Modelling the Distribution of Laser Energy in the Pulse by the Photoemulsion Method

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Abstract

Lasers have found their application in various fields of science and technology. One of the key parameters of a laser material processing is laser energy. It is extremely important to know not only the energy amount in the pulse, but also the energy distribution in the pulse during laser irradiation. This can improve processing, obtain different structures on the surface with increased accuracy and helps to explain the physical phenomena that occur.

Keywords 1

Laser, laser energy, modelling

1. Introduction

Laser radiation is a type of electromagnetic radiation in the optical range, which has a number of unique physical properties.

The unique physical properties of laser radiation - high monochromaticity and coherence, low radiation divergence and its high specific energy characteristics made it possible to create a promising type of highly concentrated energy source, which found wide application in various fields of science and technology [1].

The essence of processing materials with highly concentrated energy flows is to transform, with a certain efficiency, the energy of the source into thermal energy, which changes the structural and phase state of the surface layer of the substance. Unlike classical concentrated sources of energy (electric arc, plasma treatment, etc.), highly concentrated sources of energy (for example, lasers) have significantly greater technological capabilities and higher technical and economic indicators of conducting technological processes.

That's why, it's very important to have information not only about the amount of energy in the laser pulse, but also information about the distribution of laser energy in this pulse, that can improve processing, obtain different structures on the surface with increased accuracy and helps to explain the physical phenomena that occur.

2. The method of determining the distribution of laser energy in the pulse by the photoemulsion method

Irradiation of materials with a high-power laser can change the structure and properties of the material [2, 3] and obtain various structures on its surface (Figure 1). Energy and its distribution over the irradiation spot have an important influence here.

Modern methods of energy measurement are based on the use of different types of sensors: pyroelectric, thermopile or photodiode [4]. Another modern type of laser energy meter is the Radiation Pressure Power Meter [5]. All these devices are complex and expensive. For the Nd:glass lasers that we use in our experiments, a simple and reliable calorimetric method of energy measurement is quite often

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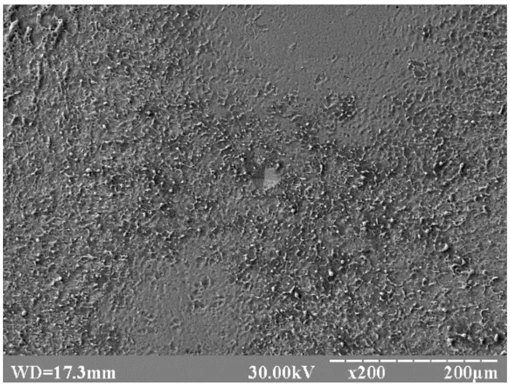
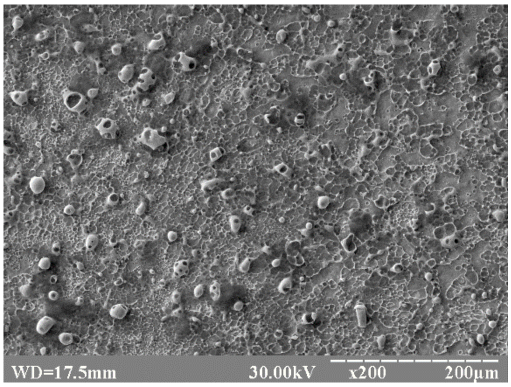
used. It allows to determine the energy in the pulse, but does not give its distribution. Different models are often used to determine energy distribution. Some of these models are quite interesting for application [6].





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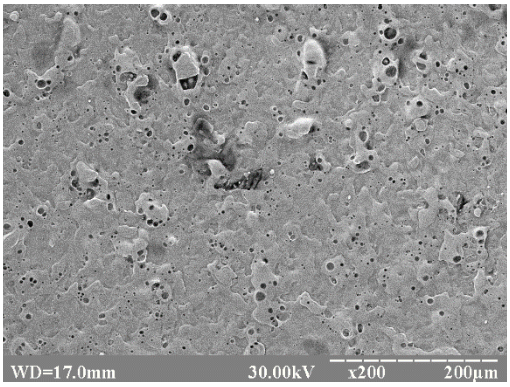

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Figure 1: Scanning electron microscopy images of the St3 steel surface after irradiation in different transparent condensed medium: a - water, b - alcohol, c - epoxy resin

In this paper, we propose a new method for determining energy distribution and its visualization, which is based on our proposed matrix model, which was implemented using the Matlab. As an example, we used an image of an unfocused laser spot on the surface of black-white photo paper. At the same time, the laser worked in the free generation mode. The output data for the model is the total energy, which falls on the entire spot, obtained by the calorimetric method. An example of an image of a laser spot on photo paper can be seen in Figure 2.

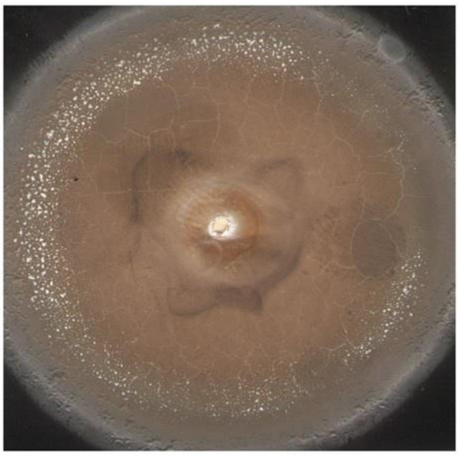

Figure 2: An image of a laser spot on photo paper

We converted the obtained color image into gray with a color gradation from 0 to 255 (Figure 3). We also set the condition that the black color is the area that was not exposed to the laser (the original color of the photoemulsion), and the white color is the area that received the maximum amount of energy (the color of the substrate of the photo paper).

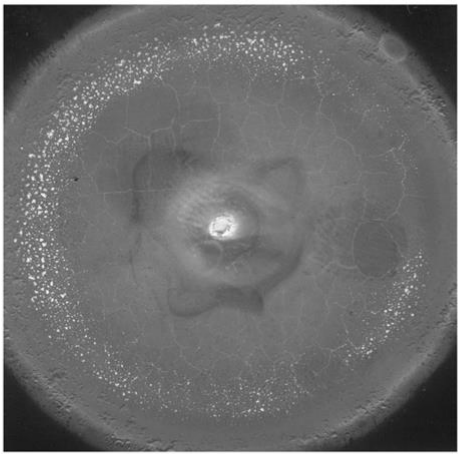

Figure 3: Grayscale image of a laser spot

Then we determined how many pixels of the corresponding shades of grey are represented in the resulting image and presented this in the form of a graph (Figure 4). The resulting graph showed that we have two peaks. It was empirically determined that pixels with a shade from 0 to 55 can be considered as not affected by laser radiation.

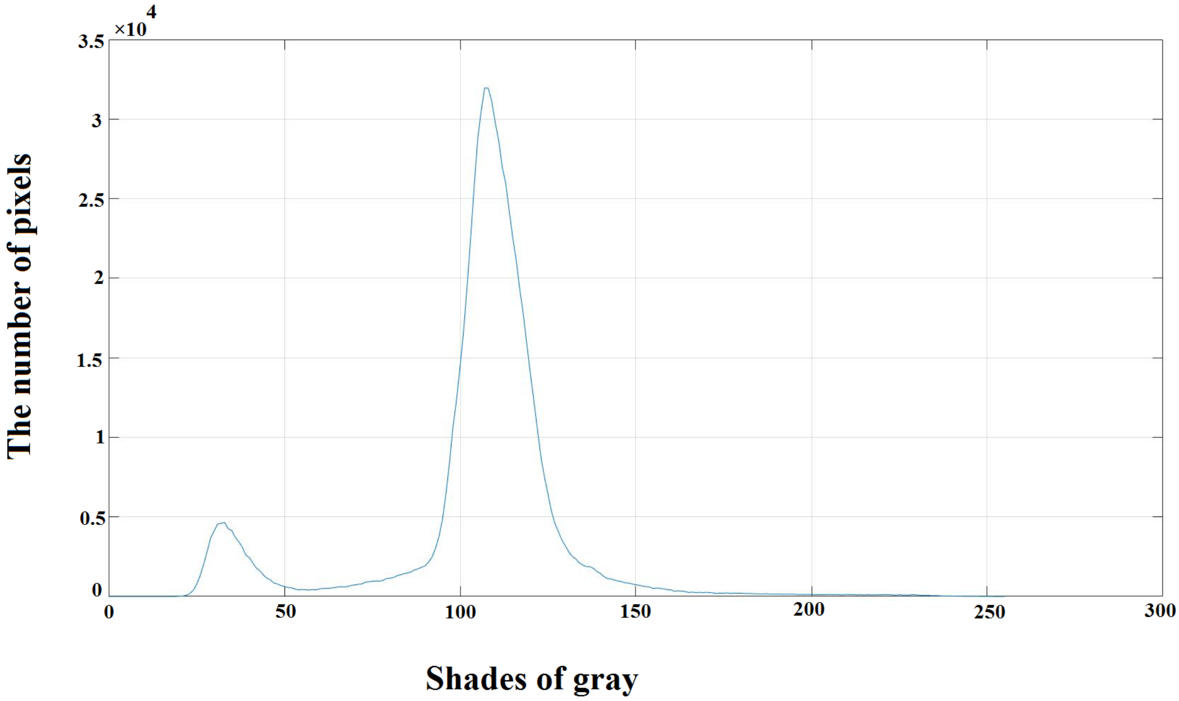

Figure 4: The number of pixels of each shade of gray

Then we made all pixels less than or equal to 55 shades of gray equal to 0, i.e. black color. To preserve linearity and the initial condition, we subtract 55 from all elements that are greater than or equal to 56. We obtained a new graph of the dependence of the number of pixels on the shade of gray (Figure 5).

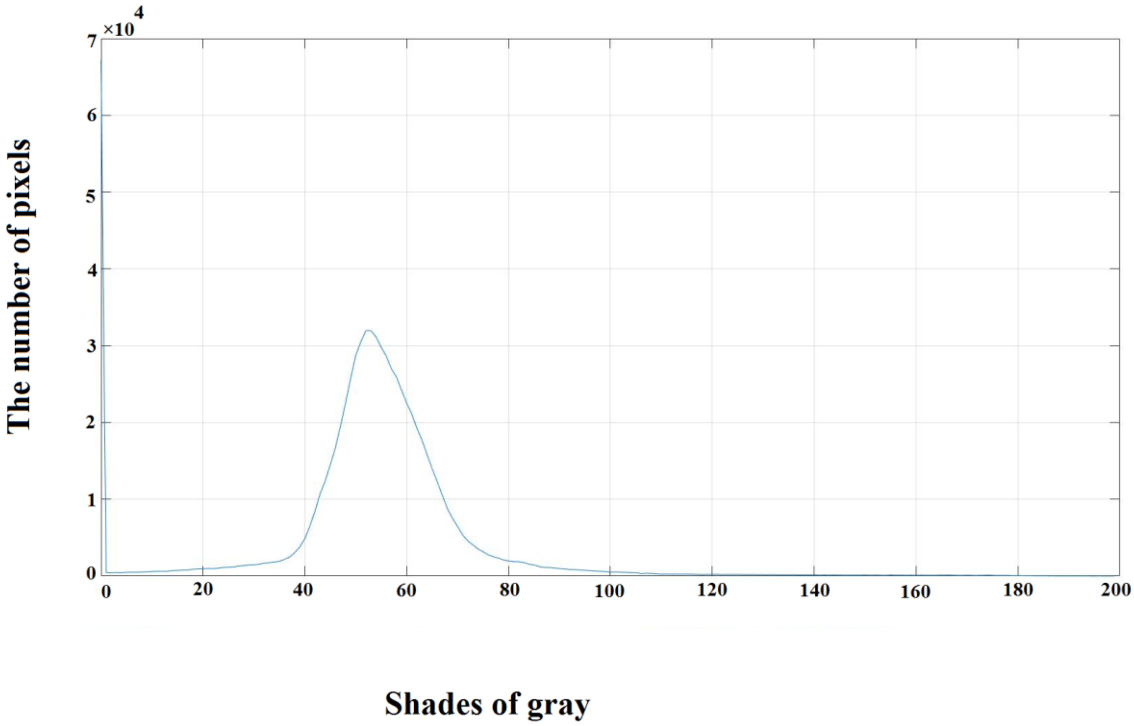

Figure 5: The number of pixels of each shade of gray after changes

After that, we got the image already in changed shades of gray, it became darker (Figure 6).

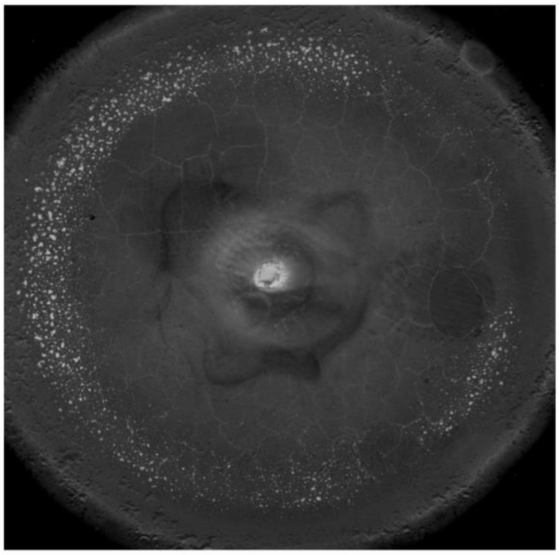

Figure 7. New grayscale image of a laser spot after changes

After that, we multiply the shade by the number of pixels of this shade and find the sum of the resulting array. This sum will be the energy per spot in relative units. Then we convert the relative units into real ones. We remember that we are given the initial value of the total real energy of the laser spot (5 J in our case), we divide the real energy by the entire sum of the relative energies, and then multiply by the hue element. We replace the numbers of shades of gray with real energy values and get graph (Figure 8).

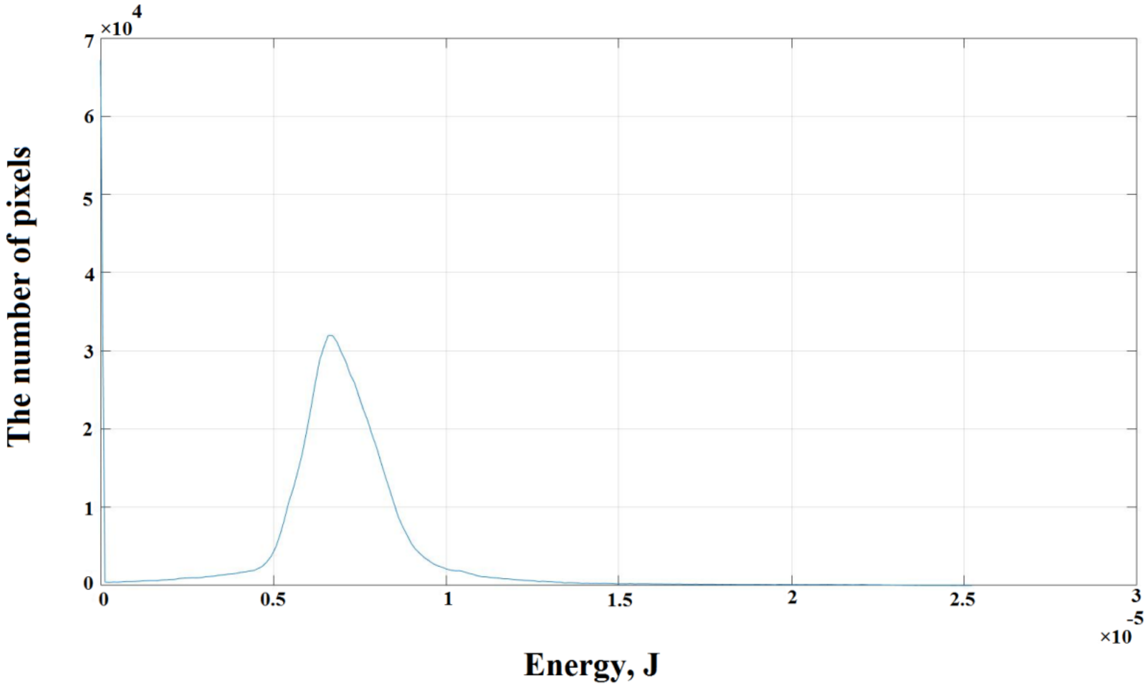

Figure 8. The number of pixels of each energy

Now we build a three-dimensional graph that will show us the real energy distribution over the spot (Figure 9).

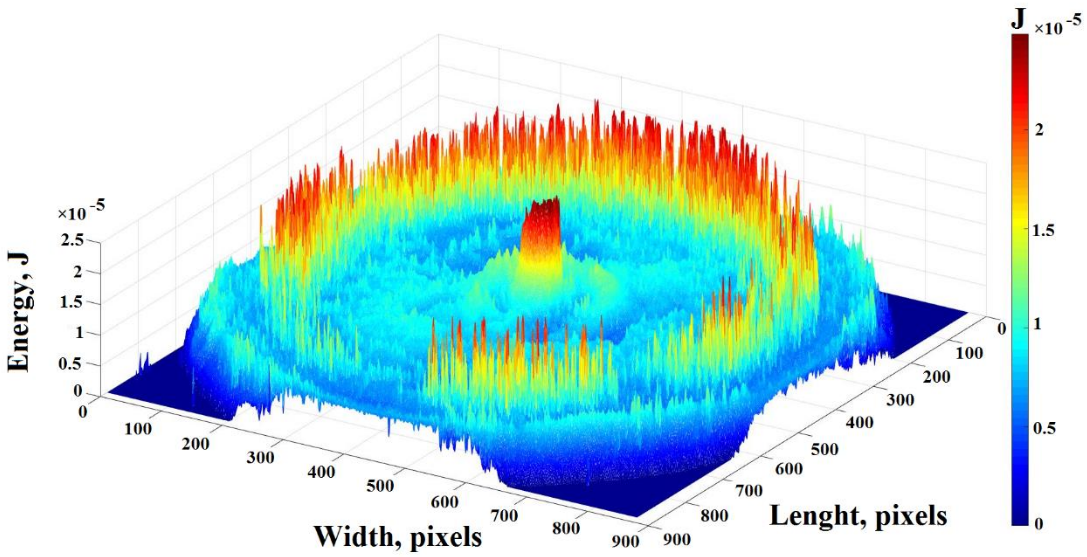

Figure 9. Distribution of energy over the spot, energy in a pulse of 5 J

It should be noted that the proposed model also allows determining the type of transverse modes with axial symmetry in the laser pulse (Figure 10). The first number means the number of intensity minima along the radius of the cross section, the second is equal to half the number of intensity minima in the azimuthal direction [1].

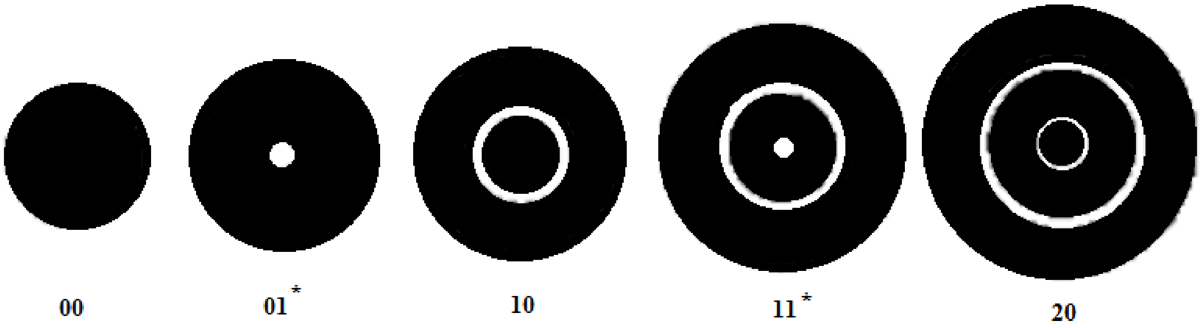

Figure 10. Transverse modes with axial symmetry

3. Conclusions

The proposed model allows determining the distribution of laser energy in the spot by the photoemulsion method. This can help to improve the processing technique, more accurately select the parameters of laser irradiation and also facilitates the explanation of the obtained phenomena.

4. References

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