Semiconductor Physics, Quantum Electronics & Optoelectronics. 2000. V. 3, N 4. P. 542-544.

PACS: 07.07.D

Thermostable power sensors for transmitted continuous radiation of CO- and CO_2- lasers

Yu.A. Zagoruiko, N.O. Kovalenko, O.A. Fedorenko
Department of Optical and Constructional Crystals
of Scientific & Technological Concern «Institute for Single Crystals»
60 Lenin Ave., Kharkov, 61001, Ukraine

Abstract. Thermostable power sensors for continuous and pulsed periodic laser IR radiation are developed. Manufactured are scale models for a multifunctional optical element which combines the functions of transmitting radiation sensor and output laser window. Technical characteristics of the developed sensors are presented; the possibilities of their use in technological CO_2 - laser units are discussed.

Keywords: transmitting, thermostable sensor, wide spectral range, sensor IR radiation.

Paper received 07.09.00; revised manuscript received 12.10.00; accepted for publication 12.12.00.

1. Introduction

Utilization of high-intensity IR laser radiation in practice (for instance, of CO- and CO_2- lasers in medicine) requires power sensors of transmitting laser radiation which can work in both continuous and pulsed periodic regimes [1,2]. Traditional methods for measuring laser power by means of attenuators or splitters of laser radiation between low-power photoreceivers complicate the design of laser units and the process of their adjustment [3, 5]. Moreover, they increase the cost of laser units.

Developed is a thermostable optical element able to operate as both a power sensor of transmitted continuous laser radiation and passive optical elements (output laser windows, lenses, quater- and halfwave plates). Scale models of such multifunctional optical elements are manufactured on the base of crystalline ZnSe and $Zn_{1-x}Mg_xSe$ [6]. The sensor may be based on a variety of IR crystalline optical materials.

The action of the said sensor consists in measurement of the power of radiation scattered by the crystal which is proportional to that of transmitted laser radiation [7].

2. Experimental procedure and results

The sensor is a transmitting optical element furnished with two plates located on the side surface and possessing essentially different absorption coefficients. Affixed to the plates' surface are differentially connected temperature sensitive elements. The external appearance of the sensor is shown in Fig. 1. A portion of transmitted radiation scattered in the crystal reaches the sensor surface areas and heats them nonuniformly. Within some period of time, a temperature difference between the surface areas is established due to the heat conduction of the optical element material. Such a difference is registered by the temperature sensitive elements.

The value of power absorbed by the plates is approximately described by the following equation:

$$P_{abs} = \frac{S\eta\beta_p}{4\pi} \int_v I_0(x, y)e^{-\beta_\Sigma z} \frac{dV}{(x_0 - x)^2 + (y_0 - y)^2} B,$$

where S is the plate area, η is the coefficient of radiation absorption in the plate material, β_p is the coefficient of radiation scattering by the crystal, β_Σ is the total scattering and absorption coefficient of the crystal, $I_0(x,y)$ is the radiation intensity distribution over the laser beam cross-section, x_0, y_0 are the coordinates of the plate center. Integration is fulfilled over the crystal volume.

This equation is valid for small surface areas of arbitrary shape. The multiplier B takes into account reflection from the opposite face of the crystal sample. As seen from the formula, the value of absorbed radiation power is proportional to the distance from the beam to the surface area. This leads to an essential dependence of the signal on the position of the beam with respect to the receiving areas. However, it should be noted that the pres-

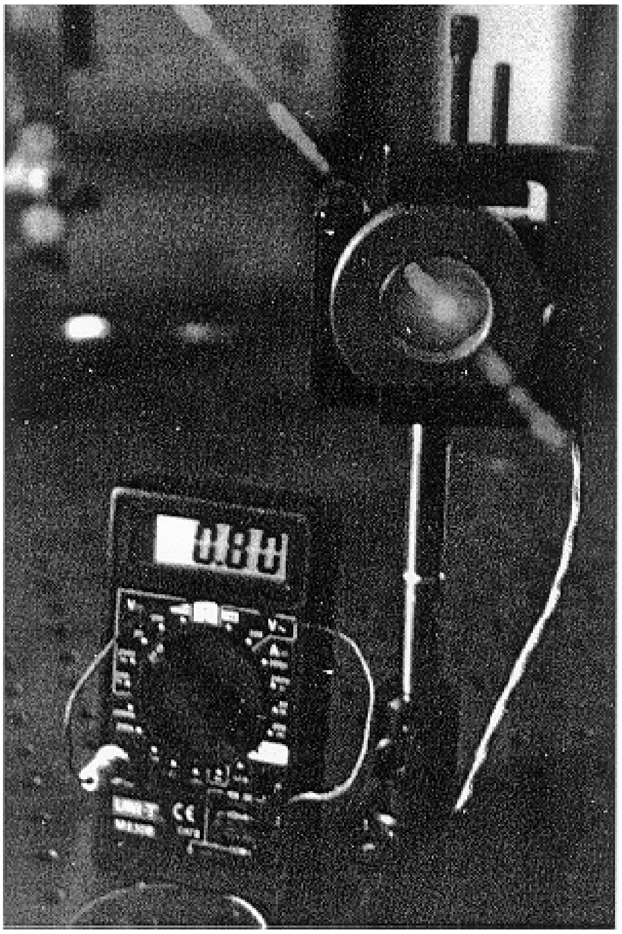

Fig. 1. The external appearance of the sensor.

ence of the coordinate dependence for the value of the signal may have practical importance for making the optical element meant for determination of the beam position.

To a considerable extent the sensitivity of the sensor depends on the location of the beam. In this experiment the said value ranged from 0.2 μV/W (at a distance of about 2.5 cm from the beam to the surface area) to 220 μV/W (at the shortest distance). Moreover, the value of sensitivity essentially depends on the crystal quality and on the presence of scattering centers. This allows to use the sensor for measuring different power levels. The dependence of the signal on the transmitted radiation power is presented by Fig. 2. As seen from the graph, the signal is linearly dependent on the transmitted radiation power.

The thermal stability of the sensor was investigated, too. For this purpose the sample under study was placed onto an electrical heater. The temperature was measured by a differential thermocouple with a compensative junction placed on the crystal at room temperature. The sensitivity of the sensor was measured at the same location of the beam with respect to the receiving areas. The range of heating was 5–100 °C. The curve of thermal stability is shown in Fig. 3.

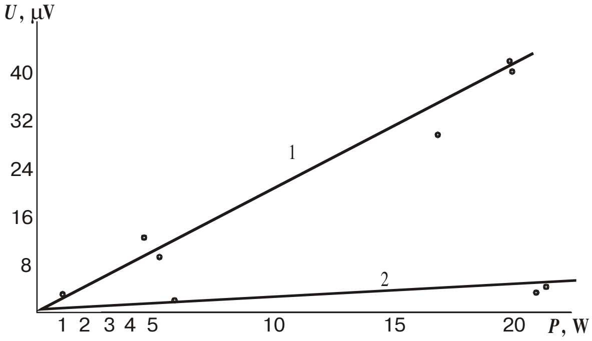

Fig. 2. Dependences of sensor signal on transmitted radiation power. Distances between laser beam and thermosensitive elements: (1) 1 and (2) 2.5 cm.

The sluggishness of the sensor was investigated in comparison with that of IMO 2N and IMO 4C power meters. The graph of the rise and drop of the signal is shown in Fig. 4. As is seen, the value of sluggishness of the developed sensor is close to that of IMO 4C meter, and is essentially lower in comparison with this parameter of IMO 2N. The time constant of the sensor is 2 s. Long-duration pulsations of output CO_2-laser radiation power have a period of about a minute. Thus, the sensor is fast enough to provide feedback for stabilization of the emitted laser radiation power.

The sensor was tested at continuous laser radiation power running into 100 W. The use of the sensor at higher powers is limited by the laser damage threshold of the optical material only.

On the base of the proposed version of the device, manufactured was the set of model samples or different types of multifunctional elements: 1) «laser window – sensor of transmitted IR laser radiation power»; 2) «lens – sensor of transmitted IR laser radiation power»; 3) «phase plate

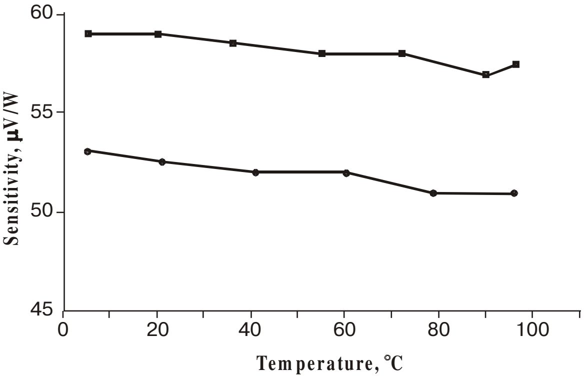

Fig. 3. Dependence of sensor sensitivity on temperature.

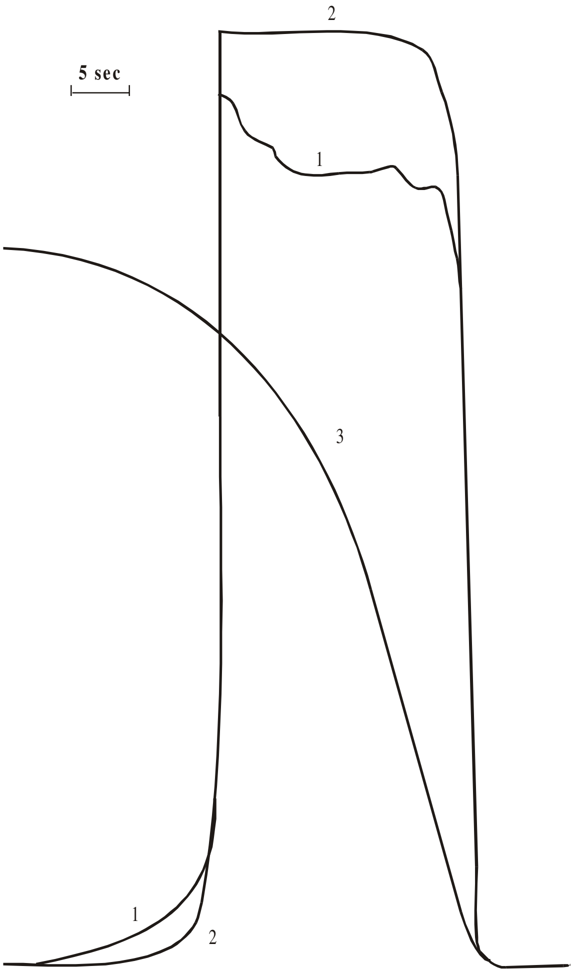

Fig. 4. Sensor sluggishness curve (2) in comparison with those of standard industrial IMO 4C (1) and IMO 2N (3) power meters.

– sensor of transmitted IR laser radiation power». The multifunctional elements of the first and the second types are manufactured on the base of crystalline ZnSe, those of the third type are based on hexagonal Zn$_{1-x}$Mg$_x$Se single crystals [6].

The main advantages of the proposed power sensor are the following: its transparency in both the visible and the IR region of the spectrum, the possibility to measure transmitted radiation power, high thermostability of its volt-watt characteristics within a wide temperature range, simplicity of design, small size, low cost. The said peculiarities of the thermostable multifunctional optical element, as well as its rather high speed of response, allow to use it as a feedback element for stabilization of continuous IR laser emitters, such as technological CO- and CO$_2$ - lasers, surgical laser scalpels, etc.

Acknowledgement

This work was supported in part by Science and Technology Center in Ukraine (STCU), Project #380.

References

1. V.F. Kosorotov, L.V. Levash, L.V. Shchedrina, Yu.A. Zagoruiko, V.K.Komar’, O.A.Fedorenko, Power sensors integrated with output CO- and CO$_2$- lasers based on tertiary pyroelectric effect // *Kvantovaya elektronika* **21**(6), pp. 588-590. (1994).
2. S.V. Babiychuk, A.I.Teslenko. Transmitted energy meter. In: Proc. of 5 th All-Union Conf. «Photometry and its metrological control». Moscow, VNIIFTRI, p.44 (1984).
3. J.F. Ready. *Industrial Applications of Lasers*. Academic Press, New York (1978).
4. G.A. Abilsiitov, V.G. Gontar, A.A. Kolpakov etal., *Technological Lasers*. Manual. Part. Moscow, «Mashinostroenie» publ. house, 544 p., (1991).
5. W.Brunner, K.Junge, *Wissenspeicher Lasertechnik*. VEB Fachbuchverlag, Leipzig (1987).
6. Yu.A. Zagoruiko, O.A. Fedorenko, N.O. Kovalenko, M.A. Rom, P.V.Mateychenko. «Physical properties of ZnSe-MgSe, ZnSe-CdS solid solutions and possibilities of their application in IR engineering». In: Abstracts of the International Conference «Advanced Materials», Symposium B, p.30, Kiev, Ukraine (1999).
7. Yu.A. Zagoruiko, V.K. Komar, V.Yu. Rostorgueva, V.N. Krivoshein. Russian Federation Patent № 1349543.