Reliable semiconductors for space and quantum technologies – from chips to systems

The Ferdinand-Braun-Institut will present space-qualified, ultra-narrow linewidth diode laser modules and optical frequency references along with further III-V components for satellite and quantum technology applications at "Space Tech Expo Europe" in Bremen, Germany from November 16-19, 2021.

Laser systems for quantum-optical precision experiments

The Ferdinand-Braun-Institut (FBH) has long-term experience in the development and fabrication of robust, compact diode laser modules for sophisticated space applications. These modules have already proven their capability several times in experiments under zero gravity conditions. Among others, FBH is currently manufacturing 55 ultra-narrow linewidth laser modules developed for the BECCAL (Bose-Einstein Condensate – Cold Atom Laboratory) apparatus. As of 2024, they will be used in the research facility operated by the German Aerospace Center DLR and the NASA for quantum optical experiments with ultra-cold atoms on board the International Space Station ISS. The facility will be used to investigate fundamental physics questions involving quantum objects with high precision near absolute temperature zero (-273.15 °C).

The core elements of these and previous diode laser modules are laser diodes developed by the FBH, which are assembled together with optics and other passive elements with maximum stability and precision. Thanks to FBH's unique micro-integration technology, the modules are extremely robust and ideally suited for use in space. They feature small dimensions of only 125 x 75 x 23 mm³, a low mass (750 g) and excellent performance parameters: Output powers > 500 mW with simultaneously narrow intrinsic linewidth < 1 kHz are achieved.

In close collaboration with Humboldt-Universität zu Berlin, such modules are also being built into compact quantum sensors and optical clocks for use in space and for industry-compatible system solutions in quantum technology. The collaborative Joint Lab presents a novel, fully autonomous frequency-stabilized laser source with integrated DFB laser diode based on the D2 transition in rubidium, operating at 780 nm.

Laser modules for satellites: from communications to climate protection

FBH is also developing a range of laser modules for satellite applications. The institute's laser diode benches (LDB) have been used successfully for many years as pump lasers in Tesat-Spacecom's laser communication terminals (LCT). They are used, among other things, to transmit high volumes of earth observation data particularly quickly between satellites and to earth. The LDBs are developed and qualified according to the standards of the European Space Agency (ESA) for space applications. Their wavelength is stabilized to the pump transition band of a Nd:YAG laser such that the pump laser beam ensures stable LCT performance. On top of that, the pump laser features excellent reliability over the entire 15-year lifetime of the mission.
FBH will also show a DBR laser array module that offers both low noise and high reliability thanks to an integrated Bragg reflector, stabilizing the wavelength on chip level. The suitability of such modules has been demonstrated for continuous operation of more than 15 years, thus qualifying them as flight hardware for the next LCT space missions. Another pump laser is to be used in the future on the MERLIN climate satellite, which is to measure the methane concentration in the atmosphere. For this purpose, FBH has developed, qualified and delivered laser modules, each equipped with two high-power laser half-bars. These modules deliver 130 W pulsed emission at 808 nm wavelength and pump a Nd:YAG laser. Performance and reliability over the mission lifetime have been demonstrated through extensive qualifications of the technology and independently confirmed by ESA’s Technology Center ESTEC. Thus, even with a long operational lifetime of more than four billion pulses, the performance degrades only insignificantly.

Energy-efficient components for satellite communications and sensors

Due to their high radiation hardness and capability of switching at high frequencies, gallium nitride (GaN) switching transistors are particularly suitable for power conditioning in satellites. FBH’s new developed 10 A/400 V aluminum nitride power core with GaN power transistors in a half-bridge configuration minimizes parasitic inductances and capacitances of the switching cell. Power switch, gate driver and DC link capacitors are hetero-integrated in an extremely compact manner, and heat is efficiently dissipated through the aluminum nitride substrate. In this way, the switching times of the power cell could be halved compared to a traditional design with discrete devices. High switching frequencies combined with high converter efficiency are the prerequisite for power converters with particularly high power density. A decisive advantage, since weight is key in space.

Energy consumption and dissipated power are further critical issues when operating power amplifiers in space. Thus, FBH develops concepts for envelope tracking – a well-proven technique for increasing the efficiency of solid-state power amplifiers.

URL zur Pressemitteilung: https://www.spacetechexpo.eu/exhibitor-list/exhibitor?boothid=a3R4V000001DnRK - the FBH exhibits at the Berlin-Brandenburg joint stand in hall 5, P42
URL zur Pressemitteilung: https://www.fbh-berlin.de/en/transfer-services/modules-systems/pump-lasers-space-satellites - information on pump laser sources
Extremely low-noise, reliable pump laser module with integrated Bragg reflector for space applications and optical data transmission.

Bernhard Schurian
Compact optical frequency reference uniting a narrow linewidth DFB laser diode with an integrated spectroscopy system suited for cold-atom quantum sensors and atomic clocks, including electronics and software for autonomous operation.

Petra Immerz