Lidar Technology for Remote Sensing of Constituents of Microparticles in Air

Background

The remote identification of the chemical composition of atmospheric aerosols and clouds is useful for the study of acid rain and for developing global climate models. In addition, the remote sensing for atmospheric microparticles such as saltwater aerosols is desirable to solve the corrosion problem of buildings, such as electrical power plants, by sea salts.

However, a technology to remotely measure the constituents of microparticles in air at a distance of more than several tens meters is not the level of practical use. Laser-induced breakdown spectroscopy (LIBS)*1 is attractive for the real time remote sensing of the constituents of microparticles in air. A bundle of filaments, which propagate for long distances with a focused condition, can be generated using a recently developed ultrashort-pulse high-intensity laser. This unique laser beam is expected to drastically improve the sensitivity of LIBS measurements of microparticles in air because a large number of microparticles can be ionized along filaments in air for a long distance, which can realize lidar measurements.

Objectives

To develop a remote sensing technology combining LIBS and lidar (LIBS-lidar) for the measurement of constituents of microparticles in air.

Principal Results

1. Measurement of Na fluorescence from artificial saltwater aerosols using filaments generated by ultrashort high-intensity laser pulses*2

The propagation of an ultrashort high-intensity laser pulse (pulse width: 7.5×10^{-14} s, peak power: 2×10^{12} W) in the air produced filaments (Fig.1). The Na fluorescence from the artificial saltwater aerosols irradiated by the laser pulses with filaments was successfully detected, which shows that the saltwater aerosols were ionized. Just after laser shot, Na fluorescence was not observed due to a strong white light emission generated by the self-phase modulation*3 of the laser pulses and the plasma produced in saltwater aerosols. However, Na fluorescence was most clearly observed at 20 ns after laser shot by adjusting ICCD-camera gate delay time from the laser shot, which is an important parameter of measurement (Fig.2, 3).

2. Demonstration of LIBS-lidar*2

Na fluorescence from the artificial salt water aerosols irradiated by the ultrashort high-intensity laser pulses was successfully observed remotely at a distance of 16 m by lidar measurement. Although improvement of the measurement sensitivity is necessary for the practical use, these results demonstrate the remote sensing of the constituents of microparticles in air by LIBS-lidar using ultrashort high-intensity laser pulses (Fig.2, 4).

Future Developments

The measurement sensitivity and range will be improved, and the remote sensing of the constituents of the atmospheric aerosols will be performed.

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Reference

T. Fujii, et al., 2006, “Lidar measurement of constituents of microparticles in air by laser-induced breakdown spectroscopy using femtosecond terawatt laser pulses”, Opt. Lett. Vol. 31, pp. 3456-3458.

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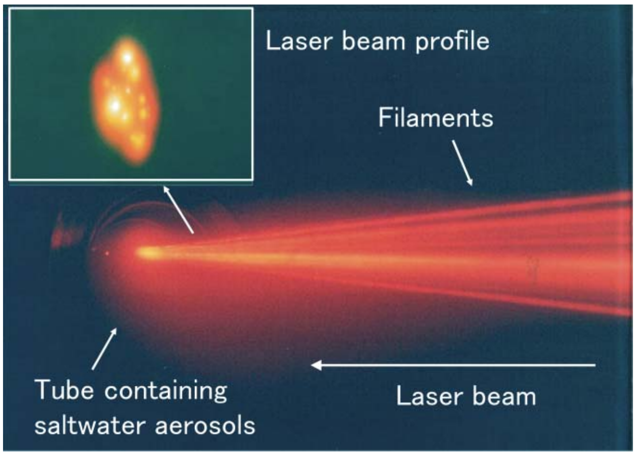
*1：A method to measure the constituents of materials by measurement of the fluorescence spectra of plasma generated by laser irradiation.
*2：A patent has been applied for these results (No: 2005-272665).
*3：Spectra enlargement due to phase moduration of laser beam because of the refraction change of materials by the laser intensity.



Multiple filaments are observed as bright lines and bright spots in the laser beam.

Fig.1 Laser beam propagation and profile around the measurement point

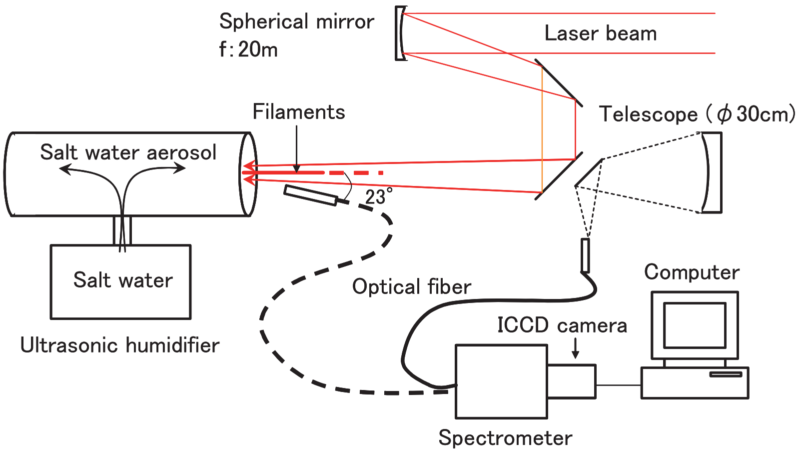


Fig.2 Experimental setup

The fluorescence from the saltwater aerosols irradiated with laser pulses was corrected directly by an optical fiber or by a telescope connected with the optical fiber, and was analyzed using a spectrometer and an intensified charge-coupled device (ICCD) camera.

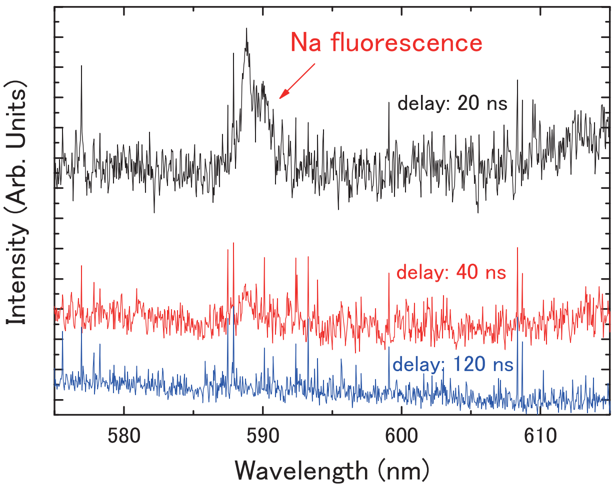


Fig.3 Spectra of Na fluorescence from saltwater aerosols irradiated by laser pulses when adjusting ICCD-camera gate delay time from the laser shot

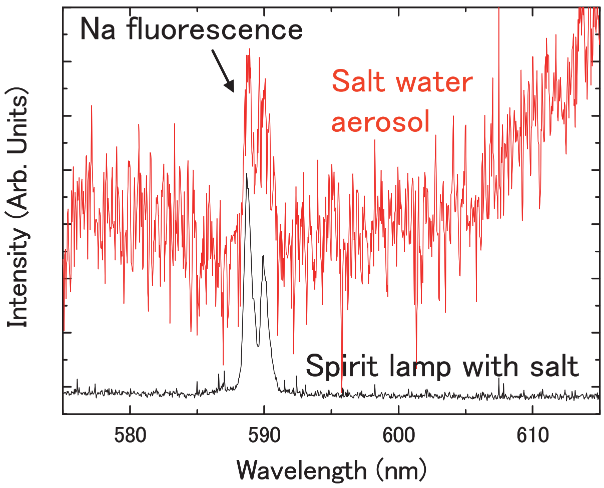


Fig.4 Spectra of Na fluorescence from saltwater aerosols irradiated by laser pulses measured by lidar, along with emission from a spirit lamp containing salt as a reference