Modulating the Radiative Transmission of the Atmosphere with High Power Laser Filaments

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Laser filament induced water condensation in the atmosphere is one of the most spectacular phenomenon associated with filamentation. Although observed both in controlled laboratory conditions and directly in the atmosphere[1,2], the underlying processes leading to the nucleation of particles from the gas phase and its further growth by water accommodation remain partially unclear. A further step towards understanding laser cloud formation was recently achieved by analyzing the composition of the nucleated particles *in situ* and in real time in the filamenting region with a time-of-flight mass spectrometer[3] directly in the outdoor atmosphere. A key result of the measurement campaign was the discovery of a new paradigm in laser assisted water condensation, namely the dramatig increase of the hydrophilicity of organic aerosols, which usually occurs in nature only during ageing over long periods of time. For relative humidities larger than typically 90-95% and warm temperatures, these nuclei would generate a local fog of droplets of several micrometers in diameter, altering significantly the atmospheric transmission.

Conversely, we recently found that the cloud transmission could be enhanced by filaments, especially in the case of cirrus clouds[4,5]. More precisely, cirrus cloud are consistuted of large (20-100 um) ice crystals, which both reflect the solar visible radiation and the heat emitted from the Earth, contributing to global warming. We found that by shining a filament on individual, trapped, ice crystals, the particles were shattered and evaporated, which, in turn produced a large number of smaller (micrometer sized) particles. This modulation of the ice crystal size distribution by filaments would invert the radiative forcing of cirrus clouds, as they would transmit the IR emission from the Earth, but still reflect the visible solar radiation.

Finally, we also found that transmission could be strongly enhanced in clouds by the use of high average power ultrashort lasers. With a picosecond, kHz laser with average powers > 100 W, we found that in addition to shattering and evaporating the cloud droplets, the droplets were moved away from the center of the beam in a steady state manner, by the repetitive laser filament induced shock waves. The applications of such enhancement of radiative transmission through fogs and clouds are of paramount importance for the recent programs on laser based earth to satellite or drone communication programs (like,e.g., the LCRD program from NASA, the Airbus Hyperion project, the Facebook Connectivity lab, etc..).

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