# Soviet 'science-production teams' bring lasers to industrial processes

*Academician Ye. P. Velikhov, vice-president of the Academy of Sciences of the U.S.S.R., director of the program, "Creation and Production of Laser Technology for the National Economy," wrote the following article which appeared in the Soviet Party Central Committee's economic weekly,* Ekonomicheskaya Gazeta, *No. 14 for 1983, entitled "The Laser Beam Is Working."*

The development of laser technology is convincing confirmation of the determinative influence of fundamental scientific discoveries on the economy. The laser effect, predicted, discovered and researched with the decisive participation of Soviet scientists, has in a comparatively short period—a little more than two decades—gone through all the stages of development and emerged into the open range of multi-purpose utilization in the national economy. . . .

The potentialities of lasers serve as one of the paths towards solving the problem of the controlled thermonuclear [fusion] reaction.

In the Eleventh Five-Year Plan, the special complex scientific and technological program "Creation and Production of Laser Technology for the National Economy" is being carried out. Work is being done in the following major directions: development and creation of lasers of more than a kilowatt of radiation power for technological applications; organization of experimental areas and laboratories at foremost enterprises and leading scientific research institutes in various branches of industry, for the final development and application of laser technology processes; creation of an industrial base for the widespread mass production of lasers and laser technological equipment; development and organization of production of various types of laser of less than a kilowatt power and laser equipment for all sorts of applications in the national economy; labor protection and safety techniques during work with laser radiation.

Over 20 ministries and agencies and more than 100 fulfilling organizations are participating in the program. Its main implementers are the Academy of Sciences of the U.S.S.R., the Ministry of the Electrical Equipment Industry and the Ministry of the Machine Tool Industry.

## The effect of the new technology

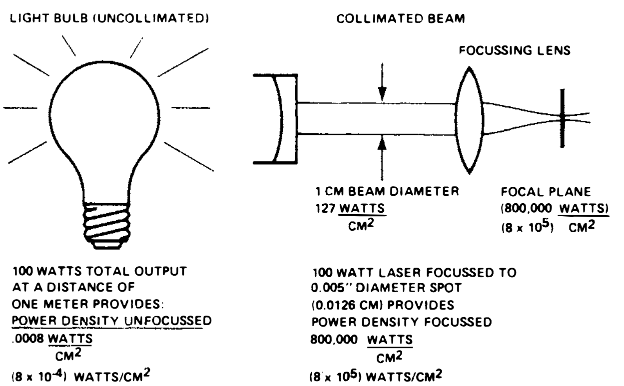
The most promising lasers for metals processing in machine building are gas lasers of more than one kilowatt power. Radiation of this magnitude is used for cutting, welding, heat treating, surface fusing and making alloys of materials. This area of application promises to become the broadest. It is already clear now, that laser technology more than doubles the yield of processes, measured by their basic indicators, or permits the realization of fundamentally new operations.

A common property of all laser heating technological processes is their high productivity and the rapid time in which the equipment pays for itself. Despite a relatively low efficiency (for existing laser equipment, approximately 10 percent), there is, in the final analysis, conservation of energy expenditures, due to the improved quality of the treatment.

Comparison of the laser and the argon-arc methods of welding, which require approximately equal energy expenditure per unit of length of the joint, shows that as a result of the prolongation of the serviceability of components welded by laser, fewer of them have to be produced. . . . And it must be considered that the introduction of laser technology gives . . . social advantages—elevation in the cultural level of production, reduction of use of manual labor, and improvement of conditions.

Cutting of materials by laser is carried out with a density of radiation power of $10^5$-$10^7$ watts per square centimeter, sufficient for melting and evaporation of the substance. In this, the velocity is 15-40 meters per minute, the breadth of the cut is from 0.2 to 0.05 millimeters. The expenditure of materials being processed is three to five times less than with other methods. It is possible to cut out components with complex configurations, with an accuracy of up to hundredths of a millimeter. Lasers make it possible to cut refractory metals, ceramics, fabrics, plastics, wood, composition materials—whatever you like. The process takes place so quickly, that the surface does not heat up significantly, so that the properties of the materials in the zone of the cut practically do not change and the components do not suffer deformation from residual tensions.

The need disappears for cutting instruments made of superhard materials, which are expensive and subject to rapid wear and tear. The high quality of the operation makes it possible to do without subsequent, further processing of components. Thus, laser cutting is highly effective in the ship-building, aviation, electrotechnical and other branches of industry, for

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A laser produces radiative light energy in a coherent form: all the light rays are of the same wavelength and are traveling in the same direction. A laser converts incoherent energy, such as white light or electrical energy into light of one specific wavelength, or color.

A lasing medium (a solid, liquid or gas), provides the atoms, ions or molecules that are stimulated to emit coherent radiation. Second, the laser must have a source of energy, or a "pump," such as light, an electrical pulse, or even a nuclear explosion, which excites the lasing medium to emit photons spontaneously. Third, a series of mirrors provide an optical resonator to bounce the coherent light produced back and forth, stimulating more emissions, until it gathers enough intensity to be transmitted out of the laser for use.

An ordinary light bulb, pictured on the left, emits photons randomly and is described as an uncollimated source of light. Its radiant energy is incoherent, as it includes all of the wavelengths in the visible spectrum, and is therefore called "white light." The power density of a 100-watt incandescent bulb measured at a distance of one meter is only 0.8 milliwatts per square centimeter. It is impossible to focus all this radiant energy into a coherent, collimated beam.

On the right is a diagram of a laser-produced collimated beam of light. It is almost perfectly collimated, i.e., its rays are parallel. A highly focused coherent laser beam can have an intensity of several hundred watts per square centimeter. It is also monochromatic, meaning it is in a very narrow wavelength band in the electromagnetic spectrum. Helium-neon lasers, for example, glow with a brilliant red light since their wavelength is in the visible spectrum.

The carbon dioxide laser, broadly used in industry, emits its coherent energy in the far infrared part of the spectrum, and is not visible to the eye. More advanced lasers will, in the future, emit their coherent energy in even shorter wavelengths, emitting X-rays and gamma rays.

precision cutting of materials, perforation, cutting notches and marking components. The economy of materials in cutting is up to 70 percent. The time in which the equipment pays for itself is about one year.

Laser welding requires a power density of $10^5$-$10^6$ watts per square centimeter. Here, the thickness of the components being processed is approximately one millimeter per kilowatt of power of laser radiation. The speed of welding is from 0.3 to 2 meters per minute. The zone affected by the heat is so small, that the components being welded are not threatened with any noticeable deformation. Very firm joints are obtained. Furthermore, it is possible to combine different types of material. Laser welding is unsurpassed by electron-beam welding, and . . . does not require that the components be in a vacuum.

Laser fusing of high-resistance materials . . . makes it possible to double or triple the service life of components, under conditions of very high mechanical loads. Consequently, the volume of spare parts production can be reduced many times over. . . .

Among the types of laser processing, the most widely used is heat-strengthening. With a power density of $10^4$-$10^5$ watts per square centimeter, the radiation quickly heats up the surface of components to a temperature close to their melting point. Upon rapid quenching by means of heat transfer, there is a sort of "tempering" of the surface layer of the material; its structure becomes finely dispersed and even amorphous. This significantly raises its hardness and durability.

A good example of the effectiveness of this type of equipment is the process of laser heat-strengthening of cylinder block heads of the ZIL-130 automobile engine, introduced at the "AvtoZIL" association. According to calculations, it saves about 2 million rubles per year. Laser heat-strengthening can be widely applied also in engine-building, machine tool-building and other branches. . . .

It is well known that molecules and atoms in the gaseous state absorb radiation only in narrow spectral intervals. And these bands differ for various substances. One can choose the laser radiation wave length in such a way, that only one, desired sort of molecule will accept it. The laser radiation energy suffices not only for heating, but also for the separation of molecules and ionization of atoms.

By removing the residues of separated molecules or ionized atoms from the irradiated volume of material, by means of an electrical field, for example, it is possible to cleanse a substance. This method, which makes it possible to carry out fundamentally new chemical processes, is already being used in research laboratories. . . .

## The road to production

The 26th Party Congress directive for the integration of science with production defined an approach to . . . the problem of introducing laser technology. An inter-agency scientific and technological council has been established under the State Committee on Science and Technology and the Presidium of the Academy of Sciences of the U.S.S.R. . . .

A Scientific Research Center for Technological Lasers of the Academy of Sciences of the U.S.S.R. (NITsTLAN) is functioning. Among its basic tasks is not only the development, but the introduction of laser installations and methods in industry. The center has its basic laboratories at the Likhachov Auto Factory (ZIL) and other machine building enterprises, where scientists and production men together determine concrete technological operations carried out with the help of powerful lasers. As practice shows, this is the most effective way of conveying to industry what science has developed.

The training of cadres occupies a special place. In particular, on the base of NITsTLAN and the Bauman Higher Technical School there has been organized the Scientific Training Center for Laser Technology of the Academy of Sciences of the U.S.S.R. and the Ministry of Higher Education of the U.S.S.R., which is training people in new specialties.

The 1981-82 tasks of the special complex program were basically accomplished. The Ministry of the Electrical Equipment Industry received from scientists lasers of from one to five kilowatts, for the organization of mass production of technological installations. These are the 1.2 kilowatt LOK-2M laser, created at the Institute of Theoretical and Applied Mechanics of the Siberian Division of the Academy of Sciences of the U.S.S.R.;
the Institute of Problems of Mechanics of the Academy of Sciences of the U.S.S.R.; the five kilowatt TL-5 laser developed by NITsTLAN;

Experimental sections were set up and laser technology is being introduced at the Likhachov and Leninist Komsomol auto plants in Moscow, at the VAZ, the Cherepovetsk metallurgical plant, and in the following industrial associations: "Salyut" and "Znamya Truda" in Moscow, "Baltiiskii Zavod" in Leningrad, "Tulachermet" in Tula, and several others.

Mass production has been increased and the scale of assimilation into production broadened for solid, gas, and superconductor lasers of less than one kilowatt of power, as well as apparatus based on them. In health care, not single experimental models, but mass-produced laser instruments are already being applied and used. . . .

The Institute of Spectroscopy of the Academy of Sciences of the U.S.S.R., the Kurchatov Institute of Atomic Energy, NITsTLAN and other organizations have obtained good results in gas physics research, and also in the creation of the theoretical and experimental basis for selective laser atomic-molecular technology. Research and development is being carried out on the application of lasers in instrument-building, the production of measurement and monitoring apparatus, information processing systems, and spectral devices. . . .

It would have been possible and it was necessary to have done significantly more. The mass output of technological lasers and special equipment for laser processing, unfortunately, has not yet reached the scale it should.

## Problems of introduction

The road from idea to its concrete, practical incarnation is covered the most rapidly, when there is unity of scientific, design, and production forces. . . . For the assimilation of new technologies that span several branches of industry and have arisen on the basis of fundamental research, such [scientific-production] associations should, in our opinion, be created on the basis of leading inter-branch scientific institutions, such as the institutes of the Academy of Sciences of the U.S.S.R. usually are. . . .

Laser equipment is comprised of complex systems, which have to be prepared from different types of production. The corresponding directives are submitted to the fulfilling ministries. However the work on setting up specialized, staffed groups, materials, and equipment in the Ministry of the Chemicals Industry, the Ministry of Chemical and Petroleum Machine Building, the Ministry of the Electrical Equipment Industry and the State Committee on Standards is moving slowly. In the Ministry of the Machine Tool Industry and the Ministry of Instrument Making, Automation Equipment, and Control Systems, it has not been started at all. The question of providing optics for the serial production of laser installations has not been solved organizationally either.

To the extent that the Ministry of the Electrical Equipment Industry is not fully satisfying the demand for lasers, the branches that use them are beginning to make the equipment themselves. For example, the Ministry of the Shipbuilding Industry is producing several types of installation for its needs. . . .

In order to develop a concrete technological process in factory laboratory conditions, one needs a rather deep knowledge of physics in the field of lasers, methods of measurement, and the bases of the interaction of laser radiation with materials. This circumstance was the condition making necessary the creation of basic laboratories and experimental sections at leading enterprises in the branches and in leading inter-branch institutes, with the direct participation of organizations of the Academy of Sciences of the U.S.S.R.

The processes in laser processing of materials are to a large extent universal and uniform for various branches of machine building. Therefore, it is appropriate to form inter-branch regional centers for research on the applications of laser technology and for fulfilling single-ticket orders for laser processing. Subsequently they will be able to grow over into specialized enterprises.

While earlier we used to talk only about the gain lasers give in individual technological processes, today it is a question of speeding up work on creating flexibly redeployable automated manufactures using them. The laser, being an extremely productive and universal instrument, is used most effectively, when there are no halts and power losses during the preparation for an operation. Consequently, an installation should service several technological posts at once, each of which is working within a certain framework. Then the advantages of laser equipment can grow dozens of times over. This is a question of creating "integrated" automated and robotized laser technological systems, shops and factories. This is one of the perspectives for the development of work in the special program. . . .