FTD-ID(RS)T-0894-80

FOREIGN TECHNOLOGY DIVISION

LASER STRUCTURES FOR PROJECTIONAL TELEVISION
AND OTHER APPLICATIONS

by

O. N. Talenskii

Approved for public release;
distribution unlimited.

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

EDITED TRANSLATION

FTD-ID(RS)T-0894-80 29 July 1980

MICROFICHE NR: FTD-80-C-000906

LASER STRUCTURES FOR PROJECTIONAL TELEVISION AND OTHER APPLICATIONS

By: O. N. Talenskii

English pages: 8

Source: Rozprawy Elektrotechniczne, ~~Vol. 25, Nr. 3, 1979, pp. 765-771~~

Country of origin: Poland

Translated by: SCITRAN
F33657-78-D-0619

Requester: FTD/SDEO

PREPARED BY:

TRANSLATION DIVISION
FOREIGN TECHNOLOGY DIVISION
WP-AFB, OHIO.

LASER STRUCTURES FOR PROJECTIONAL TELEVISION AND OTHER APPLICATIONS.[1] 765

Oleg Nikolaevich Balenskii (Moscow)
The Physics Institute of the Academy of Science
of USSR (P.N. Lebedev Institute)

Received Nov.17,1977

The article contains a review of the construction of various types of semiconductor structures for lasers excited by an electron beam. The type of structure used depends on the purpose of the laser. A brief analysis of technological problems is presented. Some data concerning the parameters of the lasers obtained are also presented.

1. Resonators with transverse geometry.

The present article will discuss structures made of semiconductor crystals representing lasers excited by an electron beam (1). The simplest laser structure is a structure with the so-called transverse geometry (Fig.1), in which the light energy is radiated in a direction perpendicular to the direction of the electron beam. The principal part of this structure is a semiconductor crystal forming a resonator of length of 300-500μm. 766

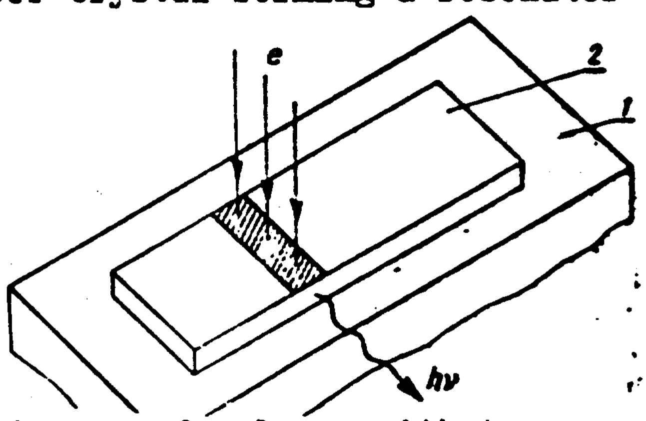

Fig.1.Diagram of a laser with transverse geometry. 1-crystal frame; 2-crystal.

[1]Article based on the lecture given by the author at the meeting "Semiconductor lasers" organized by the Physics Institute of PAN on Sept.26,1977 in Warsaw.

In this case the mirrors of the optical resonator are the natural crystal walls obtained by chipping.

The crystal used as a laser should thus have parallel borders. This condition is fulfilled for crystals with cubic symmetry, in particular for GaAs. In crystals with hexagonal symmetry, surfaces should be chipped off$(11\bar{2}0)$. A fortunate circumstance is the possibility of growing crystals with hexagonal symmetry, such as CdS or CdSe, in the form of plates with orientation surface $(11\bar{2}0)$. Laser activity was obtained for the first time in such plates, and for a long time they constituted the only object of studies. The surface bombarded by electrons should approach the ideal. Any perturbations of the surface quality lead to the generation of centers of non-radial recombination, and therefore to an increase of the threshold of laser activity. The plates with surface close to the crystallographic one made it possible to obtain laser radiation at relatively low threshold currents.

The depth of electron penetration, and therefore the crystal area in which radiation generation takes place, is several μm for energy of the order of several tens of keV. The remaining part of the crystal is, because of the conditions of generation, unnecessary. In addition, this part of the crystal makes it more difficult to remove the heat formed in the generation area. The theoretical efficiency of lasers excited by an electron beam does not exceed 33%. Thus, at least 70% of the pumping power is transformed into heat and should be removed to the crystal frame, usually made of copper and cooled by liquid nitrogen. A serious problem is posed by manipulation of crystals of 50μm thickness. Serious technological difficulties arise in soldering the crystals to the frames. Materials of the group A_2B_6 are wettable with difficulty by most of the known solders. The use of solders with high temperature of softening is also unacceptable because of the possibility of damaging the crystal. This is why so far it is not possible to remove the heat in amounts larger than 600W from cm^2. This limits the light power to 100-150W per pulse. The threshold values for current density in structures with transverse geometry are several A/cm^2 at an electron energy equal to 40-50 keV.

As mentioned above, plates of crystals of type A_2B_6, having good surface, have served to carry out the basic studies on the physical properties of the lasers in question. However, an obstacle in their practical utilization was posed by their two important disadvantages: a. small thickness, which, with brittle material, has seriously hampered technological operation, and b. limited size of the plates (it is not possible to grow a crystal of linear dimensions greater than 1-2cm). In addition, considerable part of the surface is covered with pyramids of growth, scars, and other defects of crystal growth. For physical studies it was sufficient to chip off a part of the plate free of defects, with dimensions of the order of several millimeters, while for physical applications such crystals are too small.

2. Laser resonators with longitudinal geometry.

Semiconductor lasers excited by an electron beam find applications in technology as devices transmitting information, including television projection devices, address elements for selecting information etc. All these applications require a 1767 structure sufficiently large, which could be scanned with an electron beam along two axis. Attempts of finding a solution by using a system of mosaic structures have not given positive results. Only single crystal structures promised any success.

Obtaining large crystals was possible thanks to the method of Markov and Davydov (2) of growth an a closed ampoule. A characteristic of this method is the fact that the crystal is not in contact with the walls of the ampoule during growth, and therefore contains fewer defects. However, the surface of the crystal undergoes considerable damage during cutting of the material obtained into separate plates. Even polishing to optical quality could not recover the necessary degree of clean surface. In structures made of such crystals it was either impossible to obtain laser activity at all, or it was achieved at very high threshold current, which made practically impossible to use them. The use of structures of volume-type crystals was possible only after chemical-mechanical polishing method was introduced.

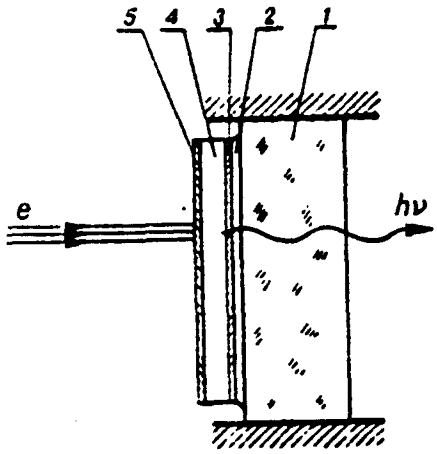

Fig.2. Diagram of a laser with longitudinal geometry. 1-sapphire circle, 2-layer of glue, 3-mirror with reflection coefficient of 98%, 4-crystal, 5-mirror with reflection coefficient of 100%.

As we have stated previously, for lasers used in systems for transmitting information it is natural to use scanning along two axis. In this case the geometry of the structure is altered. It is more convenient to apply the so-called longitudinal geometry, in which the direction of the radiated light and of exciting electrons is concordant (Fig. 2).

In this case the thickness of the crystal is limited not only by the conditions on heat removal, but also by the absorption strata of the light. Therefore it is advantageous to use crystal thickness as small as possible, which leads to an increase of the threshold current density. The longitudinal structure gives rise to specific technological difficulties (3). Nonparallel surfaces lead to an increase of the threshold or even to an interruption of laser activity. Experimental results indicate that the admissible deviation from parallel surfaces is at most 1-2μm for 20-25μm. 1768
Such stringent requirements make it difficult to polish the crystal and the sapphire base. The layer of glue should also be flat to the same degree of accuracy.

The thermal conditions are better for the geometry in question, since heat removal takes place over the entire surface of the structure, and the excitation is at a single point. This fact has allowed to obtain laser activity at room temperature with decreased crystal thickness (4).

3. Materials used for lasers in projection television.

Projection television requires obtaining a light signal from lasers for three areas of the visible spectrum range. This can be achieved by using various semiconductor materials for constructing laser structures. Cadmium sulfide, CdS, makes it possible to obtain a green image. Cadmium selenide, CdSe, radiates in very dark red. Solid solutions of these materials give, depending on the composition, any desired color of radiation within the range 4900-6900Å. Solid solutions of sulfide in selenide are rather easy to obtain during crystal growth from a mixture of starting components. It is much more complicated to obtain blue light. In this case it is necessary to obtain crystals of solid solutions of cadmium sulfide in zinc sulfide or of zinc selenide in zinc sulfide. However, the vapor tension of the starting materials are quite different, and thus it is only possible to obtain solid solutions of these compounds in a narrow composition range. Cadmium sulfide has a hexagonal crystal structure while zinc sulfide - cubic, which results in a nonhomogeneous crystal having domain structure and many defects.

A very interesting problem is obtaining a thin monocrystallic layer directly on the sapphire base. Such a solution would simplify considerably the technology and would decrease the cost of generating the structure. For a long time no positive results were obtained in this direction. Lately, however, studies have been conducted which may bring success. For instance (5), it has been reported that laser activity was obtained in a monocrystallic layer of zinc selenide. The layer is obtained by the method of vacuum epitaxis on sapphire base. It is separated, however, from the base in order to introduce the mirrors.

4. The problems of the technology of laser structures for projection television.

The semiconductor structures discussed up to now require relatively high accelerating voltages, of the order of 50-75kV.

This fact causes various drawbacks in the operation of the apparatus and makes it necessary to use protection against X-ray radiation. On the other hand, lowering the accelerating voltage causes an increase of diffraction losses (especially in lasers with transverse pumping), related to the penetration depth of the electrons. In order to avoid this problem the concept of using a wave-conducting structure was developed (Fig.3). As in the case of joint lasers, such a structure should lead to lowering of threshold conditions.

First it was possible to achieve the expected effect or lowered accelerating voltage for gallium arsenide (6). Next, the same effect was also obtained for the visible part of the spectrum (7,8).

From the technical point of view the problem consists in the increase of the epitaxial layer of the semiconductor with a higher refraction coefficient on a base with a lower refraction coefficient. As the base, zinc sulfide ($n = 2.47$) has been used with an orientation surface $(10\bar{1}0)$. On this basis a layer of zinc selenide ZnSe was grown ($n=2.86$) by the method of gas transport in an open tube. The carrying gas was hydrogen.

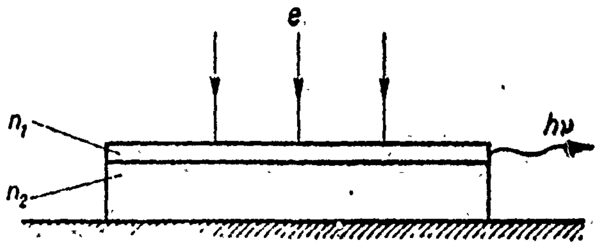

Fig.3. Diagram of the wave-conducting laser structure.

The layers formed had a thickness of 20-100μm. The layers had uneven surfaces which were then polished by the mechanical-chemical method. The resonators were obtained by chipping the base together with the layer. Experiments were conducted for structures with transverse geometry.

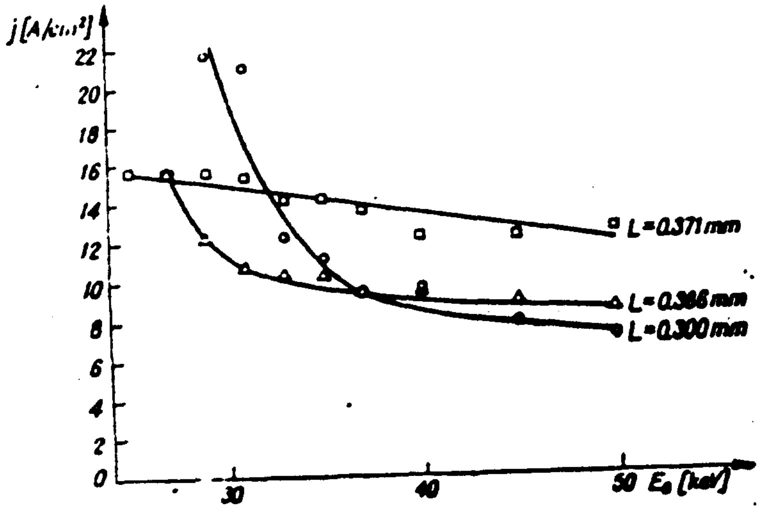

Fig.4. Dependence of the threshold current density on the energy of excitation electrons.

At the temperature of 80 K the threshold current density was 4.5 A/cm^2, which is 4-5fold lower than the value for a homogeneous resonator. A characteristic property of a wave-conducting resonator is the existence of a range of accelerating voltage E in which the threshold current density depends weakly on E. 779

A comparison of the curves $j_{th}(E)$ for a homogeneous and non-homogeneous resonator is shown in Fig.4.

It should be noted that working voltages for wave-conducting structures are considerably lower than for homogeneous structures.

Laser activity of wave-conducting structures was observed at room temperature. The current density was 42 A/cm^2, the energy of excitation electrons was 50 keV, and the radiation power was 6W.

5. Summary.

In closing it is worth noting that studies in the area of the physics of phenomena in semiconductor lasers excited by an electron beam and the technology of structures for such lasers have permitted to work out the prototype devices which fulfill the requirements of many practical applications[2].

[2] A rather complete description of cathodoluminescence lasers in information and projection television can be found in V.I. Popov, Application of semiconductor lasers in optical memory systems, in the collection "Semiconductor Sources of Electromagnetic Radiation," A. Herman, Ed., PWN Warsaw, 1976.

Obviously, not all problems have been completely solved. In particular, a lot remains to be done in the area of improving the quality of semiconductor crystals (perfection of the crystallic structure, decrease in the number of dislocations, etc.). The effect of the state of the surface on the generation of laser activity is not sufficiently well understood, although it is known that this effect is very strong. Thus, we are not yet in a position to propose optimal methods for surface processing. The optimization of the two technological processes mentioned will allow, it seems, to lower the pumping power at least by an order of magnitude. This will undoubtfully help to expand considerably the range of the possible uses for this type of laser.

Translated by Marek Ocinski.

1. O.W. Bogdankiewicz, S.A. Darzniek, E.G. Jelisiejew. Semiconductor lasers. Nauka, Moscow, 1976.
2. E.W. Markow, A.A. Dawydow. Sublimation of crystals, Izw. An SSSR Inorg. Materials, 7 (1971), p.575-579.
3. W.I. Kozlowskij, A.S. Nasibow, A.N. Pieczenow, U.M. Popow, C.N. Talenskij, P.W. Szapkin. Laser screens of monocrystallic alloys CdS, CdS, Se, ZnSe. Quant. Electr. 4 (1977), p.351-354.
4. W.I. Kozlowskij, A.S. Nasibow, A.N. Pieczenow, U.M. Popow, P.W. Reznikow. Obtaining generation in the television mode of operation of a laser electron-radiation tube at room temperature of the laser screen. Quant. Electr. 4 (1977), p.2246-2248.
5. A.W. Dudenkowa et al., Quant. Electr. (in press).
6. U.A. Bykowskij, W.L. Wieliczanskij, I.G. Gonczarow, W.A. Maslow, N.F. Uzkij. PKG with electron excitation on GaAs with wave-conducting structure. Phys. Techn. Semicond. 5 (1971), p.137-138.
C.W. Bogdankiewicz, N.A. Borisow, B.N. Lawrussin, W.W. Lebiediew, A.G. Niegodow, S.S. Strielczenko. Wave-conducting structure of resonator in semiconductor laser with electron-beam-pumping. Quant. Electr. 3 (1972), p.61-63.
7. C.W. Bogdankiewicz, B.N. Lawruszin, C.W. Matwiejew, W.F. Piewcow, M.M. Chalimon. Laser with electron-beam-pumping on a ZnSe-ZnS heterostructure. Quant. Electr. 3 (1976), p.612-614.
8. W.S. Pietuchow, A.N. Pieczenow, C.N. Talenskij, M.M. Chalimon. Semiconductor laser on the wave-conducting structure ZnSe-ZnS with electron-beam excitation. Quant. Electr. 5 (1978), p.682-684.

LASER STRUCTURES FOR PROJECTION TELEVISION AND OTHER APPLICATIONS

Summary

The article reviews the construction problems of different types of semiconductor structures for electron-beam-pumped lasers. The type of laser structure used depends on the application. Some technological problems are briefly discussed. Some data concerning laser parameters obtained are given.