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The High-Speed Photography Research of Femtosecond Laser Ablation Process

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Abstract

Using the research of high-speed photography method to carry out the dynamic characteristics of the femtosecond laser ablation process, at the same time, explore a kind of high spatial resolution, response rate and the sensitivity of the new technology means and methods, the thorough analysis and research for dynamics of femtosecond laser ablation of crystal material characteristic has been carried on, we have gotten the characteristics of crystal material.

Keywords: crystal material ,high-speed photography, dynamic characteristics, femtosecond laser ablation;

1. Introduction

In recent years the research of the ablation process of femtosecond laser is becoming more and more widely. Study means increasingly update, the ablation medium types also gradually increased, to detect the active the ablation process of femtosecond laser mechanism is becoming a hot spot of research. Femtosecond laser ablation process is a complex physical process including a variety of dynamic mechanism. When the femtosecond laser ablation of crystal materials, can form micro plasma. Many usually plasma diagnostic methods, such as high-speed photography method, the beam deflection method, holographic interferometry, time-resolved shadow figure method, etc. For femtosecond laser ablation crystal materials produce micro plasma kinetics research, many researchers at home and abroad due to the current laboratory equipment, conditions, constraints, and the study of the shearing section. At fast process is relatively small, the development process of laser induced shock wave in the early research is relatively weak.

In view of the above limitations, this paper using the high-speed photography method to carry out the dynamic characteristics of the femtosecond laser ablation process of research, at the same time, explore a kind of high spatial

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resolution, response rate and the sensitivity of the new technology means and methods, dynamics of femtosecond laser ablation of crystal material characteristic carried on the thorough analysis and research.

2. Flash photography research at a high speed

This part establishes the flash, high-speed photography system under different femtosecond laser energy, the femtosecond laser ablation of pure aluminum is studied, pure copper, pure iron, monocrystalline silicon slice of the characteristics of the micro plasma expansion process induced directly on the expansion of the micro plasma process were studied.

2.1. Experiment device

Designed with measurement of the ablation process of femtosecond laser for crystal material produces micro plasma kinetics experiment system. It has been shown in Fig.1, mainly by femtosecond laser system and the system composition, Fig.2 real figure for high-speed photography experiment system.

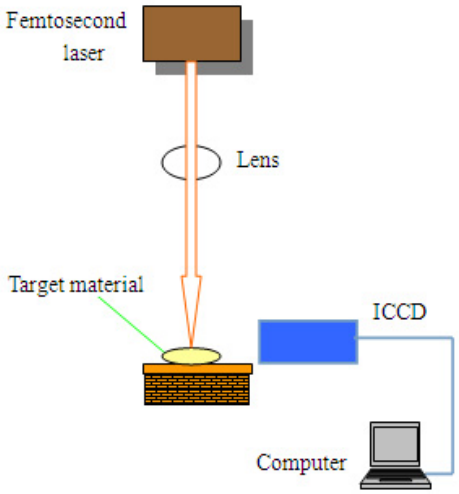

Fig.1 The experimental device diagram of high-speed photography

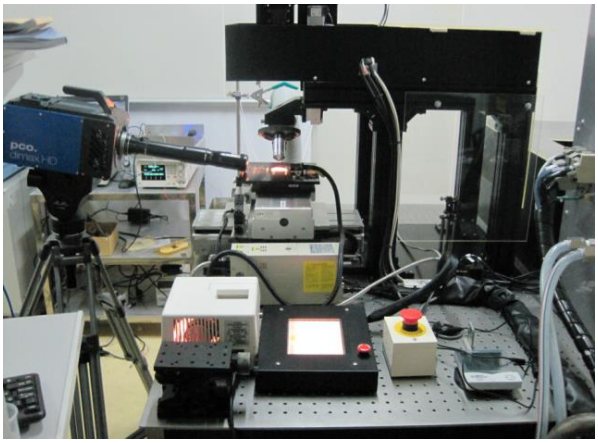

Fig.2 the object graph of high-speed photography experimental device

2.2. Experiment method

Experiments using femtosecond laser is a Japanese company LS - IF - FW - C - 401 type femtosecond laser experiment system, the main parameters of the femtosecond laser is: 180 fs pulse width and center wavelength of 780 nm, 1 kHz pulse frequency, pulse energy of 1.1 mJ, 1.1W is the power of average output, laser output beam diameter 6 mm, pulse stability between 1.5% RMS, three-dimensional workbench mobile range + x + 100 mm x 100 mm + / - 25 mm, moving accuracy of 1.0 mu mu m x 0.5 m x 1.0 microns. Femtosecond Laser experiment system is mainly composed of femtosecond lasers (Cyber Laser Inc.), optical path system, monitoring and three-dimensional work platform, Fig.3 for femtosecond Laser experiment system schematic diagram, Fig.4 for femtosecond Laser experiment system physical figure.

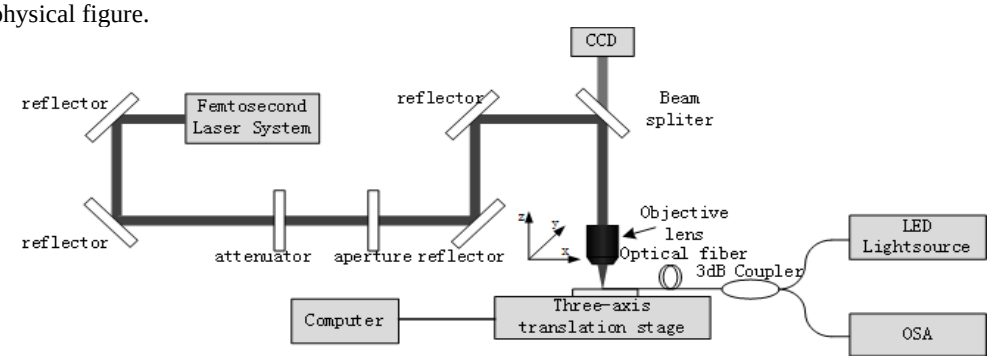

Fig.3 the schematic diagram of femtosecond laser experiment system

Fig.4 the object graph of femtosecond laser experiment system

digital camera, exposure time of 1.5 mu s - 40 ms. Experiments using high power density, short pulse produced by femtosecond laser beam irradiation femtosecond laser crystal materials, through high speed enhanced shot femtosecond laser ablation crystal material produces micro plasma expansion process. Storage of photography figure is by connecting the computer to complete, German PCO company produces take relevant programs and software, the researchers used convenient experiment. In the experiment, the process of crystal materials, use of ICCD monitoring system for real-time online monitoring, observation of the ablation process of femtosecond laser, by adjusting the parameters such as pulse energy, detection range to control the ablation process of femtosecond laser.

2.3. The result of the experiment and analysis

Using German PCO company produces the PCO. Dimax HD on plasma flash type high speed digital cameras, femtosecond laser pulse energy, respectively for 300 mw, 400 mw, 500 mw, the femtosecond laser ablation, respectively, of monocrystalline silicon films, pure aluminium, pure copper, pure iron produced by the micro plasma photo as shown in Fig.5, Fig.6, Fig.7, as shown in Fig.8. As can be seen from the above picture, under the action of different energy of femtosecond pulse laser, femtosecond laser ablation monocrystalline silicon slice, pure aluminium, pure copper, pure iron to produce plasma dynamic expansion process. By means of femtosecond laser ablation of pure aluminum, pure copper, iron, monocrystalline silicon slice of the four groups of images under different energy analysis concluded femtosecond laser ablation form micro plasma crystal materials, depending on the materials of the femtosecond laser ablation crystal general physical process, part of the femtosecond laser energy will continue to be absorbed by the micro plasma, lead to the micro plasma temperature, degree of ionization increases, resulting in a outward expansion of the dynamic process. Micro plasma in does not terminate in the process of expansion of femtosecond laser energy absorption, continue to absorb the energy of the part of the micro plasma internal energy, another part of the energy provides the expansion of the micro plasma against the direction of the laser beam movement.

Under the same experimental conditions, when the femtosecond laser pulse energy increases, the femtosecond laser ablation of crystal material to produce micro plasma increase energy absorption, outward expansion movement speed, the size of the micro plasma will increase, and the size of the micro plasma photography figure on the longitudinal than horizontal direction. It was found that with the increase of femtosecond laser energy, femtosecond laser ablation of monocrystalline silicon chip micro plasma obviously, the expansion of the longitudinal changes in the femtosecond laser ablation of pure iron micro plasma minimum longitudinal expansion of the scale of the change.

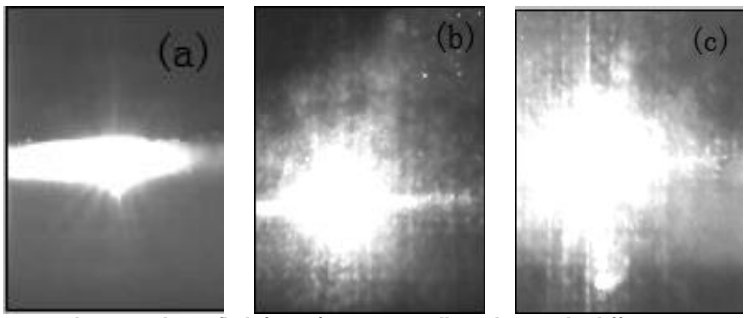

Fig5 the micro plasma flash figure for monocrystalline silicon under different energy
(a)300mw (b)400mw (c)500mw

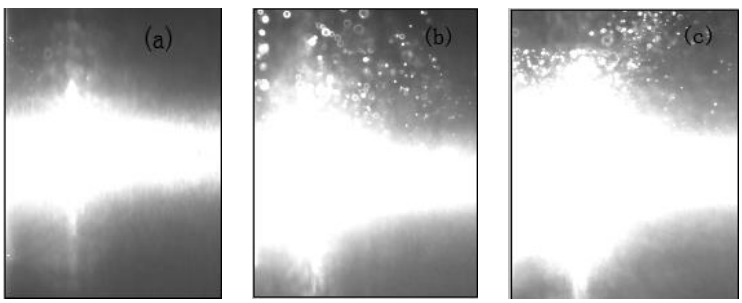

Fig.6 the micro plasma flash figure for pure aluminium under different energy
(a)300mw (b)400mw (c)500mw

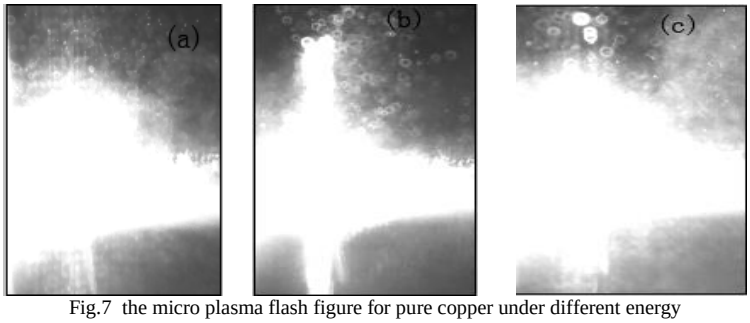

Fig.7 the micro plasma flash figure for pure copper under different energy
(a)300mw (b)400mw (c)500mw

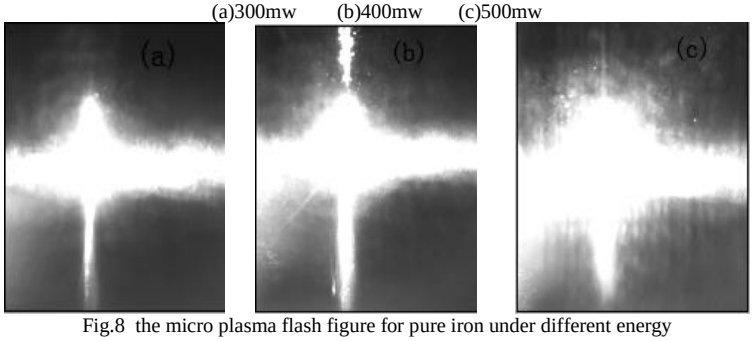

Fig.8 the micro plasma flash figure for pure iron under different energy
(a)300mw (b)400mw (c)500mw

3. Conclusions

This paper applying the method of high-speed photography, the different femtosecond laser energy under 300 mw, 400mw, 500mw of femtosecond laser ablation of pure aluminum, pure copper, pure iron, monocrystalline silicon micro plasma dynamic process was studied. Experiments can be seen through this part, the high-speed photography method can directly reflect the femtosecond laser ablation of crystal materials produced by micro dynamic process and the basic characteristics of plasma. At the same time, the femtosecond laser ablation crystal materials to produce micro plasma a droplet on the space shape, the size of the micro plasma photography figure on the longitudinal than horizontal direction. With the increase of femtosecond laser energy, the micro plasma on the space also increases as the size. The experimental conclusion can be used to interpret the generating mechanism of laser plasma. These phenomena and theories analysis provide a reference for research in the field of femtosecond laser application value, to further explore the mechanism of the ablation process of femtosecond laser has the important practical significance.

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