# Development of a 3D Laser Scanning System for Laser-induced Breakdown Spectroscopy


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***Abstract*—We report a new laser scanning device to be used in a laser-induced breakdown spectroscopy (LIBS) system. The system consists of a tunable lens, a cold mirror that transmits infrared wavelengths, two galvano mirrors, a condenser lens, and an optical axis adjusting laser. Conventional laser scanning technologies have two main applications: (i) in the industry, for drawing simple dots/lines with high power lasers; and (ii) in laser art projections, where far more complex illustrations and animations using visible lasers have been achieved. These two applications have been developed separately. Our scanning system combines the advantages of both these technologies by employing high-strength galvano mirrors as well as a driving system that meets the international laser display association (ILDA) standard. Moreover, by assembling the electrically controlled tunable lens, any measuring point where the generation of laser-induced plasma is needed, can be reached in a given space.**



***Keywords—laser; galvano mirror; laser measurements; laser projector; laser-induced plasma***


## I. INTRODUCTION

Our recent research efforts have been in the application of the LIBS system to environmental monitoring, like cesium detection in soil [1–3], fine particulate analysis in the air [4–8], and so on. A positional relationship between the measuring sample and the laser focal point is an important factor on these LIBS measurements. In a field measurement, it is easier to adjust the laser focal point to the sample position, than guide the sample to the laser focal point. Along with achieving these requirements, the laser scanning system is innovated upon. The laser scanning technique on LIBS will play an important role in the LIBS installed with remote micro-imager [9–11], microscope [12, 13] and other LIBS applications for chemical composition analysis [14–25].

## II. EXPERIMENTAL SETUP

### A. The LIBS System

Fig. 1 shows the schematic of the LIBS system attached with the 3D laser scanner. A Q-switched, pulse operated Nd:YAG laser beam is condensed to generate plasma at the focal point. The plasma emission is guided into the spectrograph, time-resolved by the streak camera, and finally

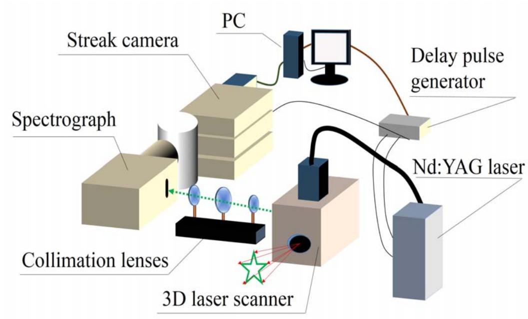


Fig. 1. Schematic of the LIBS system using the 3D laser scanner

processed by a PC. All signal timings are controlled by a delay pulse generator.

### B. The 3D laser scanning system

Fig. 2 illustrates the 3D laser scanning system. The focal point depth is electrically controlled by a tunable lens within 2.5 msec to adjust the focal point depth. Scanning directions on the left, right, top and bottom are controlled by the X-axis and Y-axis galvano mirrors. The operation tests show that the mirrors work normally at 10 K mode (10,000 dots per second), 20 K mode (20,000 dots per second) and 30 K mode (30,000 dots per second). The cold mirror works like a half mirror. It transmits the infrared laser beam, while reflecting visible light. The cold mirror is used to reflect plasma emissions.

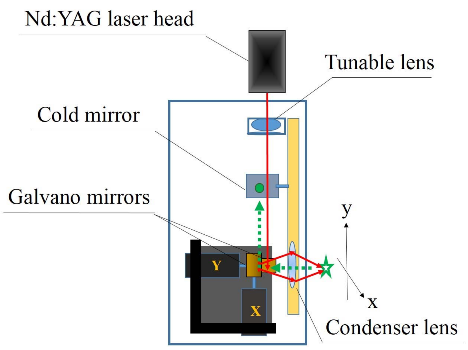


Fig. 2. Side view of the 3D laser scanner as seen from the spectrograph

## III. EXPERIMENT

The half mirror used on the system is called a cold mirror, and has the special characteristic that it transmits light in the infrared range and reflects light in the visible range. The mirror was located between the galvano mirrors and tunable lens. It is easy to efficiently separate the optical path of the infrared laser and visible plasma spectra, which have different wavelengths, using this characteristic of the cold mirror. In order to verify this attribute, transmission and plasma generation tests were carried out. Figure 3 shows transmission ratio of the cold mirror at 45° incident angle in the range 250–680 nm wavelengths obtained from bremsstrahlung spectra using the LIBS system. Figure 4 shows intensity reduction of spectra obtained from air plasma generated by the laser (λ = 1064nm) penetrated through the cold mirror at 45° incident angle. The results show that the cold mirror reflects well in the ranges of 250–350 nm and 450–680 nm wavelength. However in the wavelength range of 350–450 nm, part of the emission light penetrates through the cold mirror. With the penetration of infrared laser beam operated at 1064 nm wavelength, intensity of plasma emission was decreased to 86.8% of its original intensity, on average (Fig. 5). This has little effect on plasma generation.

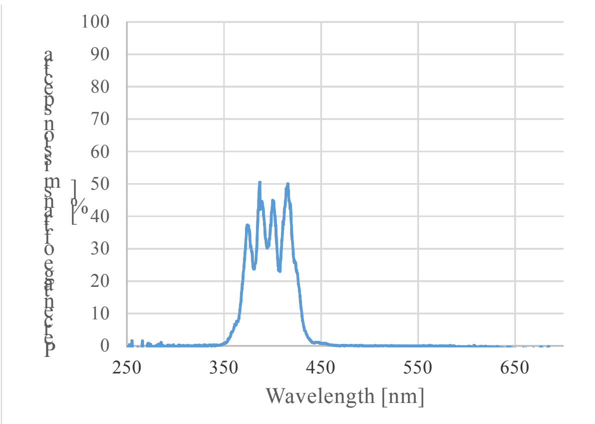


Fig. 3. Transmission ratio of the cold mirror for visible light

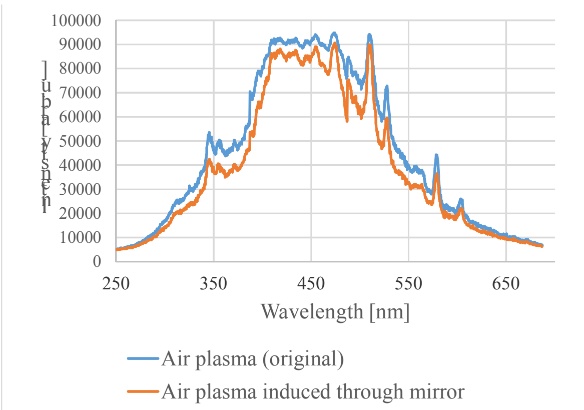


Fig. 4. Intensity reduction of air plasma spectra

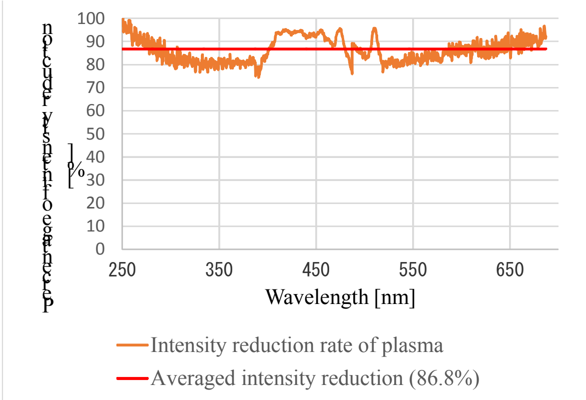


Fig. 5. Percentage of intensity reduction rate of plasma and avaraged value

Actuators and driver boards to scan x and y directions were applied from typical galvanometer components. To use the mirrors with the high-power infrared Nd:YAG laser, the highly durable new mirrors made from Cr-Au coated synthetic quartz glasses (split a mirror: 14×10×1.9 mm in two, reflectivity: 75% at 530 nm, 95% in the range 700 nm–1100 nm) were employed (Fig. 6). The new mirrors were attached to the actuators using specially made joints (Fig. 7).

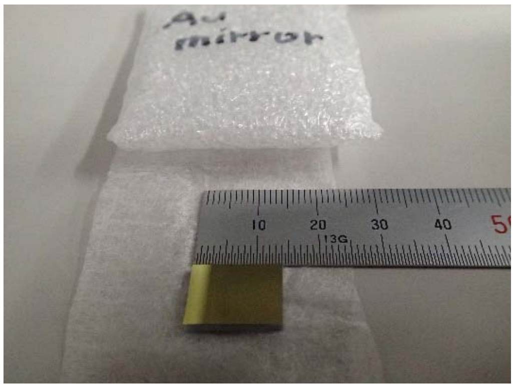


Fig. 6. Photograph of a Cr-Au coated synthetic quartz glass mirror

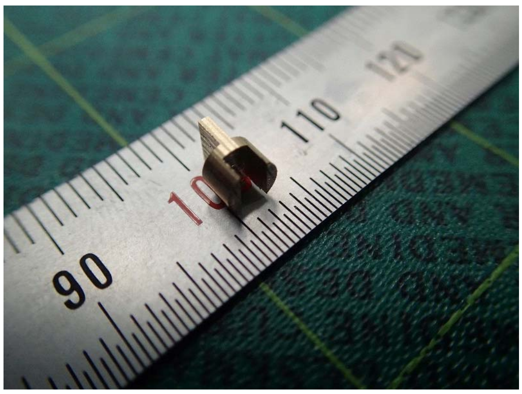


Fig. 7. Photograph of a specially made joint

A tunable lens was used for z-axis positioning of the focal point. The plasma generation point was located short of the focal point because the energy threshold for generating the plasma was overcome at this point. The operational principle of the tunable lens is that the shape of an optical fluid sealed within an elastic polymer membrane can be changed by operating the electrical current. This device yields focal lengths in the range 210 mm–80 mm for current values in the range at 0 mA–300 mA and allows adjustment of focal length with high response time (2.5 ms in a 10%–90% step). Fig. 8 shows a photograph of the 3D laser scanner system. For confirmation test of the galvano scanner, drawing test was conducted. The drawing workload level depends on the momentum of the galvano mirrors and the torque capacity of the motors. Fig. 9 is the international laser display association (ILDA) test pattern. Sample result is shown in figure 10.

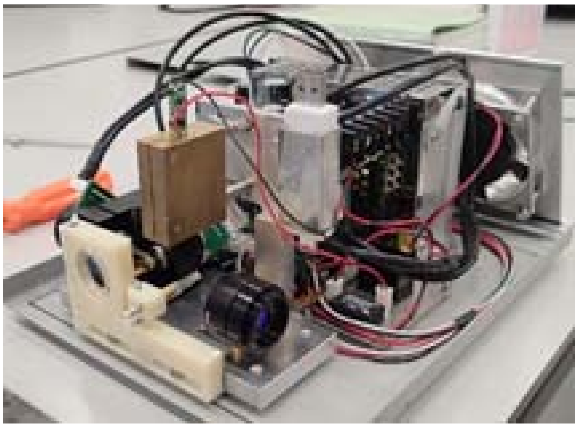

Fig. 8. Photograph of the 3D laser scanner attached with a semiconductor laser for adjustment of optical axis.

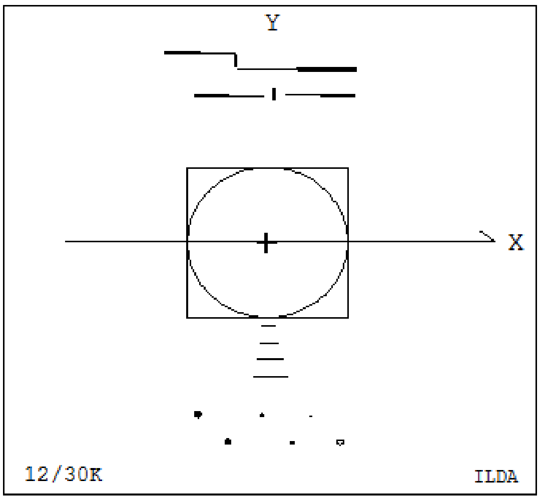


Fig. 9. ILDA test pattern image. (This material is copyright ©1999 by the International Laser Display Association and is used with permission)

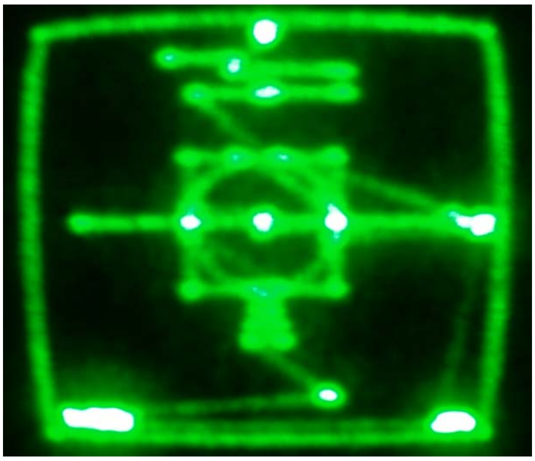

Fig. 10. Photographs of ILDA test pattern image at 10,000 points per second scanning speed (10 K mode).

From the results of these experiments, we found that if a continuum laser was used for the laser measurements, the system had to be operated at 10,000 points per second or less with blanking/shutter operation. Fig. 11 shows results of laser scanning output drawing the letters “IEEE” using (a) a semiconductor laser, and (b) laser plasma spot mark using Nd:YAG laser.

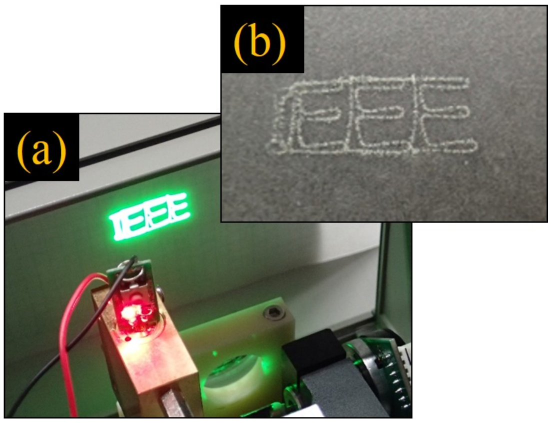


Fig. 11. Photographs of (a) operation test for galvano mirrors using semiconductor laser and (b) result of the laser-induced breakdown on a black paper.

From the results of laser-induced breakdown using a paper screen put in front of the condenser lens at a distance of 25 mm–45 mm from the lens surface, a few hundred of spots were marked on the paper and the drawing area size was approximately 20 mm × 20 mm at the imaging location on the screen.

## IV. CONCLUSION

Demonstration of confirmation experiments of a 3D laser scanning system for laser-induced breakdown spectroscopy is reported in this paper. From the results of these experiments, it was found that the system had to be operated at 10,000 points per second or less due to the replacement of the galvano scanner mirrors with thicker Au-Cr coated mirrors. Farther, if a continuum laser is used for the laser measurements, blanking/shutter operation is required. However, if a low frequency pulsed operated laser is used, the scan speed is sufficient to set focal point positions and blanking/shutter operation is less affected the marking. The galvano mirrors need to be improved to prevent deposition of dust particles in the air and new materials must be investigated as substitute for the mirrors with higher durability. Additionally, the condenser lens we used causes geometrical distortion. Another kind of lens, such as an F-theta lens, as a condenser lens is suitable for the presented scanner in future works.

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