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# Effect of laser wavelength and energy on the detecting of trace elements in steel alloy

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ABSTRACT

In order to investigate the effect of laser wavelength and energy on the detection of the trace elements in alloy steel, pulsed laser at 1064 nm and 532 nm wavelength have been employed to generate plasma. The effects of the laser energy of these two laser wavelengths on plasma emission intensity, plasma temperature and electron density were studied. The trace elements of Ni, Al and Cr in the sample were quantitatively analyzed by internal standard method under these two different laser wavelengths with different laser energies. The results have shown that the intensities of the spectral intensities increased with the increasing of laser energy at different wavelengths, and then tended to change gently. The plasma temperature also increased with the increasing of laser energy, and the change of plasma temperature under 532 nm wavelength is slower. The plasma electron density firstly increased with laser energy, and then decreased when the laser energy exceeded the threshold. The quantitative analysis results show that the elements of Ni and Al have lower detection limits at 1064 nm wavelength, while the lower detection limit of Cr corresponding to the 532 nm wavelength. When the sample was ablated at 1064 nm wavelength, the detection limit of the three elements was gradually reduced with the increasing of laser energy.



## 1. Introduction

Laser-induced breakdown spectroscopy (LIBS) uses a high power pulsed laser to generate plasma by ablating the sample. The qualitative and quantitative analysis of the sample can obtain through analyzing the emission spectra from the plasma. This technique has been widely concerned with the advantages of no sample pretreatment required, rapid analysis speed, multi-element simultaneous process. It has been applied to a large range of fields such as environment [1–3], metallurgy [4–6], agriculture [7,8], nuclear industry [9] and archaeology [10].

Because the spectra of LIBS depend on several parameters of the experiment system, the analysis capability of this technology has been limited. In recent years, the performance of LIBS has become one of the main research directions of researchers. The laser source is the important composition of LIBS system. The wavelength and energy of the laser played an important role in the detection ability of the element. The sample material is related to the absorption character of laser energy and wavelength [11,12], as well as the physical-chemical characteristics of species affect the character of laser plasma [13,14].

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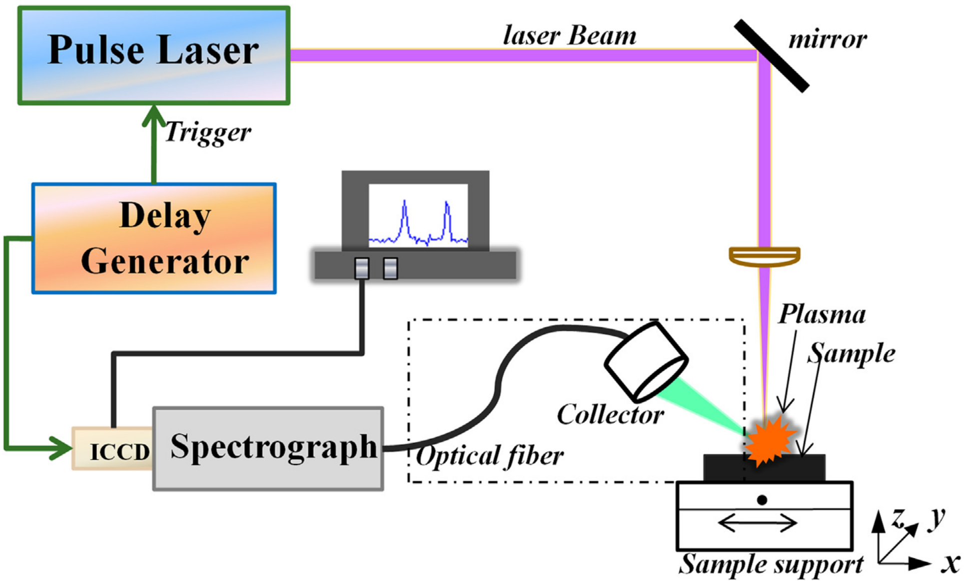


**Fig. 1.** Schematic diagram of experimental setup.

In this paper, the steel alloy samples have been ablated by the laser with the wavelength of 1064 nm and 532 nm respectively. We have studied the influences of the laser energies on the spectral parameters of the plasma. The quantitative analyses for the three minor elements of Ni, Al and Cr in the sample have been investigated at different laser energies. Finally, we analyzed the influence of the laser wavelength and energy on the detection ability of elements.

## 2. Experimental setup

The experimental setup of the LIBS is shown in Fig. 1. A Q-switched Nd:YAG pulse laser at wavelengths 1064 and 532 nm with pulse duration of 7 ns was used. The laser energy can be adjusted according to experimental requirements. The range of pulse energy is from 25 mJ to 200 mJ when the laser wavelength is 1064 nm, and it is from 20 mJ to 70 mJ when the laser wavelength is 532 nm. The repetition rate has been set with 1 Hz. The laser beam was focused on the surface of the alloy steel sample by a 100 mm focal length plano-convex quartz lens. The focused laser has high energy density which can breakdown the sample and produce dense plasma. An UV-NIR light collector (Andor technology) was used to couple the whole plasma emission into the fiber. The core diameter of the fiber (UV–VIS fused silica) was 100 μm, and its length was 3 m. The plasma emission was sent to detect by an Echelle spectrometer (Andor technology, Mechelle 5000) equipped with an Intensified Charge-Coupled Device(ICCD) detector (Andor technology, iStar 334). The ensemble provided a spectral range of 230 nm–920 nm, a resolution power($\lambda/\Delta\lambda$) of 5000. A delay generator (SRS, DG645) was used to control the delay time between the laser and spectrometer.

## 3. Results and discussion

### *3.1. Influence of the laser wavelength and energy on the spectral intensity*

The laser at wavelengths 1064 nm and 532 nm were used to ablate the alloy steel sample respectively. The spectral were collected at different laser energy with a delay of 1.5 μs and a gate width of 2 μs. Each spectrum was accumulated for 50 laser pulses. For each new measurement, before spectral collection, 20 laser pulses were performed to clean the sample surface. The atomic lines of Fe I:374.57 nm, Mn I:403.08 nm, Cr I:425.43 nm and ionic lines of Fe II:275.59 nm, Mn II:259.37 nm, Cr II:283.56 nm were selected as analytical lines.

Fig. 2 shows the line intensities with the change of laser energy. Obviously, at a wavelength of 1064 nm, the intensities of atomic and ionic lines gradually increase with the laser energy increasing. The curves show a relatively flat region at the laser energy from 120 mJ to 140 mJ. The line intensity increases with the laser energy again when the energy exceeds 140 mJ. The curve tends to be saturated after the energy of 180 mJ. The reason of that is connected to the energy density. The front edge of the laser pulse ablates the target surface and produces laser-induced plasma, and the back edge interacts with the plasma complicatedly forming the laser supported absorption wave [15] which depends on laser energy density. It changes the density of the laser energy and effects the model of the laser supported absorption wave with the changing of the laser energy. We kept the distance from the lens to the target surface, simply, where the focused laser diameter is not changed. Therefore the change of the laser energy density is consistent with the laser energy. It meets the model of the