Geophysical Research Abstracts
Vol. 21, EGU2019-16896, 2019
EGU General Assembly 2019

Frequency-Agile Ti:sapphire Laser Transmitter of a Water Vapor DIAL: A Tool for Spectroscopic Analyses of the Atmosphere

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Measuring the absolute humidity in the atmosphere with the differential absorption lidar (DIAL) technique calls for a transmitter that has to meet demanding technical specifications. First and foremost, these are spectral properties of the laser radiation (narrow bandwidth, high frequency stability and spectral purity). A high power and energy output is important as well, since it determines the resolution, precision, and maximum range of the measurement. This is especially true for scanning measurements in the lower troposphere, where the water-vapor number density is higher, and the online laser radiation is strongly absorbed.

In the ground-based mobile water-vapor DIAL of the University of Hohenheim, the transmitter is a pulsed Ti:sapphire laser system. The laser system was developed to fulfill the above-mentioned stringent requirements and enable high performance operation. It is pumped with a frequency-doubled diode-pumped master-oscillator power-amplifier Nd:YAG laser and injection seeded alternately with two external-cavity diode-lasers. By the latter, the necessary operation at two wavelengths on and off the absorption line of water vapor close to $\lambda = 818$ nm is achieved. The Ti:sapphire laser provides a high average output power of $P = 10$ W (corresponding to a pulse energy of $E = 33.3$ mJ at a repetition rate of $f = 300$ Hz; pulse duration $\Delta t \approx 30$ ns), and—with the implementation of an active resonator stabilization—excellent spectral characteristics (bandwidth $\Delta\nu < 63$ MHz, frequency stability $\delta\nu < 2$ MHz std. dev., and spectral purity $SP \geq 99.97$ %). Thus, water-vapor DIAL measurements with high spatial and temporal resolution as well as high accuracy and precision are realized with this laser transmitter.

However, the laser system also features versatile frequency tuning options by means of the injection seeders in addition to the alternating online-offline operation. This offers not only the possibility to perform usual two-frequency DIAL measurements but to execute various frequency functions and thus to analyze the atmosphere spectroscopically. We will present measurements that show the extension of the DIAL technique by continuously tuning the online frequency while the offline frequency remains unchanged as one application example. The online tuning range was chosen in such way that one side of the water-vapor absorption line including its peak was covered. The measurement results demonstrate that the absorption line is captured well with this method. A comparison with the spectrum of the HITRAN database and further evaluation options will be discussed.