

High Spectral Brightness UV Laser for Airborne Wind-Lidar Observations

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Laser sources employed in light detection and ranging (lidar) systems for the quantification of atmospheric parameters such as wind velocity, temperature or trace gas concentration need to fulfill a large set of strict requirements regarding their power performance as well as their spatial and spectral properties. In particular, the generation of high-energy output pulses in the UV spectral region with excellent spectral purity is mandatory for the precise measurement of wind velocities by means of direct-detection Doppler wind lidar systems. Here, the frequency stability of the laser transmitter must be better than 5 MHz to ensure low systematic errors in wind velocity of about 1 m/s. The realization of reliable, high spectral brightness laser sources is further complicated when operating in severe vibration environments such as on ships or aircraft.

Within the framework of pre-launch campaigns for the Atmospheric Dynamics Mission (ADM) Aeolus of the European Space Agency (ESA) which strives for the global observation of wind profiles from the ground to the lower stratosphere employing a satellite-borne wind lidar system (ALADIN), an airborne demonstrator (A2D) has been developed over the past years, aiming at the validation of the satellite instrument as well as at performing wind-lidar observations under various atmospheric conditions [1,2].

The laser transmitter of the A2D is based on an injection-seeded, frequency-tripled Nd:YAG master oscillator power amplifier (MOPA) system generating 30 ns output pulses at 354.89 nm wavelength. The laser provides 60 mJ pulse energy at 50 Hz repetition rate (3.0 W average output power), while showing near-diffraction-limited beam quality ($M^2 < 1.5$). In addition to the strict requirements in terms of frequency stability, a further challenge is imposed by the fact that, due to a preparation time of the CCD detectors of the A2D receiver, the electronics have to be triggered 60 μ s before the laser pulse emission with an error of less than 100 ns. Therefore, a dedicated active frequency stabilization technique was developed which is based on the Ramp-Delay-Fire method [3]. Fast detection of the master oscillator cavity resonances with the seed laser frequency, combined with two adjustable delays, enabled accurate timing of the Q-switch trigger and effective compensation of higher-frequency vibrations, while providing a sufficiently early trigger for the detector electronics with a timing stability of around 80 ns.

The resulting frequency stability of the A2D laser was evaluated under laboratory and vibration conditions in airborne operation, showing pulse-to-pulse fluctuations in the order 1.9 MHz and 3.3 MHz, respectively (see Fig. 1a). The corresponding Allan deviations plots, depicted in Fig. 1b, indicate even lower mean frequency variations in the sub-MHz-regime on longer time scales of several seconds to minutes.

The A2D lidar system was recently successfully employed for wind profile measurements in an international aircraft field campaign conducted in Iceland in autumn 2016, yielding valuable data for the ADM-Aeolus satellite mission that is planned to be launched in December 2017.

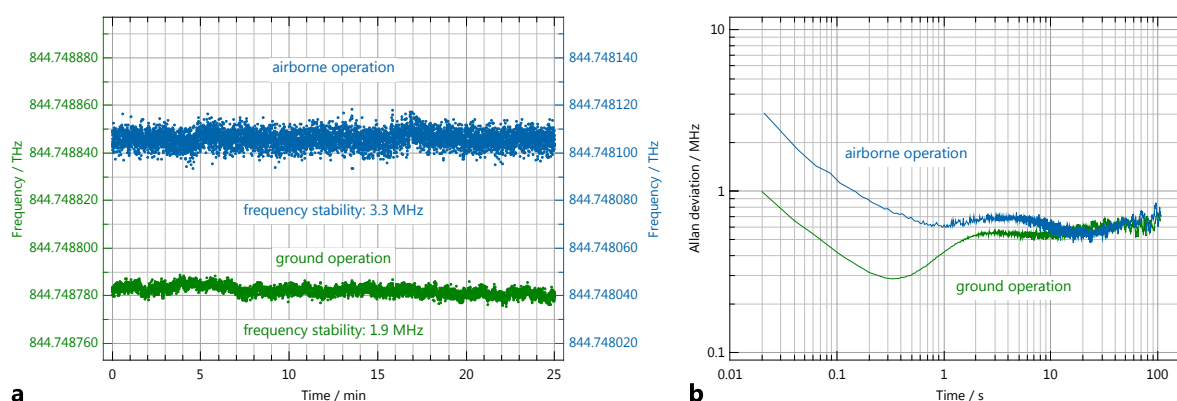


Fig. 1 a Frequency stability and b Allan deviation of the A2D laser transmitter in ground and airborne operation.

References

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