The Effects of Total Ionizing Dose on the Transient Response of SiGe BiCMOS Technology

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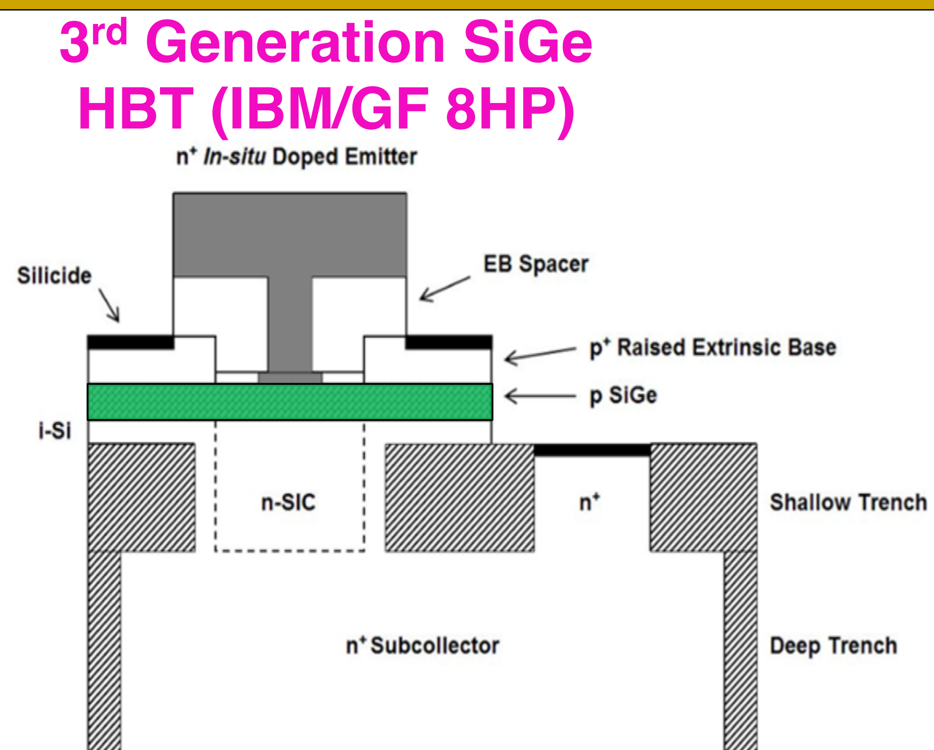
I. Motivation

- **SiGe Technology** (SiGe HBT + CMOS)
- **100% Si Compatible Manufacturing**
- **High-Speed** (RF, analog) **+ Integration**
- **Built-in TID Tolerance for HBT** (**Mrad!**)
- **SET Sensitivity for HBT + CMOS**

Key Question:

Is The Transient Response Affected by TID Exposure (SiGe HBT + CMOS)?

3rd Generation SiGe HBT (IBM/GF 8HP)



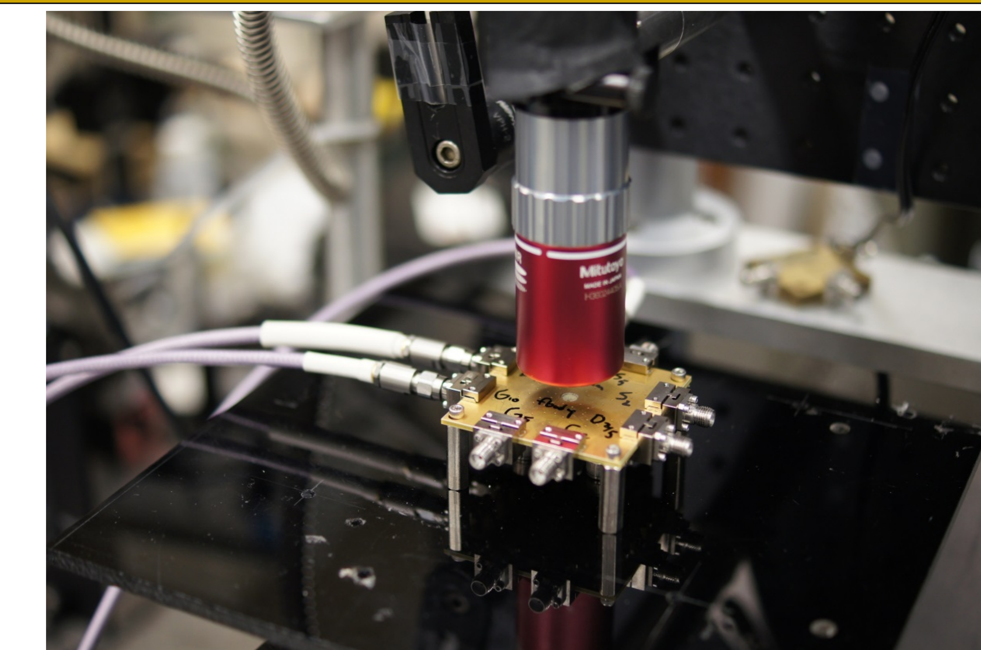
II. Measurement Setup

Measurement Facilities:

- **Total Ionizing Dose** (NRL)
  - ARACOR 10-keV X-ray source
  - Dose rate of 60 krad(SiO_2)/min
- **Pulsed-Laser TPA for SET** (NRL)
  - Two Photon Absorption laser source
  - 1 μm FWHM spot size
  - SETs captured with high BW oscilloscope
  - Forward-active bias for NPN
  - nFET in saturation mode

Device Test Structures:

- GlobalFoundaries' 8HP SiGe BiCMOS
- *npn* SiGe HBT (0.12 x 0.58 μm^2)
- nFET (W/L=10/0.12 μm)
- Biased to worst case conditions for TID



High-frequency PCB mounted on The NRL TPA measurements station.

III. Total Ionizing Dose Response

TCAD Modeling:

- 3-D nFET TCAD Model (Sentaurus)
- Calibrated to PDK
- Illustrates Leakage Mechanism
- HBT minimal change in leakage

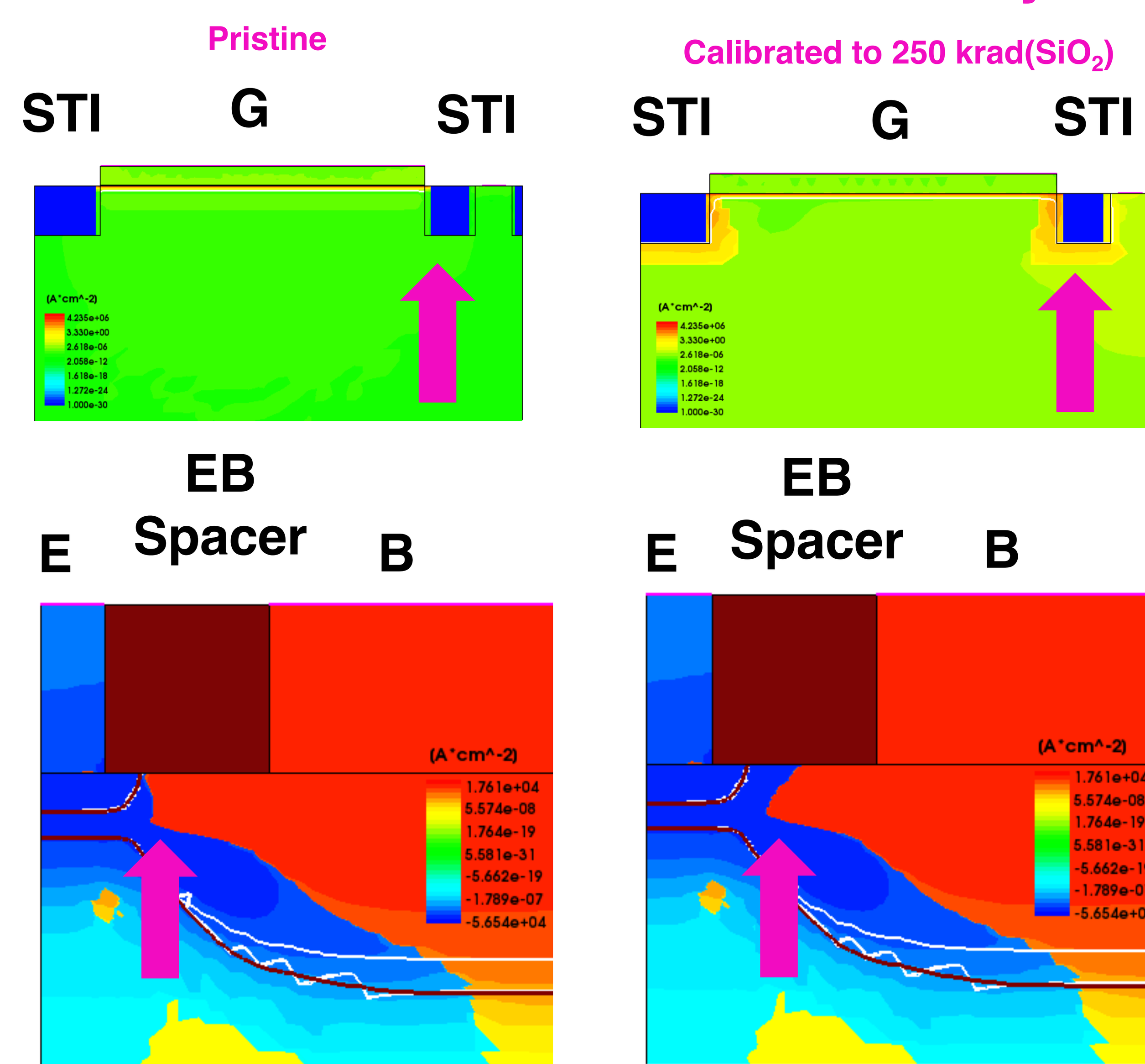
nFET X-ray TID Results:

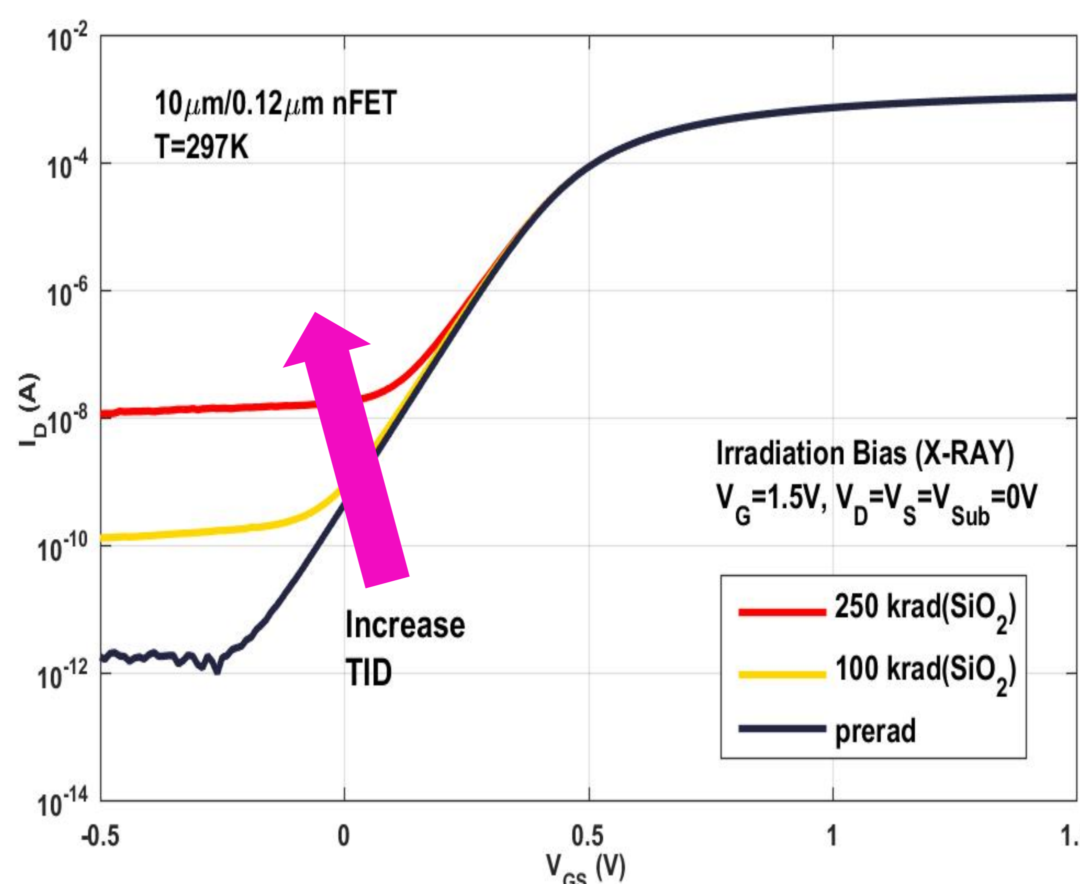
- Minimal Damage to Gate Oxide
- V_{TH} and g_m unchanged
- Off-state Leakage
  - traps at STI edge
  - shunt leakage path

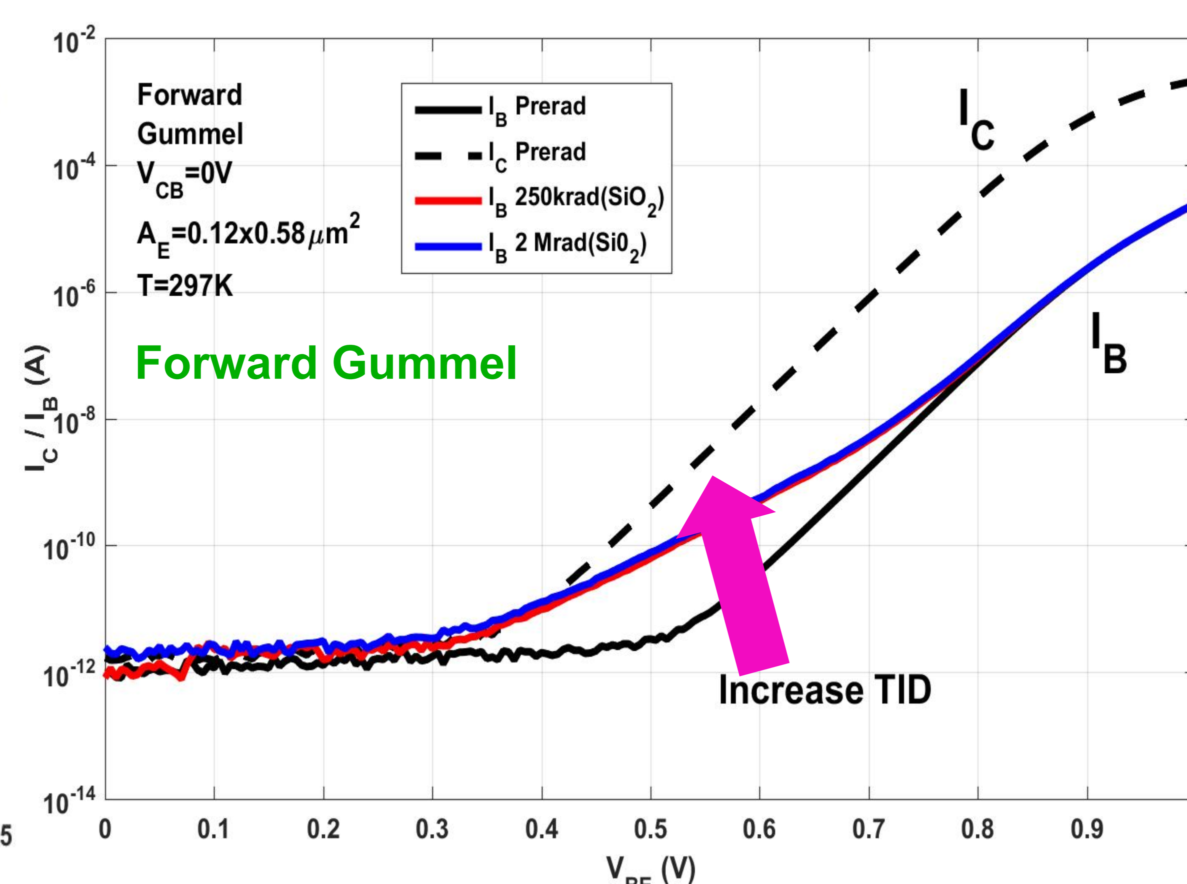
HBT X-ray Results:

- accumulation of traps at EB spacer
- increase in I_B at low injection
- excess recombination current

Simulated Hole Current Density



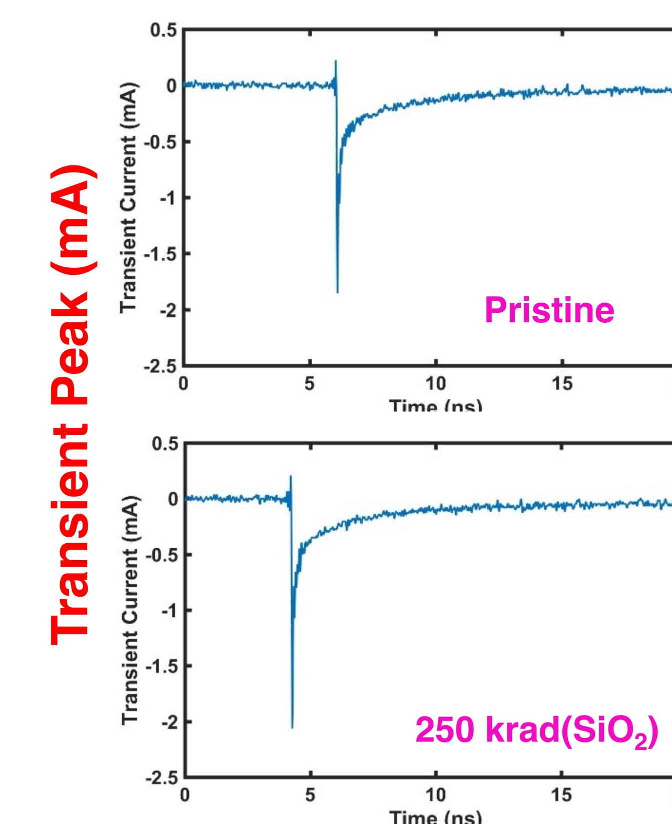


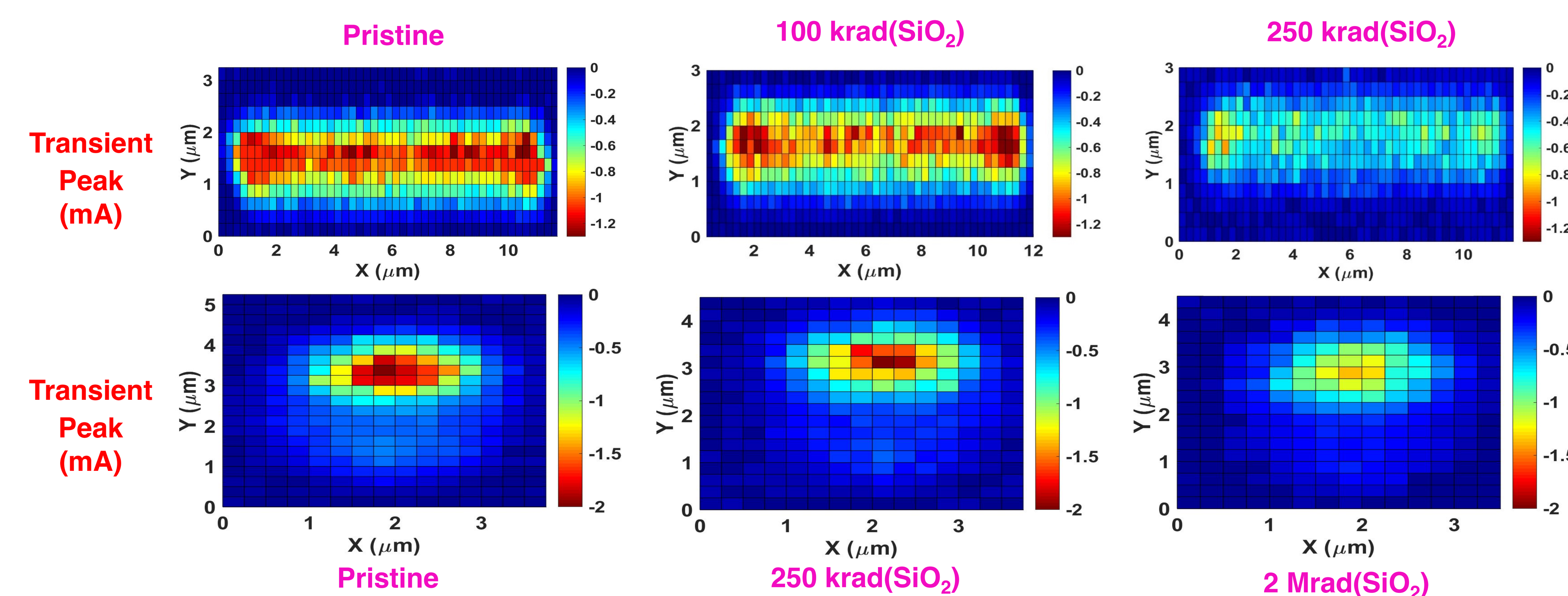


IV. Single Event Transient Response

Single Event Transient Observations:

- **nFET Transient Response Improves as a Function of TID**
  - decrease in transient peak at output node (drain)
  - full transient duration decrease
- **SiGe HBT Transient Response Improves as a Function of TID**
  - decrease in transient peak at output node (collector)
  - full transient duration decrease
- **TCAD Simulations Match Leakage Mechanisms**
  - STI sidewall shunt leakage path for nFET
  - EB leakage path for SiGe HBT





V. Summary

- **First Investigation of Impact TID on SET in SiGe BiCMOS**
- **HBT Can Tolerate Much Higher TID Level than nFET**
- **No Change in SET Response in HBT at Highest nFET TID Level**

1. M. T. Wachter. The Effects of Total Ionizing Dose on the Transient Response of SiGe BiCMOS Technology, presented at *2016 16th European Conference on Radiation and its Effects on Components and Systems.*