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Quasi-ballistic transport in AlGaN/GaN heterostructures in extremely high electric fields

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Electron transport in two-dimensional (2D) conducting channels of AlGaN/GaN heterostructures in extremely high electric fields at 4.2K has been studied. Sample's mesa was designed with a special geometry in order to achieve the electric field as high as possible without breakdown. We observed ballistic transport of 2D-electrons in the channel of an AlGaN/GaN heterostructure with reduced carrier concentration. In the ballistic transport regime, the highest carrier velocity attained was 6.8×10^{7} cm/s at an electric field of 0.3 MV/cm in the channel. This velocity is 85% of the natural limit in the velocity predicted for the carrier transport based on the band structure of wurtzite GaN and is the highest ever achieved in semiconductors in an externally applied electric field. The results of our experimental studies are in good agreement with analytical and Monte Carlo theoretical predictions of high-energy carrier kinetics implying a negative mass state contribution to transport phenomena in GaN-based materials. These results provide evidence of approaching to the regime with negative differential conductivity (NDR), which is expected at a field of about 0.6MV/cm. The revealed ballistic transport regime with the highest drift velocity attained is an important step towards reaching the theoretically predicted region with NDR.

The rough estimations show that in our particular case the dissipated electric power density in the sample constriction reaches ~10^{12} W/cm^{3}. Thus, the further progress in the study of the transport phenomena in such huge electric fields requires overcoming the problem of efficient heat removal from the active region of the device.