V.S. Kovalenko

LASER AIDED MANUFACTURING IN UKRAINE

Laser Technology Research Institute
of the National Technical University of Ukraine,
Pr. Peremohy, 37, 03056, Kiev, Ukraine

Introduction

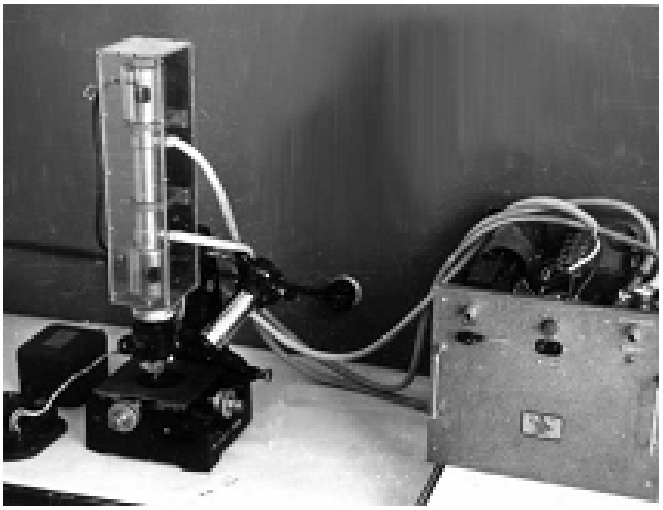
Global economic developments present new challenges for human activity. Advent of information technologies, airspace developments, new success in health care, new results in biotechnology and other science and technology achievements are possible due to, among others, fundamental changes in manufacturing science and possibilities to use new approaches in product developments. Laser technology born in the middle of the last century, continues to bring new challenges but also opens new horizons for scientists and manufacturers. It is impossible to imagine now the globalization without laser technology like it is impossible to imagine modern laser technology without globalization.

First research activities in laser aided manufacturing in Ukraine dated back to 1964 and had been initiated at the Kiev Polytechnic Institute (now The National Technical University of Ukraine "KPI"), in the Paton Welding Institute and at other institutions. There was a splash of interest in this advanced technology in the last two decades. The interesting feature of this process is the appearance of the number of small private organizations, different job-shops and the development of new R&D activity in a number of universities and research institutes (total around 50). Along with traditional industrial laser applications (cutting, surface treatment, welding, cladding, marking, cleaning, etc) some new fields are emerging such as - rapid prototyping, micro- and nanoprocessing, and development of the new types of lasers.

R&D Activities

The first industrial laser system based on the ruby laser was developed at KPI in 1964. It was installed on the universal tool microscope of the "Karl Zeiss" Co, and had an energy of only 2J per pulse (Fig.1). Later, a series of different pieces of equipment were developed at the Laser Technology Laboratory of KPI based both on more powerful ruby laser and on Nd-glass, YAG, CO2 and other lasers. The main research was conducted in the development of technologies of precise microholes piercing, spot welding, studying hardening effects, surface alloying possibilities, micro cutting and marking.

In other institutions some pieces of industrial laser systems, manufactured in the former Soviet Union, eventually had appeared together with self-made experimental setups.



First Ukrainian industrial laser system based on ruby laser for precise holes piercing, developed at LTL (KPI) in 1964

© Kovalenko V.S., Электронная обработка материалов, № 3, 2007, С.87–91.

Laser hole piercing. The main problem at laser hole piercing was to get the high quality and precision of the hole, which was dependent mainly on the amount of molten phase in the erosion products. To lessen this effect or to avoid the molten phase entirely the shorter pulses were used. For the last two decades the evolution was drastic – from milliseconds to microseconds, then to nanoseconds, picoseconds and finally femtoseconds.

Laser welding. This research is done to a large extent at the Paton Welding Institute, using mostly powerful CO_2 lasers. At LTRI we are involved in studying joining of very delicate components like electronic device parts, different parts of medical instrumentation and others, which are gaining wide popularity in recent years.

Promising results had been achieved in joining parts made from plastic, ceramic and composite materials. Good example of high efficiency of such joining is laser welding of diamond composite cutting segments to the steel body of disk saw for cutting stones without water cooling. Besides the latter advantage the implementation of such joining process gives the significant saving of silver, used for traditional brazing of segments.

Laser hardening. At laser hole piercing improvement the great problem was to control the heat-affected zone (HAZ) and to make it minimal. The study of this zone demonstrated the ability to vary the parameters and dimensions of the zone in wide range. The studied phase transformation phenomena and different other metallurgical effects in this zone brought to life the new applications of laser technology: welding, surface hardening, surface alloying, cladding, shock hardening, glazing (amorphization), etc.

The development of different hardening technologies created the new possibilities to form locally in the component the regions with unique properties and thus to improve the quality of the whole product. Thanks to laser processing the wear resistance of cutting tools, moulds, dies, and of different machines components had increased by factor 3-6.

Cutting and material shearing. First cutting applications were mainly connected with manufacturing small slots in different parts, with sharing brittle materials (like diamond crystals) using scribing mechanism, with shearing silicon plates for solar elements using high frequency pulse lasers etc. The fundamental research of the cutting process with supporting gas helped to better understand the mechanism of material removal and of high quality edge formation.

3D object forming. Thanks to information technology integration into laser processing it became possible to develop the new technology of 3D objects forming, based on the principle of biological growth taken from nature. Known as rapid prototyping this technology allows not using moulds, dies and other traditional expensive tools to manufacture components with complicated shape at very high productivity. Started first from manufacturing components from polymer materials using stereo lithography this technology now came to the new stage – possibility to create components from metal, ceramic or different composite materials.

The research is carried out by studying the influence of different working conditions on sintering quality, on cracks formation, etc. Two schemes of process realization were developed and corresponding laser industrial systems were manufactured.

Based on research results in laser sintering the technology of manufacturing thin diamond cutting tools is proposed and is currently under more detailed investigation.

Micro and nanomachining. Thanks to information technology integration into laser processing it became possible to develop the new technology of 3D objects forming, based on the principle of biological growth taken from nature. Known as rapid prototyping this technology allows not using moulds, dies and other traditional expensive tools to manufacture components with complicated shape at very high productivity. Started first from manufacturing components from polymer materials using stereo lithography this technology now came to the new stage – possibility to create components from metal, ceramic or different composite materials

Marking, engraving. This technology became widespread for many fields of industry thanks to very high productivity and quality of the process. The unique application is marking inside the transparent for laser beam material using 3D laser scanning.

Sheet material deformation. The possibility to control the heating process and thus the resulting thermal deformation of sheet material by use of laser irradiation enabled the development of the new technology for forming components of complicated shape from sheet metal, plastic or other materials. It became possible to deform the material according to the given program without any traditional mechanical deforming technique using only a scanning laser beam.

In addition to these research activities, the possibilities to use laser heat treatment to increase the rigidity of thin sheet components is also being studied.

Combined or hybrid processing. Taking into account that laser itself is a very low efficient energy transformer different ways of additional energy supply into the working zone had been proposed. The most efficient was the direct electric energy addition to the concentrated laser energy. Depending on way of this additional energy supply different techniques had been developed:

- Electro-laser hole piercing;
- Arc-augmented laser welding;
- Laser cladding with electro-magnetic agitation;
- Laser alloying in electro-magnetic field;
- Laser-electrochemical processing;
- Plasma-laser processing.

Additional mechanical energy is applied to stimulate plastic deformations to control the thermal stressed material state:

- Laser ultra-sonic hardening;
- Laser-plastic deformation hardening etc.

Process simulation. This stage of laser technology is quite well represented. Different models had been successfully developed based mainly on heat conduction theory and presenting “heat history” of the irradiated materials. Different limitations are considered making these models quite adequate for the simple cases of laser processing. For complicated cases when processing is connected with evaporation, explosion, plasma formation, ablation mechanism etc. such physical models doesn’t “work” properly and can not be used at the industrial level.

Mathematical statistical models based on experimental results had been developed for industrial use but they are usually adequate only for some specific factor space and not always may be extrapolated for more complicated working conditions.

Lasers in industry

The developed technology and equipment are quite widely used at different plants – "Arsenal", "Bolshevik", "AVIANT" (Kiev), Malysheva plant", "Tractor plant"(Kharkov), "AvtoKraz" (Kremenchuk) and many others. At these plants the soviet made CO2 lasers and Nd:YAG lasers are mainly used for components welding, hardening, cladding, material cutting etc. Last time more than 60 new industrial laser systems had been bought by companies from foreign manufacturers – "Trumph", "Bistronic", "Rofin Sinar" etc. The number of small private organizations, different job-shops appeared at the market in the last few years, which are specializing on sheet material shearing, welding, components restoration by cladding, marking and engraving etc.

Different types of industrial laser systems are widely used in industry to manufacture precise holes in the range of few microns up to 1-2 mm in diameter with very high productivity.

Among nontraditional applications the one should be mentioned connected with treatment of highly radioactive materials – the study of opportunities to use robotized laser system to disintegrate the "Object Shelter" of the Chernobyl Atomic Station.

Academic program

From the very beginning of the laser era, activities on the development of academic programs in laser technology were initiated at KPI. Thus, at KPI, the first graduates of this course received their Engineering Diploma in 1966-1967 from the Mechanical Engineering Department. This course has the official status of the new specialty named "Technology and Equipment for Laser Processing" and created in 1984. The corresponding academic program started first in the FSU and in Ukraine at KPI in Kiev and at Bauman Institute in Moscow.

During the last years the academic program is being adapted to the Bologna Agreement concept, the main goal of which is the integration of the national education systems into the Europian and global one.

From that time up to now more than 1000 engineers and masters (both from Ukraine and other 32 countries) in laser technology graduated KPI. For the last decades 27 Ph D thesis and 6 D. Sc. thesis of researchers from different countries had been successfully defended at KPI as well.

International collaboration and integration initiatives

The international collaboration in the field of laser technology has improved significantly for the last decade. Different mechanisms are involved in stimulating such moves. Besides bilateral agreements on scientific collaboration between Ukraine and different countries there a number of straight ties between universities and laser centers (for example the LTRI has such agreements with Okayama University, Japan; Ohio State University, USA; Jzenjzan University, China, etc). A number of projects is financed by NATO, by different institutions of EU (INTAS, EURIKA etc), by Scientific and Technological Center of Ukraine (STCU). By the way the STCU is sponsoring the projects financed ether from combined three sources –

USA, Canada and EU, or from separate source. LTRI had developed the STCU project #2379 “Laser 3D prototypes forming from powder metal and ceramic materials”**,** financed by USA, Canada and EU in 2005 (Co-partners from USA, Canada, Netherlands, Italy). The technology and laser industrial system had been recommended for commercialisation in 2005. In 2006 another STCU project #3350 is approved with financing from EU: "Development of new design medical stents and their manufacturing using laser radiation" (Co-partners from USA, Canada, Netherland, Belgium and Portugal).

It is obvious that globalisation goes parallel with integration process. We witness such integration in every field of human activity, in different regions, in America in Europe and in Asia. Ukraine as country located in a very geographical centre of Europe is trying to be integrated in European community and supports different integration initiatives.

Prof. V. Kovalenko (NTUU) and Prof. A. Grabchenko (Kh.NTU) had been invited by EU officials as coordinators from Ukraine to develop the National ManuFuture Technological Platform. Based on achieved results and gained experience in advanced technology R&D activity such ManuFuture Technological Platform of Ukraine had been developed recently and proposed for integration in EU ManuFuture Platform. Laser aided Manufacturing is considered as a key technology of this concept.

In spite of chronic financial problems experts in laser technology from Ukraine are becoming to participate quite regularly in different international professional institutions LIA, CIRP, IEEE, LEOS, LAS etc. and their events: ICALEO, ISEM, CIRP General Assemblies etc. I would like to stress that ICALEO event is usually considered as a real Global Congress in laser technology.

Ukrainian experts are quite active as referee in the LIA "Journal of Industrial Laser Applications" and as contributors to the "LIA Handbook on laser material Processing".

Few international laser conferences had been organized last years in Ukraine. One of them is becoming traditional – International Conference on Laser Technology in Welding and Material Processing (LTWMP), organized by Paton Welding Institute and by the LTRI. They had been held in Katcively, Crimea in May 2003 and 2005 and gathered the expert from more than 16 different countries. The 3d LTWMP will be held in 2007.

One of the initiatives directed to the further development of integration processes is the concept proposed by LTRI on the development of the virtual enterprise to increase the efficiency of the use of industrial laser systems. Such e-enterprise may improve the competitiveness of different small and medium plants using unique and expensive industrial laser systems.

Problems

The permanent efforts are directed to the achievement of highest quality and productivity of processing at lowest possible cost.

This may be achieved by:

- better understanding of laser beam interaction with processed material ;
- full control of all parameters involved in the process;
- adequate process simulation and optimisation of all working conditions;
- development of process monitoring devices and fully adaptive systems for processing;
- reducing the laser industrial systems maintenance cost;
- useing efficient devices, instrumentation and methodics for express measuring the processing results;
- improving the academic programs for the young generation of specialists studying laser technology and other nontraditional processing,
- wider development of interdisciplinary studies,

intensifying the international collaboration.

Conclusions

1. Research, industrial and academic activity in laser technology in Ukraine has the obvious trend to globalization.

2. Ukraine has significant potential in laser technology for participation in the integrated international R&D projects.

3. The gained academic experience, industrial and scientific potential of the laser community of Ukraine may be used for a wider integration into the global economy.

REFERENCES

1. *Kovalenko V.S.* Opportunities to use laser technology in automotive and aerospace industry, “Electron material machining”, N 36, 2002, p.9–18.

2. *Kovalenko V., Uno Y., Okamoto. Y. et al.*Laser cutting of semiconductor elements, Int. J. Electrical machining, N 7 (January), 2000, p.9–14.
3. *Kovalenko V., Anyakin M., Karpachov Y.* Robotized laser technology – solution for the problem of destroyed reactor dismantling at Chernobyl Atomic Station, Proceedings of the 12th International Symposium for electromachining, (ISEM), Aachen,1998, p.613–623.
4. *Kovalenko V.S., Golovko L.F., Novikov N.V. et al.* Laser technology application for diamond tool manufacturing, Proceedings of International Conference LTWMP-2003, PWI NASU, Kiev, 2003, p.159–164.
5. *Meijer J., Gillner A., Kovalenko V., Hoffman D. et al.* Laser machining by short and ultra short pulses: state of the art, Proceedings of CIRP General Assembly, San Sebastian, Aug. 18–25, 2002, 22 p.
6. *Kovalenko V.S., Mamalis A., Kolpakov V.V.* WEB-technologies application to increase the efficiency of laser industrial systems, Proceedings of International Conference LTWMP-2005, PWI NASU, Kiev, 2005, p.64–66.

Received 28.01.07

Paper had been presented at laser technology summit meeting "GARELAM – Global Application, Research and Education in Laser Aided Manufacturing", held in American Academy of Science in Washington, DC, USA in July 2006.

Summary

Started in the early sixties of the last century R&D development in laser technology in Ukraine is still in progress in spite of some decline in 1990–1993 caused by drastic political and economic changes in the country. There are, indeed, some interesting and original results in all known industrial applications. Some of them are presented in this report. The international ties with colleagues and joint projects with copartners from different countries are becoming the common practice. The significant intellectual potential and gained research and industrial experience serve as a basis for more than 40 years of academic activity in laser technology in the country. Graduates of the Laser Technology and Material Science Department of the Kiev Polytechnic Institute (engineers, masters, PhD holders) are quite successful in their career both in Ukraine and in different countries of the world. Collaboration within the framework of the European Union as well as with different institutions in North America and Asian countries is increasing quite rapidly.

Симонов Юрий Александрович - 70 лет

Доктор физико-математических наук, Заслуженный деятель науки Республики Молдова, Дважды лауреат Государственной премии Молдовы в области науки и техники

В системе Академии наук работает с 1960 года, после окончания физического факультета Горьковского университета им. Н. Лобачевского; в 1967 году защитил диссертацию на Ученом совете физического факультета.

С 1996 года заведующий лабораторией “Физические методы исследования твердого тела” им.Т. Малиновского.

Автор более 1000 печатных работ, 20 авторских свидетельств; неоднократно выступал с докладами на международных совещаниях; руководитель и консультант 14 докторских диссертаций. Руководитель и исполнитель большого количества грантов, постоянно проводит совместные исследования с научными центрами многих стран.

С участием юбиляра и сотрудников лаборатории выполнены исследования, результаты которых опубликованы в журнале “Электронная обработка материалов”.

Искренне желаем Юрию Александровичу дальнейших творческих успехов, благополучия и счастья!

Редколлегия