Radiation-Induced Current Transients in SiGe HBTs

Jonathan A. Pellish[1], R. A. Reed[1], D. McMorrow[2], J. S. Melinger[2], J. A. Kozub[3], P. W. Marshall[4], A. K. Sutton[5], R. M. Diestelhorst[5], S. Phillips[5], J. D. Cressler[5], N. D. Pate[1], R. A. Weller[1], R. D. Schrimpf[1], A. D. Tipton[1], and G. F. Niu[6]

1: Department of Electrical Engineering and Computer Science, Vanderbilt University, Nashville, TN USA
2: Naval Research Laboratory, Washington, DC USA
3: Free Electron Laser Center, Vanderbilt University, Nashville, TN USA
4: Consultant, Brookneal, VA USA
5: School of Electrical and Computer Engineering, The Georgia Institute of Technology, Atlanta, GA USA
6: Electrical and Computer Engineering Department, Auburn University, Auburn, AL USA

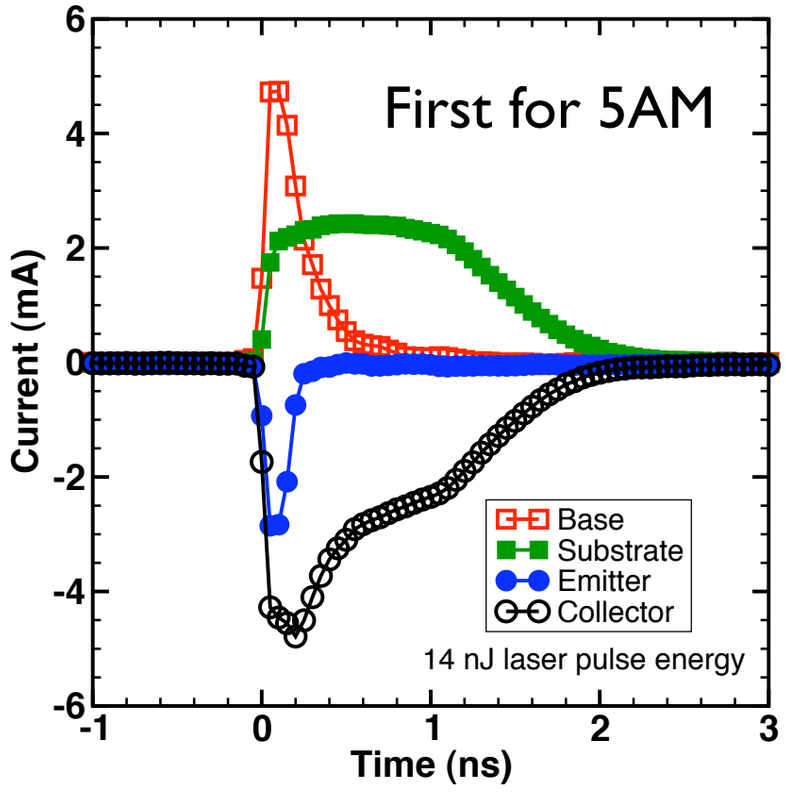
jonathan.a.pellish@vanderbilt.edu

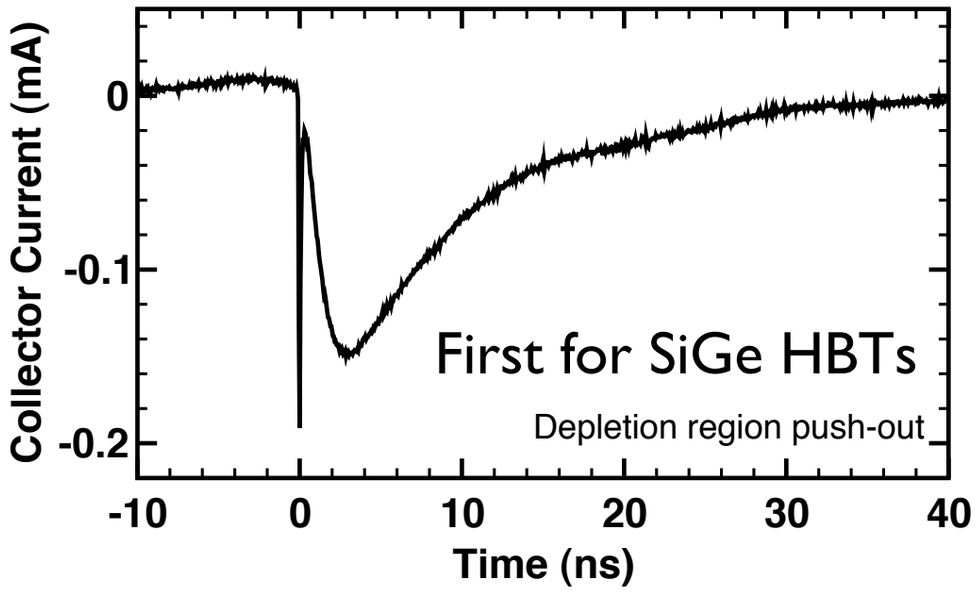
Acknowledgement

- Support provided by:
  - Air Force Office of Scientific Research
  - NASA Electronic Parts and Packaging Program
  - Georgia Electronic Design Center
  - NASA ETDP RHESE Program
  - DTRA Radiation Hardened Microelectronics Program
  - Naval Research Laboratory
- Thanks to the SiGe Team at IBM

Presentation Synopsis

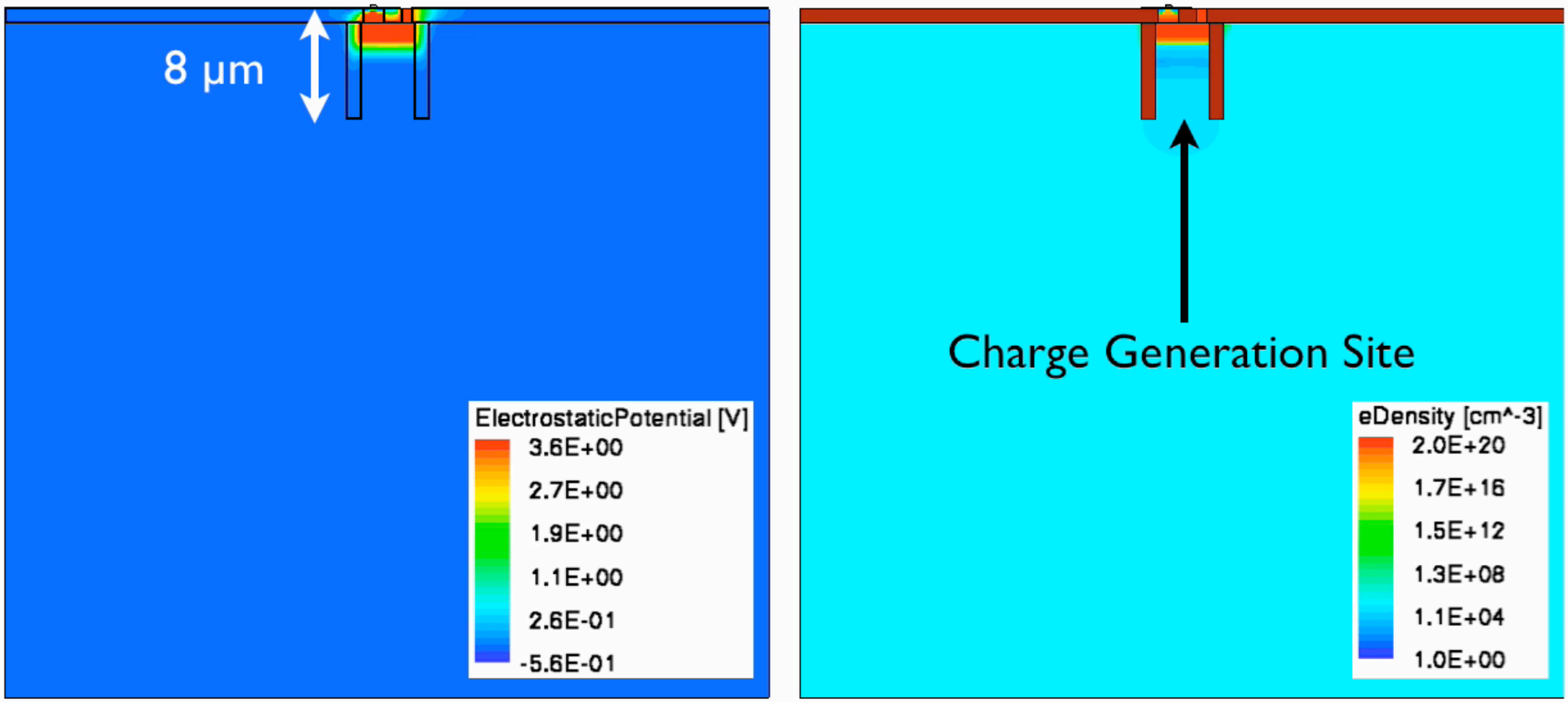
- Demonstrate need to measure current transients
- Describe relevant aspects of test vehicle: IBM 5AM SiGe HBT
- Utilize two-photon absorption as radiation source
- Validate heavy ion burst error data with measured transients
- Confirm substrate potential modulation in SiGe HBTs





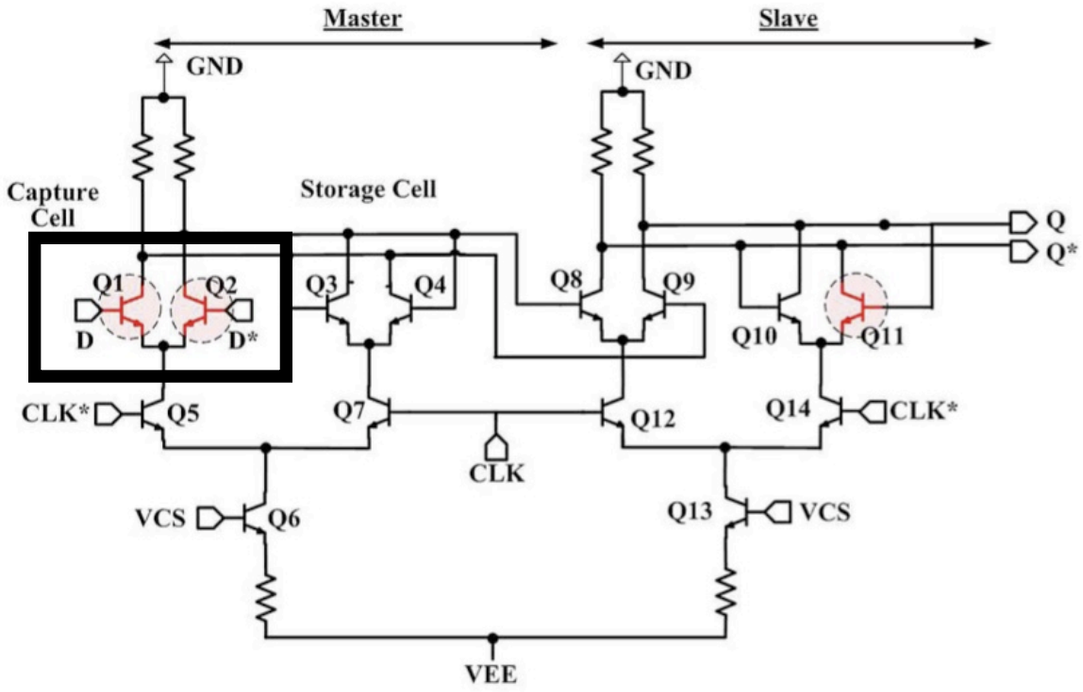
SiGe HBT Substrate Potential Modulation

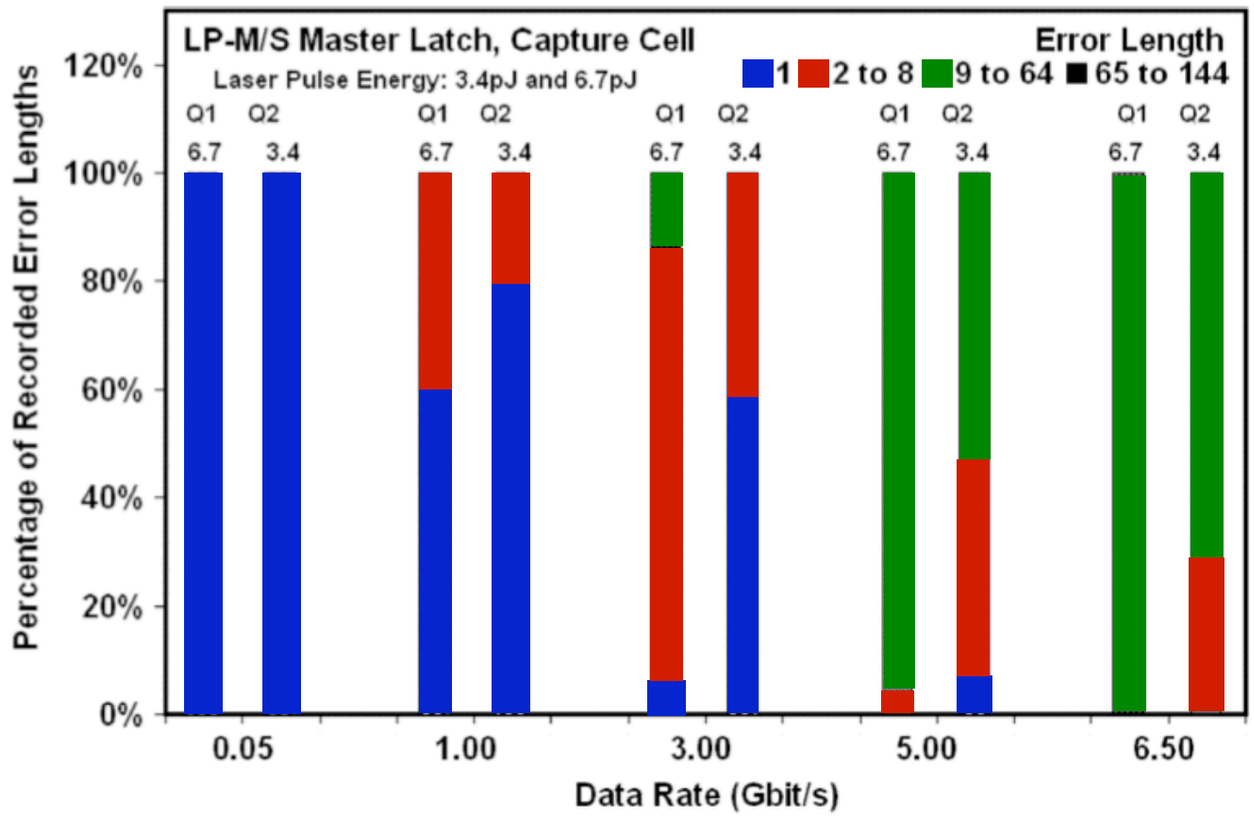
1.0×10^{-14} s



Setup is similar to laser-induced carrier generation

Time-Profile Matters: Laser-Induced Burst Errors

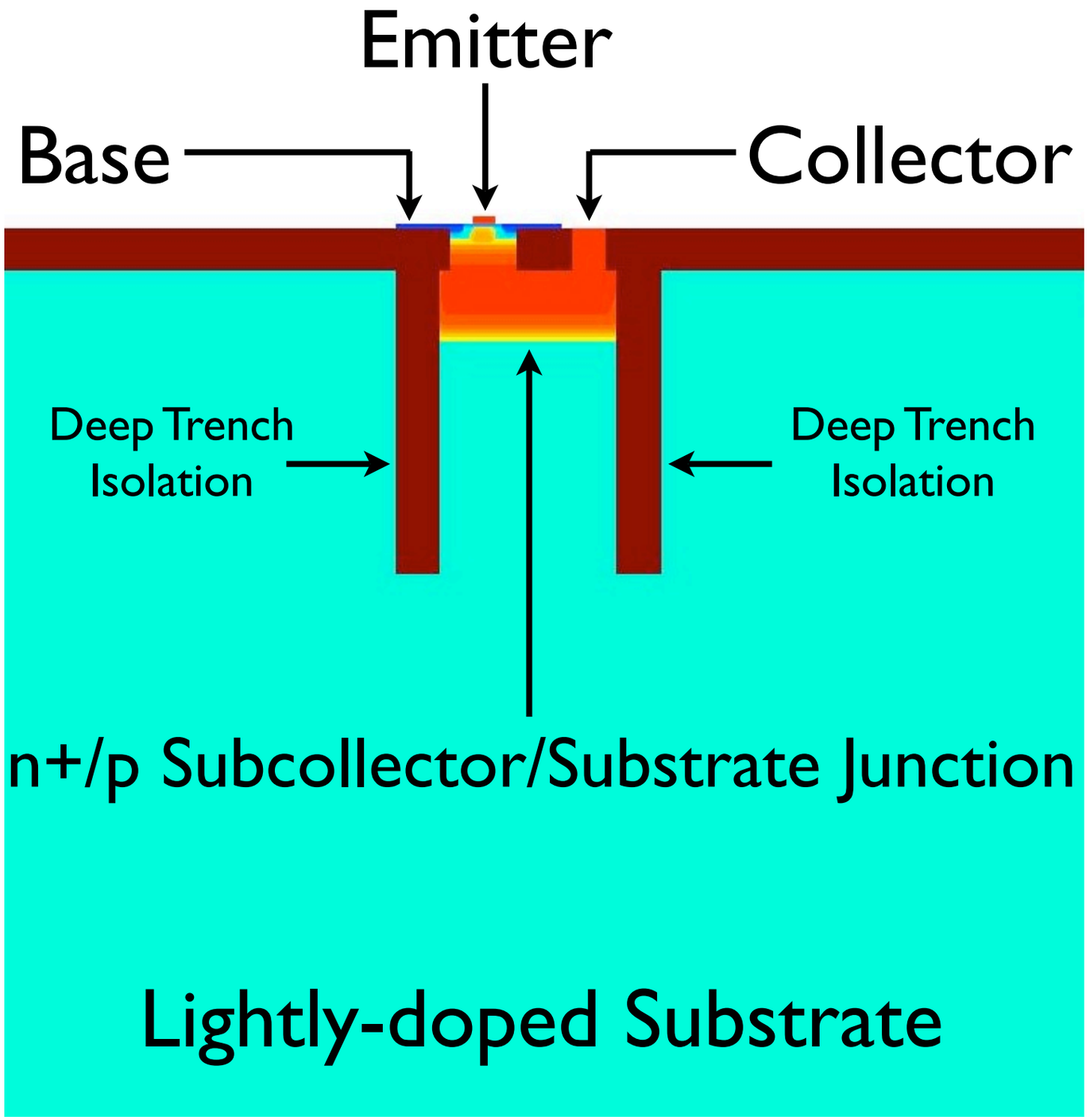




A. K. Sutton, *et al.*, "SEU error signature analysis of Gbit/s SiGe logic circuits using a pulsed laser microprobe," *IEEE Trans. Nucl. Sci.*, vol. 53, pp. 3277-3284, Dec. 2006.

- Same laser pulse in all equal-energy cases
- Error length and composition changes with data rate
- Depends explicitly on current pulse characteristics

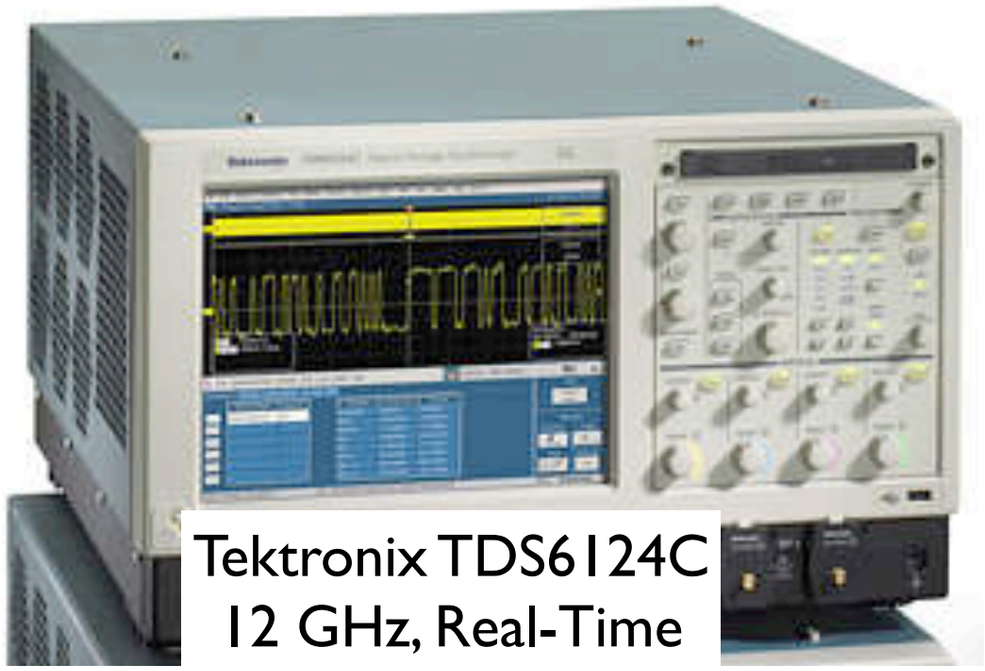
Radiation Relevant Features of SiGe HBTs



IBM 5AM SiGe HBT

- Attention focused on the process features that dominate the single-event response
- Also the features that dominate the transient response

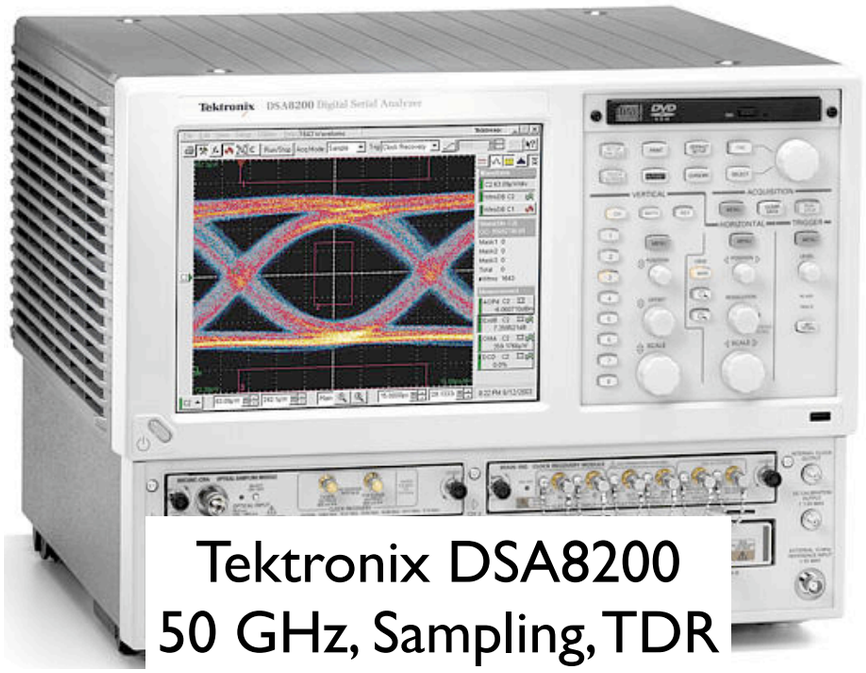
High-Speed Measurement Systems



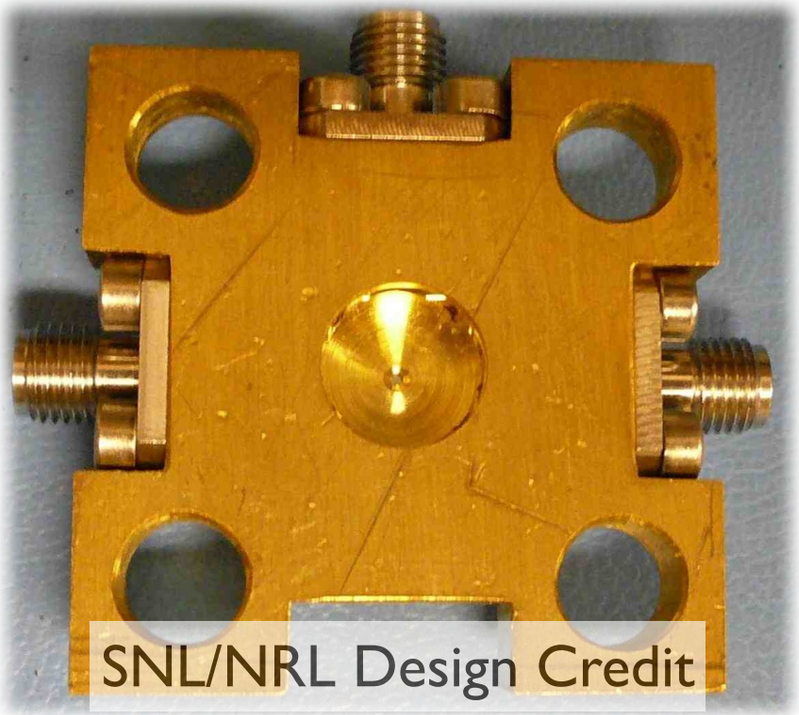
Tektronix TDS6124C
12 GHz, Real-Time

SNL/NRL Design Credit

40 GHz



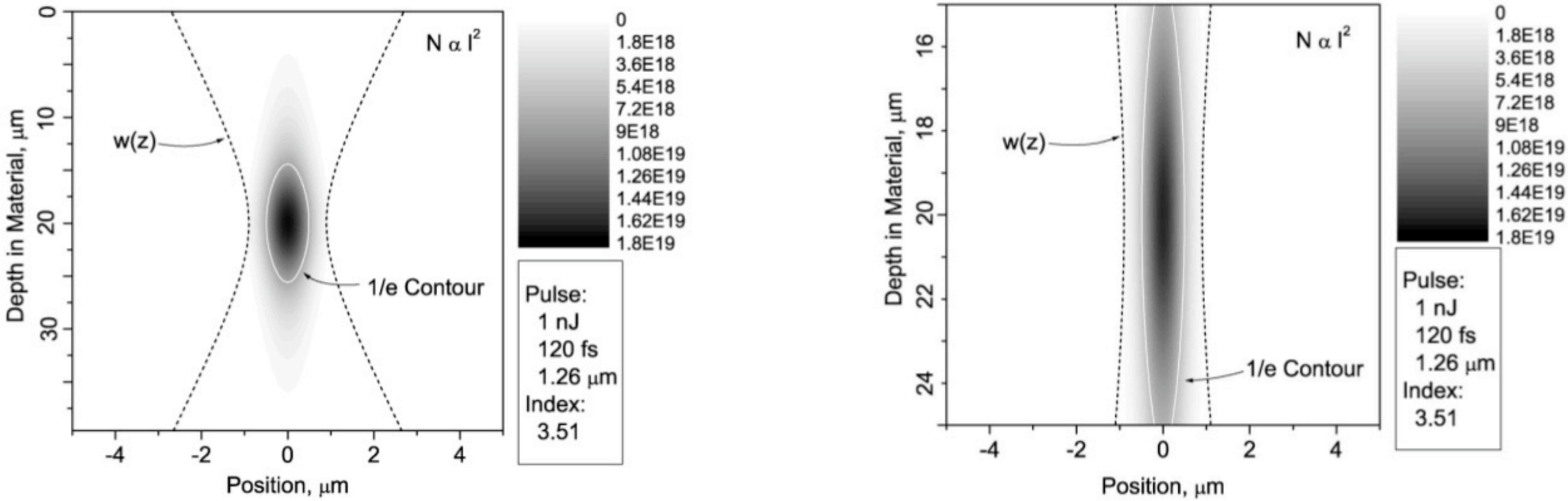
Tektronix DSA8200
50 GHz, Sampling, TDR



SNL/NRL Design Credit

2.92 mm

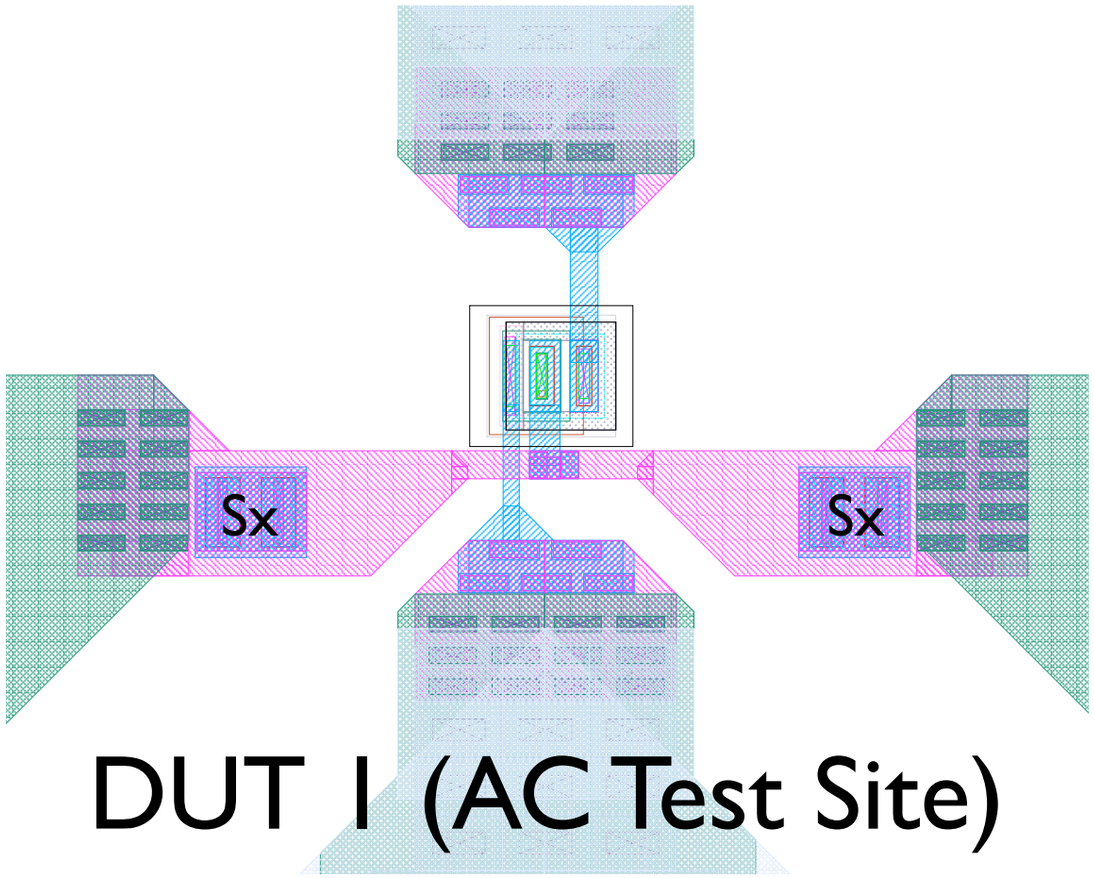
Two-Photon Absorption Generation



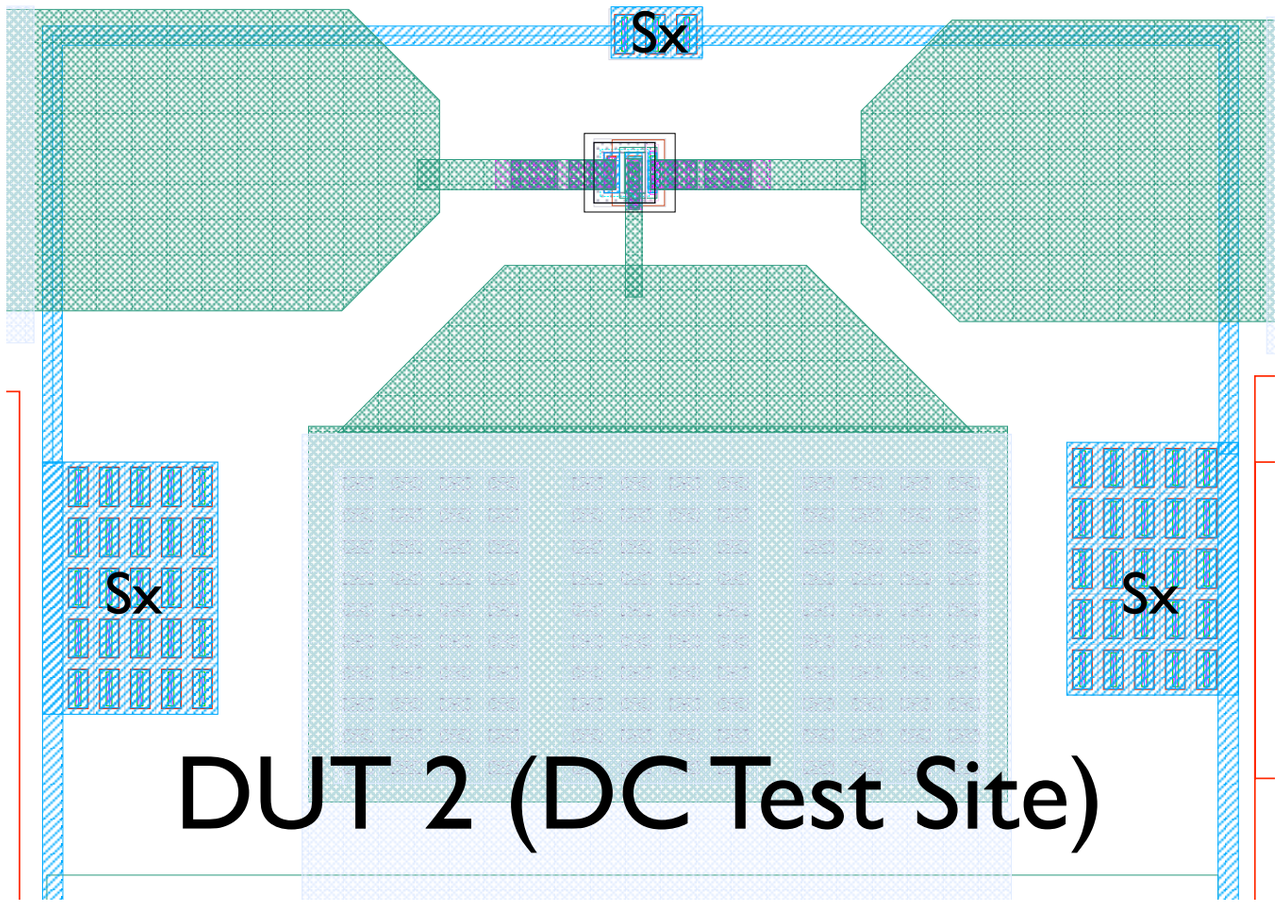
D. McMorrow, *et al.*, "Subbandgap laser-induced single event effects: carrier generation via two-photon absorption," *IEEE Trans. Nucl. Sci.*, vol. 49, pp. 3002-3008, Dec. 2002.

- 1260 nm wavelength (non-linear absorption)
- Irradiate through the backside of the die (no BEOL)
- Allows for 3-D response mapping

SiGe HBT Devices Under Test



DUT 1 (AC Test Site)

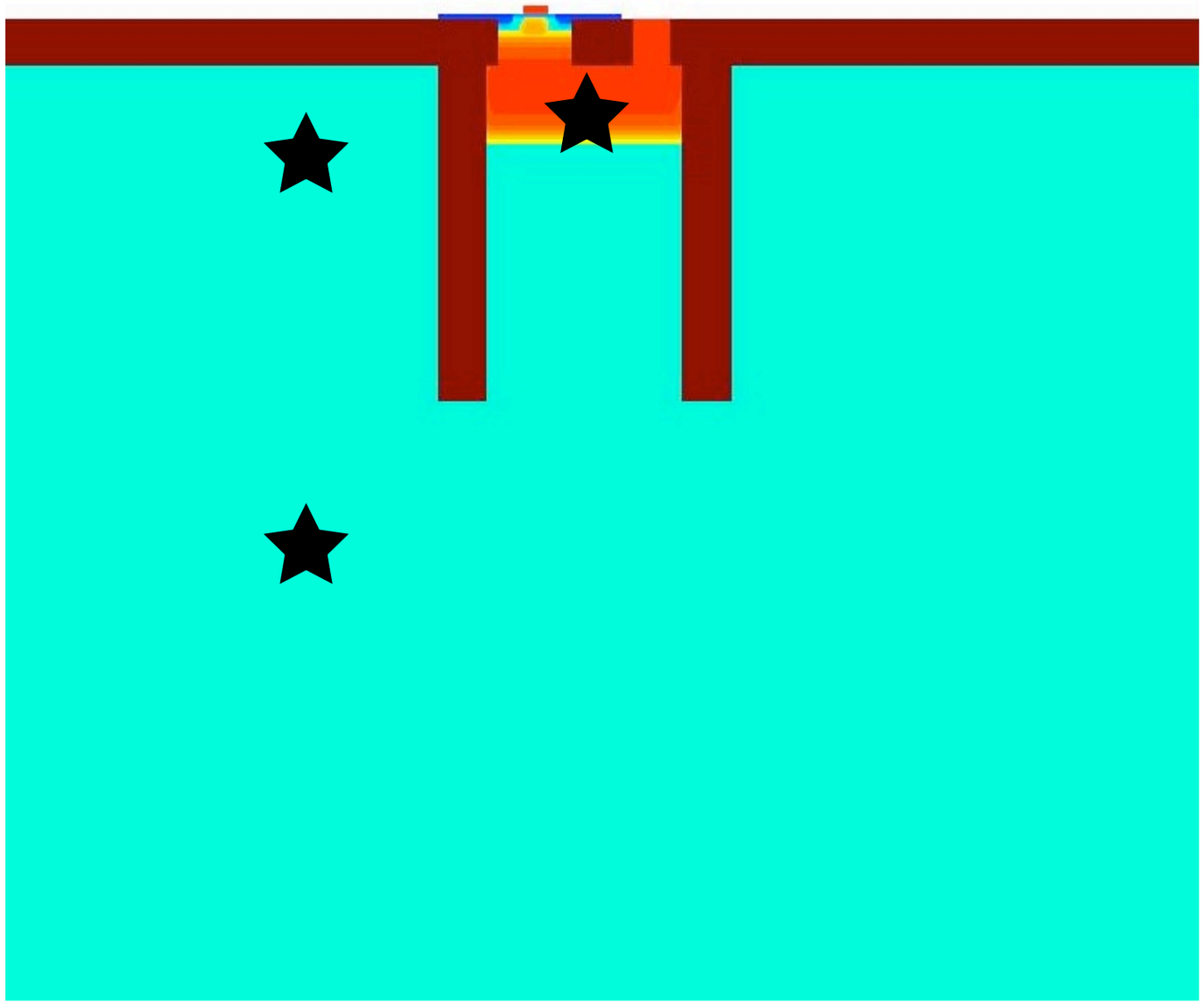


DUT 2 (DC Test Site)

Drawings are not on the same scale

Same 0.5×2.5 μm² emitter geometry
Different substrate contact and metal routing schemes

Two-Photon Laser-Induced Transients



<u>DUT 1</u>

3 V dropped across the subcollector junction

<u>DUT 2</u>

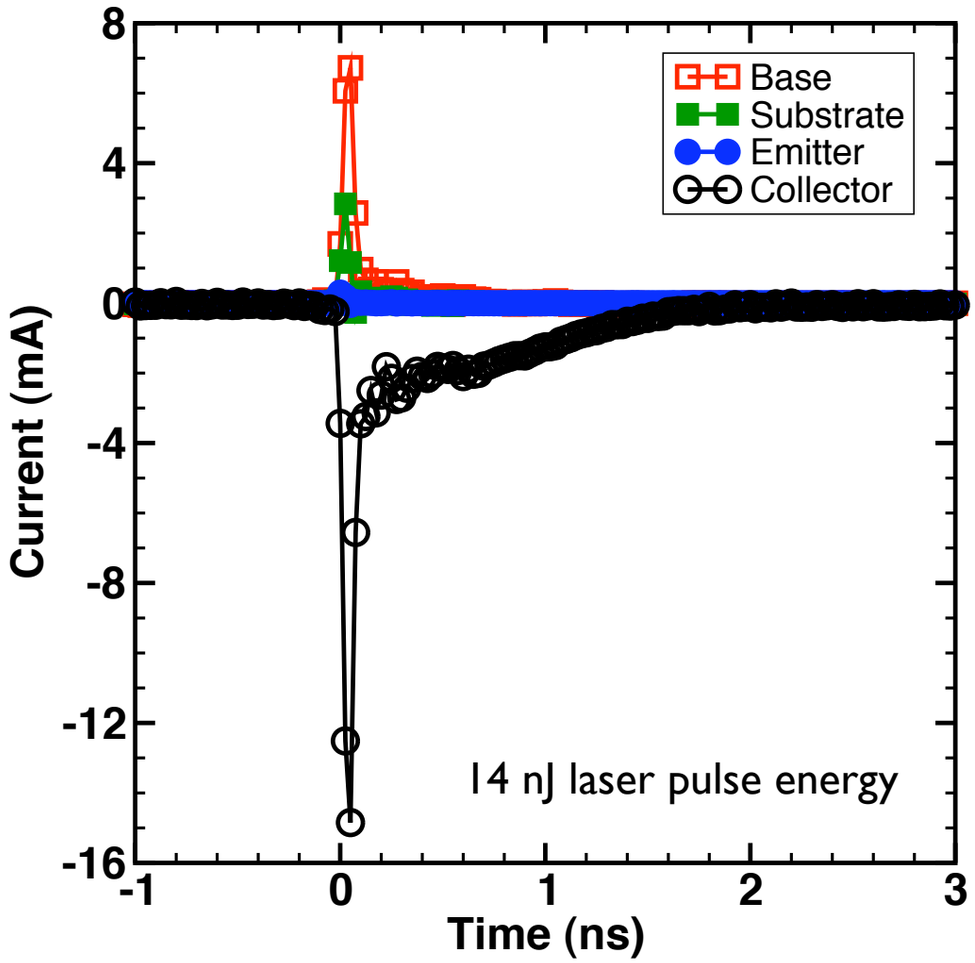
4 V dropped across the subcollector junction

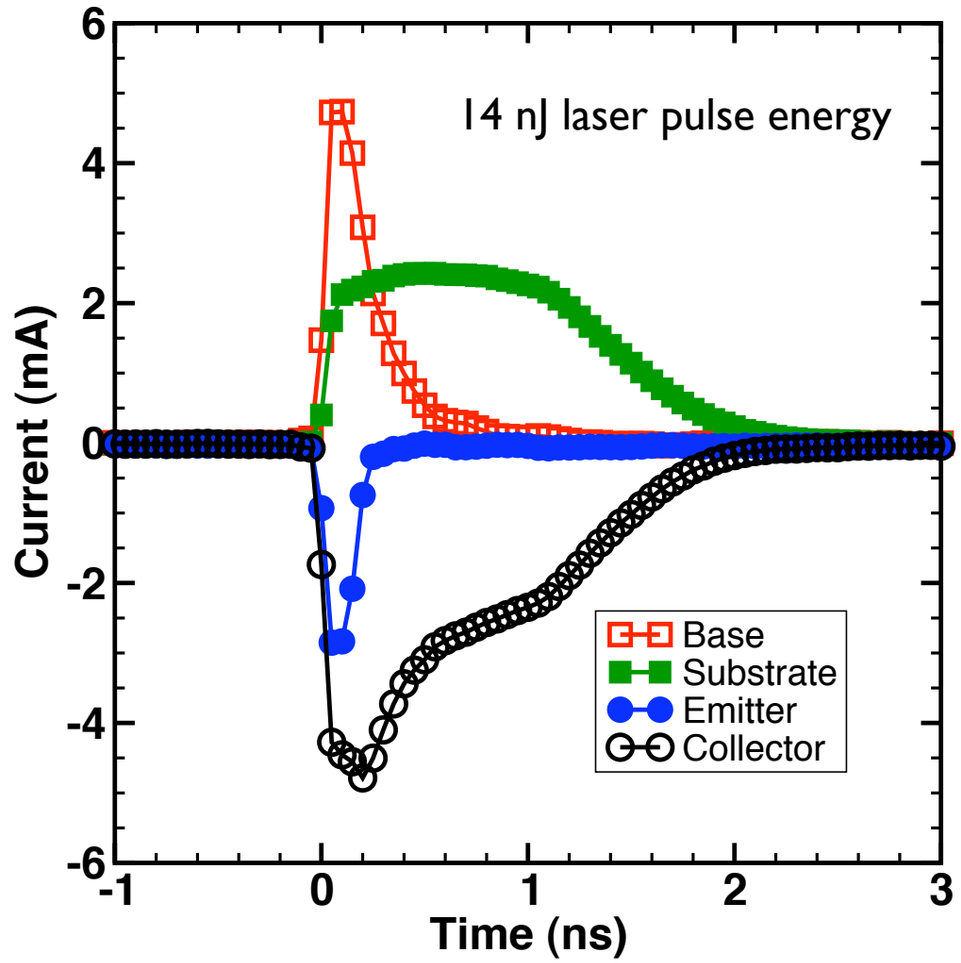
All other terminals grounded

3 Strike Locations

Data collected at the Naval Research Laboratory

Two-Photon Laser-Induced Transients

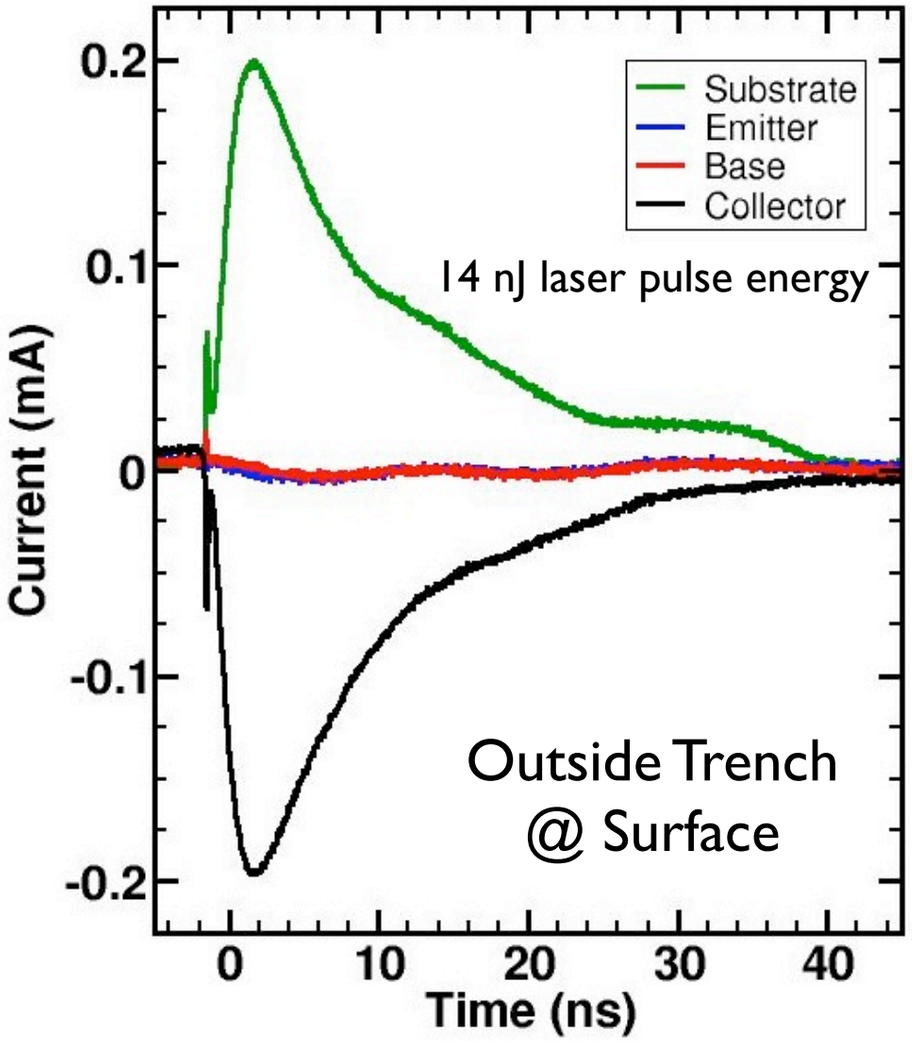




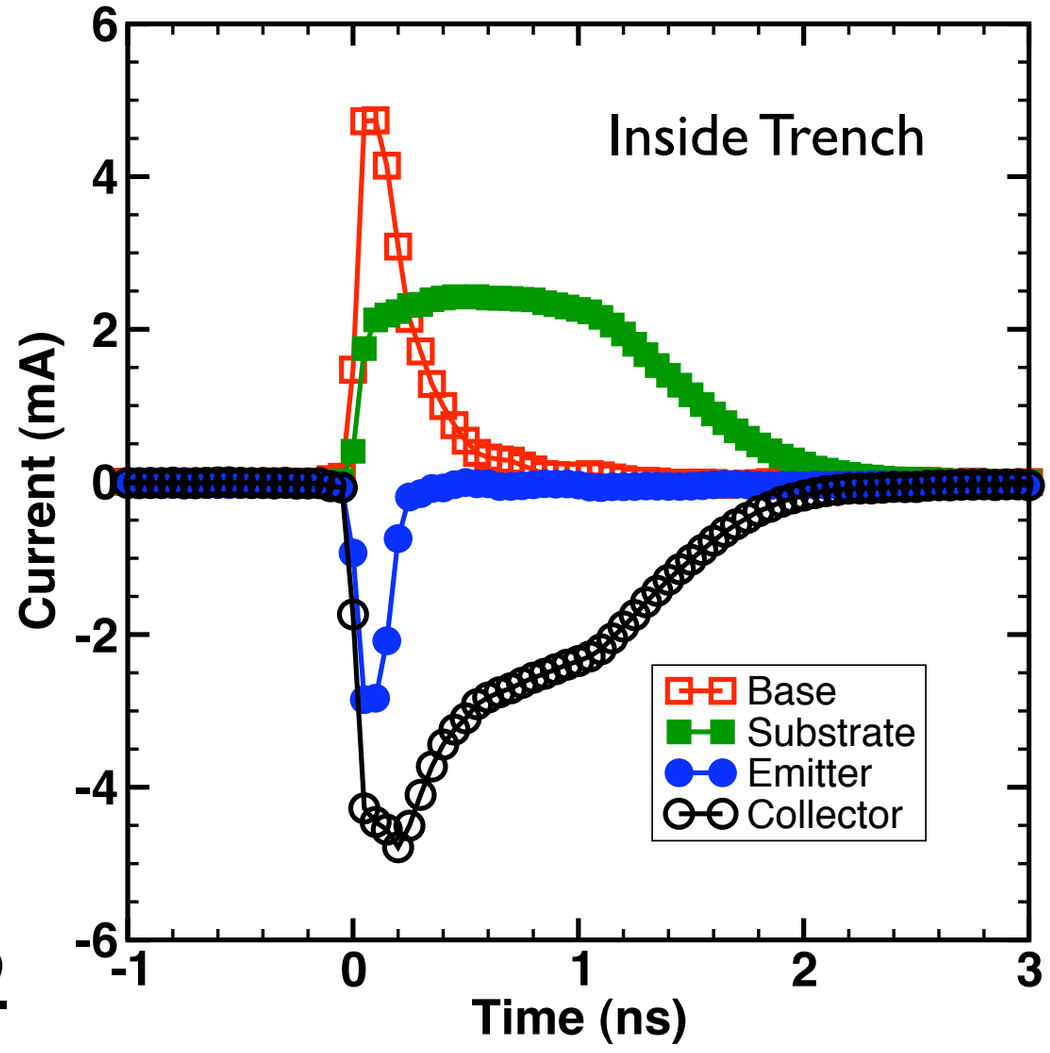
DUT 1 Inside Trench DUT 2

Compared to DUT 2, DUT 1 collector fall time is shorter by about 1.5x

Two-Photon Laser-Induced Transients

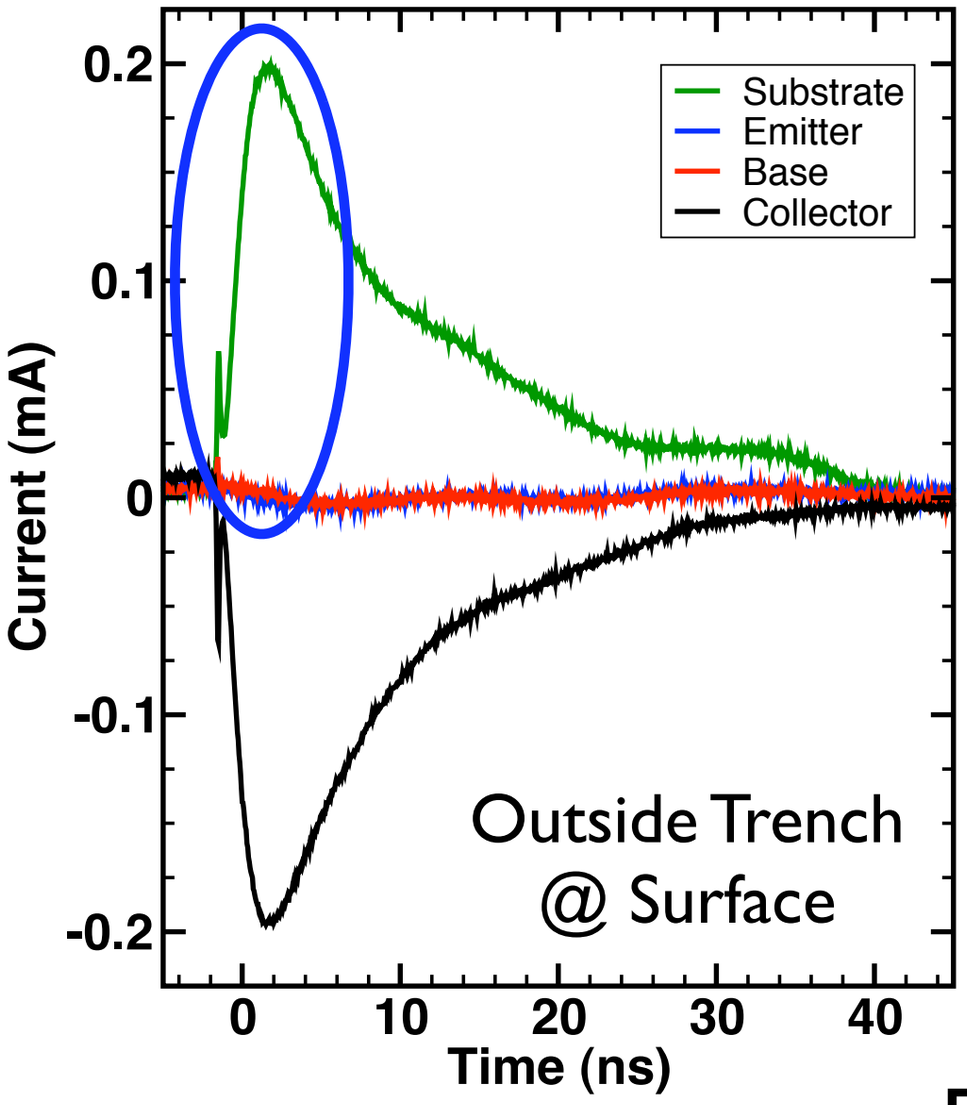


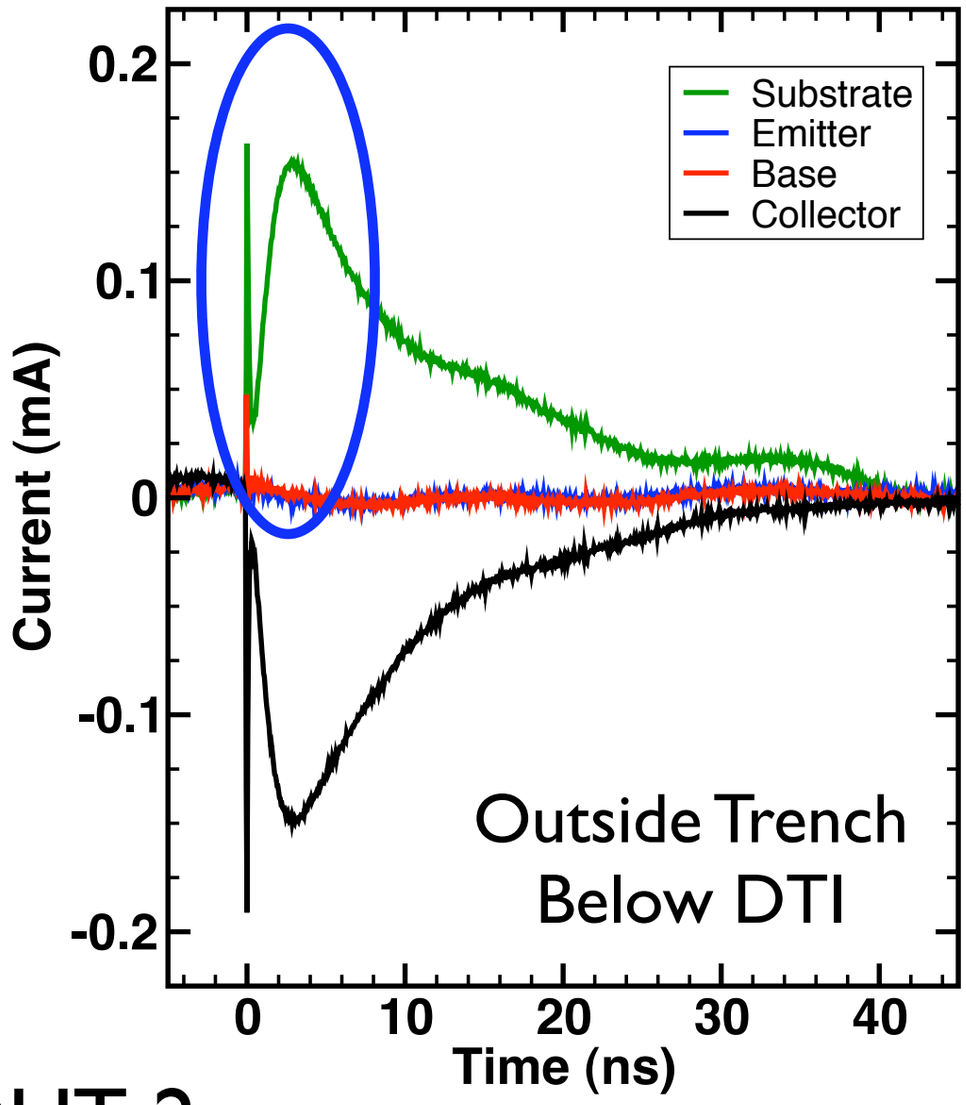
DUT 2



Transients originating outside the trench are consistent with diffusion processes (location- and energy-dependent)

Two-Photon Laser-Induced Transients





DUT 2

Measured evidence of substrate potential modulation

Conclusions

- The detailed characteristics of radiation-induced current transients are important for both high-speed and scaled technologies
- SiGe HBT radiation-induced transients are driven by the substrate doping, deep trench isolation, subcollector/substrate junction, and surrounding environment
- Substrate potential modulation in SiGe HBTs is a function of process, generation location, and energy