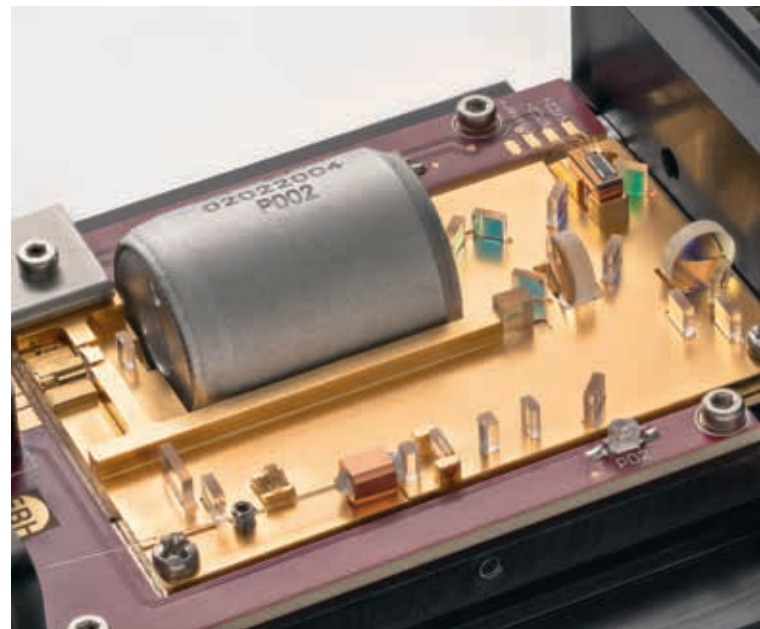
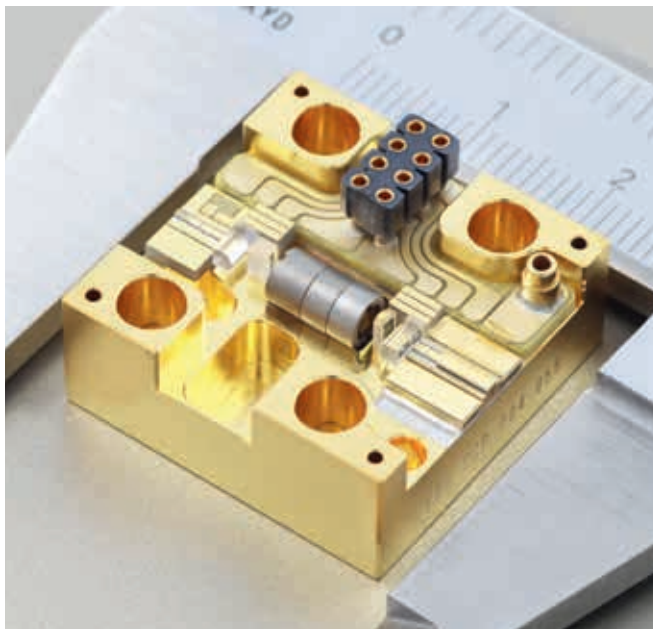
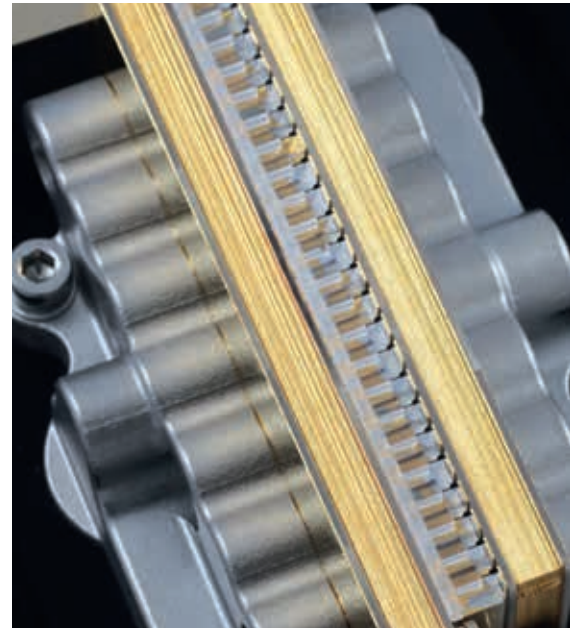
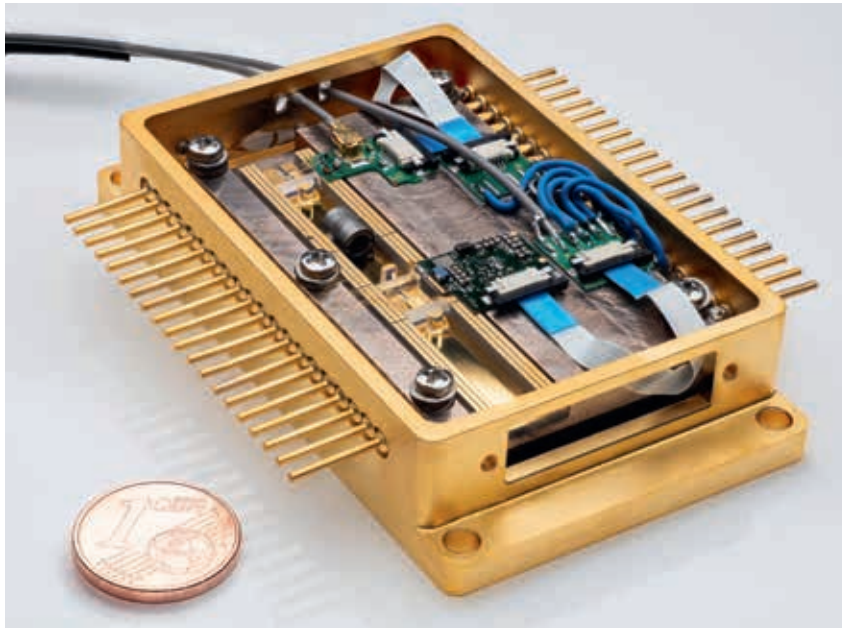




Leibniz  
**Ferdinand  
Braun  
Institut**



# Compact Diode Laser Modules

# Advanced Capabilities in Semiconductor Laser Solutions

The FBH is a center of competence for compound semiconductors comprising the full value chain – from device design to epitaxy, process, and mounting technology through to sophisticated ready-to-ship modules and plug-and-play prototypes.

FBH's hybrid diode lasers are compact, highly brilliant light sources which are meeting the demands of a wide range of applications. Excellence in brightness, efficiency, and reliability defines FBH's diode laser research and development efforts.

The institute achieves cutting-edge results through continuously improving technology and by innovation in design. Building on FBH's state-of-the-art technology, the institute develops tailor-made diode lasers and laser modules that meet the specific requirements of its customers in research and industry. In addition, photonic integrated circuits for a wide range of applications are being developed and investigated using various material platforms. The FBH has long-term experience in commercial delivery and in collaborating on development projects with industrial partners.

## Products & Services

The FBH offers a broad portfolio of cutting-edge modules making full use of its unique know-how in diode laser technology. Developments include CW and high-power short-pulse (ps...ns range) laser sources that combine FBH laser technology with FBH customized electronic circuitry, using GaN transistors to realize compact and efficient short-pulse high-current drivers and switches.

High-power and high-brightness laser modules based on laser diodes emitting in the wavelength range 620–1180 nm are realized using optimized beam combining methods in one module. These include "Dense Wavelength Division Multiplexing" (DWDM), polarization coupling, and "Coherent Beam Combining" (CBC). Such laser modules can be used as powerful and efficient pump sources for solid-state lasers and frequency conversion.

### for medical applications

- **yellow lasers** with up to 2 W CW at 561 nm or 574 nm using frequency conversion (via nonlinear crystals) for ophthalmology
- **ps lasers** with watt-level output power at 561 nm and 589 nm for STED and time-resolved fluorescence measurements
- **quantum light modules** based on entangled photon pairs used for hyperspectral imaging – enabling significantly shorter clinical cancer diagnostics

### for display technology and entertainment

- **RG(Y)B sources** up to 1 W with  $M^2 < 3$  at 460 nm, 488 nm, 532 nm, 561 nm, 590 nm (frequency conversion) 619 nm, 638 nm, 660 nm (direct application)

### for space applications

- **high-power modules for pump applications in space** 808 nm for pumping Nd:YAG lasers for atmospheric sensing applications
- **laser modules for coherent optical communications** < 100 kHz linewidth, up to 1 W optical power at 1064 nm
- **space-compatible design, manufacturing, testing, and validation** of semiconductor lasers and photonic modules

### for quantum technology (sensing and computing) applications (400 nm to 1100 nm)

- **narrow and ultra-narrow** linewidth diode laser modules
- **light control units** for high-accuracy pulse shaping, phase control, and phase/frequency chirping

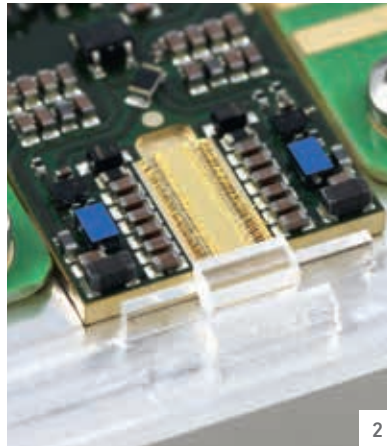
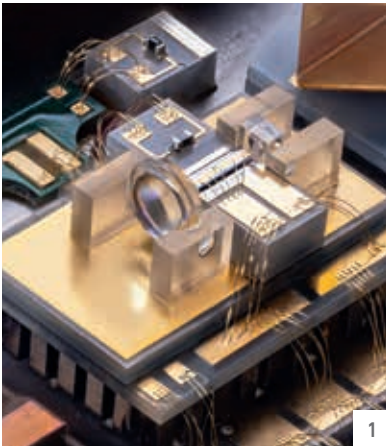
### for sensing applications (Raman and fluorescence spectroscopy)

- **background-free visible laser sources with blue, green, and yellow emission** up to 100 mW available by combining FBH's DFB and DBR diode lasers with second harmonic generation (SHG)
- **single-chip dual-wavelength diode lasers for Shifted Excitation Raman Difference Spectroscopy (SERDS)** up to 200 mW, devices demonstrated and applied at 671 nm and 785 nm

### for LiDAR, THz generation, and materials processing

- **nanosecond pulsed high power laser source for LiDAR applications:** 2–10 ns pulse laser sources with up to 360 W from single emitters for point scanners and with > 2000 W from 48 emitter laser bars for line scanners
- **830 nm mode-locked tapered diode lasers for THz time-domain spectroscopy (THz-TDS)** with compressible 3 ps pulse width and 40 W peak power at 6 GHz repetition rate
- **780 nm mode-locked tapered diode lasers for 2-photon polymerization (2PP) in 3D micro-structuring processes** with compressible 8 ps pulse width and 40 W peak power at 7 GHz repetition rate
- **high power direct diode laser modules for efficient additive manufacturing**, e.g. with 1 kW CW optical output power at 780 nm in a 1 mm spot, for processing aluminum
- **Q-switched diode lasers for pulse widths around 100 ps with high repetition rate:** multi-section DBR laser diodes and modules, peak power up to 50 W with repetition rates up to 10 MHz





- 1 Laser cavity of a micro-integrated ECDL-MOPA laser module with separate TECs for laser chip and Bragg grating
- 2 High current ns laser driver with integrated distributed Bragg reflector laser diode for LiDAR applications
- 3 Compact diode laser module for biophotonics and medicine
- 4 PM fiber-coupled micro-integrated ECDL-MOPA laser module for high-precision spectroscopy
- 5 Turnkey laser system for easy integration of diode laser-based light sources
- 6 Compact direct diode laser module for use in additive manufacturing

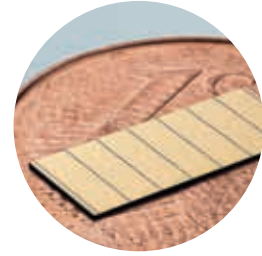
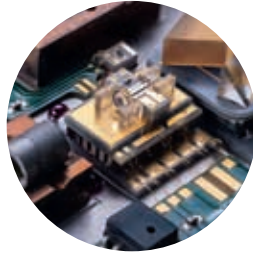
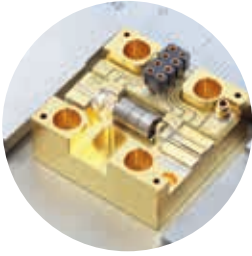
## Full Technology Chain In-house – from Epitaxy to Reliability Testing

AllInGaAsP-based layer structures for highly sophisticated optoelectronic devices are grown on 2", 3", and 4" wafers in multiwafer MOVPE reactors. Single and multiple GaInP, GaAsP, (In)AlGaAs and InGaAs quantum wells are grown as active regions for use in semiconductor lasers at wavelengths between 620 nm and 1180 nm.

The FBH runs a highly flexible and industry-compatible process line for compound semiconductor devices on 2", 3", and 4" wafers. It includes i-line wafer steppers, electron-beam exposure of sub-micron structures, and customized facet coating.

High-performance automated die bonding and assembly tools are used for mounting laser chips on submounts and assembling laser modules. Micro-optic components are fixed in place using an adhesive technology which is qualified for space applications and enables stable attachment with sub-micron precision.

The performance of these high-brightness, high-power, narrow-linewidth laser diodes is comprehensively characterized in FBH's test laboratories by using state-of-the-art measurement technology.



# translating ideas into innovation

The Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) is an application-oriented research institute in the fields of high-frequency electronics, photonics, and quantum physics. It researches and realizes electronic and optical components, modules, and systems based on compound semiconductors. These devices are key enablers that address the needs of today's society in fields like communications, energy, health, and mobility.

Specifically, FBH develops light sources from the infrared to the ultra-violet spectral range: high-power diode lasers with excellent beam quality, UV light sources, and hybrid laser modules. Applications range from medical technology, high-precision metrology, and sensors to optical communications in space and integrated quantum technology. In the field of microwaves, FBH develops high-efficiency multi-functional power amplifiers and millimeter wave frontends targeting energy-efficient mobile communications, industrial sensing, and imaging as well as car safety systems. In addition, FBH realizes electronic devices based on wide- and ultrawide-

bandgap semiconductors for efficient and compact power converter systems.

The FBH is a center of competence for III-V compound semiconductors covering the full range of capabilities, from design through fabrication to device characterization. Within Research Fab Microelectronics Germany (Forschungsfabrik Mikroelektronik Deutschland – FMD), FBH joins forces with 14 other German research institutes, thus offering the complete micro and nanoelectronics value chain as a one-stop shop.

In close cooperation and strategic partnerships with industry, FBH's research results lead to cutting-edge products. The institute also successfully turns innovative product ideas into spin-off companies. With its Prototype Engineering Lab, the institute strengthens its cooperation with customers in industry by turning excellent research results into market-oriented products, processes, and services. The institute thereby offers its international customer base complete solutions and know-how – from design to ready-to-use modules and prototypes.

## contact

**Ferdinand-Braun-Institut**  
**Leibniz-Institut für Höchstfrequenztechnik**  
Gustav-Kirchhoff-Straße 4  
12489 Berlin, Germany  
[www.fbh-berlin.de](http://www.fbh-berlin.de)

## Interested?

Get in touch with us!  
Phone +49 30 6392 2634  
Email [sales@fbh-berlin.de](mailto:sales@fbh-berlin.de)

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