Research Overview of the
Terahertz Integrated Electronics Group

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Pushing the Speed Boundary of Integrated Circuits

- **Higher Resolution Transmission Windows**

- **Compact Hardware**
  - MHz Array (Basketball Field Size)
  - GHz Array (Table-Top Size)
  - mmWave Array (PCB-Panel Antennas)
  - THz Array (Chip-Scale)

- **Broadband Communication**
  - Low Terahertz Spectrum

- **High Resolution Sensing**

- **Interactions with Molecules**
  - Gas Spectrometer [ISSCC 2017]
  - Molecular Clock [Nature 2018]
  - 105Gbps Link [ISSCC 2021]
Miniature and Secure Tagging and Sensing Platforms

① THz Energy Harvester

260GHz CMOS Harvester with 15% Efficiency (PhD Student: Muhammad Ibrahim) [M. Ibrahim, et al, RFIC, 2022]

② Retro-Backscatter THz-ID


Multi-Functional Electromagnetic Design (PhD Student: M. Jia and D. Sheen)
Ultra-Miniaturized Sub-THz Wake-Up Receiver

PhD Student: Eunseok Lee (Collaboration with A. Chandrakasan)

260GHz Wake-Up Receiver with 1.5mm² Size, 0.7µW and Lightweight Cryptography

[E. Lee, et al. CICC, JSSC (Invited) 2023]

EM wake-up receiver

This Work

Smaller Antenna ∝ λ²
Anti-Tampering THz-ID

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PhD Student: Eunseok Lee (Collaboration with A. Chandrakasan)

④ Physical Unclonable Function Based on the THz Backscattering of the Glue Interface

High-Angular-Resolution Imaging

98x98 Reflectarray for Beam Forming at 260GHz

140GHz Radar with Shared TX-RX Antenna

2. 3D Radar Imaging
[X. Chen, et al, to be submitted to JSSC]
Full Imaging System Using AiP and Chiplet Integration

- All-silicon implementation for a low-cost imaging system
- Antenna-in-Package and chiplet-based integration
  - Silicon area reduction: >10x
  - Antenna radiation efficiency: 20%→80%
  - Quasi-optical transmitter power combining
  - Overall link budget improvement: >1000x

PhD Student: Xibi Chen (Collaboration with Intel)
Scalable Photonic-Electronic Quantum Processor

PhD Students: Jinchen Wang, Cole Brabec (Collaboration with D. Englund)

Spatial Light Control/Readout

Diamond Quantum Microchiplets
[L. Li, et al, CLEO 2023]

High-Precision Strain Tuning

Low Crosstalk Microwave Control

Differential Microwave Driving Signals

Pre-Loaded Instruction Sets

On-CMOS Pixel Tuning Structures

Analog Voltage Memory / Buffer
Gated DAC
Address Decoder & SPI

Static voltage bias (Single-use adjustment)

Thick metal layer (M10)

Thick metal layer (M11)

Au (fabricated in clean room)
Current metal RF/data cables pose large thermal load to the cryogenic platform of quantum system

Proposal: non-contact wireless up/down links using THz waves
  - Uplink: 176fJ/bit @ 4Gbps
  - Downlink: 34fJ/bit @ 4.4Gbps

Pulse control is critical for quantum information processing

NV and SiV center chiplet on CMOS (from D. Englund’s team)

Intel-16 FinFET technology

Demonstration at 5K
Other Active Projects

• CMOS- control for optical quantum transfer  
  (J. Wang, Y. Hu (D. Englund))

• Under-epidermis THz-ID  
  (M. Jia (co-advised with A. Chandrakasan))

• LLM-assisted electronic design  
  (Y. Xu, M. Cox, L. Skelic, W. Lu (ADI), T. Yu (ADI))

• Ultra-low-noise radio-astronomical receiver with built-in calibration  
  (D. Sheen, F. Lind (MIT Haystack Observatory))

• High-stability THz signal synthesizer for CMOS molecular clock  
  (J. Jung (co-advised with A. Chandrakasan))

• Intensity-detection-only, large-scale THz array with 3D sensing capability  
  (C. Brabec (co-advised with D. Englund))
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- **Collaborators:**
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