Diode laser based vapor-cell frequency references for metrology and sensing applications in space

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In this talk, we give an overview on diode laser system technologies developed for precision measurements in space and their application in optical frequency references, vapor-cell clocks and ultra-cold atom experiments onboard sounding rockets. The systems are based on a micro-integrated laser technology platform developed at the Ferdinand-Braun Institute in a joint lab activity with Humboldt-Universität zu Berlin, providing compact, robust and energy-efficient semiconductor laser modules.

Within the QUANTUS consortium, we operate laser systems at the Bremen drop tower to study ultra-cold Rubidium (Rb) and Potassium (K) Bose-Einstein condensates (BEC) with the long-term goal of differential atom interferometry in microgravity [1]. As a next stepping stone towards orbital deployment of quantum sensors, we have developed several laser payloads for operation on sounding rockets. Design, assembly and qualification of a system capable of atom interferometry with Rb BECs in context of the MAIUS mission will be discussed [2], as well as FOKUS [3] and KALEXUS [4], which successfully demonstrated key technologies for optical frequency references based on vapor cell stabilized DFB and ECDL lasers, respectively. In JOKARUS [5], we have realized an autonomous, absolute optical frequency reference based on hyperfine transitions in molecular iodine at 532 nm which is scheduled for launch in May 2018. We apply modulation transfer spectroscopy on a quasi-monolithic spectroscopy module with an unsaturated iodine cell, using a micro-integrated ECDL MOPA at 1064 nm as a compact high power light source and a fiber coupled laser system.

Moreover, we will discuss mission scenarios in which laser systems and related optical quantum technologies can be studied in Low Earth Orbit, specifically regarding long-term performance, radiation effects, and autonomous operation [6,7]. In QUEEN, we investigate two-photon frequency references and their implementation on small satellites. This would not only complement our existing drop tower and sounding rocket heritage but contribute towards the TRL of laser systems for future missions, such as BECCAL, a DLR-NASA bilateral multi-user facility for ultra-cold atoms onboard the International Space Station.

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References

[1] M. Schiemangk et al., “High-power, micro-integrated diode laser modules at 767 and 780 nm for portable quantum gas experiments”, Applied Optics 54, p. 5332-5338 (2015)
[2] V. Schkolnik et al., „ A compact and robust diode laser system for atom interferometry on a sounding rocket “,Applied Physics B 122 (2016), p. 1–8
[3] M. Lezius, et al. "Space-borne frequency comb metrology", Optica 3, 1381-1387, (2016)
[4] A. Dinkelaker, et al. „Autonomous frequency stabilization of two extended-cavity diode lasers at the potassium wavelength on a sounding rocket“, Appl. Opt. 56, 1388-1396 (2017)
[5] V. Schkolnik, K. Döringshoff, et al. „JOKARUS - design of a compact optical iodine frequency reference for a sounding rocket mission“, EPJ Quantum Technol. 4: 9 (2017)
[6] M. Barschke et al., “Optical Quantum Technology in Space using Small Satellites”, 68th International Astronautical Congress (IAC), IAC-17,B4,2,9,x39017 (2017)
[7] D.K.L. Oi et al., “Nanosatellites for quantum science and technology”, Contemporary Physics, Volume 58, (2017)