Non-Equilibrium Green's Function Simulation of Nano-GaN HEMT

CROSSLIGHT Software Inc.

APSYS Models for FET

Quantum ballistic current transport model

- Device divided into classical drift-diffusion (DD) regime (mainly in vicinity of contacts) and quantum ballistic transport (QBT) regime.
- NEGF model employed in QBT regime [1].
- Seamless integration of QBT and DD in the APSYS software.
- Same global Poisson's equation solver used in both DD and QBT regimes.
- Space charge from QBT model fed back into the global Poisson's equation solver to achieve self-consistency.

[1] Ren, Z. (2001). "NANOSCALE MOSFETS: PHYSICS, SIMULATION AND DESIGN ".

NEGF Simulation of GaN HEMT by APSYS

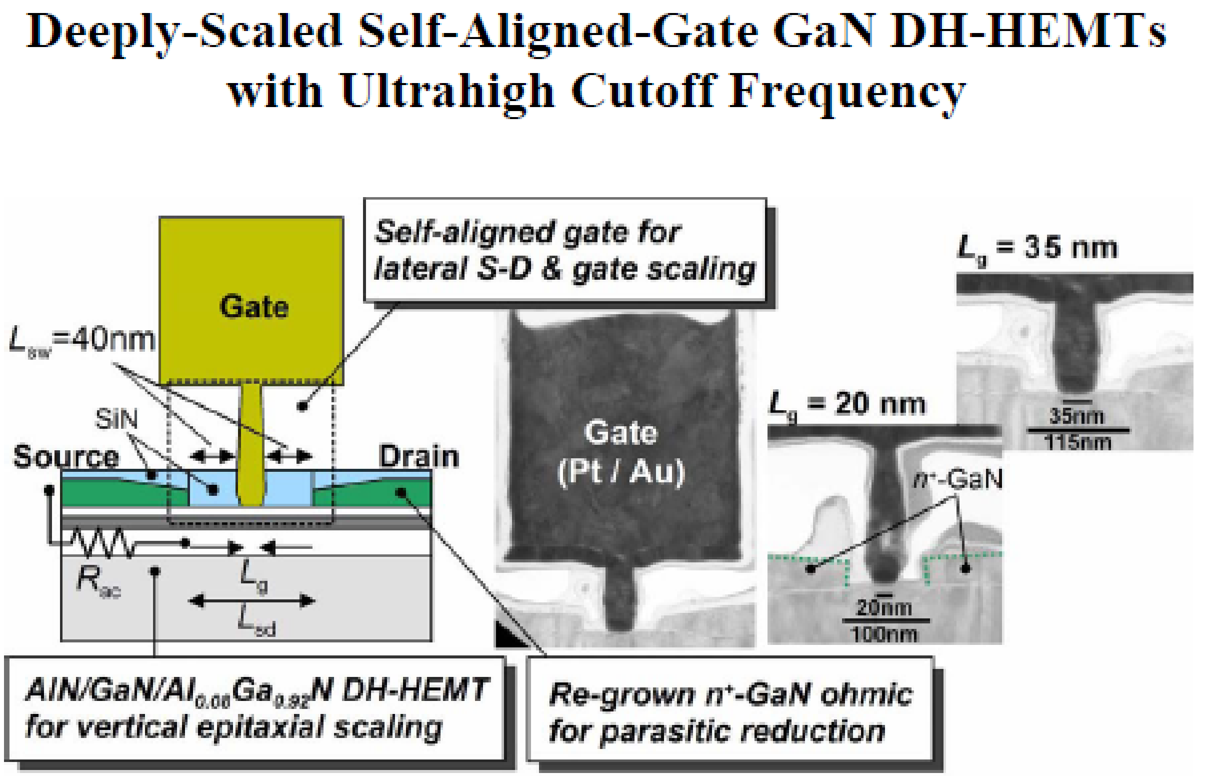
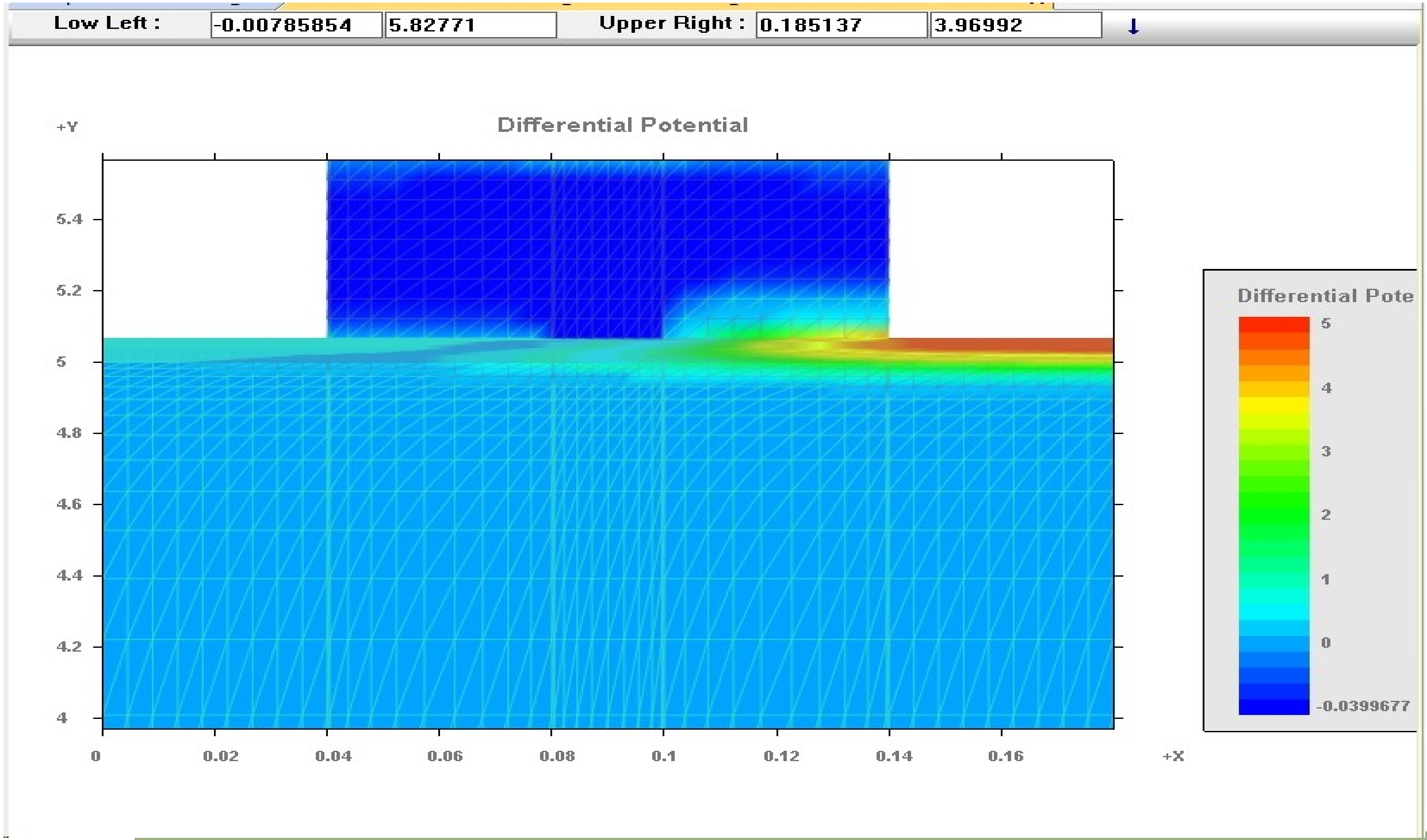


Fig. 1. Highly-scalable self-aligned gate (SAG) GaN DH-HEMT technology with n^+-GaN re-grown ohmic contacts. Cross-sectional TEM images show 20-nm and 35-nm T-shaped gates self-aligned to the n^+-GaN.

Ref: K. Shinohara, et. al, IEDM 11-453

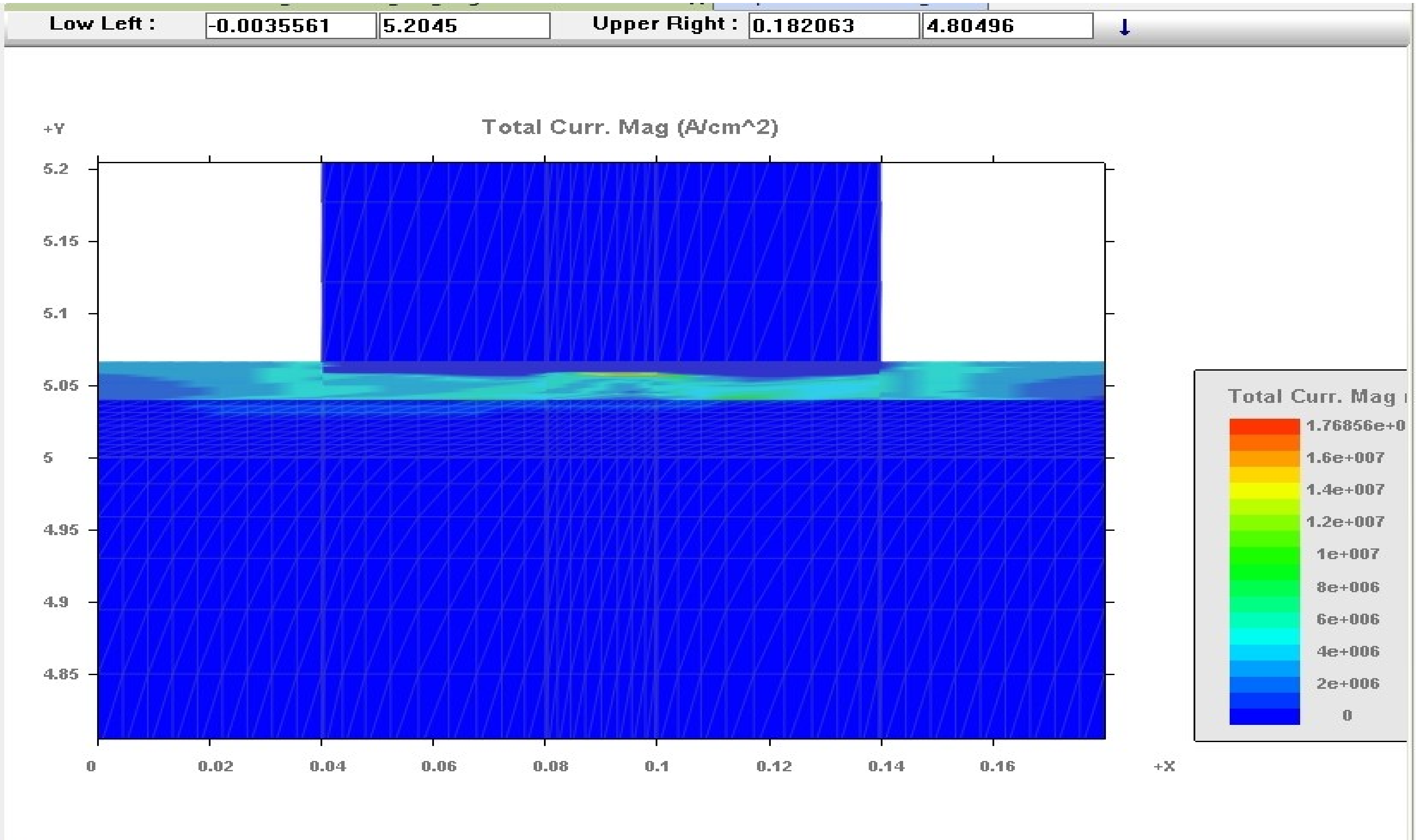
NEGF Simulation of GaN HEMT by APSYS

Differential potential at Vd=5V Vg=0



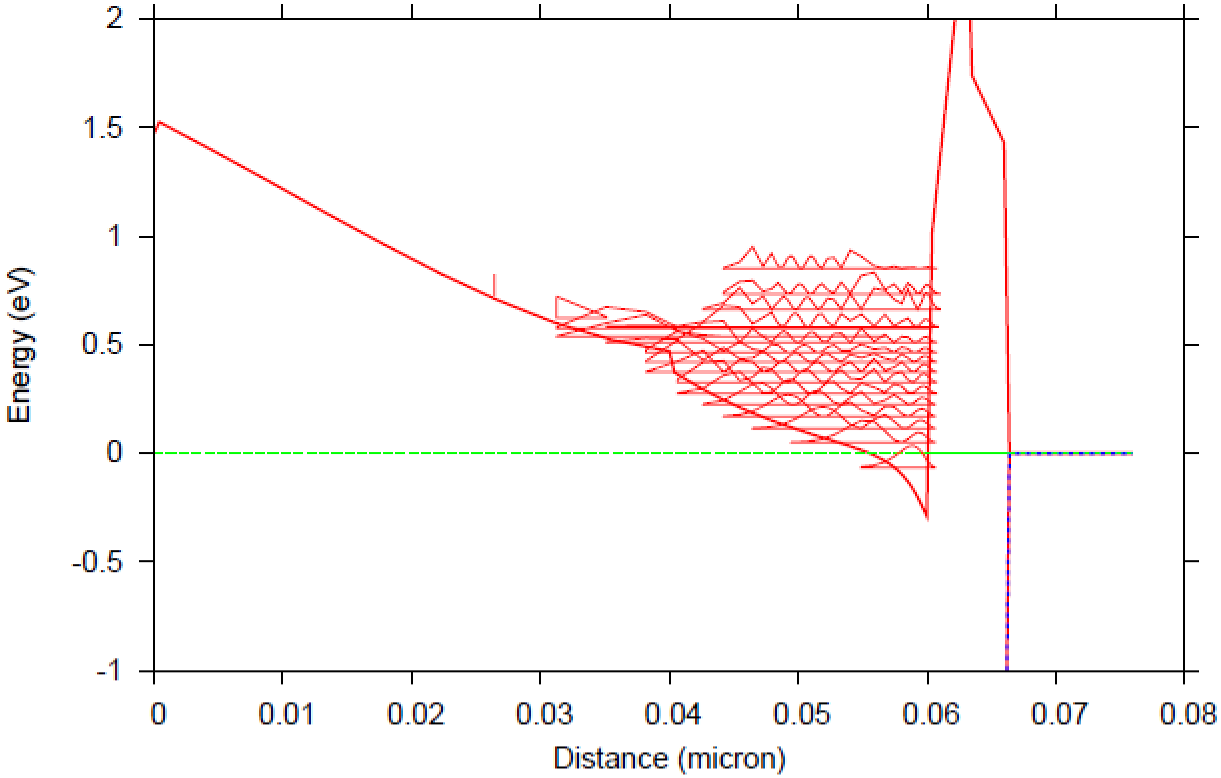
NEGF Simulation of GaN HEMT by APSYS

Current magnitude at Vd=5V Vg=0



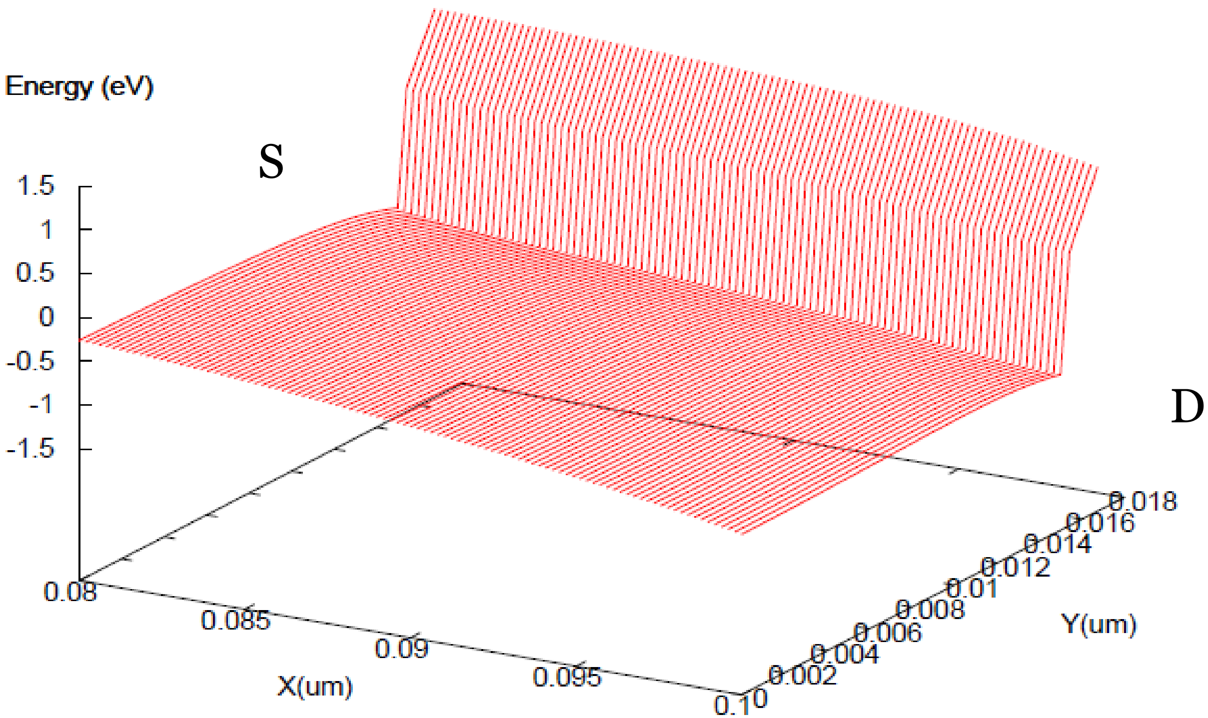
NEGF Simulation of GaN HEMT by APSYS

Quantum confined states in channel region at equilibrium



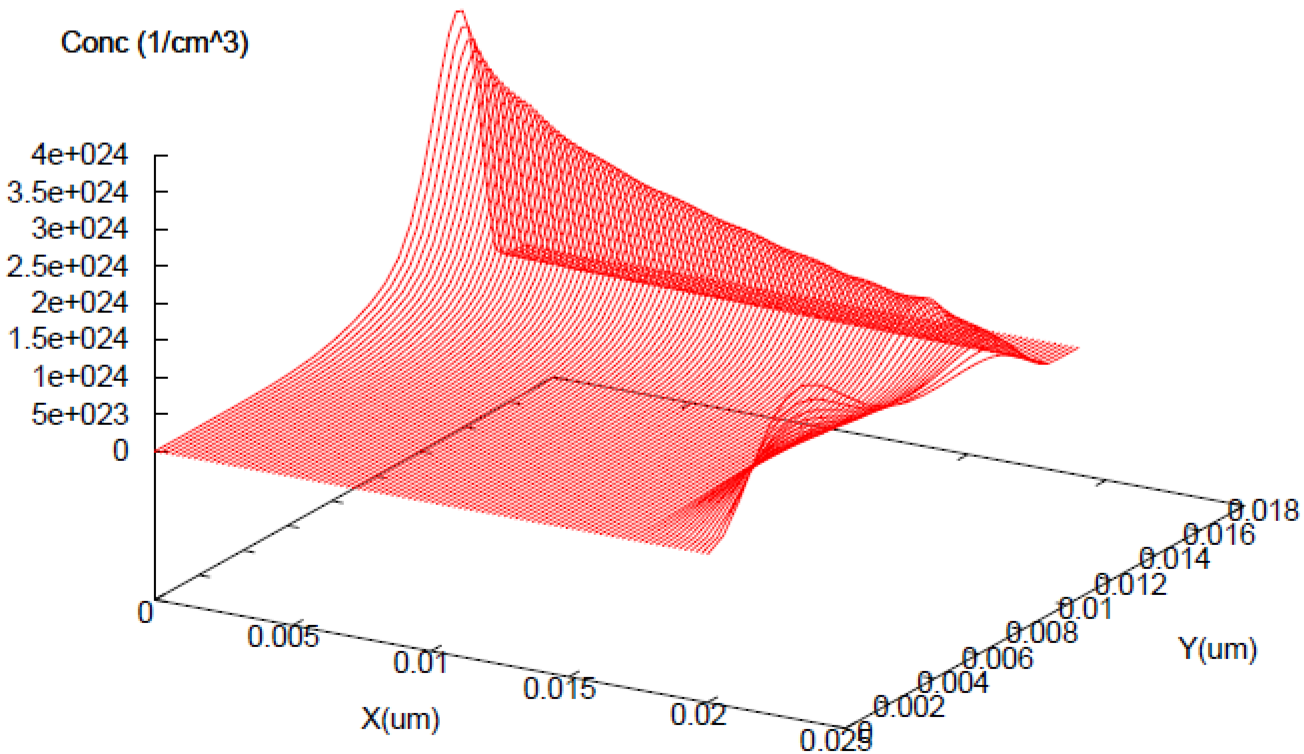
NEGF Simulation of GaN HEMT by APSYS

QW channel potential profile at Vd=5V Vg=0 subband1



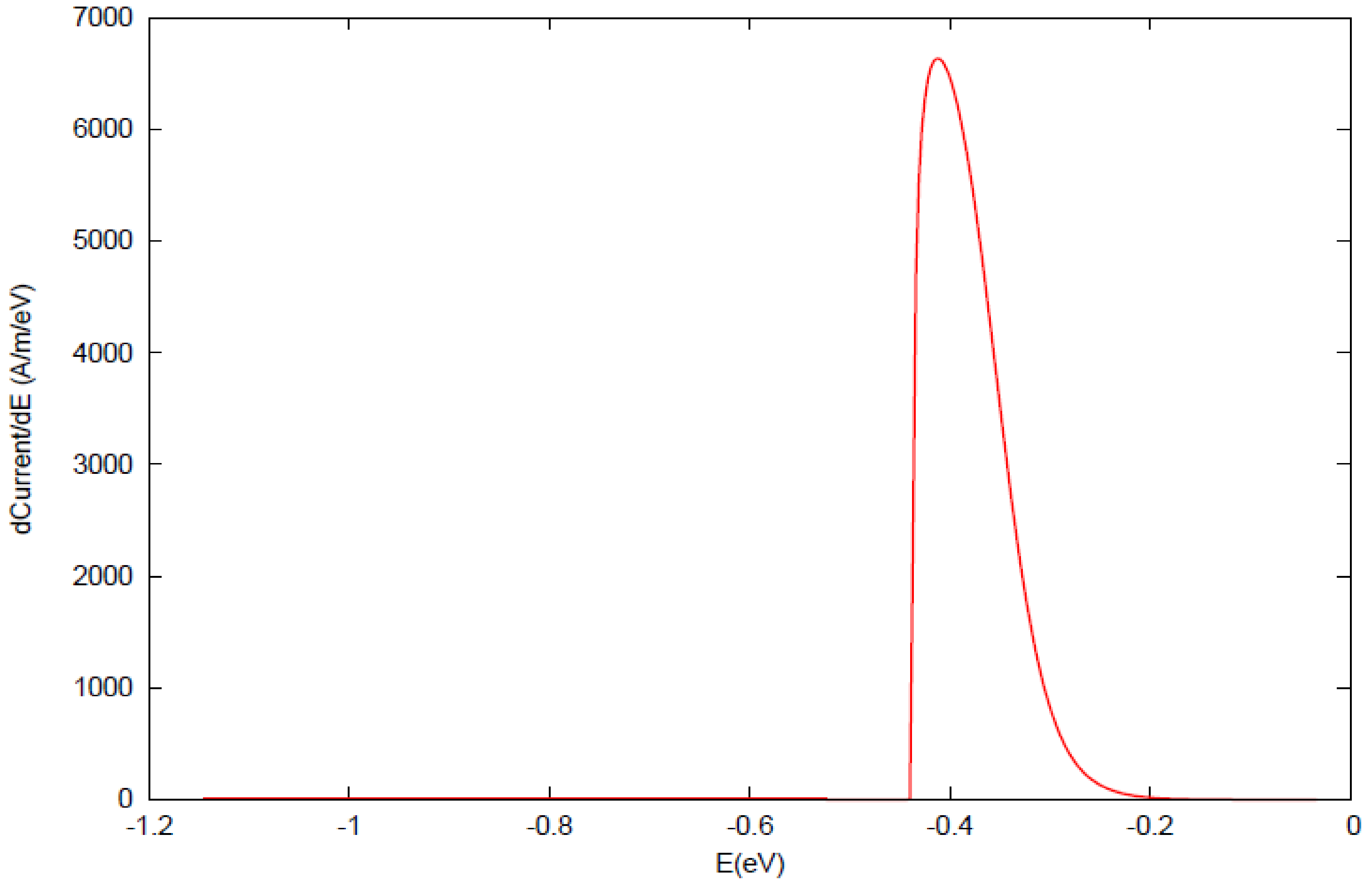
NEGF Simulation of GaN HEMT by APSYS

QW Elec. Conc. With Quant. Conf. at Vd=5V Vg=0



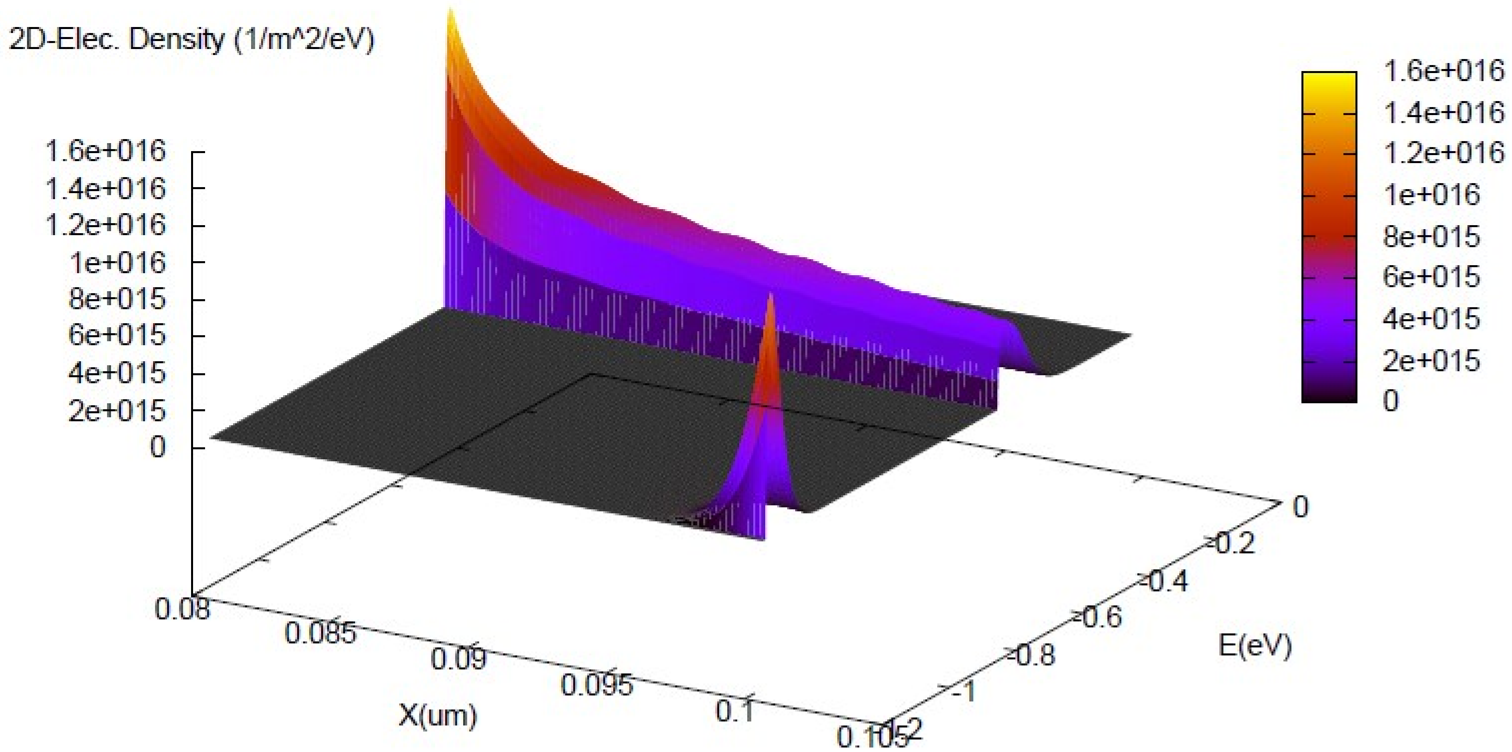
NEGF Simulation of GaN HEMT by APSYS

Quant. Ballistic Transp. Current Spectrum at Vd=5V Vg=0



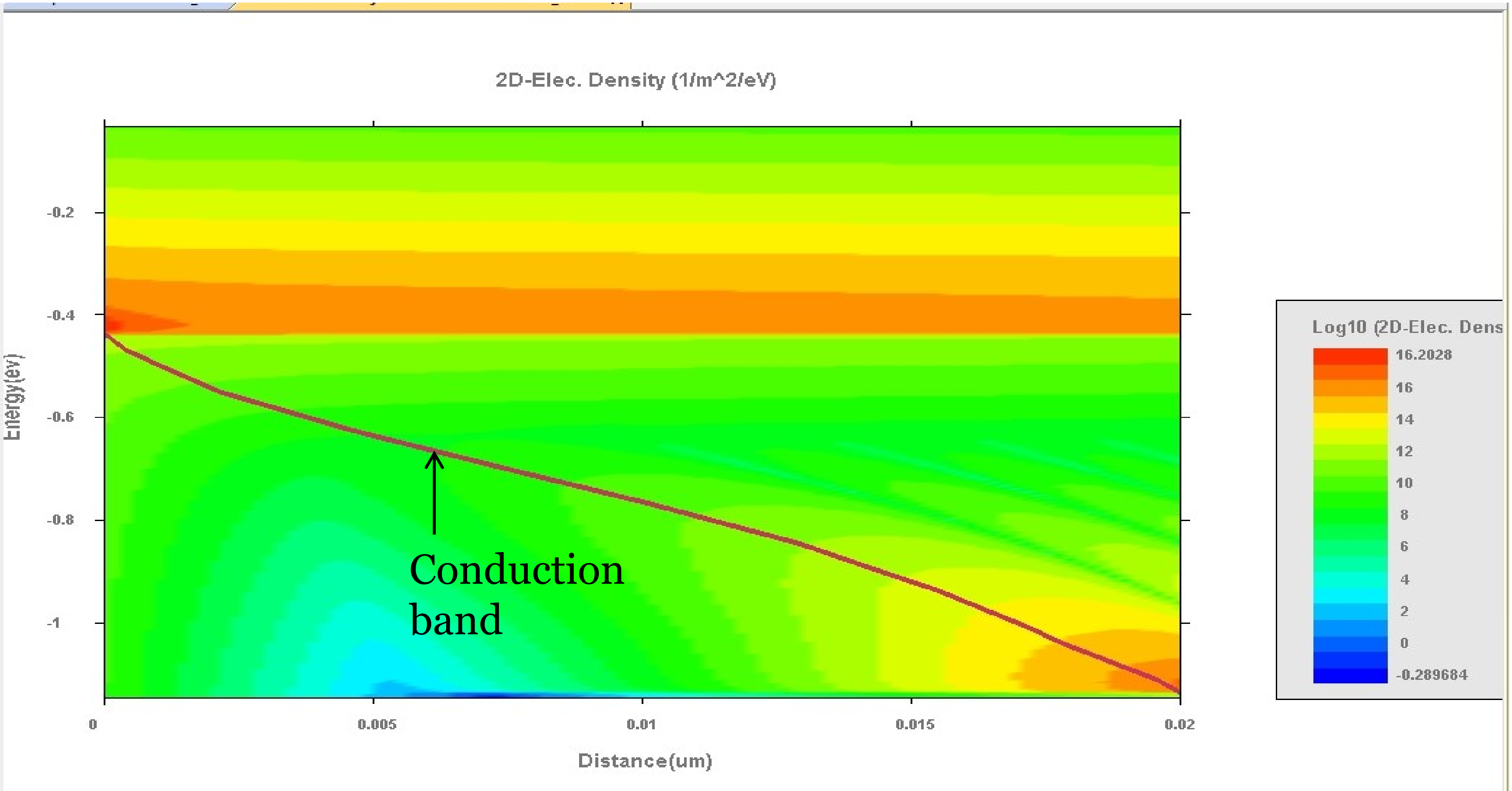
NEGF Simulation of GaN HEMT by APSYS

Quant. Ballistic Transp. Elec. Density Spectrum at Vd=5V Vg=0



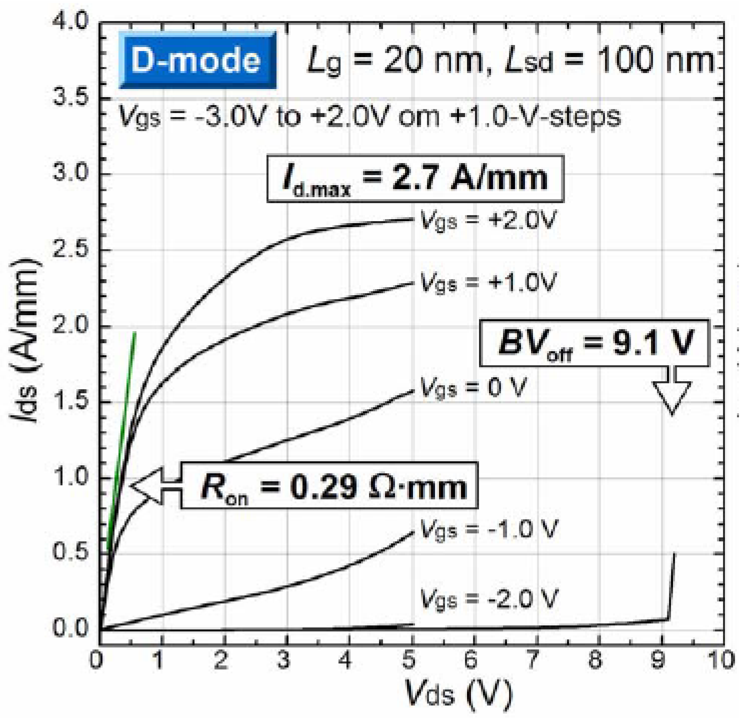
NEGF Simulation of GaN HEMT by APSYS

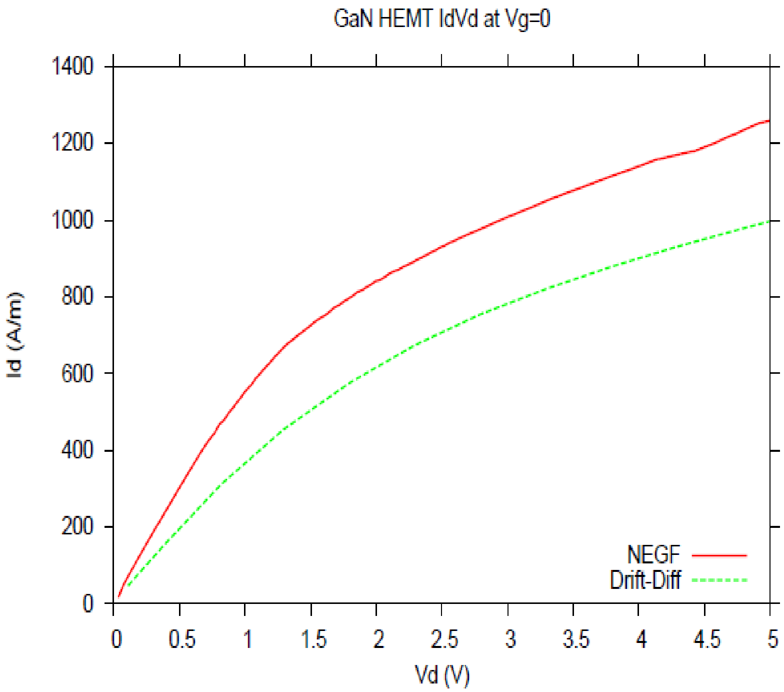
Quant. Ballistic Transp. Elec. Density Spectrum at Vd=5V Vg=0



NEGF Simulation of GaN HEMT by APSYS

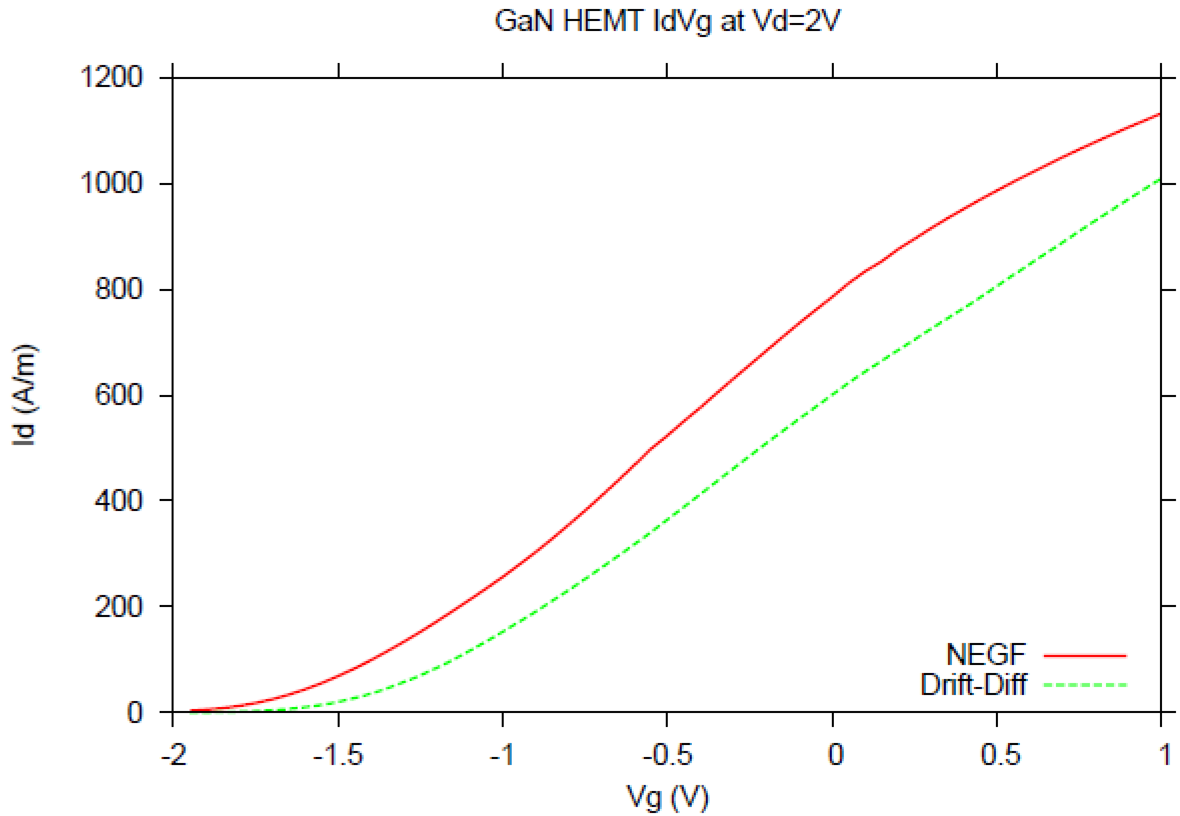
IdVd compared with experiment





Remark: Trend of NEGF closer to experiment

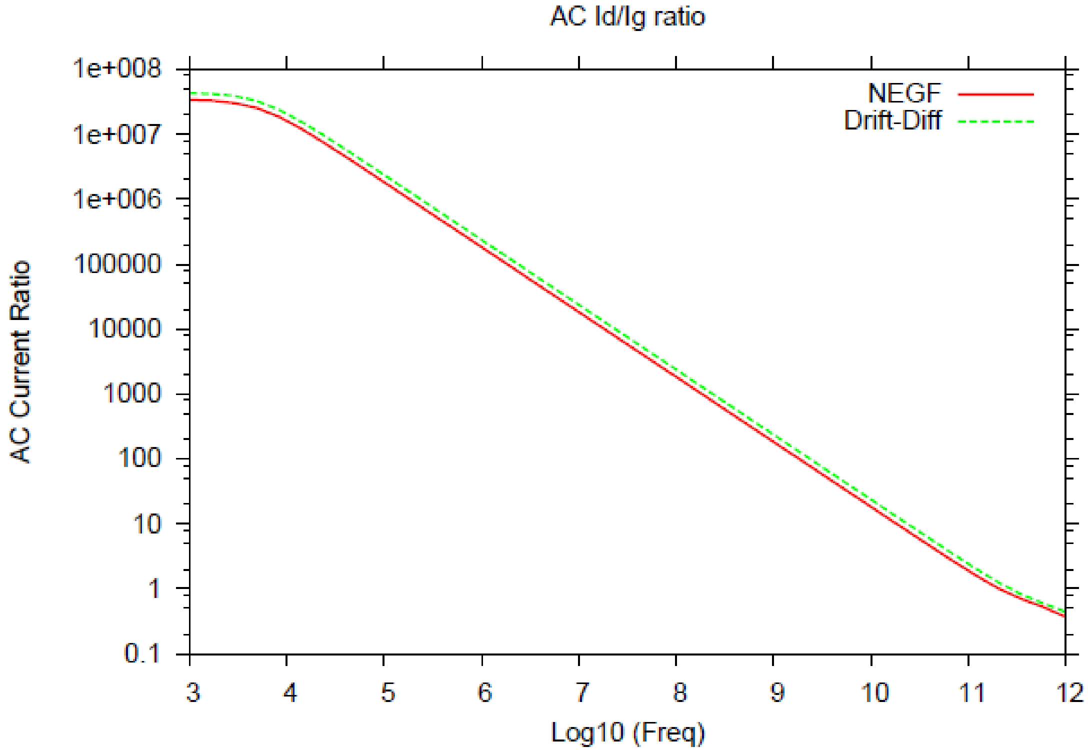
NEGF Simulation of GaN HEMT by APSYS



Due to different shape of IdVg curve, significant difference in Vt has been observed.

NEGF Simulation of GaN HEMT by APSYS

Comparison of AC Current Ratio



Remark: AC cut off at about 300 GHz is more determined by internal capacitance and NEGF or Drift-diffusion makes little difference

APSYS Models for nano-GaN HEMT

Quantum ballistic current transport model summary

- The shape of IdVd for NEGF closer to experiment.
- NEGF with ballistic transport impose a limit of Id-on from quantum reflection.
- High frequency cut off behavior is similar from NEGF or Drift-Diff.
- Crosslight TCAD for HEMT/HFET offers NEGF computation at high efficiency and with great accuracy.

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