Optagon Photonics

Photonics enabled Terahertz wireless communications for 5G systems

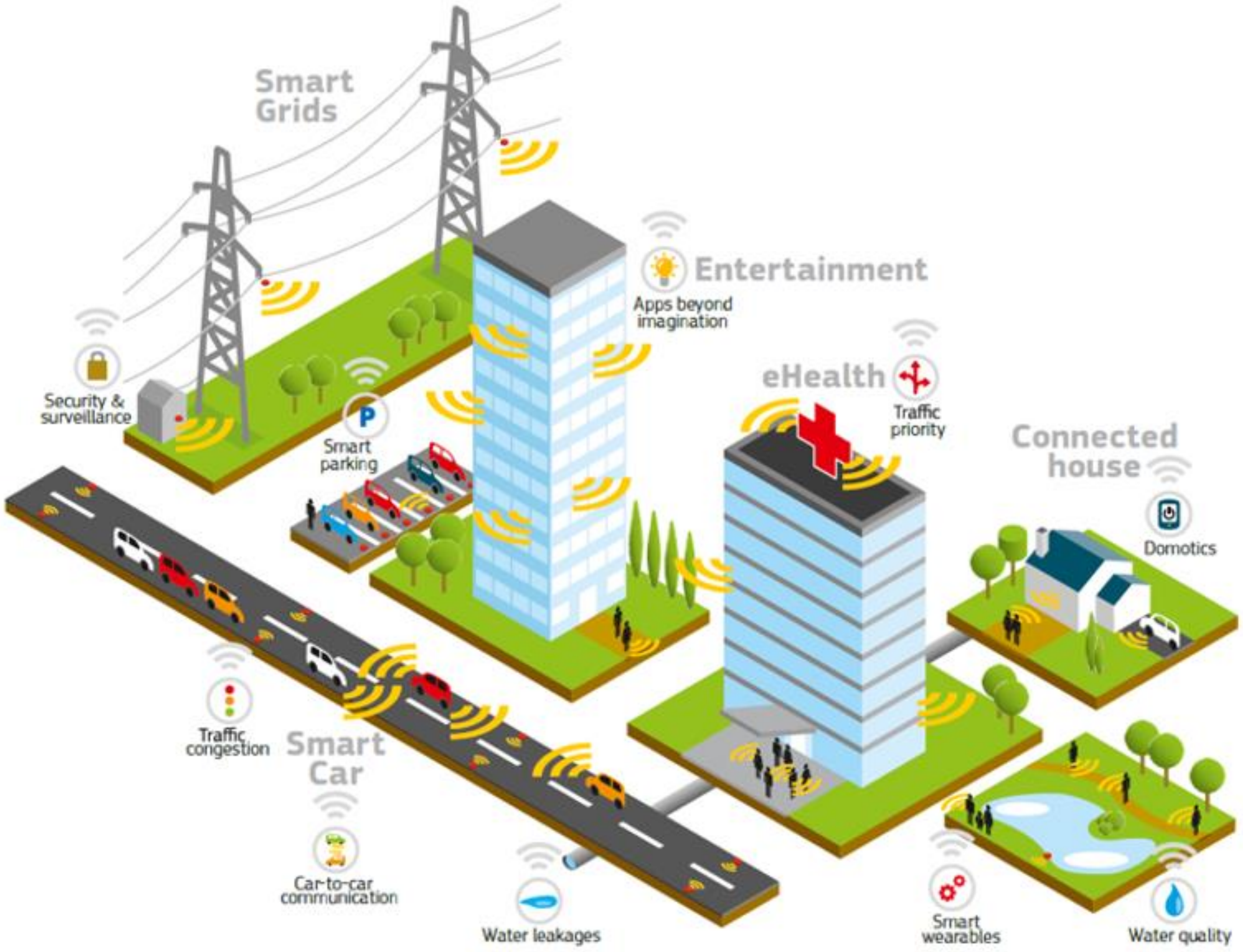
Panos Groumas - Christos Kouloumentas

Athens 25 May 2022

Outline

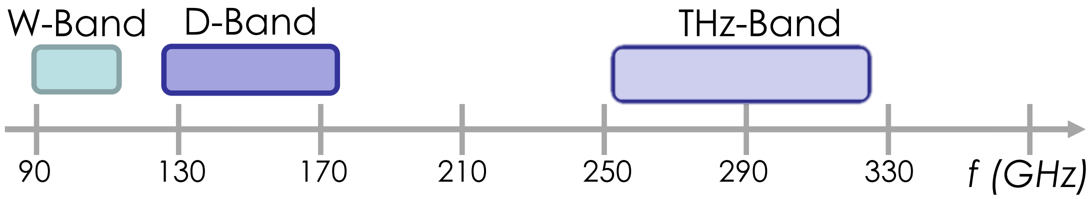
- ❖ 5G and beyond vision
- ❖ Photonics enabled THz wireless communications
- ❖ H2020 TERAWAY: Photonic Integrated Circuits for 5G and beyond systems
- ❖ Driving solutions for complex Photonic Integrated Circuits
- ❖ Conclusions

5G and beyond vision



- Highly mobile and fully connected society
- More connected devices and more bandwidth - hungry applications (human hand-held devices, sensors, machines etc)
- FR2 (24.25 – 52.6 GHz) and FR2-2 (up to 71 GHz) might not suffice in the near future
- Need to move the operating frequencies to higher bands
- Need for beam-forming (steer the narrow beams)

Available spectrum slots > 90 GHz



- **W-band**: 92 – 114.5 GHz
- **D-band**: 130 – 174.8 GHz
- **THz-band**: 252 – 322 GHz

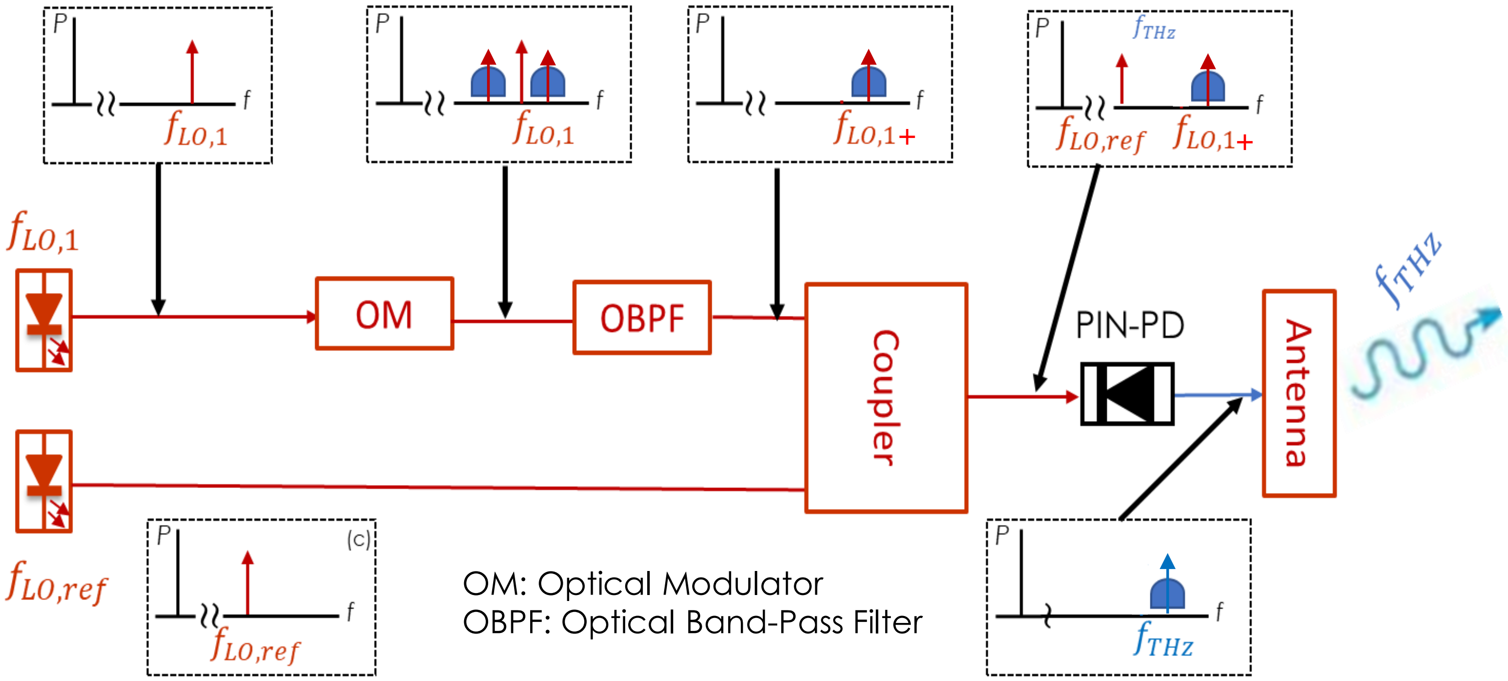
Main technological challenges related to components at these frequencies:

- Lack of conventional (electronic) broadband signal sources
- Lack of conventional (electronic) broadband receivers
- Lack of electronic beamforming units at such high frequencies

However:
High frequency signals can be generated, processed and received easily using photonic technology

Photonics for the generation and emission of mmWave / THz signals

- Using photonic components to seamlessly generate signals in the W, D, THz bands

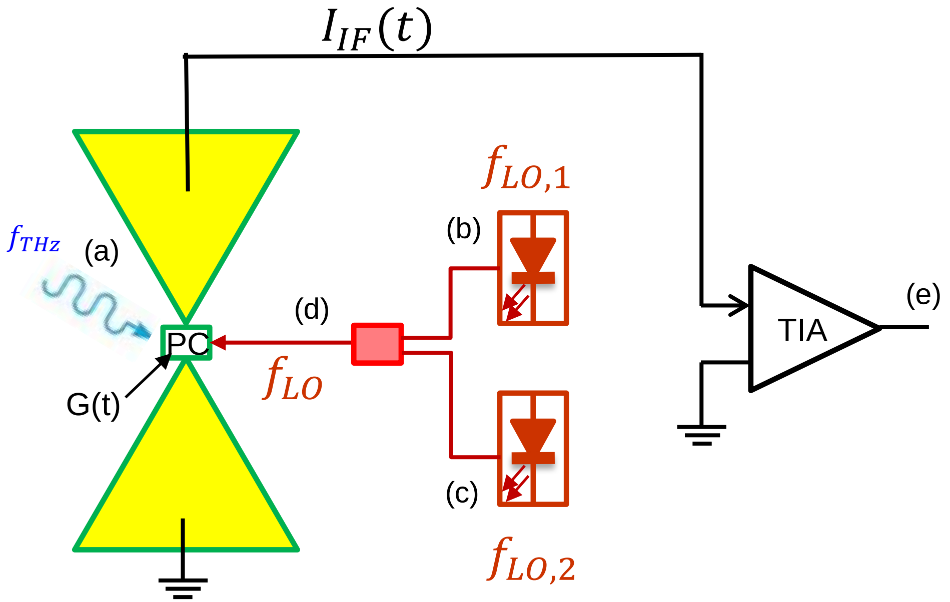


- Two optical carriers $f_{Lo,1}$, $f_{Lo,\text{ref}}$ are generated by tunable laser sources.
- The frequency of the generated RF THz signal will be equal to $f_{THz} = |f_{LO,1+} - f_{LO,fre}|$.
- The first optical carrier is modulated and filtered
- The beating of the modulated optical signal with the reference optical carrier on the high bandwidth PD will generate the modulated RF-THz signal.
- The modulated RF-THz signal is coupled and emitted by an antenna

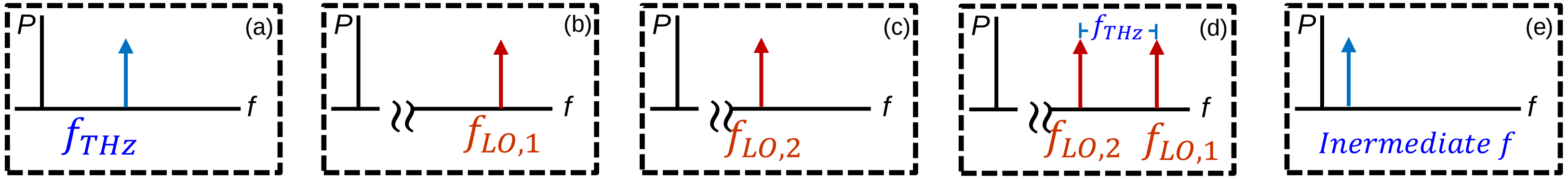
Changing the frequency difference between the two optical carriers we can **seamlessly select the frequency of the emitted signal**

Photonics for the down-conversion of mmWave / THz signals to IF

- Using photonic components to receive mmWave / THz signals and down-convert them



- The THz signal (f_{THz}) is received by an antenna with a photoconductor (PC) between the antenna feed points (a)
- Two unmodulated optical carriers $f_{Lo,1}$, $f_{Lo,2}$ are generated by tunable laser sources (b, c)
- The photoconductance G(t) is modulated at frequency equal to $f_{Lo} = |f_{LO,1} - f_{LO,2}|$ (d)
- Changing the frequency difference between the two optical carriers we can down-convert the THz signal to IF (e)

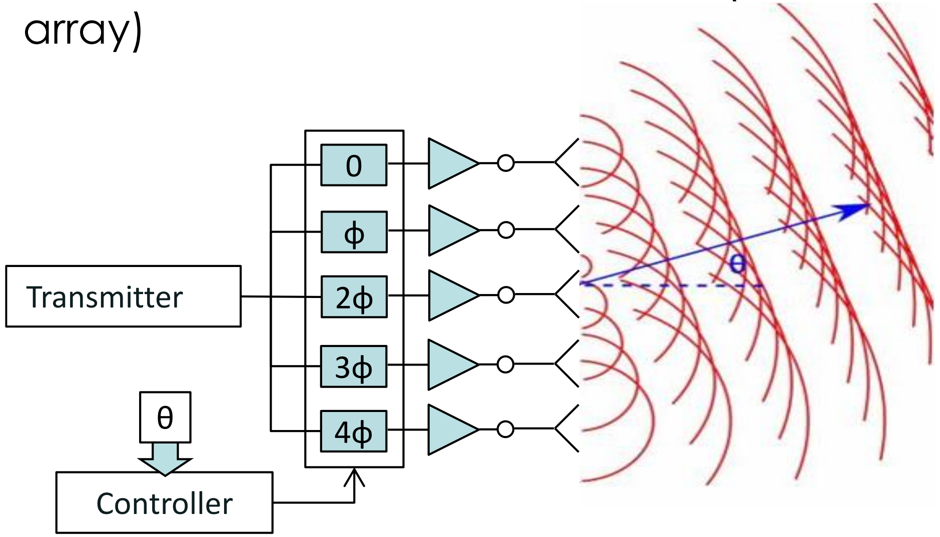


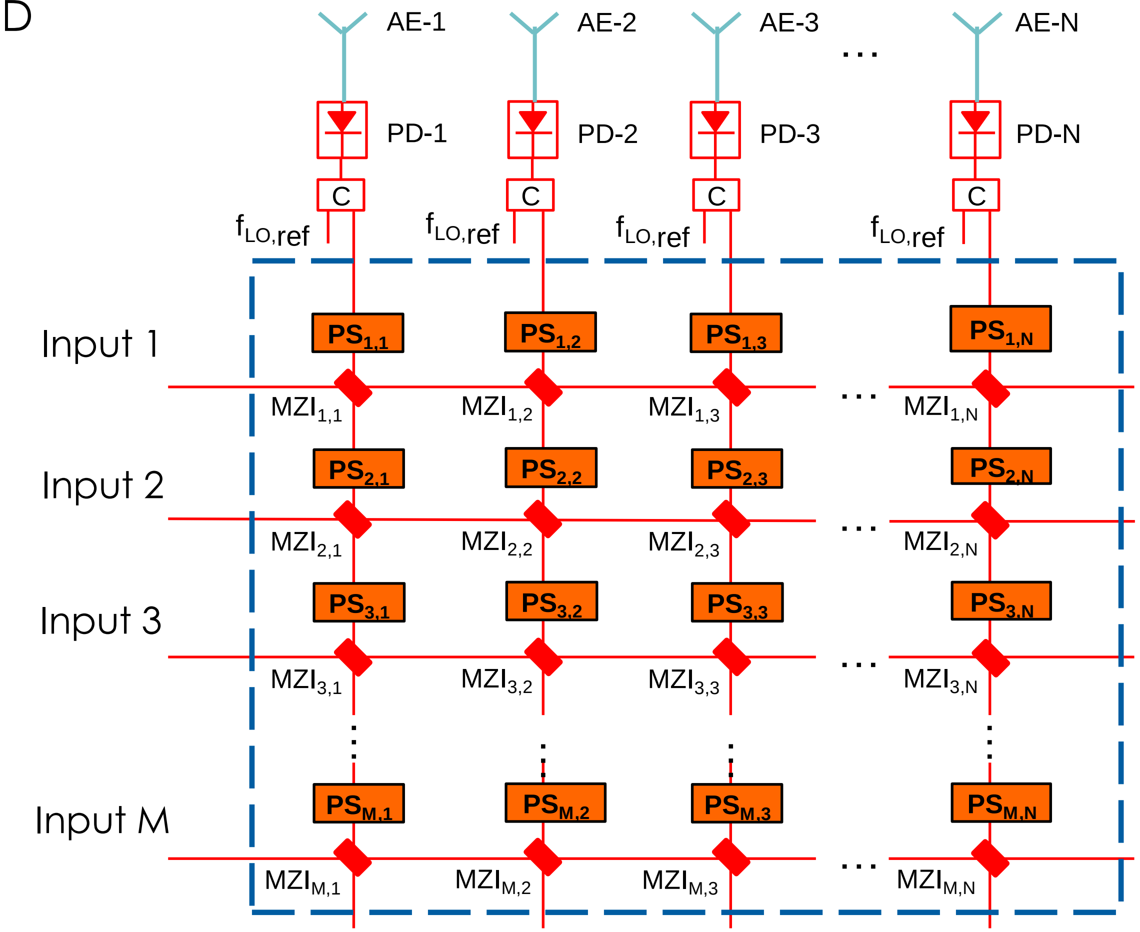
Changing the frequency difference between the two optical carriers we can **down-convert the THz signal to IF.**

Optical Beamforming Networks on Photonic Integrated Circuits

Operating principle:

- By appropriately adjusting the phase at each AE, the beam can be steered in either direction (azimuth or elevation if 2D array)





AE: Antenna Element PS: Phase Shifter

Blass matrix OBFN architecture:

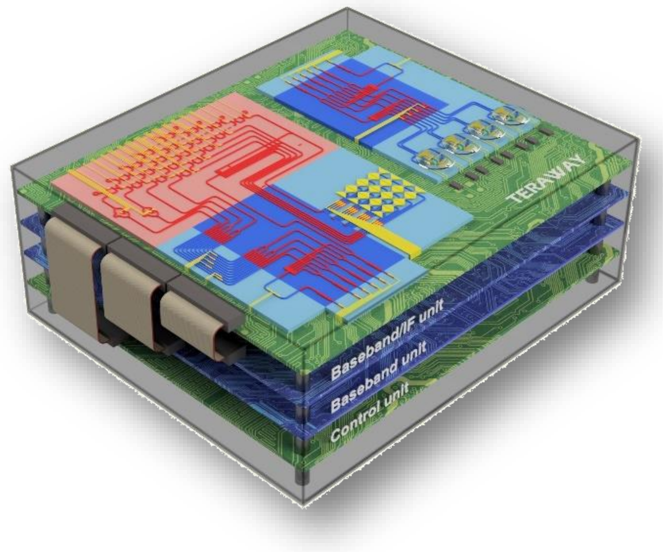
- Operation at optical domain
- Multi-beam capability
- Good scalability (w respect to beams and AEs)
- Independent beam steering using single Antenna array

TERAWAY

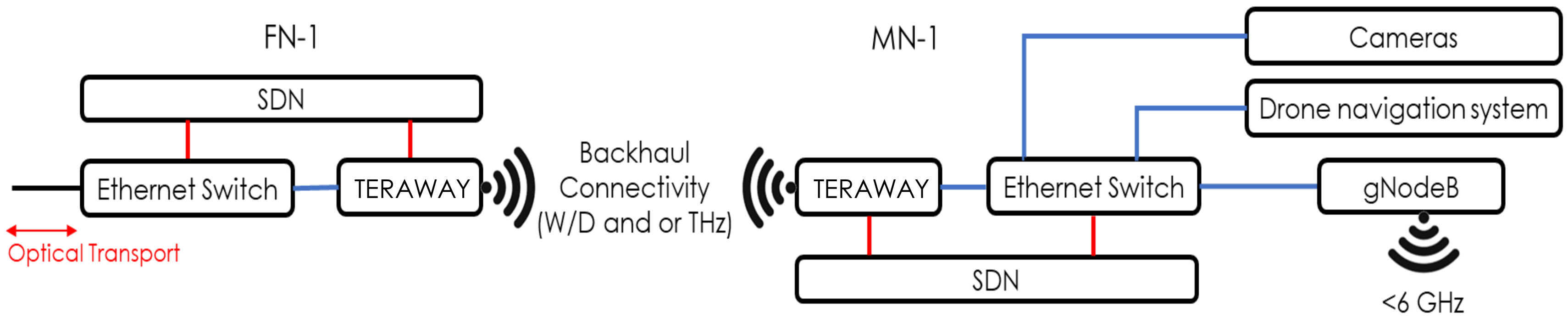
A new disruptive generation of photonic-enabled THz transceivers for high-capacity BH and FH links in Beyond 5G networks

Concept

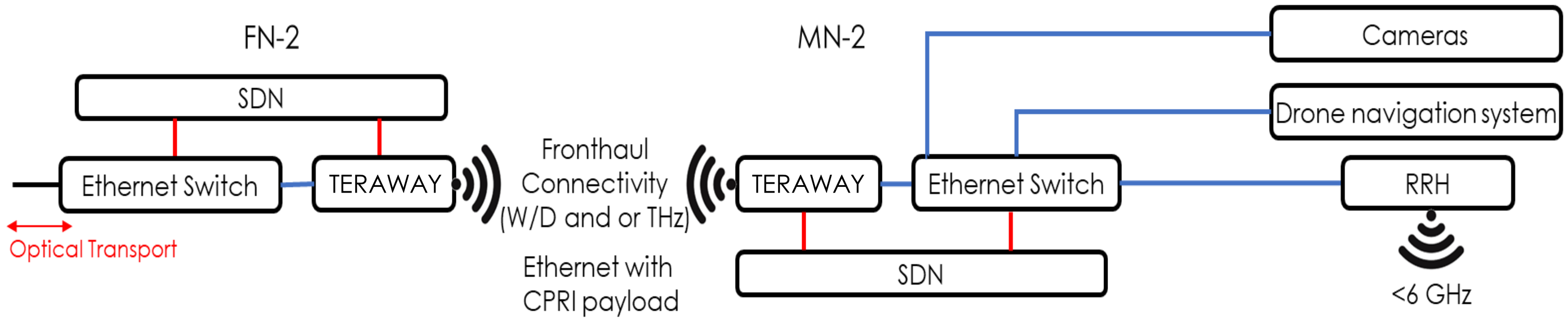
- **Multi-channel, ultra-wide band transmitters**: Generation/emission and of THz/W/D signals with selectable symbol rate and high bandwidth.
- **Multi-channel, ultra-wide band receivers**: Detection of THz/W/D band signals and their down-conversion to IF.
- **Multi-beam operation**
- **Optical beamforming network on chip**
- **Hybrid photonic integration combining 3 different materials:** Optical polymers, Silicon Nitride, Indium Phosphide



Use case #1: Backhaul connectivity between Fixed Nodes and Moving Nodes

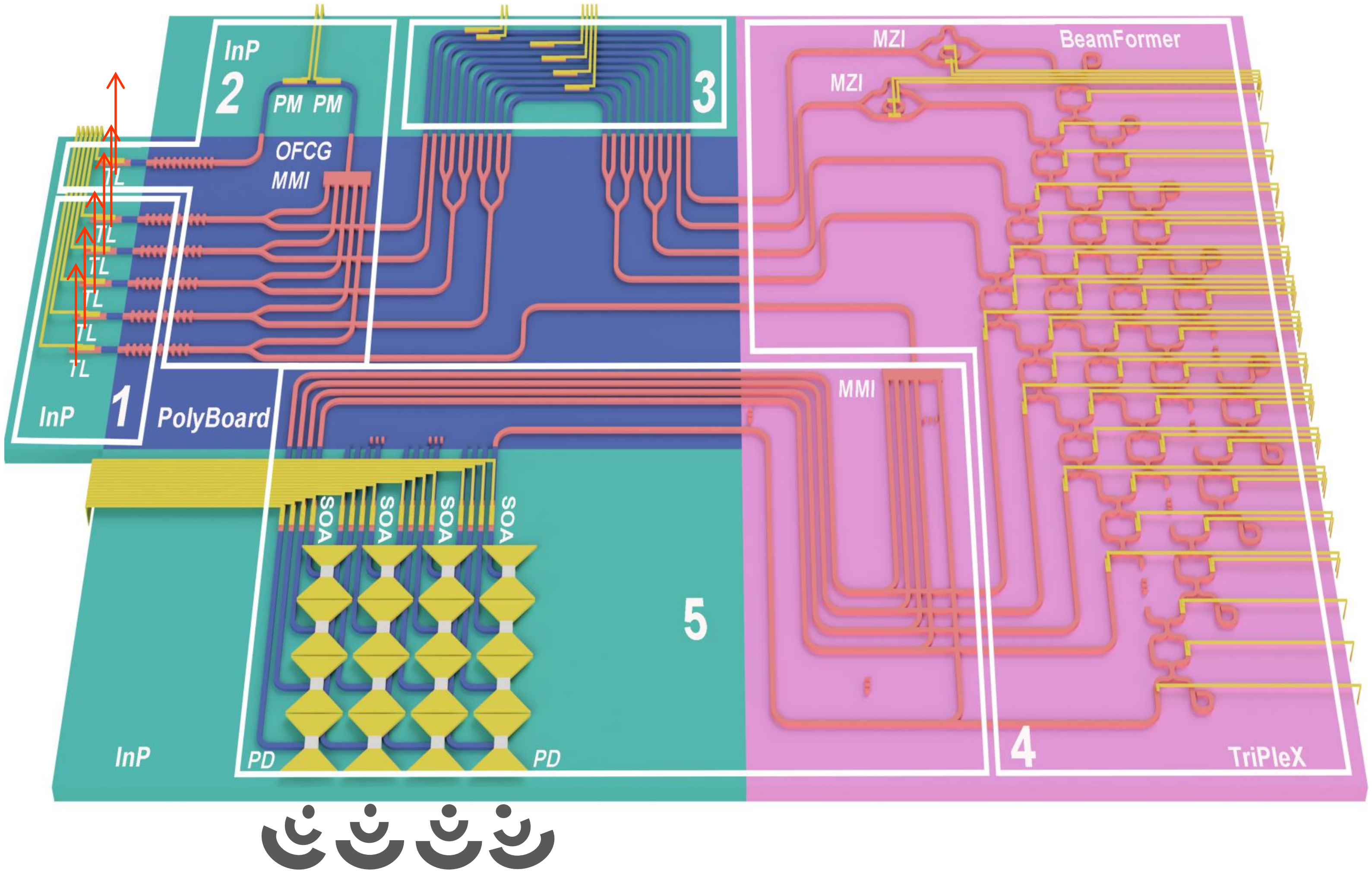


Use case #2: Fronthaul connectivity between Fixed Nodes and Moving Nodes



Hybrid photonics-based platform for **ultra-wideband signal generation and emission**

TERAWAY Transmitter (Tx)



1. Optical carrier generation unit
Tunable Lasers (TLs): Free selection of the emission wavelength (10 nm range ~ 1 THz)

2. Optical phase locking unit
Injection of Optical Frequency Comb (OFC) back to the cavities of the TLs

3. Optical modulation unit
- Phase Modulators for low-capacity channels
- IQ Modulators for high-capacity channels

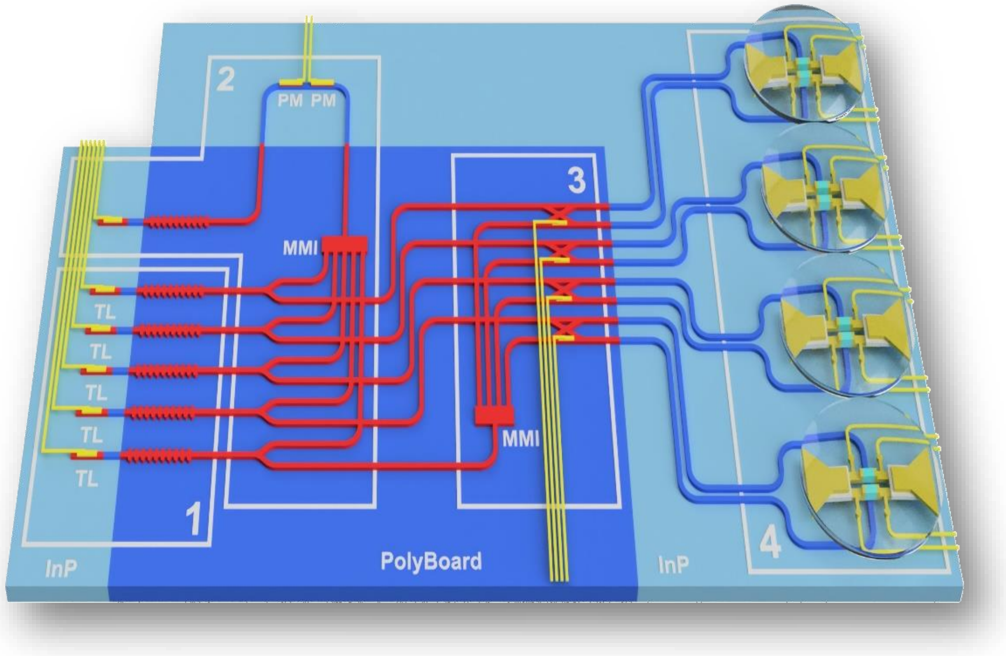
4. Optical multi-beamforming and optical filtering unit
Independent steering of the transmitted wireless beams

5. Optical amplification, frequency up-conversion and wireless emission unit
Semiconductor optical amplifiers, PIN- photodiodes as photonic mixers and bow-tie antennas

TERAWAY

Hybrid photonics-based platform for **ultra-wideband signal detection and reception**

TERAWAY Receiver (Rx)



1. **Optical carrier generation unit**
   Same as transmitter
2. **Optical frequency comb generator unit**
   Same as transmitter
3. **Optical combining and phase shift unit**
   Introduction of 90° phase difference between copies of the same optical carrier
4. **Wireless detection and IQ photonic mixing unit**
   Bow-tie antennas and photoconductive elements for down-conversion to IF

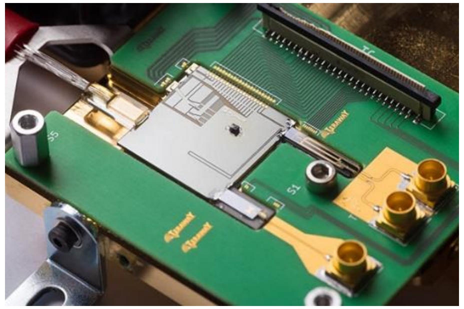
The Tx and Rx functionalities (Laser tunability, OBFN etc) rely on a large number of phase shifters (heaters), laser diodes etc

TERAWAY

TERAWAY precursor prototypes

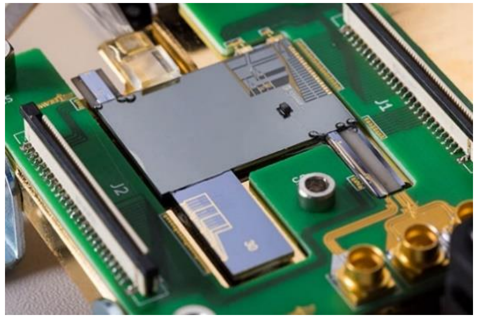
TERAWAY Rx:

- 3 Laser Diodes
- 11 heaters on Polymer
- TIAs
- Peltier

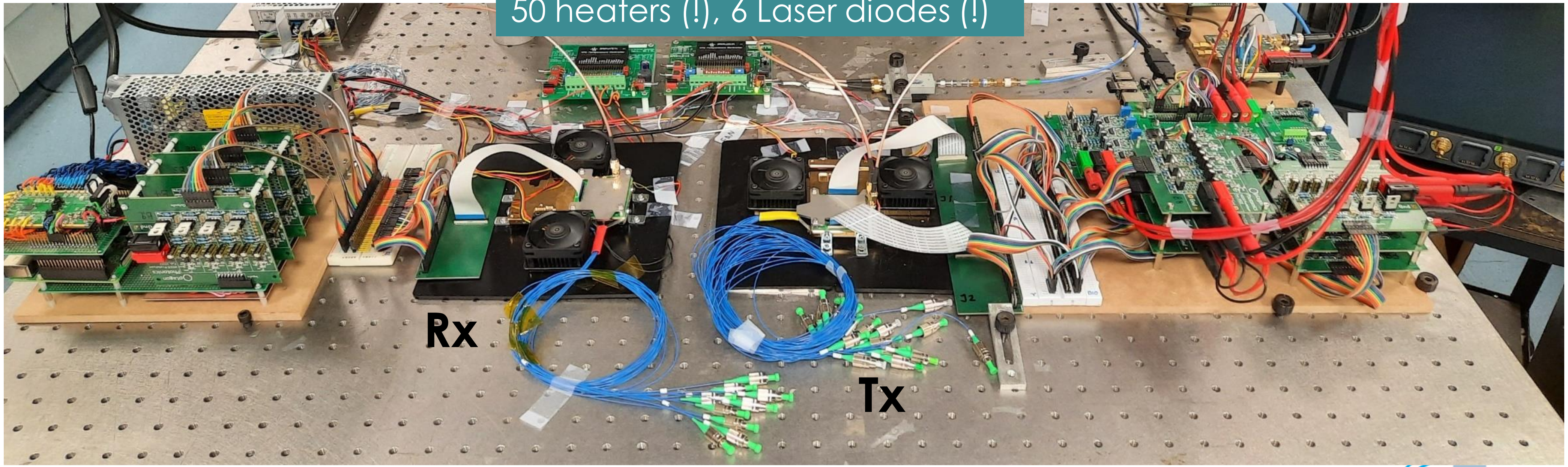


TERAWAY Tx:

- 3 Laser Diodes
- 13 heaters on Polymer (~15 Ohm)
- 16 heaters on Si3N4 (~240 Ohm)
- SOAs
- PMs
- Peltier

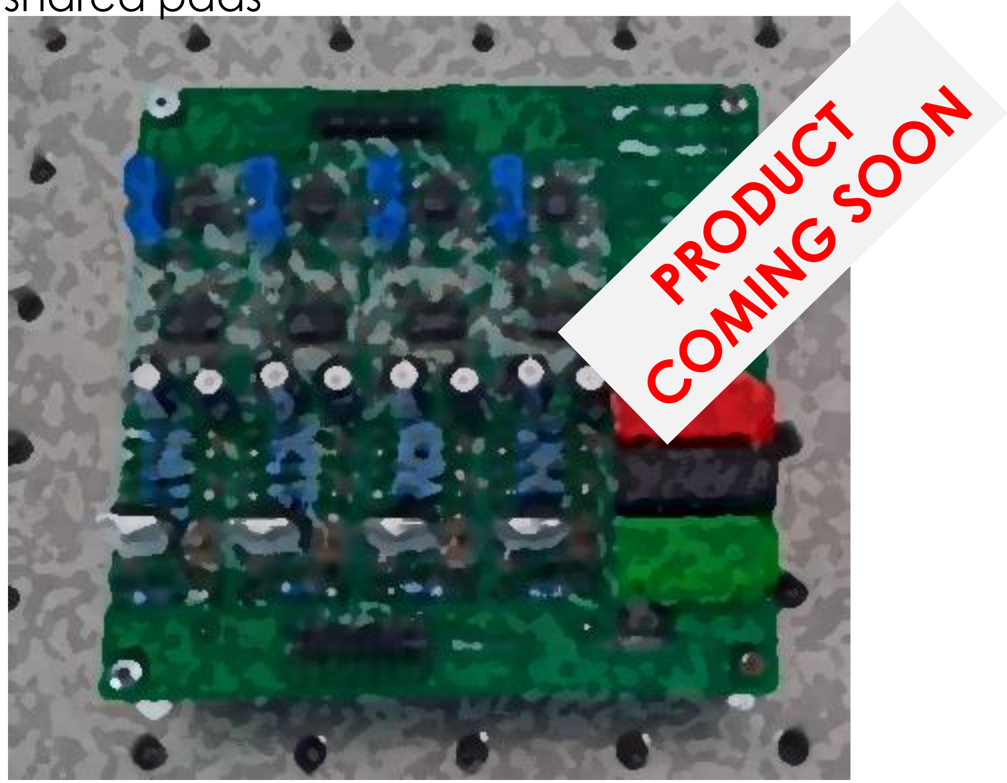


50 heaters (!), 6 Laser diodes (!)



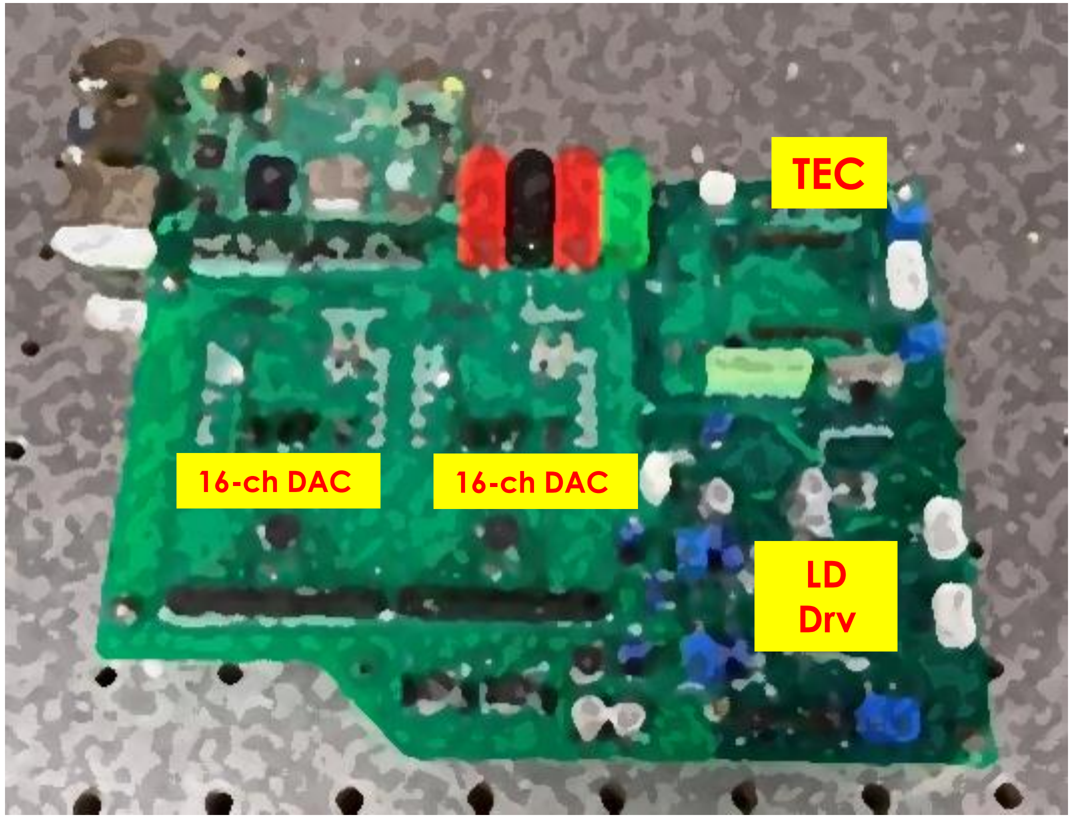
Multi-channel LD drivers

- up to 500 mA or 1 A
- safety features (soft start, current limit, overvoltage protection)
- For Laser diode arrays, semiconductor optical amplifiers (SOAs) with common cathodes and shared pads



Integrated LD drivers + TEC + DACs

- Integrated LD drivers with TEC controllers
- 2x 16-ch DAC integration for analog signal generation



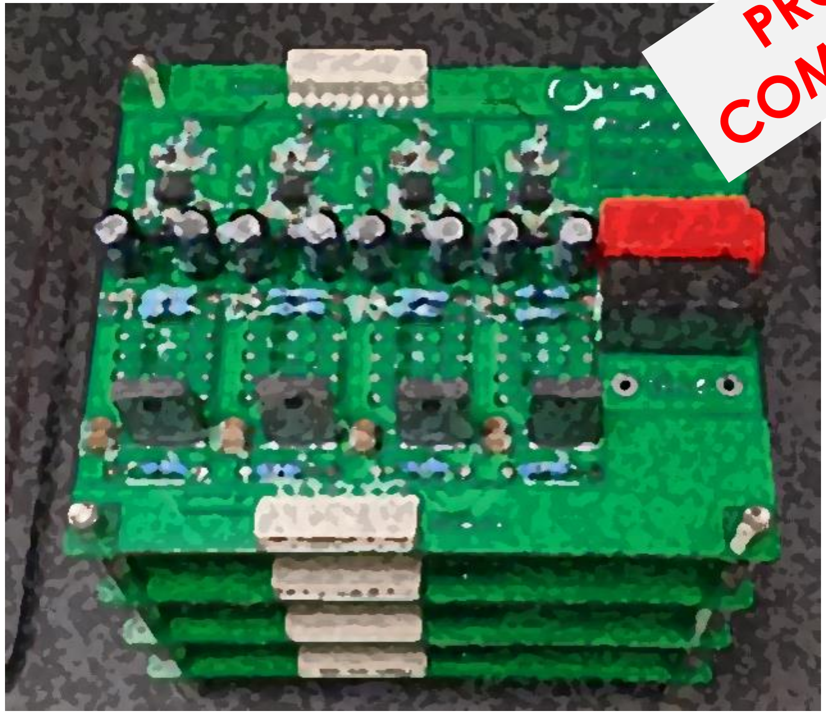
Solutions for driving or controlling complex PICs (II)

Optagon Photonics

Multi-channel voltage controlled current sources

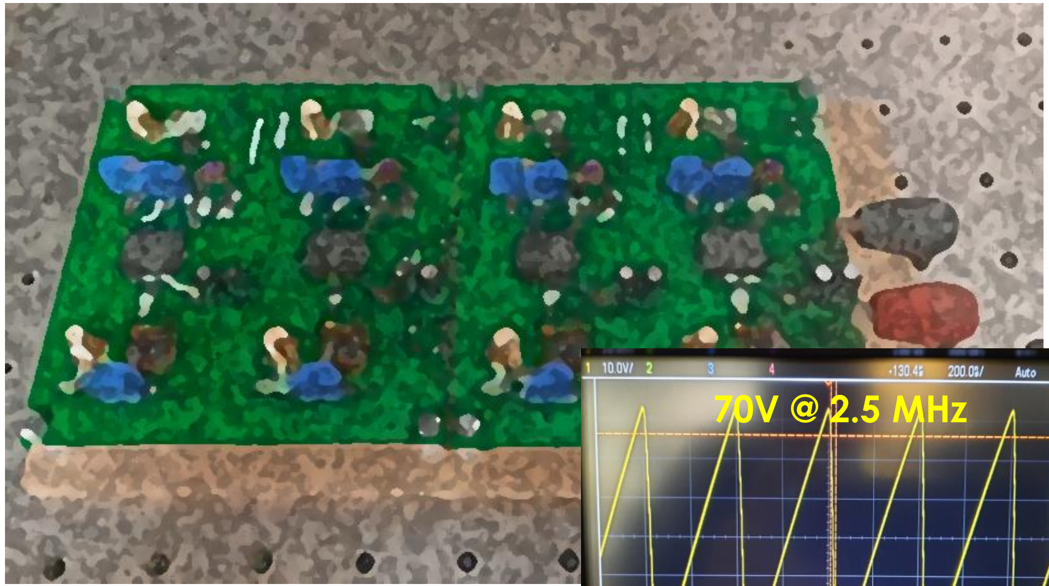
- 4x or longer arrays
- In: 0 – 10 V control signal
- Out: 0 - 50 mA independent of load
- Resistive loads

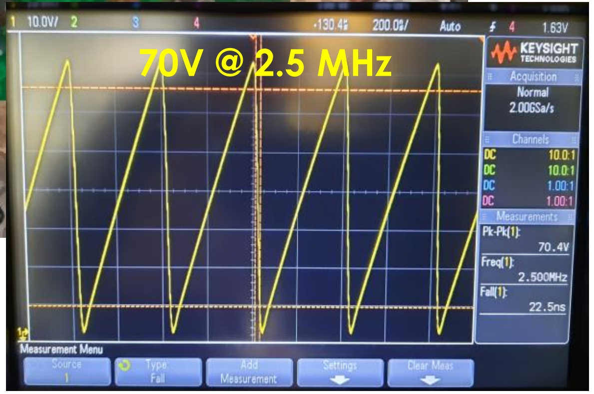
PRODUCT COMING SOON



Multi-channel MHz speed high-V drivers

- Up to 40 MHz bandwidth
- In: 2 V
- Out: 70V
- capacitive loads (PZTs, MEMS etc)

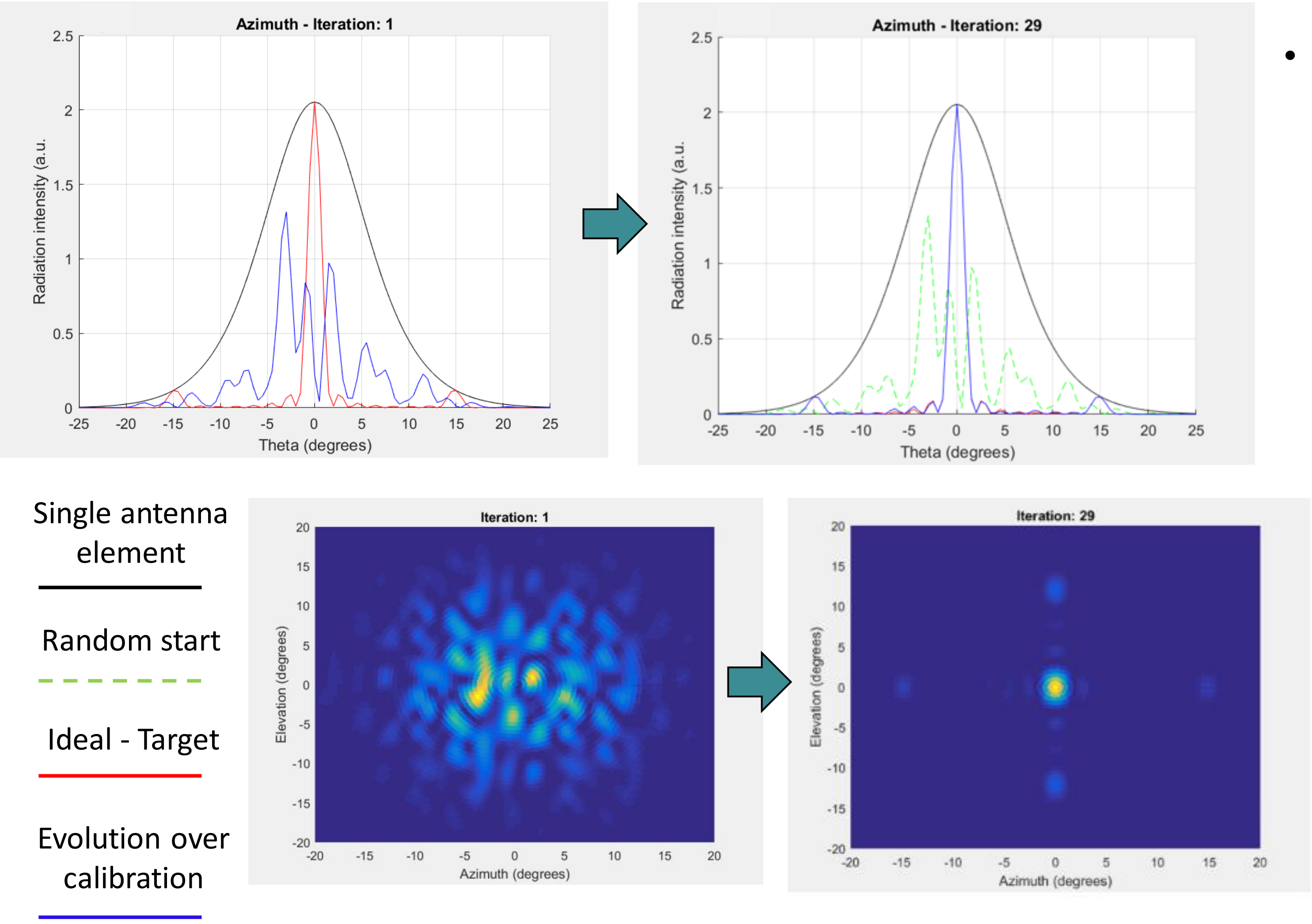




Solutions for driving or controlling complex PICs (III)

Calibration and configuration algorithms for OBFNs, Optical Phased Arrays (OPAs)

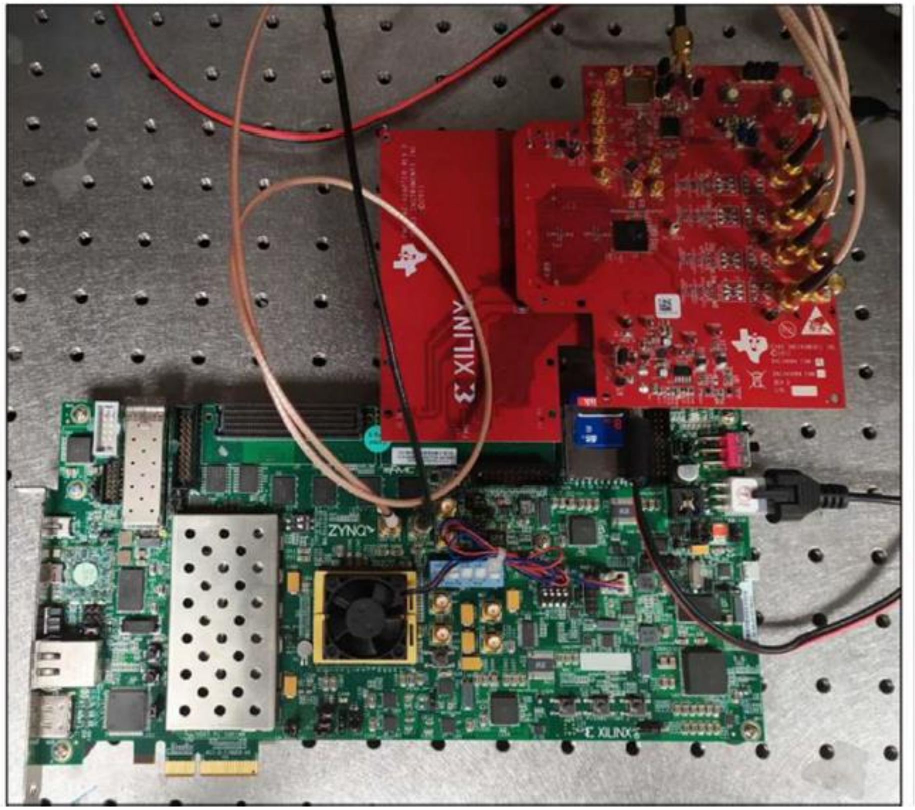
- OPA calibration algorithm soon to be transferred for OBNs



FPGA + DAC platforms

- Generation of analog and IQ signals at MHz with FPGA platforms and DACs
- For optical modulation etc

FPGA and DAC



Conclusions

- 5G and beyond systems will require higher carrier frequencies. W, D or even THz bands are good candidates as there is still unlicensed spectrum
- Photonics can enable signal generation, processing and detection at higher frequencies seamlessly and with great flexibility
- Generation, detection and beam-forming of mmWave/THz signals using photonic components is being leveraged by TERAWAY project to develop high bandwidth wireless transceiver PICs
- PIC functionality greatly relies on phase shifters (heaters) and laser diodes
- Electronic driving solutions were developed to operate the PICs to full potential and enable standalone operation

Thank you!

Optagon Photonics

TERAWAY

Contact:
christos.kouloumentas@optagon-photonics.eu
panos.groumas@optagon-photonics.eu

https://ict-teraway.eu/

http://www.optagon-photonics.eu