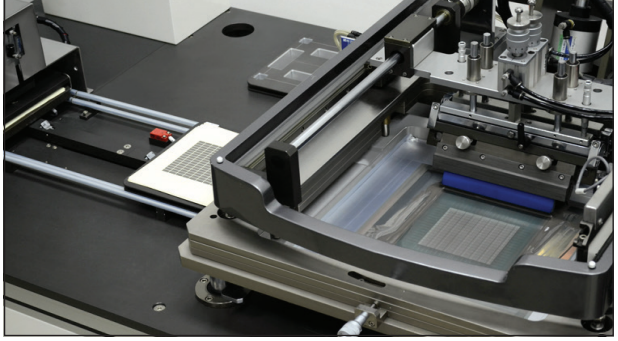
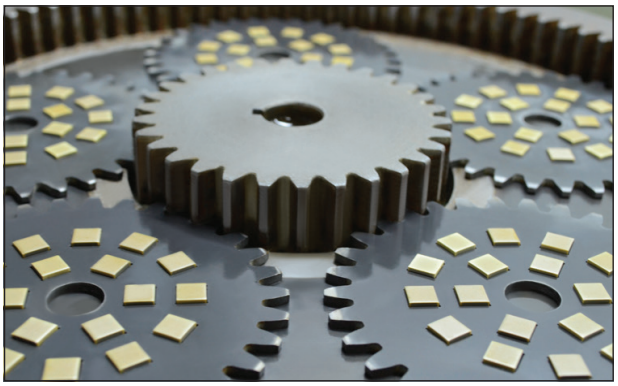
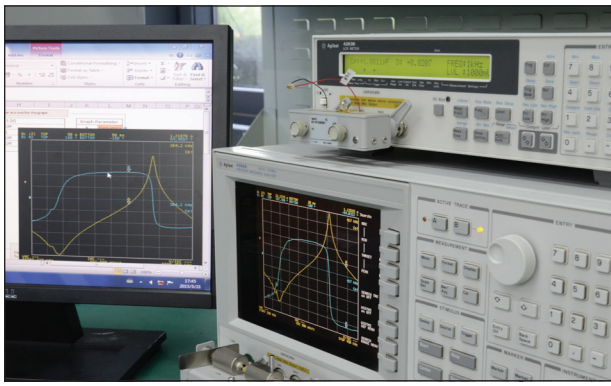
Piezo Actuators

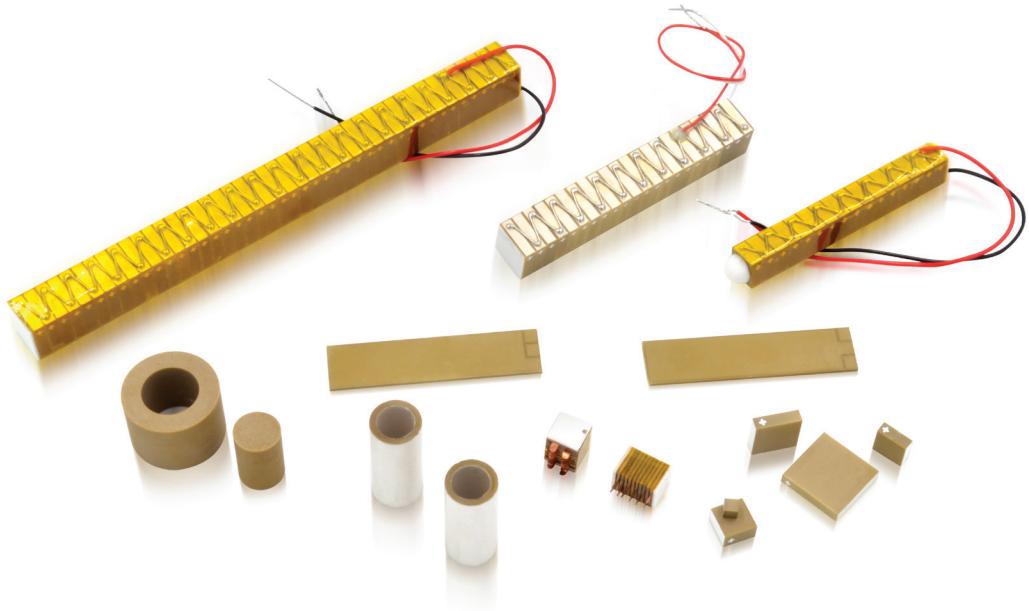






Piezo devices made of lead zirconate titanate (PZT) are capable of driving mechanical devices for precision positioning. Thorlabs manufactures a wide range of high-quality piezo actuators, including chips, stacks, tubes, and bimorphs. Various dimensions are available, and all piezo actuators can be custom designed to match specific requirements. In addition to actuators, PZT materials are offered for experimental purposes.

Our integrated in-house manufacturing facility allows us to produce precise, reliable piezoelectric devices to meet OEM and special application needs. Thorlabs' capacity for high-volume production ensures short lead times for large quantity orders.



THORLABS

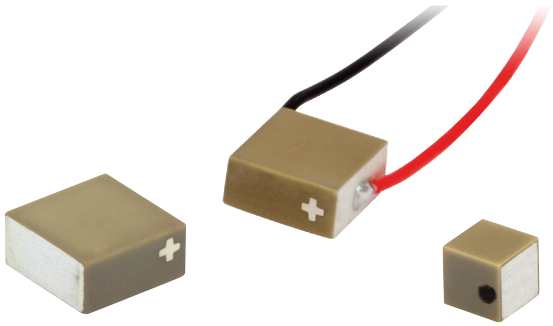
Standard Products

Thorlabs currently offers low-voltage piezo chips, discrete piezo stacks, and amplified piezo actuators as catalog products. All of them consist of stacked piezoelectric ceramic layers with interdigitated electrodes. The multilayer design enables high resonant frequencies and sub-millisecond response times, while the use of interdigitated electrodes minimizes the drive voltage range. Items with alternative dimensions, displacements, and voltages are available.

Low Voltage Piezo Chips

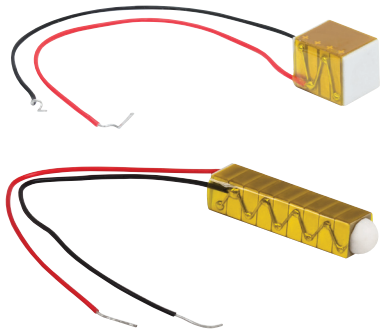
Features

- Sub-Micron Resolution
- Drive Voltage Range of 0 - 45 V, 0 - 75 V, 0 - 100 V, or 0 - 150 V
- For Use in Open-Loop Experimental Setups
- Many Chips Available with Pre-Attached Wires
- Ideal for Vacuum and OEM Applications



These compact piezoelectric chips can be easily integrated into systems for precision movement and are designed to provide maximum displacements from 0.7 µm to 3.6 µm. Through a precision grinding process, the accuracy of the design height is ensured to better than ±5 µm.

Discrete Piezo Stacks

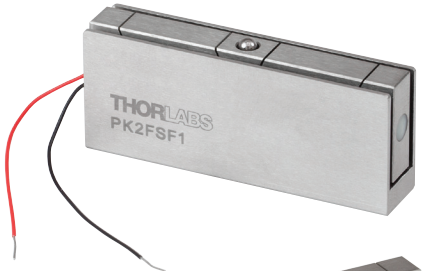


Piezo Stacks with a Flat or Hemispherical Plate on One End

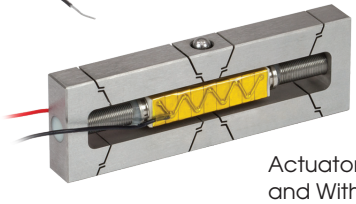
Thorlabs' Discrete Piezoelectric Stacks consist of multiple piezoelectric chips stacked face-to-face and bonded via epoxy and glass beads. By combining many chips, these stacks are able to achieve a free stroke displacement that is significantly larger than their single chip counterparts while maintaining sub-millisecond response times and low drive voltage ranges. Free stroke displacement of stacks ranges from 5.2 µm to 100.0 µm.

Amplified Piezo Actuators

Thorlabs' Amplified Piezoelectric Actuators consist of a discrete PZT stack housed within a flexure mount. By combining a discrete stack with a flexure mount, the free stroke displacement is lever amplified. This provides significantly larger displacement (an amplification factor of ~9) than that of the corresponding discrete stack while maintaining sub-millisecond response times and low drive voltage ranges. Thorlabs offers versions with 220 µm and 1500 µm free stroke displacements as catalog products.



Arrow Indicates Direction of Expansion

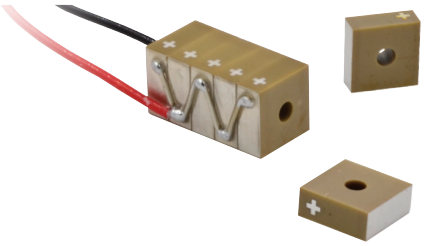


Actuators Shown With and Without Cover

Custom Options

In addition to standard chips and stacks, we are capable of producing piezo ceramic devices in other shapes and styles: piezo chips with an insulated inner hole, shear piezo chips and stacks, piezo tubes, and bimorphs.

Piezo Chips/Stacks with Inner Hole



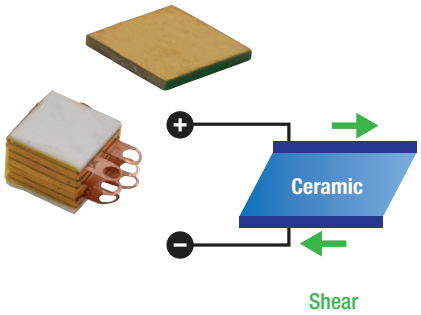
The through hole in the center gives the actuator more flexibility to be integrated with other devices. We offer chips with 5 mm x 5 mm x 2 mm dimensions and a Ø2 mm insulated inner hole. Driven with 150 V, they provide a maximum displacement of 1.8 µm. Other dimensions or stacks are also available upon request.

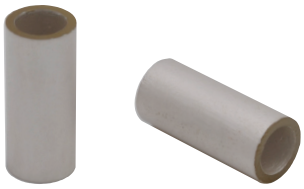
These chips are ideal for laser tuning, micro-dispensing, and life science applications. Our in-house precision drilling and lapping machines allow manufacturing with tight dimensional tolerance and many customization options.

Shear Piezo Chips/Stacks

Shear piezo chips provide a shear deformation, as shown in the diagram to the right, and are more compact than other types of chips. The standard dimensions measure 5 mm x 5 mm x 0.5 mm with a maximum lateral displacement of 1.3 µm. Other dimensions or stacks are available upon request.

These chips are ideal for optical stages and other linear piezo motors.





Piezo Tubes

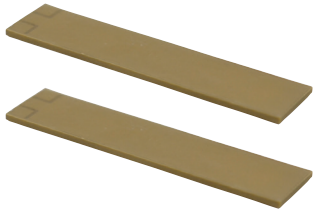
Tube actuators allow motion in both radial and axial directions when a voltage is applied. Thorlabs' piezo tubes are manufactured using high-precision core drilling equipment resulting in enhanced quality. They are ideal for microdosing, micromanipulation, and nanopositioning applications.

For example, our tube of 17 mm length, Ø8 mm outer diameter, and Ø7 mm inner diameter offers an axial displacement of 2.8 µm and radial movement of 1.8 µm when driven at 500 V. Other dimensions are also available.

Bimorphs

Bimorphs, which have a multi-layer design, bend due to contraction of one active layer and expansion of the other when voltage is applied. Driven with a bipolar 150 V bias, our bimorph measures 32 mm x 7.8 mm x 0.8 mm and can offer a displacement of 0.90 µm.

These bimorphs are manufactured via tape casting and co-firing, enabling high reliability. They are ideal for optical choppers and benders, as well as pumping and dosing applications.



Manufacturing Capabilities

Facilities and Processes

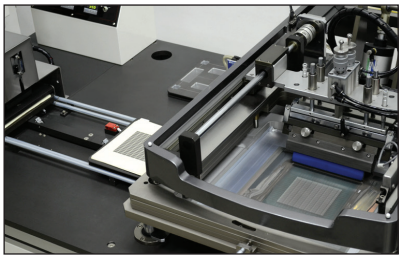
Our engineers utilize a large selection of tools and design capabilities to create an extensive product line of piezo actuators and devices. Thorlabs' manufacturing capabilities give us control over every step of the construction and assembly of piezoelectric devices.

Key Process

- Screen Printing of Inner Electrodes & Stacking
- Isostatic Pressing
- Cutting
- Micro Dicing
- De-Binding and Sintering
- Lapping
- Screen Printing Outer Electrodes
- Poling

Screen Printing Inner Electrodes & Stacking

Our automatic screen printing equipment prints the inner electrodes onto every layer of ceramic tape using a silver/palladium paste and a mask. Stacking these layers with interdigitated electrodes creates the multilayer PZT block.



Isostatic Pressing

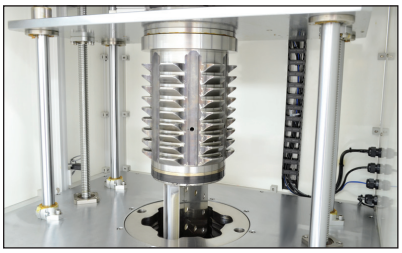
The PZT block is packaged in a vacuum-sealed container and placed under a well defined pressure using an isostatic pressing machine. This process increases the density of the piezo device, resulting in improved mechanical properties and workability.

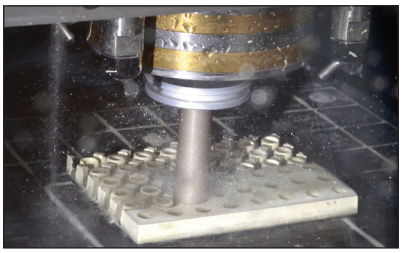
Cutting

The piezo block can be cut into individual pieces with a programmable cutting machine. We can cut the block into any size necessary for the final product and according to the pattern of the inner electrodes. This gives us significant customizability options as well as large volume production capabilities.

Micro Dicing

A CNC system is used to manufacture piezo items of cylindrical or tubular shape. The high precision of 0.1 µm and long drilling distance of 40 mm allow a variety of specifications to be realized. Piezo blocks with other 3D profiles are also available.





De-Binding

Once cut into pieces, the binder materials and solvent residues inside the ceramic material are cleaned and removed by subjecting the PZTs to a predetermined heating cycle. This de-binding (binder burnout) process helps to remove batch-to-batch performance variations and defects, ensuring that our product line functions reliably and reproducibly.

Sintering

Once de-binding has been completed, the chips are prepared for sintering. This process is performed at high temperatures that do not melt the ceramic body, but rather fuse the material together. The process continues as crystallites form and grow until the optimum device density is achieved.

Lapping

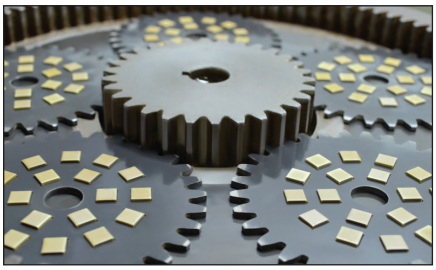
To ensure tight dimensional tolerances, we employ high-precision lapping machines to control the thickness of the PZT device in the direction of translation. A 5 µm tolerance is guaranteed on these chips.

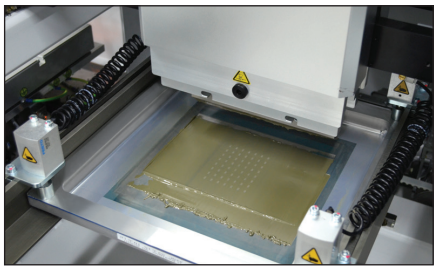
Screen Printing Outer Electrodes

Silver metal is printed onto the surfaces of the ceramics to create the outer electrodes in an automatic printing machine. The chips are baked at specific temperatures multiple times and then silver fired to enhance the adhesion between the silver electrodes and the ceramics.

Poling

At this point in manufacturing, the sintered ceramic pieces are isotropic and must undergo poling in order to function as a piezoelectric device. Poling subjects each device to a strong electrical field across the electrodes, which activates the ceramic's piezoelectric properties.

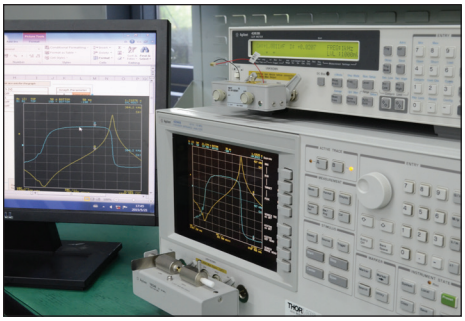




Testing

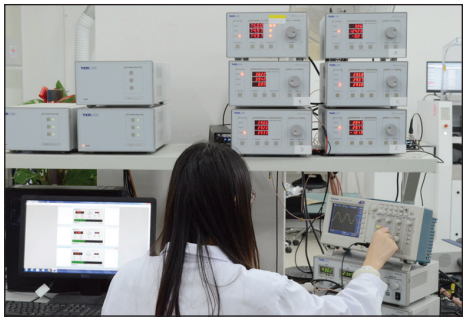
Each PZT product manufactured by Thorlabs is subjected to several performance and safety tests before they are shipped to customers. This lab quality management system follows rigorous quality control procedures, which ensure the high quality and performance of each of our piezo devices. Our test capabilities include the following:

- Performance Testing (Free Stroke, Resonant Frequency, Impedance, etc.)
- Accelerated Lifetime Testing (Assesses the Reliability and Average Lifetime of the Piezo Device)
- Alternating Current Testing (Examines the Insulation Strength)



Basic Electronic and Performance Testing

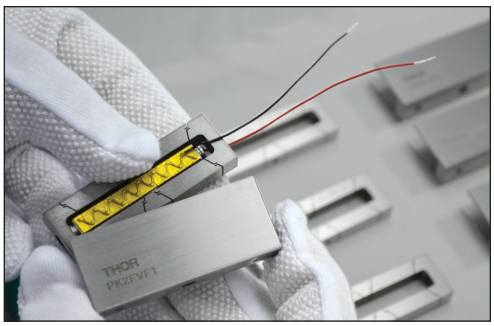
Accelerated Lifetime Testing



Alternating Current Testing

Assembly

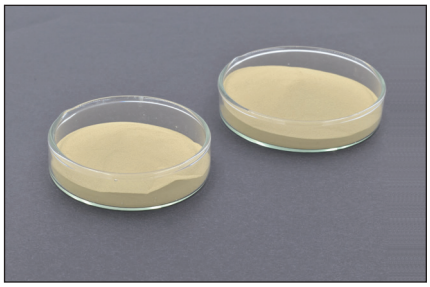
Thorlabs' Discrete Piezoelectric Stacks are assembled from our individual PZT chips. Multiple chips are stacked face-to-face and bonded via epoxy and glass beads. Using multiple chips in tandem allows these stacks to achieve significantly larger free stroke displacements than those of individual chips, while maintaining the sub-millisecond response times and low drive voltage ranges.



PZT Materials

In addition to actuators, Thorlabs also offers piezoceramic materials based on modified lead zirconate titanate (PZT). These kinds of ceramic materials are used to create different piezoelectric cells that convert mechanical stress into voltage and vice versa.

"Hard" PZT powder for high dynamics, "Soft" PZT powder for high displacement, and custom materials are available for different applications. Characteristics such as dielectric properties, coupling, frequency, capacitance, and mechanical properties can be found in the table below.

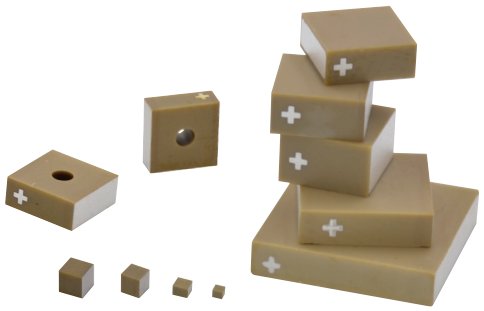


Thorlabs' PZT Material Specifications

Property	Symbol & Unit	THP42	THP44	THP46	THP8	THP5A	THP51	THP5H
Type		"Hard"				"Soft"		
Dielectric Properties (Tolerances ±10%)								
Relative Dielectric Constant	$\varepsilon^{T}_{33}/\varepsilon_0$	1200	1380	1350	1030	2300	3300	4500
Dielectric Loss Factor	tgδ (%)	0.5	0.5	0.8	0.4	2	2.2	2.2
Electromechanical Properties (Tolerances ± 5%)								
Coupling Factors	K_p	0.65	0.68	0.59	0.59	0.7	0.68	0.72
	K_{31}	0.36	0.33	0.33	0.34	0.39	0.37	0.42
	K_{33}	0.7	0.68	0.65	0.6	0.7	0.63	0.78
	K_t	0.47	0.48	0.47	0.47	0.51	0.5	0.5
Piezoelectric Charge Constants	d_{31} (10^{-12}C/N)	-130	-145	-140	-150	-220	-320	-300
	d_{33} (10^{-12}C/N)	280	315	310	320	450	710	680
	g_{31} (10^{-3}V/N)	-13	-13	-13	-10	-10	-11	-9
	g_{33} (10^{-3}V/N)	24	26	27	28	23	25	20
Frequency Constants	N^{Ep} (m/s)	2200	2250	2230	2300	2000	2010	2000
	N^{Dt} (m/s)	2000	2050	2050	2050	2040	1950	2030
	N^{E1} (m/s)	1500	1600	1500	1630	1400	1400	—
	N^{D3} (m/s)	1350	1500	1800	1500	1350	1500	—
Physical Properties (Tolerances ± 5%)								
Mechanical Quality	Q_m	800	1600	1300	1000	90	60	60
Density	ρ (10^3kg/m^3)	7.6	7.75	7.7	7.7	7.85	7.7	7.85
Elastic Compliances	S^{E11} (10^{-12}m^2/N)	13	13	13	16	16	17	17
	S^{E33} (10^{-12}m^2/N)	17	16	20	17	19	23	21
Curie Temperature	T_c (°C)	320	305	315	300	260	230	200
Process Properties								
Sintering Temperature	T_s (°C)	1260	1260	1050	1260	1260	985	1260

Customization and OEM Solutions

Thorlabs' piezoelectric design and engineering team has extensive expertise in the design, manufacture, and development of piezo devices, allowing us to create customized items. We support a vast selection of actuators with a variety of package sizes, operating voltages, and free stroke displacements. Each of these parameters is individually customizable, making our piezos extremely easy to integrate into larger assemblies.



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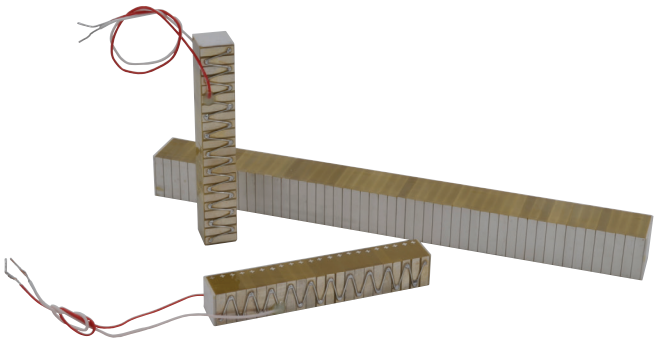

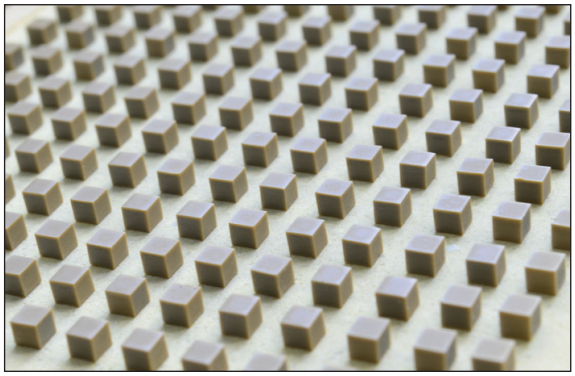

Industries

- Semiconductor Technology
- Optoelectronics
- Communications and Integrated Optics
- Biotechnology and Life Science Technology
- Precision Machining
- Medical Technology and Drug Design
- Data Storage Technology
- Nanomanufacturing and Nanoautomation
- Aeronautics and Astronautics
- Image Processing

Screen Printing of Electrodes and Stacking of Ceramic Layers

Worldwide Support

Thorlabs, Inc.
Newton, New Jersey
Phone: 1-973-300-3000
Email: sales@thorlabs.com

Thorlabs Vytran® Division
Morganville, New Jersey
Phone: 1-973-300-3000
Email: sales@thorlabs.com

Thorlabs Measurement Systems (TMS) - NJ
Blairstown, New Jersey
Phone: 1-908-362-6200
Email: tms-sales@thorlabs.com

Thorlabs Measurement Systems (TMS) - NH
Londonderry, New Hampshire
Phone: 1-973-300-3000
Email: tms-sales@thorlabs.com

Thorlabs Quantum Electronics (TQE)
Jessup, Maryland
Phone: 1-973-300-3000
Email: sales-TQE@thorlabs.com

Thorlabs Imaging Systems
Sterling, Virginia
Phone: 1-703-651-1700
Email: imagingsales@thorlabs.com

Thorlabs Spectral Works (TSW)
West Columbia, South Carolina
Phone: 1-973-300-3000
Email: sales@thorlabs.com

Thorlabs Ultrafast Optoelectronics
Ann Arbor, Michigan
Phone: 1-973-300-3000
Email: sales@thorlabs.com

Thorlabs Laser Division - CO
Lafayette, Colorado
Phone: 1-973-300-3000
Email: sales@thorlabs.com

Thorlabs Crystalline Solutions (TCS)
Santa Barbara, California
Phone: 1-973-300-3000
Email: sales@thorlabs.com

Thorlabs Canada
Phone: 1-973-300-3000
Email: sales@thorlabs.com

Thorlabs Ltda, Brazil
Phone: +55 (16) 3413 7062
Email: brasil@thorlabs.com

Thorlabs Ltd.
Phone: +44 (0)1353 654440
Email: sales.uk@thorlabs.com

Thorlabs SAS France
Phone: +33 (0) 970 444 844
Email: sales.fr@thorlabs.com

Thorlabs GmbH / Thorlabs Lübeck
Phone: +49 (0) 8131 5956-0
Email: europe@thorlabs.com

Thorlabs Elliptec® GmbH
Phone: +44 (0)1353 654440
Email: sales.de@thorlabs.com

Thorlabs Vytran® Europe
Phone: +44 (0) 1392-445777
Email: vytran.uk@thorlabs.com

Thorlabs Sweden AB
Phone: +46 31 733 30 00
Email: scandinavia@thorlabs.com

Thorlabs China Ltd.
Phone: +86 (0)21-60561122
Email: chinasales@thorlabs.com

Thorlabs Japan
Phone: +81-3-6915-7701
Email: sales@thorlabs.jp