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East Europe Report

SCIENTIFIC AFFAIRS

(FOUO 10/81)

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CZECHOSLOVAKIA

PHOTODIODE LASER RADIATION DETECTOR DESCRIBED

Prague CESKOSLOVENSKY CASOPIS PRO FIZIKU in Slovak No 3, Jun 81 pp 272-276

[Article by Frantisek Lindner, BAZ National Enterprise, Bratislava; and Anton Strba and Pavel Vojtek, Department of Experimental Physics, PFUK, Bratislava: "Detection of Laser Radiation With a Semiconductor Photodiode"]

[Text] Laser Radiation Defection by the Help of Semiconductor Photodiode

This article analyzes the possibilities for use of the 1PP75 silicon semiconductor diode for detection of helium-neon (He-Ne) and ruby laser radiation. The spectral sensitivity of the diode and its range of linear response to radiation flux and pulse energy are determined.

1. Introduction

Alongside thermal detectors such as calorimetric and modern pyroelectric detectors, photoelectric radiation detectors continue to be a main topic of interest. These devices include semiconductor photodetectors, an important feature of which is their integrating capability, and particularly semiconductor diodes.

The magnitude I_d of the current which an illuminated photodiode passes into an external circuit can be determined from the well-known Shockley equation [1]

$$I_d = I_f - I_o\left(\exp\frac{qU}{AkT} - 1\right) \quad (1)$$

where I_f is the photoelectric current, I_o is the saturation current of the diode in the forward direction at temperature T, q is the magnitude of the elementary charge, U is the voltage across the diode, A is a coefficient characterizing the p-n junction, and k is the Boltzmann constant. The photoelectric current I_f is a linear function of the radiation flux Φ which produces it:

$$I_f = s_\lambda \Phi \quad (2)$$

where S_λ is the spectral sensitivity of the diode. Its magnitude for a given wavelength S_λ depends on the material and design of the diode.

2. A Detector for Continuous Laser Radiation

In practice, two ways of connecting the diode to the external circuit are most frequently encountered, the gate connection (Fig. 1a) and the resistive connection (Fig. 1b). In both circuits, the resistance R represents the load resistance and the internal resistance of the diode connected in parallel.

In the gate circuit, the voltage U in Equation 1 is equal to the voltage U_R across resistance R. The increase in the current I_d resulting from illumination of the diode changes the voltage across resistance R, which in turn affects the magnitude of the current I_d. In this case the diode current I_d and the voltage U_R will not be linear functions of the radiation flux Φ according to Equation 1. Linearity is maintained only for a small voltage U_R, such that $qU_R \ll AkT$. Under these conditions the second term of Equation 1 can be ignored and the current I_d will be equivalent to the photoelectric current I_f.

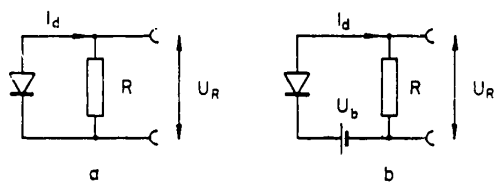

Figure 1. Connection of the Photodiode to the External Circuit: a) gate; b) resistance

In the resistive connection (Fig. 1b) the voltage U is equal to the difference between the power supply voltage U_b and the voltage U_R. A suitable selection of this bias voltage U_b and the resistance R will satisfy the condition

(3) $$\exp\frac{qU}{AkT} \ll 1$$

and according to Equation 1, the diode current I_d will be a linear function of the radiation flux Φ with the form

(4) $$I_d = S_\lambda \Phi + I_0$$

Accordingly the current I_d can be considered a measure of the radiation flux Φ. Because of the small magnitude of the current, it is more convenient to measure the voltage U_R across resistance R:

(5) $$U_R = S_\lambda R\Phi + I_o R$$

The photoelectric voltage $U_f = S_\lambda R\Phi$ can be separated from the dark saturation voltage $U_{OR} = I_o R$ by intermittent illumination or one-time illumination of the diode. The photoelectric voltage U_f will be the pulse component of the voltage U_R and can easily be measured through a buffer capacitor using an oscilloscope or some other measuring device. The sensitivity $S\Phi$ of such a detector, which depends on U_f, is

(6) $$S_\Phi = S_\lambda R$$

The magnitude of this quantity can be varied linearly by changing the resistance R. The spectral dependence of the sensitivity $S\Phi$ is governed by the nature of S_λ as a function of the wavelength. Because of their spectral sensitivity, commonly used silicon diodes are suitable for use in this manner to detect the radiation flux of He-Ne lasers.

The maximum current which can be recorded by a detector with linear response depends on the maximum value of the voltage U_R at which condition (3) can still be met. The condition for the maximum photoelectric voltage $U_f = U_R - Y_{OR}$ follows from Equation 5. It is assumed that there is no saturation of the photoelectric effect in the vicinity of the p-n junction. The threshold flux for registration of radiation depends on the noise characteristics of the diode.

The properties of such a radiation flux detector using a 1PP75 diode can be seen from the experimental curves for photoelectric voltage U_f as a function of the radiation flux from an He-Ne laser which are presented in Fig. 2. In this case, continuous He-Ne laser radiation interrupted by a mechanical modulator was scattered by a frosted screen located directly in front of the diode. The curves for $U_f(\Phi)$ given in Fig. 2 also shows the change in sensitivity $S\Phi$ as a function of R. These curves can be used to determine the spectral sensitivity of the 1PP75 diode and frosted screen to He-Ne laser light (λ = 632.8 nm), i.e., S_λ = 25 ±1 mA/W. Thus, by a suitable choice of R, it is possible to measure radiation flux in a range of from 10^{-3} to 10^{2} MW by this method, which exceeds the measuring range of the TKGM-203 Czechoslovak-produced detector now available.

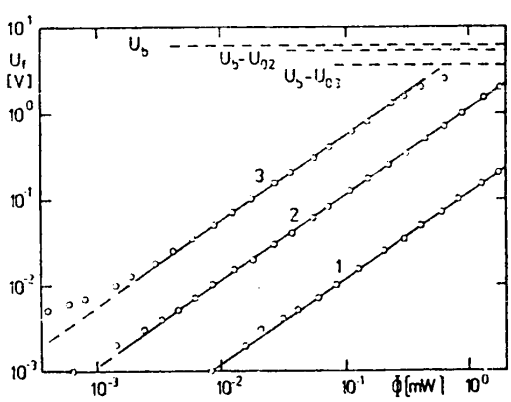

Figure 2. Amplitude Characteristics of the He-Ne Laser Radiation Flux Detector Using a 1PP75 Diode With Different Values for Resistance R: 1 - R = 4k7; 2: R = 43 k; 3: R = M27.

3. A Laser Pulse Energy Detector

The detector's ability to register single radiation pulses and the spectral sensitivity range of the 1PP75 photodiode (360 to 1,100 nanometers) [2] make it possible to use the detector for detection of ruby laser pulses as well (λ = 694.3 nm). But because of the large radiation flux, an attenuator must be placed before the photodiode. This prevents saturation or suppression of the photoeffect in the diode and assures linear response to the incident radiation.

One suitable type of attenuator is a cavity attenuator, which is shown schematically in Fig. 3. It consists of a hollow cylinder with circular openings in the ends. The openings are covered by frosted screens M. One opening is used for the radiation input and the other for the output. The radiation is prevented from passing directly through the attenuator by movable disk D which is the same size as the input opening. The transmissivity T of the attenuator can be changed by changing the interior coating or by varying the distance L between the disk and the input opening (Table 1).

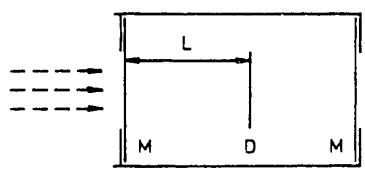

Figure 3. Arrangement of Cavity Attenuator

Table 1. Transmissivity of Cavity Attenuator With Different Inner Surface Coatings

Cylinder surface	Ends	Disk	L(mm)	T
White	white	--	--	$3.6 \cdot 10^{-2}$
White	white	white	40	$8.8 \cdot 10^{-3}$
Black	white	white	40	$4.2 \cdot 10^{-4}$

In detecting ruby laser pulses with a typical width of 10^{-8} sec, the intrinsic capacitance of the diode and of the leads in Fig. 1 cannot be ignored. These can be represented in the form of a capacitor with capacitance C connected in parallel with resistance R. The time constant RC of the resulting integrating circuit makes it practically impossible to monitor changes in the radiation flux Φ (t) during the pulse. The time dependence of the photoelectric voltage $U_f(t)$ will be different from that of the incident light pulse $\Phi(t)$. Fig. 4 shows the response $U_f(t)$ of the detector to a single radiation pulse for difference values of the ratio RC/τ. The pulse has the form

(7) $$\Phi(t) = \Phi_M \cos^2\left(\frac{\pi}{2}\frac{t-\tau}{\tau}\right)$$

where Φ_M is the maximum flux in the pulse and τ is the pulse width at the $\Phi_M/2$ level. The pulse duration is 2τ. The magnitude $U_f(2\tau)$ of the photoelectric voltage across resistance R after the end of the light pulse can be expressed in the form

(8) $$U_f(2\tau) = \frac{U_M}{2}\frac{1}{\left(\frac{\tau}{\pi RC}\right)^2 + 1}\left[1 - \exp(-2\tau/RC)\right]$$

where $U_M = S_\lambda \Phi_M R$. For small values of τ/RC, i.e. when $RC \gg \tau$, Equation 8 can be simplified as

(9) $$U_f(2\tau) = \frac{U_M}{2}\frac{2\tau}{RC} = S_\lambda \frac{\Phi_M \tau}{C}$$

The expression $\Phi_M\tau$ in the numerator of Equation 9 gives the pulse energy E. When the integration condition $RC \gg \tau$ is maintained or, as can be seen from Fig. 4, when $RC > 10\tau$, the photoelectric voltage $U_f(2\tau)$ is a measure of the pulse energy. The integration condition can be met by connecting a capacitor of sufficiently large capacitance in parallel with the load resistance. The sensitivity S_E of the resulting detector can be expressed, according to Equation 9, in the form

(10) $$S_E = \frac{S_\lambda}{C}$$

When an attenuator with transmissivity T is used, the sensitivity S_{DE} of the detector with the attenuator is increased by a factor of T over that of the detector without the attenuator S_E

(11) $$S_{DE} = TS_E$$

The laser pulse energy E measured by a detector with sensitivity S_{DE} can accordingly be determined from the measures voltage $U_f(2\tau)$

(12) $$E = \frac{U_f(2\tau)}{S_{DE}} = \frac{C}{TS_\lambda}U_f(2\tau)$$

Since we know how to determine the pulse length τ approximately, the detector may also be used for an approximate estimate of the maximum radiation flux in the pulse $\Phi_M = E/\tau$.

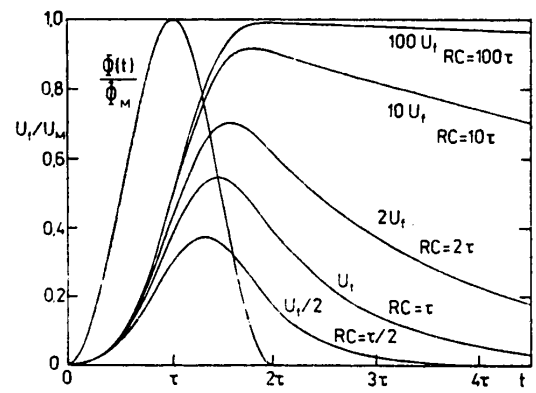

Figure 4. Deformation of Radiation Pulse by Energy Detector With Different Time Constants RC

The spectral sensitivity S_λ of the 1PP75 diode for ruby laser light with λ = 694.3 nm can be determined from the value for the HE-NE laser using the following equation:

(13) $$S_{694.3} = 1.33\, S_{632.8}$$

For typical values, i.e., $T \approx 10^{-3}$, $C \approx 10^{-8}$F and S_λ = 1.33 x 25 mA/W, the sensitivity of the energy detector is S_{DE} = 3.3 V/mJ, and for $\tau \approx 3 \cdot 10^{-8}$ sec, $S_D\Phi \approx 0.1$ V/kW. The linear response range of the energy detector is limited by the same factors as in the case of the radiation flux detector. The radiation flux in short laser pulses can now be recorded without deformation by a photodiode specially designed for the purpose [3]. These diodes differ from the types studied here in both their design and their operating principle.

4. Conclusion

We have shown by theoretical analysis and experimental measurements that the 1PP75 semiconductor photodiode can be used satisfactorily in a resistive circuit to detect either continuous or pulsed laser radiation. The simplicity of the circuit and the small bias voltage make it possible to use the detector in various measurement systems with either He-Ne or ruby lasers as the radiation source. The oscilloscope recording the photoelectric voltage may in this case replace suitable measuring devices of another kind.

BIBLIOGRAPHY

1. Pavlov, A. V. Optiko-elektronnyye pribory [Optoelectronic Devices]. ENERGIYA, Moscow, 1974 [in Russian].

2. Bem, J., et al. Czechoslovenske polovodicove soucastky [Czechoslovak Semiconductor Components], SNTL, Prague, 1973.

3. Misek J., and Kratina, L. Optolektronika [Optoelectronics], SNTL, Prague, 1979.

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