Space-based femtosecond laser filamentation

Type of activity: Standard Study

1. Background and study motivation

Laser filamentation, resulting from the nonlinear propagation of intense ultrashort laser pulses in the atmosphere, has become a promising tool in various fields such as the remote sensing of pollutants using Lidar (Light Detection and Ranging) technology, wireless power transmission, electric field mapping of thunderstorms, and propulsion [1-2].

In this technique, femtosecond laser pulses in the terawatt optical power range propagate in the atmosphere behaving as quasi solitons thanks to a dynamic competition between the optical Kerr effect focusing the beam and the induced plasma effect defocusing the beam. This results in the formation of thin filaments where efficient nonlinear phenomena take place, including self-phase modulation leading to the generation of a coherent broadband continuum spanning from 300 nm to 14 µm [3].

This phenomenon could be of interest for lidar systems. The white-light continuum generated from femtosecond filamentation can provide additional information about water vapour and temperature profiles, enabling the direct measurement of relative humidity, and can simultaneously acquire multispectral Lidar information using a single laser source. Ground-based white-light lidar has been demonstrated recently by firing TW laser pulses in the atmosphere and measuring the backscattered white-light using a telescope and a few detectors and spectrometers [4-6]. Furthermore, laser filamentation can also deliver strong optical intensities at kilometric distances in a self-focused optical beam and can guide microwave radiation along induced-plasma channels for wireless power transmission applications [7].

2. Study Objectives

This study aims to investigate the scientific aspects of applying a femtosecond laser filamentation system from orbit. The first objective is therefore to model the downward vertical nonlinear propagation of intense femtosecond laser pulses launched from orbital altitude (~400 km). The second objective is to use these insights in order to derive sets of laser parameters for optimal efficiency.

Applications of such a technology can be envisaged in the areas of:

- White-light Lidar for the remote sensing of aerosols
- Wireless power transmission
- Electric field mapping of thunderstorms
- Lightning control
- Cloud seeding
- Propulsion

3. Proposed Methodology

The following study logic is proposed, though the universities and research groups are invited to propose different approaches to achieve the main goals.

- Construct a model for long-distance femtosecond filamentation.
- Add the effect of air turbulence, density variations, and humidity on the long-distance propagation.
- Study the impact of initial laser parameters such as beam shape, laser wavelength, initial focusing, and initial chirp on the filament formation.
- Determine the set of laser parameters optimal for efficiency of femtosecond filamentation from orbital altitudes.
- Study the impact of orbital parameters such as altitude and orbital inclination.
- Identify the impact of rarefied plasma and other upper atmospheric conditions on femtosecond filamentation.
- Assess the use of fs filamentation for wireless power transmission applications.
- Assess the ecological and climatic impact of femtosecond filamentation on the atmosphere.

4. ACT Contributions

This study is addressed to research groups having expertise in theoretical and computational nonlinear optics.

The project will be conducted in close scientific collaboration with ESA researchers. In particular ESA researchers will provide support on the theoretical aspects of this study and will investigate the wireless power applications of femtosecond filamentation. ESA researchers will also provide a technical and experimental knowledge of space-based instrumentation to ensure realistic simulation parameters. Finally ESA researchers will run the simulations in parallel to help identify the best set of laser parameters for efficient laser filamentation from orbital altitude.

References

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