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On-line monitoring of moisture carryover in steam generator using dual-pulse laser-induced plasma

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1. Introduction

The water droplets in the steam generator for pressurized water reactor can cause not only a reduction in turbine cycle efficiency but also damage to the turbine blade and housing. The quality of the steam can be measured using a chemical tracer (Li^+) that is only carried over with the main steam in the form of water droplets. For regular monitoring of steam quality, ion chromatography and atomic absorption spectrometry have been utilized for the detection of lithium in water as analytical tools. Here we have introduced laser-induced breakdown spectroscopy (LIBS) that employs two sequential laser pulses to determine lithium concentration in water. To achieve sensitive lithium detection, the optimal timing between two laser pulses, different laser wavelength, and influence of the ambient gas were investigated.

2. Experimental

The sequential laser pulses were generated by two Q-switched Nd:YAG lasers (Surelite-20, wavelength 355 nm and 532 nm, pulse width 6 ns, repetition rate 20 Hz). The interpulse delay between two pulses was controlled by two delay generators, as shown in Fig. 1.

Two pulses were delivered in the same direction to the surface of water jet using a fused-silica plano-convex lens with 54.2-mm focal length. A laminar flow was formed by a nebulizer with peristaltic pump. The plasma emission was collimated and focused by a 30-mm focal lens onto the entrance of fiber optic and delivered to the echelle spectrometer (LLA, ESA3000).

3. Result and Discussion

The dual-pulse configuration of LIBS provides a significant enhancement of emission intensity comparing with a conventional single-pulse configuration. The enhancement effect has been explained by several mechanisms such as re-heating by the second laser[1], increased ablated mass[2], rarified atmosphere[3], reduced continuum background[4] and so on. To verify the effect of dual-pulse configuration, we simultaneously observed the emission signal intensities of atomic line of lithium (20 ppb) and nitrogen at interpulse delay time of 12 μs and detector gate delay of 5 μs. No line emission of lithium was observed through single-pulse configuration, as shown in Fig. 2. On the contrary, much higher strong emission intensity of Li atomic line was detected with dual-pulse configuration.

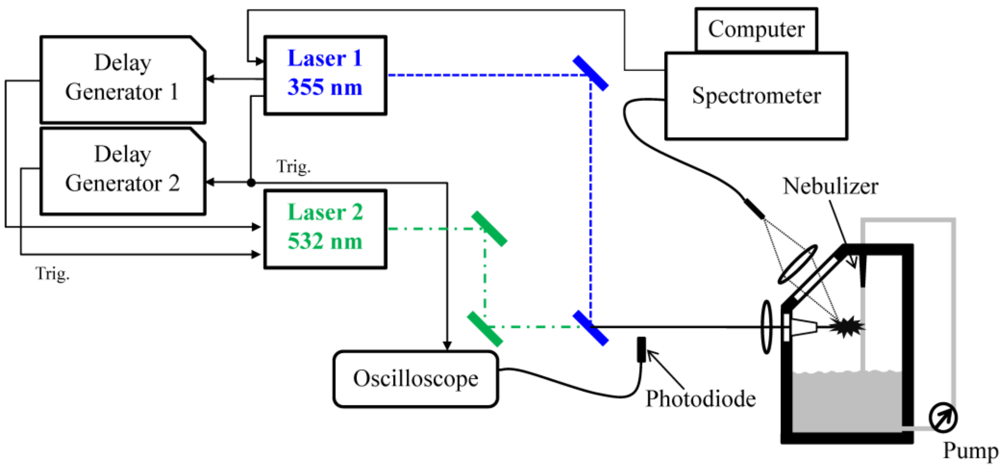

Fig. 1. Schematic drawings of the experimental setup for dual-pulse laser-induced breakdown spectroscopy.

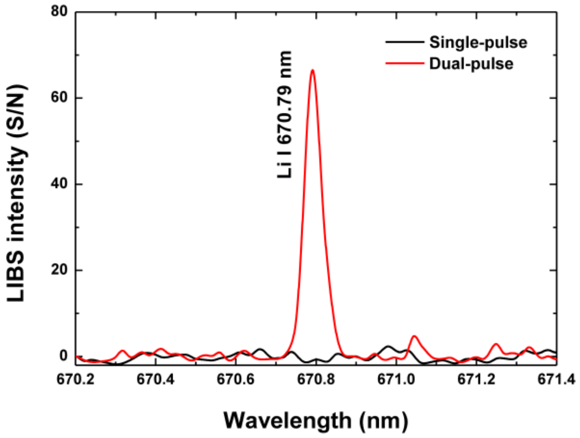

Fig. 2. Emission spectra of Li I by single and dual pulse excitation in aqueous solutions containing 20 ppb lithium.

The experimental result in Fig. 3 indicates that in the case of dual-pulse excitation, the ambient gas surrounding the plasma plume was rarified. Thus the intensity of the nitrogen atomic emission line was extremely reduced, and the decrease of continuum background was also observed. The effect of various ambient gases such as helium, argon, and nitrogen on the enhancement of Li atomic emission signal has been investigated for achieving more sensitive detection.

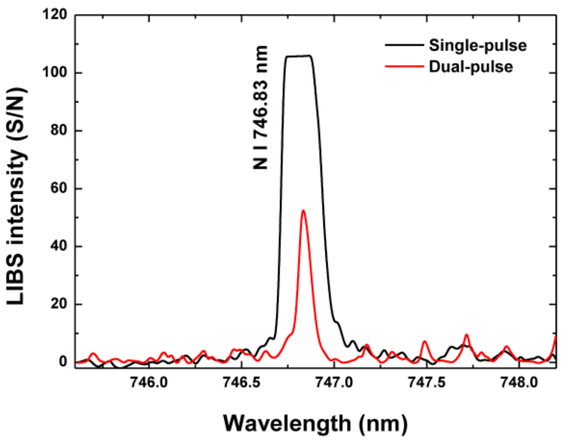

Fig. 3. Emission spectra of N I by single and dual pulse excitation under normal aerobic conditions.

4. Conclusions

The lithium ions in water serving as chemical tracer for steam quality analysis have been measured with extremely high sensitivity by dual-pulse LIBS configuration. Under the optimized conditions, the detection limit of Li was achieved in the range of sub parts per billion. This sensitivity of LIBS is very useful for the *on-line* monitoring of lithium with rapid and no sample preparation.

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