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THE LASER EMISSION CHARACTER OF CO_2 LASER

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ABSTRACT:
Results of the laser micromachining – surface quality of product and his utility in specific application – depend on the laser parameters and the polymer material type. Commercial CO_2 laser Mercury L-30 by firm LaserPro, USA was used for cutting of the different plastics materials - PMMA, ABS. The output parameters were evaluated as the entering data for the laser emission distribution. This exploration was realized on the optical microscope MU ZEISS. Than digital camera was installed in microscope and it scanned photo of specimens. Photo of grooves and melted boundaries were made. Finally nonlinear regression was realized with the help of DATAFIT V.8.

Keywords: CO_2 laser, mode TEM, nonlinear regression

1 INTRODUCTION

1.1 The Lasing Process

The term „laser"tells us that a simplified description of the lasing process could be „opposite of absorption". At the heart of the lasing phenomenon is the ability of photons to stimulate the emission of other photons, each having the same wavelength and direction of travel as the original.
According to quantum theory, atoms and molecules have discrete energy levels, and can change from one level to another in discontinuous jumps. Under normal conditions, most atoms or molecules remain quiescent at their lowest energy level, or ground state. But if these particles are exited into higher energy states-by an intensive flash of light, an electrical charge, or other means-they will, in dropping back to the normal ground state, emit incoherent light in the process. In a laser cavity, such emitted photons are trapped between highly polished and parallel mirrors. Whenever a photon passes close to another excited particle of the same wavelength, the second particle will also be stimulated to emit a photon that is identical in wavelength, phase, too, become part of the growing wave between mirrors (figure 1). Lasing begins when enough photons are present, and if one of the mirrors is partially transparent, a highly disciplined, intense, and now, coherent beam is emitted.

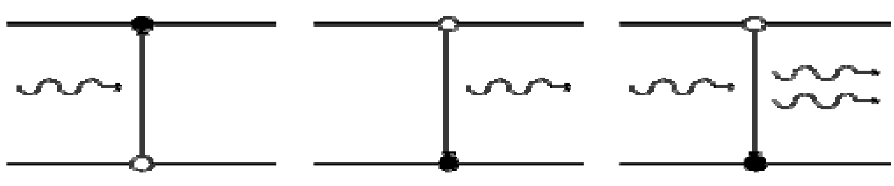


Figure 1. Stimulated Emission

1.2 Transverse Beam Modes

The photons oscillating from one end of the resonator to the other constitute electromagnetic energy which forms an intense electromagnetic field. The shape of this field is critically dependent not only on the photon wavelength, but also on the mirror alignment, curvature, and spacing, and on the bore diameter of the laser tube. This field can assume many different cross-sectional shapes, termed *transverse electromagnetic modes (TEM)*, but only certain modes, or mixtures of them, are useful for processing materials. The TEM $_{00}$ mode is ideal for most cutting, drilling, and welding applications because it produces a beam that can be focussed to a minimum spot size for very high power density. It is a Gaussian mode, with most of the energy in the center.

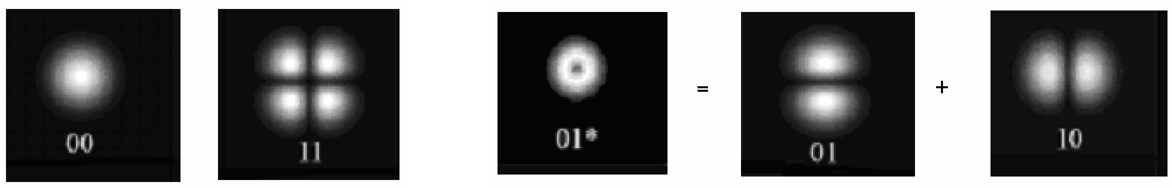


Figure 2. Selected Mode TEM

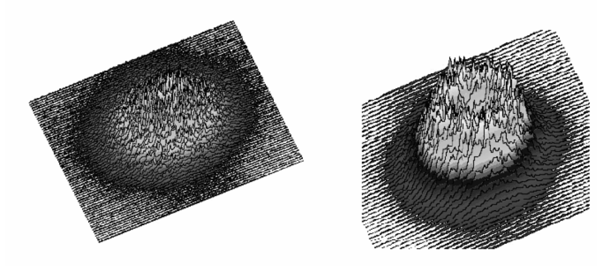


Figure 3. TEM_{00} a TEM_{01}

The TEM_{01} mode cross section shows a “hollow” center, with most of the energy concentrated near the periphery of the focussed area. This mode distributes the beam energy efficiently for other heat-treating and drilling applications. TEM_{01} also has its particular uses.
But not the difference between the cross-sectional representation of the widely used TEM_{00} mode and that of mode called TEM_{11}.It is evident that the distribution of power across the TEM_{00} beam (shown at the in figure 4 as a single Gaussian curve), results in a more efficient tool for cutting than does the more fragmented power distribution of the divided TEM_{11} beam (shown at the right in figure 4 as two curves).

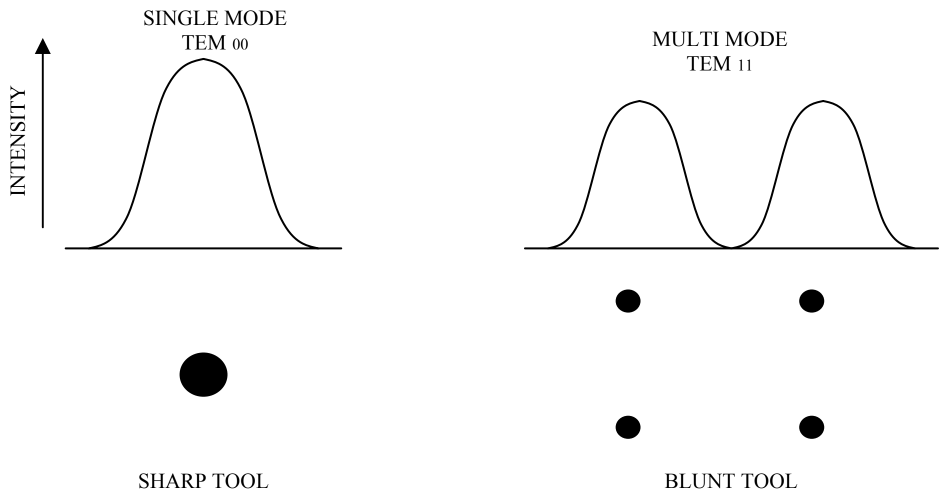


Figure 4. Analogy of Beam Modes to tool

2 THE EXPERIMENT

2.1 Preparation of Specimen

Results of the laser micromachining – surface quality of product and his utility in specific application – depend on the laser parameters and the polymer material type. Commercial CO_2 laser Mercury L-30 by firm LaserPro, USA was used for cutting of the different plastics materials – PMMA and ABS. It is possible to change power and feed rate of laser system. Ray of laser could be focused on mark diameter d = 185 μm. The maximum value of density of energy flow is q = 1,1 GWm^{-2}. The maximum value of power is 30W and maximum value of feed is 1066 mm/s. Laser is cutting with the software help of Corel Draw. Wide spectrum of different materials (ceramic, quartz, plastic, rubber, wood and certain composite structures) can be described and cut by laser MERCURY L-30. This kind of laser is used for commercial description by laser.

Desired symbol was created in program Corel Draw, slot width was 2 mm in all cases. Cutting parameters (output power and feed) were adjusted and these were changed gradually. Values of power and feed are presented as percents from maximum power (P = 30W) and maximum feed (f_{max} = 1066 mms^{-1}) in charts of parameters combination and graphs.

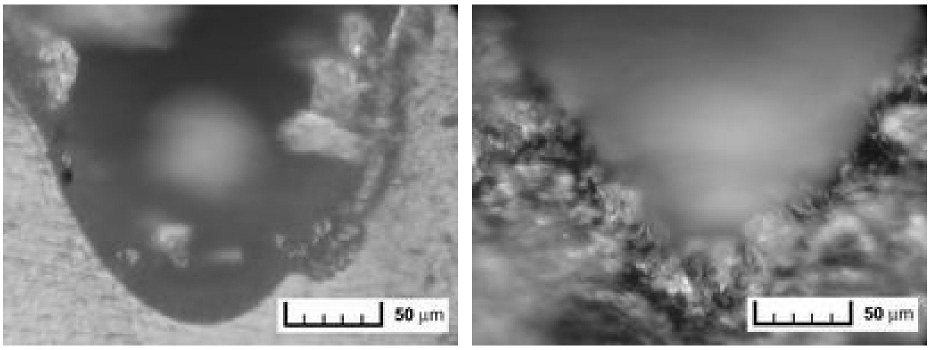
The output parameters were evaluated as the entering data for the laser emission distribution.

2.2 The Laser Emission Distribution of groove profile.

Because of exact evaluation of machined groove profile cuts of specimen were made and then these ones were grinded. This exploration was realized on the optical microscope MU ZEISS. Suitable microscope optics which ensured 250 x enlargement was set first of all. Than digital camera was installed in microscope and it scanned photo of specimens. Photos of grooves and melted boundaries were made.

PMMA and ABS are presented on pictures by these cutting parameters: power 50% and feed 10% (fig. 5, 6). Description 50/10 means 50% value from power 30W and 10% value from maximal feed 1066 mms^{-1}.

You can see the photo of groove detail ABS, PMMA on the following picture.



Figures 5, 6. The illustration of groove 50/10 ABS; 50/10 PMMA

Digital photos were modified with the help of software ADOBE PHOTOSHOP 6.0 and AUTOCAD 2002. Scales factor corresponding used optics of microscope were assigned at modified photos.

Modified photos in JPG format were imported into software AUTOCAD 2002 for the purpose of profile groove digitalization of cut. Lower left corner was localised into coordinate global basic origin.

Profile groove of cut was digitized by 30 pixel at coordinates [x, y]. These coordinates were multiplied by corresponding scale so that value corresponded to real values in μm (bitmap inserts into AUTOCAD 2002 is not in real scale). Subsequently the model was defined with the help of software DataFit V.8 :

$$h = A + B.e^{-(x-C)^2} \quad , \qquad (1)$$

and numerical values of coefficients A, B, C were itemized.

Finally nonlinear regression was realized with the help of DATAFIT V.8. These tests are presented in given study.
Models and graphs are presented thereinafter.

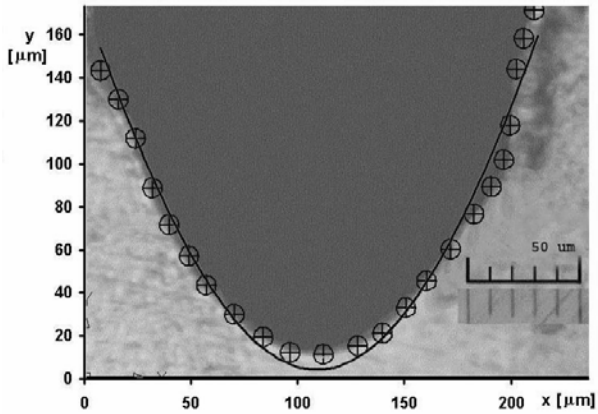


Figure 7. Gaussian density distribution of laser beam energy for cutting parameters – power 50% and 10 %, material ABS

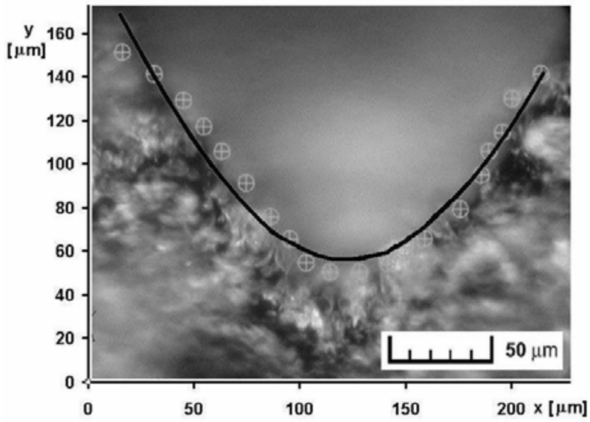


Figure 8. Gaussian density distribution of laser beam energy for cutting parameters power 50% and 10 %, material PMMA

3. CONCLUSION

From results of experiment is evident that density distribution of used laser beam is Gausssian. The TEM $_{00}$ mode is ideal for most cutting, drilling, and welding applications because it produces a beam that can be focussed to a minimum spot size for very high power density. It is a Gaussian mode, with most of the energy in the center.

Laser beam is the tool of the future. It can cut without affecting the surrounding material. Its energy is clean, reliable and docile it's ready to be tamed and handled to give an unequalled quality to the process. Quality of cut depends from working parameters of laser cutting process (laser power, feed rate, material thickness.)

If technological conditions (moving speed of the laser head, the beam output, mode parameters of the optics) are optimized, a good quality of the cut can be reached for wide spectrum of materials.

At the conclusion, it is possible to state that it is necessary to know output parameters combination of concrete laser system and properties of machined polymer materials for obtaining good results of micro-machining by laser. It is possible to obtain high accuracy of machined texture with respect to these conditions. The result machining is different at the use of various kind of laser.

4. REFERENCES

[1] Hendrychová, B.: Výzkum mikroobrábění polymerních materiálů laserem. (Diplomová práce) FT VUT ve Zlíně, 2000.

[2] Lukovics, I., Sýkorová, L.: Study of the effect of concentrated energy on plastics and metals. In.: Workshop 97, p. 1433, 1997.

[3] Chytil, P.- Dvořák, Z.: Dělení materiálů vysokotlakým hydroabrazivním paprskem řezacího stroje FLOW INTERNATIONAL (USA). In: 3. Mezinárodní nástrojářská konference 2003, 21.-22. května 2003, Zlín, 2003.

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