BLUE-GREEN ALGAE MONITORING BY A FLUORESCENCE LIDAR -OBSERVATION AT LAKE SUWA-

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ABSTRACT

A fluorescence lidar based on laser-induced fluorescence spectroscopy was developed for detection of blue-green algae. Among several types of algae, only blue-green algae have a peculiar peak of fluorescence at 650 nm by irradiation of 355 nm laser. Origin of the 650 nm fluorescence was phycocyanin molecule inside the blue-green algae. The system performance was investigated by outdoor observations at Lake Suwa. Lidar intensity data of the 650 nm fluorescence were compared with the phycocyanin concentration analyzed by a chemical method. The results showed a quite similar pattern of the variation of the concentration. One year observation confirmed the usefulness of the fluorescence lidar as blue-green algae detection.

1. INTRODUCTION

In Lake Suwa (Suwa and Okaya cities, Nagano Pref., Japan) outbreak of blue-green algae often happens in summer. The phenomenon causes several problems like that as some blue-green algae form noxious chemical substances, the water can not be suitable for water source; as the area around Lake Suwa is a popular place for sightseeing, brown-colored water and bad-smelling of the lake caused by the blue-green algae do a great deal of damage to the tourist industry in the area.

Therefore, some techniques for measurement and evaluation of the aquatic environment, especially development of the blue-green algae detection system is required. Chemical methods require sampling, liquid treatments and much time, although such methods may provide detailed information on algae. On the other hand, optical methods can overcome such troubles. We are especially interested in application of laser-induced fluorescence spectroscopy to aquatic environment investigation.

2. FLUORESCENCE CHARACTERISTICS OF BLUE-GREEN ALGAE

It is known that there are three types of algae in Lake Suwa, they are blue-green algae, diatom, and green alga. Observation of fluorescence characteristics of these algae was attemped. Figure 1 shows fluorescence spectra of them by irradiation of 355 nm pulse laser. Each of them had the peak at around 685 nm and 740 nm. They are fluorescences from chlorophyll that is a well known photosynthesis pigment. Important characteristic on the spectra is that only blue-green alga possesses the peak at around 650 nm. This means the possibility of discrimination of blue-green algae from other algae. It was confirmed that origin of the 650 nm fluorescence was phycocyanin molecule in laboratory experiment using cultured blue-green algae.

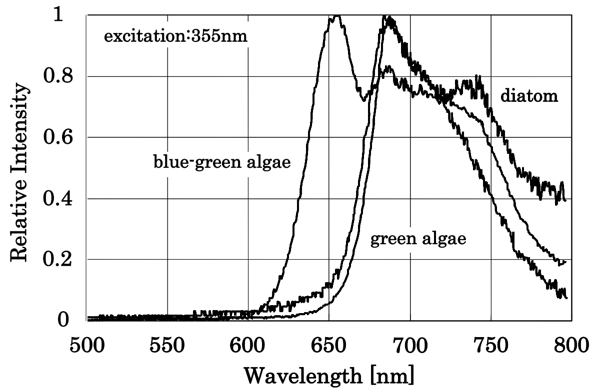

Fig. 1. Fluorescence spectra of three different kinds of algae

3. FLUORESCENCE LIDAR SYSTEM

The fluorescence lidar system we developed is shown in Fig. 2. It was constructed with a 355 nm pulsed Nd:YAG laser with 40 mJ, 6 ns, and 10 Hz and a cassegrainian telescope with 254 mm diameter and 1600 mm focal length. The fluorescence was detected by a small metal package photomultiplier through a 650 nm interference filter with 10 nm spectral width. After 5-fold amplification, the electronic signal was digitized by a 100 MHz oscilloscope with 8bit resolution. Range resolution was 0.15 m. System Operation was synchronized to the laser oscillation detected by a pin-photodiode. Operation control and data processing of the system was made by a personal computer.

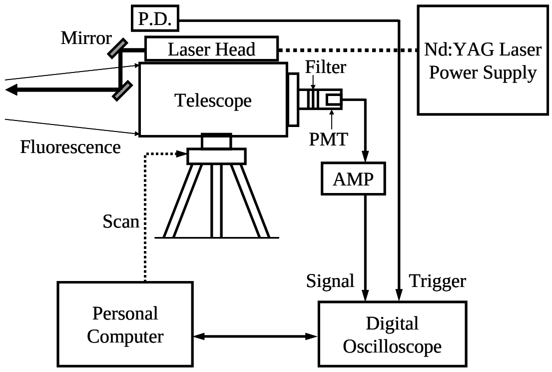

Fig. 2. System configuration of fluorescence lidar

4. OBSERVATION

Performance evaluation of the fluorescence lidar was carried out at Lake Suwa. The laser irradiated a point of water falling from a water gate that was 60m away from the lidar system. Figure 3 is a photograph of the observation.

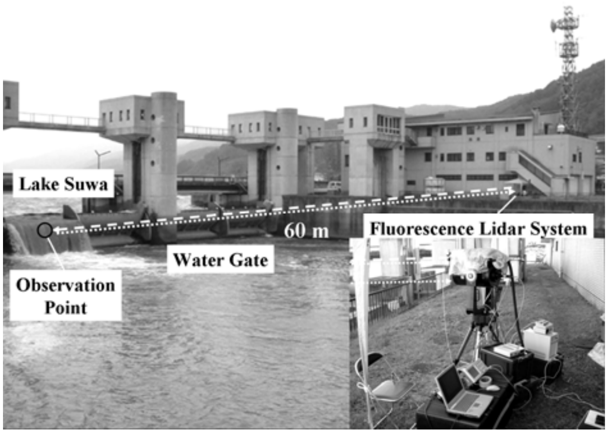

Fig. 3. Observation

The observation was performed once a month from June to December. Lidar results compared with concentration of phycocyanin. The chemical analysis of phycocyanin was made using the water sampled at the same time and the same place that the lidar observation was performed. It should be added that the lidar data could offer a real time observation results, but the chemical analysis to obtain the concentration needed one day at least after the lidar observation.

An example of the observation result is shown in Fig. 4, which is time variations of the lidar signal intensity and phycocyanin concentration. The lidar signal increased with the phycocyanin concentration until 13:00 and stayed constant in the afternoon. Their variations were in good agreement.

Comparison of all data of the observation from June to December is shown in Fig. 5. Although a good correlation between them can be seen, there are small differences if the phycocyanin concentration is lower than 40 μg/l. This results from spectral overlap of the three algae at 650 nm showing in Fig. 1. This can be also seen in Fig. 4 as a bias of the lidar data. The linear regression line derived at a phycocyanin concentration over 40 μg/l was

$$y=1.35x+75.64$$

where y is lidar signal intensity and x is the concentration. The decision coefficient was 0.95.

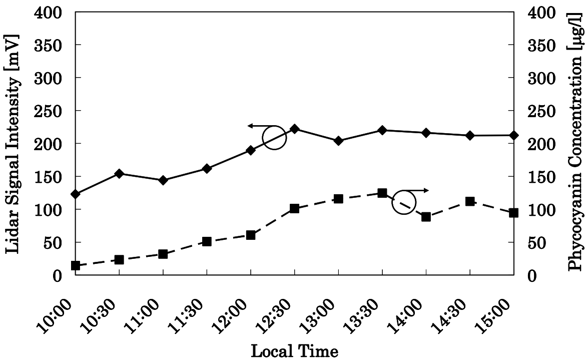

Fig. 4. Observation result on 7th of October

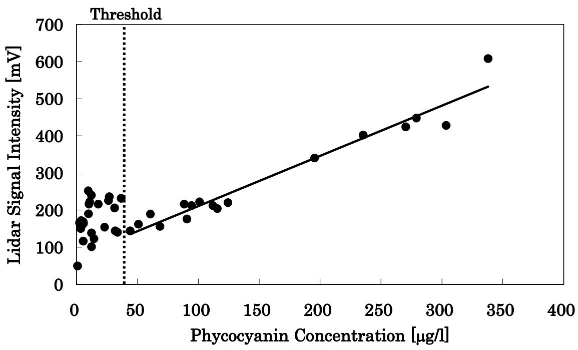

Fig. 5. Comparison of the lidar signal intensity with phycocyanin concentration

5. CONCLUSION

This paper described;

1) Blue-green algae had a peculiar peak at 650 nm in its fluorescence spectra, which origin was phycocyanin molecule inside the blue-green algae,
2) The fluorescence lidar was developed to monitor blue-green algae by phycocyanin detection,
3) One year observation at Lake Suwa showed a good correlation of the lidar data to phycocyanin concentration, and the detectable concentration of phycocyanin by the lidar was estimated to be 40 μg/l.

These experimental results confirm that the lidar based on laser-induced fluorescence spectroscopy is a powerful apparatus for water related environmental monitoring.