Single Event Transient Response of InGaAs MOSFET

Kai Ni[1], En Xia Zhang[1], Nicholas C. Hooten[1], William G. Bennett[1], Michael W. McCurdy[1], Ronald D. Schrimpf[1], Robert A. Reed[1], Daniel M. Fleetwood[1], Michael L. Alles[1], Tae-Woo Kim[2], Jianqiang Lin[3], Jesús A. del Alamo[3]

[1]Vanderbilt University, Nashville, TN 37235, USA
[2]SEMATECH
[3]Massachusetts Institute of Technology, Cambridge, MA 02139 USA

Motivation

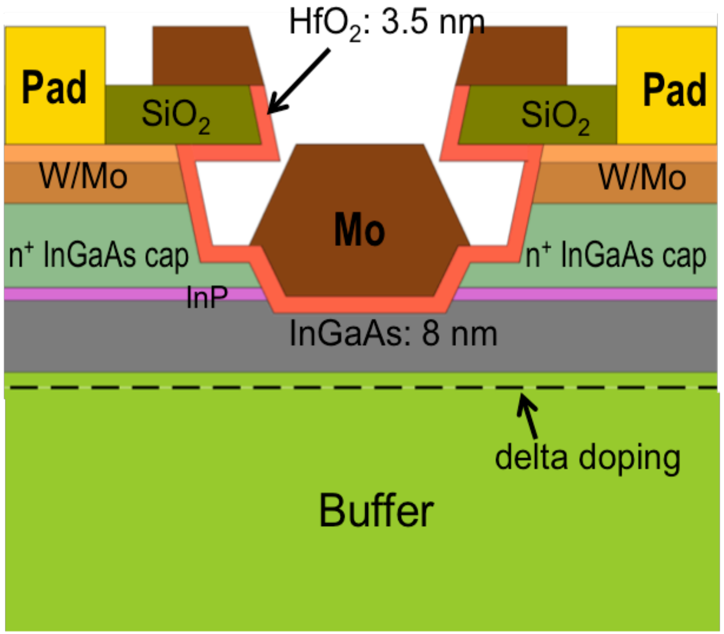
- III-V materials are promising channel candidates at beyond 14nm technology node

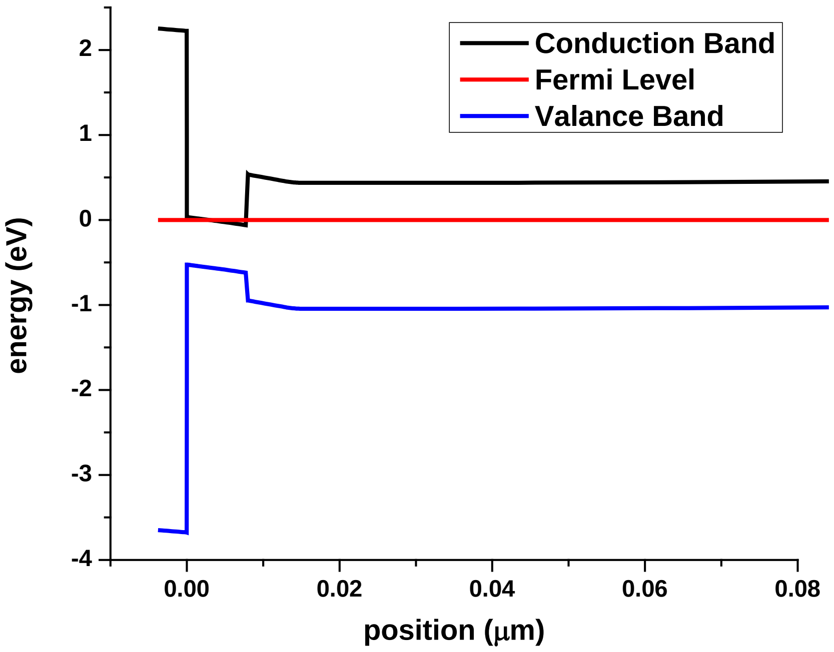
- Previous transient studies focus on III-V MESFET/HEMT
  - Gate transients
  - Charge enhancement due to source drain pathway
  - Gate bias dependence shows a peak at threshold voltage

- It's important to study the transient response of III-V MOSFET

Device II

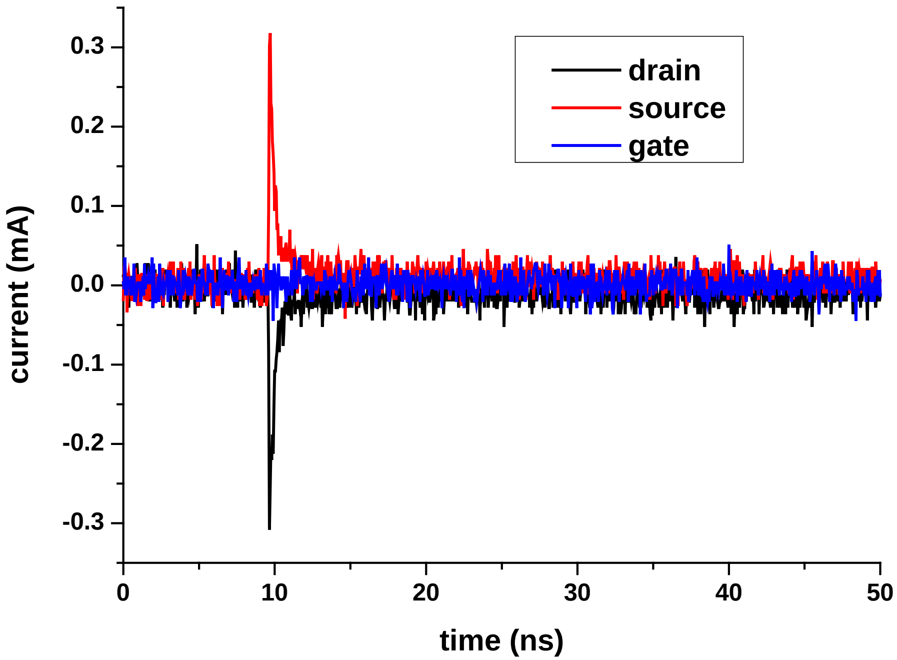
- Cross section and vertical band diagram





Heavy Ion Results

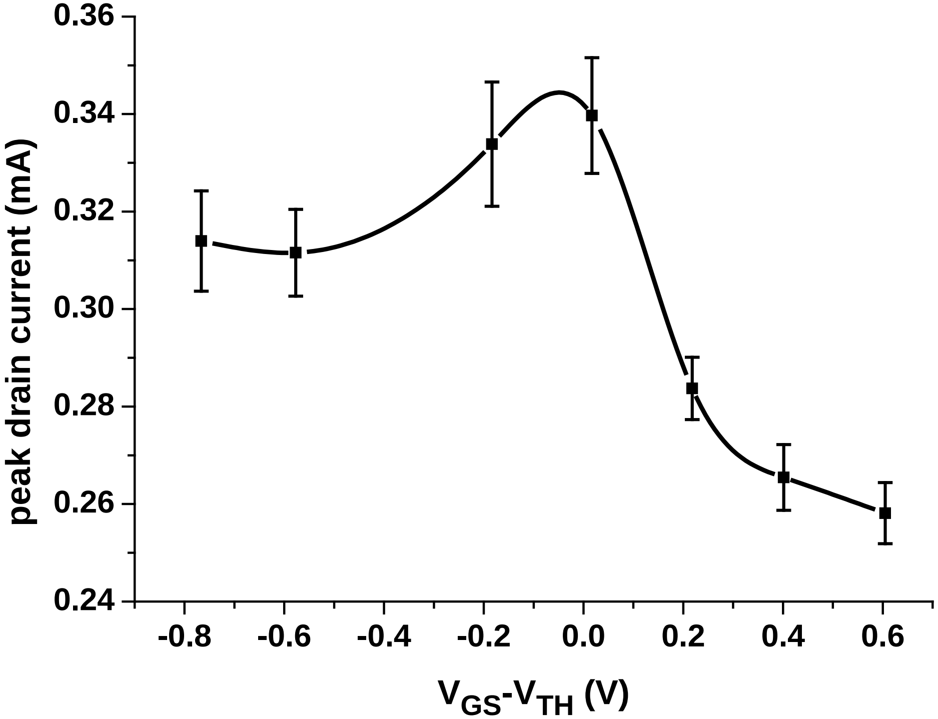
- No gate transient due to large barrier
- Source and drain transient have the same magnitude
- Two processes with different time constant



- Fast collection: τ≈ 100 ps, direct collection
- Slow collection: τ≈ 3 ns, source-to-drain pathway

Gate Bias Dependence

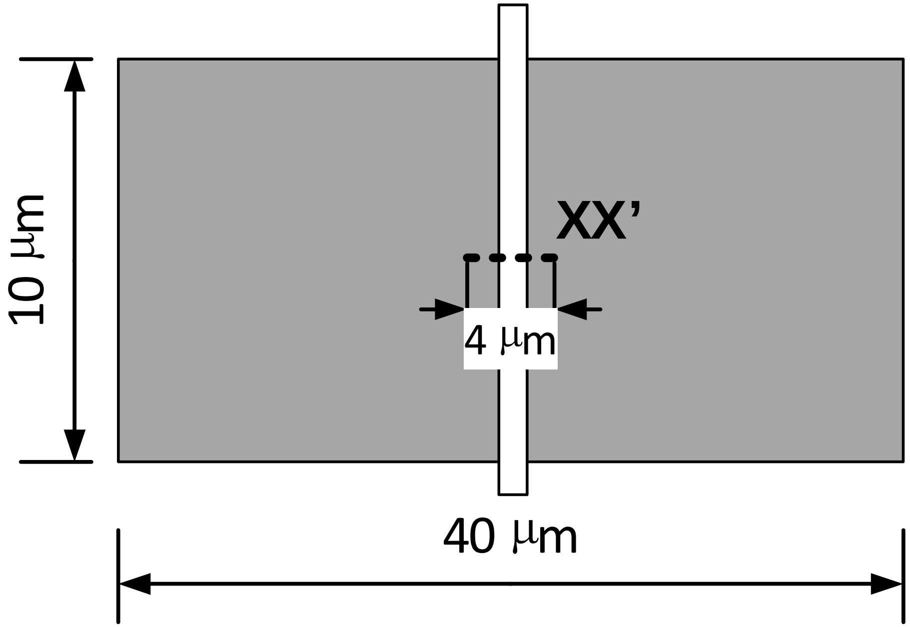
- Peak drain current reaches a maximum around threshold voltage



- Peak drain current decreases considerably in inversion and slightly in depletion and accumulation

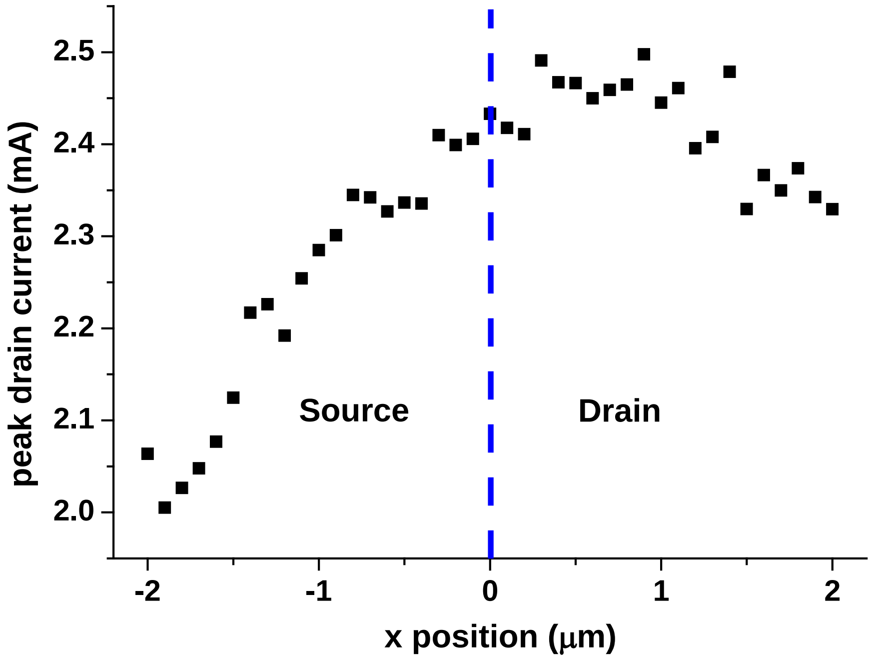
Laser Irradiation

- Laser wavelength 1.26 μm
- Photon energy 0.98 eV, larger than the channel material bandgap, smaller than the other matherials



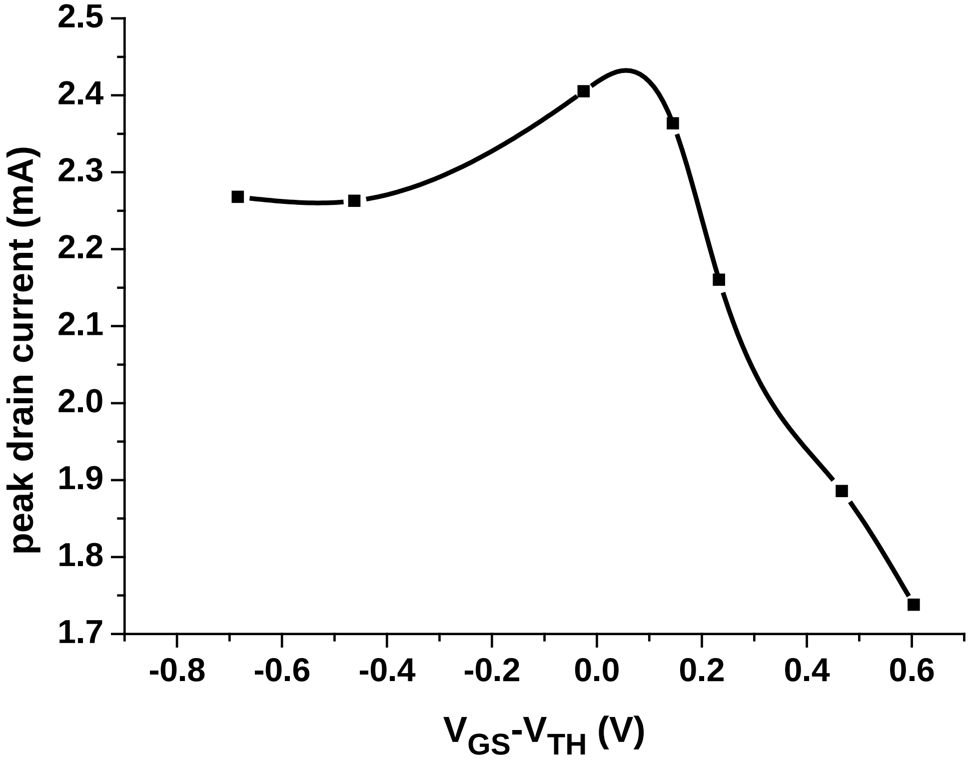
Laser Results

- Line scan
  - The drain side strike has a larger peak drain current than the source side strike
  - The drain side has a higher electric field than the source side (V_{DS}=0.5 V), so the electron velocity is higher in drain side, the peak drain current is larger



Gate Bias Dependence

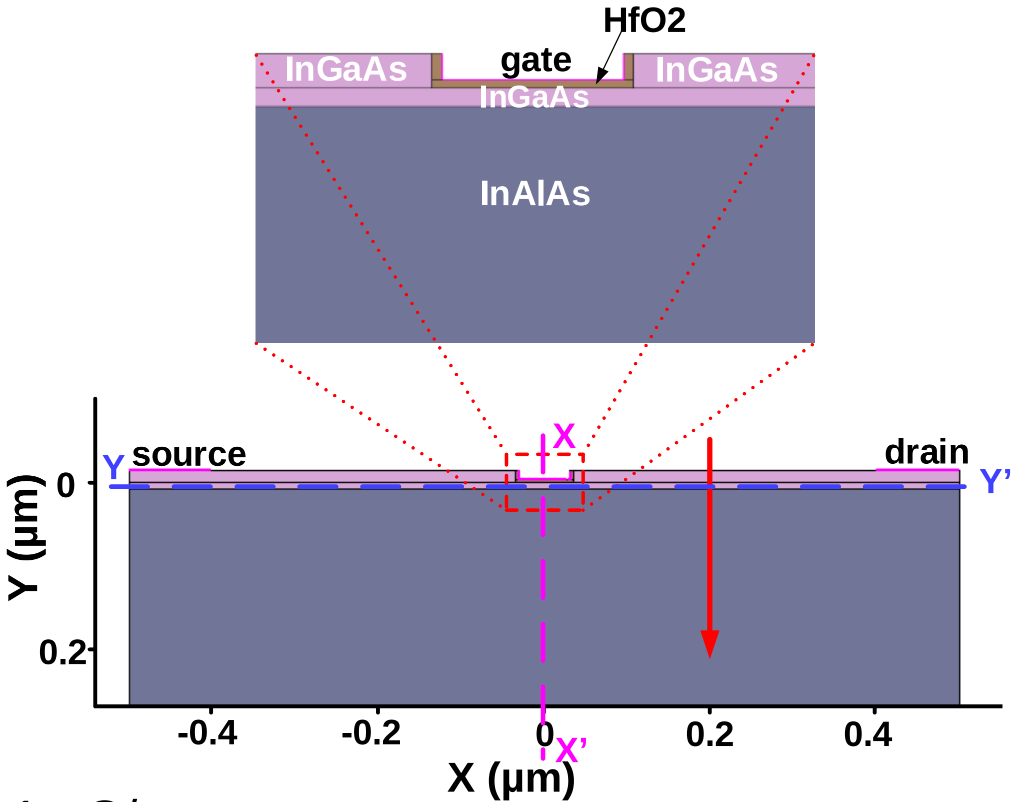
- The laser data is consistent with heavy ion data



- The peak drain current is maximum around threshold and decreases considerably in inversion while slightly in depletion and accumulation

2D TCAD Simulation

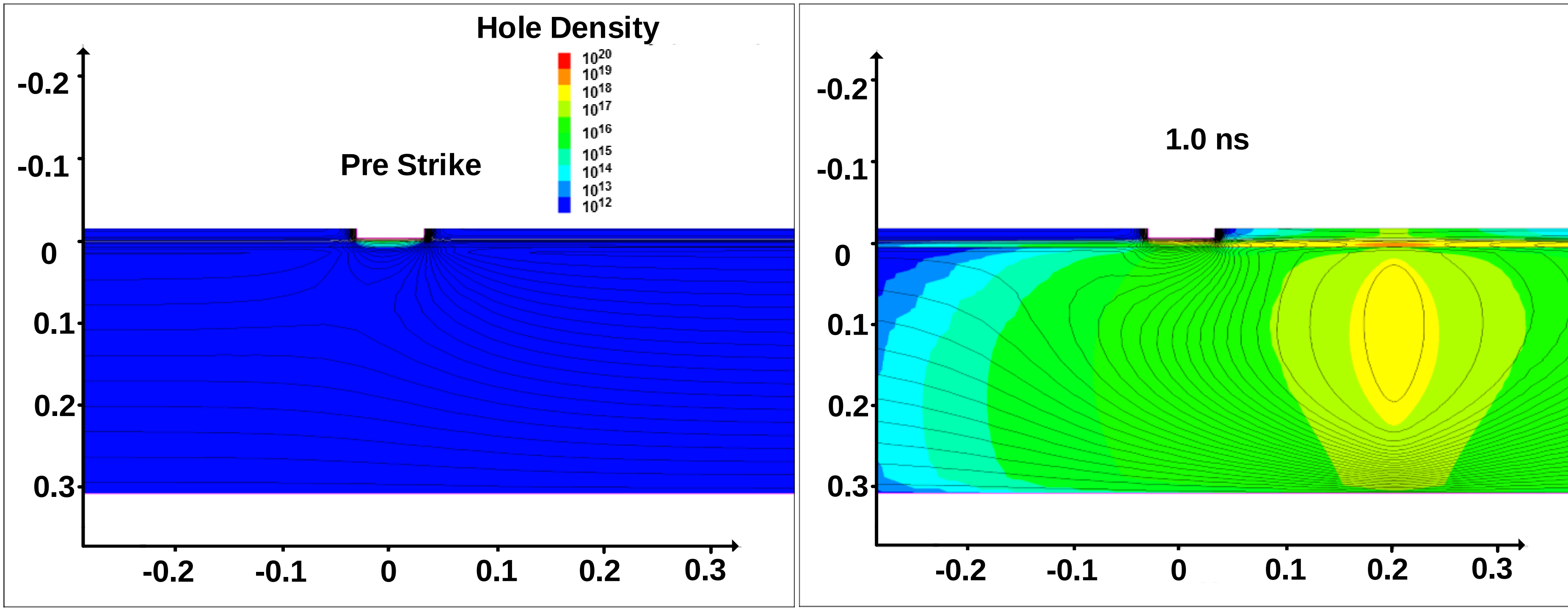
- Model



- The LET is 0.1 pC/µm
- The ion strike is gaussian both in space and time
- The strike center is at 0.2 µm and 1.0 ns

2D TCAD Simulation

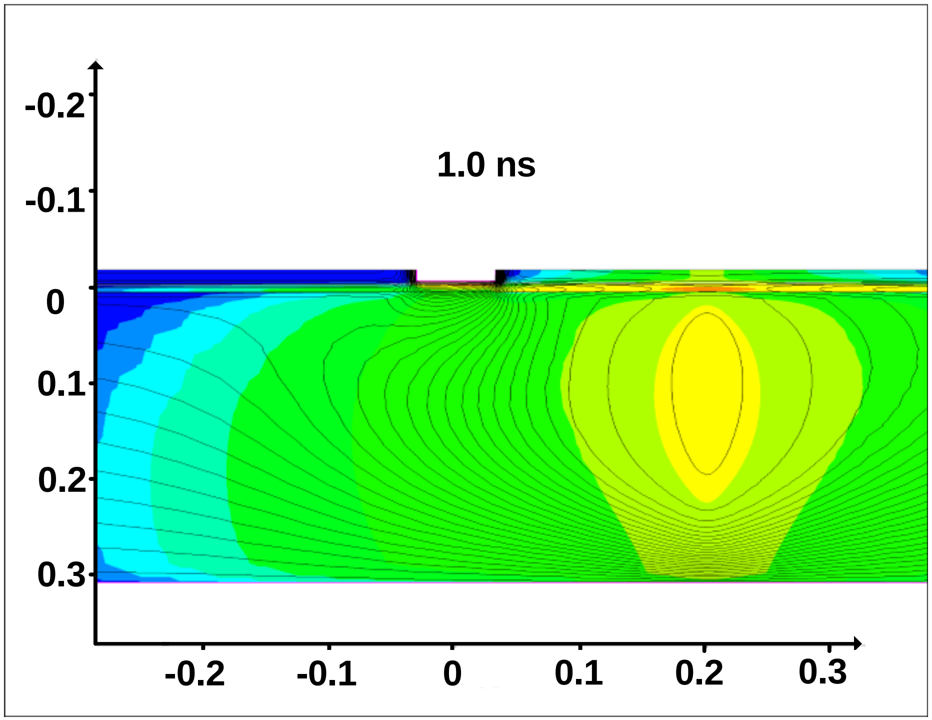
- Hole density (colored map) and electrical potential (contour)

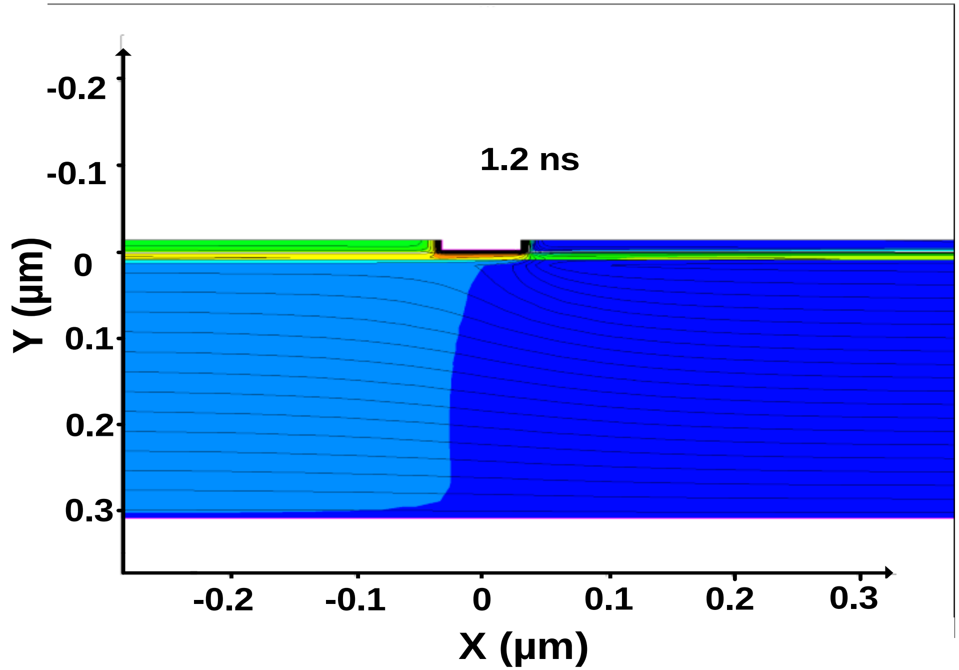


- At the center of the strike, the electric potential is strongly distorted due to a large number of electrons and holes are generated around the strike location

2D TCAD Simulation

- Hole density (colored map) and electrical potential (contour)

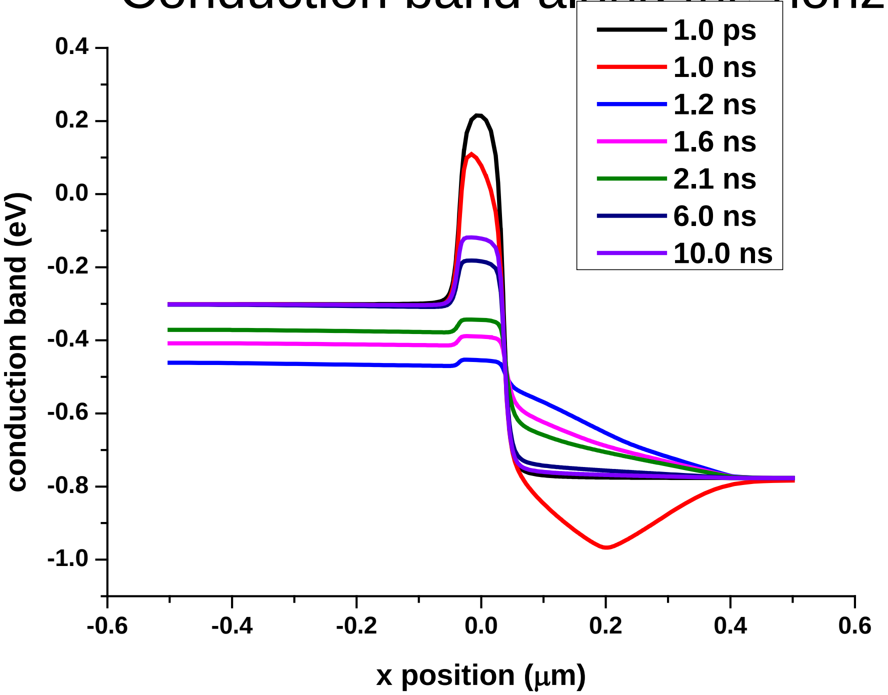


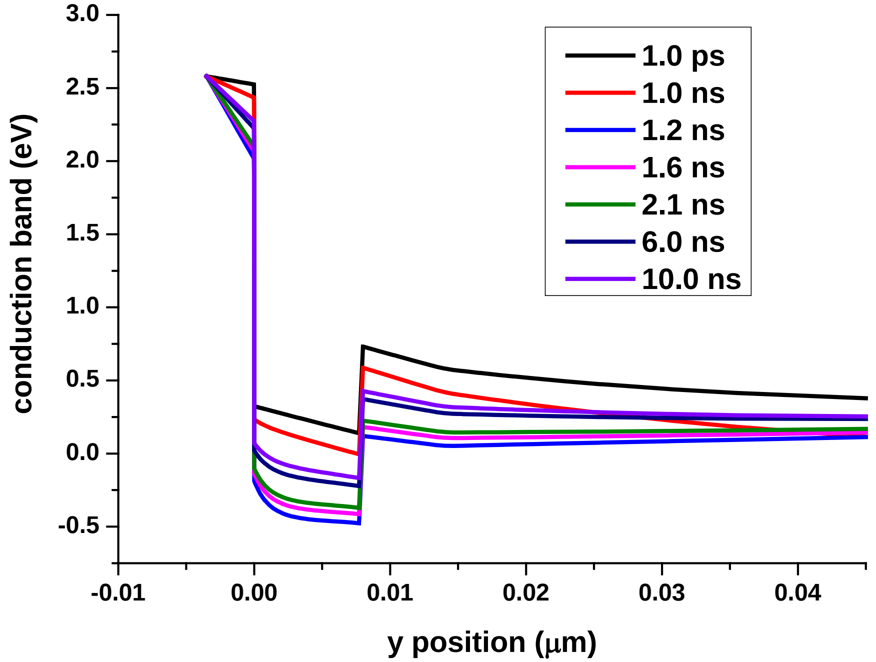


- At 1.2 ns, the electric potential in the buffer recovers. Electrons and holes move to the channel layer. Only the channel layer is strongly perturbed

2D TCAD Simulation

- Conduction band along the horizontal cut and vertical cut

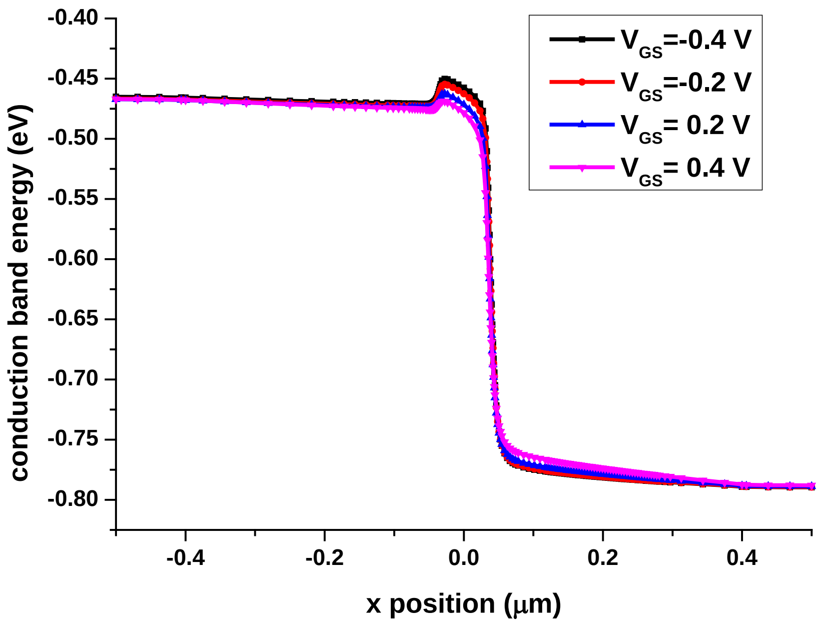


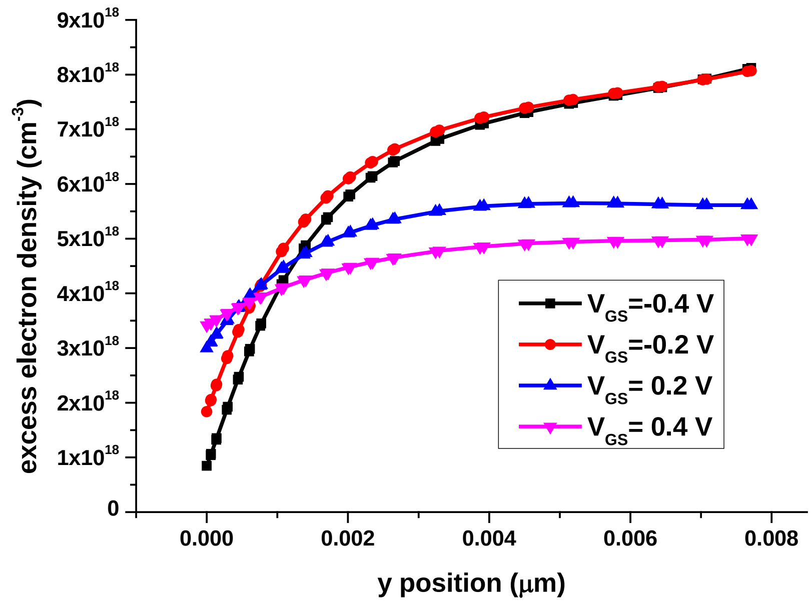


- Electric field exists before strike to stop holes entering channel, but it is almost zero after strike. Electrons and holes flood into the channel
- Electric potential is distorted around the strike location at the center of strike (1.0 ns) but recovers quickly
- At pre-strike, the source-channel barrier is 0.52 eV, but reduces to 0.03 eV at 1.2 ns. The device is ON
- The source-channel barrier is slowly recovered, which lasts for a few nanoseconds

2D TCAD Simulation

- Conduction band and excess electron density at different gate biases

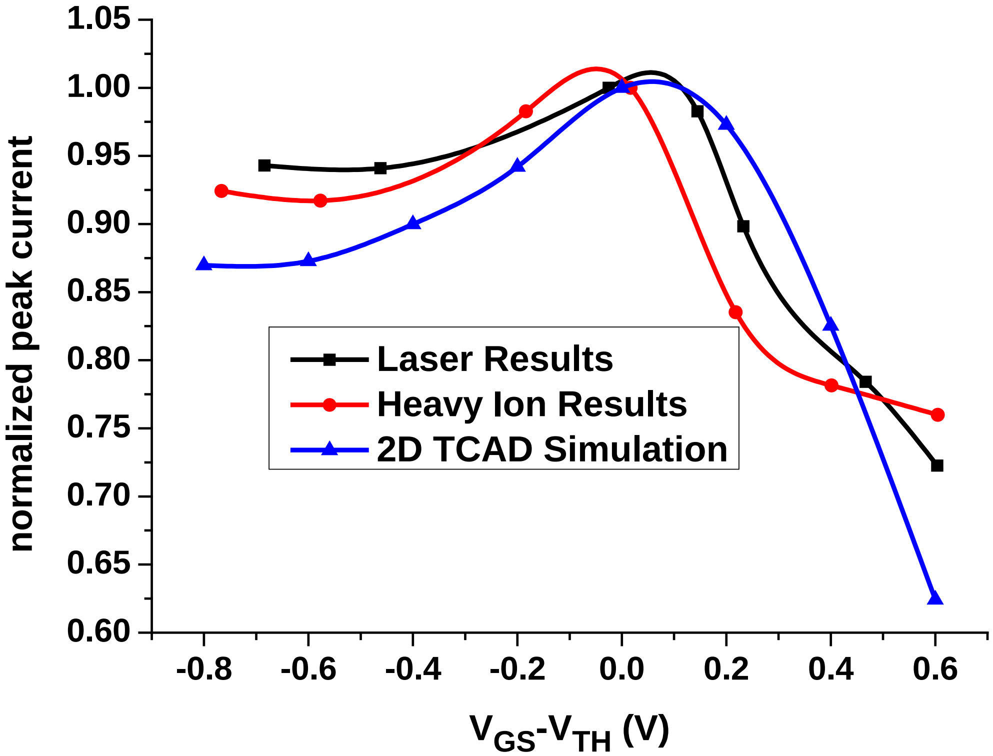




- The voltage drop along the channel region decreases with gate bias, leading to smaller horizontal electric field, hence smaller velocity
- The absolute excess electron density, the difference between post-strike and pre-strike electron density, reaches a maximum around threshold, decreases considerably in inversion and slightly in depletion and accumulation

Comparison

- Comparison of the gate bias dependence between heavy ion, laser and 2D TCAD simulation



- The heavy ion data, the laser data and 2D TCAD simulation data agree very well

Conclusion

- No gate transients due to large barrier for both electron and hole between gate dielectric and semiconductor
- The slow holes piling up under the gate and the source access region modulates the source channel barrier, turning ON the device and enhancing the collected charge
- The peak drain current is maximum for gate biases around threshold and decreases considerably in inversion and slightly in depletion and accumulation
- Depending on the application and the opportunities for remediation, these transient responses may impose limitations on the use of some types of alternative-channel materials in space applicaiton