Terahertz integration concepts based on micromachining

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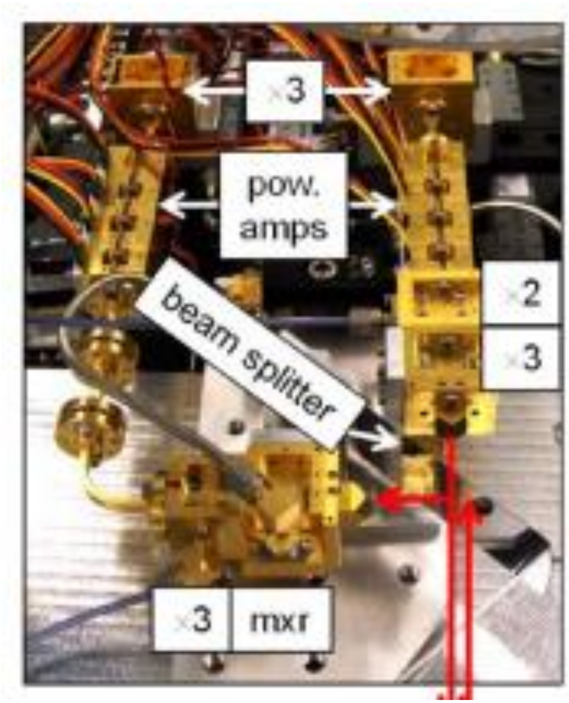
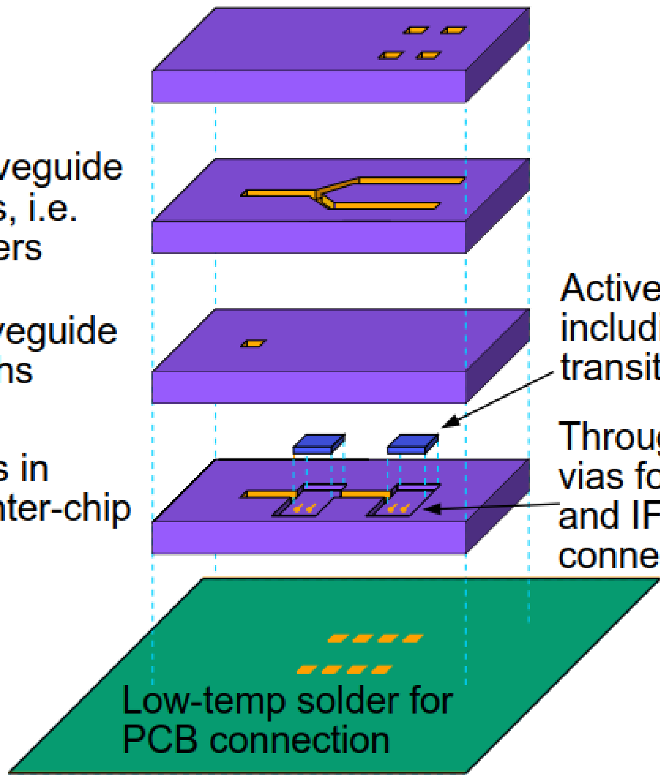
TERAFLAG workshop, Cassis, France, September 6th 2018

How to build a mass-producable sub-millimeter wave or THz system?



- Good progress have been done with mass-producible active components on MMIC
- Integration of MMICs to a system is a challenge
  - Planar integration methods, such as PCB, LTCC, IPD, typically fail at around 100 GHz.
- State-of-the-art at THz range integration is split-block integration
  - Expensive, and leads to big systems
- Need for integration method that enables optimal combination of small MMICs and high quality passives and antennas
- **We foresee Micromachining on silicon as a potential integration platform of THz systems**

Our Vision
Waveguides on Silicon



- Optimal use of MMIC area
- Low cost integration platform with simple process
- Low temperature bonding process to reduce need for external mechanical support
- Enables integration to small package

Communications:
Complex systems can be built with waveguides

- Rapid evolution of semiconductor technologies, like SiGe, enable electronic THz systems
- High gain antennas are a prequisite for THz communications
- Adaptation of phased array technology to the THz range is needed
- Beam steering is essential for high-resolution radar tracking, security imaging and adaptive THz communications

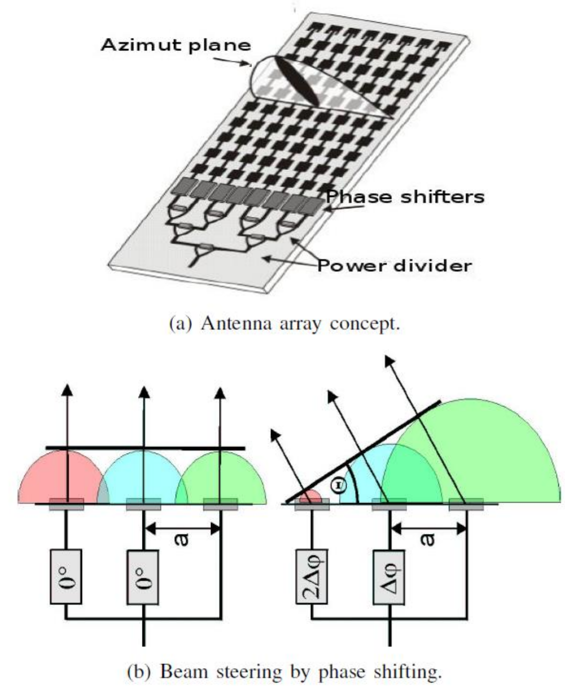
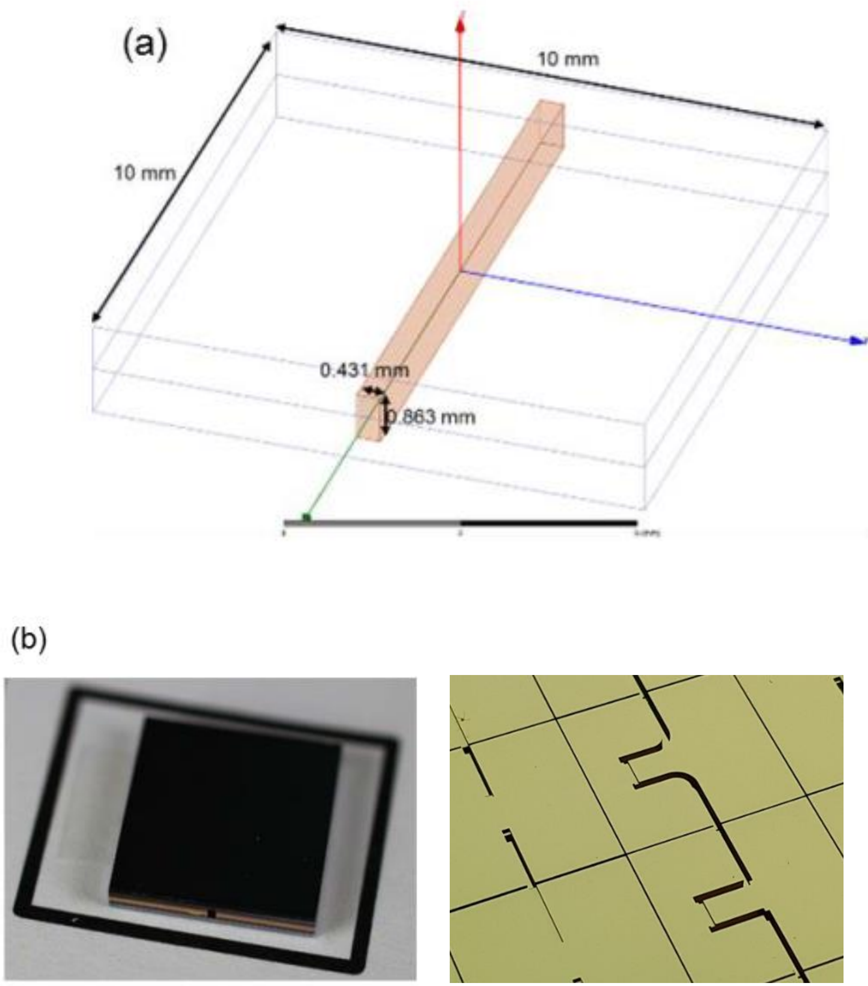
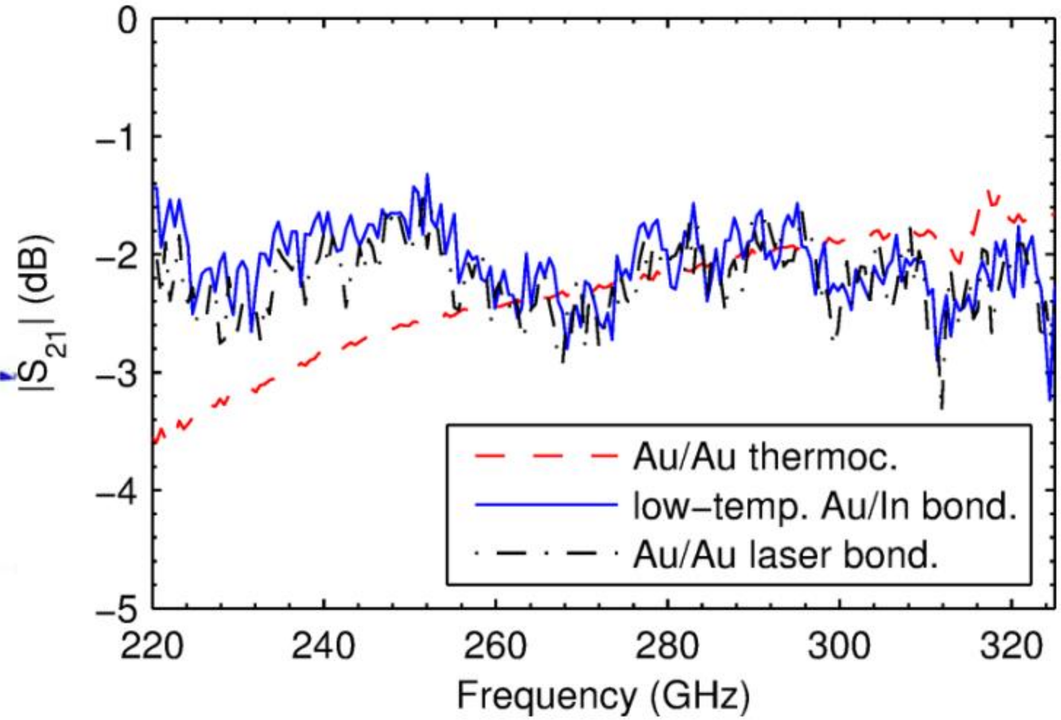


Fig. 1. Antenna array concept and beam steering.

P. Herrero et al., " Planar Antenna Array at D-Band Fed By Rectangular Waveguide for Future Automotive Radar Systems", EuMC'08

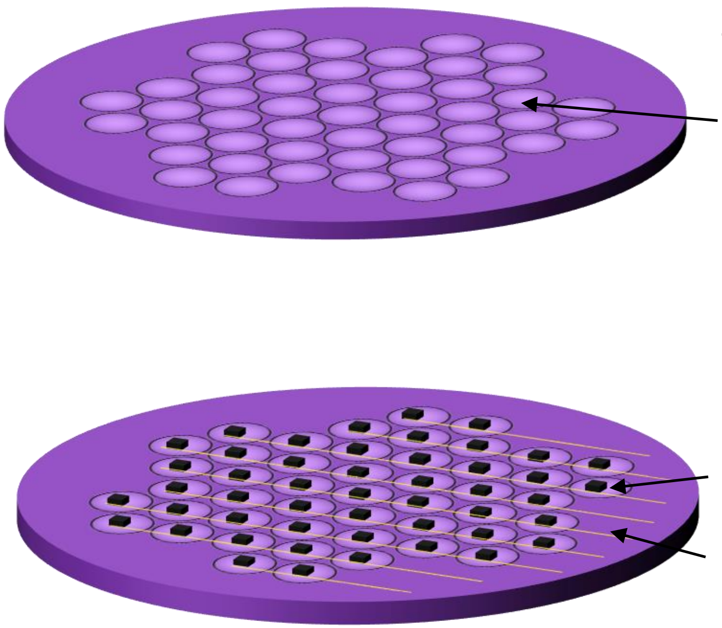
Waveguide Measurement Results



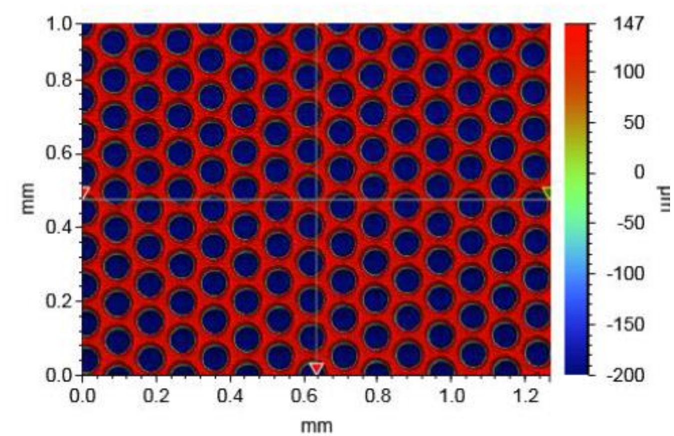


- Waveguide loss 0.2 dB/mm
- Also filters, bends and MMIC transition demonstrated.

Our Vision
Micro-optical, Planar Integration of Sensor Arrays

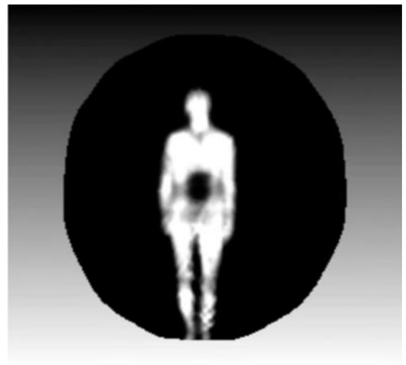


- Small MMIC area
- Low cost integration platform with simple process
- Easy to integrate large arrays

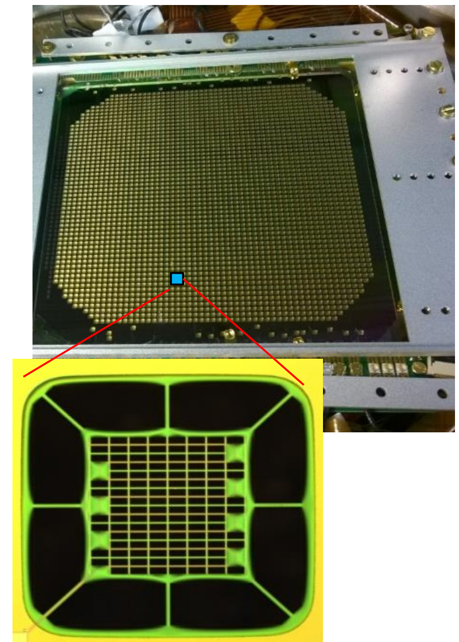


Security imaging:
Micro-optics enable big arrays of detectors





Asqella ARGON^{TM} scanner and video imagery.




Multi-kilopixel kinetic inductance bolometer array and imager prototype.

Background

- Commercialized imaging technology for security
    - VTT Spinoff Asqella

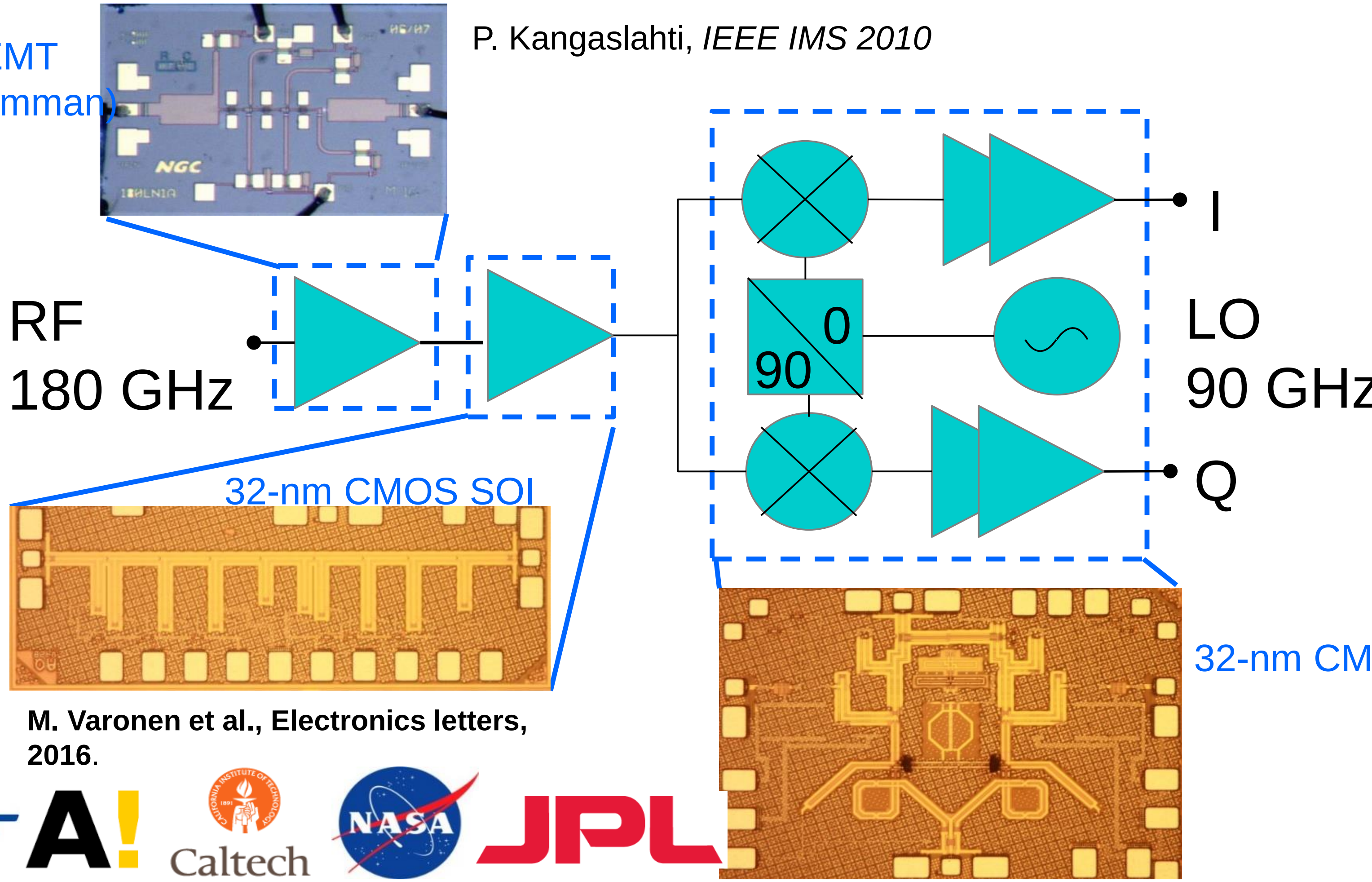
Ongoing research:

- Scalable ~10 kpixel cryogenic bolometer sensor arrays
- ”Digital camera sensor” for millimeter waves

Heterogenious integration of different MMIC processes and components

35-nm InP HEMT
(Northrop Grumman)

P. Kangaslahti, *IEEE IMS 2010*



32-nm CMOS SOI

M. Varonen et al., Electronics letters, 2016.

D. Parveg, M.Varonen et al., IEEE MWCL 2016.
D. Parveg, M. Varonen et al., IEEE SiRF, 2017.

Conclusion

- New low cost integration technologies are key element of successful commercialization of THz systems

- We envision a micromachined sub-millimeterwave and THz integration systems based on Silicon micromachining
  - Smaller package
  - Lower cost
  - Mass-producible

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Acknowledgment

Vladimir Ermolov, Mikko Kantanen, Antti Lamminen, Jaakko Saarilahti, Pekka Pursula, Mikko Varonen, et al.

More information

- P. Pursula, A. Lamminen, M. Kantanen, J. Saarilahti, V. Ermolov, ”Sub-THz micromachined waveguides for wafer level integration of MMICs”, Proc. 47th European Microwave Conference (EuMC), Nürnberg, Germany, Oct., 2017, pp. 1061–1064.
- Vladimir Ermolov, Antti Lamminen, Jaakko Saarilahti, Ben Wälchli, Mikko Kantanen, Pekka Pursula, “Micromachining integration platform for Sub-Terahertz and Terahertz systems”, International Journal of Microwaves and Wireless Technologies, 2018.