Measurements of RF noise in InGaAs/InAlAs recessed diodes: Signatures of shot-noise suppression

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I. INTRODUCTION

Beyond being an obstacle to any electronic communications system, noise can also be an important source of information on the different mechanisms of electron transport in a given device[1]. Studies on electronic noise can provide valuable information to better understand the electron transport mechanisms in semiconductor devices. More concretely, the effect of Pauli principle and/or Coulomb interaction on the carrier statistics in ballistic media, and how it may result in suppressed shot-noise levels with respect to the full Poissonian value ($2qI$), is a field of interest for physicists and electronic engineers[2-3]. However, the experimental evidence of such shot-noise suppression mechanisms is rather difficult to obtain.

II. EXPERIMENTAL RESULTS

In this work the measured noise characteristics of a set of recessed planar InGaAs/InAlAs diodes are presented. For the measurement, a PNA-X N5244A with Option 029 from Agilent Technologies has been used, which allows acquiring the output power density from an electronic device with high levels of accuracy and sensitivity[4]. The data in the range between 20 and 30 GHz (in the plateau beyond $1/f$ noise) was averaged in order to improve the precision of the results. The geometry of the diode is depicted in Fig. (1) and basically consists in an ungated HEMT topology with a recess between the drain and source terminals[5]. The recess leads to the presence of a barrier in the potential profile [see Monte Carlo results in the inset of Fig. (1)], which, by modulating the passage of ballistic carriers, is expected to suppress the associated shot-noise by virtue of Coulomb correlations[2].

In Fig. (2) we present the results of a first experiment with three devices of different recess lengths (L_R), i.e. 200, 500 and 800 nm.

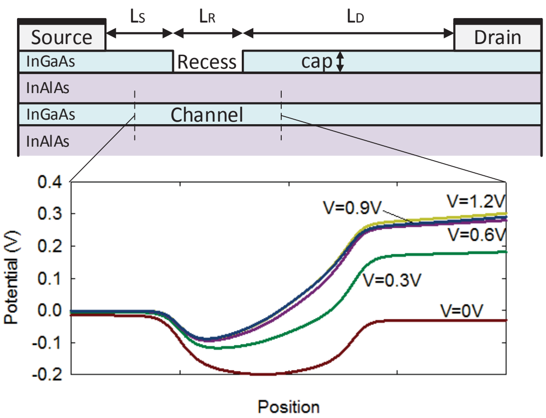

FIG. 1: Sketch of the device and simulated potential profiles in the recess region for several bias voltages.

The drain/source accesses (L_D and L_S) are 550 nm and 200 nm length in all three cases. For comparison, another device without recess and 1300 nm total length has also been measured. The *I-V*

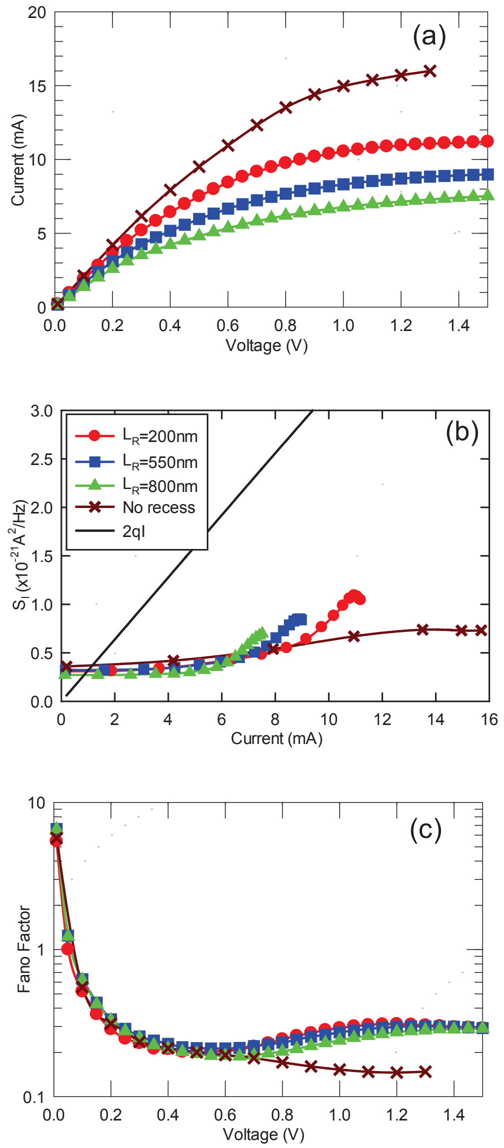

FIG. 2. Measured results of three devices with different recess lengths (L_R): (a) I-V curves, (b) current noise density (S_I) vs. bias current, and (c) Fano factor (F) vs. bias voltage.

curves of all the devices are plotted in Fig. (2a). As expected, longer recess regions make the device more resistive, which in turn provides lower current levels. The current noise density (S_I) and the Fano factor ($F=S_I/2qI$) are shown in Figs. (2b) and (2c), respectively. The current-noise density of the device without recess is nearly constant with bias, which indicates that thermal noise dominates due to the diffusive nature of the transport along the device, leading to a Fano factor continuously decreasing with bias. On the opposite, recessed devices present different response. For low bias, they also show flat current noise density. However, above certain voltage (around 0.6 V, when intervalley mechanisms are activated) the current noise density begins to significantly increase proportionally to current, indicating the presence of shot-noise due to ballistic transport in the recess region, but suppressed with respect to the full shot-noise value. Also, the Fano factor is slightly lower in the device with longer recess due to the presence of a higher barrier in the potential[2] (counteracting the expected decrease of F due to a lower contribution of the thermal noise of the accesses).

In a second experiment, three devices with different drain access lengths have been characterized. The source (L_S) and recess (L_R) lengths are both 200 nm in all three cases. The *I-V* curves of the devices are plotted in Fig. (3a). In this case, the three devices present similar characteristics, indicating that the current levels are mainly determined by the recess, which has the same length in this case. The current noise densities are shown in Fig. (3b). Again, noise proportional to current appears, suppressed with respect to the full Poissonian value. Also, it can be observed how for very high bias, the current density decreases in some cases. This effect is more noticeable for longer drain accesses, which in turn present higher resistivity and further attenuate the shot noise generated in the ballistic recess region. As it can be observed in Fig. (3c), F is correspondingly lower in the case of longer drain access, presumably due to the attenuation of the shot noise contribution to the total noise when this region becomes very resistive.

III. CONCLUSIONS

The noise measurements performed in a set of recessed planar InGaAs/InAlAs diodes show evidences of shot noise suppression due to the potential barrier imposed by the recess. An increase of the spectral density at voltages above 0.6 V, in parallel to that of the current, could be understood as a signature of the presence of suppressed shot noise in the recess region where electron transport is quasiballistic and a fluctuating potential barrier is able to regulate the electron flow. The dependence of the total noise and F on the geometrical parameters is consistent with this explanation. However, the thermal noise contribution of the source and drain access regions (together with the one associated to the ohmic contacts) does not allow to precisely extract the value of the noise generated below the recess, and whether it is full or suppressed shot noise.

ACKNOWLEDGEMENTS

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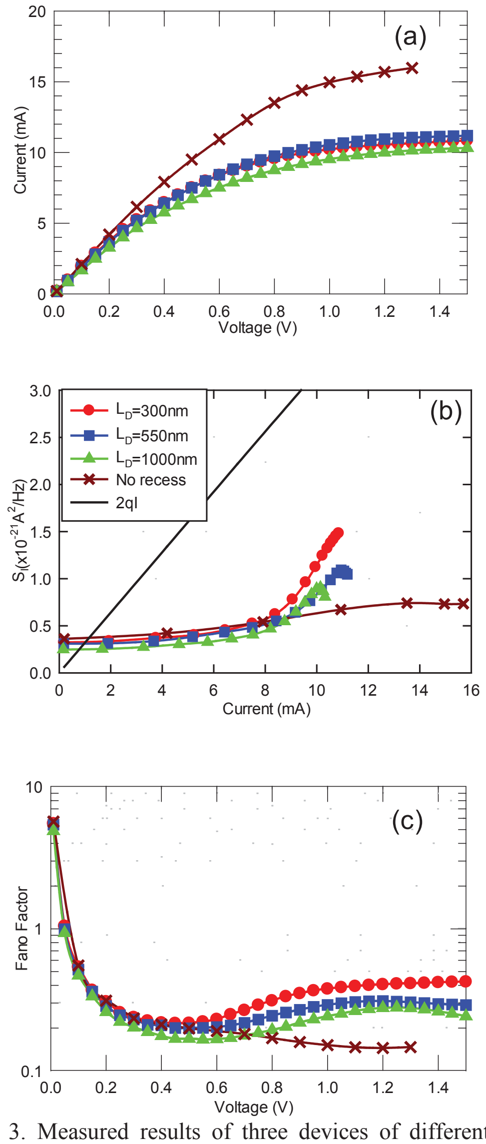

FIG. 3. Measured results of three devices of different drain access lengths (L_D): (a) I-V curves, (b) S_I vs. bias current, and (c) F vs. bias voltage.

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