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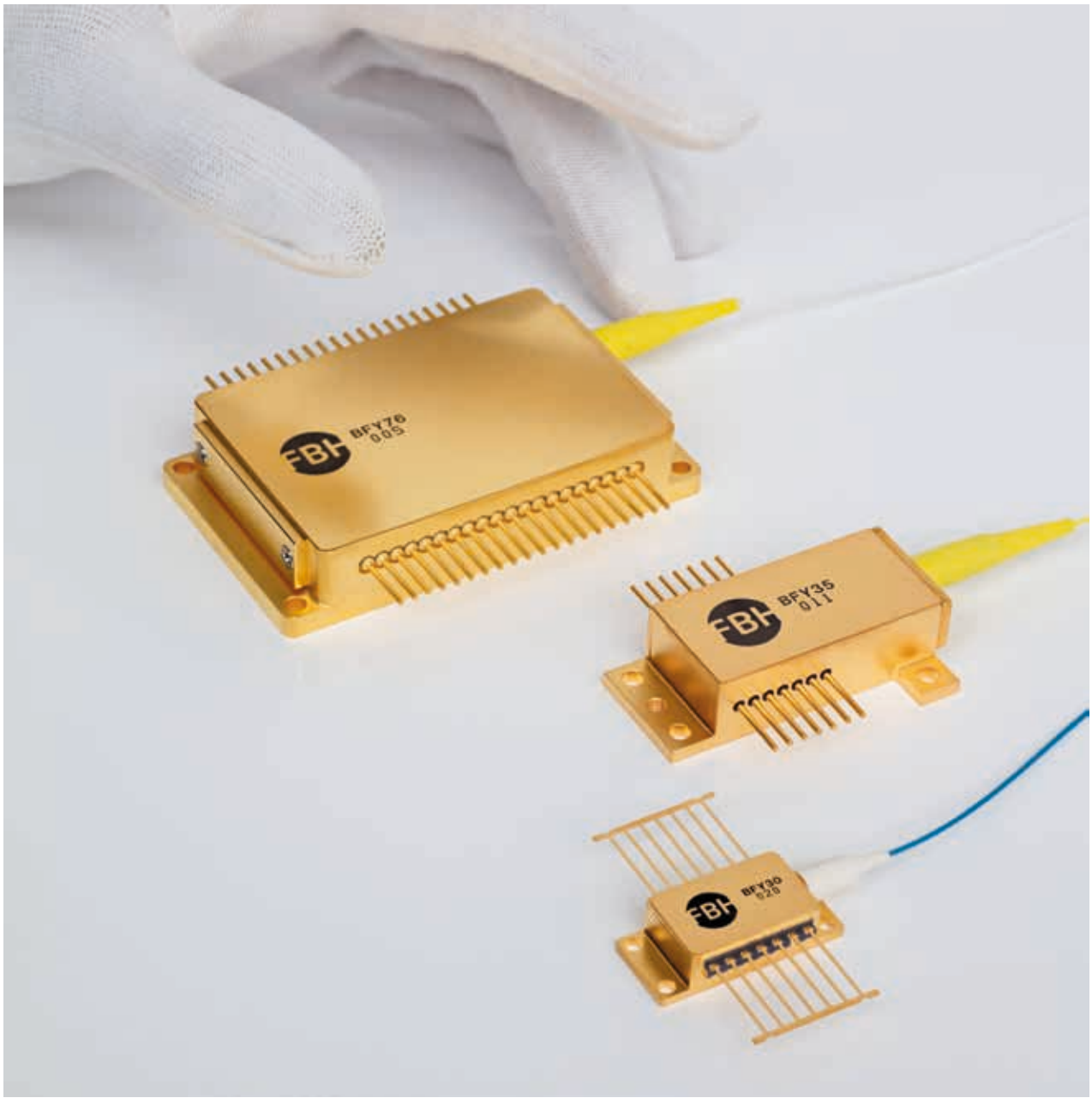

Diode Lasers for Medical Diagnostics & Treatment

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 wide variety of cutting-edge diode lasers and modules that are tailored to meet the specific requirements of the targeted application. Light sources emitting at specific wavelengths, with excellent beam quality and capable of delivering the desired output power in either pulsed or continuous-mode operation, can be designed and realized. Necessary optical and electronic components are integrated with highest precision into compact modules or turnkey laser systems, enabling easy and efficient application for customers.

Laser sources for diagnostics

The FBH develops quantum light sources for **hyperspectral imaging** of tissue samples in cancer diagnostics, using its unique high-power diode lasers and amplifiers. Entangled photon pairs in the mid- and near-infrared (MIR and NIR) spectral ranges are generated via nonlinear crystals and employed for advanced imaging applications.

The institute also provides light sources according to the needs of modern **confocal imaging** instruments. By precisely adjusting the grating periodicity, any desired wavelength or set of wavelengths can be selected, thus exciting even exotic dyes (e.g. in the NIR).

For time-resolved fluorescence spectroscopy or in situ measurements of living cells by means of **STED microscopy**, the FBH offers short-pulse lasers in the yellow-green spectral range from 532 nm to 590 nm. They deliver intensive laser pulses with pulse lengths around 100 ps and pulse peak powers of several watts.

Raman spectroscopy as label-free technology offers the chance to distinguish between different molecules and thus also between healthy tissue and pathological changes. The FBH uses **shifted excitation Raman difference spectroscopy** (SERDS) to extract Raman signals efficiently and rapidly from disturbing backgrounds such as fluorescence. For

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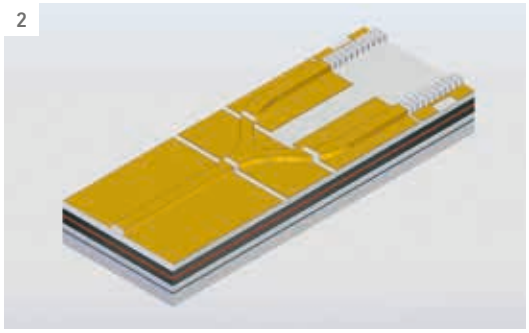

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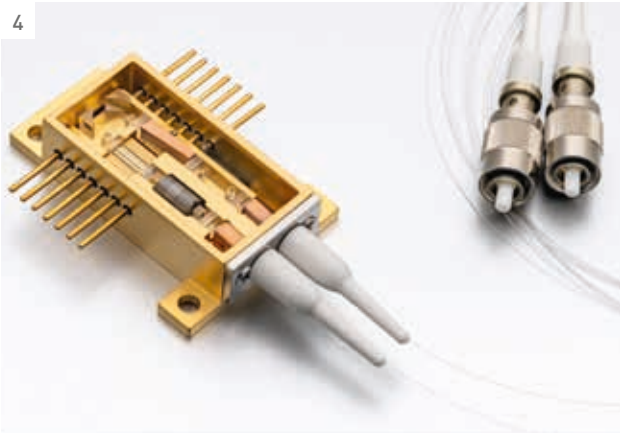
1 Turnkey laser system for dual-wavelength light sources, suited for shifted excitation Raman difference spectroscopy

2 Scheme of a dual-wavelength diode laser for shifted excitation Raman difference spectroscopy

3 Quantum light module suited for OCT and spectroscopy measurements in the MIR range with "undetected photons"

4



4 Fiber coupled module for amplification of NIR radiation and frequency conversion to visible wavelength for high resolution fluorescence spectroscopy

this purpose, narrow-linewidth dual-wavelength diode lasers with a small spectral distance have been developed and successfully tested with in-house manufactured portable Raman systems.

The FBH develops RW DBR laser arrays with up to 24 individually addressable emitters with independently adjustable wavelengths and small spectral widths for **precise surface detection** including digital holography.

Microscopy

To reach wavelength ranges that are not directly accessible with laser diodes (e.g. yellow & orange), frequency doubling of highly brilliant diode lasers has been successfully realized with hybrid-integrated modules in the wavelength range 530 - 590 nm. The light can be guided via polarization-maintaining fiber directly to the place of application.

low-power (confocal)
– very compact size: 34 x 47 x 12 mm³
– output power: up to 100 mW (CW)

high-power (super resolution)
– compact package: 76 x 44 x 15 mm³
– output power: up to 2 W (CW)
– operational modes: CW with direct modulation capability

pulsed (fluorescence & STED)
– compact package: 76 x 44 x 15 mm³
– pulse characteristics: 100 ps FWHM, up to 80 MHz repetition rate
– pulse peak power: > 2 W

Raman spectroscopy

monolithic dual-wavelength diode lasers
(VIS & NIR spectral range), suitable for SERDS
– wavelengths: 671 nm ≤ λ ≤ 1064 nm
– output power: up to 200 mW
– fast switching with frequencies reaching into the kHz range

wavelength-stabilized laser sources for imaging, providing high output power to excite larger spots for Raman imaging
– wavelengths: VIS to NIR
– output power: up to several watts

Laser sources for medical treatment

The FBH develops tailored diode laser sources with excellent beam quality and output powers in the watt range for various medical applications.

coagulation in ophthalmology – compact SHG laser sources as replacement for dye & copper bromide lasers
– wavelengths: yellow-green spectral range (e.g. 577 nm)
– output power: > 2 W with very high beam quality
– operational modes: CW with direct modulation capability in the microsecond range

photodynamic therapy & hair removal
– typical wavelengths: red to NIR, depending on the used dyes or photosensitizers, adjustable (wavelength & output power) to the specific needs of the therapy

dentistry – for periodontal disease treatments
– wavelengths: NIR
– high output power: up to 10 W

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

AlInGaAsP-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

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