

**TuoTuo Technology**



Optical Inspection / Optical Microfabrication

**TuoTuo Technology**



Web



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**TuoTuo Technology (Singapore) Pte. Ltd.**

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**TuoTuo Technology (Singapore) Pte. Ltd.**

# Company Profile

TuoTuo Technology

TuoTuo Technology (Singapore) Pte. Ltd. is part of a fast-growing technology-driven enterprise group, focusing on the development and manufacturing of optical equipments.

- TuoTuo Technology (Suzhou) Co., Ltd. and TuoTuo Optoelectronics (Suzhou) Co., Ltd. are located in Suzhou, the world's largest industrial city, leveraging comprehensive and efficient domestic production and manufacturing capabilities to ensure product delivery and provide high-quality localized services. Our technical research and development cover a wide range of fields including optics, machinery, electronics, electrical, software, and systems, building domestically high-end equipment with professional expertise.
- TuoTuo Technology (Singapore) Pte. Ltd. is situated in the Republic of Singapore, and has deep connections with the National University of Singapore. The Singapore company undertakes both the fundamental technological research and the mission of global supply chain integration.

## Products

Our six core products—Maskless UV Lithography, Ultra-high-precision 3D Lithography, Electro-optic Probe stations, Multi-modal Optoelectronics Microscope, 3D Microscope, and Magneto-optic Kerr Microscope systems—have achieved world-class standards and garnered high praise from research users.

Maskless UV Lithography    Ultra-High-Precision 3D Lithography    Magneto-Optic Kerr Microscope Systems



Electro-Optic Probe Stations



Multi-modal Optoelectronics Microscope



3D Microscope



Intelligent Optical Inspection



Microstructure Processing

## Core business

Development of high performance optical system with optical inspection and optical microfabrication at the core.

## Underlying technology

Over the years, we have developed comprehensive engineering development capabilities giving us extensive experience in design integration, research and development, manufacturing, sales and consulting services. We are committed to providing customers with a full range of technical support, through the integration of optical, electronic and mechanical equipments, We have received wide recognition for our cutting-edge technology, corporate responsibility, excellent product design, exceptional quality and customer services.



## Core components

Breakthrough in the performance of core equipment requires innovation and breakthroughs in the underlying components. We have expanded our technical research and development to core components, related to our core business. At present, key progress has been made in the areas of translational stage, vibration isolation platform, laser, and low-temperature systems which are the core components in most of our systems. The development of these core components not only enhance the capabilities of our equipment but also any other integrated system using these components.



Translational stage



Vibration isolation platform



Laser



Low-temperature systems

## Collaboration with scientific research institutes



## Join us

- **Technical cooperation**  
Industry-university collaboration can bring excellent technology. We are happy to provide production, engineering technology, capital and other aspects for great technologies.
- **Technology leader**  
"Scientists discover things that are unknown, engineers create things that have never existed". If the latter is more interesting for you, welcome to join us!
- **R&D position**  
We are looking for outstanding PhDs and masters in engineering to join us to invent exceptional products.
- **Joint training**  
We provide co-mentoring with professors to train the next generation of engineering and technical talents.
- **Internships**  
We offer internship opportunities to students interested in high-end optical instrument manufacturing industry.

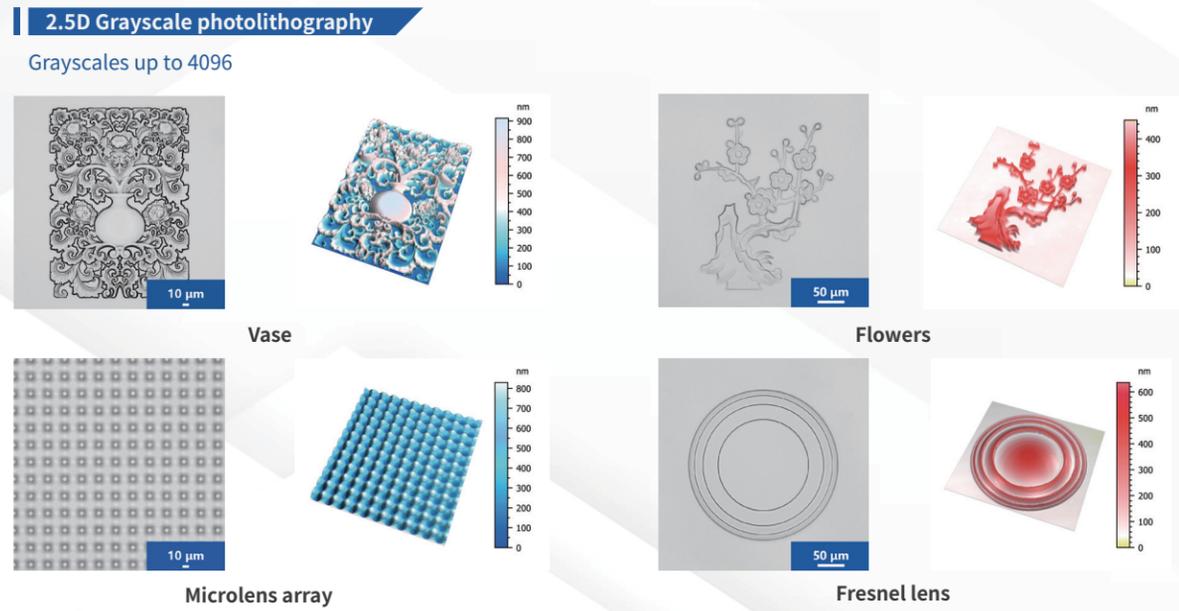
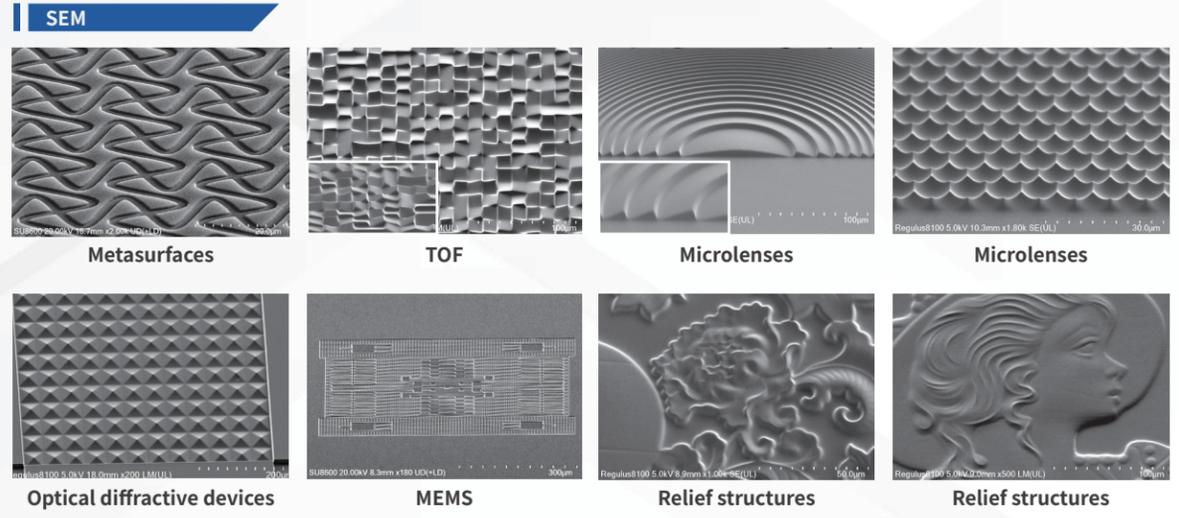
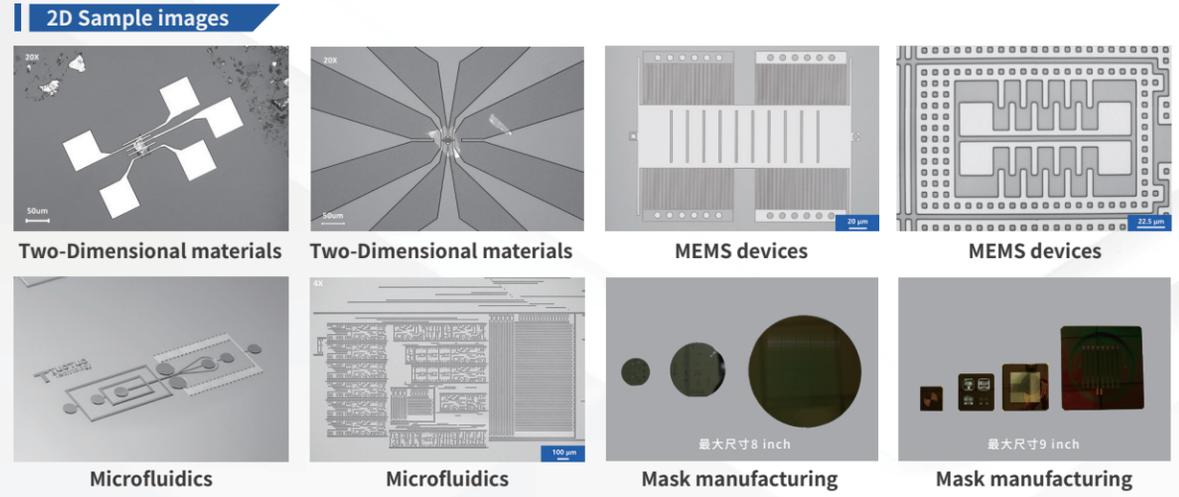
# Maskless UV Photolithography

- ✓ High Flexibility
- ✓ Wafer Scale Exposure
- ✓ Cost-effective
- ✓ Accurate Overlay
- ✓ Real Time Observation
- ✓ Grayscale Lithography



- Highly Precision
- Maskless
- Fully Automatic

## Selected samples fabricated by the lithography equipment from TuoTuo



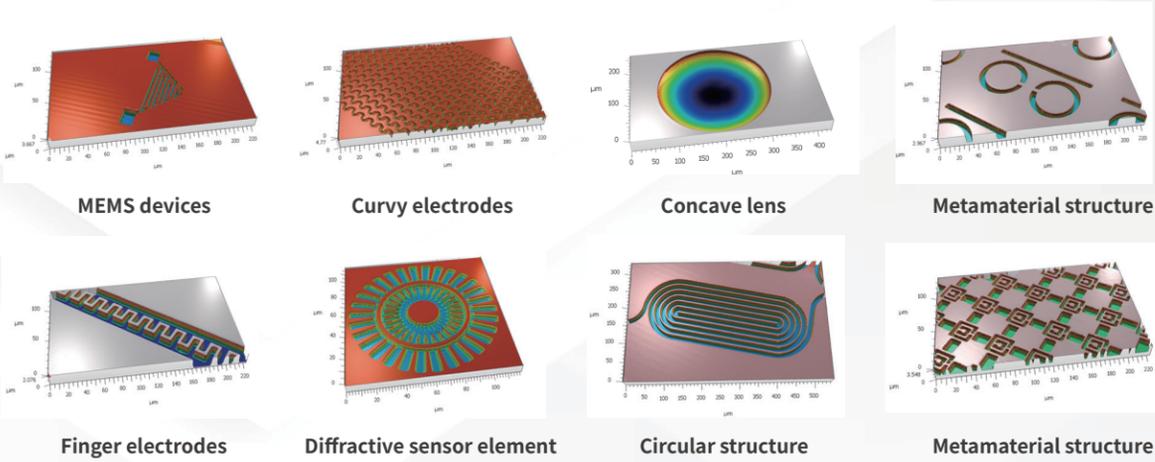
Product	Maskless UV Photolithography		
	UV Light	UV Academia	
Model	UV Litho-Y	UV Litho-ACA	UV Litho-ACA Pro+
Minimum parallel linewidth	2.0 μm	1.0 μm	0.8 μm
Critical dimension (CD)	1.5 μm	0.8 μm	0.4 μm
Exposure speed	Lenses①: 20 mm²/min	Lenses①: 3 mm²/min Lenses②: 20 mm²/min Lenses③: 100 mm²/min	Lenses①: 1 mm²/min Lenses②: 3 mm²/min Lenses③: 20 mm²/min Lenses④: 100 mm²/min
Alignment precision/Overlay accuracy(5 mm × 5 mm)	1000 nm	400 nm	350 nm
Alignment precision/Overlay accuracy(50 mm × 50 mm)	1500 nm	1000 nm	700 nm
Light source*	LED: 405 nm or 380 nm	LED: 405 nm or 380 nm	LED: 405 nm or 390 nm
Exposure lens changer module	-	✓	✓
Grayscale Lithography	Non-optional	Optional	Optional
Wafer/Sample size (min)	3 mm × 3 mm	3 mm × 3 mm	3 mm × 3 mm
Wafer/Sample size (max)	50 mm × 50 mm	150 mm × 150 mm	150 mm × 150 mm

Product	Maskless UV Photolithography		
	UV Academia	UV Speed	
Model	UV Litho-ACA Master	UV Litho-S	UV Litho-S+
Minimum parallel linewidth	0.8 μm	2.0 μm	0.5 μm
Critical dimension (CD)	0.4 μm	1.0 μm	0.5 μm
Exposure speed	Lenses①: 10 mm²/min Lenses②: 60 mm²/min Lenses③: 150 mm²/min	Lenses①: 1000 mm²/min Lenses②: 2500 mm²/min	Lenses①: 75 mm²/min Lenses②: 300 mm²/min Lenses③: 1200 mm²/min
Alignment precision/Overlay accuracy(5 mm × 5 mm)	350 nm	500 nm	250 nm
Alignment precision/Overlay accuracy(50 mm × 50 mm)	700 nm	1000 nm	500 nm
Light source*	LED: 405 nm or 390 nm	LD: 405 nm or 375 nm	LD: 405 nm or 375 nm
Exposure lens changer module	✓	✓	✓
Grayscale Lithography	Non-optional	Optional	Optional
Wafer/Sample size (min)	3 mm × 3 mm	1 inch wafer	1 inch wafer
Wafer/Sample size (max)	150 mm × 150 mm	8 inch wafer	8 inch wafer

\*The specifications and parameters of all the above products depend on individual process conditions and may vary based on equipment configuration. The writing speed depends on the exposure area.  
 \*The standard light source is 405nm, with other wavelengths available as options.  
 \*Specifications and parameters are subject to change without prior notice.

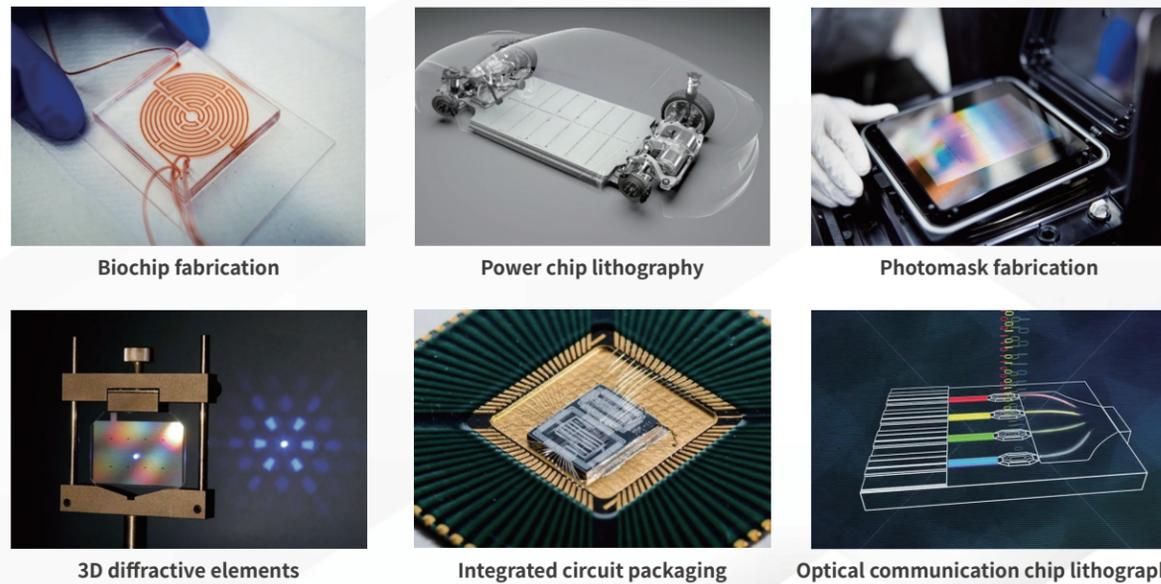
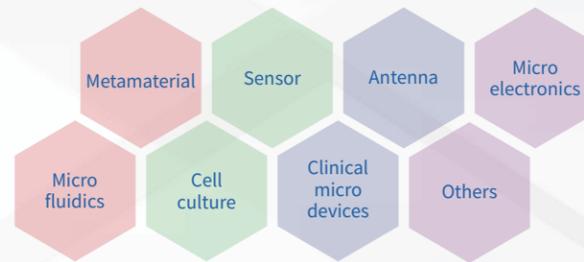
### 3D reconstruction of the fabricated patterns

Contact us to know more about our 3D microscopes!



### Application examples

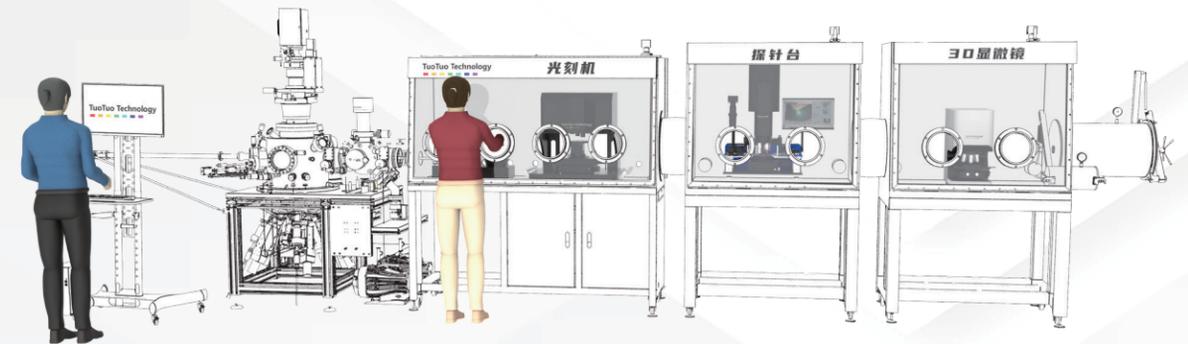
Our maskless UV projection photolithography system has **high precision** and **high stability** to realize complex patterns. Our flexible pattern designing is able to realize grayscale patterning thus achieving what-you-see-is-what-you-get.



### More related solutions

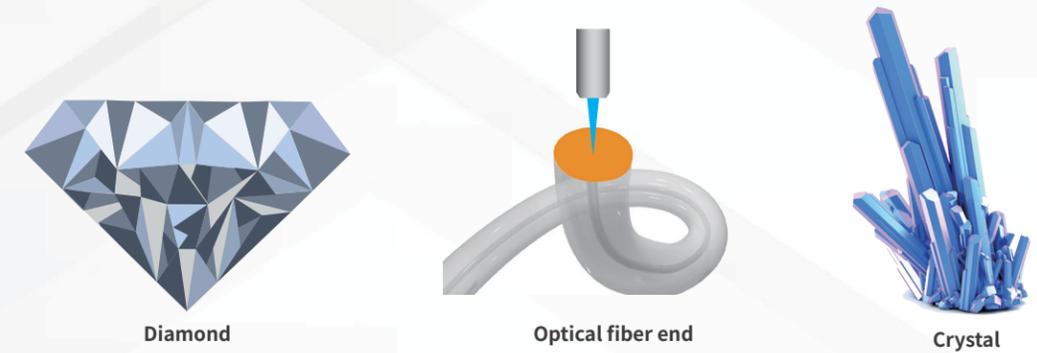
- One-stop solution for advanced material device fabrication

If your research involves hydrophobic, anaerobic materials (such as magnetic oxides, Micro-LEDs, OLEDs, etc.) and requires photolithography experiments, we can provide a glove box version photolithography system solution for you.



- lithography on special substrates

Photolithography is not only applicable to conventional silicon-based substrates, but can also be performed on various special substrates, such as diamond, optical fibers, and even small engine blades (curved surfaces), providing solutions for various application fields.



- Ultra-large frame lithography

In addition to processing wafer-sized samples, we are also capable of handling larger-sized samples. For example, the equipment supports ultra-large-area (2-meter) micro-nano fabrication to meet various research and industrial needs.



# Premium 3D Lithography

- Lithography accuracy 1 μm
- Switchable among multiple precisions (1 μm / 2 μm / 5 μm)
- Support printing with various resin/ceramic materials.
- Support 4D docking
- Full-frame map navigation
- Full-frame focus scanning
- Minimum processing material tank volume is 15 ml



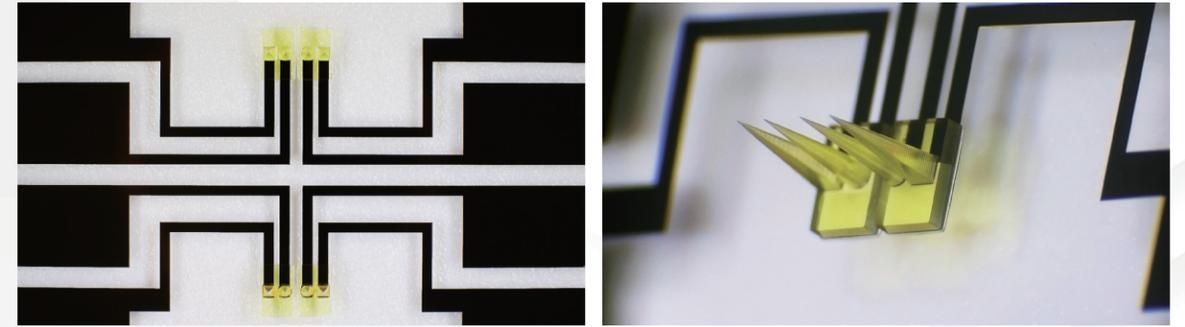
The Ploceus series micro-stereoscopic 3D printing equipment is a micro-nano 3D printing device independently developed and produced by Tuotuo Technology. It is a micro-nano processing device capable of large-format, high-precision, and high-resolution micro-stereolithography.

Product Highlights	High Precision & High Cost-Effectiveness	Ultra-High Precision & Multi-Functionality
Ploceus 3D Lithography		



Model	PL-3D-10	PL-3D-05	PL-3D-02	PL-3D-PD		PL-3D-PT		
Specification	Desktop level (single-objective)	Desktop level (single-objective)		Vertical (dual-objective)		Vertical (Tri-objective)		
Lithography accuracy	10 μm	5 μm	2 μm	2 μm	5 μm	1 μm	2 μm	5 μm
Machining tolerances	±25 μm	±10 μm	±5 μm	±5 μm	±10 μm	±3 μm	±5 μm	±10 μm
Print size	30 mm * 30 mm * 50 mm 50 mm * 50 mm * 50 mm	30 mm * 30 mm * 50 mm 50 mm * 50 mm * 50 mm		30 mm * 30 mm * 50 mm 50 mm * 50 mm * 50 mm		30 mm * 30 mm * 50 mm 50 mm * 50 mm * 50 mm		
Min printing thickness	5 μm	3 μm		2.5 μm		2.5 μm		
Single exposure area	19 mm * 10 mm	3.84 mm * 2.16 mm @ 2 μm 9.60 mm * 5.40 mm @ 5 μm		3.84 mm * 2.16 mm @ 2 μm 9.60 mm * 5.40 mm @ 5 μm		1.92 mm * 1.08 mm @ 1 μm 3.84 mm * 2.16 mm @ 2 μm 9.60 mm * 5.40 mm @ 5 μm		
Configure	Bubble elimination device	Bubble elimination device		Support 4D docking		Support 4D docking		
Materials	Photosensitive resin / Ceramics	Photosensitive resin / Ceramics		Photosensitive resin / Ceramics		Photosensitive resin / Ceramics		
Fabrication speed	2100 mm <sup>3</sup> /h @ 10 μm (Layer thickness 10 μm), 500 mm <sup>3</sup> /h @ 5 μm (Layer thickness 10 μm), 100 mm <sup>3</sup> /h @ 2 μm (Layer thickness 10 μm)							

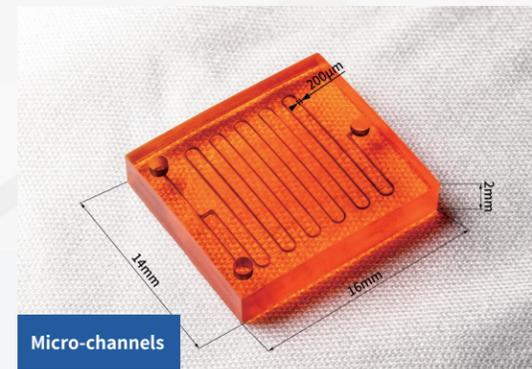
## 4D connection printing demonstration



4D docking micro-needle sensor (top view and close-up shot)

## PL-3D Resin-Based fabrication showcase

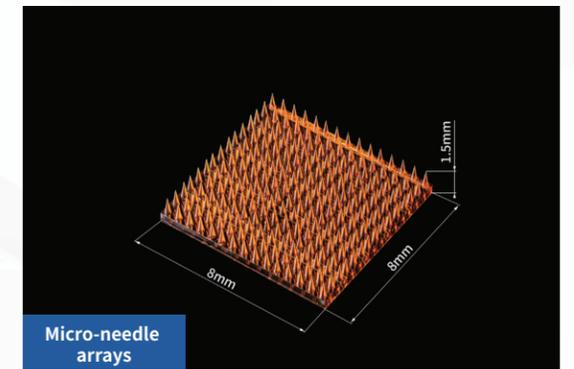
### 5 μm Optical precision



Micro-channels

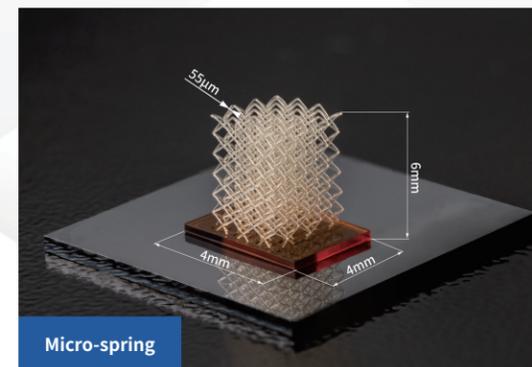
Dimensions: 16 mm × 14 mm × 2 mm  
Channel diameter: 200 μm  
Material: PR-TO-A-05  
Processing time: 65 min

### 2 μm Optical precision



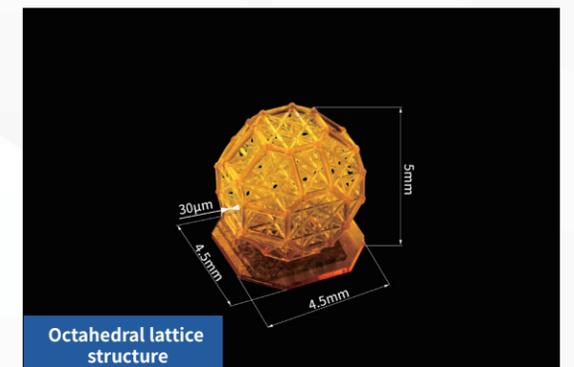
Micro-needle arrays

Dimensions: 8 mm × 8 mm × 1.5 mm  
Tip size: <5 μm  
Material: PR-TO-A-05  
Processing time: 52 min



Micro-spring

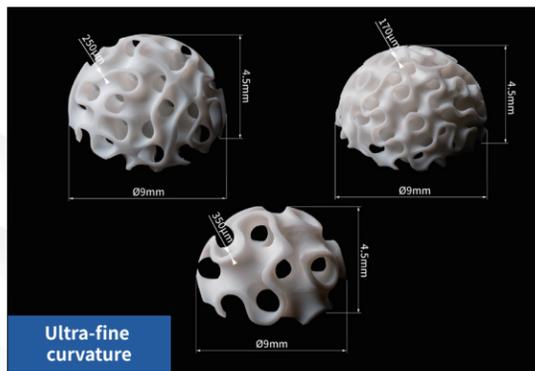
Dimensions: 4 mm × 4 mm × 6 mm  
Rod diameter: 55 μm  
Material: PR-TO-A-05  
Processing time: 25 min



Octahedral lattice structure

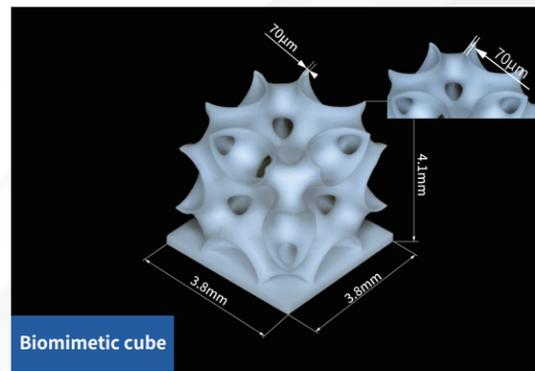
Dimensions: 4.5 mm × 4.5 mm × 5 mm  
Minimum Rod Diameter: 30 μm  
Material: PR-TO-A-05  
Processing time: 65 min

## PL-3D Ceramic-based fabrication showcase

5  $\mu\text{m}$  Optical precision

Ultra-fine curvature

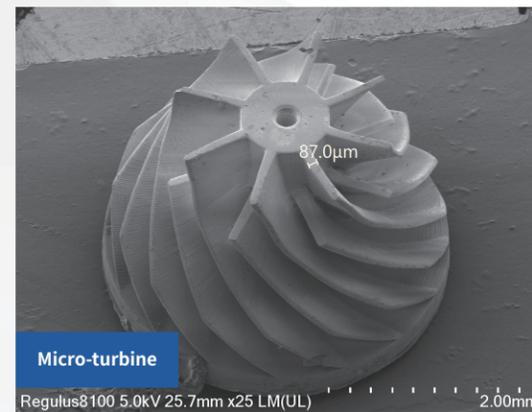
Dimensions: 9 mm  $\times$  9 mm  $\times$  4.5 mm  
 Minimum wall thickness: 170  $\mu\text{m}$   
 Material: CA03 (Aluminum oxide)  
 Processing time: 95 min

5  $\mu\text{m}$  Optical precision

Biomimetic cube

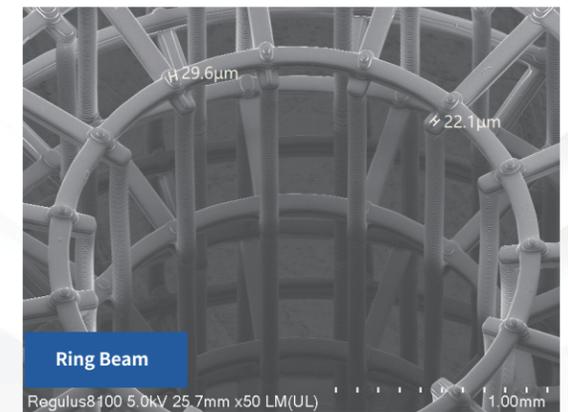
Dimensions: 3.8 mm  $\times$  3.8 mm  $\times$  4.1 mm  
 Wall thickness: 70  $\mu\text{m}$   
 Material: CA03 (Aluminum oxide)  
 Processing time: 35 min

## PL-3D Scanning electron microscope measurements

5  $\mu\text{m}$  Optical precision

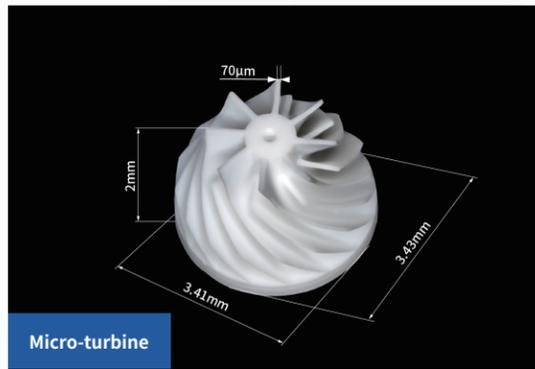
Micro-turbine

Dimensions: 3.41 mm  $\times$  3.43 mm  $\times$  2 mm  
 Wall thickness: 87  $\mu\text{m}$   
 Material: CA03 (Aluminum oxide)  
 Processing time: 12 min

2  $\mu\text{m}$  Optical precision

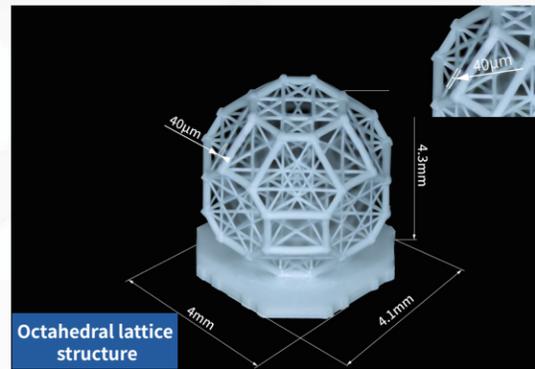
Ring Beam

Dimensions: 5 mm  $\times$  5 mm  $\times$  6 mm  
 Minimum wall thickness: 22  $\mu\text{m}$   
 Material: PR-TO-A-05  
 Processing time: 45 min



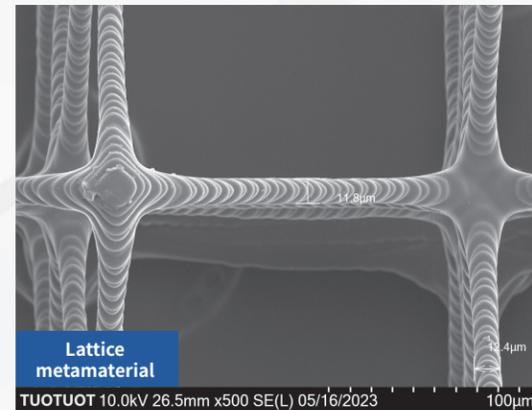
Micro-turbine

Dimensions: 3.41 mm  $\times$  3.43 mm  $\times$  2 mm  
 Wall thickness: 70  $\mu\text{m}$   
 Material: CA03 (Aluminum oxide)  
 Processing time: 12 min



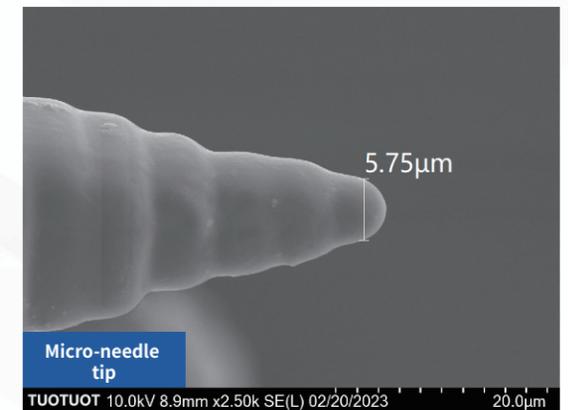
Octahedral lattice structure

Dimensions: 4 mm  $\times$  4.1 mm  $\times$  4.3 mm  
 Minimum rod diameter: 40  $\mu\text{m}$   
 Material: CA03 (Aluminum oxide)  
 Processing time: 35 min



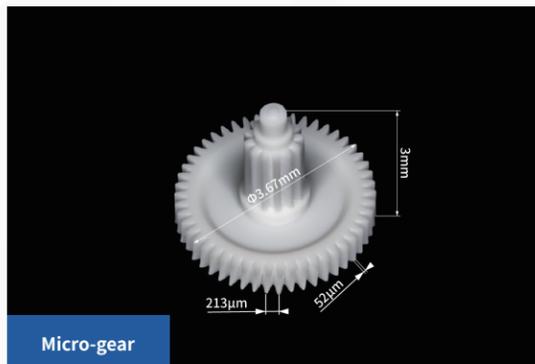
Lattice metamaterial

Dimensions: 1.2 mm  $\times$  1.2 mm  $\times$  1.2 mm  
 Rod diameter: 11.8  $\mu\text{m}$   
 Material: PR-TO-A-05  
 Processing time: 10 min



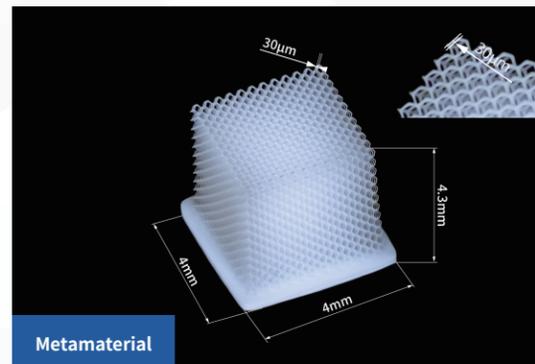
Micro-needle tip

Dimensions: 11.2 mm  $\times$  8.3 mm  $\times$  1.06 mm  
 Tip size: 5.75  $\mu\text{m}$   
 Material: FR-PB-C-01  
 Processing time: 52 min



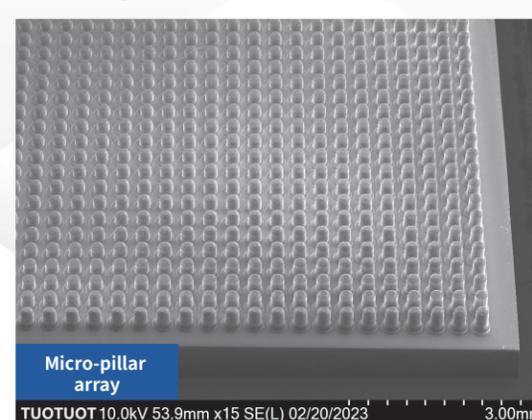
Micro-gear

Dimensions: 3.67 mm  $\times$  3.67 mm  $\times$  3 mm  
 Gear tip: 52  $\mu\text{m}$   
 Material: CA03 (Aluminum oxide)  
 Processing time: 24 min



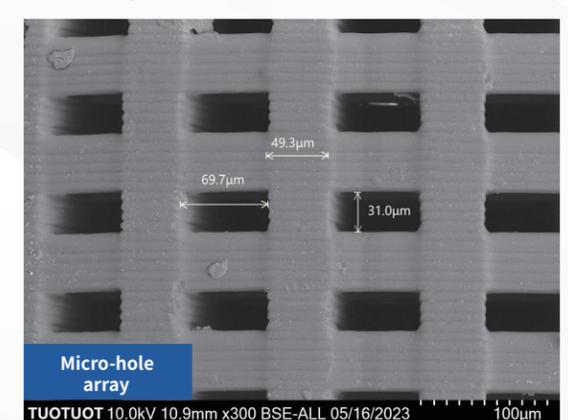
Metamaterial

Dimensions: 4 mm  $\times$  4 mm  $\times$  4.3 mm  
 Minimum Rod Diameter: 30  $\mu\text{m}$   
 Material: CA03 (Aluminum oxide)  
 Processing time: 35 min



Micro-pillar array

Dimensions: 15 mm  $\times$  15 mm  $\times$  1.1 mm  
 Pillar diameter: 203  $\mu\text{m}$   
 Material: FR-PB-C-01  
 Processing time: 160 min



Micro-hole array

Dimensions: 2 mm  $\times$  2 mm  $\times$  10 mm  
 Minimum cross-sectional dimension: 31  $\mu\text{m}$   
 Material: PR-TO-A-05  
 Processing time: 95 min

# Aurogon series Multi-Modal Optoelectronic Microscopy

- ✓ Ultra-wide multi-wavelength excitation light source
- ✓ Light information collected from reflecting microscopes
- ✓ Support measurement modes of fluorescence, Raman, photocurrent, etc.
- ✓ Support sample mobile scanning and galvanometer scanning and other solutions
- ✓ Highly automated system



Photodetector

Solar cell

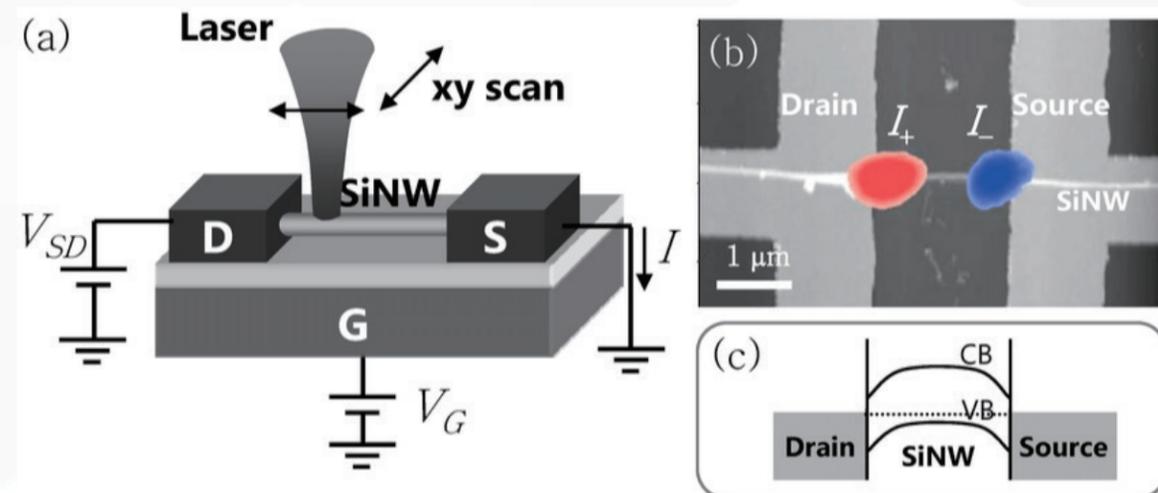
Fluorescence Spectroscopy and Imaging

Nanophotonics

Two-dimensional materials

Based on photocurrent scanning imaging technology, Aurogon series scanning photocurrent microscopes are widely used in material analysis or device analysis.

The charge distribution on the surface of the device is studied by measuring the photocurrent signal on the surface of the device. In semiconductor devices, when light is irradiated to the surface, photon energy is absorbed and electrons are excited, resulting in the generation of electron-hole pairs. These electron-hole pairs may be separated under the influence of an applied electric field or a surface electric field, resulting in photocurrent. Therefore, the charge distribution on the surface of the device can be inferred by measuring the intensity and spatial distribution of the photocurrent signal. Photocurrent imaging technology can be used to study the surface charge distribution, charge carrier distribution, surface potential, and other information of semiconductor devices, which is of great significance to understanding the performance and characteristics of devices.

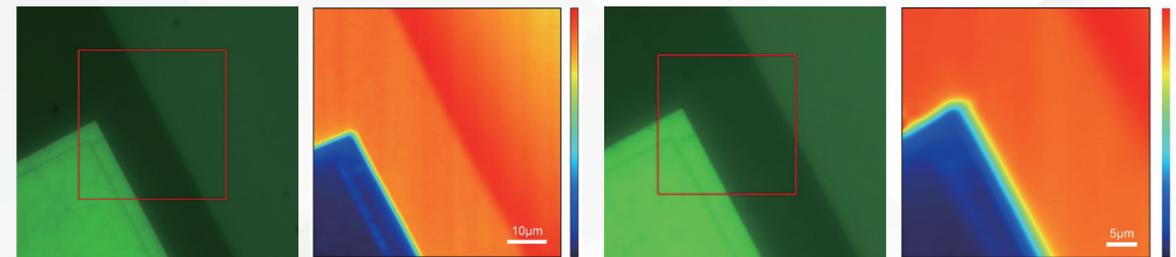


DOI:10.3938/jkps.51.2040

## Application cases

### Solar cell / Photocurrent test

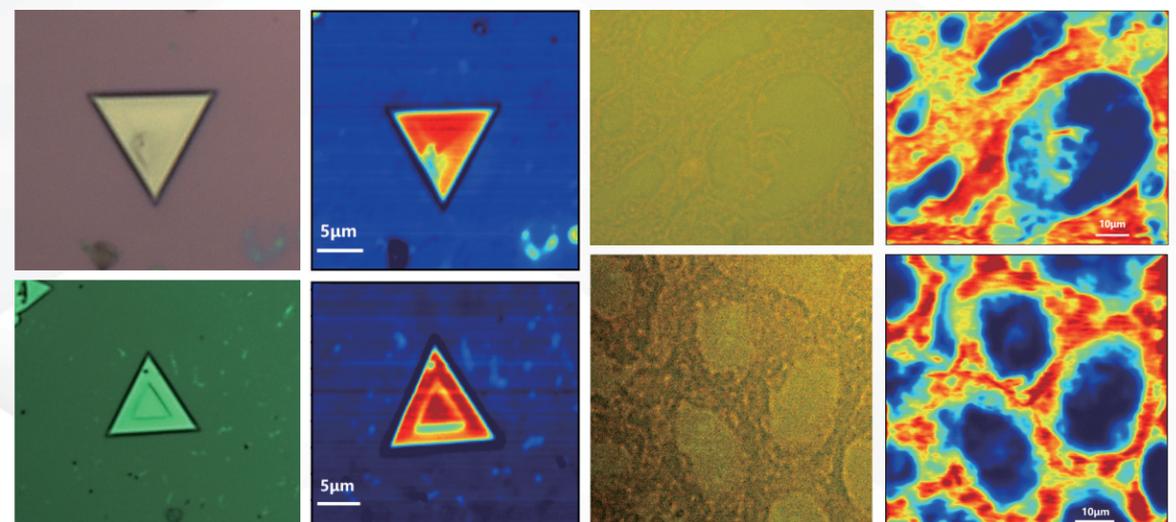
- Photocurrent scanning imaging for devices with dimensions down to submicron level.
- Switchable between stage scanning and galvanometer scanning based on application requirements.
- Switchable between stage scanning and galvanometer scanning based on application requirements, allowing characterization of sample performance in the same area under variable temperature, polarization, and different excitation wavelengths.
- Supports collection and characterization of photocurrent signals from three-terminal devices under different biases.



Silicon-based solar cell scanning results

### Two-dimensional materials / PL Mapping and raman mapping

- Simultaneously collect data on both photocurrent signals and photoluminescence spectra from the sample.
- Raman scanning characterization and research can be conducted on two-dimensional materials.
- Photocurrent scanning of submicron-sized samples at extremely high spatial resolution.

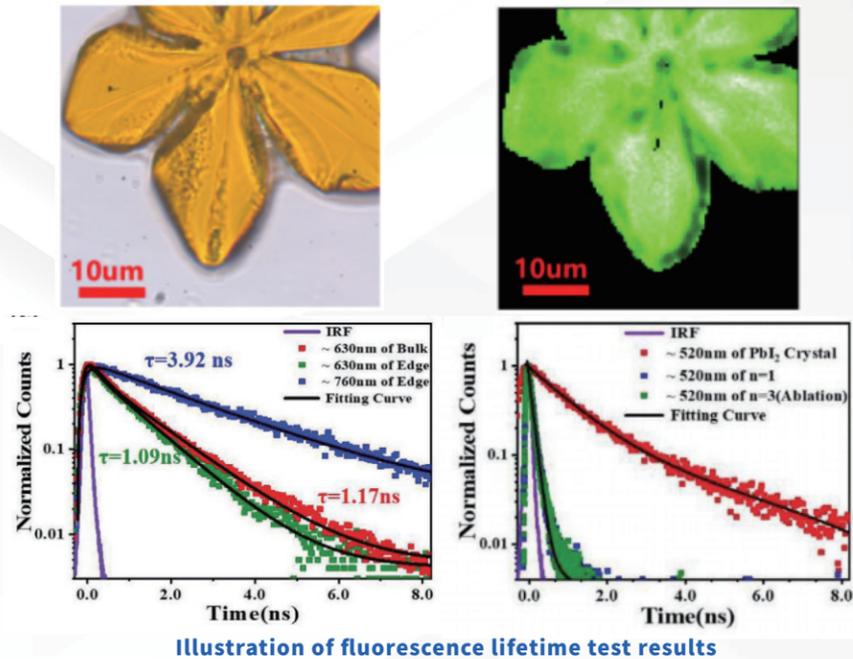


The photoluminescence scanning results of two-dimensional materials

The photoluminescence scanning results of fluorescent samples

## Testing and mapping of luminescent materials/fluorescence lifetimes

- Collect data on photocurrent signals, PL spectra, and fluorescence lifetimes from samples.
- Perform characterization and research of sample Raman characteristics and fluorescence lifetime properties.



## Material micromachining and laser modification

- The femtosecond laser processing schemes using stage-based and galvanometer scanning mirrors enable rapid microprocessing and laser modification of material surfaces.
- A user-friendly processing software that allows customers to customize operations across various materials.

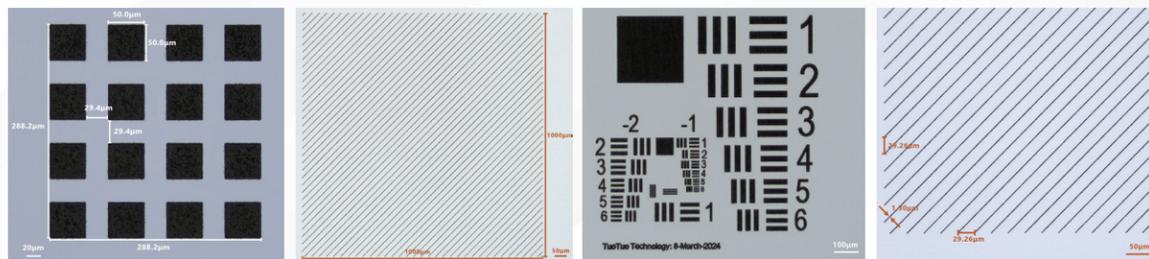


Illustration of the results of laser processing samples

## List of selections

Laser beam combining module: ① Fiber version A ② Fiber version B QCL Quantum cascade laser

Microscopic objective:

- ① Visible light microscope objective ② Near infrared microscope objective  
③ Reflective microscope objective ④ Ultraviolet microscope objective

Low temperature module:

- ① Liquid nitrogen compact cryostat ② Liquid nitrogen low-temperature probe station  
③ Liquid helium high and low temperature cryostat ④ Closed cycle cryocooler

Spectral modules:

- ① Back-illuminated spectrometer ② High-performance imaging grating spectrometer

TCSPC module: ① Board-type TCSPC module ② Multi-channel TCSPC module

## Aurogon series Multi-modal optoelectronic microscopy

Light source	Excitation light source	Standard single-mode polarization-maintaining fiber laser: 405 nm, 520 nm, 1550 nm * Optional choices include picosecond pulse lasers, quantum cascade lasers (QCL), LED light sources, continuously tunable supercontinuum lasers, laser-driven white light sources, and deuterium-halogen broad-spectrum light sources. The light source of the entire set of equipment and the associated optical components such as the associated filter can be completely controlled by computer software.
	Lighting source	Equipped LED white light source with optional R/G/B monochromatic modes
Optical objective lens	Objective lens nasal wheel	A manual 5-hole revolver nosepiece, compatible with microscope objectives from companies like Zeiss, Nikon, and others.
	Objective lens magnification	Visible light far-field correction objective lens: 20 x, 50 x Near-infrared flat-field apochromatic objective lens: 10 x * Microscope objectives optionally available for other wavelengths.
Scanning platform	XY Motion module	The XY direction stroke is 150 mm each, the closed-loop accuracy is 50 nm, the minimum moving step is 100 nm, and the repeat positioning accuracy is 0.25 µm.
	Z-axis motion module	Z-axis load : > 20.0 kg, stroke : ≥ 15 mm, repeat positioning accuracy : ± 1 µm
	Stage	Two axis tilt stage α axis : ± 2°, β axis : ± 2° and wire bonding module * Optional vacuum sample adsorption module
	Probe seat	Four probes with displacement accuracy of 5 µm and coaxial probe diameter of 5 µm, connected with BNC coaxial cable. Breakdown voltage: 500 V, leakage current: < 10 pA * Ultra-low leakage coaxial probe, RF probe and non-magnetic probe are optional, according to the application requirements.
Electrical transport test module	A sample tray	With four room temperature sample holders, with leakage current is less than 100 pA.
	Electrical transport expansion box	An electrical transport expansion box, featuring 15 BNC female ports, designed to extend and expand connections to densely packed test points for electrical signal detection. It includes 1 ground connection interface to prevent electrostatic discharge damaging the samples.
Source meter	Four-quadrant precision voltage and current source meter	· Maximum current source range 1 A · Maximum voltage source range 200 V · Measurement resolution (current / voltage) 10 fA / 10 nV
	Lock-in amplifier	· Differential or single-ended input mode · Current or voltage signal input mode · Gain setting range from 2 nV to 1 V (full range range) · Frequency response range from 0.001 Hz to 102.4 kHz · Automatic adjustment of gain, phase, dynamic reserve, compensation setting time constant range: 10 µs to 30 ks · Dynamic Reserve : > 100 dB · Computer interface : GPIB and RS-232
Optical table	Optical table	Vibration isolation platform

# Integrated Kerr Microscope with Probe Station

## Smart illumination

- High Brightness (4X brighter than market product)
- Optimized for IMA films
- Better illumination uniformity

## Multifunction microscope

- Linear polarized light & circular polarized light
- Improved achromatic aberration
- Motorized focusing unit & high precision analyser

## Versatile magnetic field

- PMA up to 1.4 T @1 cm gap (good uniformity)
- IMA up to 1.0 T @1 cm gap & 0.36 T @4 cm gap for cryostat & 0.35 T with in plane vector field
- Fast switching between electromagnetic fields

## High-end camera

- Ultra-high dynamic range 30,000:1 (10X improved)
- High quantum efficiency >80% (1.2X improved)
- High speed capture & high resolution

## DC/RF Probe

- Compatible electronic equipment (Keithley 6221, Keithley 2400, etc.)
- Compatible RF SMU
- Compatible wire bonding

## High-precision optical table

- Active antivibration platform with air compressors
- Upgrade option electronically active vibration isolation



## Introduction

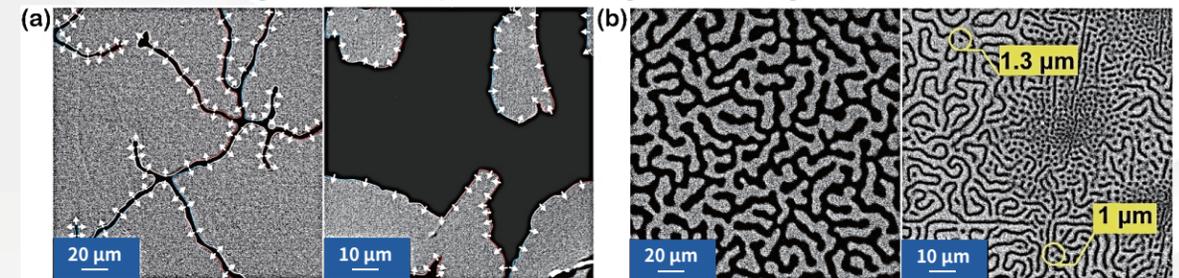
Spintronics has been widely interested for its applications in many areas. From magnetic sensors to nonvolatile magnetic storage and investigating materials properties, spintronics is not only playing an important role of the hot spot in the scientific research, but also attracts significant attention in the industry. The ability to directly detect and record the state of the magnetic domain in material research is important for magnetism related studies. This is because observation of the domain wall motion provides an intuitive picture of magnetic switching which elucidates the underlying physics.

Compared to traditional static magnetic hysteresis loop analyzer, the integrated Kerr microscope test platform has the ability to image real time magnetic information with sub micron resolution. The system's DC probes and high-frequency probes offer versatile methods for driving magnetic switching. In spintronics research, progress has evolved from magnetic field-driven switching to various methods, including DC current, pulse current, microwave pulse, and optical pulse-driven magnetization switching.

The integrated Kerr microscope test platform has an ability to track the real time magnetic information with millions of data point acquisition. The spatial resolution of the magnetic domain is better than  $0.5 \mu\text{m}$ , and the angular resolution of the magneto-optical Kerr is better than  $0.0001 \text{ deg}$ . The standard system provides external magnetic field and bias current, which is a powerful technical method for spintronics research.

## Application Cases

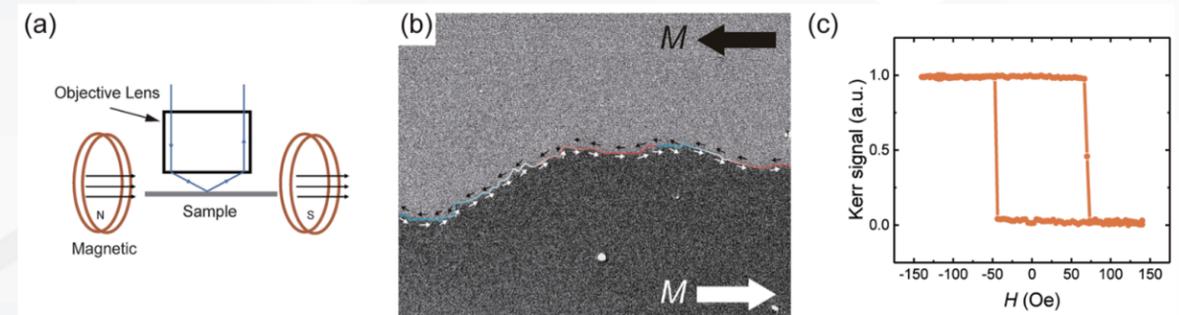
### 1. Perpendicular magnetic anisotropy films (Ferromagnetic/ferrimagnetic thin film)



(a) Field driven domain wall motion. Dendritic magnetic domain in Ta (4 nm)/CoFeB (0.7 nm)/MgO (2 nm)/Ta (2 nm) heterostructure. The small white arrows indicate the direction of the magnetic moment in the Neel domain walls and indicate the direction of domain wall motion.

(b) Skyrmions-based memory (SK-RM). Labyrinth-like domain in CoTb (6 nm)/SiN (4 nm). The 1  $\mu\text{m}$  size of skyrmions bubble has been captured, which can be formed at near-zero magnetic field.

### 2. In-plane magnetic anisotropy films

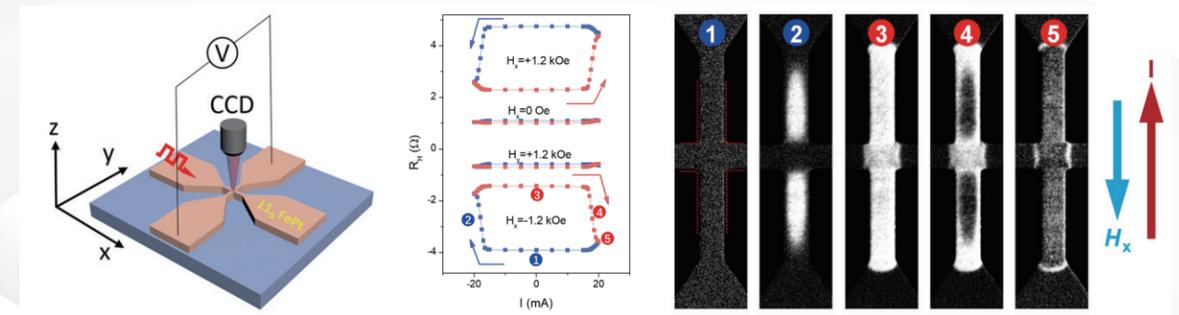


(a) Longitudinal Kerr setup

(b) Magnetic field driven domain wall motion in Pt (4 nm)/Co (5 nm)/Ta (2 nm) sample. The domain wall contrast is significant and it is easy to distinguish the directions of domain wall motion.

(c) Kerr signal vs magnetic field.

### 3. Current induced magnetic switching



Hall measurements and current induced magnetization switching in  $L1_0$  FePt.

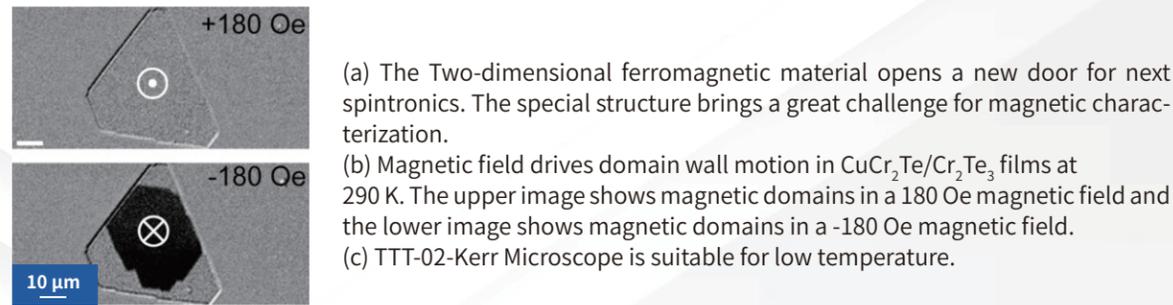
(a) Schematic for measurements of current induced magnetization switching simultaneously recorded by Hall voltage measurement and Kerr microscopy imaging.

(b) Hall resistance  $R_H$  versus pulsed DC current  $I$ . External magnetic field is indicated with each curve.

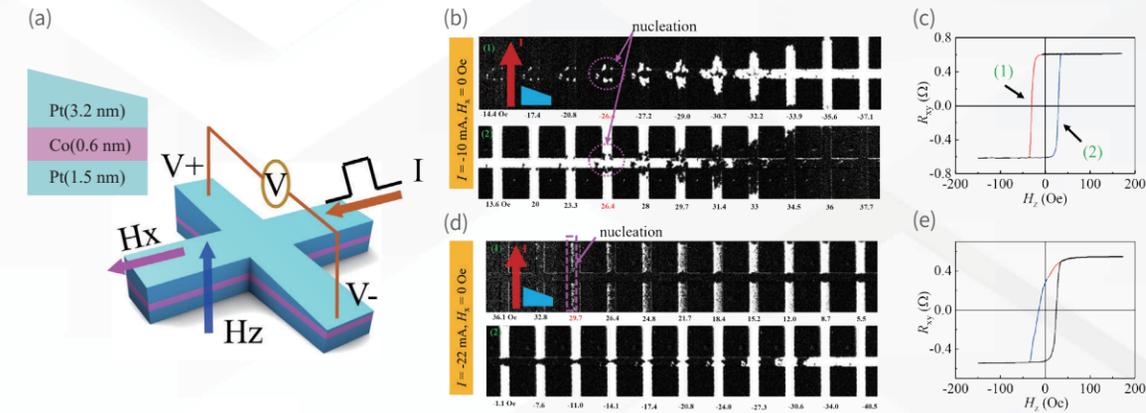
(c) Kerr images recorded for the states 1-5 as indicated in (b).

## Application Cases

### 4. Domain wall switching of two-dimensional ferromagnetic films CuCr<sub>2</sub>Te/Cr<sub>2</sub>Te<sub>3</sub>



### 5. Gradient spin current accumulation

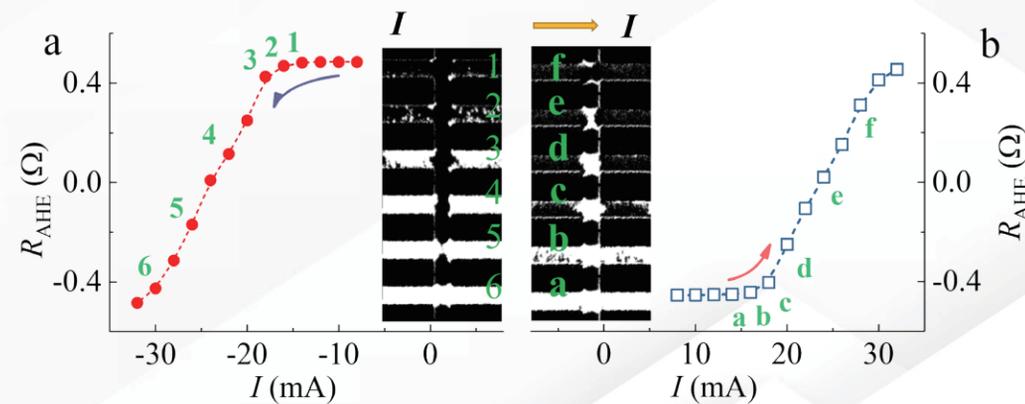


(a) Measurement setup of Pt (up to 3.2 nm)/Co (0.6 nm)/Pt (1.5 nm) wedged sample.

(b) and (d) show the magnetic domain wall measurement with varying DC values ( $I = 10$  mA,  $H_x = 0$  Oe)/( $I = 22$  mA,  $H_x = 0$  Oe). When the DC value is small, the magnetic domain wall grows at the cross. As the DC current increase, the magnetic domain wall grows at the one side of the Hall bar arm.

(c) and (e) show the anomalous Hall resistance with small ( $I = 10$  mA) or high ( $I = 22$  mA) DC current at  $H = 0$  Oe

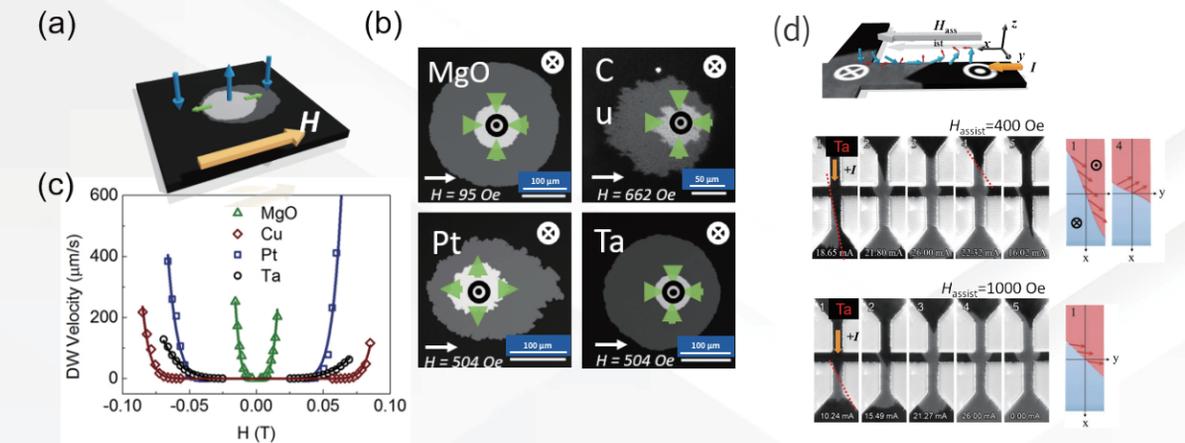
### 6. Field-free switching due to high z-component spin polarization current



Pulse current induced domain wall motion and switching at  $H_z = 0$  Oe,  $H_x = 0$  Oe. MOKE images of current switching in Hall bar of Pt (1.5 nm)/Co (0.6 nm)/Pt (wedge) for (a) increasing  $-I$  in the order of 1, 2, 3,... 6 and (b) increasing  $+I$  in the order of a, b, c...f (at  $t_{topPt} = 2.5$  nm).

## Application Cases

### 7. DMI effective field and domain wall velocity measurement



(a) DMI effective field ( $H_{DMI}$ ) measurement setup.

(b) The anisotropic domain wall expansion with an in-plane magnetic field.

(c) The asymmetric domain wall creep velocity as a function of the applied in-plane magnetic field for different capping layer films.

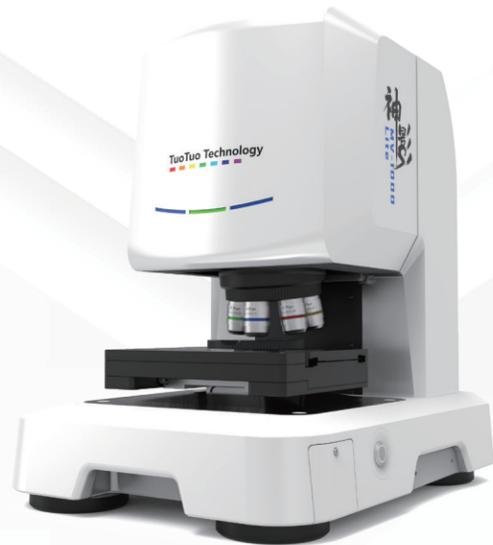
(d) (b) Schematics of the tilted magnetic domain wall due to the  $H_{DMI}$ .

### Key parameters (TTT-02-Kerr Microscope)

<b>Instrument body</b>	Active antivibration platform with air compressors
<b>Optical main body</b>	Microscope main body, High resolution auto analyzing module, High resolution motorized focus module, None-magnetic, ultra-long working distance objective lens.
<b>Light source</b>	Smart lighting system with tunable radiation angle (resolution 2degree, @ 50 X, NA 0.55). Support arbitrary radiation pattern with programmable light intensity for each R, G, B light source.
<b>Magnetic field</b>	<ul style="list-style-type: none"> <li>Perpendicular magnetic field: Maximum 1.4 T@1 cm gap; Maximum 0.7 T@2.3 cm gap for cryostat;</li> <li>In-plane magnetic field: Maximum 1.0 T@1cm gap; Maximum 1.4 T@0.5 cm gap; Maximum 0.36 T@4 cm gap for cryostat.</li> <li>Non-uniformity of the magnetic field under the field of view of the objective lens is less than 2%</li> <li>Air cooling</li> <li>Magnetic field read resolution:0.01 mT</li> </ul>
<b>Variable temperature</b>	<ul style="list-style-type: none"> <li>77 K - 450 K with liquid nitrogen</li> <li>4.2 K - 450 K with liquid helium</li> <li>10 K - 450 K with closed-cycle cooling system</li> </ul>
<b>Sample holder</b>	<ul style="list-style-type: none"> <li>XYZ actuators for perpendicular/in-plane magnetic field system</li> <li>Accuracy 3 <math>\mu</math>m with 10 <math>\mu</math>m readable</li> </ul>
<b>Probe station</b>	DC, high frequency probe (configured according to user's requirement)
<b>Electric transport instruments</b>	Compatible with spin measurement equipment such as Keithley 6221 & 2182A, lock-in amplifiers, etc. (configured according to customer requirements).
<b>Device software</b>	The device software integrates various variable controls, including optical control, magnetic field control, gate voltage control, pulse current control, temperature control, etc.

# 3D Microscope

From mm to nm  
Multifunctional microscope  
beyond expectations



0.01 nm

1 nm

1000 mm

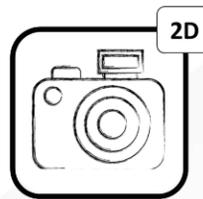
Surface roughness repeatability: 0.01 nm

Surface topography repeatability: 1 nm

Sample size up to 1000 mm, customizable

- Tool microscope
- Extended depth of field microscope
- Nanometer-level topography

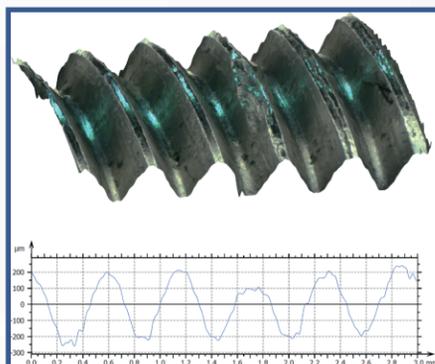
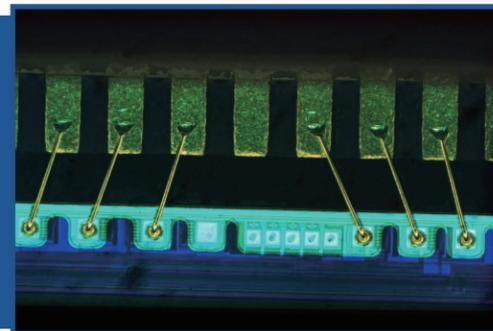
## Products



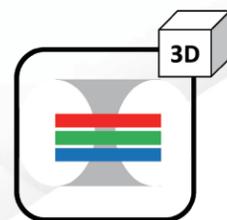
2D

Depth of field fusion  
Clear 2D imaging

Due to the small resolution of the objective lens and the long depth of field, it is not possible to obtain high-resolution images through a single shot. In order to observe small-sized features and structures within a long depth of field, we adopt the technique of depth of field fusion, enabling the simultaneous observation of high-resolution images at different depths of field.

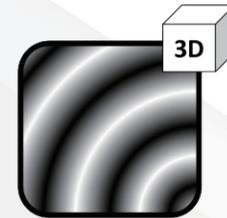


Extended depth of field is achieved by analyzing the contrast changes at different focus heights, allowing for three-dimensional topography measurement and feature description of objects. This method enables detailed examination of the object's surface and provides precise three-dimensional imaging with a long depth of field.



3D

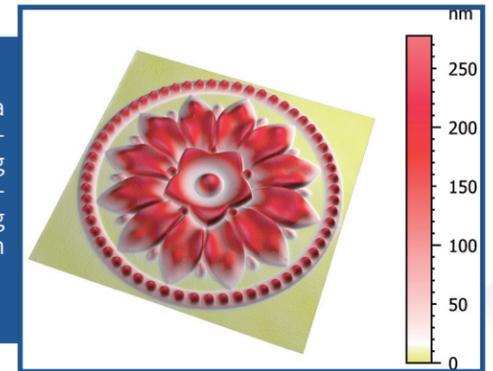
Extended depth of field  
Extended depth of field 3D imaging



3D

White light interferometry  
Nanometer-level topography

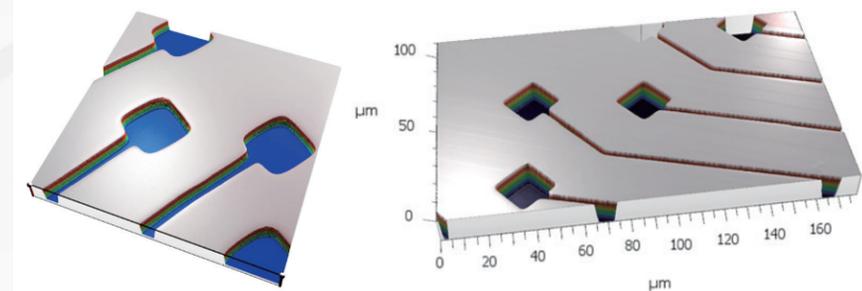
White light interferometry is a fast and high-resolution technique used for wide-ranging surface topography measurements, capable of achieving sub-nanometer resolution topography.



## Application Scenarios

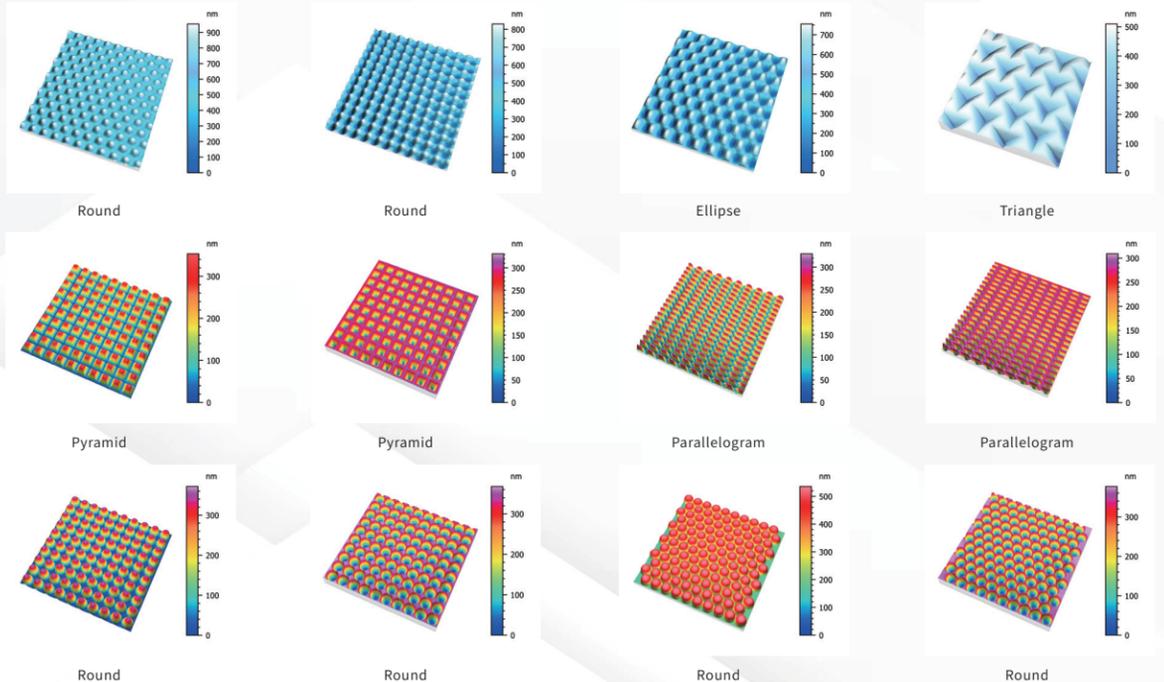
Miracle Vision series offer non-contact measurements with high repeatability which is suitable for the measurement of topography, roughness, length, curvature, depth, volume, particle distribution, etc. of semiconductor chips, optical lenses, metal surfaces, and automotive coatings. Miracle Vision series can detect surfaces of devices with various roughness and reflectivity, and measure device surface dimensions ranging from nanometers, micrometers to millimeters, all achievable with the same equipment, resulting in applications in aerospace, medical, material and scientific research fields. They provide a wide range of measurement parameters based on mainstream international standards, visualizing and digitizing details, all completed in a single operation.

### Semiconductor

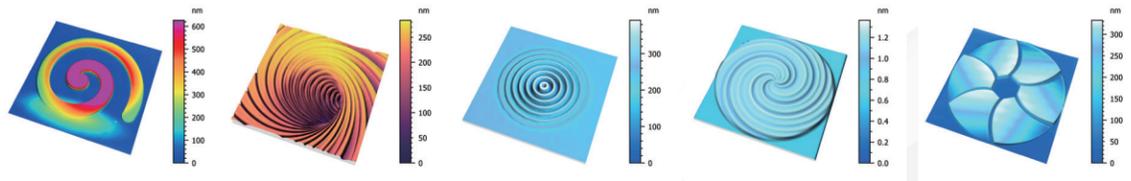


Micrometer sized electrodes

### Material Science

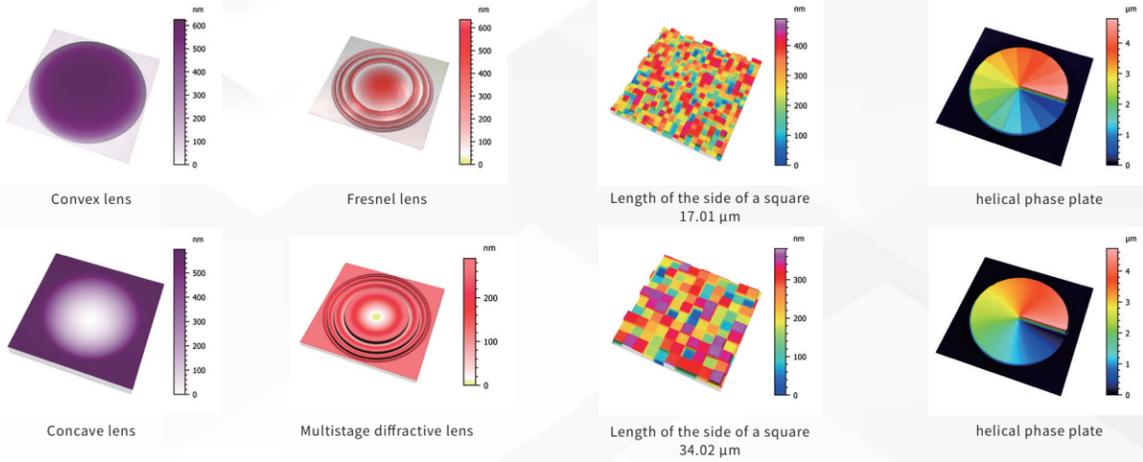


**Nanotechnology**



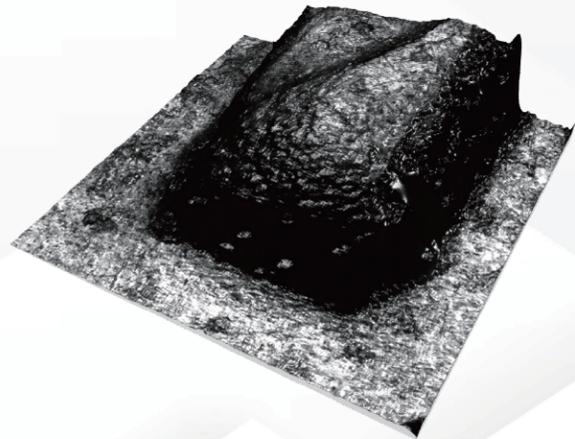
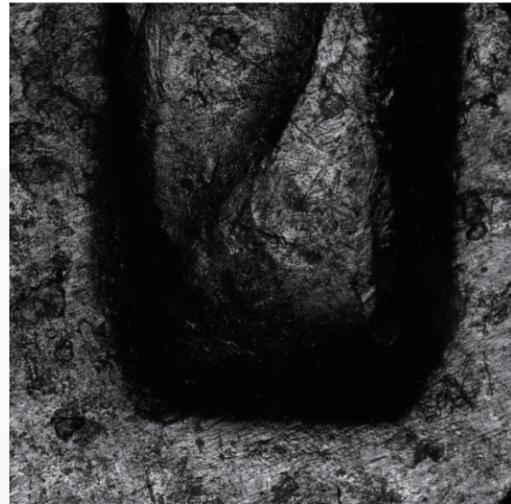
Gray-scale lithography / nanofabrication

**Optics**

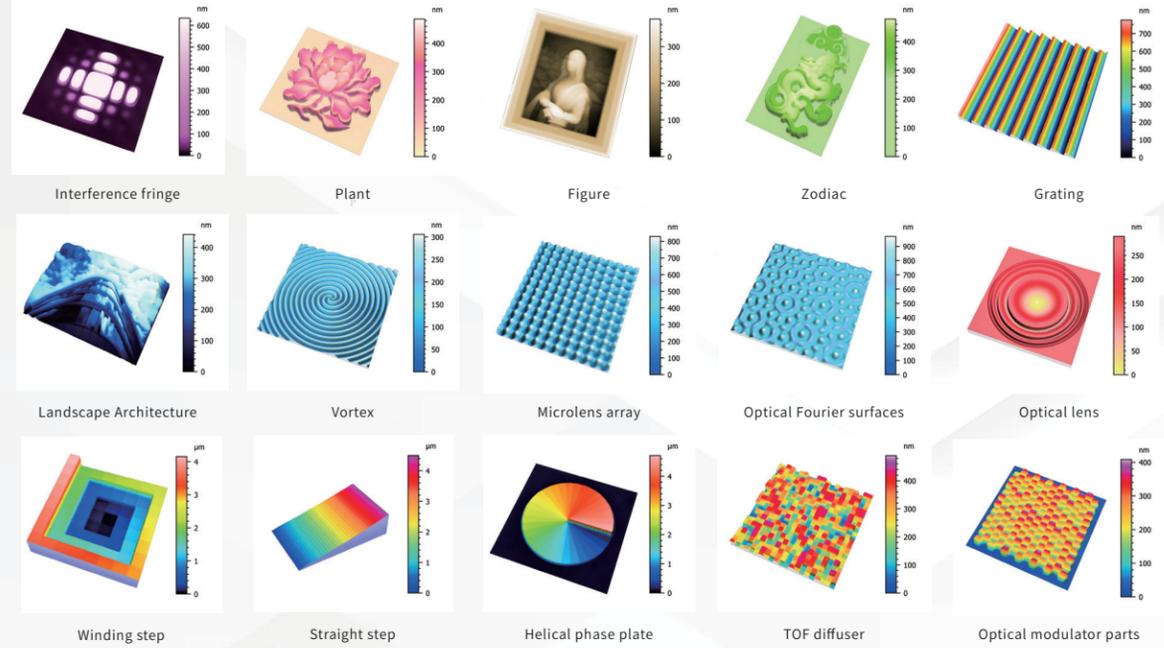


**Depth of field fusion**

**Extended depth of field**



**White light interferometry**



**Miracle Vision system specifications**

<b>Measuring principle</b>	PSI, CSI, tf-PSI, and FV	<b>Measurement types</b>	Image, thickness, Profile and coordinates etc.
<b>Camera</b>	4 Mpx: 2048 x 2048 pixels	<b>LED light source</b>	White (575 nm; centre)
<b>Vertical scan range coarse</b>	50 mm range; 5 nm resolution	<b>Optional advanced software analysis</b>	TView, TAnalysis
<b>XY stage range</b>	Manual: 80 x 50 mm	<b>XY Stages</b>	Manual or mototized
<b>Objective turret</b>	5 position fully motorized	<b>Tilt angle</b>	±3°
<b>User management rights</b>	Engineer, administrator and operator		

**Performance**

<b>Surfac opography Repeatability</b>	0.25 nm	<b>Repeatability of RMS</b>	0.01 nm
<b>Optical Lateral Resolution</b>	340 nm (100 X objective)	<b>Spatial Sampling</b>	55 nm (100 X objective)
<b>Max. Data Scan Speed</b>	6.48 μm/s @ 2048 x 2048 (PSI); 21.96 μm/s @ 2048 x 2048 (CSI)		
<b>Step Height Repeatability</b>	0.1 %		

**Test Part Characteristics**

<b>Material</b>	Opaque, transparent, coated, specular, rough		
<b>Sample weight</b>	Up to 1 kg	<b>Sample height</b>	Up to 50 mm

# High-performance optical motion stage

- Direct-drive motor with magnetic force
- Closed loop position feedback for high precision
- Zero backlash, standard step accuracy 50 nm  
Bidirectional positioning accuracy <200 nm
- Fast response, high-speed motion, up to 1000 mm/s

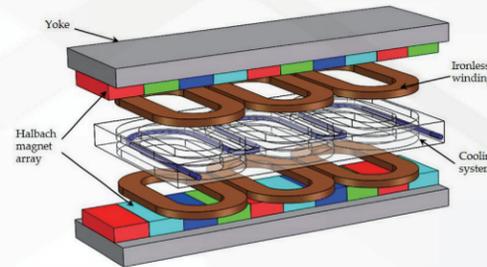


The iMotion standard product series offers high-quality solutions for the semiconductor industry.

## Ironless linear motor

Traditional DC, AC or stepper motors use lead screws and/or other components to convert rotational motion into linear motion. While linear motors are directly driven by electromagnetic force to achieve linear motion. This allows the stage to achieve frictionless high speed and high acceleration motion. Additionally, there is no backlash in the linear motors.

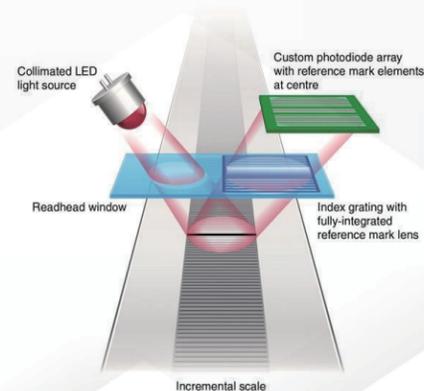
Compared with iron-core motors, ironless motors have the advantage of ultra-high precision motions. Without the iron core, the motion units will not be strongly affected by the permanent magnet allowing for smooth and controlled linear



Schematic of ironless linear motor structure

## High-precision grating

The iMotion series use a non-contact, ultra-high-precision optical encoder (grating scale) to directly measure the position of the motion platform, also known as a closed loop system. Motion control of the standard stage can achieve a high-precision of 50 nm incremental motion and +100 nm bidirectional repeatability. In contrast, in the conventional lead screw driven platform, the position reading is calculated from the rotation of the motors, combined with the transmission ratio measurement. Due to the non-linear mechanical parts, gaps between the mechanical components, temperature variation and elastic deformation, the control of the position accuracy typically cannot meet the needs of optical microscopy applications without a linear position feedback.



Schematic of high-precision grating

## Application

- Thanks to the high precision and high speed of the iMotion series, the products are widely used in the photocurrent/spectroscopy and photolithography system.
- iMotion Series is also a premium choice for semiconductor inspection/processing, biological scanning imaging, medical diagnosis, optical device inspection, etc.

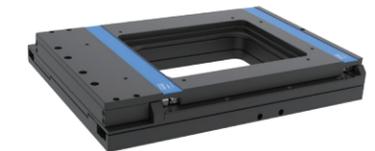
## Products



Linear lens changer



Motorized turret



Ultra-thin hollow XY stage



Motorised rotation stage



Precision XY stage



Multi-axis motion platform

In the optical inspection and processing industry, it is necessary to automate standard microscopes. The right side figure shows the combination of a thin XY translational stage and an optical microscope. Our products are highly customizable to be integrated with main stream microscopes, such as Nikon, Olympus and Carl Zeiss according to the customer request. The laser based auto-focus module paired with the motorized Z-axis stage is one of our standard products.



Ultra-thin XY stage

Hollow design, high speed, high accuracy



Compatible with microscope

Easy to integrate, both transmission & reflection modes

## Case study: Stages in lithography/laser manufacturing

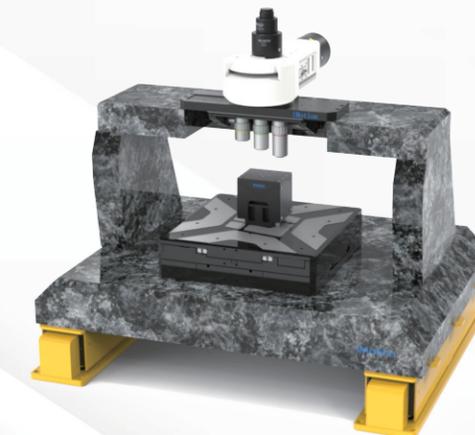
The following figure is an image of the standard motion control system in lithography/laser manufacturing

Four axes: X, Y, Z, O (Linear Objective changer)

Feedback to the Z axis by auto-focus modules to achieve real-time focusing

Wafer scale, high-precision lithography stitching in XY plane

The equipment is installed on an active vibration isolation system



Application of the XYZO four-axis stages

# High- and Low-Temperature MicroStat



## End-to-End Solution Delivery

Turnkey low-temperature solutions that are user-friendly and easy to maintain.



## Low Vibration

Specially designed to significantly reduce sample-end vibrations, making it particularly suitable for high-precision and low-temperature experiments under a microscope.



## Compatible with Micro-spectroscopy

Focusing on microscopy, and easily compatible with various magnification objective lenses.



## Compatible with transport characteristics

Providing two options, low-temperature probe stations or wire bonding.



## Compatible with ultra-broadband spectrum

Various options for optical windows, selected based the interested spectral range.

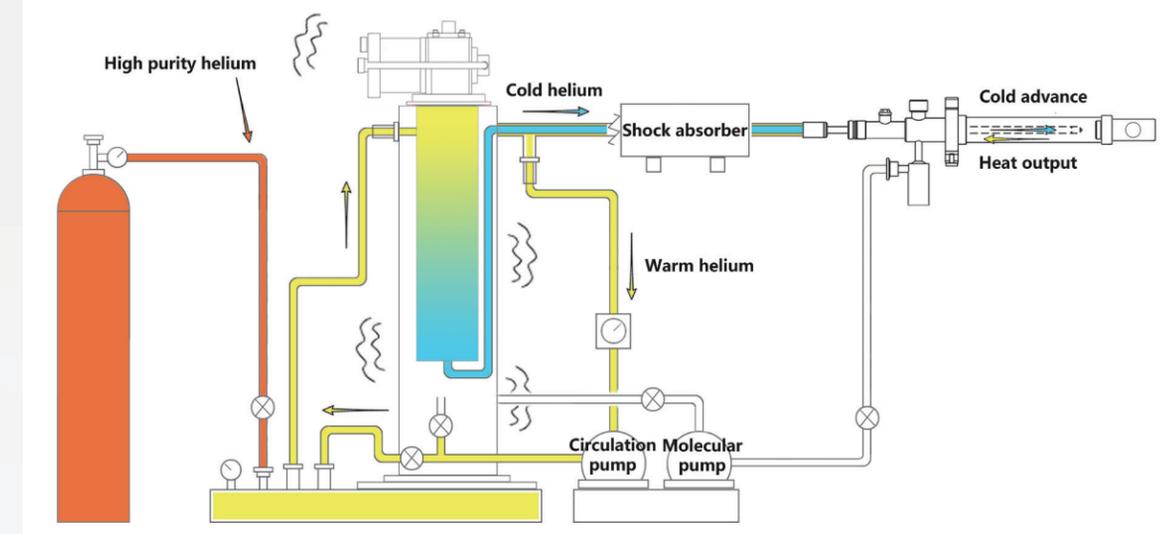


TuoTuoTech's low-temperature cryostats are specialized for microscopy and transport measurements. Furthermore, we offer customised sample holders, plug-and-play transport extension boxes, and low-temperature cryostats and probe stations that are tailored for low-temperature transport measurements, accommodating various SMU meters.

### Key parameters (TTT-CCC-03)

Temperature range	5 - 500 K
Dimensions of cryostat <sup>1</sup>	426 mm × 200 mm × 120 mm
Vibration level at Cryostat	<100 nm
Electronic connectors	Default 16-pin plug-socket pairs × 2, 14 pins among them are user definable, and upgradable to 25-pin
Optical windows	Default double-sided polish quartz window, effective aperture 18 mm on both side of cryostat, and changeable according to preferred spectral range
Temperature sensor	Silicon diode sensor, suitable for 5 - 500 K
Heater	Nichrome wires
Cooling time	4 hours
Heating time	~24 hours

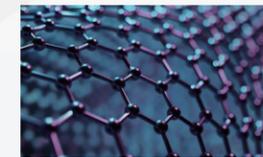
## Schematics



### ▲ Schematics of Closed-Cycle Cooling System

The refrigerant is provided from ultrahigh purity (>99.999%) cylinder where the helium gas flows from the cylinder to the gas buffer volume which is subsequently cooled in the cold head shield. The cooled gas/LHe flows through flexible transfer line, reaches the cold finger to cool down sample holder. The "warm" helium gas then returns to the buffer volume which is then cooled by the cold head again to complete the gas closed-cycle loop.

## Application Fields



Two-dimensional materials, quantum dots



Fluorescent materials

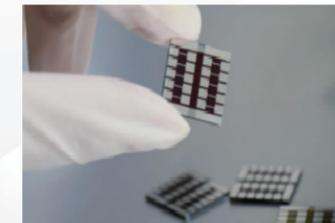


Semiconductors

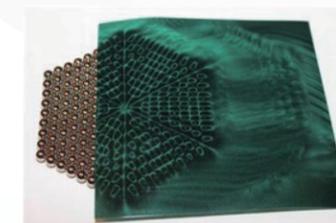


Magnetic materials

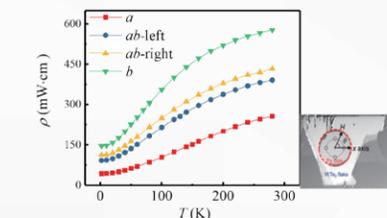
## Application Cases



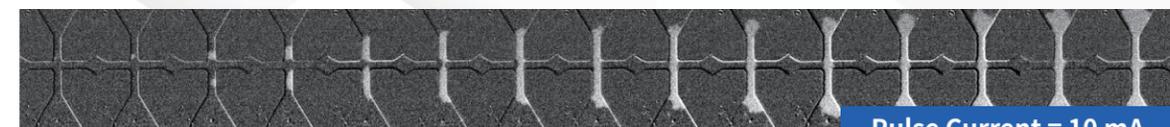
Photodetectors



Magnetic materials



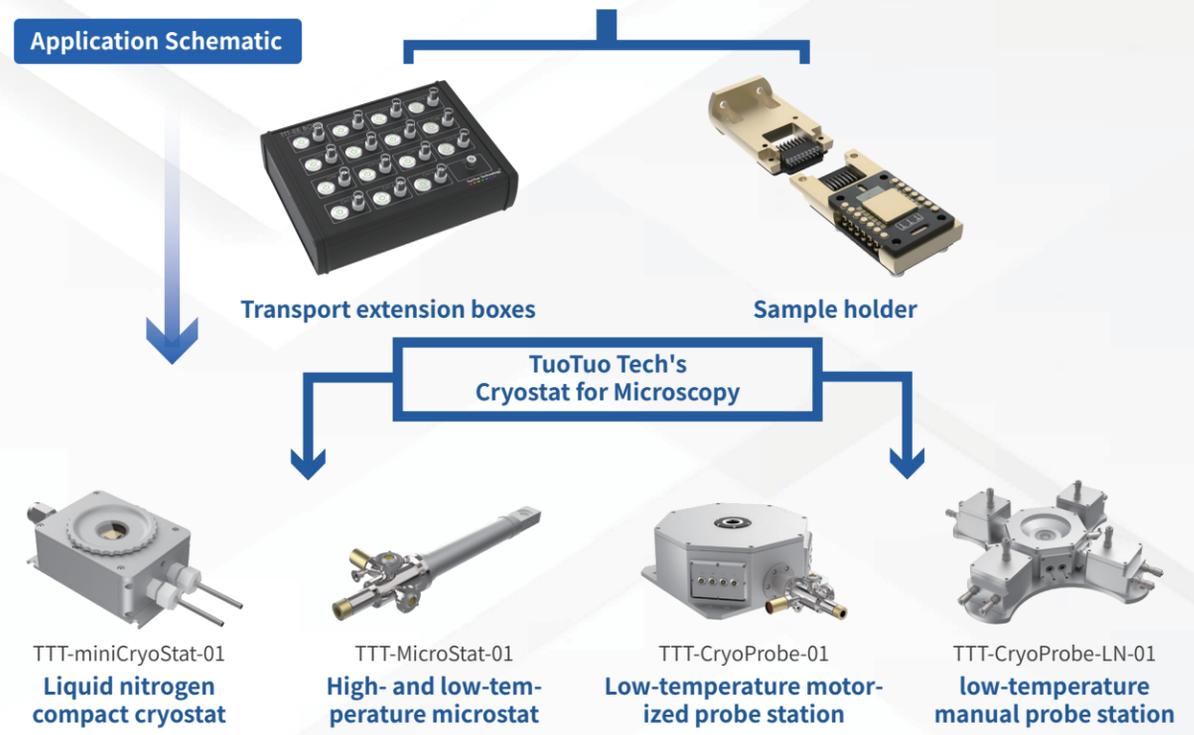
Temperature-dependent resistance for various orientations of two-dimensional materials



▲ Magneto-optical Kerr effect at low-temperatures

## High- and Low-Temperature Solutions

TuoTuo Tech's cryostats focuses on microscopy and electrical transport measurements. We have designed specially sample holders, plug-and-play electrical transport extension boxes, and highly compatible microstates and low-temperature probe stations that can adapt to various Source Measure Units (SMUs), which are tailored specifically for low-temperature electrical and/or optical measurements.



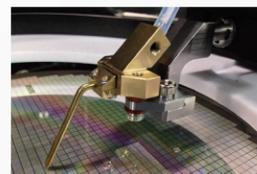
### The equipment includes:

- Compact cryostat
- 26 user-defined electrical control channels
- Nitrogen recirculation pump
- Temperature controller
- Vacuum pump (optional)
- Liquid nitrogen, or liquid helium Dewa (optional)

### The equipment includes:

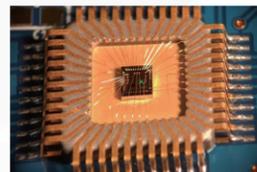
- TTT-MicroStat-01 cold finger
- Octagonal cryostat
- Top measurement window, side observation window
- 4 high-precision XYZ motorized/manual translation stages
- 12 interchangeable electrical interfaces

## Transport Measurement Mode



### Probe Mode (suitable for batch sample testing)

- Features:
- Coaxial cables to reduce system background noise
  - Non-magnetic probes to minimize environmental magnetic field interference



### Wire Bonding Mode (suitable for electrostatic discharge testing)

- Features:
- Aluminum/gold wire bonding for more stable Ohmic contact
  - Larger working distance, suitable for high-magnification testing

## Key Specifications

Key parameters		
Model	TTT-miniCryoStat-01	TTT-MicroStat-01
Refrigerant	Liquid Nitrogen	Liquid Helium
Temperature Range	77 - 450 K	4.2 - 450 K
Temperature Stability	0.1 K	0.1 K
Cooling Time	30 mins (77 K)	60 mins (4.2 K)
Sample Size	10 mm × 10 mm	10 mm × 10 mm
Working Distance	7.5 mm	11 mm

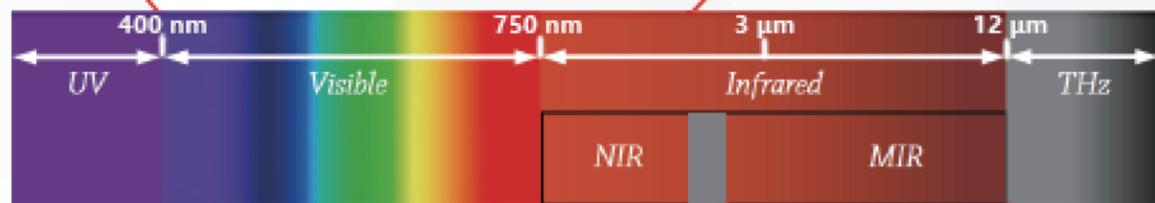
Key parameters		
Model	TTT-CryoProbe-LN-01	TTT-CryoProbe-01
Refrigerant	Liquid Nitrogen	Liquid Helium
Temperature Range	77 - 450 K	4.2 - 450 K
Temperature Stability	0.1 K	0.1 K
Cooling Time	30 mins (77 K)	60 mins (4.2 K)
Sample Size	10 mm × 10 mm	10 mm × 10 mm
Working Distance	12 mm	12 mm
Probe Movement Range	6.5 mm	6.5 mm
Number of Electrical Channels	16	28

# Laser and Laser Light Source

## UV-VIS-NIR

TuoTuo Technology (Suzhou) Co., Ltd. provides multiple types of lasers with wavelengths covering the UV-VIS-NIR range, including but not limited to 405 nm, 460 nm, 473 nm, 488 nm, 520 nm, 532 nm, 561 nm, 635 nm, 640 nm, 671 nm, 808 nm, 980 nm, 1064 nm, 1310 nm, 1550 nm and other wavelengths, covering the photo-response range of most materials. In addition, TuoTuo Technology (Suzhou) Co., Ltd. provides multi-type laser integration solutions to meet the needs of customers. Our company can now provide standard all-in-one laser beam combining modules, which adopt fiber-coupled output and free-space output. The single-channel laser output power is adjustable (0-20 mW, 0-150 mW), with high stability ( $\pm 0.5\%$ @RMS, 25°C, 8h), adjustable frequency (1-100 kHz), easy operation and other advantages. All types of lasers support software and hardware regulation, and the corresponding control software is open to facilitate customer reintegration.

### 375 nm - 1550 nm Laser Combo



### 4 - 12 μm QCL MIR Laser

#### Fiber optic version of four-in-one laser beam combining module

- ① 405 nm / 460 nm / 520 nm / 635 nm  
Power: 0-50 mW, Frequency: 1-100 kHz  
Stability:  $\pm 0.1\%$  @ RMS, 25 °C
- ② 808 nm / 1604 nm / 1310 nm / 1550 nm  
Power: 0-150 mW, Frequency: 1-100 kHz  
Stability:  $\pm 0.1\%$  @ RMS, 25 °C



TTT-00-Laser Combo

#### Cautions!

- The system is a precision equipment. Please handle it with care.
- The system performance might be affected under severe environments.
- The warranty is void if users dismantle the system without permission.

#### Key parameters (TTT-00-Laser Combo)

Laser wavelength	375 nm - 1550 nm optional		
Laser combo accuracy	Aligned collinearly with position error less than $10\lambda$ in 2 meters		
Laser beam	Fiber	Control mode	LabView program control
Laser output	Continuous wave, collimated beam in free space or through optical fiber, TTL modulation, adjustable modulation frequency (0-100 kHz)		
Laser power	Adjustable, up to 150 mW. Please contact us if higher power is required.		
Beam size	<2 mm gaussian beam	Power stability (typical value)	$\pm 0.1\%$ RMS @ 25°C @ 8 h
*System size	490 mm × 435 mm × 200 mm		
Power supply	220 V, 50 Hz	Operating environment	20 - 40°C, RH < 60%

\*This size does not include electrical wiring .

# Mid-infrared Laser

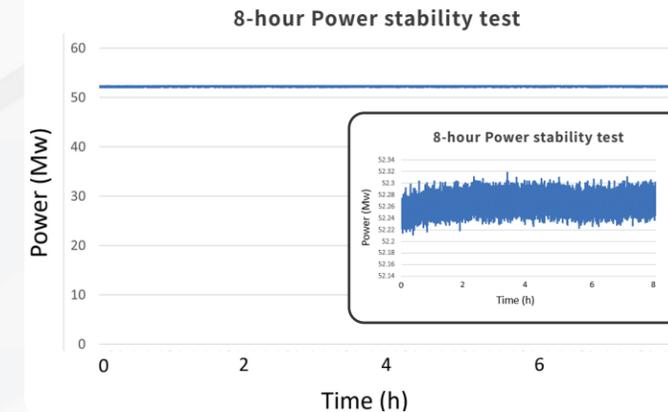


TTT-00-MIR

With the gradual maturity and stability of quantum cascade laser technology, high quality, maintenance-free and cost-effective mid-infrared laser becomes possible. TuoTuo Technology has launched a standardized mid-infrared laser module, which supports one-button operation and has the advantages of stable performance, high power, easy to use and small size. The product is a single wavelength laser module, can be optional wavelength of 4 μm - 10 μm in any band. The default laser power is 50 mW, if you need a higher power (up to 1000 mW), please contact us to customize.

As shown in the left figure, the mid-infrared laser is composed of a laser head and a control box, in which the laser head module is built with a visible laser collimation of mid-infrared laser, greatly simplifying the optical adjustment process of mid-infrared laser. The controller contains a laser drive and temperature controller, which can be adapted to a computer program through a USB control terminal.

#### Laser power stability and beam quality data



#### Key parameters (TTT-00-MIR)

Laser type	Quantum cascade laser (QCL)		
Laser output	Continuous wave, collimated beam in free space or through optical fiber, TTL modulation, adjustable modulation frequency (0-20kHz)		
Wavelength	Selectable from 4 μm to 10 μm, with a single wavelength		
Laser power	Adjustable, up to 50 mW. Please contact us if higher power is required.		
Beam divergence	<6 mrad	Power stability (typical value)	$\pm 0.1\%$ RMS @ 25°C @ 8 h
Guiding laser	Equipped with co-linear guiding light for mid-infrared laser (default 660 nm)		
Control mode	LabView control / Laser control box touchscreen control		
*System size	Laser header: 183.5 mm × 135 mm × 85 mm / Controller: 305 mm × 200 mm × 105 mm		
Power supply	220 V, 50 Hz	Operating environment	20 - 40°C, RH < 60%

\*Dimensions are measured with an error of not more than  $\pm 1$  mm.