Noise features in InP semiconductors operating under static or sub-TeraHertz electric fields

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ABSTRACT

The sensitivity of semiconductor based circuits is strongly affected by the presence of intrinsic noise, which limits the performance of electronic devices. For this reason, several studies have investigated and characterized the transport properties of hot-electrons in semiconductor structures, by analyzing the electronic noise in systems operating under static and/or large-signal periodic driving conditions [1-3]. Previous studies on electron velocity fluctuations in III-V and covalent semiconductor crystals, driven by periodic electric fields, have shown that the total noise power depends on both the amplitude and the frequency of the excitation signals [3]. On the other hand, to the best of our knowledge, very little has been done in the study of the noise characteristics in InP structures operating under high-frequency periodic conditions.

In this contribution, we study the hot-carrier noise in n-type InP crystals operating under static or cyclostationary electric fields. In order to simulate the dynamics of electrons inside the material at kinetic level, we employ a Monte Carlo approach. It allows us to take into account the main details of the band structure, scattering processes as well as heating effects [4]. Electronic intrinsic noise is investigated by computing the correlation function of velocity fluctuations, the spectral density and the total noise power.

Our results show that the noise features are significantly affected by the amplitude and frequency of the driving electric field (see Figures 1-3). In fact, in the presence of the oscillating electric fields, the noise spectra exhibit, especially at very low frequencies, some peculiarities, which are severely different from those obtained in the static field case. In particular, in the presence of a periodic driving, the spectral density significantly deviates by the partition noise behaviour. Moreover, the circumstance that the peaks in the noise spectra are very sensitive to the amplitude and frequency of the excitation signals could be very significant for harmonics extraction purposes.

Our findings also highlight a non-monotonic behaviour of the integrated spectral density (ISD), i. e. the total noise level, as a function of the amplitude of applied electric field (see Figure 4). Moreover, the ISD monotonically reduces its value with the increase of the field frequency, for each amplitude of the applied field. This effect could be a consequence of the cooling of the distribution function, but further investigations are needed to better clarify this result.

Studies concerning the constructive aspects of noise and fluctuations in different non-linear systems have shown that the addition of external noise to systems with an intrinsic noise may result in a less noisy response [5]. Indeed, the possibility of reducing the diffusion noise in GaAs crystals by adding a random Gaussian correlated or dichotomous fluctuating contribution to the driving electric field has been found [6]. Recently this possibility has been investigated also in a Si MOS inversion layer [7]. Our preliminary results show that it is possible to reduce the electronic intrinsic noise also in InP crystals. The best conditions to realize this effect are addressed.

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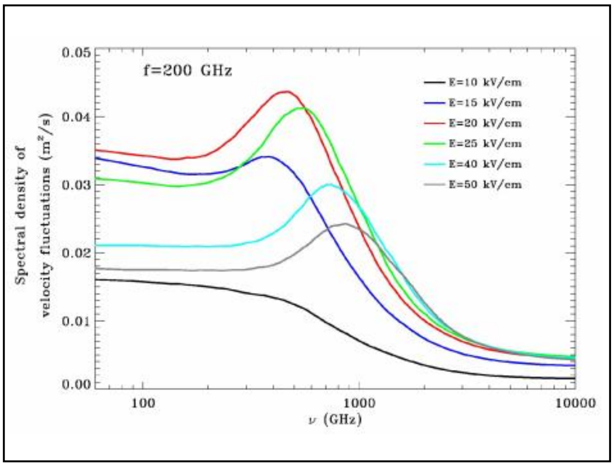

Fig. 1. Spectral density of the electron velocity fluctuations calculated at the frequency of the driving field f = 200 GHz, T= 77 K, n=10^{13} cm^{-3}.

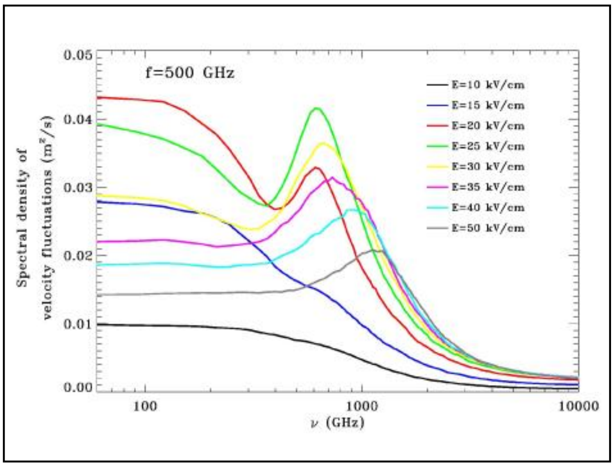

Fig. 2. Spectral density of the electron velocity fluctuations calculated at the frequency of the driving field f = 500 GHz, T= 77 K, n=10^{13} cm^{-3}.

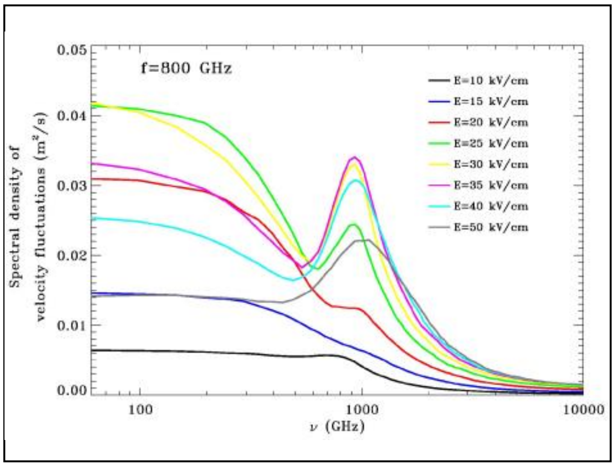

Fig. 3. Spectral density of the electron velocity fluctuations calculated at the frequency of the driving field f = 800 GHz, T= 77 K, n=10^{13} cm^{-3}.

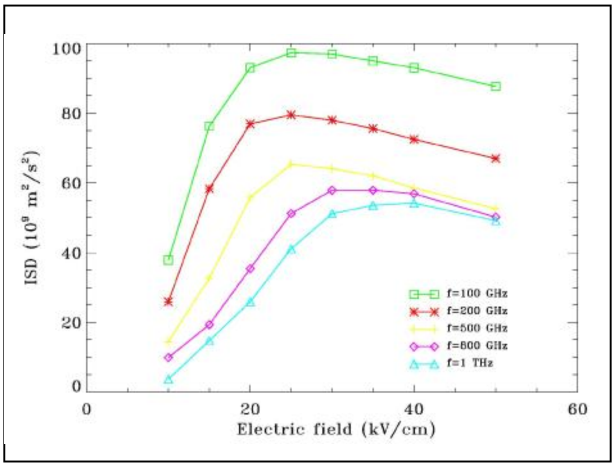

Fig. 4. Integrated spectral density (ISD) of the electron velocity fluctuations as a function of the applied electric field amplitude, at different values of the driving field frequency.