Probing the atmosphere using a femtosecond terawatt Lidar

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Abstract: We present applications of the nonlinear propagation of ultra-short ultra-intense laser pulses in air for multicomponent remote sensing, aerosol detection by in-situ nonlinear processes, as well as anomalous transmission through clouds.

OCIS Codes: 010.3640 Lidar; 010.3310 Laser beam transmission; 190.7110 Ultrafast nonlinear optics ; 010.1100 Aerosol detection

Ultrashort ultraintense laser pulses propagating in air produce self-guided filaments, with typically 100 µm diameter, where self-phase modulation generates a coherent supercontinuum (from 230 nm to 4 µm) providing an ideal source for Lidar measurements. We developed and constructed the first mobile femtosecond Terawatt Lidar ("Teramobile"[1]) dedicated to atmospheric applications.

Recently, we showed that filaments can propagate up to 2 km altitude and that the generated supercontinuum can be detected as high as 18 km[2]. The backscattered white-light is used for remote multicomponent analysis. Direct access to relative humidity profiles is obtained from the simultaneous retrieval of water vapor concentration and temperature. The wide UV emission by third harmonic generation and cross-phase modulation in air down to 230 nm was used for multiwavelength ozone measurements in Lyon, allowing correction of the ozone Lidar profiles from aerosol interference.

Non-linear interactions with atmospheric aerosols also give rise to particularly attractive applications. Multiphoton excited fluorescence (MPEF) and LIBS using femtosecond lasers are efficient methods to analyze the composition of aerosol particles. We demonstrate the first range-resolved detection and identification of biosimulant aerosols in the air by non-linear Lidar[3]. Ultrashort laser pulses from the Teramobile are used to remotely induce two-photon-excited fluorescence (2PEF) in riboflavin containing particles. In the case of amino acids detection, 2PEF-Lidar is more efficient than 1PEF-Lidar beyond a typical distance of 2 km, because of the higher atmospheric transmission at longer excitation wavelengths.

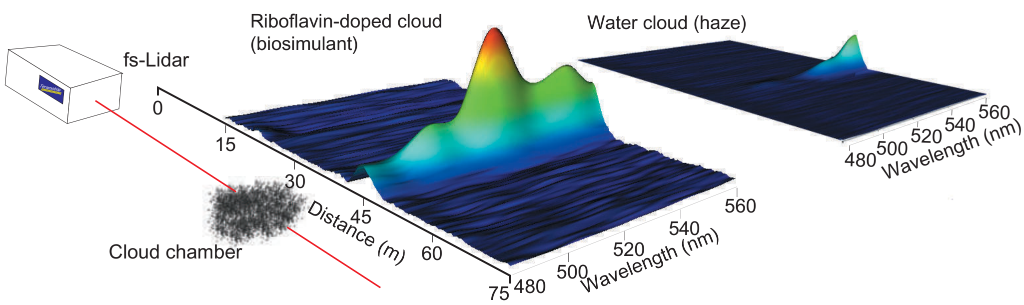

Figure 1. Remote detection and identification of bioaerosols. The femtosecond laser illuminates a plume of riboflavin containing microparticles 45 m away (left). The backward emitted 2-photon excited fluorescence (2PEF), recorded as a function of distance and wavelength, exhibits the specific RBF fluorescence signature for the bioaerosols (middle) but not for pure water droplets (simulating haze, right).

An important question arises about the stability of filaments as they interact with cloud droplets. We demonstrate that light filaments survive their interaction with water droplets as large as 95 µm, and that they are transmitted through clouds with an optical thickness as high as 3.2 (transmission 5 %)[4]. This remarkable transmission through turbid media results from a dynamic energy balance between the quasi-solitonic structure and the surrounding laser photon bath, which acts as an energy reservoir. Implications for free space laser communications, remote sensing and telemetry are discussed.

References

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