Photo-Electron Multiplier on the Basis of Multilayered Semiconductor Structure

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ABSTRACT

In the paper, a new physical principle for designing of a new optoelectronic device and its theoretical description are presented. The basic idea of the device consists in providing inside a multilayered semiconductor structure such conditions for photoelectrons that enable sequential avalanche multiplication of electrons and holes inside two depletion slabs created around p-n junctions of a reverse biased *pn-i-pn* structure [1]. The mathematical model and computer simulation results are presented for various versions and regimes of Semiconductor Photo Electron Multiplier (SPEM) for different semiconductor materials. Besides SPEM performance evaluation and comparison with those of conventional devices are presented.

1. INTRODUCTION

Photoelectron multiplier or Photo Multiplier Tube (PMT) is the most efficient device for detection and amplification of weak optical signals. In the end-on PMT design, photons impact an internal photocathode and transfer their energy to electrons, which then proceed through a chain of electron multipliers termed dynodes ending in the anode. The physics behind that design requires application of vacuum as a media for photoelectrons propagating from dynode to dynode, while rather high voltage is to be applied to the dynodes and anode to get an appreciable amplification. It is very attractive to have a solid-state photomultiplier which will enable lowing of the working voltage, widening of photon detection area, etc. The famous PMT manufacture Hamamatsu advertised several years ago a new flatted solid-state photomultiplier composed of an array of avalanche photodiodes, but they are not available yet.

In the paper, a new physical principle for designing such optoelectronic device and its theoretical description are presented. The basic idea of the device consists in providing inside a multilayered semiconductor structure such conditions for photoelectrons which enable sequential avalanche multiplications of electrons and holes at the two depletion slabs created around pn junctions of $pn-i-pn$ structure when a reverse biased voltage is applied [1-3]. The mathematical model and computer simulation results are presented for various versions and regimes of Semiconductor Photo Electron Multiplier (SPEM) made of different semiconductor materials, such as: Germanium, Gallium Arsenide and Silicon. Besides, design and performance evaluation of SPEM and comparison with those of conventional devices are presented. In Section 2, we present the model of the device, in Section 3 we describe the numerical simulations and in Section 4 we carry out numerical

Lukin, K. (2005) Photo-Electron Multiplier on the Basis of Multilayered Semiconductor Structure. In *Emerging EO Phenomenology* (pp. 3-1– 3-12). Meeting Proceedings RTO-MP-SET-094, Paper 3. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

simulations of the above regimes in order to justify the results obtained in [1, 2] within the frame of the drift-diffusion model.

2. PROBLEM POSING

Multiple amplification of photoelectrons due to impact ionization inside $p-n$ junctions occurs in reverse biased $pn-i-pn$ structure devices, which give rise to current oscillations [1, 2]. Applications of such structures for the design of high energy particle detectors, in particular SPEM, have been suggested in [1], while in [2] it is shown that this structure could be used for chaotic waveform generator design. In those papers the analysis of spatio-temporal dynamics of the currents inside the reverse biased $pn-i-pn$ structure has been carried out with the help of a simplified model, which is constructed within the framework of a phenomenological approach. The device studied is a multilayered semiconductor structure, consisting of two $p-n$ junctions, connected through an intrinsic semiconductor and brought close to, rather than exceed, the avalanche breakdown limit via reverse bias voltage. Two depletion slabs with a low conductivity arise in the neighborhood of these junctions due to the reverse bias voltage applied. The conductivity of the intrinsic region will be much larger than the one of the depletion and the distribution of the electric field strength across this structure will have two peaks around the physical $p-n$ junctions. Therefore, in the structure described above, conditions can exist such that, in the neighborhoods of the junctions there will be an **E**-field strength large enough to be close to its value for avalanche-threshold (but will not exceed it!), and at the same time it will be much lower than the field in the intrinsic region. This means that, the impact ionization will take place only inside the slabs. This impact ionization produces two clouds of charges - holes and electrons ones. The electrons generated move from left to right while holes will move in the reverse direction. The electric field inside the intrinsic region is not large enough to provide electron-hole pairs generation, then the electrons just generated will reach the second slab and being accelerated by the local **E**-field will cause another impact ionization. Now, the cloud of holes will move towards the first depletion slab without changing inside the **i**-region and will induce the next charge multiplication via impact ionization inside the first slab, and so on. Thus, current oscillations can exist in this structure due to successive transformation of the electrons (holes) pulses into the holes (electrons) ones at the narrow depletion slabs and their propagation through the intrinsic region. We introduced a simplified model for this process that enables us to reduce the initial-boundary problem for partial differential equations of drift-diffusion model presented in Refs. [1] and [2] to that of the much simpler mathematical object: a difference equation (DE) or difference–delay equation (DDE). The boundary conditions have been obtained within the frame of a phenomenological approach using charge multiplication due to impact ionization inside the depletion slabs. In general case of different mobilities the primary problem is reduced to the coupled nonlinear DE or DDE. In the case of symmetric junctions the problem under consideration is reduced to the two independent DE or DDE. The evolution of the initial current pulse (produced by a photons) is studied for different combinations of the device parameters. It is shown in [1] that it is possible to obtain an oscillatory-like response of the considered structure after the passage of a high energy particle, when the reverse bias voltage does not exceed the avalanche break down threshold. This regime provides an internal amplification of the initial photocurrent pulse and is similar to the amplification in PMT. In order to have a complete, self consistent, description of the structure under consideration and obtain a reliable evaluation of its performance, we need to make numerical simulations of a more realistic model.

The semiconductor $pn-i-pn$ structure (Fig.1) under consideration is compound of five layers which form two $p-n$ junctions. The external p_1 and n_2 layers have a higher impurity doping while the middle n_1 and p_2 regions are rather weakly doped. The profile of the doping inside the junctions corresponds to the so-called

abrupt $p-n$ junction with a step-like approximation for the distribution of impurities. This approximation describes adequately the alloyed, fine diffusion and ion-implanted $p-n$ junctions [3].

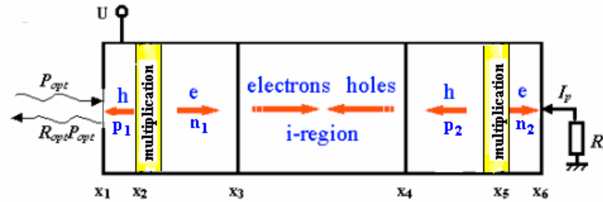


Fig.1. Schematic of Semiconductor Photo Electron Multiplier
on the basis of avalanche $pn-i-pn$ structure

Under the reverse bias voltage applied across the $pn-i-pn$ structure ("-" refers to the p_1-region while "+" to the n_2-region) the p_1-n_1 and p_2-n_2 junctions are connected in the opposite direction. Two depletion slabs with low conductivity arise in the neighborhoods of the $p-n$ junctions due to the reverse bias voltage applied. The strength of this field does not exceed its threshold value at which the avalanche breakdown starts, but it is sufficiently large for the existence of impact ionization inside the depletion layers of the $p-n$ junctions.. The photon flow of power P_{opt} falls onto the $p_1$region of the semiconductor and part of the radiation is reflected $R_{opt}P_{opt}$, where R_{opt} is the reflection coefficient. The absorbed photons generate electron-hole pairs inside the semiconductor, forming the initial pulse of electrons that is injected into the multiplication area of the p_1-n_1-junction, where the impact ionization produces multiplication of the electrons. After that, the amplified electron current pulse flows out of the p_1-n_1-junction and moves through the **i**-region towards the p_2-n_2 junction. The constant electric field of the **i**-region forces this pulse to move with a drift velocity. In the multiplication layer of this junction the charge carriers are multiplied again due to impact ionization. Now, the pulse of holes current flows out of the p_2-n_2 junction and moves through the **i**-region towards the p_1-n_1 junction with a constant velocity. Flying into the multiplication layer of this junction, the holes current induces impact ionization and, as a result, the number of charge carriers increases again. Thus, the number of pulses, and their amplitudes grow with time. This process can be stopped canceling the reverse biasing of the structure at an appropriate time. In this way, high amplification coefficients in SPEM are due to sequental multiplcations of photocurrent pulse taking place inside pn junctions because of positive feedback described above. In this sense SPEM may be treated as a semiconductor analogue to PMT.

3. AMPLIFICATION COEFFICIENT

In order to calculate the amplification coefficient of this kind of systems, we use a model which is quite adequate describes to study the process of impact ionization: a one dimensional drift-diffusion model (DDM), which describes both the static as well as the dynamic behavior of the charge carriers inside the semiconductor structure under the effect of both external and intrinsic fields. At impact ionization in a $p-n$ junction, we can neglect the diffusion current since it is much less than the drift current. Under these approximations the equations, in dimensionless form, can be written as [1, 2, 4]:

$$\frac{\partial E(x,t)}{\partial x} = -N(x) - p + n;\ \ \frac{\partial \varphi(x,t)}{\partial x} = E(x,t); \tag{1}$$

$$\frac{\partial n}{\partial t} = -\frac{\partial J_n}{\partial x} + \alpha_n J_n + \alpha_p J_p - R(n,p); \tag{2}$$

$$\frac{\partial p}{\partial t} = \frac{\partial J_p}{\partial x} + \alpha_n J_n + \alpha_p J_p - R(n,p); \tag{3}$$

$$J_n = v_n n,\ \ J_p = v_p p,\ \ J_d = \frac{\partial E}{\partial t}; \tag{4}$$

$$J = J_n + J_p + J_d; \tag{5}$$

$$R(n,p) = (np-1)/[\tau_{p0}((n+n_1) + \tau_{n0}(p+p_1)]. \tag{6}$$

Here E is the intensity of an electric field; φ is the electric potential; J , n , p, J_n , J_p and J_d are the densities of the complete current, electrons in the conduction band, holes in the valence band, electron current, hole current and displacement current respectively; $v = v_n + v_p$; v_n, *and* v_p are the saturation velocities of electrons and holes; $N(x) = \begin{cases} -N_{a1},\ -L_{p1} < x < x_2;\ N_{d1},\ x_2 < x < L_{n1}; \\ -N_{a2},\ L_{p2} < x < x_5;\ N_{d2},\ x_5 < x < L_{n2} \end{cases}$ is the density of impurities; N_a and N_d are the concentrations of ionized acceptors and donors respectively; $J_{st} = J_{ph} + J_{ns} + J_{ps}$ is the initial current density in the multiplication layer of the $p_1 - n_1$ junction; J_{ph} is the photocurrent generated by photons; J_{ns} (J_{ps}) is the saturation electron (hole) current density; α_n, α_p are the impact ionization coefficients of electrons and holes; $R(n,p)$ is the speed of recombination of electrons and holes when the Shockley-Read-Hall impact mechanism is taken into account; τ_{n0} (τ_{p0}) is the electron (hole) lifetime in a *n(p)*-type semiconductor; p_1 is the density of holes in valence band, if a Fermi level coincides with an energy level of the recombination centers; n_1 is the density of electrons in conduction band, if a Fermi level coincides with a energy level of the recombination centers; L_{pi}, L_{ni} are the widths of the depleted regions of the $p_i - n_i$ junction ($i = 1,2$); t is the time; x is the coordinate.

Under the transformations $\bar{E} = E/E_0$; $\bar{\varphi} = \varphi/\varphi_0$; $\bar{J} = J/J_0$; $\bar{n} = n/n_i$; $\bar{p} = p/n_i$; $\bar{N} = N/n_i$; $\bar{t} = t/t_0$; $\bar{x} = x/L_0$, where $E_0 = \varphi_0/L_0, V/m$; $L_0 = \sqrt{\varepsilon\varepsilon_0\varphi_0/qn_i}, m$; $J_0 = \frac{qn_i D_0}{L_0}, A/m^2$; $D_0 = 1, m^2/s$; $t_0 = L_0^2/D_0, s$, the dimensionless form of the DDM equations (1) – (6) can be found. Here n_i is the equilibrium electron concentration in the semiconductor, T is the temperature; q is the electron charge; $\varepsilon\varepsilon_0$ is the static dielectric constant of the semiconductor; ε_0 is the static dielectric constant of vacuum and k is Boltzmann constant.

Equations (1) – (6) are to be supplied appropriately by the following initial and boundary conditions, as well as the continuity conditions for electric field and potential at the interface between p an n and i areas:

$$J_{pi}(L_{n1},0)=J_{ps}\,;\; J_{ni}(L_{p2},0)=J_{ns}, \tag{7}$$

$$\left.\begin{aligned} J_p(-L_{p1},t)=J(t)-J_{n0}(-L_{p1},t);\;\; J_n(L_{n1,}t)=J(t)-J_{pi}(L_{n1},t);\\ J_p(L_{p2},t)=J(t)-J_{ni}(L_{p2},t);\;\; J_n(L_{n2},t)=J(t)-J_{ps}(L_{n2},t);\end{aligned}\right\} \tag{8}$$

$$\left.\begin{aligned} E(-L_{p1},t)=0;\;\; E(L_{n1},t)=E_i(L_{n1,}t);\\ E(L_{p2},t)=E_i(L_{p2},t);\;\; E(L_{n2},t)=0;\end{aligned}\right\} \tag{9}$$

$$\left.\begin{aligned} \varphi(-L_{p1},t)=V;\;\; \varphi(L_{n1},t)=V_i+V_2;\\ \varphi(L_{p2},t)=V_2;\;\; \varphi(L_{n2},t)=0;\qquad\quad\end{aligned}\right\} \tag{10}$$

$$\left.\begin{aligned} E(x_{2,5}-0,t)=E(x_{2,5}+0,t);\\ \varphi(x_{2,5}-0,t)=\varphi(x_{2,5}+0,t);\end{aligned}\right\} \tag{11}$$

Here $J_{pi}\left(x,t\right)$ and $J_{ni}\left(x,t\right)$ are the electron and hole of current densities in p_i-n_i junction ($i=1,2$).

Equations DDM (1) – (6), along with intitial conditions (8), boundary conditions (9) and (10) and continuity conditions (11) have been solved with the help of specific finite difference methods [5].

SPEM amplification coefficient is determined by expression [1, 4]

$$M=\prod_{j=1}^{K} M_{1j}M_{2j}\,; \tag{7}$$

$$M_{1j}=\left\{1-\int_{-L_{p1j}}^{L_{n1j}}\alpha_p\left(E_j\right)\exp[-\int_{-L_{p1j}}^{x}\left[\alpha_n\left(E_j\right)-\alpha_p\left(E_j\right)\right]dx']\right\}^{-1}; \tag{8}$$

$$M_{2j}=\left\{1-\int_{L_{p2j}}^{L_{n2j}}\alpha_n\left(E_j\right)\exp[-\int_{x}^{L_{p2j}}\left[\alpha_p\left(E_j\right)-\alpha_n\left(E_j\right)\right]dx']\right\}^{-1}, \tag{9}$$

where M_{1j}, M_{2j} are the multiplication coefficients inside p_1-n_1 and p_2-n_2 junctions respectively at the j-th trip of electrons and holes through the **i**-region; $j=1,2,3,...,K$; K is the number of return trips of electrons and holes pulses through the **i**-region of the structure. This number may be calculated from the formula

$$K=t/T$$

where $T = t_{j1} + t_{j2} + t_{d_i}$; t_{j1}, t_{j2} is the drift time of electrons and holes inside $p-n$ junctions; $t_{d_i} = d_i(v_{ni} + v_{pi}) / v_{ni}v_{pi}$ is the transit time of electrons and holes through **i**-region; $v_{ni} = \mu_n E_i$ and $v_{pi} = \mu_p E_i$ are the drift velocity of electrons and holes in **i**-region, respectively, μ_n, *and* μ_p is the mobility of electrons and holes respectively; d_i is the thickness of **i**-region.

The results of computer evaluation of the SPEM amplification coefficient of the avalanche Si *pn-i-pn* structure are presented in Fig. 2.

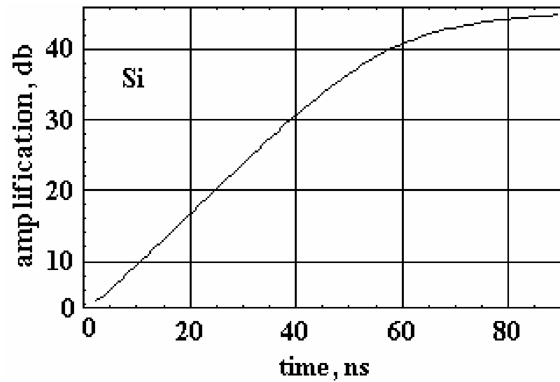
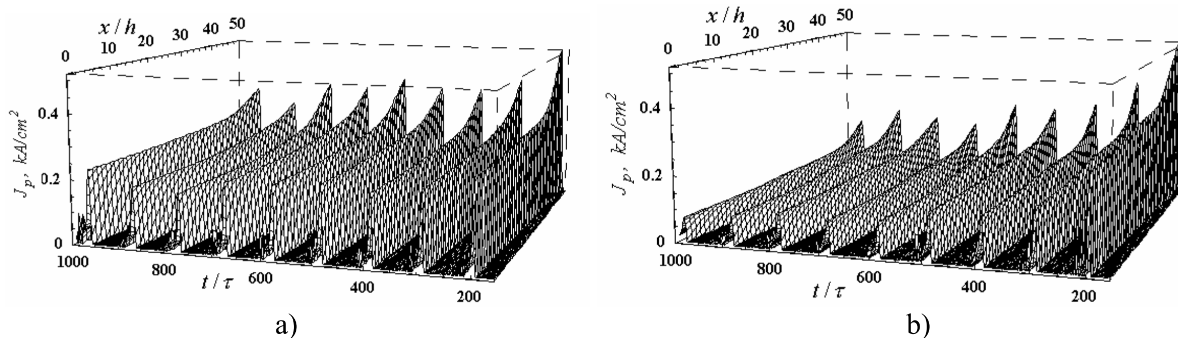


Fig.2. Dependence of the amplification coefficient inside SPEM as function of amplifying time.

It is seen that the amplification coefficient in Si SPEM exceeds *40 dB*, that considerably exceeds coefficient of internal amplification of APD [3]. In the avalanche *pn-i-pn* structure at the absence of an external signal the electron-hole of pairs generation may be initiated by thermal current. It results in instability of equilibrium state of the structure which make it impossible implementation of a stand-by regime. That is why the holes traps are to be implanted into the i-region of the *pn-i-pn* structure for providing its stability.

Fig.3 shows the drift and recombination of holes inside the i-region of the *pn-i-pn* structure having hole's traps. In Fig.3, the holes drift along the negative direction of the axis *x*.



a) b)

Fig.3. Drift and recombination of holes inside i-region of GaAs SPEM:
a) hole's lifetime: 0.21 ns; b) hole's lifetime: 0.20 ns
$\tau = 0.15$ ns; $h = 2.77$ ηm

Fig 3a shows that with the decrease in the hole's lifetime n the traps the capture of holes on traps is multiplied. If the lifetime equals 0.20 ns, the holes recombination current exceeds the avalanche current generated in depleted areas of the p-n junctions (Fig. 3b) and therefore the output signal fades with time.

In Fig.4 the thresholds values of the current density as functions of hole's lifetime are shown. Fig 4 shows that the threshold current value grows with reduction of the hole's lifetime. Hence, for providing the SPEM stand-by regime stability the threshold current density should exceed the saturation current density.

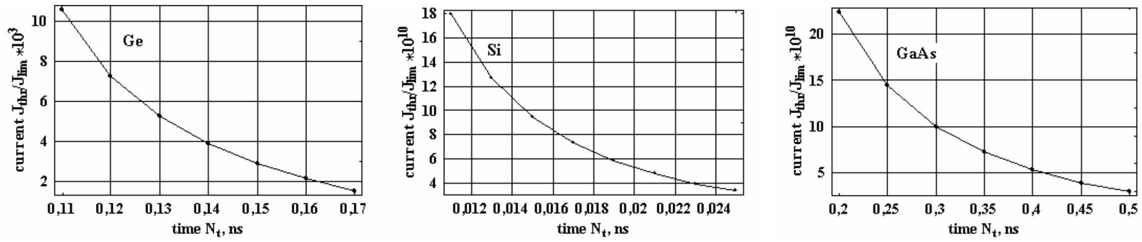
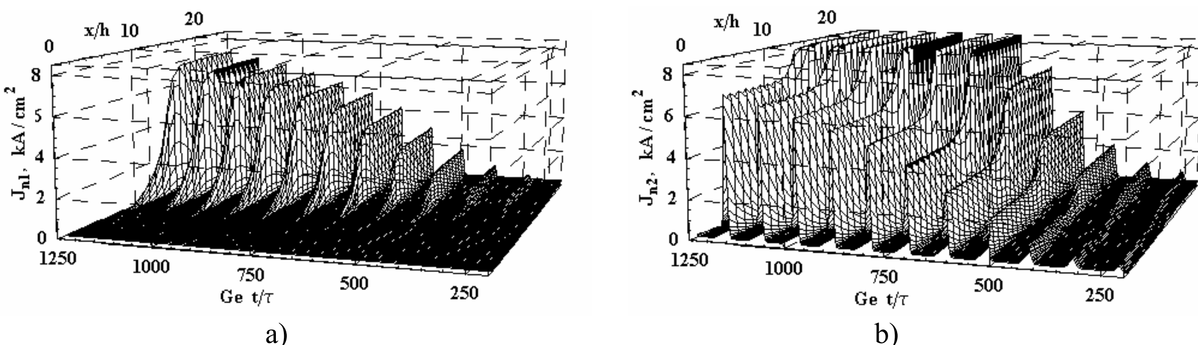


Fig.4. Dependences of the current threshold J_{thr} on the lifetime of non equilibrium carriers for $pn-i-pn$ structures made of Ge, Si and GaAs

The SPEM speed is defined by the avalanche development time $\tau_{av} = \delta M$, the drift time of carriers through the depleted areas of the structure $t_{tr} = t_{j1} + t_{j2}$, drift time of electrons and holes of $\mathrm{i}-$region of structure t_{d_i} and number of impact ionization *K*, where δ is the thickness of a layer of multiplication. For a case, when $t_{d_i} >> \tau_{tr} + \tau_{av}$, the fast-action is defined by expression

$$\tau = K * \int_0^{d_i} (1/v_{ni}(x) + 1/v_{pi}(x))dx \,. \tag{10}$$

Fig.5 shows spatio-temporal behavior of electron current inside different p-n junctions. It is seen that at the input of the $\mathrm{p}_1 - \mathrm{n}_1$ junction (Fig.5a, x/h=0) the electron current equals zero, because in this junction the electron-hole pairs generation is initiated by holes (except for a primary photocurrent).



a) b)

Fig.5. Amplification of the electron current inside different p-n junctions:
(a) - $\mathrm{p}_1 - \mathrm{n}_1$ junction and (b) - $\mathrm{p}_2 - \mathrm{n}_2$ junction;
Semiconductor type – Ge; $\tau = 2,7*10^{-13}$ ns; $h = 2,7*10^{-8}$ m

At the input of the $p_2 - n_2$ junction the electrons are coming from i-region and initiate avalanche multiplication (Fig. 5b). The SPEM speed is determined by the time of avalanche development and the time of the carrier's drift through the p-n junctions and i – region. Hence, in order to increase the SPEM speed it is necessary to enlarge the multiplication coefficients of both junctions, increase the drift velocity of charge carriers in i – region up to the saturation velocity and reduce the i-regions width.

4. NOISE FACTOR AND SIGNAL-TO-NOISE RATIO

The basic sources of noise in SPEM are current fluctuations caused by those of the multiplication coefficient. Thermal fluctuations in $pn - i - pn$ structure and other SPEM elements are by several orders weaker of current fluctuations. That is why their contribution is negligible. The extra noise is characterized by a noise factor $F(M) = \langle M^2 \rangle / M^2$ [3]. When into the multiplication layer of $p_2 - n_2$ junction are injected only electrons, the noise factor is defined by the expression [3]:

$$F(M) = k_{eff} M + (2 - 1/M)(1 - k_{eff}), \qquad (11)$$

where $k_{eff} = \int_0^w \alpha_p(x) M^2(x) dx / \int_0^w \alpha_n(x) M^2(x) dx$; w is the width of depleted region of $p - n$ junction.

Noise factor as function of multiplication coefficient is presented in Fig.6. It is seen that the noise factor grows with increasing of the ratios α_n / α_p or α_p / α_n . It is related to that at equality of coefficients of impact ionization a positive feed-back appears in the depleted region of *p-n* junction.

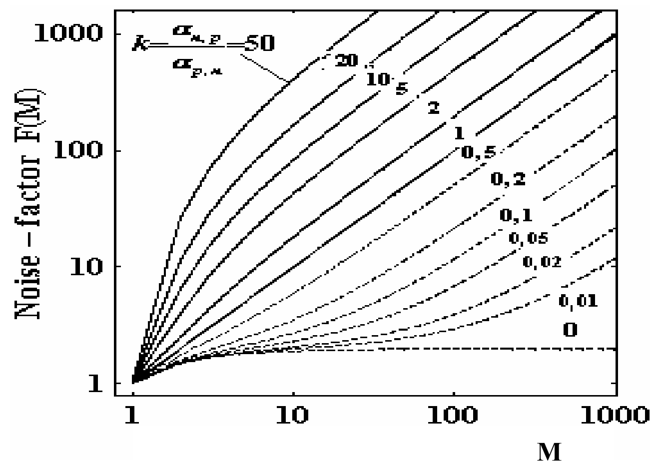


Fig.6. Dependence of the noise factor on multiplication coefficient for various ratios $k = \alpha_{n,p} / \alpha_{p,n}$.

The root-mean-square value of the photocurrent after its avalanche amplification in SPEM is described as follows:

$$i_p = q\eta P_{opt} M / \sqrt{2} h\nu, \qquad (12)$$

where q is charge of electron; η is the quantum efficiency; $P_{opt}/\sqrt{2}$ is root-mean-square power of modulated optical signal; M is the SPEM amplification coefficient; $h\nu = 1.237q/\lambda(\mu m)$ is the photon energy. For the SPEM, the quantum efficiency is defined similarly to that of usual avalanche photo diodes (APD) [3] and equals to the ratio of number of photo-generated electron-hole pairs to the number falling photons:

$$\eta = (I_p / q)/(P_{opt} / h\nu), \tag{13}$$

where I_p is the photocurrent caused by absorption of optical radiation of power P_{opt}; λ is the wavelength related to photon having energy $h\nu$.

The root-mean-square value of the shot noise after amplification is equal

$$\left\langle i_s^2 \right\rangle = 2q(I_p + I_B + I_D)\left\langle M^2 \right\rangle B, \tag{14}$$

where I_P is the average photocurrent generated by the falling optical signal; I_B is the current caused by background radiation; I_D is dark current due to thermal generation electron-hole pairs in depleted area; $\left\langle M^2 \right\rangle$ is the root-mean-square value of the SPEM multiplication coefficient; B is the SPEM working frequency band. The thermal noise for an equivalent resistance R_{eq} is defined as follows [3]:

$$\left\langle i_T^2 \right\rangle = 4kT(1/R_{eq})B \tag{15}$$

The signal-to-noise ratio we may find from Eqs. (12)- (14) [3]:

$$S/N = \frac{i_p^2 R_{eq}}{(\left\langle i_s^2 \right\rangle + \left\langle i_T^2 \right\rangle)R_{eq}} = \frac{1/2(q\eta P_{opt}/h\nu)^2}{2q(I_P + I_B + I_D)F(M)B + 4kTB/M^2 R_{eq}} \tag{16}$$

The minimal optical power P_{opt}, required for providing the given signal-to-noise ratio S/N in SPEM is determined by the expression

$$(P_{opt})_{min} = \frac{2h\nu}{\eta}\frac{S}{N}F(M)B\left\{1 + [1 + \frac{I_{eq}}{qBF(M)^2(S/N)}]\right\}^{1/2}, \tag{17}$$

where $I_{eq} \equiv (I_B + I_D)F(M) + 2kT/qR_{eq}M^2$.

One of the most important parameter characterizing quality of photoelectron multipliers is the Noise Equivalent Power (NEP). It is determined as root-mean-square power of illuminating radiation required for achieving the *unit* signal-to-noise ratio in the photomultiplier within the 1Hz frequency band. Following this definition and using Eq.**(17)** we obtaine the following expression for NEP [3]:

$$NEP = 2(h\nu/\eta)F(M)[1 + (1 + I_{eq}/qF(M)^2)^{1/2}], \text{ W Hz}^{1/2}. \tag{18}$$

It is seen from Eq. (18), that for increase in SPEM sensitivity it is necessary to increase the values of M, η and R_{eq}, while those of $F(M)$, I_B and I_D are to be reduced [3]. Fig.7 shows the dependence NEP for SPEM with taking into saturations due to thermal noise, background and dark currents for limit value of $I_{eq} / qBF(M)^2 (S/N) >> 1$.

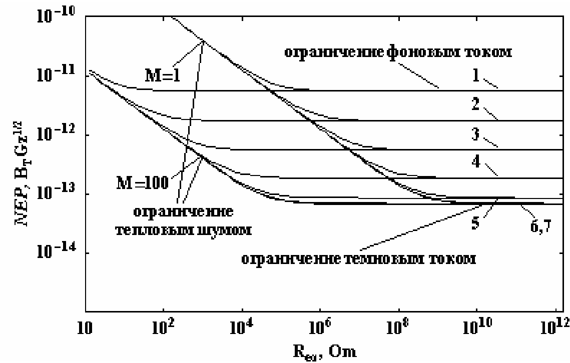


Fig.7. NEP dependencies on the load resistance for various amplification coefficients M ($F(M) = 6$), background current I_B (curve 1- $I_B = 10^{-6}$; 2- $I_B = 10^{-7}$; 3 - $I_B = 10^{-8}$; 4- $I_B = 10^{-9}$; 5- $I_B = 10^{-10}$; 6- $I_B = 10^{-11}$; 7- $I_B = 10^{-12}$ A) and constant dark current $I_D = 1.5 \cdot 10^{-10}$ A.

It is seen from Fig.7, that with having no internal amplification ($M = 1$) and at the presence of the background radiation, thermal noise and dark current the unit signal-to-noise ratio can be achieved only for high enough load resistance values: $R_{eq} \geq 10^8 \Omega$ [3], while having an appreciable internal amplification ($M = 100$) this regime is reachable for the essential smaller values of load resistance: $R_{eq} \approx 10^4 \Omega$. In the Table1, the typical values of amplification coefficient, working voltage and the detector's speed are presented for the SPEM under consideration and some known Avalanche photodetectors and Photoelectrom Multipler Tube from Hamamatsu company [3, 5].

Table 1.

Parameter / Device	Amplification coefficient	Device speed, ns	Working voltage, V
APD	$80 \div 150$	$1 \div 6$	$225 \div 390$
APD LNF [3]	$10^2 \div 10^4$	-	$50 \div 70$
SPEM (LNDES IRE NASU)	$10^2 \div 10^5$	$1 \div 100$	$11 \div 100$
PMT, Hamamatsu [5]	$10^3 \div 10^7$	$1 \div 15$	$400 \div 1500$

5. CONCLUSIONS

In conclusion, we have shown that the SPEM amplification coefficient achieves *40 dB* that exceeds substantially the amplification coefficient of traditional APDs. The SPEM speed is of order of nanoseconds and is comparable with the speed of the vacuum photoelectron multipliers. Noise Equivalent Power (NEP) of

the SPEM is less than that of APD for realistic ratios of multiplication coefficients of electrons and holes. High amplification coefficient is achieved in the SPEM suggested due to the sequential multiplications of electronic-holes pair inside the depleted areas of the *p-n* junctions. The SPEM suggested is an energy-saving device with high reliability rate because it requires rather low working voltage which decrease drastically the probability of micro-plasmas generation. Suggested Semiconductor Photo Electron Multiplier on the basis of avalanche *pn-i-pn* structure with a positive feed-back via drift currents between *p-n* junctions may be considered as a perspective device for many optoelectronic applications.

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