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Long range Propagation of Terawatt Laser Pulses in the Earth atmosphere

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Abstract: TW-fs-laser pulses are used for a novel height-resolved LIDAR detection technique. Results of the spectral content and conductivity of light-filaments generated by high-intensity lasers and height-resolved LIDAR-measurements in the visible are presented.

OCIS codes: (280.0280) Remote Sensing, (190.0190) Nonlinear Optics, (190.5530) pulse propagation, (190.7110) Ultrafast Nonlinear Optics, (280.3640) Lidar

Summary

When intense TW-fs-laser pulses propagate through the atmosphere, nonlinear effects like self-phase modulation (SPM), self-focusing (SF) or degenerated four-wave mixing (DFWM) cause an immense change of the temporal and spatial profile. The frequency content is changed, too. Depending on the initial beam profile, the pulse duration and other parameters like temporal chirp, one or several filaments are formed. These filaments can be quite stable and propagate for more than 20 meters [1,2]. It is our aim to use these filaments as a remote sensing technique (novel LIDAR detection technique), allowing a height-resolved multi-component analysis of the atmosphere.

We report on the investigation of the conductivity, the spectral content of the filaments and on our first fs-LIDAR measurements in the visible and infrared. [3,4].
Freely propagating laser pulses start to produce a white light continuum in air (fig. 1) that can be used for a new and convenient LIDAR (Light Detection and Ranging) application. Using TW-Ti-Sapphire laser systems we measured the spectral content of the filaments from 300 nm up to 4.5 µm. Combining the advantages of both conventional LIDAR and long path absorption techniques, this application has the potential to detect simultaneously different species of air constituents and to give complete information (like temperature, water content or pollutants) in freely chosen air columns. If the whole unit of laser and detection apparatus can be made mobile (Teramobile project), it represents a very powerful tool as a fast scanning atmospheric detection system. In figure 2, an atmospheric profile is depicted, revealing e.g. clouds. Since the detected signal was due to the white light content of the laser beam only, it demonstrates the potential to reach heights up to 13 km with a white light continuum. Carrying out height- and frequency resolved measurements in the visible absoprtion lines of water and oxygen were found. Figure 3 shows the absorption lines of oxygen, demonstrating the usefulness of the system for atmospheric investigations.

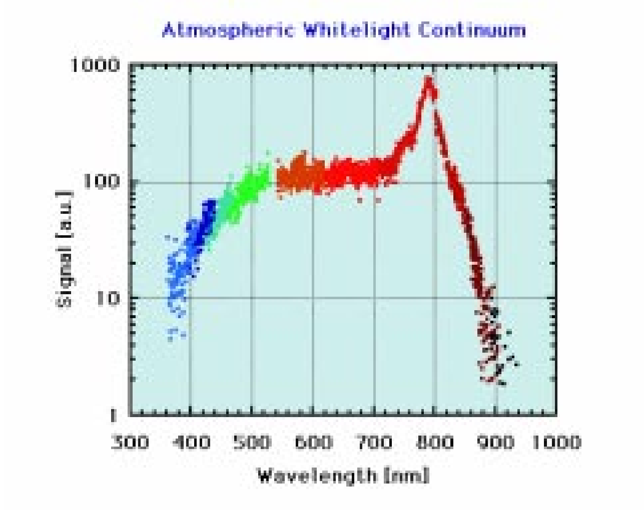

Fig. 1: White light continuum generated by a TW-laser pulse propagating through the atmosphere, the spectral clipping in the IR is due to decreasing detector efficiency.

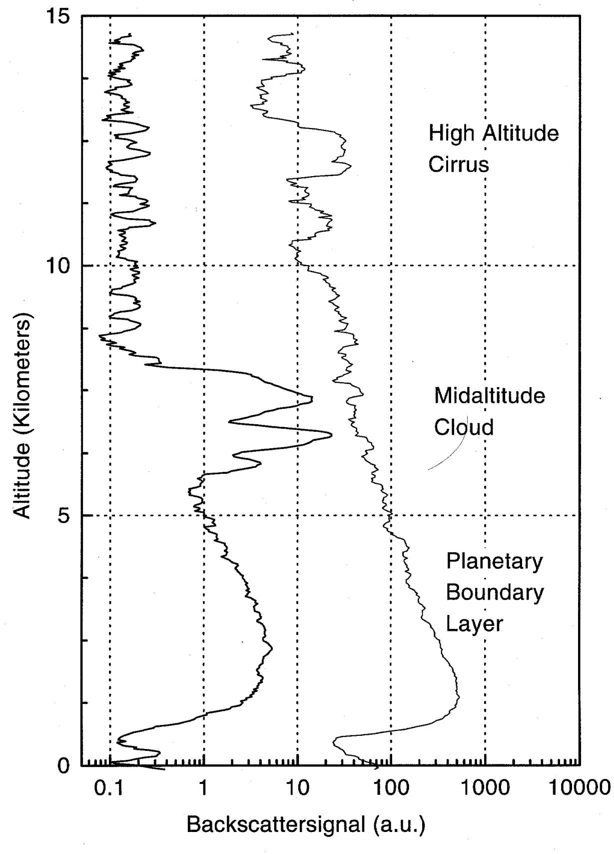

Fig. 2: Two different profiles of the atmosphere up to 15 km (with and without midaltitude cloud), as seen by Terawatt-LIDAR

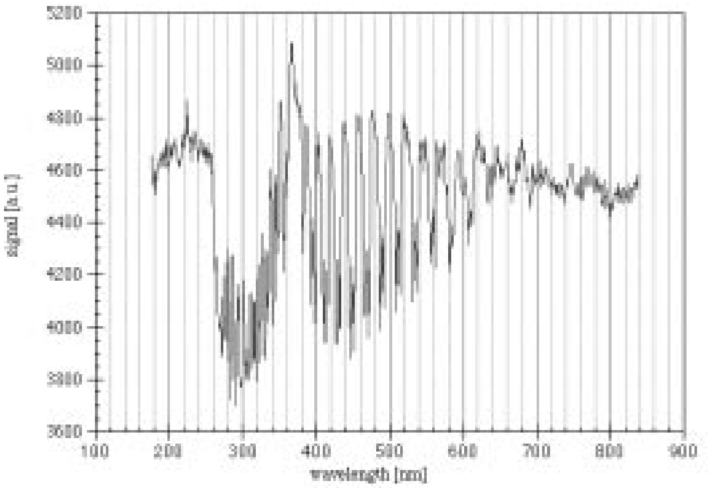

Fig. 3: Absorption lines of O_2
detected by Terawatt-LIDAR

When the laser beam is slightly focused, there is a certain threshold for the generation of light channels. These channels display beautiful colors and the visual impression indicates an almost stable and regular interplay of different channels. We examined the conductivity of these channels and found a lower limit for the electron density of $6 * 10^{11} cm^{-3}$., sufficient for the initiation of atmospheric discharges.

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