

SCHOTTKY-BARRIER TUNNEL DIODE AS A POINT FAST DETECTOR  
OF FIR LASER RADIATION

S.D.Ganichev,<sup>+</sup> K.Yu.Glooch,<sup>+</sup> I.N.Kotel'nikov,<sup>\*</sup> N.A.Mordovets,<sup>\*</sup>  
A.Ya.Shul'man,<sup>\*</sup> and I.D.Yaroshetski<sup>+</sup>

<sup>\*</sup>Institute of Radioengineering and Electronics, USSR Acad.of the Sci.,  
Moscow,GSP-3,103907

<sup>+</sup>A.F.Ioffe Physicotechnical Institute, USSR Acad.of the Sci.  
Leningrad,194021

USSR

The point fast uncooled detector for FIR laser radiation is proposed. Its operation is based on the new physical effect which consists in tunneling stimulation during plasma reflection of the laser light in the Schottky-barrier tunnel junction.

### 1. GENERAL CONSIDERATIONS.

The optical pumped pulsed submillimeter gas lasers are widely applied at present [1]. One of the problems arising in developments and applications of such lasers is the investigations of the space-time structure of the laser beam with its cross-section and time duration being of order a few millimeters and nanoseconds, respectively. It requires the single or matrix fast photodetectors of submillimeter radiation with the high space resolution. There are difficulties in application of the known fast photodetectors based on the hot-carrier  $\mu$ -photoconductivity [2], the photon-drag effects [3,4] and pyroelectricity for measurements of the space distribution of the pulse radiation intensity in the narrow laser beams because of the large sizes of resulting pixels (typical diameters are a few millimeters or more).

It will be now described the point fast photodetector of the submillimeter laser radiation. The operation of this detector is based on the change in the resistance of the Schottky-barrier metal-semiconductor tunnel junction during the plasma reflection of the laser radiation at free carriers in the semiconductor [5-7].

The point is that the Schottky potential barrier at a metal-semiconductor tunnel junction results from the self-consistent distribution of electrons in the semiconductor in the electric field of ionized impurities and the charge in surface states at the semiconductor-metal interface. The tunnel current in such a system can be largely affected by the space redistribution of free charge carriers in the depletion layer due to a change in the potential barrier shape.

[8,9]. When an electromagnetic wave is incident onto the tunnel junction at wavelengths in the plasma reflection region of the semiconductor, an additional ponderomotive force arises and acts on the electron subsystem of the semiconductor as a result of the reflection of the radiation. Thus the Schottky self-consistent potential barrier is distorted, and the junction resistance is changed (see Fig.1).

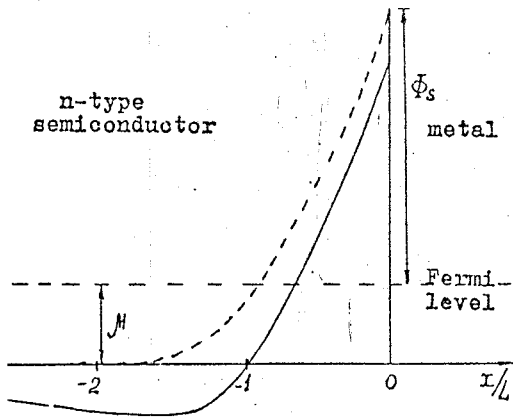


Fig.1. Draft of the scalar potential in the Schottky depletion layer with (solid) and without (dashed) radiation

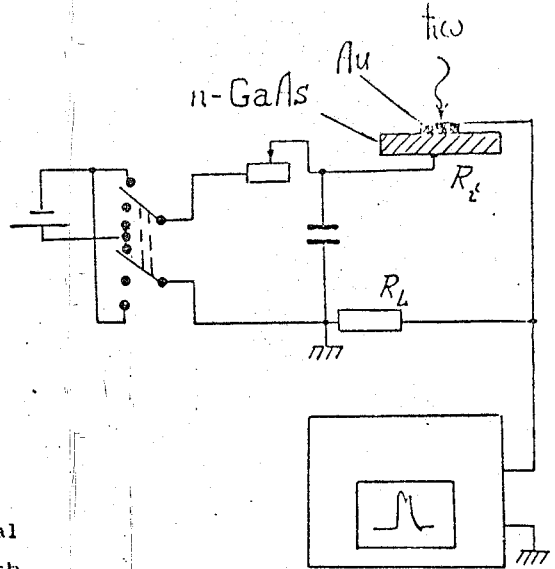


Fig. 2

In considered case the physical limitations on the response rise time result from the speed of the non-equilibrium charge redistribution among the metal electrode and the semiconductor depletion layer and are determined by the parameter  $RC$ , where  $R$  is the resistance and  $C$  is the capacity of the junction. For  $n\text{-GaAs/Au}$  junction the response time can be attained of order  $10^{-9} + 10^{-11}$  s with the junction diameter and doping reasonable elected. Such an operating speed, the sizeable magnitude of the response [6,7], and also the possibilities of the modern technology in making the junctions with small diameter (up to a few microns) and a matrix of the junctions call forth our interest in the analysis of the Schottky-barrier tunnel junction as photodetector in the submillimeter range.

## 2. SAMPLES, EXPERIMENTAL TECHNIQUES AND RESULTS

The detectors we were investigated were made of the  $n\text{-GaAs/Au}$  tunnel junctions obtained under ultra-high vacuum conditions by evaporating the metal onto the cleaned surface of  $n\text{-type GaAs}$  wafers (free carrier

densities  $(2-7) \cdot 10^{18} \text{ cm}^{-3}$  the plasma reflection minimum wavelengths  $\lambda_p = 20-11 \text{ } \mu\text{m}$ ). The thickness of the semitransparent gold electrodes was about  $200 \text{ } \text{Å}$ , and their diameter was  $1 \text{ mm}$  (Fig.2). The used radiation source was the submillimeter  $\text{NH}_3$  or  $\text{D}_2\text{O}$ -laser optically pumped by TEA  $\text{CO}_2$ -laser providing lines at the wavelengths  $\lambda = 90.55$  or  $385 \text{ } \mu\text{m}$  with the pulse duration time  $\approx 40 \text{ ns}$  [10].

The investigation of detector performance was carried out in the usual photoconductivity arrangement (Fig.2). The observed response times of the detectors were restricted by amplifier bandwidth and were less than  $5 \text{ ns}$ . Under the plasma reflection conditions  $\lambda \gg \lambda_p$  the fast response of the photoresistive type is found that reproduces the shape of the submillimeter laser pulse. The detector responsivity is roughly independent on the radiation wavelength and is about  $10^{-1} \text{ V/kW}$  with bias voltage being order of  $\leq 5 \text{ V}$  and load resistance  $R_L = 50 \text{ } \Omega$ .

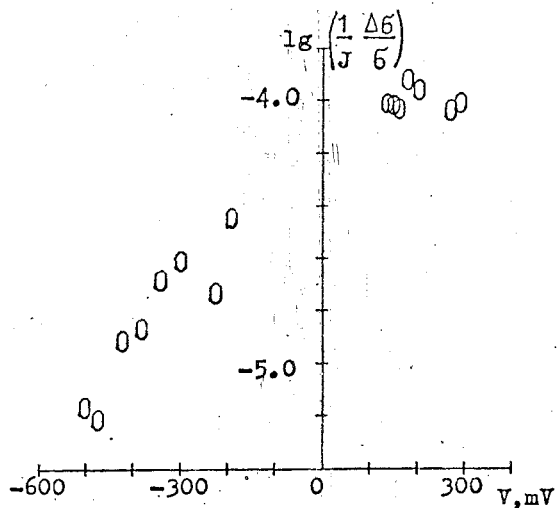


Fig. 3

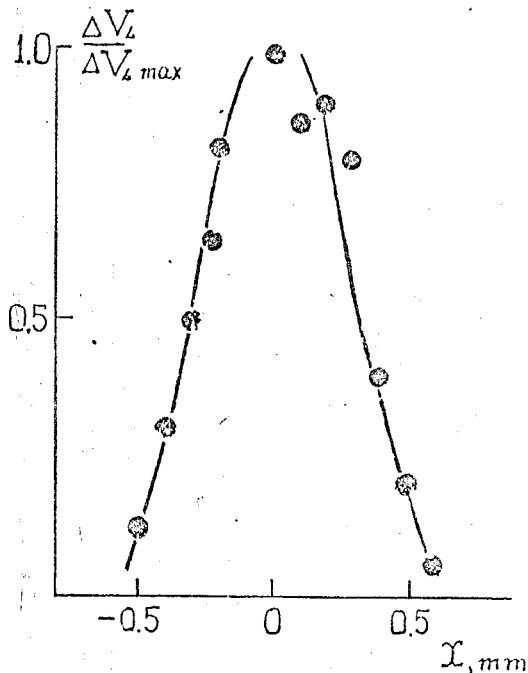


Fig. 4

The sign of the photoresistive response corresponds to a decrease in the tunnel junction resistance, i.e. the stimulation of the tunnel current takes place. In Fig.3 the relative change in the junction conductance  $\Delta\sigma/\sigma$  reduced to the radiation intensity  $J$  in  $\text{kW/cm}^2$  is shown as a function of the bias voltage. In Fig.3 the positive bias voltage corresponds the electron tunneling from  $\text{GaAs}$  to  $\text{Au}$  and the radiation intensity is  $J \approx 30 \text{ kW/cm}^2$ .

The dependence of the response on the radiation intensity  $J$  was studied in the region from 10 to  $2 \cdot 10^3$  kW/cm<sup>2</sup>, and the weak nonlinearity like  $J^{1,5}$  was observed.

To investigate the coordinate sensitivity of the detector, the scan of the focused laser beam was carried out across the gold electrode. The diameter of the focal spot was about 0.7 mm. The result is shown in Fig.4. It is seen that the response drops quickly as the irradiated domain leaves the range of the gold electrode. This measurements are too rough, to provide the limit space resolution when the detector will be scanned across the laser beam. However, the obtained results are already interesting from the practical point of view.

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