to know if a component is performing properly. High-speed photodetectors and photoreceivers—which are the interface between optical transceivers and electronic instrumentation—are needed to convert optical signals to electrical signals so they may be analyzed with instruments such as oscilloscopes, network analyzers and spectrum analyzers. MKS offers the broadest range of testing and measurement products for optical transceivers, including custom OE (optical-to-electrical) converters that enable testing of 100 and 200 GB/lane transceivers.



Schematic of an example optical transceiver



High-speed photodetectors and photoreceivers serve as the front-end optical-to-electrical converters for many electronic instruments.



Example eye diagram

The MKS Advantage for Optical Transceiver Manufacturing

As a major player in fiber alignment during the telecom buildup of the late 1990s, MKS has a deep understanding of the challenges faced in designing and building optical transceivers. We've turned this knowledge into unique product features that provide an advantage when used in optical transceiver manufacturing. Some of these features are described here.

Nanometer Scale Positioners

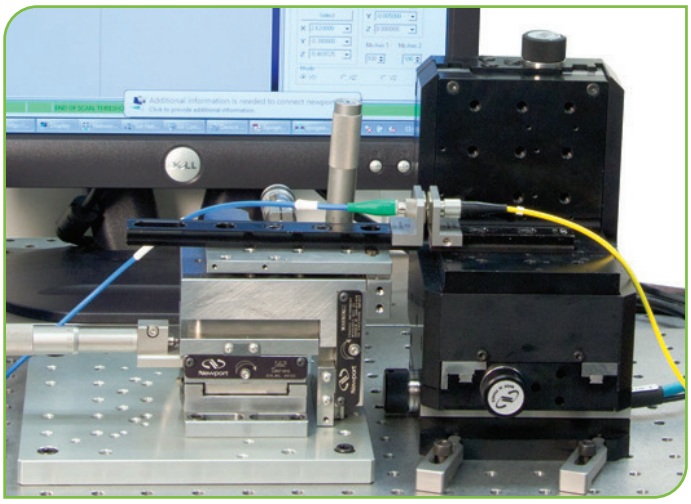
When using motion control systems for fiber alignment, the first parameter to be considered is minimum incremental motion (MIM), which is the smallest increment of motion that a device can consistently deliver. When adjusting fiber position while searching for the location at which peak power is achieved, MIM on the order of hundreds of nanometers can be necessary, especially with single mode fibers.

Next, accuracy and repeatability are critical. Accuracy is important so that a positioner moves exactly to where it is programmed, and repeatability is just as important so that it returns to the same point over and over again after having been commanded to move elsewhere. Once again, accuracy and repeatability requirements can be on the order of hundreds of nanometers.

An often overlooked parameter is motion system stability. Once the target position is reached, the fiber must be held in position for several seconds to ensure fiber attachment (e.g., epoxy dispense and curing) is completed without any drift.

To maximize throughput, positioners must obviously move quickly. Yet, speed might be a tradeoff for achieving smaller MIM, higher accuracy and higher repeatability without significantly increasing costs. Thus, an application's objectives should be thoroughly understood when selecting the optimal motorized positioning system.

MKS has been recognized as one of the leaders and innovators in motion control for over five decades. An extensive offering of Newport motorized positioners and hexapods that have been specifically designed for fiber alignment are available for R&D, assembly and production purposes.



3-axis Newport VP motorized positioner assembly (right) and multi-axis Newport ULTRAlign™ manual fiber optic alignment positioner assembly (left) in a high-precision fiber alignment system

Custom 12-axis Newport OEM fiber alignment with epoxy dispensing system.

Photonic Device Search Algorithms

In addition to employing exceptional hardware, efficient fiber alignment also necessitates positional search algorithms appropriate to the application and to the step in the alignment procedure. MKS has developed alignment algorithms in the form of application programming interfaces (API) that are available in the firmware of our Newport XPS-D high-performance motion controller. (See table #1.) When programming a fiber alignment system, these API functions may be used as a command to execute a motion pattern. Specific search algorithms are available for finding the first light (i.e., the periphery of a light beam), after which different algorithms that are faster and more precise are used to find the peak power location. The choice of the second algorithm depends on whether the beam has a Gaussian distribution or top hat profile with multiple peaks, and some algorithms can be used to profile both types of beams and can also be used in parallel.

Table #1: MKS positional search algorithm usage guide

Photonic Device Search Algorithm API	Beam Profile		Find First Light	Find Peak Power	Find Peak Power aloong Beam (Z) Axis	Stop when Trhesholds Reached	Max Number of Axes
	Gausian or Single Peak	Plateau or Multiple Peaks					
Axis-by-Axis	✓			✓			6
Dichotomy	✓			✓			6
Escalade (Continuous)				✓	✓		3
Escalade (Square)				✓	✓	✓	3
Raster		✓	✓	✓		✓	2
Spiral (Continuous)		✓	✓	✓			2
Spiral (Square)			✓	✓		✓	2

Newport XPS-D Universal High-Performance Motion Controller

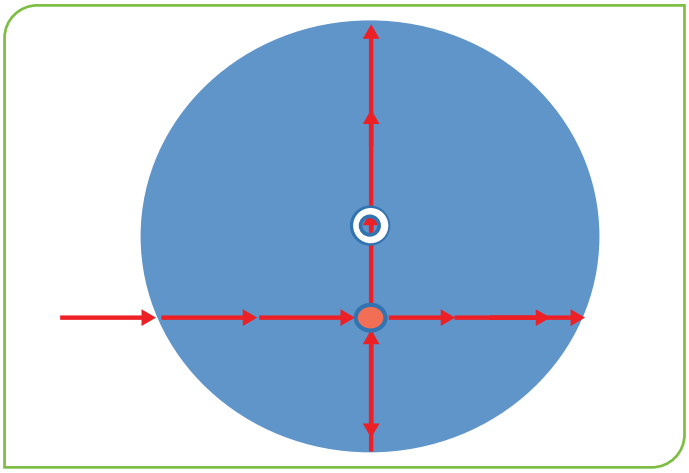


Illustration of Axis-by-Axis search algorithm

OEM Optical-to-Electrical Converters for 100 and 200 GB/lane

MKS can provide custom OEM optical-to-electrical (OE) converters to be installed into sampling oscilloscopes that are used to characterize transceivers during production. The OE converters can be custom-designed to specific application requirements including frequency responses, gain, noise and other properties. As shown in the various communication protocols in table #, MKS can enable testing of 100 GB/lane and also 200 GB/lane transceivers.

Custom-designed OEM OE Converter installed into sampling oscilloscope

Table #2: Typical testing protocols for various GB/lane transceivers

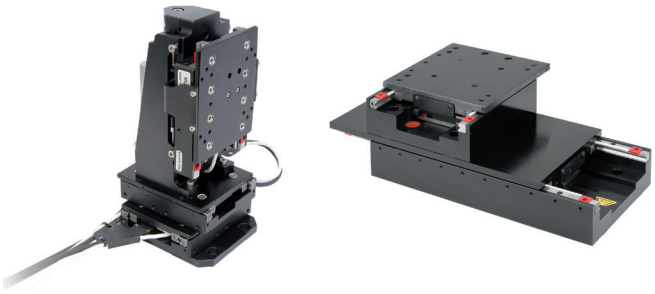
Protocol/Application	Transmitter Type
28 Gbit NRZ 53 Gbaud PAM-4	25 G short reach 100 G short reach
53 Gbaud PAM-4	100 G long reach
53 Gbaud PAM-4 Clock Data Recovery	100 G short/long reach
112 Gbaud PAM-4	200 G short reach

In addition, MKS offers the broadest range of New Focus plug-and-play high speed optical receivers and detectors that provide the lowest noise and cleanest response, with dozens of standard products to choose from.

MKS Products for Optical Transceiver Manufacturing

MKS offers many products that are broadly utilized in optical transceiver manufacturing. For more information, please visit www.newport.com or call +1 877-835-9620.

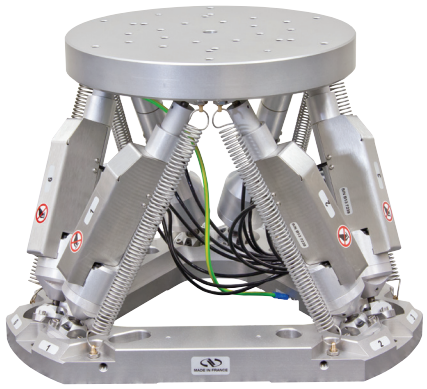
Motorized Positioners



MKS' Newport motorized positioners make up the most comprehensive offering in the industry. Many products have been designed with fiber alignment in mind, such as the MLT series and VP series linear positioners. The XM series linear positioners feature 1-nm minimum incremental motion (MIM) and 300 mm/s speed for the most complex alignments in high-volume production. Our linear positioners, rotary positioners and goniometers can be assembled together to form multi-axis fiber alignment systems. Additionally, MKS offers Newport motorized actuators to automate manual fiber alignment systems used in R&D and lower volume production.

- Linear and rotary positioners, goniometers, and actuators
- Sub-micron and nanometer MIM, accuracy and repeatability
- Can be attached together to form multi-axis fiber alignment systems
- Configurations for high- and low-volume production and R&D

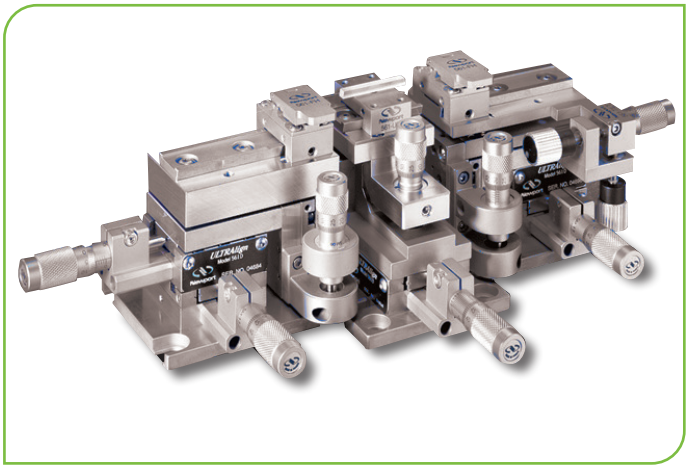
Hexapods



For an elegant and easy solution to complex, multi-axis motion in a single device, Newport hexapods offer six degrees of freedom. Some advantages that a single hexapod provides over a stacked linear/rotary positioning system include lower motion settling times, high stiffness, and no accumulation of the straightness and flatness errors of individual positioners. Moreover, a unique feature with hexapods is the ability to set two virtual centers of rotation—this enables pivoting around a separate pivot point, such as a fiber core. MIM and repeatability are sub-micron for linear motion and on the order of milli-degrees for rotation. MKS also provides controllers for our hexapods, which are recommended for high-volume production

- Six degrees of freedom in a single device
- Sub-micron and milli-degree MIM and repeatability
- Two virtual centers of rotation enable pivoting around a separate pivot point, such as a fiber core
- Recommended for high-volume production

ULTRAlign™ Precision Fiber Optic Alignment Positioner



Aligning fibers with manual positioners may be applicable for R&D and some low-volume production systems. The Newport ULTRAlign series manual positioners were specifically designed for fiber alignment. All the major structural ULTRAlign parts are constructed of stainless steel, which has excellent stability, including very high thermal stability. Thus, alignments are maintained over long periods of time. ULTRAlign components are modular, so systems with as many axes of required motion can be assembled. In addition, numerous ULTRAlign alignment accessories such as fiber holders, lens mounts and objective mounts are available for applications including fiber-to-fiber, objective lens-to-fiber, fiber-to-waveguide-to-fiber, and fiber-to-fiber with a GRIN lens in between.

- Linear, tilt and rotation positioners
- Fiber holders, lens mounts, objective mounts and other accessories
- Modular components for assembly of multi-axis alignment systems
- Stainless steel construction for ultra-stability
- Ideal for R&D and low-volume production

High-Speed Optical Receivers and Detectors

MKS offers the broadest selection of New Focus high-speed optical receivers and detectors that feature the lowest noise and cleanest response. For power levels on the order of hundreds of mW, non-amplified optical detectors are recommended. And for even lower optical power levels, New Focus optical receivers contain a low-noise, linear, high-bandwidth amplifier after the photodiode and offer bandwidths up to 38 GHz, making them ideal for signals on the order of hundreds of nW. To meet processing throughput requirements, our high-speed optical receivers and detectors can deliver rise times on the order of picoseconds. All New Focus standard catalog optical receivers and detectors are plug-and-play and easy to use, and MKS can also provide custom and OEM modules for specific requirements including frequency response, gain and noise.

- Fiber-optic receivers, frequency-domain detectors and time-domain detectors
- Lowest noise and cleanest response, even at low optical power levels
- Picosecond-scale rise-times
- Plug-and-play standard products and custom OEM capabilities

Photodiode Power Sensors

To measure optical power by converting light into electrical current, which can then be measured by a power meter, MKS provides a full array of Newport photodiode power sensors. In particular, our 818 series fiber-optic photodiode power sensors are capable of measuring power as low as 20 pW for 800-1,650 or 400-1,100 nm wavelengths, making them advantageous for low power first light scans that look for where light starts to transmit. Featuring NIST-traceable sensor calibration and the lowest calibration uncertainty in the industry, our 818 series can be used for R&D and production. Fast rise times of a few microseconds help meet throughput objectives, and exchangeable fiber adapters extend these sensors' compatibility.

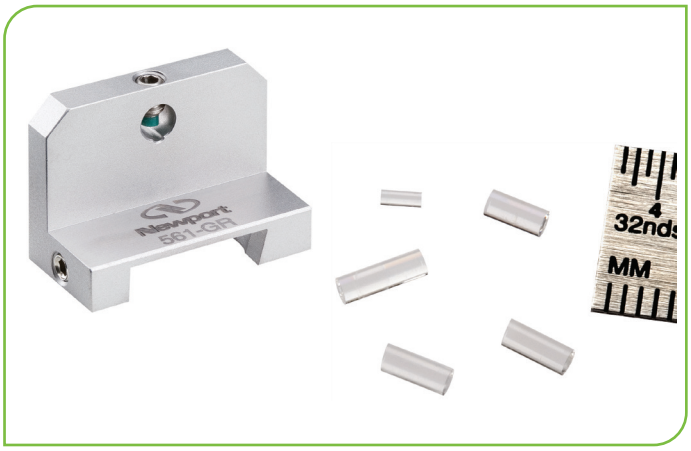
- NIST-traceable calibration, lowest uncertainty in the industry
- 20 pW minimum measurable power @ 800-1,650 or 400-1,100 nm
- Rise-times of a few microseconds
- Exchangeable fiber adapters

Optical Power Meters

When a photodiode power sensor converts light into electrical current, it must be connected to a power meter for measurement and analysis. MKS offers Newport power meters that are compatible with our sensors, including the 818 series sensors. The 1936-R is one of the most advanced optical power and energy meters in the market, featuring sub-pW noise levels, fast sampling rate of up to 10 kHz, thorough selection of measurement and analytical functions, and an analog output to provide feedback to a motion controller. For versatile, portable measurements such as transmission checks in the field, our 1919-R handheld meter provides a variety of measurements and display modes in an ergonomic design with a user-friendly interface. Another option is to use a PC as a laser measurement station—our 844 virtual power meter connects to a PC via USB and comes with application software that includes advanced measurement processing, data logging and extensive graphical displays.

- Compatible with Newport photodiode power sensors, including 818 series
- Advanced full-functionality meter for production and R&D
- Handheld meter for field-checks, R&D and manual fiber alignments
- Virtual meter with application software to enable PC as a laser measurement station

Gradient Index (GRIN) Micro Lenses



If the interface to a detector is bare fiber, a GRIN lens is the most common optical element used to collimate or focus a laser for fiber coupling. GRIN lenses have a radially varying index of refraction, causing an optical ray to follow a sinusoidal propagation path through the lens. Many Newport plano-plano (flat) GRIN lenses are available from MKS in various sizes, pitch (which defines how an optical ray propagates through the lens) and anti-reflective coatings. MKS also provides plenty of ways to mount a GRIN lens, including ULTRAlign accessories specially designed to hold GRIN lenses. (Note that depending on focal requirements, a Newport objective lens may be a better alternative to a GRIN lens.)

- 1- to 2-mm diameters, >2.5- to <6-mm lengths
- 0.23, 0.25 and 0.29 GRIN pitches
- AR coatings for 630, 830, 1,300 and 1,560 nm wavelengths
- Mounting accessories as part of ULTRAlign system

Workstations and Tables (Vibration Control)

A fiber alignment system has to be placed somewhere, but not just anywhere. A critical factor with fiber alignment is vibration control, as even the slightest disturbance can cause alignment errors. MKS has set the industry standard for vibration control for many decades. Our Newport breadboards, workstations and optical tables are available undamped or with various levels of precision damping. For the ultimate in damping performance, our SmartTable® optical tables were the first active damped tables available in the market. When vibration isolation is required, MKS offers Newport pneumatic, elastomeric and mechanical isolators. Hundreds of standard configurations are available, and MKS can also deliver custom solutions.

- Breadboards, workstations, optical tables and isolators
- Passive damping and active SmartTable damping
- Pneumatic, elastomeric and mechanical isolators
- Hundreds of standard configurations and custom design capabilities

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 Photonics Solutions 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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