Compact semiconductor laser modules designed for precision quantum optical experiments in space

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We present the design and implementation of a compact, robust and energy-efficient semiconductor laser technology that is suitable for field applications or even for a deployment in space. We concentrate on GaAs-based laser systems engineered for emission at 780 nm, which aim at meeting the requirements for precision spectroscopy on ultra-cold rubidium atoms.

We discuss different laser module concepts (master oscillator power amplifier module concept, low power local oscillator module, high power dual stage amplifier module) and compare them w.r.t. electro-optical performance, power and mass budget, and form factor.

We report on the implementation of an extended-cavity-diode-laser (ECDL) combined with a power amplifier (PA) on a hybrid-integrated micro-optical bench. Diode-laser chips, volume holographic Bragg gratings (VHBG), micro-optics, micro-mirrors, DC and HF-electronics, as well as fiber-coupling into a single-mode, polarization maintaining fiber are all micro-integrated within a footprint of 80 x 30 mm². The combination of ECDL and PA provides simultaneous narrow linewidth and high output power emission.

Moreover, we present the packaging of the AlN-Substrate into a hermetically sealed housing including custom-made feedthroughs for all DC, HF and optical signals. Emphasis is put on the choice of CTE-matched and low-outgassing materials and packaging processes, such that the laser modules are ready to undergo a complete cycle of mechanical and thermal stress tests in view of a deployment in space.

We further outline the next step in the development of the laser technology discussed above in order to extend the accessible wavelength spectrum from the NIR, across the visible spectrum into the UV. A scheme is presented, where the laser technology is directly transferred to semiconductor chips emitting in the NIR to form the local oscillator of a UV-laser system. The UV-wavelength is then achieved through two frequency-doubling stages, at least one of which consisting of a micro-integrated monolithic enhancement cavity.