SiGe Research Activities

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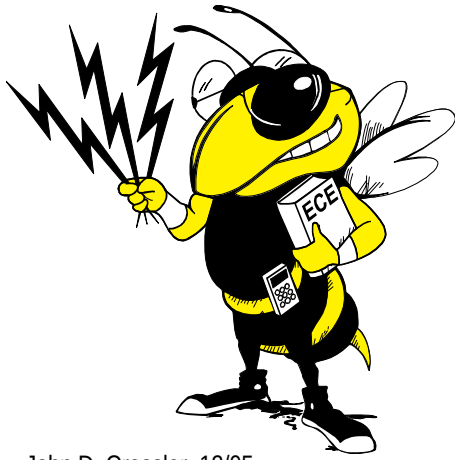

SiGe: Why The Fuss?

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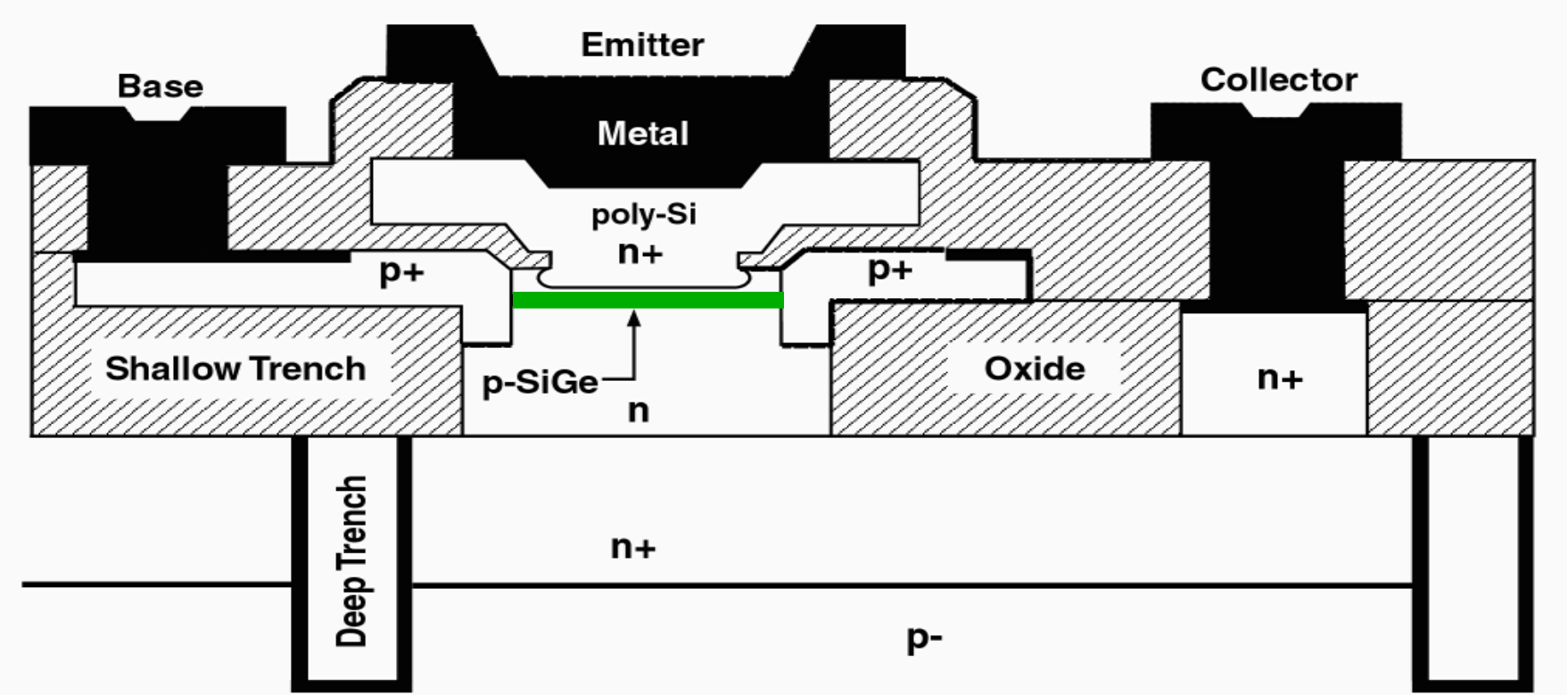
- **21st Century Communications Market**
  - wireless + wireline + transportation + satellites + radar + other DoD + …
  - ⇨ **frequency bands are pushing ever higher**
  - ⇨ **huge market but stringent device requirements**

Moral: Need High-Performance Device Technology at Low-Cost!

- **The SiGe HBT**
  - first bandgap-engineered Si transistor (nanotechnology!)
  - better β, V_A, f_T, f_{max}, NF_{min} than Si BJT
  - III-V performance + Si fabrication yield and cost (win-win scenario!)
  - 200 GHz SiGe HBTs are a reality! … 300 GHz is on the way!
- **SiGe HBT BiCMOS Technology**
  - very high performance SiGe HBT + best-of-breed Si CMOS
  - RF/MMIC + analog + digital + passives for integrated SoC / SiP solutions
  - in production (e.g., IBM, Jazz, National, TI, ST, Infineon, Hitachi, etc…)

The SiGe HBT

- **Conventional Shallow and Deep Trench Isolation + CMOS BEOL**
- **Unconditionally Stable, UHV/CVD SiGe Epitaxial Base**
- **100% Si Fabrication Compatibility**
- **SiGe HBT + Si CMOS on the same wafer**



Performance Trends

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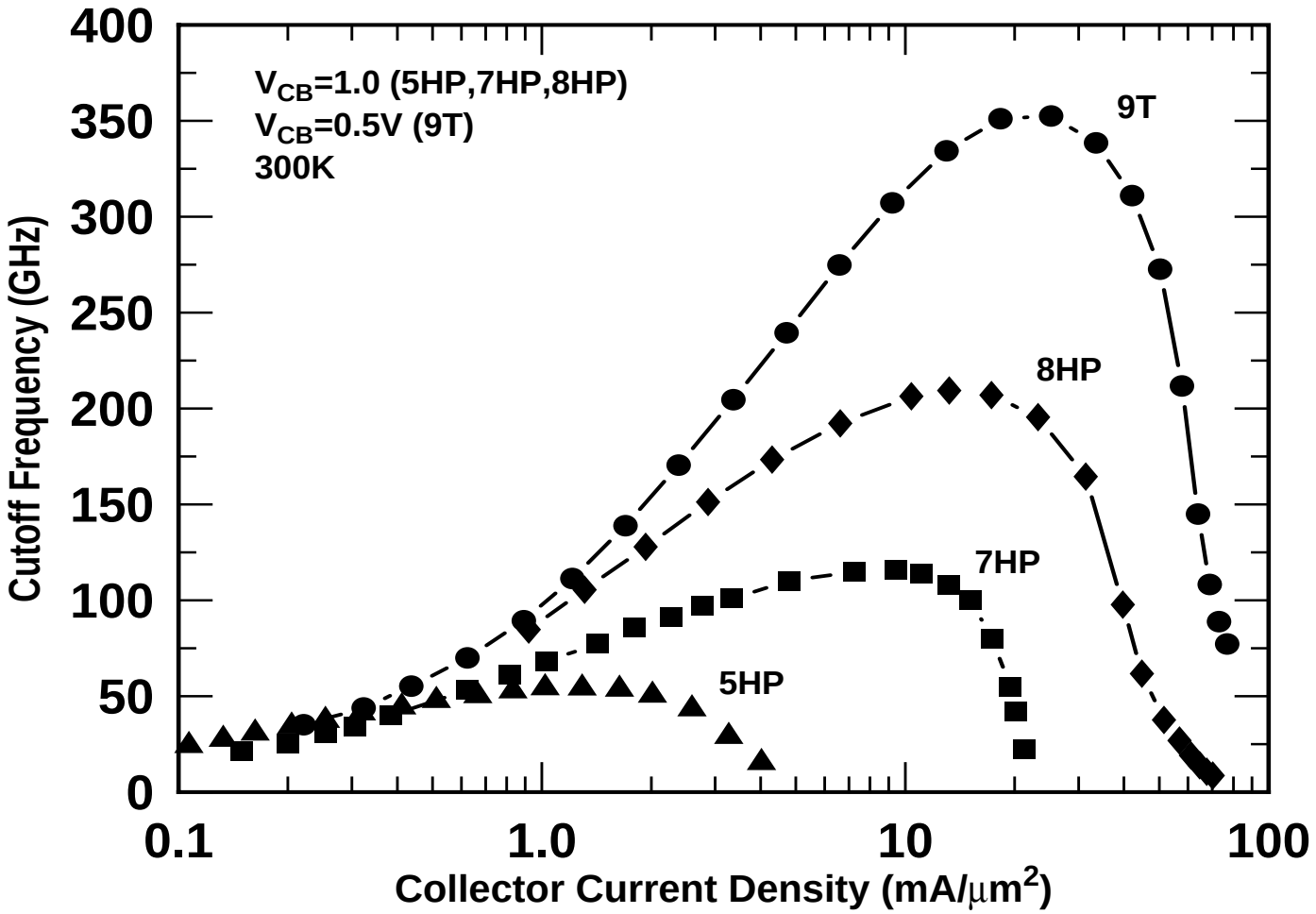
- **Unprecedented Device Performance in Si!**



Performance Trends

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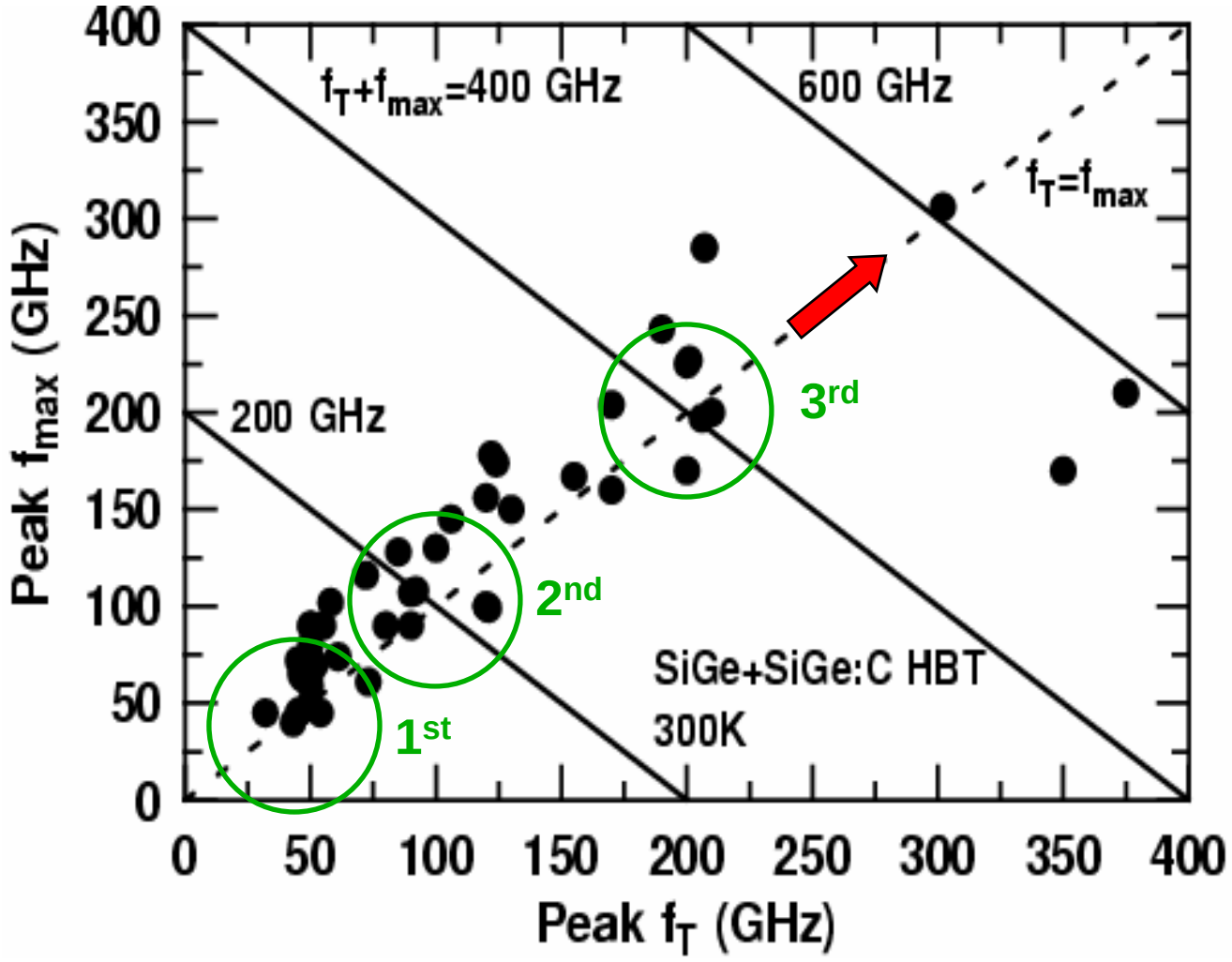
- **Generational Evolution (full BiCMOS)**



SiGe for Mixed-Signal

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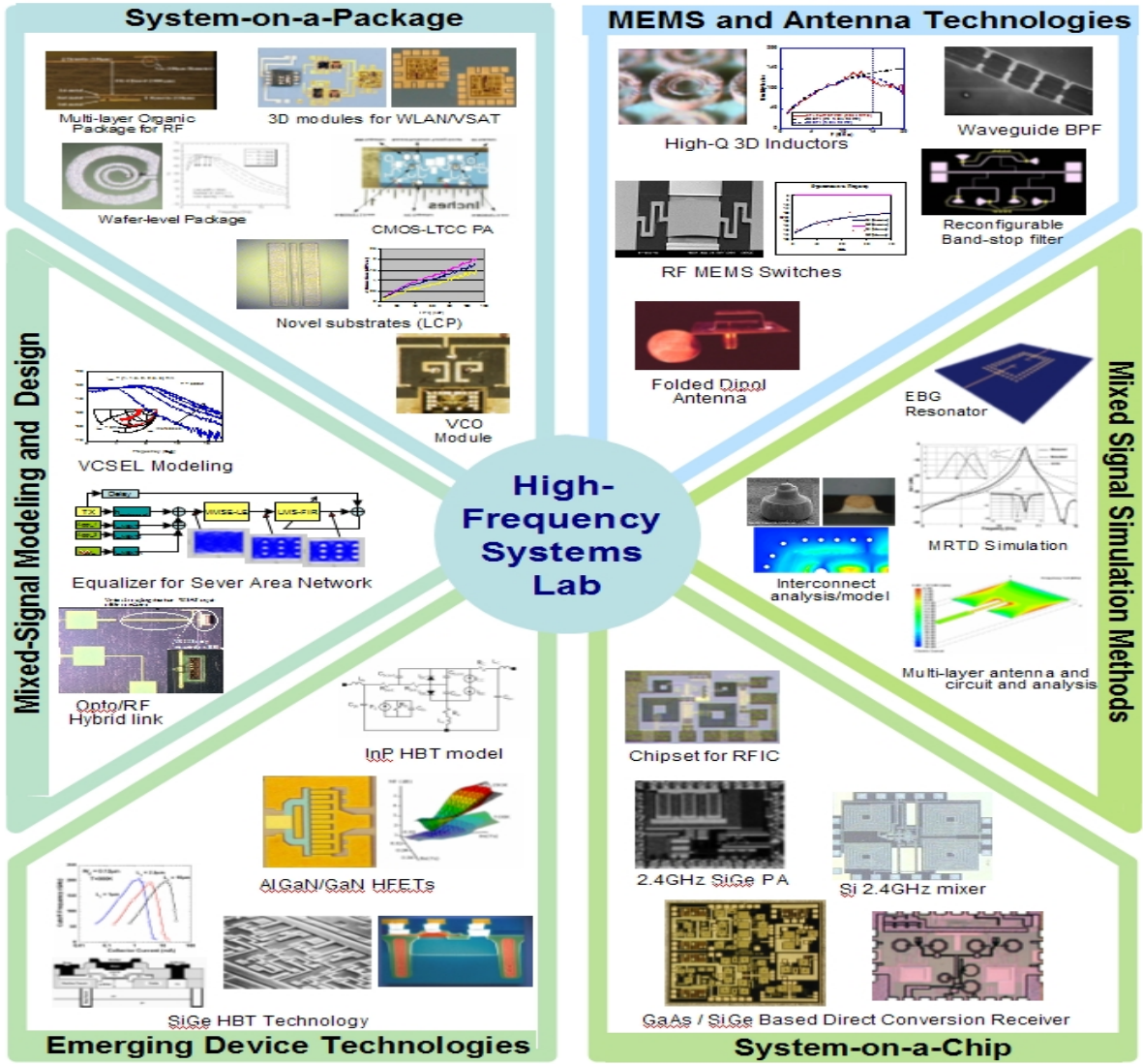
- **The Virtues of SiGe HBTs**
  - high g_m
  - low NF_{min}
  - very low power dissipation at NF_{min}
  - low 1/f noise corner + phase noise
  - very high output resistance and high βV_A product
  - very high frequency response (can trade f_T for power!)
  - high power gain
  - good linearity
  - potential for operation at cryogenic temperatures / high temperatures
  - all device parameters are in principle tunable!
  - high levels of integration + passives + t-lines
  - built-in total dose radiation tolerance
  - CMOS is already on-board to use where needed / beneficial

Moral: SiGe is a Natural for Mixed-Signal!

High-Frequency Systems Lab - Research Facilities -

The 5th Floor Team: Professors Laskar, Tentzeris, Papapolymerou, and Cressler

Theme: "Devices-to-Systems"



Research Specialties:

- *Device / Circuit Characterization*
- *Compact Modeling*
- *Device Optimization*
- *Analog / Digital / RF Circuit Design*
- *RFIC / MMIC Design*
- *Advanced Integrated Modules*
- *Packaging / Interconnects*
- *mm-wave Circuits / Modules*
- *Antennas*
- *Embedded Passives*
- *RF MEMS (Switches,Tunable Filters …)*
- *Computational Electromagnetics*
- *Transmission Lines*
- *Mixed-signal ICs / Systems for High-Speed Digital Applications*

High-Frequency Systems Lab - Research Facilities -

>$10 M

The 5th Floor Team: Professors Laskar, Tentzeris, Papapolymerou, and Cressler

- **Exhaustive Device and Circuit Characterization Capability**
- **dc – 100 GHz; 4K to 500C; fA to A, uV to kV**
- **Lab Manager Oversight**
- **Web-based Instrument Scheduling**

Research Program

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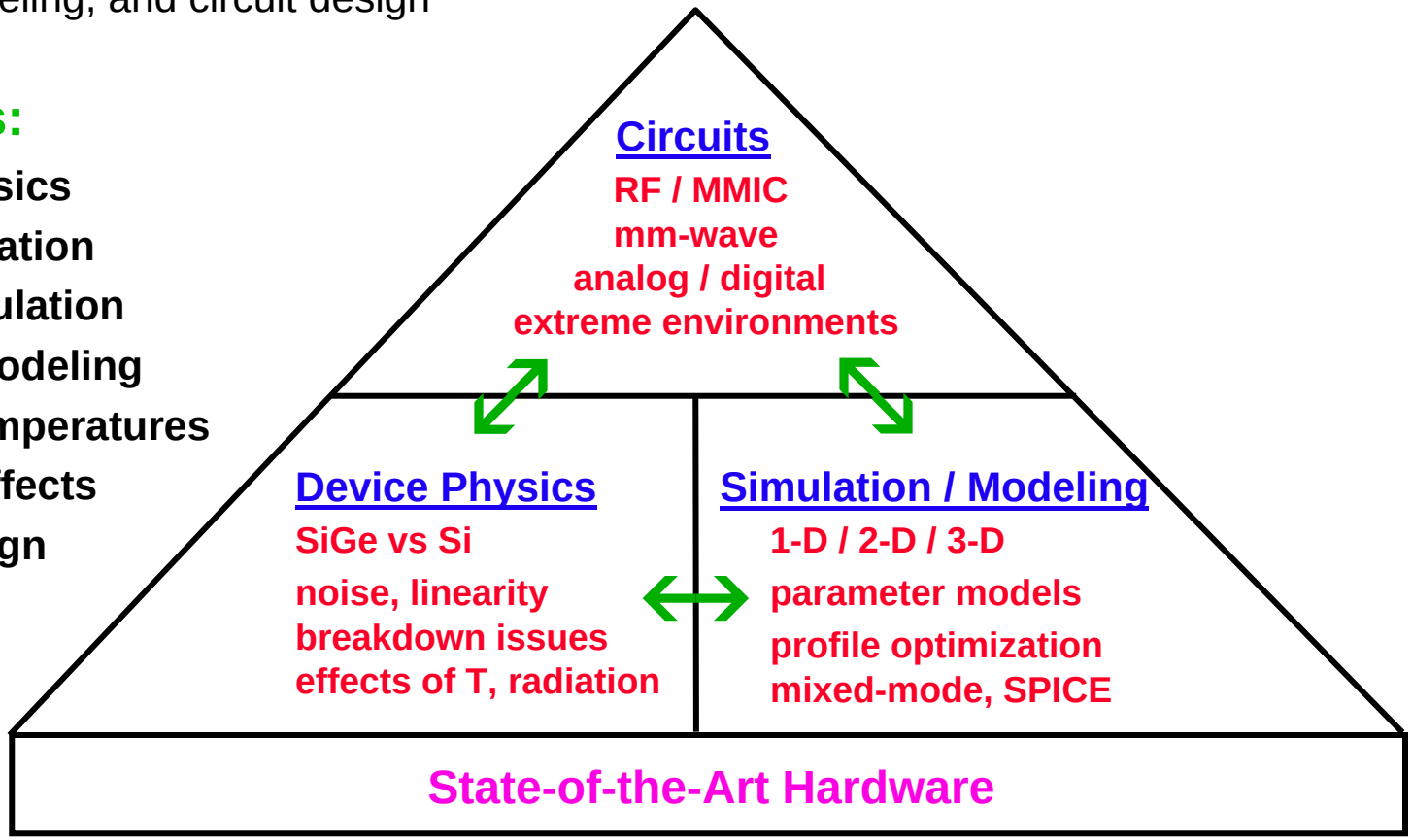
- **Focus:** **"SiGe Devices and Circuits"**

  Fundamental device physics, fabrication, device and circuit characterization, RF / microwave / mm-wave properties of devices, profile optimization for specific circuit / system applications, device-to-circuit interactions, device simulation, compact modeling, and circuit design

- **Specialties:**
  - **device physics**
  - **characterization**
  - **device simulation**
  - **compact modeling**
  - **extreme temperatures**
  - **radiation effects**
  - **circuit design**



New Opportunities

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- **SiGe Millimeter-wave Communications Systems**
  - **60 GHz ISM band (> 1Gb/sec wireless links)**
  - **wavelength at mm-wave enables monolithic antennae integration**
- **SiGe Radar Systems**
  - **defense theater radar (10 GHz)**
  - **automotive radar (24 GHz, 77 GHz, 94 GHz)**
- **SiGe Core Analog Functions**
  - **data converters (10Gb/sec 8 bit ADC!)**
  - **references, op-amps, drivers, etc.**
- **SiGe Extreme Environment Electronics**
  - **cryogenic temperatures** (e.g., to 77K or 4K)
  - **radiation** (e.g., space)
  - **high-temperatures** (e.g., to 200C or 300C)

Current Activities (10/05)

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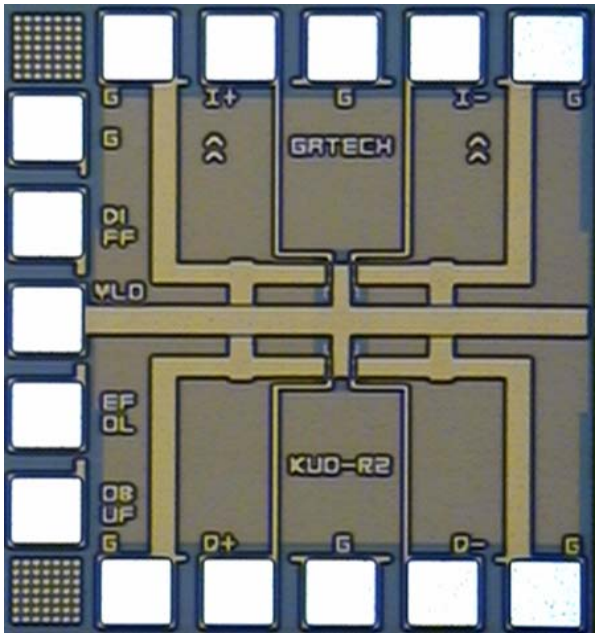
- **SiGe Devices and Circuits**
  - Profile optimization issues, stability limits, and new device physics phenomena
  - RF / microwave / mm-wave understanding of noise and linearity
  - Understanding device-to-circuit interactions
  - Radiation effects in devices and circuits (total dose + SEU + RHBD)
  - Breakdown limits and voltage constraints and their impact on circuit design
  - 1/f noise physics, microscopic noise simulation, and its up-conversion to phase noise
  - Reliability physics and geometrical scaling / thermal issues
  - New de-embedding techniques for mm-wave characterization of devices / circuits
  - 2-D / 3-D device-level simulation and compact circuit modeling issues
  - Cryogenic operation of devices and circuits
  - **Circuit Design Thrusts:**
    - transceiver building blocks (high RF to mm-wave)
    - SiGe radar (X-band and up)
    - high-speed analog (ADC, op-amps, etc.)
    - radiation-hardened digital logic (SEU)
    - specialized circuits (UWB LNA, cryogenic amps, etc.)
- **Other Stuff**
  - SiC devices for high-power / high-temperature switching systems, SOI CMOS, etc.
- **Personnel**
  - 15 PhD, 3 MS, 2 post-doc, 4 UG

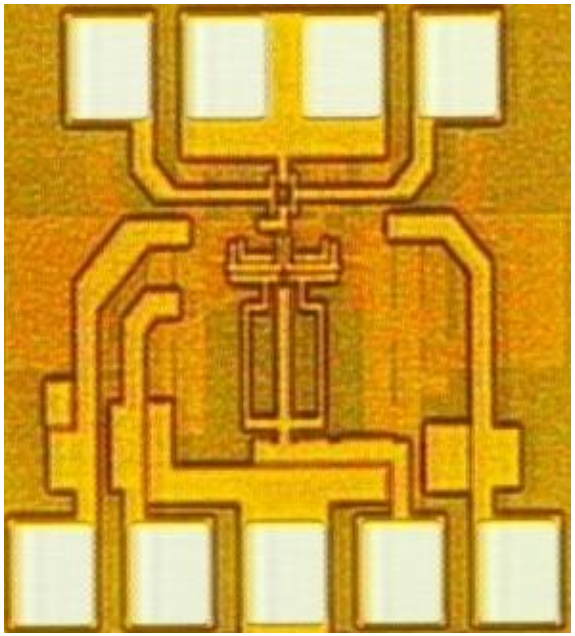
Cressler – SiGe Circuits

Georgia Institute of Technology

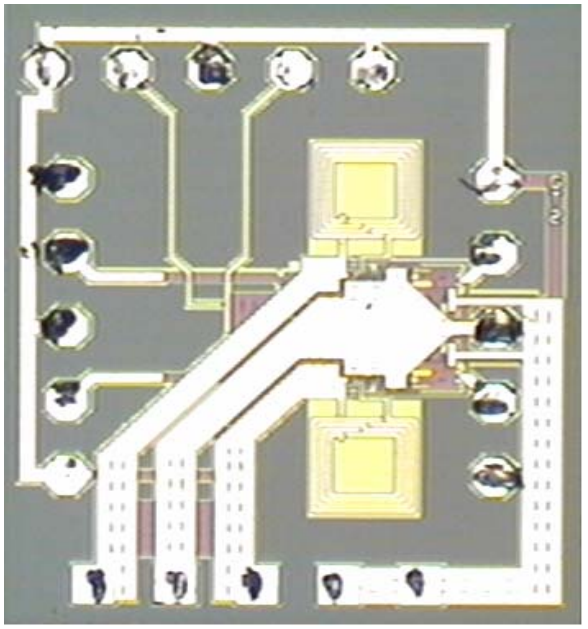
- **Major Circuit Design Thrusts in Cressler's Team:**
  - transceiver building blocks (high RF to mm-wave)
  - SiGe monolithic radar T/R modules (X-band to W-band)
  - high-speed data converters (ADC, DAC, opamps, references, etc.)
  - radiation-hardened mixed-signal circuits (RHBD for SEU + TID)
  - specialized circuits (UWB, cryogenic circuits, switches, T-lines, etc.)



21 GHz Oscillator



33 GHz VCO



8b 12 GS/sec T/H Amp

Cressler – SiGe Circuits

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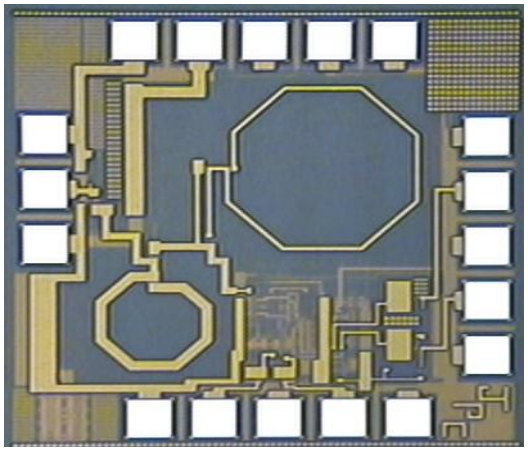
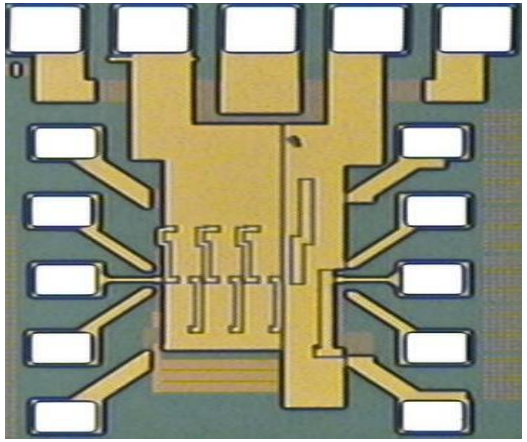
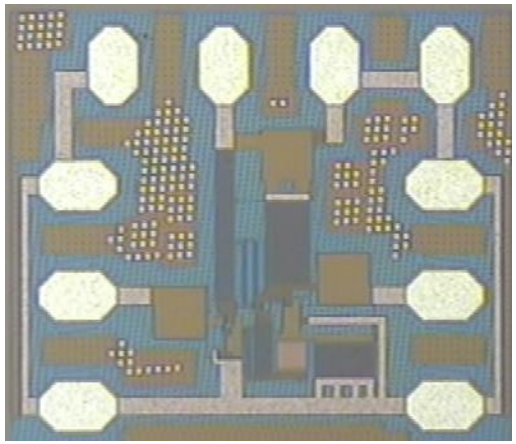


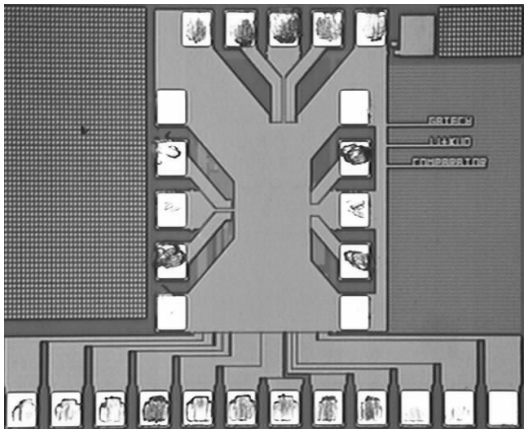
10 GHz Down-Mixer



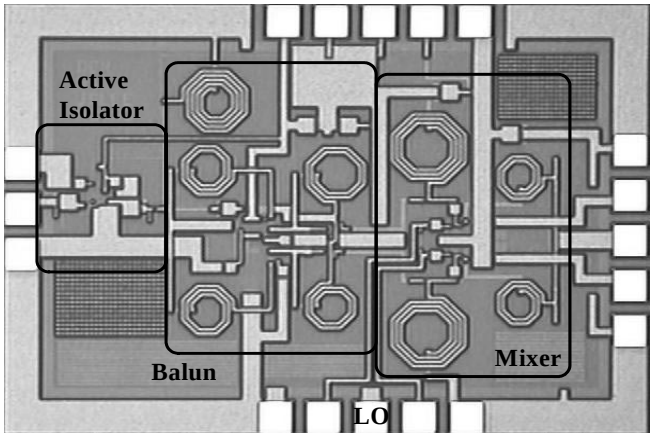
24 GHz Limiting Amp



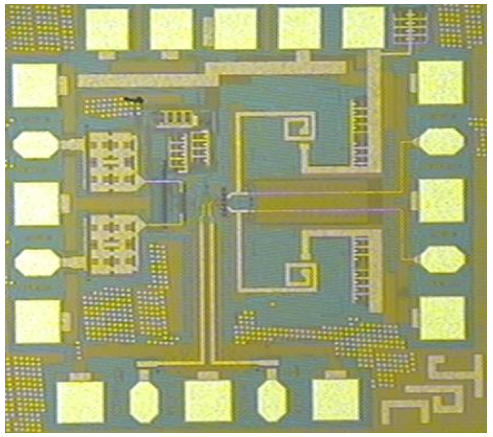
3-10 GHz UWB LNA



7b 18 GHz Comparator



5 GHz Active Mixer with Isolator



28 GHz Up-Mixer

My Gang at Georgia Tech

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