## NEAR FIELD ENHANCEMENT OF PHOTORESISTIVE EFFECT IN n-GaAs TUNNEL SCHOTTKY JUNCTIONS

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The conductance of tunnel junctions formed by *n-GaAs* and a semitransparent metal electrode on its surface is changed by normally incident electromagnetic irradiation with frequency below the plasma edge of the electron gas in *GaAs*. In this case the electromagnetic wave is totally reflected by the plasma transferring momentum to the electrons. This leads to a photoresistive effect which is due to a spatial redistribution of the electrons resulting from the radiation pressure and the corresponding reconstruction of the self-consistent Schottky-barrier shape. Using a pulsed FIR laser the intensity dependence of the response has been measured yielding a superlinear increase of the tunnel conductance at high intensities. This nonlinearity depends strongly on the grade of homogeneity of the metal electrodes. The intensity dependence of the response turns out to be highly nonlinear (close to third power of intensity) and corresponds to an enhancement of the intensity in the near-field zone by a factor of $10^5$. It is shown that this enhancement arises due to the near-zone field formed by diffraction of the incident radiation at inhomogeneities of the metal electrodes. The experimental results are compared with known phenomena of near-zone field enhancement on rough metal surfaces observed in the visible spectral range like surface enhancement of Raman scattering and second harmonic generation. Similarities and differences in the underlying physical mechanisms are discussed.

## 1 Ponderomotive effect of near-zone field in Schottky-barrier junctions

In the initial stage of the reported work, the weak nonlinear dependence of the photoresistive response of tunnel n-GaAs/Au junctions on the FIR-laser radiation intensity was observed [1]. It was noted that this nonlinearity may allow to estimate the absolute value of the electromagnetic field the ponderomotive force of which produces the change in the shape of the self-consistent potential of the Schottky barrier. First evaluations indicated the enhancement of the field that corresponded

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to the effective enhancement of the intensity of incident radiation about $10^3$ times (Fig. 1). Such an enhancement could be related to the near-zone field effect only.

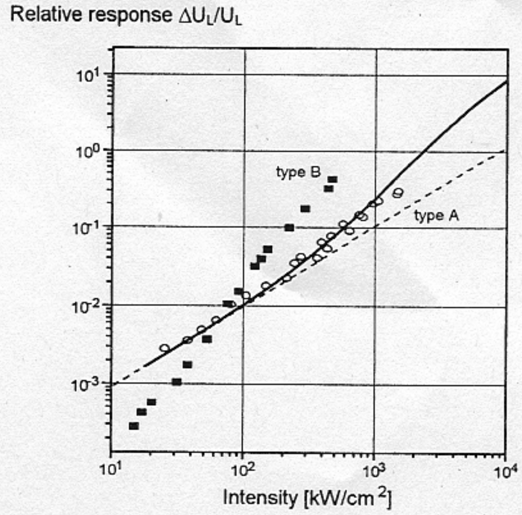


Fig. 1. Intensity dependence of the response for two kinds of tunnel junctions. The letters A and B correspond to low and high near-zone enhancement of the radiation field, respectively. The full line shows the response calculated with the enhancement parameter $K_e=3\cdot10^3$. The dashed line indicates the linear behavior.

To test this suggestion the investigation of the dependence of the enhancement on the degree of the metal electrode inhomogeneity has been undertaken, using *n-GaAs/Al* junctions obtained in MBE chamber (Figs. 2).

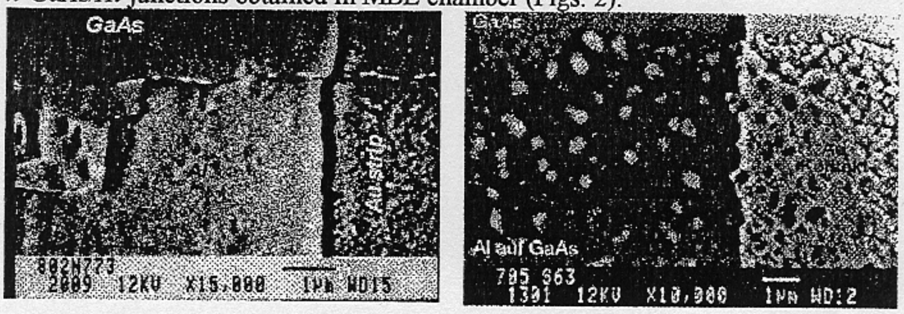


Fig. 2. Microphotographs of the metal film of the Schottky-barrier junctions for various film morphologies. Smooth film is left (type A junction) and rough film is right (type B junction).

Special studies were made to obtain the intimate GaAs/Al contact under various conditions of the metal evaporation. The last process is decisive for the degree of the metal film inhomogeneity. The quality of the used junctions was checked by means of the tunneling spectroscopy technique.

The strong nonlinear response was observed with the effective enhancement about $10^5$ times (Fig. 3).

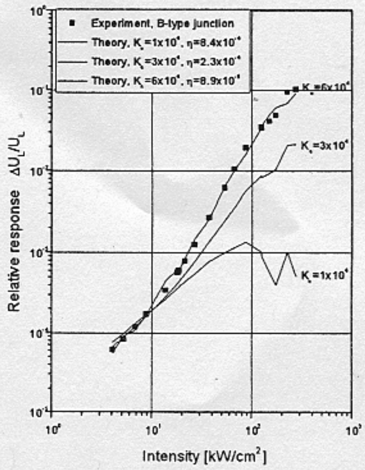


Fig. 3. Theoretical fitting for the response of the tunnel junction with high near-field enhancement at positive bias. The interplay among the increase of the Schottky-barrier transparency and the decrease of the bias during the laser pulse is well illustrated by the set of the theoretical curves for different values of the enhancement coefficient $K_e$.

While these values of the surface-enhanced local field are comparable with that observed in visible region for giant surface Raman scattering or second harmonic generation, it must be stressed that this is the first observation of the giant surface enhancement in far-infrared region. As a result, the theoretical models explaining the surface enhancement by plasma resonance effects in the metal film should be questioned because the characteristic frequencies of the plasma effects of good metals lie in UV region and cannot be responsible for the effect in FIR region.

The strong nonlinearity leads to the large magnitude of the voltage response that becomes comparable with the bias voltage without the irradiation. It has required to reformulate the algorithm of the theoretical calculations of the response relative to the described in [1].

To explain the observed effect some reformulating of the diffraction theory for the conducting screen with aperture was suggested. The approach is based on the separation in Maxwell equations the physical sources of the diffracted field. In contrast to the fictitious sources introduced by Bethe these physical sources are well-defined before the diffraction problem is solved and are fully-determined as the problem for unperturbed screen can be solved. In addition, it allows to carry out the qualitative or semiquantitative evaluation of the near-zone field without cumbersome numerical solution of the integral equations. The simple calculations predict the field enhancement in the small aperture of order of $\lambda/\delta$, where $\lambda$ is the radiation wavelength and $\delta$ is the skin-depth of metal film. For $\lambda\approx10^{-2}$ cm and $\delta\approx 5\cdot10^{-6}$ cm this gives the expected field enhancement about $10^{3}$ and respective effective intensity enhancement about $10^{6}$. Moreover, this approach allows to explain the observed dependence of the enhancement on the metal film thickness. The more thick film the more high enhancement may be obtained as far as the thickness is less than skin-depth.

## 2 Electron heating in near-zone field

Because of very high magnitude of the local filed the effect of the electron heating in the surface layer of the semiconductor free carrier plasma has to be reconsidered. While in the case of linear and weak-nonlinear response the electron heating was rejected [3], the junction with strong nonlinear response revealed the presence of the electron heating. Most explicit appearance of that gives the observation of the response without bias voltage, i.e. electromotive force. The sign of the signal in this case corresponds to the heating of the electrons of the semiconductor. But the response has very specific dependence on the radiation intensity which points out that the heated electrons tunnel across the barrier modified by ponderomotive force of the near-zone filed. This dependence was elaborated theoretically with account for the exclusion of the heated electrons above the bottom of the L-valley of GaAs. Numerical calculations have shown that the observed dependence corresponds to the electron overheating in the range up to 1500- 2000 K at the maximum incident intensity of order of 1 $MW/cm^{2}$.

## 3 Acknowledgments

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