# Analysis of Trace Elements in Leaves Using Laser-Induced Breakdown Spectroscopy

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**Abstract:** Laser-Induced Breakdown Spectroscopy (LIBS) is a new way to analyze the plant ecology. The experimental used a Q-switched Nd:YAG laser to be the laser source and equipped with an eight-channel model spectrometer which's wavelength range between 200 and 1100 nm. Studying the spectrum of the air-drying leaves and the nature leaves and detected the elements which contain Fe, Ca, Na, Mg, K, Cu, Al and Mn. Displaying the list which shows the all spectrum and elements. Refer to Fe as the benchmark, obtain the relative content of trace elements. At the same time, this technology can be employed for food safety and environment pollution evaluation. It will be the based for studying the portable LIBS instrument of detecting the pollution of heavy metal.

**Key-words:** LIBS, Trace element, Leaves, Air-drying, Relative content

## 1 Introduction

Laser-Induced Breakdown Spectroscopy (LIBS) is a new technology which can analyse the constitution and concentration of the matter. It is a laser-based omnipotent molecular and elemental analysis tool. This technology doesn't need to deal with the samples in complicated. And it can anslyse several elements at the same time. LIBS is non-destructive, rapid detection, high sensitivity, on-site and online analysis. It is widely applied in the detection of trace elements in solid, liquid and gas, such as soil[1] alloy steel[2] solution[3] and even in biomedicine[4]. There are some reports about analysing the leaf by laser-induced breakdown spectroscopy. Lidiane[5] and other partners used LIBS to analyse the leaf by neuro-genetic approach. Miloslav[6] and his partners analysed the crop leaves and detected six certified reference materials of leaf tissues by LIBS.

Recently, in order to develop the level of LIBS, there are some experiments include nanosecond, femtosecond, monopulse, dipulse[7-8]. Although LIBS has been made a very great achievement in the analysis of material. But there are still many problems to be solved, such as how to decrease the matrix effect[9] in detecting several elements and how to increase the signal to noise radio.

In our work, we analyzed trace elements in leaf by LIBS. This works about the analysis of leaf can help to study the information of tea leaf and tobacco in the

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future. In this paper, first of all, we introduce the information of sample and the experimental setup. We displayed the results of trace elements analysis and all spectral lines to the correspanding elements table in leaves by LIBS.

## 2 Experimental setup

In our experiments, we used a Q-switched Nd:YAG laser (BeamTech, Nimma-200, China) to be the laser source and the experimental setup includes an eight-channel model spectrometer, mirror, DG535, lens, optical fiber(1.5 m length, 400 um core diameter), fiber-optical probe, rotating stage, computer as shown in figure 1.

The fundamental wavelength of the laser is 1064 nm. And other parameters about laser are 8 ns pulse width, 10 Hz repetition rate. Laser beam was reflected to 45° by the mirror, and through the mirror with a hole focused on the sample which were put on the rotating stage by the lens which's focal length is 200 nm. The plasma was launched and focused on the fiber-optical probe through the lens which's focal length is 100 nm. The probe position is adjustable. We used an eight-channel model AVS-Rackmount-USB2 spectrometer(Avantes, France) which's wavelength range between 200 and 1100 nm to collect and analyse the plasma emission. The spectrometer has eight wavebands which is 200-317nm, 315-417nm, 415-499nm, 497-565nm, 563-673nm, 671-750nm, 748-931nm, 929-1100nm. The integration time and the delay time respectively were 2ms and 1.28 us by taking the signal-background ratio and signal-noise ratio into account.

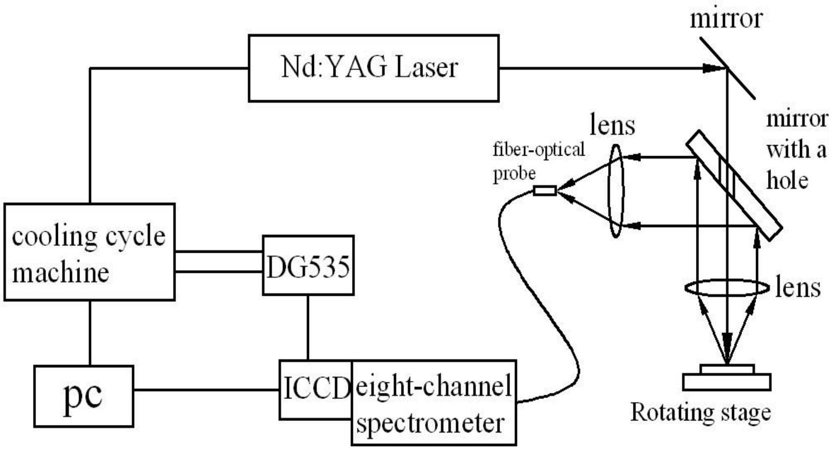


**Fig. 1.** LIBS experimental setup

## 3 Experimental results and analysis

The leaves came from the ecological orchard of Jiangxi Agricultural University. We picked the leaves in different orange trees. And then we washed the leaves by the deionized water. The leaves were divided into two parts, a part of all was wiped dry using filter paper, the others was dry by air drying in the air. Because the laser would produce the points which the laser hit on samples into high temperature, we used a rotating stage in order to make the effects of the laser in different points.

The figure 2 shows that a part of the spectra of capsicum in leaves. Refer to the NIST atomic database[10] and the spectral data of the elements from the papers[11-13], we obtain the specific wavelength of trace elements and analysed all peak of waves showing table 1. From the table 1, we can find several elements such as Fe, Ca, Na, Mg, K, Cu, Al, Mn. The spectrum of Fe is most, reaching 61. At the same time, the elements C, H, O, N, Cl were detected by LIBS. But these elements which were detected maybe were in the air. In addition, we detected Mo which was the indispensable element in plants. Because Fe was the most element and spectrum. We choose Fe for the datum to compared with other elements.

As shown in table 2, the intensity of Na is strongest of all. According to the intensity of spectrum being proportional to the concertration, we can obtain the conclusion that content of Na is the highest in leaves. The intensity of the same elements in air-drying leaves is stronger than in nature leaves. It explaines that water in leaves will affect the detection of elements. But the spectral intensity of Al and Na almost is the same between air-drying and nature. The water has a little effect to Al and Na in leaves.

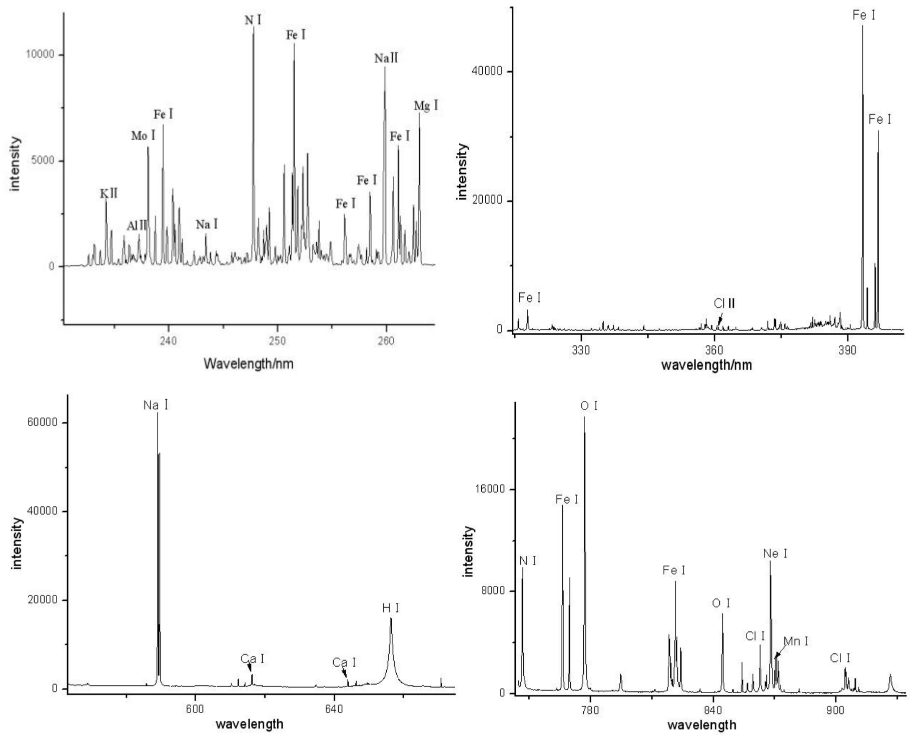


**Fig. 2** A part of spectrum in leaves

**Table 1**. The spectrum of LIBS in leaves

| Wavelen-gth/nm | Elem-ents | Waveleng-th /nm | Elem-ents | Waveleng-th /nm | Elem-ents | Waveleng-th /nm | Elem-ents |
|---|---|---|---|---|---|---|---|
| 232.606 | O Ⅱ | 253.231 | Mo Ⅱ | 381.977 | He Ⅰ | 742.361 | N Ⅰ |
| 233.120 | Fe Ⅱ | 253.787 | Mn Ⅱ | 388.193 | Fe Ⅰ | 744.219 | N Ⅰ |
| 233.698 | Na Ⅱ | 254.834 | C Ⅱ | 393.263 | Fe Ⅰ | 746.814 | N Ⅰ |
| 234.212 | K Ⅱ | 256.125 | Fe Ⅰ | 396.775 | Fe Ⅰ | 766.340 | Fe Ⅰ |
| 234.725 | C Ⅱ | 257.412 | Ne Ⅱ | 422.742 | Fe Ⅰ | 769.678 | Fe Ⅰ |
| 235.365 | Fe Ⅱ | 258.452 | Fe Ⅰ | 438.406 | Na Ⅱ | 777.072 | O Ⅰ |
| 235.877 | K Ⅱ | 259.854 | Na Ⅱ | 445.518 | Na Ⅱ | 794.791 | O Ⅰ |
| 236.325 | Fe Ⅱ | 260.584 | Fe Ⅱ | 498.216 | Fe Ⅰ | 818.404 | N Ⅰ |
| 237.218 | Al Ⅰ | 261.070 | Fe Ⅰ | 517.303 | Fe Ⅰ | 821.545 | Fe Ⅰ |
| 238.047 | Mo Ⅰ | 262.463 | Fe Ⅰ | 518.410 | Fe Ⅰ | 824.163 | N Ⅰ |
| 238.747 | Mg Ⅱ | 262.705 | Fe Ⅰ | 520.880 | Fe Ⅰ | 844.481 | O Ⅰ |
| 239.446 | Fe Ⅰ | 263.008 | Mg Ⅰ | 527.061 | Fe Ⅰ | 849.626 | Fe Ⅰ |
| 239.827 | Ca Ⅰ | 267.634 | Mn Ⅰ | 532.857 | Fe Ⅰ | 854.050 | Fe Ⅰ |
| 240.335 | Cu Ⅱ | 273.859 | Na Ⅱ | 537.208 | Fe Ⅰ | 856.662 | N Ⅱ |
| 240.969 | Na Ⅱ | 274.564 | Fe Ⅰ | 541.031 | Fe Ⅰ | 859.256 | Fe Ⅰ |
| 241.222 | Fe Ⅰ | 275.502 | Fe Ⅰ | 553.604 | K Ⅱ | 862.839 | Cl Ⅰ |
| 242.297 | Fe Ⅱ | 279.463 | Fe Ⅰ | 558.914 | Ca Ⅰ | 866.025 | N Ⅱ |
| 243.370 | Na Ⅰ | 280.157 | Al Ⅱ | 568.837 | Na Ⅰ | 867.923 | Ne Ⅰ |
| 244.315 | Na Ⅱ | 285.095 | Na Ⅱ | 585.729 | Ca Ⅰ | 870.169 | Mn Ⅰ |
| 245.760 | Fe Ⅰ | 288.046 | Fe Ⅰ | 588.977 | Na Ⅰ | 871.063 | N Ⅱ |
| 246.074 | Na Ⅱ | 301.973 | Fe Ⅱ | 589.571 | Fe Ⅰ | 871.777 | Mg Ⅰ |
| 247.201 | Mo Ⅰ | 308.113 | C Ⅱ | 610.303 | Fe Ⅰ | 881.872 | Fe Ⅰ |
| 247.764 | N Ⅱ | 309.167 | Fe Ⅰ | 612.246 | Ca Ⅰ | 904.486 | Cl Ⅰ |
| 248.201 | Fe Ⅰ | 315.809 | Fe Ⅰ | 614.173 | Fe Ⅰ | 909.387 | Fe Ⅰ |
| 248.700 | Fe Ⅰ | 317.849 | Fe Ⅰ | 616.203 | Ca Ⅰ | 911.025 | O Ⅱ |
| 248.949 | Fe Ⅱ | 334.884 | O Ⅱ | 643.895 | Ca Ⅰ | 926.633 | O Ⅰ |
| 249.199 | Fe Ⅰ | 343.986 | Fe Ⅰ | 646.244 | Ca Ⅰ | 938.644 | Fe Ⅰ |
| 249.759 | Fe Ⅱ | 358.042 | Fe Ⅰ | 656.229 | H Ⅰ | 940.518 | Fe Ⅰ |
| 250.565 | Fe Ⅰ | 359.263 | Fe Ⅰ | 670.770 | Fe Ⅰ | 945.993 | N Ⅰ |
| 251.064 | Fe Ⅱ | 360.478 | Cl Ⅱ | 693.816 | K Ⅰ | 962.024 | C Ⅰ |
| 251.498 | Fe Ⅰ | 361.792 | Fe Ⅰ | 714.761 | Fe Ⅰ | 965.786 | C Ⅰ |
| 251.808 | Fe Ⅰ | 363.048 | Ca Ⅰ | 715.673 | O Ⅰ | 1011.511 | N Ⅰ |
| 252.304 | O Ⅱ | 364.713 | Mn Ⅰ | 720.172 | Ca Ⅰ | 1053.882 | N Ⅰ |
| 252.737 | Fe Ⅰ | 371.923 | Mo Ⅰ | 732.544 | Ca Ⅰ | | |

**Table 2.** The trace elements' specific wavelengths, average spectral intensity and the ratio

| Trace element | Specific wavelength (nm) | Average spectral intensity | | The ratio of air-drying to nature | The ratio of element to Fe in Air-drying leaves |
|---|---|---|---|---|---|
| | | Air-drying | Nature | | |
| Fe | 422.743 | 10147.72 | 7485.75 | 1.36 | 1.00 |
| K | 234.212 | 3225.88 | 2050.70 | 1.57 | 0.32 |
| Al | 237.218 | 1563.05 | 1525.63 | 1.02 | 0.15 |
| Mg | 263.008 | 7307.31 | 4734.69 | 1.54 | 0.72 |
| Na | 588.977 | 62501.57 | 64445.97 | 0.97 | 6.16 |
| Ca | 643.895 | 3152.75 | 1782.66 | 1.77 | 0.31 |
| Mn | 870.169 | 2755.64 | 1692.33 | 1.63 | 0.27 |

## 4 Conclusion

In this paper, we used the Laser-Induced Breakdown spectroscopy to detect the trace elements in leaves and obtained the spectrum of Fe, Ca, Na, Mg, K, Cu, Al, Mn, C, H, O, N, Cl. Concertration of Na is the highest. And we compared the air-drying leaves with nature leaves and got the conclusion that the water will affect the detection of elements in leaves. Experiment shows LIBS can quickly analyse the relative content of trace elements in leaves.

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