High-power green diode laser systems for biomedical applications

High-power green diode laser systems for biomedical applications

Due to their unique characteristics, diode lasers are increasingly attractive for numerous applications. For example, in the biomedical field the provided output power, spatial quality, and wavelength coverage of diode lasers has enabled their applications in, e.g., dermatology, diffuse spectroscopy and imaging, and fluorescence measurements. A major challenge in diode laser technology is to obtain high-power laser emission at wavelengths < 600 nm. Especially the green spectral range is of high importance, for example, in dermatology or for direct pumping of ultrashort pulsed lasers in conjunction with optical coherence tomography, two-photon microscopy or coherent anti-Stokes Raman scattering microscopy.

In order to provide high-power green diode laser emission, nonlinear frequency conversion of state-of-the-art near-infrared diode lasers represents a necessary means. However, the obtained output power of frequency doubled single emitters is limited by thermal effects potentially resulting in laser degradation and failure. In this work new concepts for power scaling of visible diode laser systems are introduced that help to overcome current limitations and enhance the application potential.

The underlying principle is spectral beam combining of multiple, comparable diode lasers with subsequent nonlinear frequency conversion. In the former approach multiple lasers are incoherently combined with an external optical component. With two 1062 nm tapered diode lasers and a reflecting volume Bragg grating more than 16 W of output power at combining efficiencies > 93% are obtained. Utilizing the wavelength tunability of diode lasers enables less critical optical alignment compared to lasers limited to specific atomic transitions. It is shown that spectral beam combining does not affect the beam propagation parameters and therefore efficiently increases the brightness of compact and cost-effective diode laser systems.

The condition of overlapping beams is an ideal scenario for subsequent frequency conversion. Based on sum-frequency generation of two beam combined diode lasers a 3.2 fold increase in visible output power compared to frequency doubling of a single emitter is achieved. It is shown that nonlinear frequency conversion significantly improves the spatial quality, which results in 3.9 W of diffraction-limited green light at maximum performance.

In order to increase the output power even further, the developed concept is expanded combining multiple diode lasers in a multiplexed grating. In case of three diode lasers, the unique tunability allows for matching emission wavelengths of simultaneous second harmonic generation and sum-frequency generation. The obtained output power is given by the sum of the individual contributions and indicates the potential for power scaling. Limited mainly by the acceptance bandwidths of nonlinear crystals and the practical realization of multiplexed gratings, this concept can be extended towards higher numbers of simultaneous nonlinear frequency conversions in advanced, visible, high-power diode laser systems with increased application potential.

In order to prove the application potential of green diode laser systems a frequency doubled tapered diode laser is applied for direct pumping of a mode-locked titanium sapphire laser. The resulting pump efficiencies are reduced to 75% of the values achieved with a commercial green solid state laser. However, due to a superior wall-plug efficiency of the diode laser the overall efficiency of the titanium sapphire laser is improved by a factor of 2. In mode-locked operation, a spectral bandwidth of 112 nm allows for sub-20 fs pulses and proves the potential for future diode based compact and efficient titanium sapphire lasers.

Applying such a diode pumped titanium sapphire laser in optical coherence tomography of the retina and skin shows similar results as obtained by solid state pumped systems. Implementing the developed concept of frequency converted, beam combined diode laser systems will help to overcome the high pump thresholds for ultrabroad bandwidth titanium sapphire lasers, leading towards diode based high-resolution optical coherence tomography with enhanced image quality.

In their entirety, the obtained results clearly strengthen the application potential of diode lasers, including the biomedical field.

General information
State: Published
Organisations: Department of Photonics Engineering, Diode Lasers and LED Systems
Contributors: Müller, A.
Number of pages: 100
Publication date: Jun 2013

Publication information
Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark (DTU)
Original language: English
Electronic versions:
13_11_24_Thesis_AMUL.pdf
Research output: Research › Ph.D. thesis – Annual report year: 2013