

## Results of research on causes of the defects of laser marking articles

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**Abstract.** The article describes technological aspects of the marking process using solid-state fibre laser. It presents the analysis of the technological modes and errors of the precise laser marking and establishes low density of the laser system as one of the causes of the poor quality of a laser seam. The article reviews the use of the following material laser marking is performed on - plastic with fine metal and conductive surface coating.

### Introduction

The laser technologies are widely use in machine-building and device-building. Laser technological equipment is successful apply for the cutting of materials, grinding of instruments, laser soldering and welding, as well as for the marking of products. Precision laser marking is differing from others methods of marking the symbols a high productive, clear, miniature and wear-firmness of imprints.

A technology of laser marking possesses the several advantages [1]:

- high economic effectively and small prime cost of marking operation even by making articles the small batches;
- small prime cost operations of check by taking and periodic tests;
- high speed produce of inscriptions and pictures is ensure a better ability to handle of equipment and a abnormally high of coefficient its using as compared with other methods of marking;
- maximum spare method by any materials and products, absence any mechanical influences, which are can destroy a surface of article;
- high-contrast inscriptions are ensures a excellent they reading, in that number machine finishing (automatically reading);
- combination the reliability, convenience reading and defend of information (the inscriptions impossible remove or change, has fine defense from any attempts of falsification);
- high stability with influence of temperature, erasing, alkali's, acids, solvents and others aggressive substances, abnormally high a humidity of air and sea salt mist;
- possibility the making of inscriptions a enough great cubic capacity on the small grounds surfaces of articles and possibility the making of additional inscriptions.



An inculcation of laser marking is not demand great expenditures; the articles are marked on the compact plant with period repaying about five months.

That way, laser marking of articles is be the same perspective method a making of inscriptions (as compared with marking of paint, casting, fording, electro-erosion processing). Actual problem a widening of possibilities a laser marking of articles is be analysis she technological regimes and errors, as well as ground peculiarity she application in the conditions, which are tie with risk a destruction of article.

A aim this work is be analysis of quality a laser joint, technological regimes and errors of laser processing, as well as experimental ground a fit laser technology by making of inscriptions and pictures on the thin-film covers without they damage.

### Description of system laser marking and she program ensuring

In Russian Federation make the several kind of technological equipment for the laser marking. A one is kind of they equipment – a system precision laser marking SPLM «MiniMARKER-M10/20» ( «Laser Centre» Ltd, Saint-Petersburg). System is serve for the making of images in the contour and raster (filling) kinds on the surfaces of metal, plastic, rubber, foil and others articles (figure 1) [2].

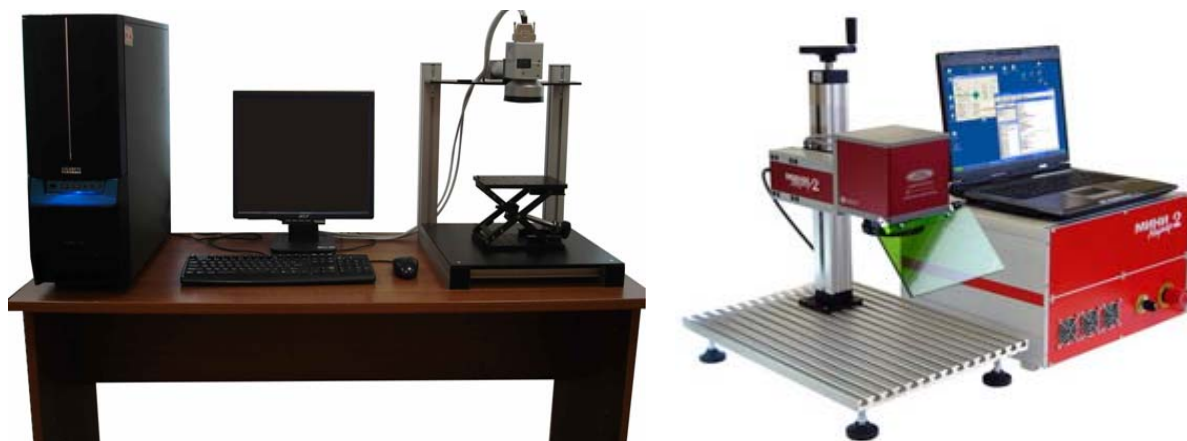


Figure 1. Versions of designs a system precision laser marking SPLM «MiniMARKER-M10/20»

Main technical characteristics of system «MiniMARKER-M10/20»:

- 1) dimensions of area of processing: 100 x 100 mm;
- 2) speed a transference of laser ray: 0 – 2.5 m/s;
- 3) type of making images: contour, raster (filling), text, graphic;
- 4) dimensions of making symbols: 0.25 – 100 mm;
- 5) breadth of line with automatic burn through: 0.05 – 3 mm;
- 6) materials, which are may be marking: metals and alloys, protective covers of metal surfaces, plastics, rubbers, foils;
- 7) type of laser: impulse, fibrous;
- 8) maximum power of laser: 10 W;
- 9) control of laser: over personal computer (Windows 2000, XP, Vista, type interface: USB);
- 10) conditions of exploitation: temperature from +15 to +35 °C, relative humidity to 80% without droplets of moisture.

A system precision laser marking SPLM «MiniMARKER-M10/20» is consisting of: block of optical transference a ray (BOTR) with optical fibro; working table with bracket for fixing a BOTR and transference they along vertical axis (OZ); block of electro-feeding and control; personal computer (from Pentium III/450 MHz, operative memory from 256 Mb, monitor from 15", video adapter from 800x600 points, interface USB 1.0 or 2.0, Windows 2000 Professional SP3, Windows XP SP1 или SP2, Vista, Internet Explorer 6.0 or higher).

A system precision laser marking SPLM «MiniMARKER-M10/20» is has original program ensuring – a program complex «SinMark TM». Basis possibilities of this complex [2]:

- 1) monitoring and testing of laser equipment;
- 2) programming of technological regimes;
- 3) possibility of inclusion a automatic regime of work a laser equipment in composition of technological line;
- 4) regimes of many-passages marking, execution the putting program;
- 5) vector and raster regimes of laser marking;
- 6) regime of marking the images wide and capacious line;
- 7) import of graphic information from format BITMAP and PCX, as well as vector information in the format HPGL/2 (PLT) and AutoCAD;
- 8) quick creation of program for the marking text and small graphic images, support print «True Type», availability the vector prints;
- 9) automatic change number and batch marking articles;
- 10) by marking of articles is indicate the real time and date;
- 11) has possibility generation touch-code all main types;
- 12) control the additional systems of transference.

Program complex «SinMark TM» is ensure a preparation of program laser marking, control of laser work station in the processing, launch the testing programs.

### **Technological itinerary and regimes the laser marking of articles**

On the undertaking Open Joint-Stock Company «Karachevsky Zavod «Electrodetal» (Russian Federation, Bryansk region, Karachev) a system precision laser marking SPLM «MiniMARKER-M10/20» is use for the making of inscriptions and trade marks on the main production this undertaking – the rectangular electrical connectors. The marking are expose to corpuses of electrical connectors, which are making of the plastics and metal, as well as the plastics corpuses of electrical connectors with thin-film and conducting electricity cover.

The technological itinerary of precision laser marking is including the several actions:

- 1) preparation a working place. It is necessary is including an electro-feeding of personal computer and laser equipment;
- 2) start a program for the marking of articles, which is create of before-hand and contain the main technological regimes of precision laser marking;
- 3) check a correct of preparation, which is will be make;
- 4) definition a focus distance, which is necessary for the laser marking. By this necessary rationality dispose of article on the working table and checking with help of mould of focus distance from objective a laser radiator to surfaces of article;
- 5) optimization the regimes of marking. By this necessary is selection the optimal regimes on the quality of making symbols;
- 6) making of symbols on the surfaces of article. By this necessary is make marking symbols way pressing on the pedal of laser equipment or with help a manipulator «mouse» of computer;
- 7) check. By this necessary is make a visual check quality of marking a surface of article and put a ready article in the package.

Fixing the technological regimes of marking are take place by include a program, which is will be create a before-hand. A program of control is maintaining several technological regimes:

- 1) frequency the impulses of laser radiation: 1 – 10 kHz;
- 2) speed transference of ray: 50 – 300 mm/s;
- 3) breadth a track of laser ray (laser joint): 0.05 – 3 mm;
- 4) power a laser radiation: 20 – 100 % from maximum power a laser radiation of equipment;
- 5) period a burn through of inscription: 5 – 10 s;
- 6) coordination's a burn through of inscription about working table: include users of program by making of working draught a inscription.

Technological regimes of laser marking are distinguished: a high degree of adaptation with peculiarities the surfaces of articles; a possibility of automation a process of marking; high mechanical and physics-chemistry properties of inscriptions. Thank to this dignities, a laser marking one may recommend as preferable method the making of inscriptions on the articles, which are has complicated forms and special properties. A flexible technology of laser marking is allow by demand of consumers is add to composition of transference additional information, which is not including in the compulsory block of dates [3].

### **Analyses the defects of laser marking**

An actual problem of precision laser marking is appearing a quality of joint. A quality of joint – it is absence the defluxions of dimensions a joint with direction, which is perpendicularity a motion of laser ray. For the appraisal a quality of laser marking joint be making experimental researches the symbols of marking with help a scientific microscope AKSTOCKOP2 MAT (equipment a «Centre of collective use measuring and testing equipments» (CCU), which is appear a structurally subdivision of Federal State Budget Educational Institution High Professional Education «State University – Education-Science-Industrial Complex»). Results the observation of marking inscriptions to scientific microscope AKSTOCKOP2 MAT are show on the figure 2 and 3.

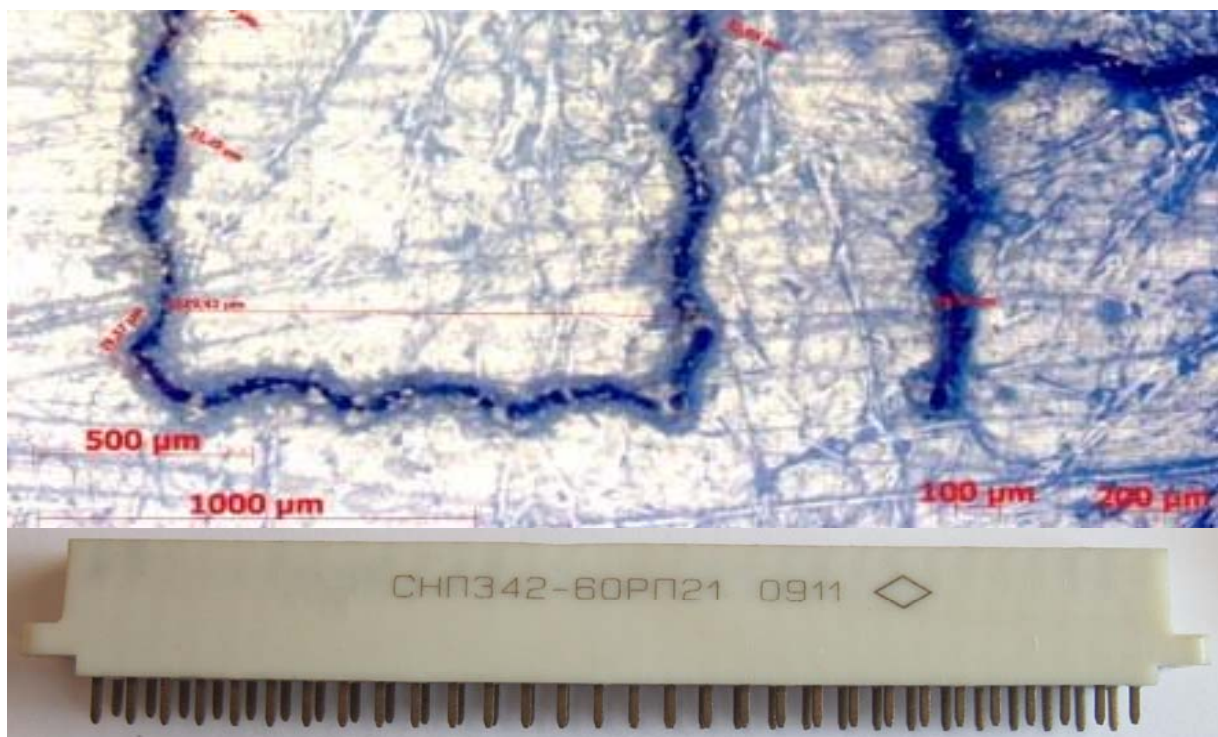


Figure 2. Appearance an electric plug of electrical connector SNP342 and increasing image of marking inscription



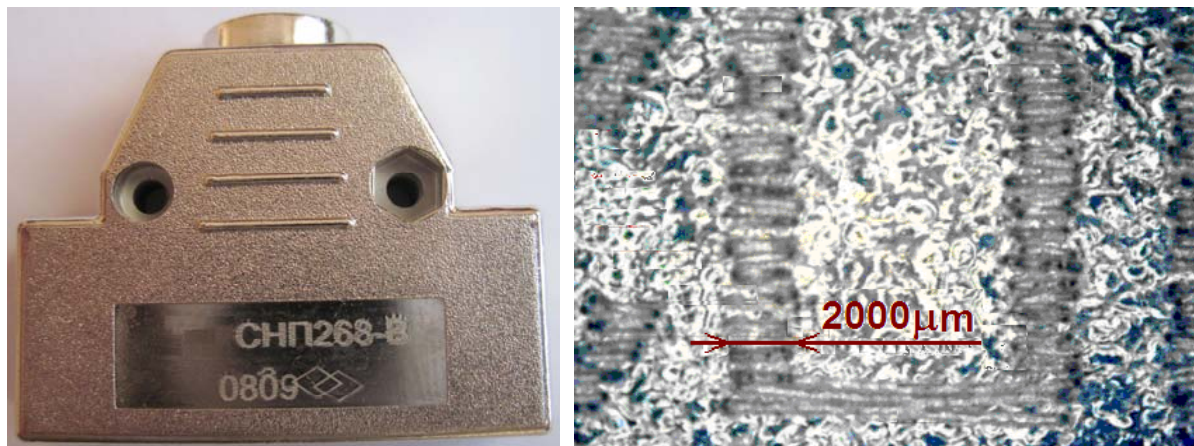


Figure 3. Appearance a electric plug of electrical connector SNP268 and increasing image of marking inscription

By photographs is one can see that laser joint is go of zigzags, and besides an unevenly of laser joint is show as to longitudinal (figure 2), so and to diametrical (figure 3) directions. By results measuring dimensions an increasing image of marking inscription (with use scientific microscope AKSTOCKOP2 MAT) is definite a step of vibration laser joint to longitudinal and diametrical directions (figure 4). Are receiving following significances (is receiving on the results of measuring a step of vibrations by electronically scales of scientific microscope AKSTOCKOP2 MAT):

1) to longitudinal direction a step of vibration laser joint ( $L_1$ ) is put together:

$$L_1 = 300 \text{ } \mu\text{m} ; \quad (1)$$

2) to diametrical direction a step of vibration laser joint ( $L_2$ ) is put together:

$$L_2 = 120 \text{ } \mu\text{m} . \quad (2)$$

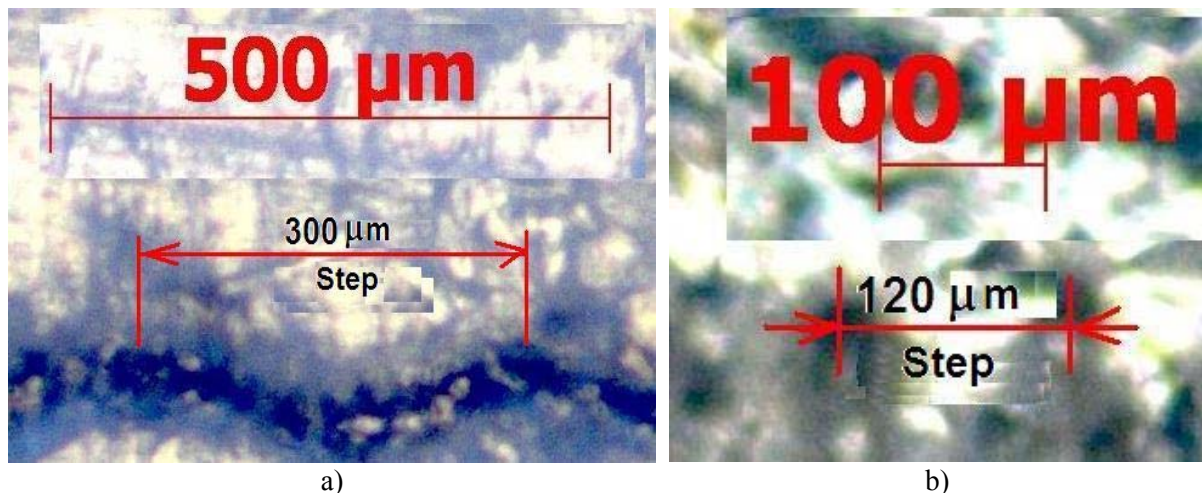


Figure 4. Vibration a laser joint to longitudinal (a) and diametrical (b) directions

Results of measuring vibration of laser joint are show, what period of vibration to longitudinal and diametrical directions is different. The possible causes uneven of laser joint are considered.

It is known speed ( $v$ ) a burn through of inscription:

$$v = 300 \text{ mm/s} . \quad (3)$$

Then one may is period, behind which a laser ray is accomplish the vibrations to longitudinal and diametrical directions, that is period of vibrations of inscription to longitudinal ( $T_1$ ) and diametrical ( $T_2$ ) directions:

$$T_1 = \frac{L_1}{v} = \frac{0,3}{300} = 1 \cdot 10^{-3} \text{ s}; \quad (4)$$

$$T_2 = \frac{L_2}{v} = \frac{0,12}{300} = 4 \cdot 10^{-4} \text{ s}. \quad (5)$$

It is known, what frequency ( $f$ ) and period ( $T$ ) of vibration are connect a formula:

$$f = \frac{1}{T}. \quad (6)$$

If knows the periods vibration of inscription to longitudinal ( $T_1$ ) and diametrical ( $T_2$ ) directions, one may calculate a frequency of vibration and compare she with frequency of vibration a laser radiation:

$$f_1 = \frac{1}{T_1} = \frac{1}{1 \cdot 10^{-3}} = 1 \cdot 10^3 \text{ Hz} \quad \text{and} \quad f_2 = \frac{1}{T_2} = \frac{1}{4 \cdot 10^{-4}} = 2,5 \cdot 10^3 \text{ Hz}. \quad (7)$$

A frequency of vibration a laser radiation is equally:  $f = 10 \text{ kHz}$ . Well then, she one may creation of vibration a laser joint with period  $T = 0.1 \text{ ms}$  and step of vibration  $L = 30 \text{ }\mu\text{m}$ . It is to four times less a step longitudinal vibration of inscription.

Consequently, a frequency of laser radiation is not being cause the unevenness of inscription. One may, that low exactness of laser joint is evoke a vibration of non-standard device for the marking. This way, main condition a security of quality laser marking is appear a hardness of technological system «equipment-device-instrument-detail» (system EDID) of laser equipment [4].

### Peculiarities of laser marking articles with thin-film covering

A one of actual problem a laser marking is appear a fixing of regimes making symbols on the surfaces of miniature articles, which has a thin-film covering. An example one may serve the corpuses of electrical connectors SNP268 (Russian Federation), which are appear analog the connectors international series «D-Sub» (figure 3).

Designing peculiarity this corpuses are appear an enough complication form, which is receive of casting from thermoplastic polymer materials. Afterwards the corpuses are cover two-coating metal covering. By this a intact of thin metal cover, which is consist a level of copper ( $30 - 40 \text{ }\mu\text{m}$ ) and a level of nickel ( $40 - 60 \text{ }\mu\text{m}$ ), is not be break. Results the observation of cut marking inscriptions to scientific microscope AKSTOCKOP2 MAT are show on the figure 5.

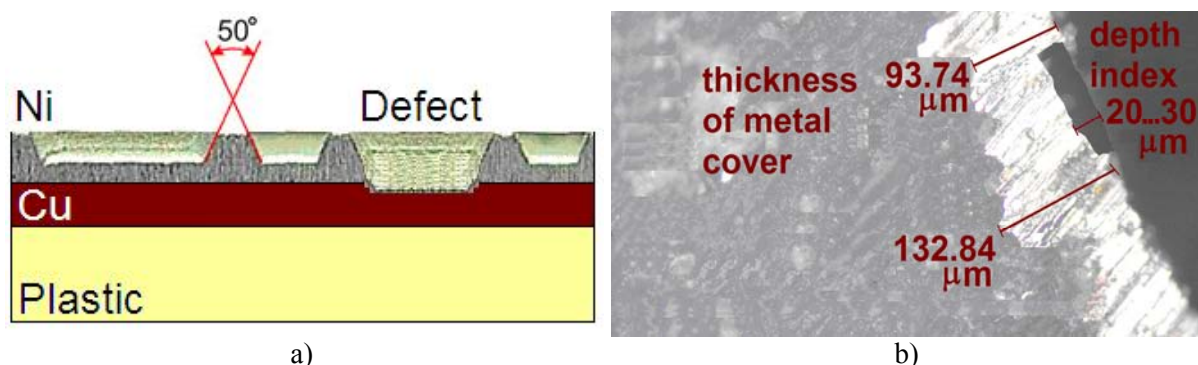


Figure 5. Rule making a marking on the thin copper-nickel cover (a) and they actual condition (b)

Are allows the insignificant (pointing) defects in the difficult-accessible sections surface of article. Such defects are arising by making a cover of chemical method, when electrolyte is not penetrating to the thin openings and ditches. A maximal risk – this defects one may not right away, but afterwards

some time, by keeping and transporting, and to the process exploitation of article. Therefore selection optimal technological regimes of laser marking surfaces articles with thin-film metal covering appear is main condition security a quality of article. By selection this regimes it is necessary a careful determine probable part of defective articles in the batch. A laser marking is appear a final technological operation, therefore defects by marking one may strongly increase a volume of defective articles in the batch [5].

Observation a cut of surface marking corpus electrical connector SNP268 to scientific microscope AKSTOCKOP2 MAT is show, what real thickness metal cover is equally 90 – 150  $\mu\text{m}$ . Depth a symbol, which is making a laser marking, is equally 20 – 30  $\mu\text{m}$  (figure 5, b).

This way, by observe the fixing regimes of processing, a technology of laser marking is ensure a double stock by thickness of cover. Therefore it is technology one may successful use for the marking of articles with thin cover of surfaces.

### Conclusions

Laser technological equipments for the precision marking of articles are one may ensure a high quality inscriptions. Allowing is unevenness with step to 30  $\mu\text{m}$ . A quality laser joint on the inscriptions one may strongly aggravate a use insufficiency of devices by fixing articles and laser radiator. This way, main condition ensures a quality of inscriptions is appearing a hardness of technological system «equipment-device-instrument-detail» (system EDID) of laser equipment.

By observe the fixing regimes of processing, a technology of laser marking is ensuring a double stock by thickness of cover. Therefore it is technology one may successful use for the marking of articles with thin cover of surfaces.

Executed researches are carrying out on order of undertaking Open Joint-Stock Company «Karachevsky Zavod «Electrodetal» – is main undertaking of Russia Federation in field of manufacturing the rectangular electrical connectors for the radio electronics and computer equipments. The results of these researches are passed to manufacture and use for the confirmation of faculty a undertaking is carry out the demands of customers with quality of connectors.

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