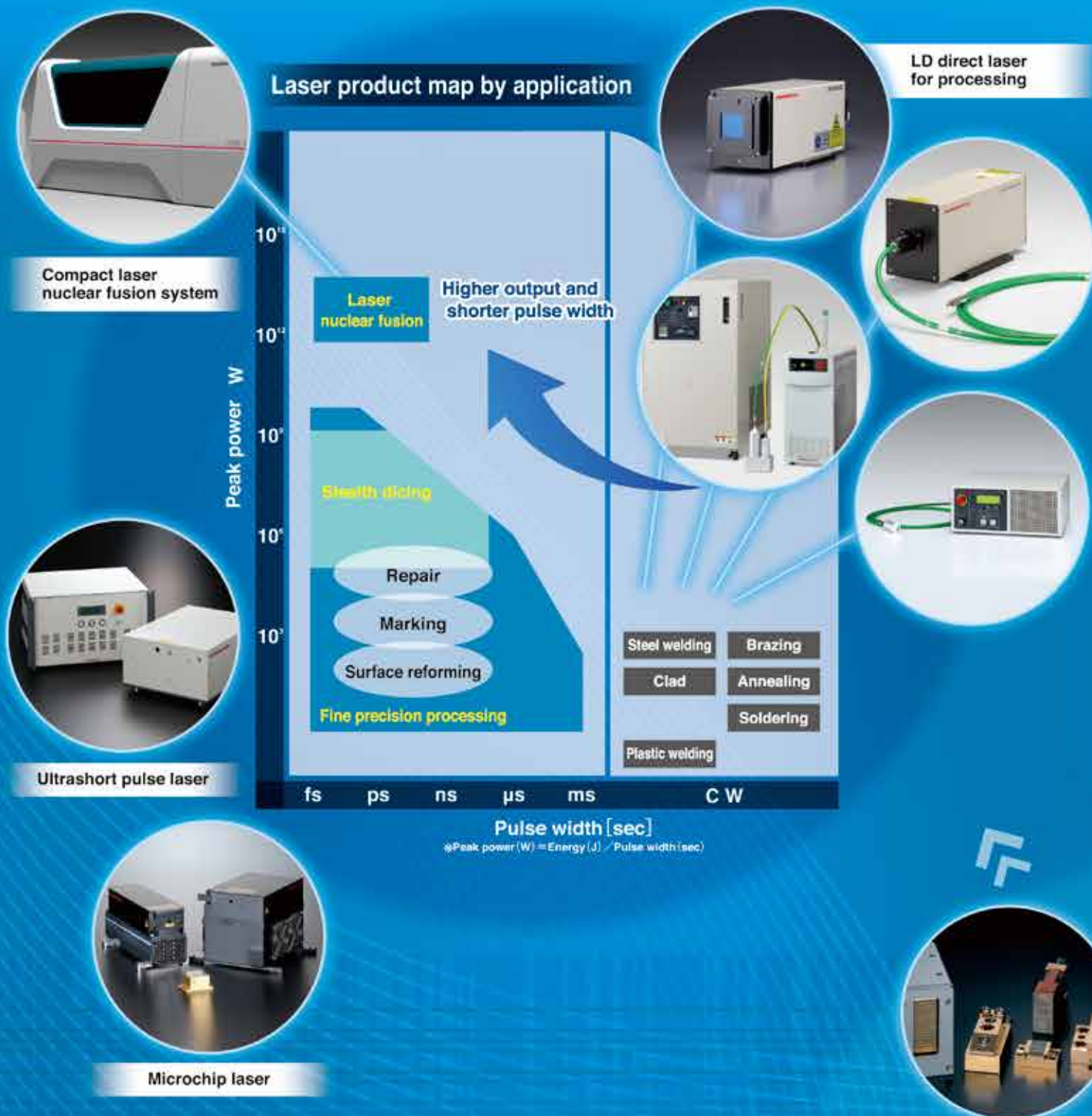


Laser Product Map

Albert Einstein established the theoretical foundations for the laser in 1917, and the first laser was demonstrated in 1960. Since then many types of lasers have been developed and amazing advances have been made in their performance and applications. At Hamamatsu Photonics, based on technologies accumulated through development and production of lasers including gas lasers, semiconductor lasers and solid-state lasers, we are continuing to explore the further possibilities of lasers by merging them with integral optics technology. Here we show a product map of our lasers in terms of the 3 axes of peak power, pulse width (including continuous oscillation) and wavelength along with an overview of laser technology.



Laser map by wavelength



High-reliability lasers developed from our exclusive optoelectronic technologies.

At Hamamatsu, we develop every part of our semiconductor lasers ourselves, from epitaxial growth to chip assembly to drivers. The finished products offer high reliability for many applications. To satisfy your needs, we now offer a variety of application-specific products and diode pumped lasers, and will continue to develop new laser products for new applications in the future.

Typical application examples

Applications		Product name	Semiconductor lasers					
			CW LD	PLD	SLD	Fiber Output Laser Diode	High-power LD Bar Modules	FOLD
								Passive cooling (conduction cooled) type Active cooling (water cooled) type
Medical	Medical (general)		●			●		●
	Blood oxygen monitoring					●		
	Light source for OCT				●			
Measurement	Measurement (general)		●		●	●		●
	Laser rangefinder (leisure, surveying)		●	●				
	Security (traffic, anti-collision)		●	●			●	
	Control, monitoring (robot, alignment)		●	●			●	
	Interference microscope				●			
	LIBS (laser induced breakdown spectroscopy)							
	Laser ionized light source							
	Quantitative gas analysis (TDLAS)							
	THz generation							
Light source	Laser printer		●				●	
	Pumping for solid state laser		●			●	●	●
	IR illumination		●				●	●
	Laser repairing							
Material processing	Laser soldering (bonding)					●		●
	Laser plastic welding						●	●
	Annealing		●				●	●
	Laser metal welding							●
	Brazing							●
	Remote processing							●
	Laser marking					●		●
	Micromachining (drilling, thin film removal, etc.)							
	Nonthermal micromachining (drilling, thin film removal, etc.)							
	Micromachining in transparent material (glass, plastic, etc.)							

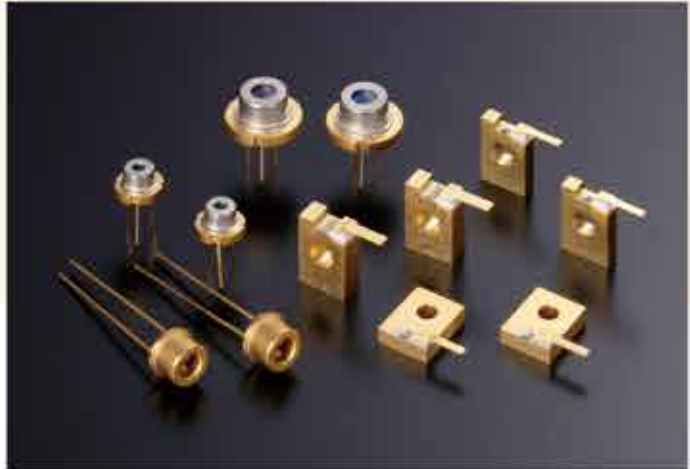
		Laser applied products	Applied products of semiconductor lasers			Solid state lasers			
DDL	QCL	THz antenna module (emission / detection module for THz electromagnetic wave)	SPOLD	SPOLD with Process Monitor	LD-HEATER	Microchip Lasers			Ultrashort Pulse Laser MOIL-ps
						High energy type	High repetition type	High beam quality type	
							●		
		●					●		
							●		
						●		●	
						●		●	●
	●								
		●						●	
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Semiconductor Lasers

Laser Diodes

CW Laser Diodes (CW LD)

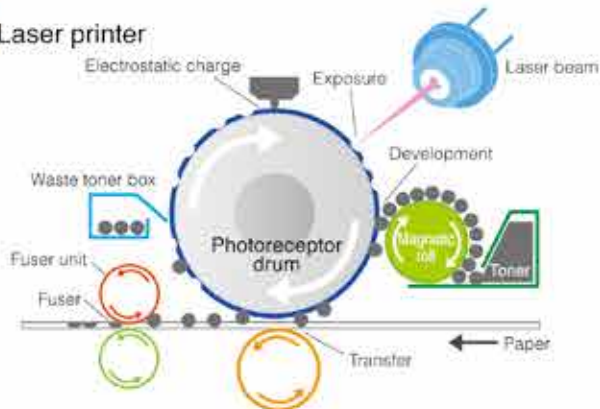
These LDs are designed to be driven in continuous wave (CW). Output power is from mW to a few W. A variety of packages are available, including C-mount, compact hermetic, and high-heat load. Fiber output modules are also available.



Lateral multimode LDs (broad stripe)

These diodes generate higher output power, operating in multiple lateral modes. The most suitable LD can be selected from an assortment of types by wavelength, size of emitting area, output power, etc.

■ Laser printer



Applications

- Processing
- Medical treatment
- Annealing
- Measurement
- Solid state laser pumping
- Communication (EDFA)

Pulsed Laser Diodes (PLD)

These LDs feature high peak power under pulsed operation. The range of peak output power is from 10 W to 90 W. Emitting area size is from 70 μm to 350 μm . These LDs can be used for distance measurements such as laser radar, hazard monitoring in security applications, etc.

■ Distance measurement



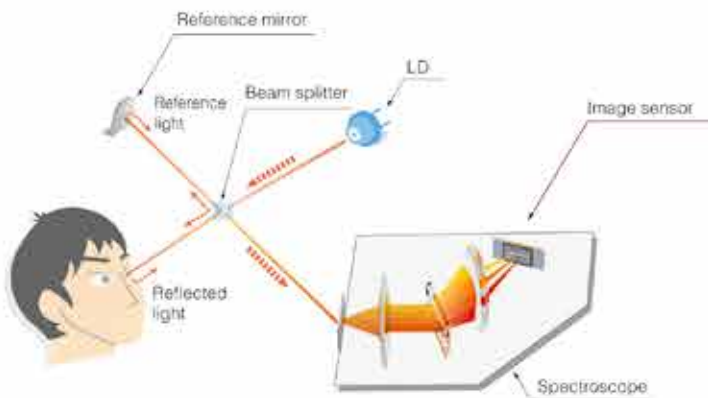
Applications

- Laser rangefinder (leisure, surveying)
- Security (traffic, collision prevention)
- Control & monitoring (robot, positioning)

Super Luminescent Diodes (SLD)

Offering both the high brightness of LDs and low coherence of LEDs, SLDs work as a high-brightness light source which compensates for the weakness of LDs such as coherent noise. They are used for optical applied measurements and medical imaging.

■ OCT (fundus oculi observation)



Applications

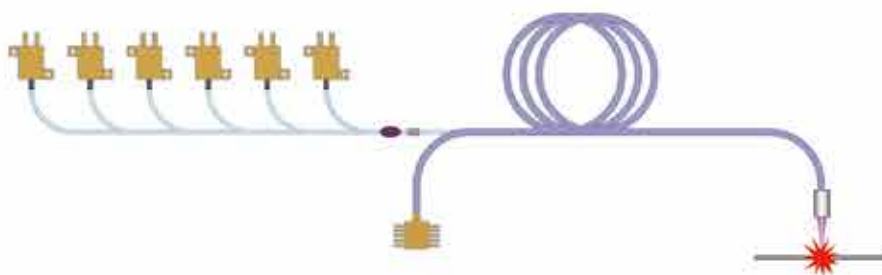
- Optical gyroscope
- Optical communication
- Measuring device using light
- Medical imaging

Fiber Output Laser Diode

This fiber-pigtailed laser diode is a high-power semiconductor laser coupled with an optical fiber that guides the laser beam while keeping it free from environmental effects and also allows easy handling. Applications include light sources that process materials by directly condensing light onto them.



■ Fiber laser excitation



Applications

- Processing by directly condensing light
- Medical treatment
- Illumination
- Fiber laser excitation
- Solid state laser pumping

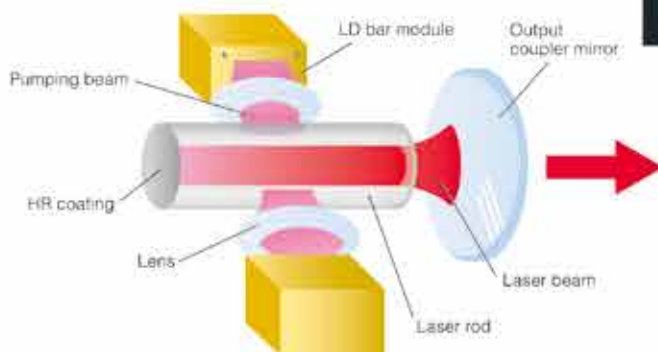
Semiconductor Lasers

High-power Laser Diode Bar Modules

With their emitting areas arranged in line to make a linear array, LD bar modules achieve high performance, high output power and high reliability when coupled with cooling devices. When stacked, the output power can be as high as a few kilowatts. There are primarily three cooling methods: the compact and simple Peltier-type Open Heatsink (OHS), the more efficient Water cooling, and Hamamatsu's original Furruyo cooling (highest cooling efficiency). The appropriate cooling method should be selected in accordance with the required output power, driving conditions, and application. Fiber output modules are also available.



■ Solid state laser pumping (side pumping)



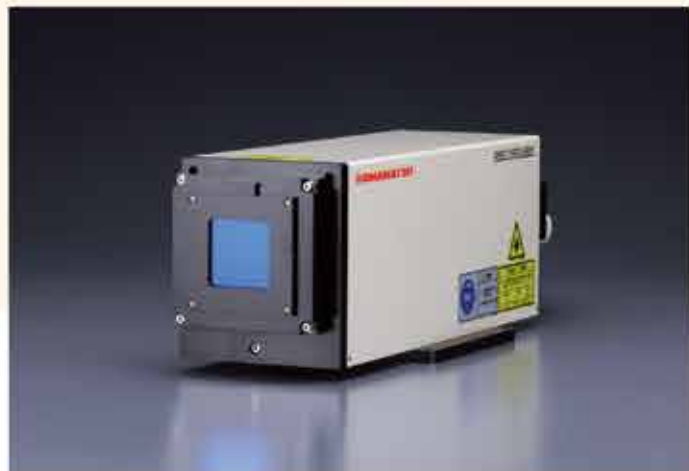
Applications

- Measurement (control & monitoring)
- Laser printer
- Solid state laser pumping
- Infrared illumination
- Heat treatment

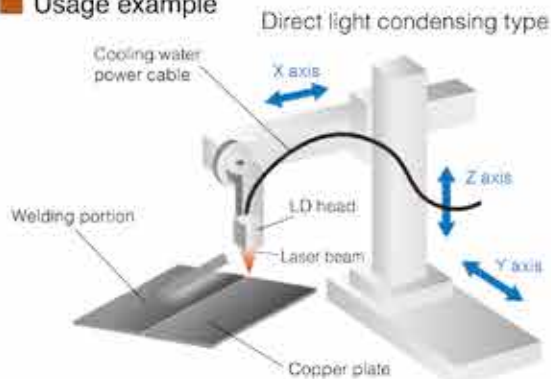
Direct Diode Laser (DDL)

DDL is a laser source that irradiates a focused laser beam from a high power LD module directly onto a target. It is suitable for various purposes such as welding, quenching, brazing, and an-nealing.

The advantages of this laser diode are the small size and low consumption of electricity compared to conventional solid state lasers or CO₂ lasers.



■ Usage example



Applications

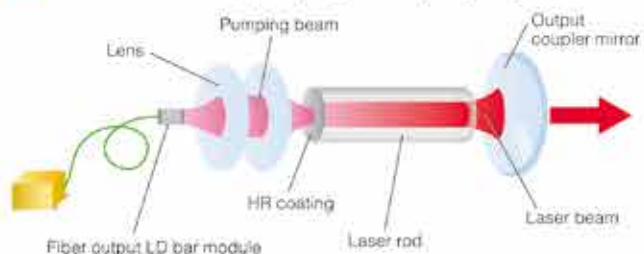
- Metal processing (welding, tailored blanks, brazing, annealing, etc.)
- Plastic welding
- Marking
- Soldering
- Surface reforming, etc.

Fiber Output Laser Diode Bar Module (FOLD)

Passive cooling (conduction cooled) type

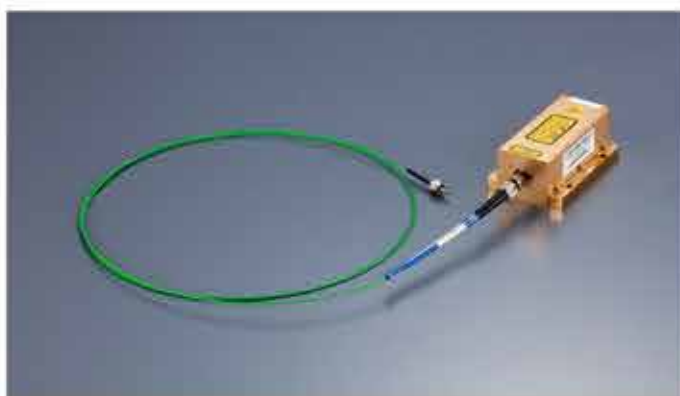
The FOLD is a passive cooled (Peltier cooled) fiber-output laser diode module designed for downsizing. An internal optical system condenses the beam spread from the single spot, input to a fiber and output from its the other end. Since the LD bar and optical system are housed in the same package, no optical axis alignment for the LD bar is required, making the FOLD easy to use.

■ Solid state laser pumping (end pumping)



Applications

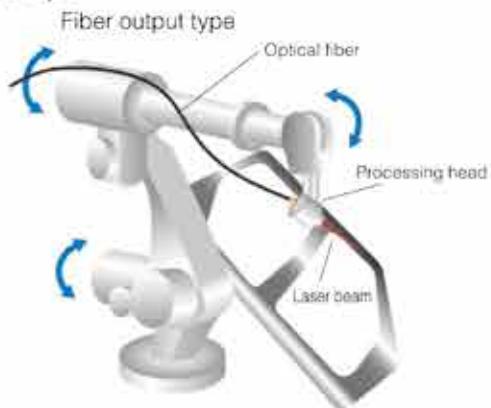
- Solid state laser pumping
- Soldering
- Laser direct processing
- Installation on material processing device such as plastic welding machine



Active cooling (water cooled) type

FOLD is a fiber-coupled type of DDL. In addition to the features of DDL mentioned on the left, FOLD's laser head is compact and lightweight. It makes it easier to set up 3-dimensional processing.

■ Usage example



Applications

- Solid state laser pumping
- Soldering
- Laser direct processing, etc.

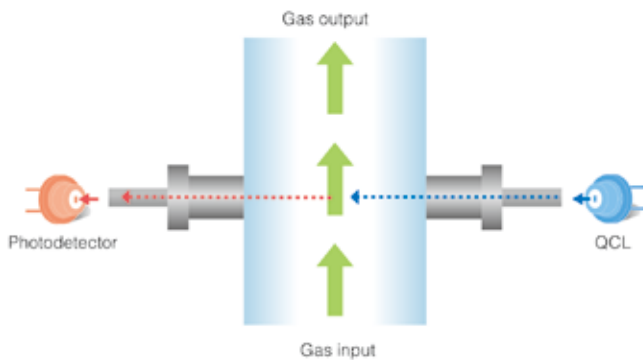
Semiconductor Lasers

Quantum Cascade Lasers (QCL)

QCL is a semiconductor laser with emission wavelength in the mid-IR range ($4\text{ }\mu\text{m}$ to $10\text{ }\mu\text{m}$). Because its emission principle is completely different from normal LDs, the QCL has gained attention as an innovative solution for mid-IR applications such as trace gas analysis in environmental monitoring. HHL package and TO-8 package are available.



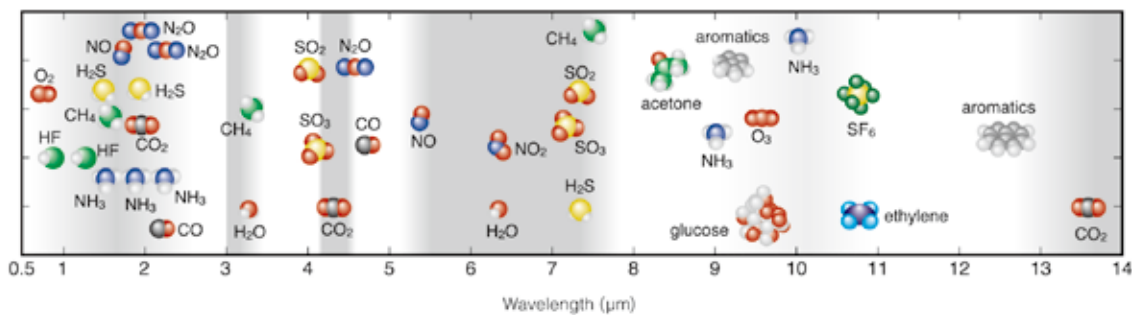
Gas analysis (transmittance)



Applications

- Trace amount gas analysis
 - Environmental measurement
 - Combustion gas measurement
 - Plasma measurement
 - Bio-related gas measurement
- Infrared molecular spectroscopy
 - Chemical sensing
 - Molecular vibration study

Gas absorption wavelength



Absorption wavelength of each gas

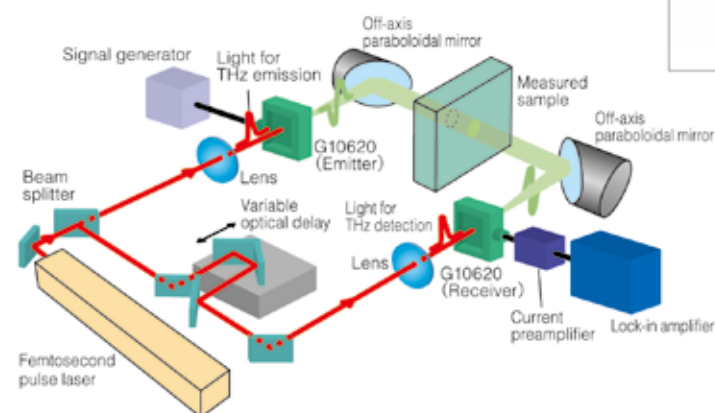
Wavelength	Gas
4.3 μm	¹² CO ₂ / ¹³ CO ₂
4.5 μm	N ₂ O, CO, CO ₂
5.2 μm	NO
6.1 μm	NO ₂
7.2 μm	SO ₂
7.4 μm	SO ₂
7.8 μm	¹² CH ₄ / ¹³ CH ₄ , CH ₄ , N ₂ O
9.0 μm	NH ₃
9.6 μm	O ₃
10 μm	NH ₃

THz antenna module (emission/detection module for THz electromagnetic wave)

This THz antenna module is THz electromagnetic waves emission/detection modules, in which a LT-GaAs "Low-Temperature-grown GaAs" based photoconductive antenna chip and a lens for THz electromagnetic wave are integrated. This module also has a SMA connector, which facilitates easy connection to other equipments. Alignment between the photoconductive antenna chip and the lens is factory set. M6 and M2 tapping holes are prepared on three faces to help easy setup.



An example of experimental setup



Applications

- Nondestructive inspection for industrial field, non-contact measurement for biological tissue
- Far-infrared spectroscopy
- Material analysis
- Structure inspection
- Security, etc.

What are terahertz waves?

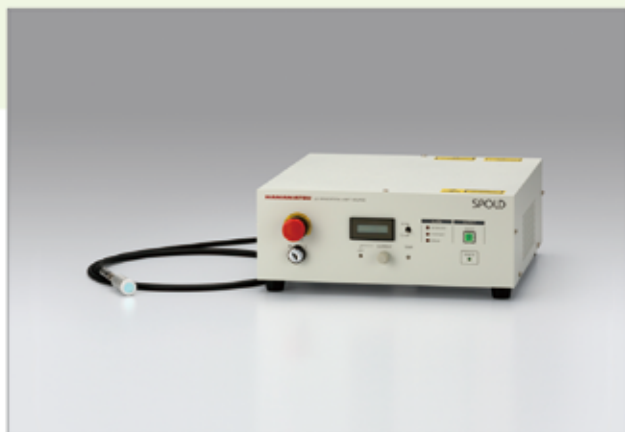
Terahertz waves are electromagnetic waves that exit in the spectrum between light and radio waves. In terms of wavelength, terahertz waves range from 3 mm to 30 μm .

	<div>Light</div>					<div>Radio wave</div>		
Wavelength	100 pm	100 nm	400 nm	800 nm	30 μm	300 μm	3 mm	1 m
Frequency	3 EHz	3 PHz	750 THz	375 THz	10 THz	1 THz	100 GHz	300 MHz
	X-ray	UV light	Visible light	Infrared ray	Terahertz wave		Radio wave region	
	X-ray diffraction	Electron transition		Intramolecular vibration	Intermolecular vibration		Orientation relaxation	

LD Irradiation Light Source SPOLD®

The SPOLD is a laser light source consists of a fiber output LD module, driver circuit, and Peltier cooling device all assembled together into one compact unit. The SPOLD allows users to select an irradiation unit that emits laser light at a desired beam diameter and beam profile. The product line-up includes a SPOLD also having a monitoring function (process monitor) that “visualizes” the effect from laser processing.

The SPOLD with process monitor constantly captures thermal information on the laser irradiation point to allow quality control during laser processing, making it ideal for use in mass-production processes such as for plastic welding and soldering.

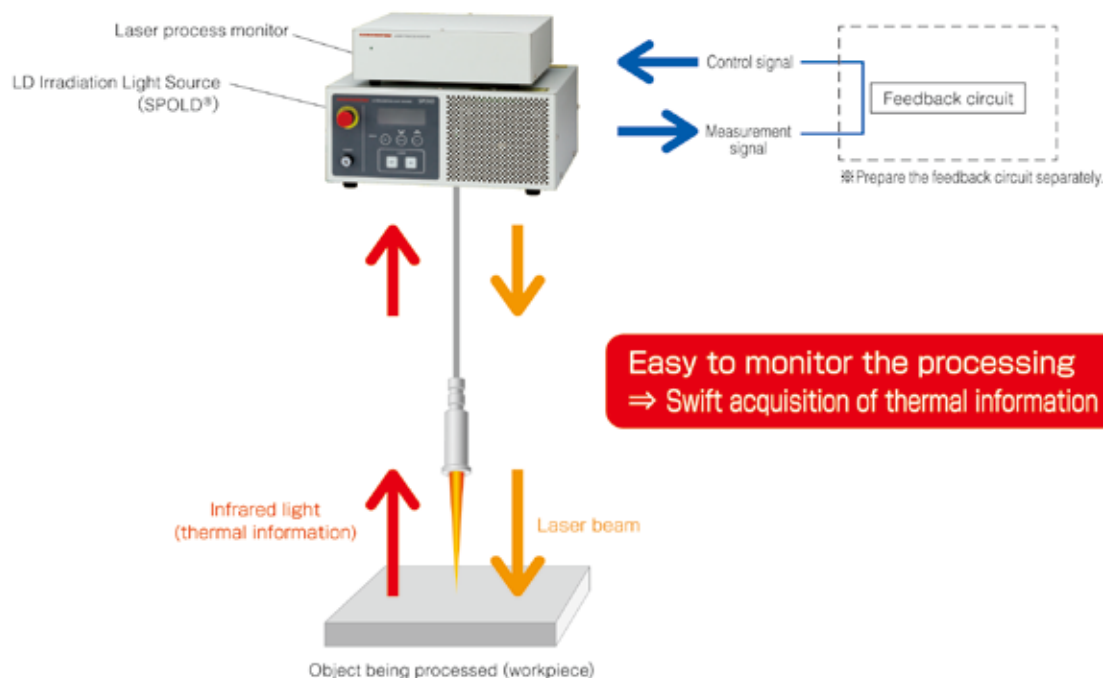


LD Irradiation Light Source



LD Irradiation Light Source (with Process Monitor)

■ Application example of LD Irradiation Light Source (with Process Monitor)

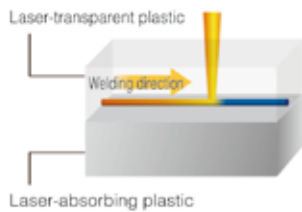


LD Heating Light Source LD-HEATER

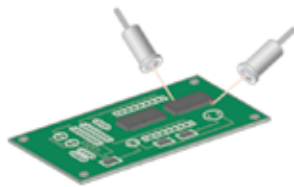
LD-HEATER is a compact, sophisticated spot-heater including a temperature monitoring function, a fiber-output semiconductor laser (LD) unit, and drive unit. It is suited for various types of processing jobs involving "optical heating" such as plastic welding, soldering, and annealing.



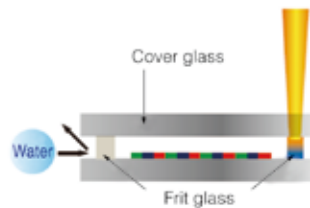
Plastic welding



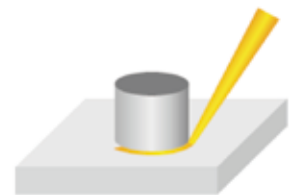
Soldering



Hermetic glass sealing (waterproof seal)



Adhesive thermal curing

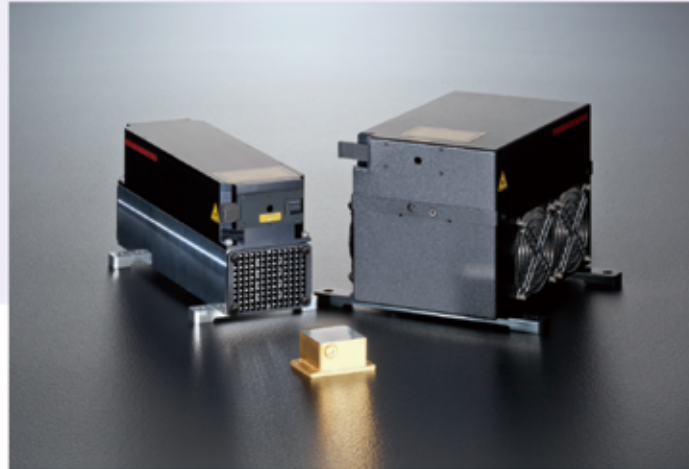


Applications

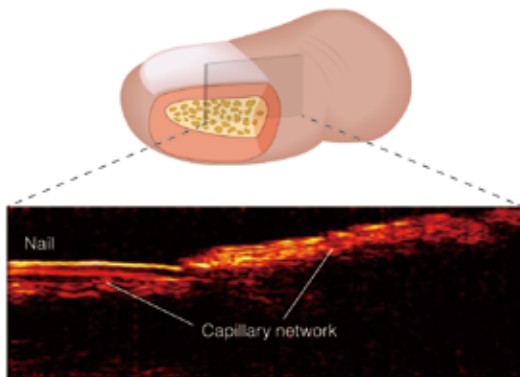
- | | | | |
|-------------------|--|-------------------------|-------------------------------|
| ■ Plastic welding | ■ Hermetic glass sealing (waterproof seal) | ■ Drying of the coating | ■ Heat treatment |
| ■ Soldering | ■ Adhesive thermal curing | ■ Brazing | ■ Infrared illumination, etc. |

Microchip Lasers

These passively Q-switched lasers are short pulse (sub-nanosecond), compact and robust due to their monolithic resonators that are fabricated using our original optical technology. Three types are available to meet needs for high energy, high repetition rate, and high beam quality.



■ Photoacoustic image of fingertip



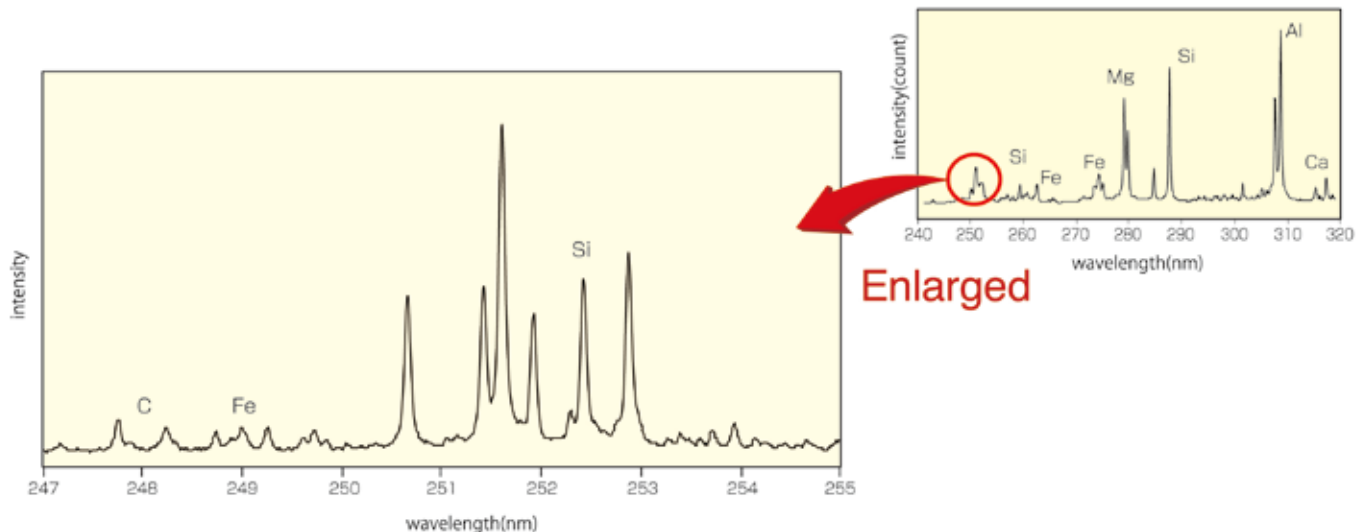
Measurement range Vertical (depth direction): 3 mm, Horizontal: 7 mm
Data courtesy: Prof. Yoshifumi Saijo
(Graduate School of Biomedical Engineering, Tohoku University)

Applications

- Light source for measurement (photoacoustic, LIBS, terahertz, Raman)
 - Light source for distance measurement
 - Light source for ablation processing
- *LIBS: Laser Induced Breakdown Spectroscopy

■ Experiments for detecting unburnt components in coal ash (LIBS applications)

Elements Fe, Si, Ca, Al and C which are the main components of coal, coal ash, and steel slag were measured.

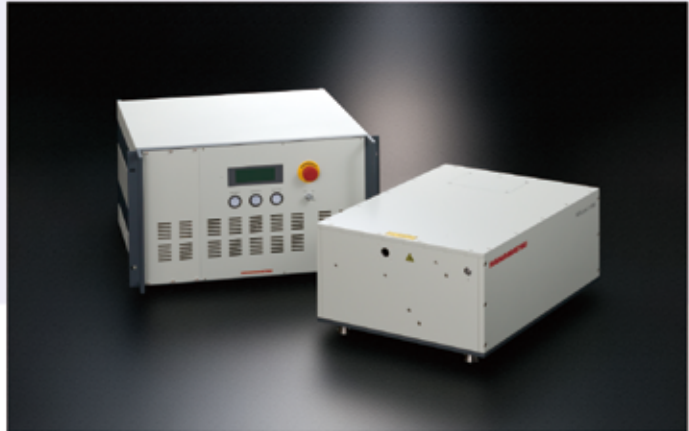


Data courtesy: Prof. Yoshihiro Deguchi
(Institute of Socio-Arts and Sciences, Graduate School of Tokushima University)

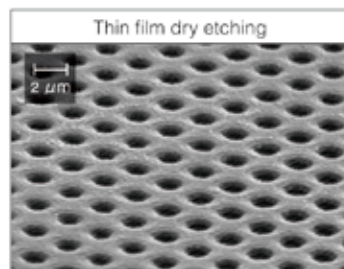
Ultrashort Pulse Laser (MOIL-ps)

The MOIL-ps is a compact picosecond pulse laser that occupies a small footprint only about 1 sheet of A3 paper in size yet generates high energy up to 200 μJ .

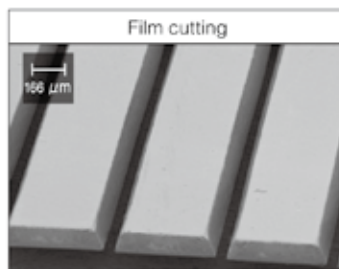
The MOIL-ps laser is simple to use since it operates under fully programmed control. Its high processing quality makes it ideal for fine detail processing on the micron scale.



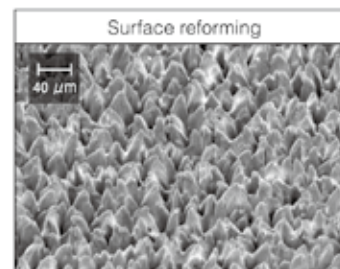
■ Processing examples



Thin film dry etching
Simultaneous multipoint ultra-fine processing of ITO film on glass substrate



Film cutting
Polyimide film ($t=125\text{ }\mu\text{m}$) cutting



Surface reforming
Minimal silicon wafer reflection

Applications

- Various types of fine detail processing
- High-aspect processing
- Thin film dry etching
- Surface reforming (fine periodic structure forming), etc.
- Film cutting

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