IMAGING OF SURFACE MICROSTRUCTURES OF MATERIALS

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Abstract: This paper describes functionality extension of a LIBS (Laser-Induced Breakdown Spectroscopy) device. Subject of the extension is surface microstructure imaging of materials. The first method uses illumination module. The module contains four sections, each individually controlled. Each segment can be regulated or switch on or off independently. Thanks to illumination from several angles one obtains better image of the surface. This is caused by visible change sample microstructure. The second method of surface optical detection uses collinear illumination.

Keywords: LIBS, Brightness Regulation, Microstructure, Surface, Design

1 INTRODUCTION

A device called Sci-Trace, made by AtomTrace a.s, is composed of a mobile carriage and an optical breadboard. LIBS interaction chamber is mounted on the optical breadboard [1], in which measurement processes take place. Inside the chamber there is a manipulator, a sample holder, a laser focusing system, a gas purge module, a gas extraction module, a camera, etc. Inside the carriage there is a pulse laser, a spectrometer, a pressure regulation system, a PC and control electronics. The interaction chamber is structurally designed for ultra-high vacuum and overpressure of up to 1500 mbar(a). The pulse laser shoots on a sample placed on the sample holder inside the interaction chamber. During the process, microplasma is created on the surface of the sample. As the plasma cools down, it radiates light on specific wavelengths. Using the spectrometer, these lines can be measured. Individual elements can be identified from these spectral lines. Measurement data can be further processed by AtomAnalyzer software. For control of the Sci-Trace software called AtomChamber is used. The software sends commands to control electronic. Then control electronics then distributes commands to individual modules via RS485 bus. This method was chosen for user-friendliness. The Sci-Trace uses technique called LIBS (Laser-Induced Breakdown Spectroscopy). The device uses camera for a visual over-

Figure 1: Sci-Trace device.

view and easier orientation on the sample. This camera overview requires light. In the previous version this was addressed by a fluorescent tube which was set manually. To solve this deficiency, an illumination module with brightness regulated by AtomChamber software by RS485 bus was designed.

2 PRIMARY INPUT MODULE

The primary input module is composed of printed circuit board (PCB) called segment illumination module (see Figure 3) and an illumination ring. The illumination ring (see Figure 2) utilizes LEDs divided into four separate segments. The segment illumination module is connected via control electronics with the computer. This module controls not only brightness of LEDs, but also a camera shutter. The shutter protects the camera protection from scattered laser radiation with high energy density, which can damage camera pixels. Furthermore. A connector for chamber door interlock is placed on the PCB. This interlock system checks the status of the door. When the door opens, the interlock system disables the. This is a safety feature helps to prevent eye damage from the laser.

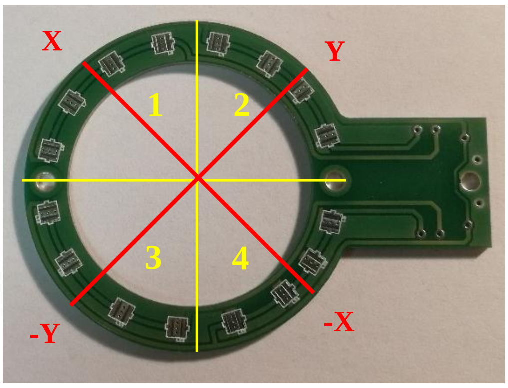

Figure 2: PCB illumination segments.

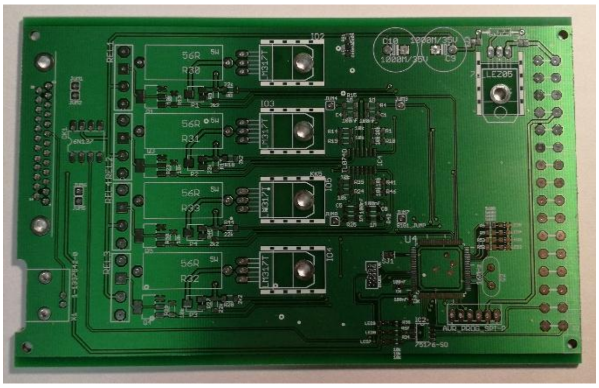

Figure 3: Primary input module.

There are total of 6 diodes on the illumination ring PCB. They are divided into four segments with 4 LEDs each (see Figure 2). The ring is mounted 45° relative to chamber axis. This orientation is chosen to illuminate samples from a direction above the chamber's X a Y axes. Individual segment's orientation relative to chamber axes are as follows.

- Segment No. 1: Sample illuminates axis X.
- Segment No. 2: Sample illuminates axis Y.
- Segment No. 3: Sample illuminates axis –Y.
- Segment No. 4: Sample illuminates axis –X.

3 SEGMENT ILLUMINATION MODULE DESIGN

Segment illumination module is designed uses ATmega2560 chip [2], because of its four 16-bits Timer/Counters (T/C). Two of the four T/C are used for digital adjustment of voltage regulator by Pulse Width Modulation (PWM) [3] [4]. In the image (Figure 4) you can see circuit diagram of the digital adjustment voltage regulator select from the schematic. The hardware PWM output pin of the microcontroller is connected to block of "Digital resistor". Inside this block there is a RC Low-pass filter and an operational amplifier. The PWM signal is transformed to the DC voltage using these components. Change of the output voltage is realized by bringing amplified DC voltage to the ADJ pin. This pin is connected to the adjustable pin of an LM317 regulator. Inside the block a resistor to shift minimum regulation voltage up to the maximum voltage (+24 V minus voltage reference of voltage regulator). This enables softer regulation of output voltage.

LEDs used are type XBDAWT-02, where typical forward voltage for one diode is 2.9 V, so for four diodes the drop voltage is 11,6 V. Cooling of the LEDs is an issue because illumination ring is placed in the vacuum chamber. To mitigate this problem,, based on cooling tests,, resistor series is used to limit the current restriction of the LEDs. The block of “Digital resistor” is designed to regulation the adjustable pin between 9 to 22.75 V. Minimal voltage was chosen smaller than the drop voltage for full regulation LEDs. The resistor is then connected to a polymeric fuse and a relay switch. The polymeric fuse is used for short-circuit protection and the relay switch is used to fully disconnect LEDs when the illumination ring is being replaced. Mechanically, the illumination ring is designed with bayonet system to change lenses without turning off of the electronics. The “Digital resistor” block can be replaced by a simple potentiometer with series resistor. This method of regulation is used due to its user-friendliness.

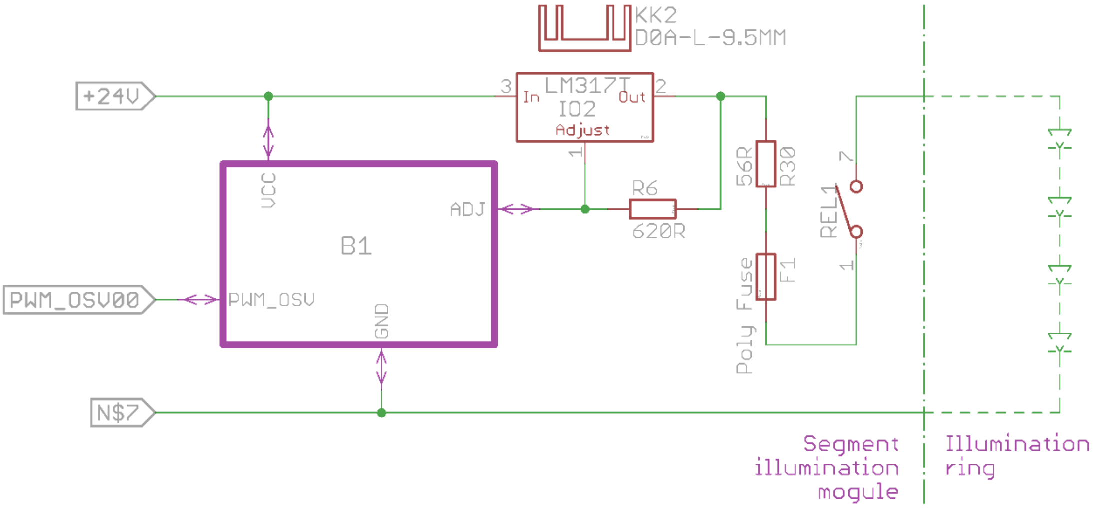

Figure 4: Schematic of one illumination segment.

The third 16-bits C/T is needed for servo motor PWM control. This motor controls the shutter. The last C/T is used for the internal counter of the RS485 bus.

The second method of the sample illumination uses a collinear illumination. This module is designed as a simple PCB with one LED of the same type as in the segment illumination. This PCB is mounted outside the interaction chamber on the camera assembly (primary input). LED regulation is performed by an external adjustable voltage source.

Some of the LIBS experiments are performed in vacuum. This poses a challenge in the LED cooling. One of the solutions is a use of uncovered copper clad on the other side of the illumination ring. Thermal grease is applied between the aluminium heat sink and the copper clad. The second solution is software limitation of PWM output. Another problem of the illumination ring is light reflected from the sample. This can be a problem for biological samples [5]. The collinear illumination method eliminates problems with warming of samples because the light source is located in a larger distance.

4 OPTICAL SEGMENT TEST

The first imaging test was performed with four segment illumination. An aluminium sample with crater from the experiments was used for the test. One of the bigger craters was chosen for the test. In the pictures, we can see the crater in the middle of the view. The crater was illuminated successively from all sides. First, the sample was illuminated from the X axis (see **Chyba! Nenalezen zdroj odkazů.**a). In this configuration we can see distorted microstructure of a crater, where outline circle is forming a little hole and subsequently goes to a little hill. If we look at the sample view in the electron microscope, this distortion is missing. In further tests switch on individual segments axis by axis: –X (see **Chyba! Nenalezen zdroj odkazů.**b), Y (see **Chyba! Nenalezen zdroj odkazů.**5d) and –Y (see **Chyba! Nenalezen zdroj odkazů.**5c). When we compare all the segments, we can see two and two similar structures. The last image is shows sample with all segments turned on at once (see Figure 6). In the picture, we can see once again different structure of the sample surface.

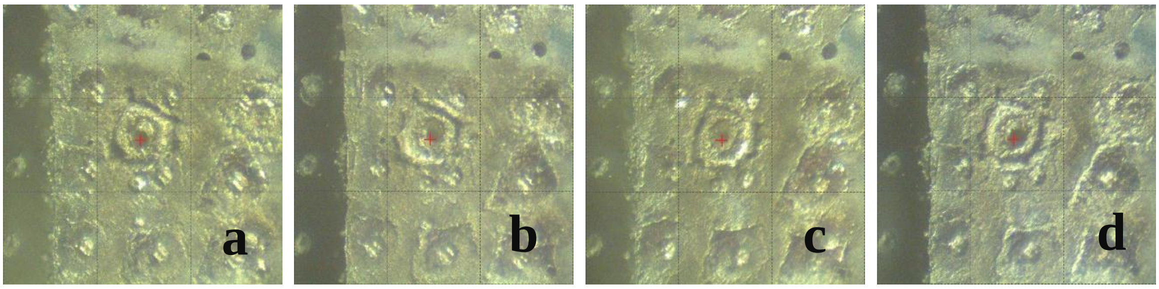

Figure 5: **a** - Illumination of segment 1, **b** - Illumination of segment 4, **c** - Illumination of segment 3. **d** – Illumination of segment 2.

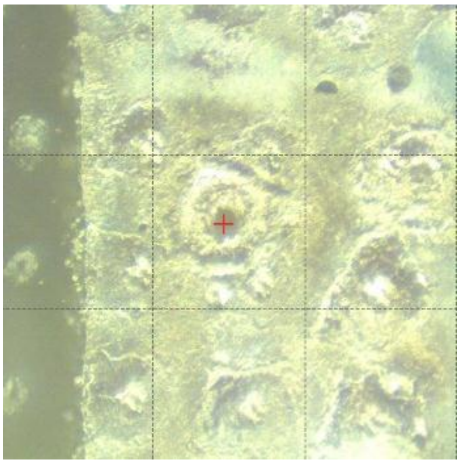

Figure 6: Turn on all segments.

The last test compared collinear and four segments illumination. It is evident that using four segments illumination (see Figure 7) renders defocused sample (in this case a PCB) but we can see shadows created by the edges. When using the collinear illumination (see Figure 8), the sample is in focus and we can see microstructure better. Unfortunately, if we want to measure depth of the copper clad, or depth of the crater, we encounter a problem. Light reflects into all direction and eliminates shadows. When using four segments illumination, we can theoretically calculate the depth of the crater from LED light angle and size of the shadow created by the edge. In essence, collinear illumination is better for materials with reflective surface and the four segments illumination is better for detection of structure viewed from different directions.

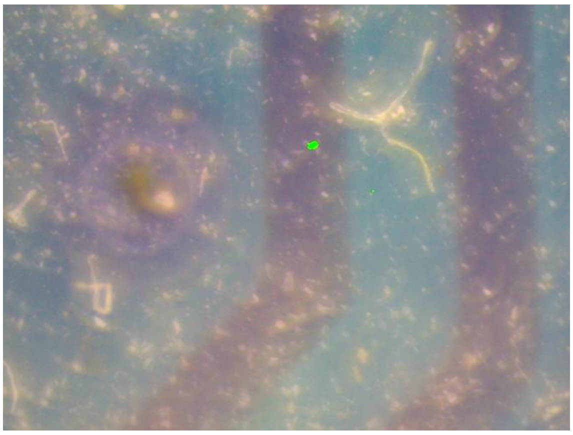

Figure 7: Segments illumination.

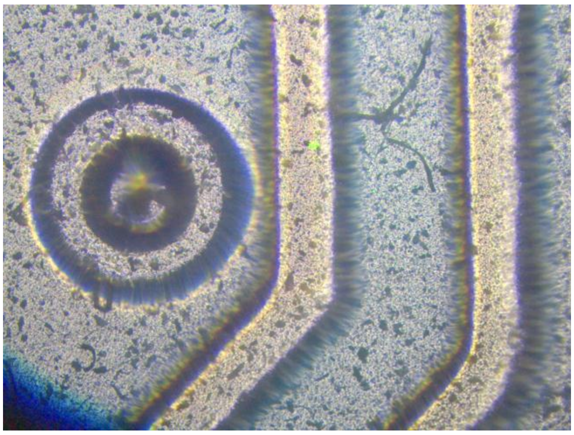

Figure 8: Collinear illumination.

5 CONCLUSION

In this paper description of four segments illumination, divided into the illumination ring and primary input module, was provided. The setting of LEDs brightness can be changed by software communication. Hardware change of LEDs brightness is performed by PWM digital settings on HW pin of the microcontroller. Voltage regulator is regulated by PWM signal. The design features short-circuit protection. The design is intended for a view of the surface microstructure of samples in the Sci-Trace device. The design enables illumination of the sample from several directions. Furthermore, a method of collinear illumination was described and compared with the segment illumination. The methods were compared on an aluminium sample with a crater.

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