WE3B-4

Antenna-Coupled Terahertz Detectors in 16nm FinFET

Christopher Chen, Richard Al Hadi,
M.-C. Frank Chang
University of California, Los Angeles, USA

UCLA

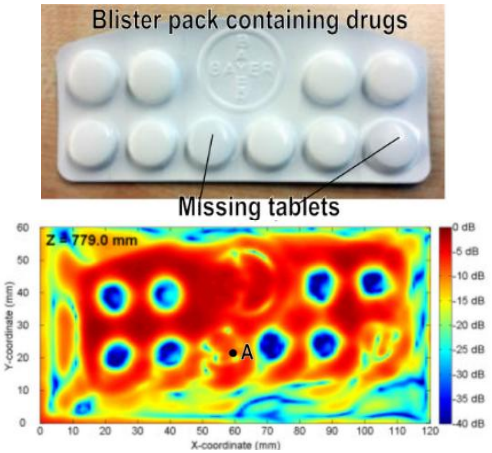
Outline

- Motivation and Background
- THz Detector Implementation
- Measurement Results
- Conclusion

THz Detector Applications

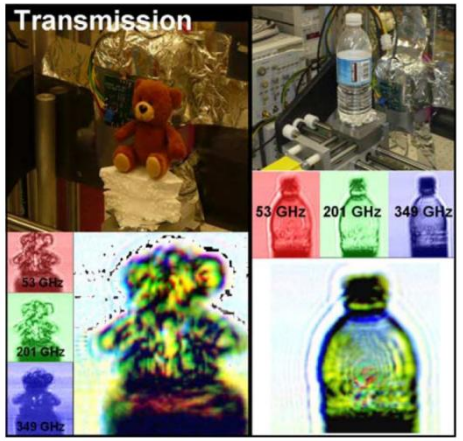
- THz frequencies are attractive for imaging and sensing
  - Detector resolution is proportional to frequency
  - Smaller wavelength is conducive to on-chip antenna integration

Medical



[Hillger, Trans. Terahertz Sci. Technol'19]

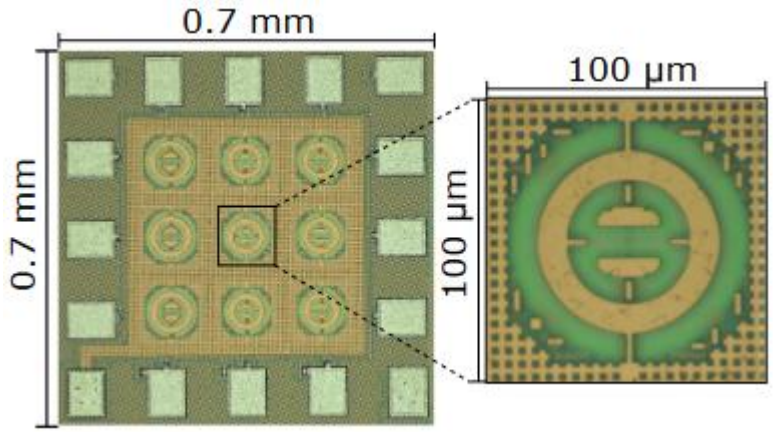
Imaging



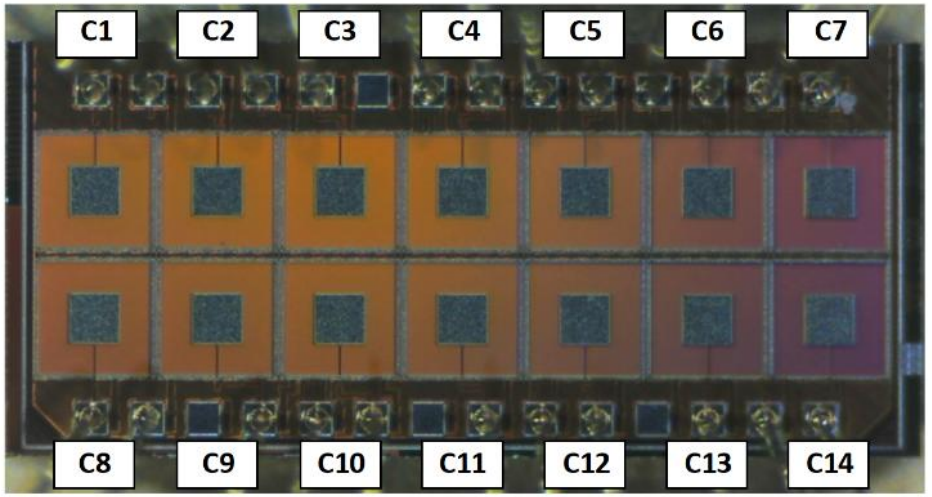
[Tang, Trans. Terahertz Sci. Technol'13]

CMOS THz Detectors

- CMOS detectors allow for better integration compared to other technologies (SiGe, InP, etc.)
- $\lambda/2$ spacing between antennas is difficult for off-chip arrays



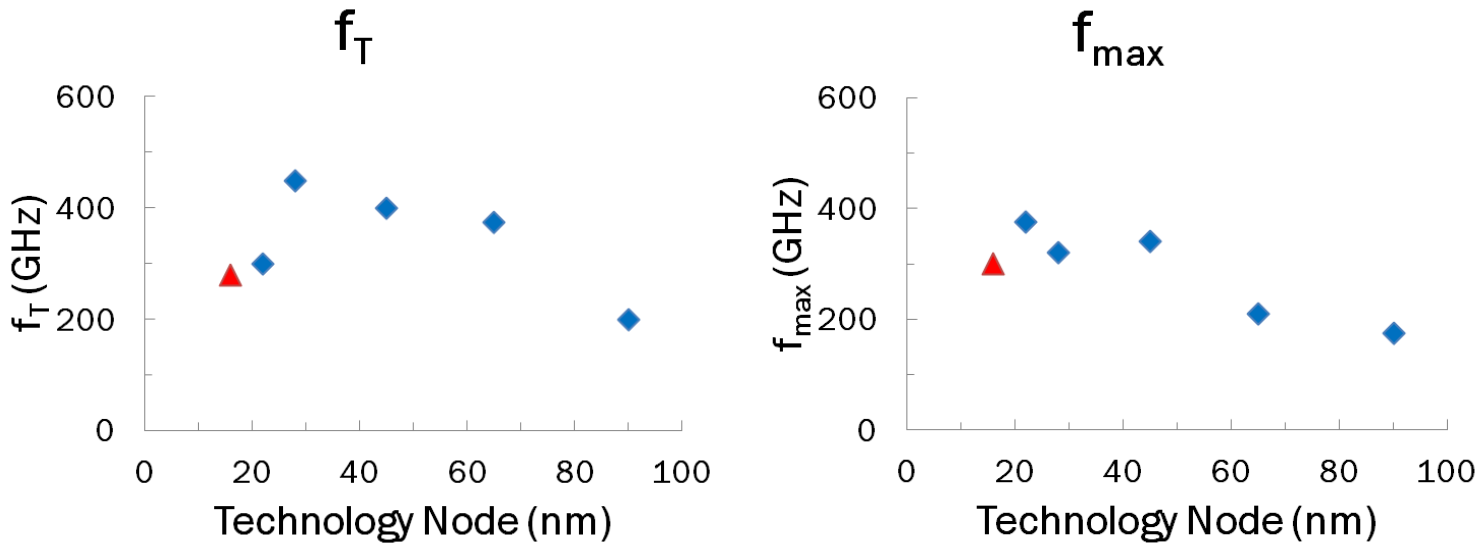
22FDSOI
[Jain, EuMIC'18]



65nm CMOS
[But, MIKON'20]

Advancements in CMOS Technologies

- FinFET has enabled further channel shrinkage for more compact design and integration
- FinFET has lower f_T and f_{max} compared to planar technologies due to the higher gate resistance and parasitic capacitance

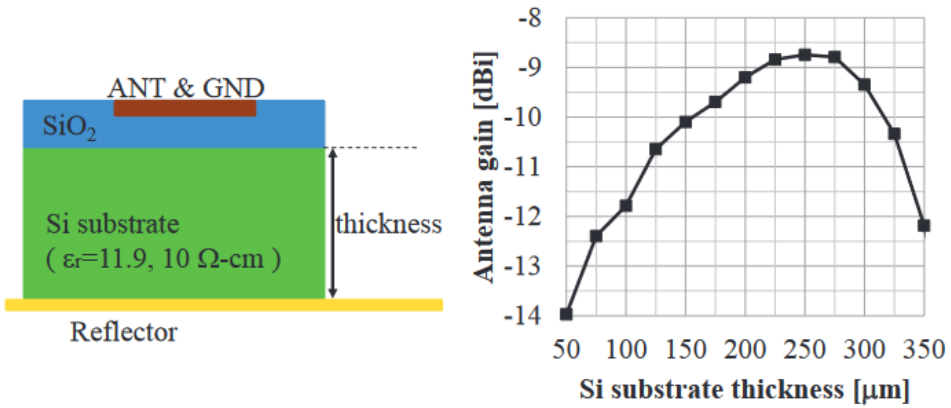


Techniques to Improve Responsivity

- Increasing antenna efficiency improves detector responsivity

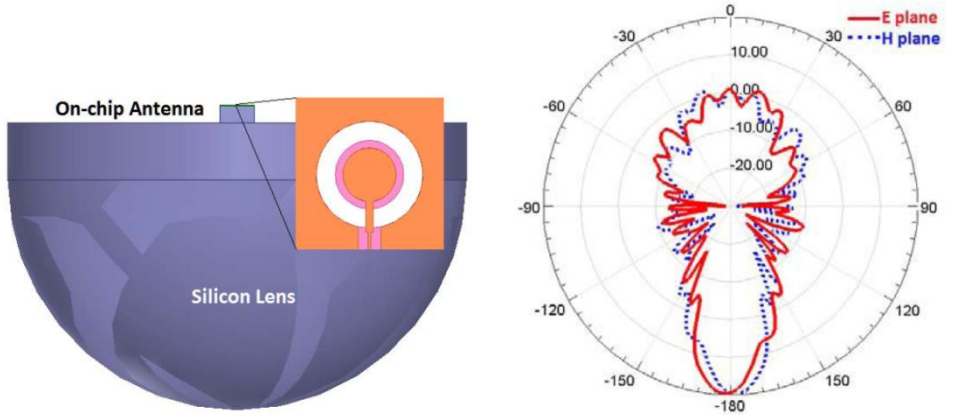
$$P_{in} = \frac{P_T G_T G_R \lambda^2}{(4\pi R)^2}$$

Backside reflectance



[Sato, ISAP'15]

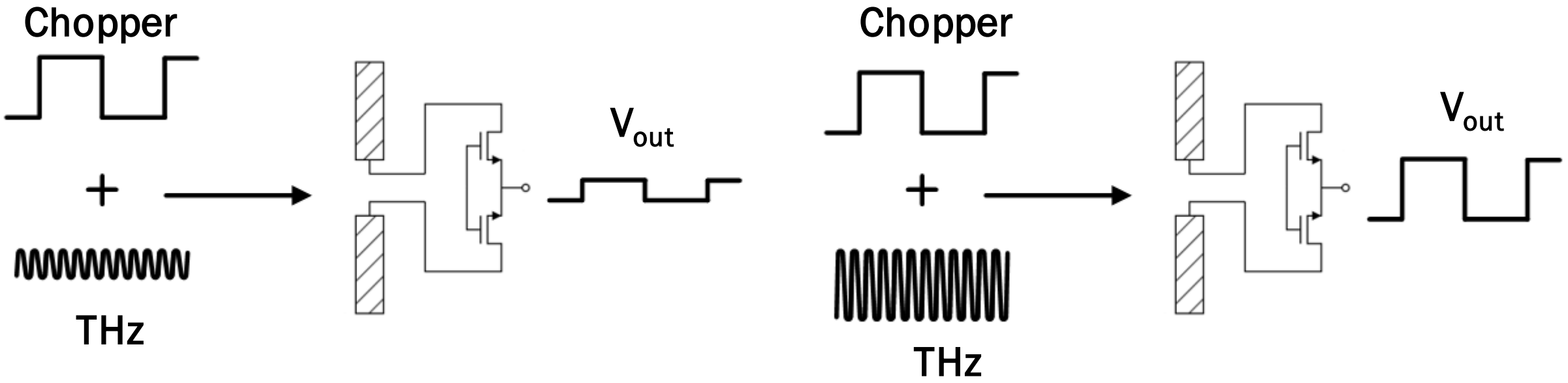
Backside radiation



[Zhao, JSSC'16]

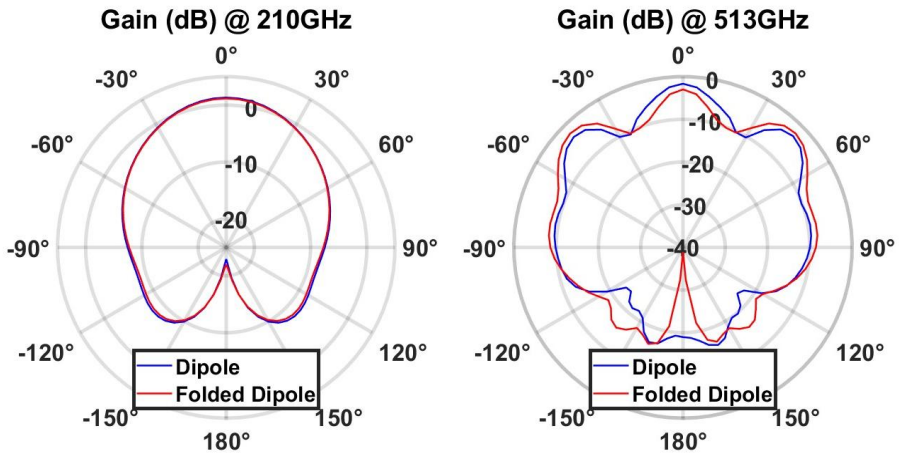
Detecting THz Signals

- Modulate input THz with a low frequency chopper signal
- Measured amplitude is proportional to input THz power



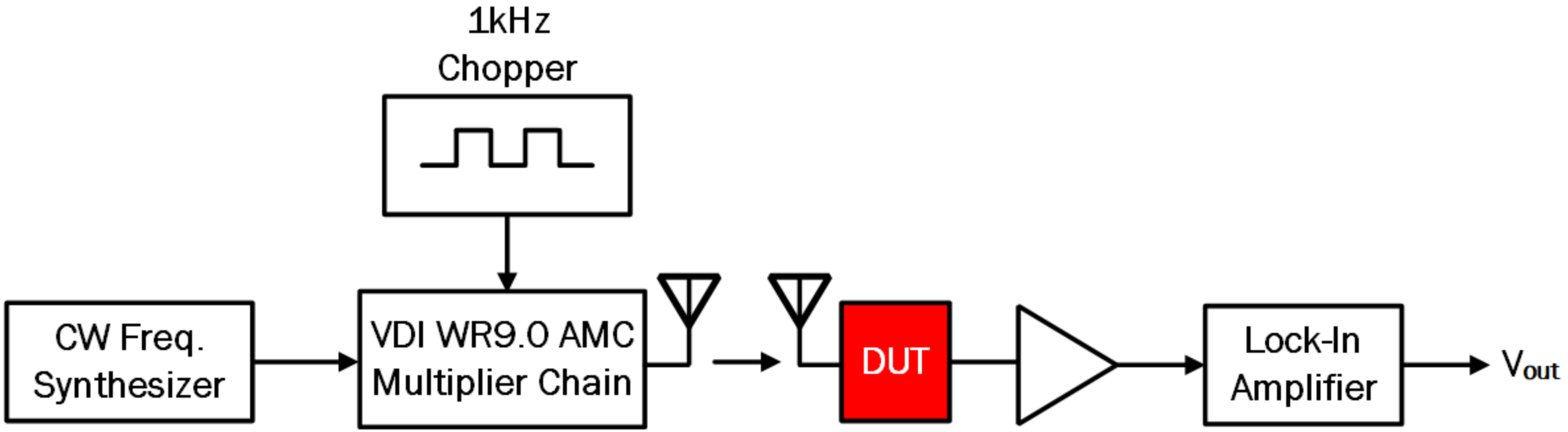
Antenna Radiation Simulations

- Dipole and folded dipole antennas were designed to radiate at 210GHz
- Additional resonant modes were observed in simulations



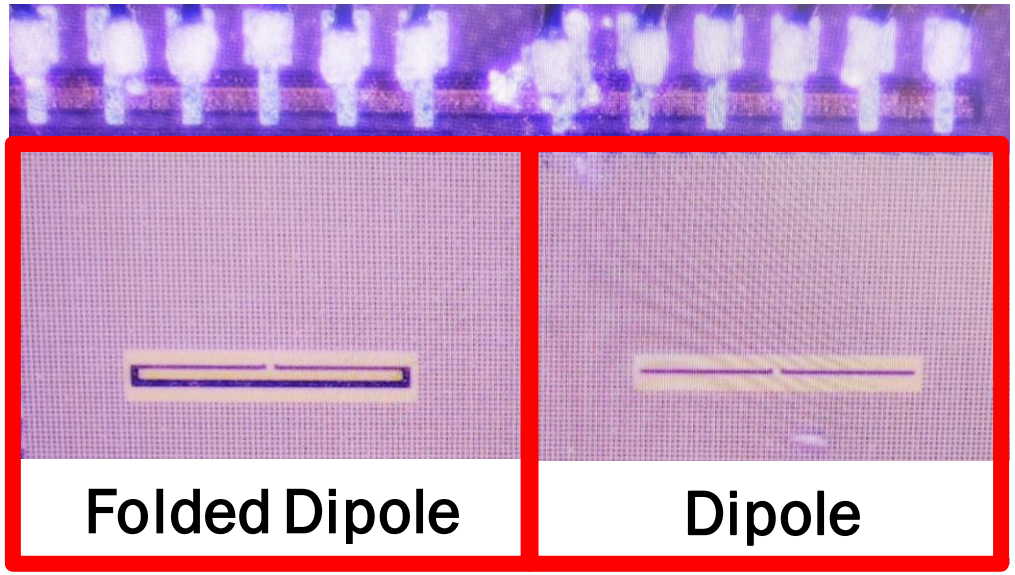
E-Plane Cuts of Radiator Gain

Detector Characterization Setup



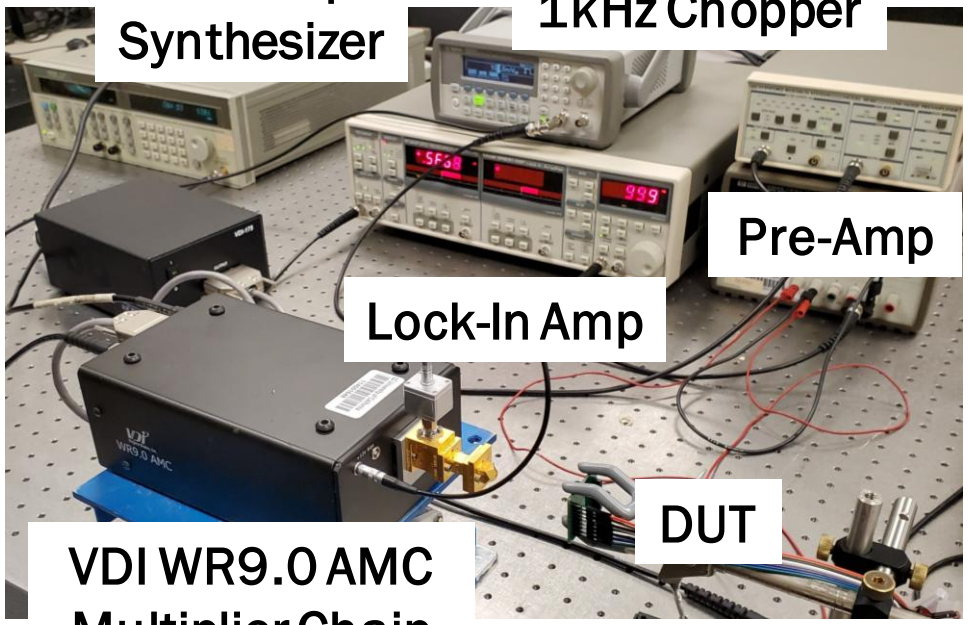
Dummy Fill and Die Photo

- Placed dummy metals manually to satisfy strict density requirements
- Tried to minimize impact of dummy metals on antenna



354.5 x 30 μm^2 354.5 x 5 μm^2

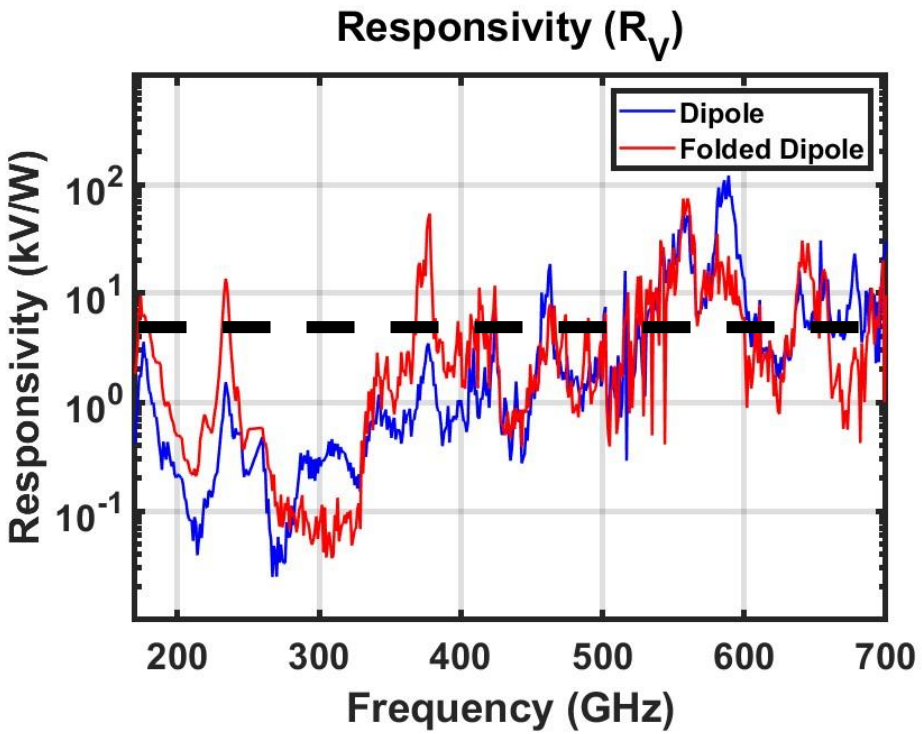
Measurement Setup

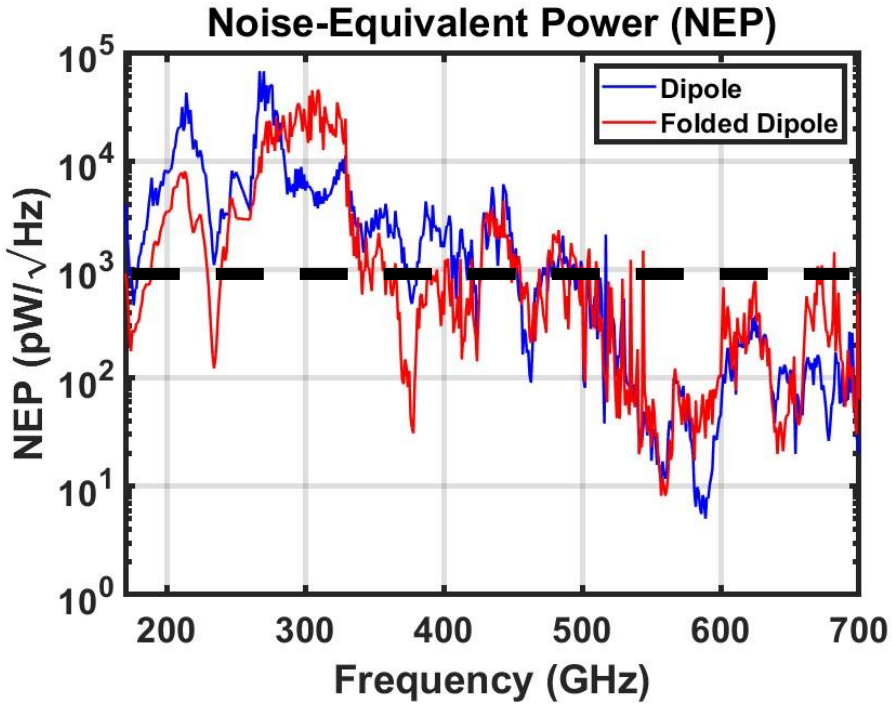


Band	Frequency Range (GHz)	Output Power (mW)	Antenna Gain (dB)	Distance (mm)
WR4.3	170-250	1.26 – 3.66 (+/- 0.01)	21	129
WR2.8	260-400	0.263 – 1.252 (+/- 0.001)	26	49
WR2.2	330 – 500	0.023 – 0.21 (+/- 0.001)	26	42
WR1.5	500 – 750	0.0051 – 0.0617 (+/- 0.0005)	26	36

Detector Characterization

- G_R is both simulated using HFSS and calculated using the physical area





Comparison with Other Detectors

	This Work		Clochiatti et al., IWMTS'21	But et al., MIKON'20	Andree et al., EuMIC'19	Jain et al., EuMIC'18
Technology	16nm FinFET		InP RTD	65nm CMOS	0.13um SiGe HBT	22nm FDSOI
Antenna	Dipole	Folded Dipole	Spiral	Patch	Differential Ring + Lens	Differential Ring + Lens
Frequency (GHz)	589*/554	560*/502	2237.5	620	220-1000	855
Max R_V (kV/W)	121*/88.8	74.5*/41.7	1.248*	-	9	1.51/ 180mA/W#
Min NEP (pW/√Hz)	5*/8.7	8.2*/18.4	1.9*	12	1.9 @ 292GHz	22/12#

*Simulated Receiver Gain
#Current Mode

Conclusion

- Demonstrated a THz detector in 16nm FinFET technology
- Exploited N-FinFet nonlinearity to rectify THz signals
- Achieved a minimum NEP of 8.7 pW/√Hz for a dipole-coupled detector

Acknowledgements

The authors would like to thank TSMC for their technology support.