# Modeling of a Semiconductor Matrix of Photosensitive Threshold Elements

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In different problems of science and particularly in ALICE experiment measurement of relative displacement is required with precision up to $1\mu$.

Difficulties in this kind of measurements often are connected with simultaneous changes of parameters of the medium in space-time where the measurements are being done. For example the change of state of air in the room that changes, for instance, trajectory and shape of light beam. If there is not sufficient information about that change of medium's state there will be more unknown parameters in the problem.

Here we can act according to classic scheme, i.e. consider a stochastic medium and obtain quasiindetermined results.

However, in [1] a multimode method was purposed for measurements. According to this method, if dispersion effect is sufficient for given aim, $n$-mode measurements allow to find $(n-1)$ additional unknown parameters, which contain information about medium state. In case of small changes of deflection index due to changes in medium state, the effectivity of method [1] depends on sensitivity and resolving capabilities of the detector.

This work is dedicated to the study of a method for information reception, allowing measurement of displacements with precision of a few microns.

**1. Description of the detector.**

Consider $n \times n$ matrix of threshold elements placed with period $d = d_e + d_i$, where $d_e$ - is elements length, and $d_i$ - interelement distance.

Let us consider a light beam with S cross-section area falling on the matrix, and light intensity outside of the surface $S$ is lower than threshold level (which is a characteristic of the element and considered as given).

The mentioned beam covers $\left[\frac{S}{d^2}\right]$ elements: we will call them illuminated. Illuminated and non-illuminated elements in matrix are in different states (for instance in states of high and low electro conductivity correspondingly). So they can be identified by their state. As the elements with their numbers in matrix are described with coordinates with precision $d$ they define points where photons more than threshold level fall.

As a result we can define beam's cross-section profile, change of the profile while distributing in the medium, and also beam's center of "gravity":

$$\vec{r}_c = \frac{\sum\limits_{\alpha,\beta}' I_{\alpha\beta}\vec{r}_{\alpha\beta}}{\sum I_{\alpha\beta}} \tag{1}$$

where $I_{\alpha\beta}$ is intensity (number of photons in a time unit) in the point with coordinate $\vec{r}_{\alpha\beta}$, and " ' " means that only the illuminated points are summed. If the element has one threshold level then $I_{\alpha\beta} = const$ and (1) is maximally simplified and describes "kinematic" center of "gravity" of the beam.

If we identify $\bar{r}_c$ point with the point where geometrical beam falls, we can trace the deflection of the beam. In other words we substitude light beam with some effective beam, which is geometrical place of centers of "gravity" of the beam (i.e. trajectory of center of "gravity").

There is a methodological mistake connected with the number of illuminated elements near the boarder of the beam profile. As an estimation of this mistake we can say that it is even smaller than $d/l$ relation, where $l$ - is diameter of the beam.

If we assume existance of an element with $N$ threshold levels (it will be established in next paragraph) we can realize reciption of $N$ profiles of beams enclosed in each other (pic.1).

Usually centers of "gravity" $0_k$ $(k = 1, \ldots, N)$ are concentrated is a small area, and secondary center of "gravity" may be found from equation (1).

Concluding, we can stress that measurments with a precision not less than $2d$ may be done, only if we assume the existance of the elements and measurment scheme is realizable.

### 2. Study and modeling of the reciption element.

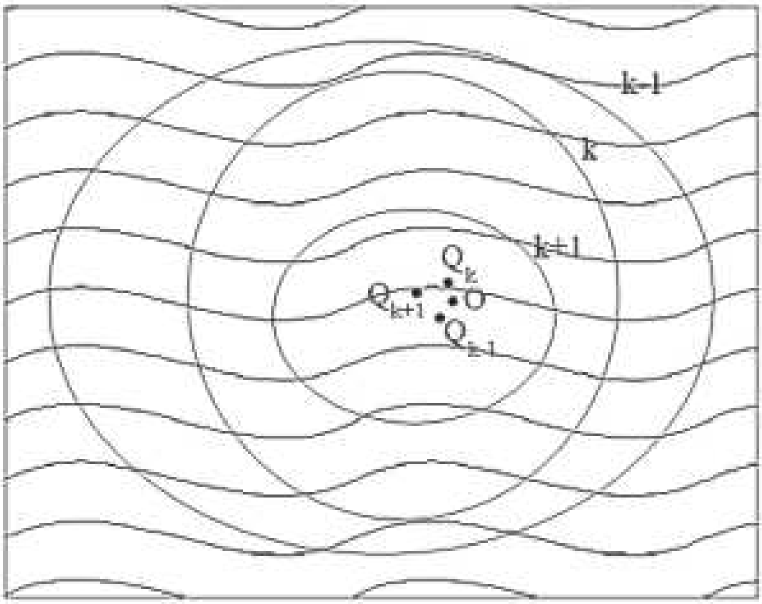
Contemporary technologies allow creation of photodiod and phototransistor matrixes with density of elements on the surface up to $10^6 elements/cm^2$ and with individual input output connections.

Unfortunately these elements are not threshold and not multistable, thus unusable for our purposes.

We offer to use multilayer semiconductor structures made with vertical bipolar integral technology [1, 2].

Considering [2, 3] we can bring multistubility problem to bistable one with new and effective parameters. Let us considere now a model of 4-layer polistoral structure (pic.2).

For simplicity we will negelect the effects due to multidimensionality of the problem and will consider onedimensional problem. As in [4] we can represent the volt




Pic. 1.

amper characterestic (VAC) of the structure in parametric form following way:

$$\begin{cases} i_1(e^{V_1}-1)+i_1\delta e^{\frac{V_1}{2}}+i_1p_2(1-e^{-V_2}) \ = \ j-j_y \\ i_1p_2(e^{V_1}-1)+i_3\beta_3(e^{V_3}-1)+i_2(1-e^{-V_2})+\sigma V_2 \ = \ j+\alpha j \\ i_1(e^{V_1}-1)+i_3\beta_3(1-e^{-V_2}) \ = \ j \end{cases} \tag{2}$$

Here $\beta_k$ is probability of transportation of not basic carriers through quasineutral base $k$, $\delta$ - index of recombination in emiter, $I$ - el. current density in collector $k$, $V_k$ - voltage (in $KT/e$ units) on junction $k$, $i_k$ - saturation current density for junction $k$, $j$ - current density in external circuit (as a parameter), and $j_c$ controling current is defined by [5]:

$$j_y = \frac{eg_0L_2}{sh\eta_2}(1-ch\eta_2) \tag{3}$$

External current is given by:

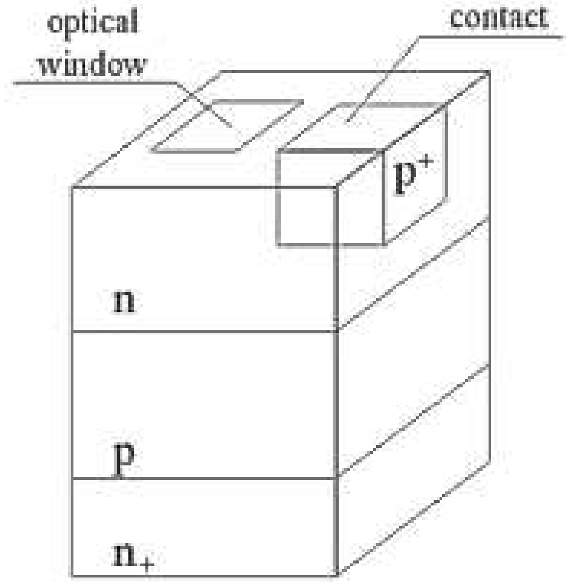
$$\mathcal{E} = \sum_k V_k(j,\ j_y) + R\cdot j \tag{4}$$

where $R$ is resistance of external circuit.

Further, choosing structure's parameters (impurity consentration, dimensions of bases, etc) we can vary indexes $\delta$, $\beta_k$, $i_k$ and satisfy some conditions.

If there is a source of internal feedback just in one junction (i.e. $\delta$), then if

$$\begin{cases} \beta_2+\beta_3>1 \\ \beta_{2k}+\beta_{2k+1}<1<\beta_{2k}+\triangle\beta_{2k+1}+\triangle\beta_{2k} \end{cases} \tag{5}$$




Pic. 2.

owing to plazma-field iteraction effect (PFIE) in structure, it will have as many different stable states as many emitter junctions it has [4]. On the other hand on the base of properties of PFIE, the problem (2)-(5) for each state may be brought to one collector problem [3, 4].

## References

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