Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Integration of high-data rate THz-wireless systems into fiber-optical networks
Date Submitted: 8 June 2020
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Re: n/a
Abstract: THz-wireless systems, due to their ability to transmit high data rates, appear to be an ideal approach to invest fiber-based networks with an unprecedented degree of flexibility. The key for this seamless interconnection is an analog baseband interface. In this presentation, we summarize our efforts to combine fiber-optics and THz-wireless in order to achieve >100Gb/s systems; first, by introducing a real-time optical modem for a purely THz-electrical setup, and second, by introducing an optic/THz baseband interface to construct a combined transmission link: a THz-wireless fiber extender.

Purpose: Information of the Technical Advisory Group THz

INTEGRATION OF HIGH-DATA RATE THZ-WIRELESS SYSTEMS INTO FIBER-OPTICAL NETWORKS

IEEE 802.15

TAG THz,

Online Meeting – 09.06.2020

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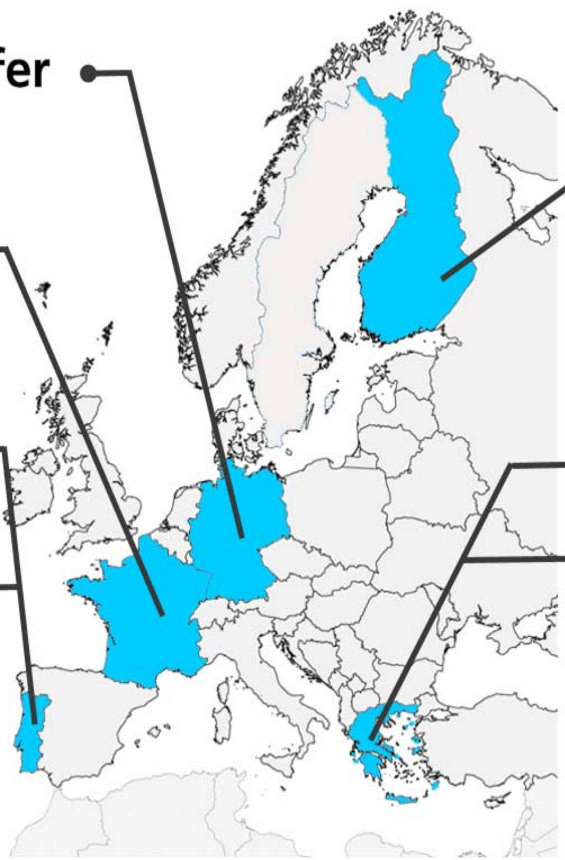
H2020 EU TERRANOVA: Terabit/s Wireless Connectivity by TeraHertz innovative technologies to deliver Optical Network Quality of Experience in Systems beyond 5G



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ICT-09-2017 – Networking research beyond 5G

Duration: 7/2017 – 12/2019

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OUTLINE

- Motivation
- 100 Gb/s real-time experiments
  - THz-wireless system
  - Optic/THz-wireless system
- Conclusions and future work

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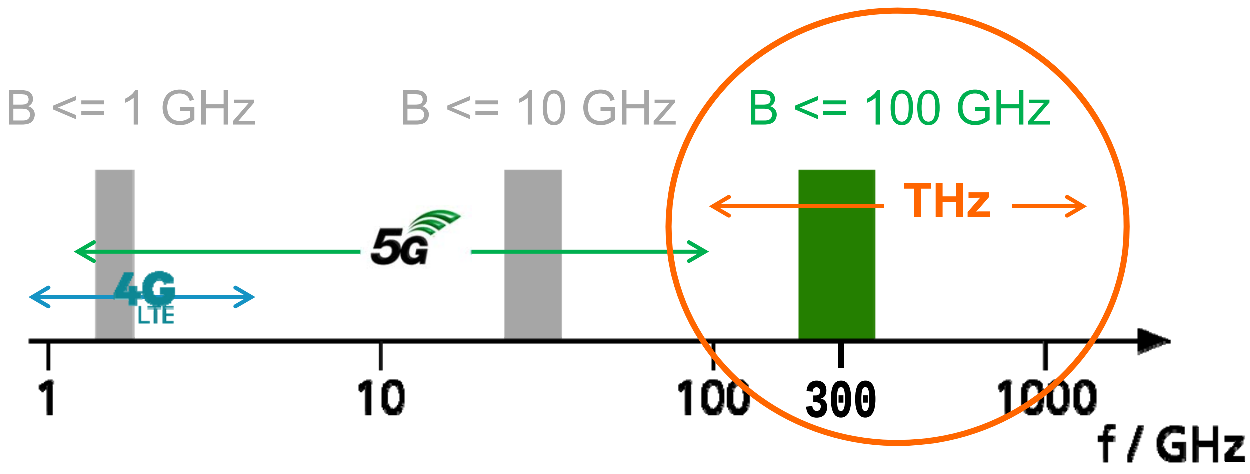
Motivation

THz transmission and the future of high-speed flexible wireless networks

- THz wireless data transmission at carrier frequencies in the 100 – 1000 GHz range
  - Large bandwidth, compatible with state-of-the-art fibre-optical transmission systems
  - This allows to design **flexible Terabit/s Wireless Systems** capable of being directly integrated into fiber-based network architectures



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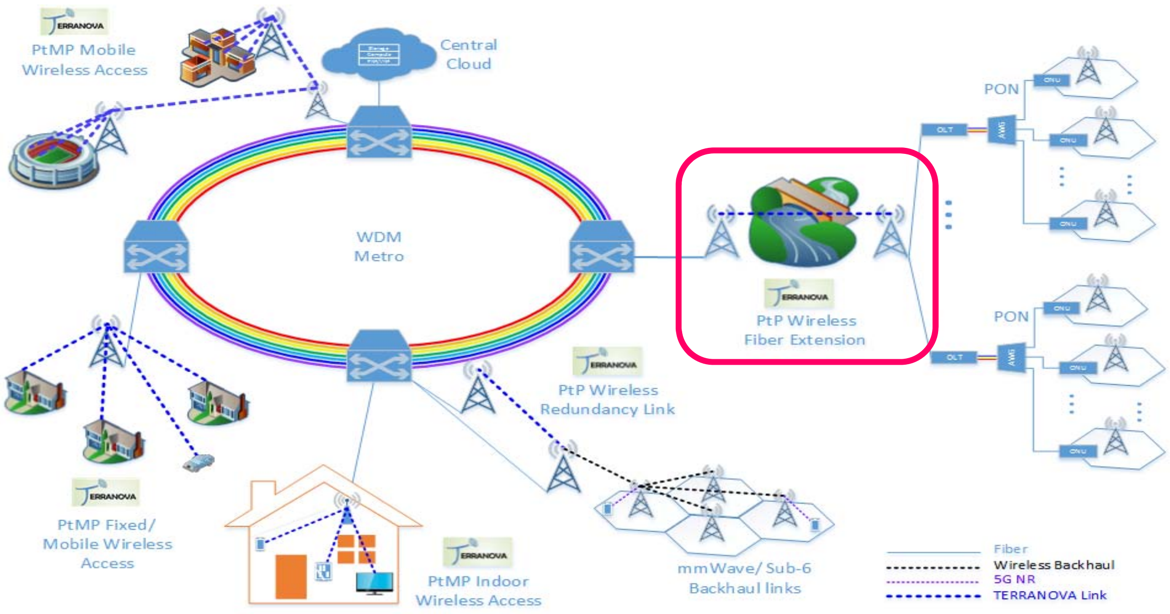
Motivation

THz transmission and the future of high-speed flexible wireless networks



- Possible applications can be grouped into 3 particular scenarios:
  - Omnidirectional
  - Point-to-Multipoint
  - Point-to-Point

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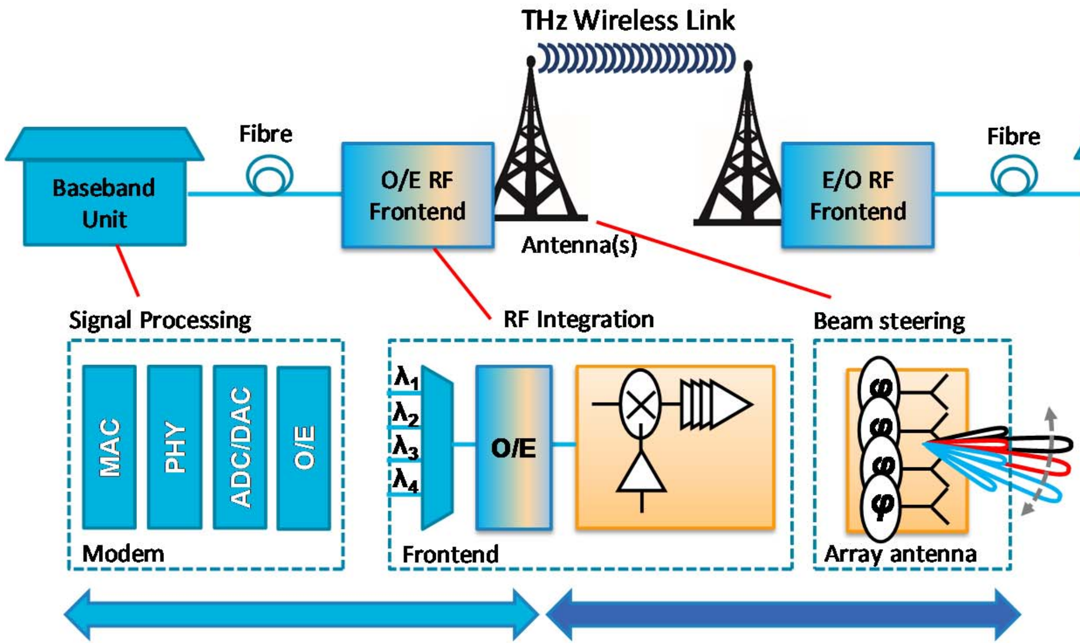
Motivation

THz transmission and the future of high-speed flexible wireless networks



- Seamless interconnection between fiber networks and THz-wireless links
- Joint impairment mitigation of the combined optic/THz-wireless link

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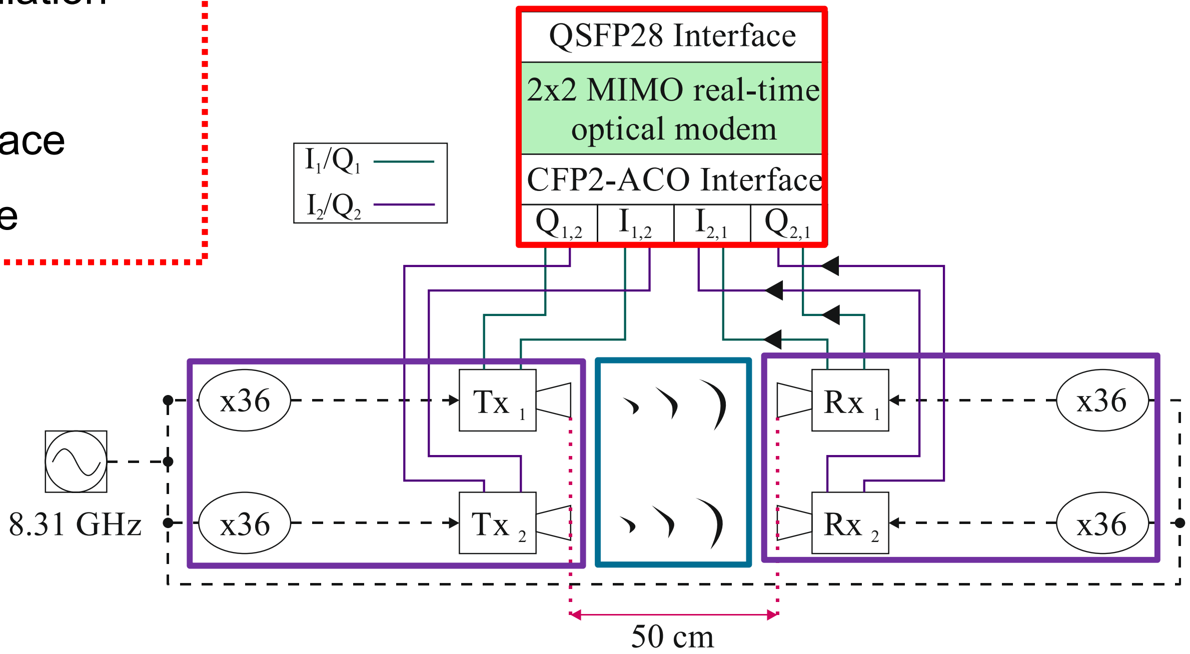
100 Gb/s real-time experiments – THz-wireless system

Experimental real-time THz-wireless system using a digital-coherent optical modem

- ~34 GBd PDM-QPSK modulation
- 2x2 polarization MIMO
- CFP2-ACO pluggable interface
- QSFP28 client side interface

- InP MMIC technology
- BW: 25 GHz (Tx)
  50 GHz (Rx)
- 23 dBi antennas
- ~300 GHz carrier



- Length: 50 cm
- Height: 20 cm above the metal ground plate
- Separation: 12.5 cm lateral displacement

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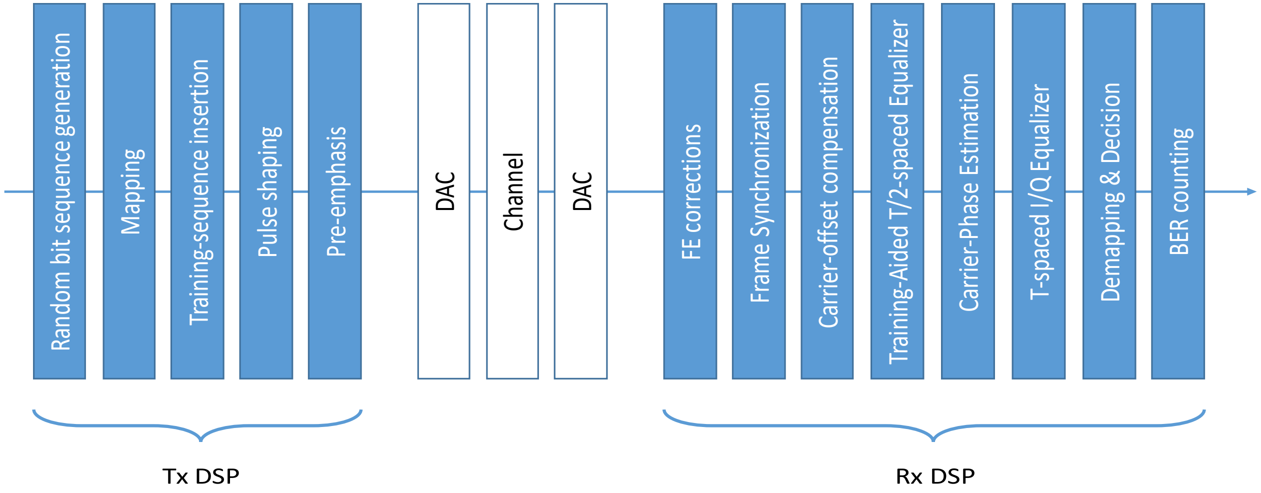
100 Gb/s real-time experiments – THz-wireless system

DSP chain used for the 100 Gb/s THz-wireless link



- Reference case: Offline DSP commonly used in fiber-optical experiments
- Similar algorithms implemented in real-time modem

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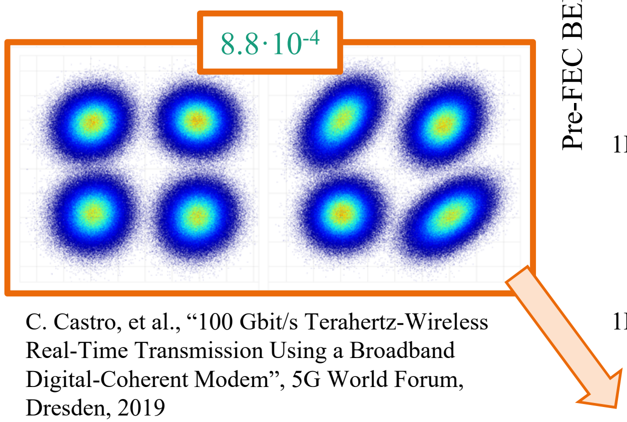
100 Gb/s real-time experiments – THz-wireless system

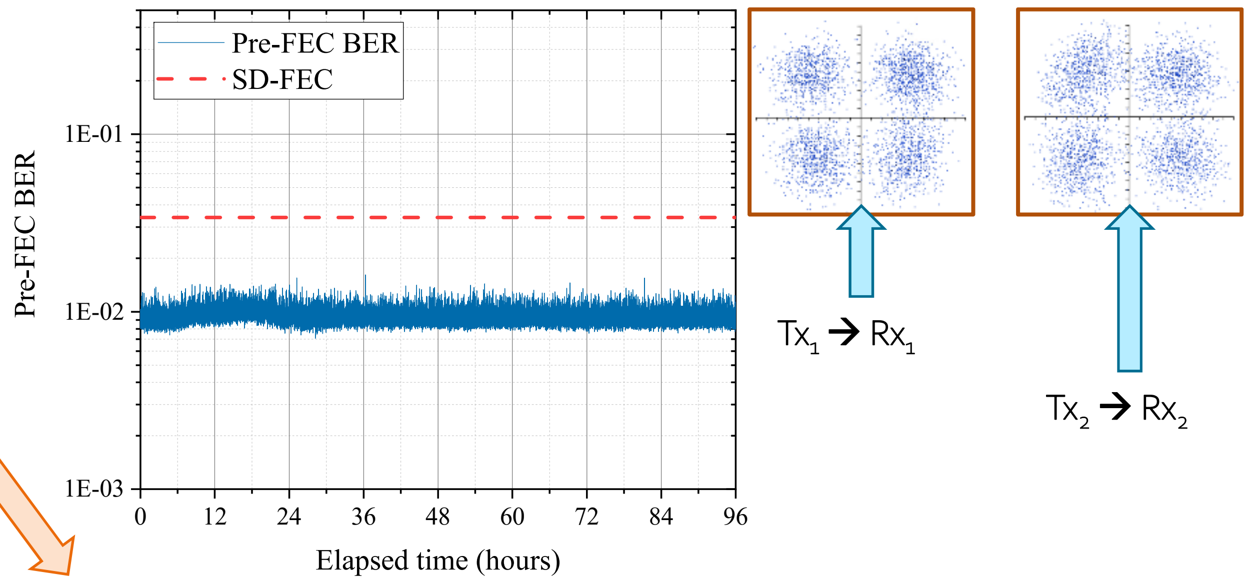
Physical layer performance using a digital-coherent real-time optical modem

- Long-term stable (4 days of continuous operation) pre-FEC BER below SD-FEC threshold
- Comparison to offline DSP: Pre-FEC BER better due to optimized DSP

Offline 100 Gb/s QPSK



C. Castro, et al., "100 Gbit/s Terahertz-Wireless Real-Time Transmission Using a Broadband Digital-Coherent Modem", 5G World Forum, Dresden, 2019



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100 Gb/s real-time experiments – THz-wireless system

Ethernet tests using an IXIA XGS12 100 GbE traffic platform – Frame loss rate

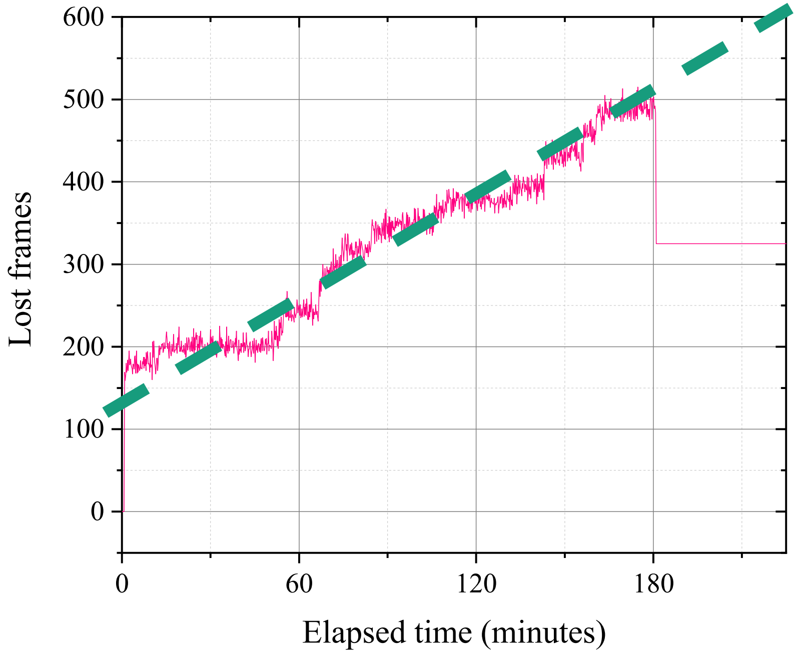
- The traffic platform defines the number of lost frames as follows:

  lost frames = Tx frames – Rx frames

- 'In transit' is therefore an actual condition

$$8.545\ \mu\text{s} \ / \ (794\,\frac{\text{B}}{\text{frames}} \cdot 8\,\frac{\text{b}}{\text{B}} / 100\,\frac{\text{Gb}}{\text{s}}) = 135 \text{ frames}$$

- Frame loss rate: 0.03 fps (1.85 fpm)
- Frame size: random (70 – 1518 Bytes)



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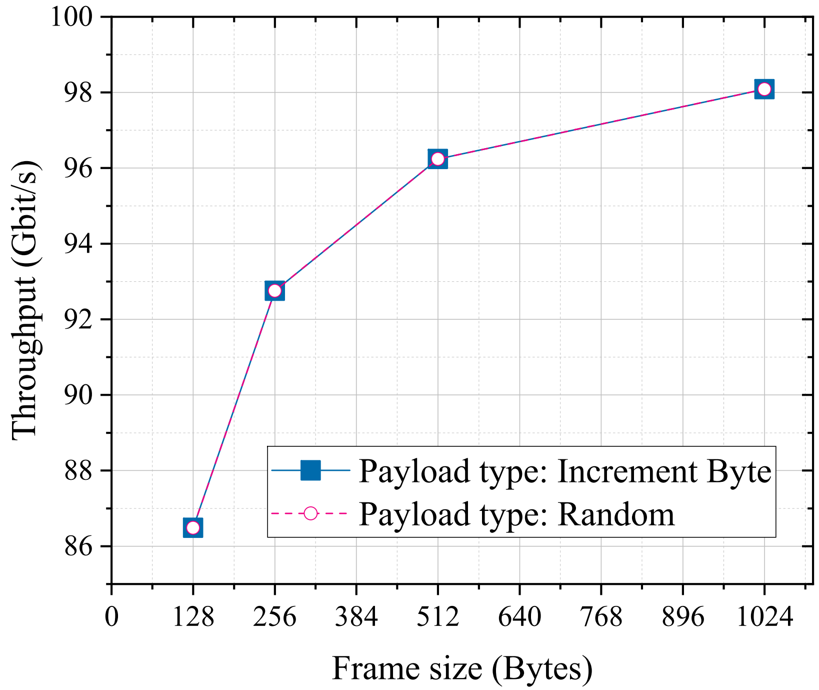
100 Gb/s real-time experiments – THz-wireless system

Ethernet tests using an IXIA XGS12 100 GbE traffic platform – Throughput

- Payload type **does not** influence the overall throughput of the system
- Frame size **does** affect the overall throughput of the system
  - 12-Byte long 'interframe gap' between frames
  - More frames → more idle time → less actual transmitted data
- Max. measured data rate was 98.07 Gb/s



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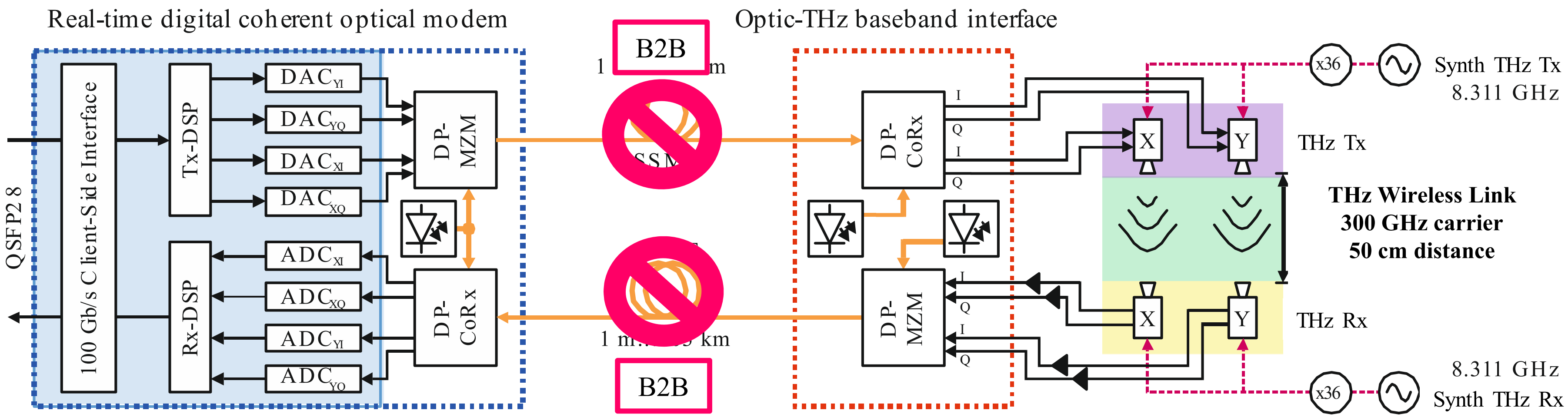
100 Gb/s real-time experiments – Optic/THz-wireless system

Link configurations for a THz-Wireless Fiber Extender

- The goal was to construct a short-range real-time implementation of a high-speed *THz-wireless fiber extender* as a proof-of-concept



- Fiber – THz Wireless – Fiber
- Fiber – THz Wireless
- THz Wireless – Fiber

PC: phase conjugation. Inversion of in-phase components of both polarizations at the optic-THz BB interface

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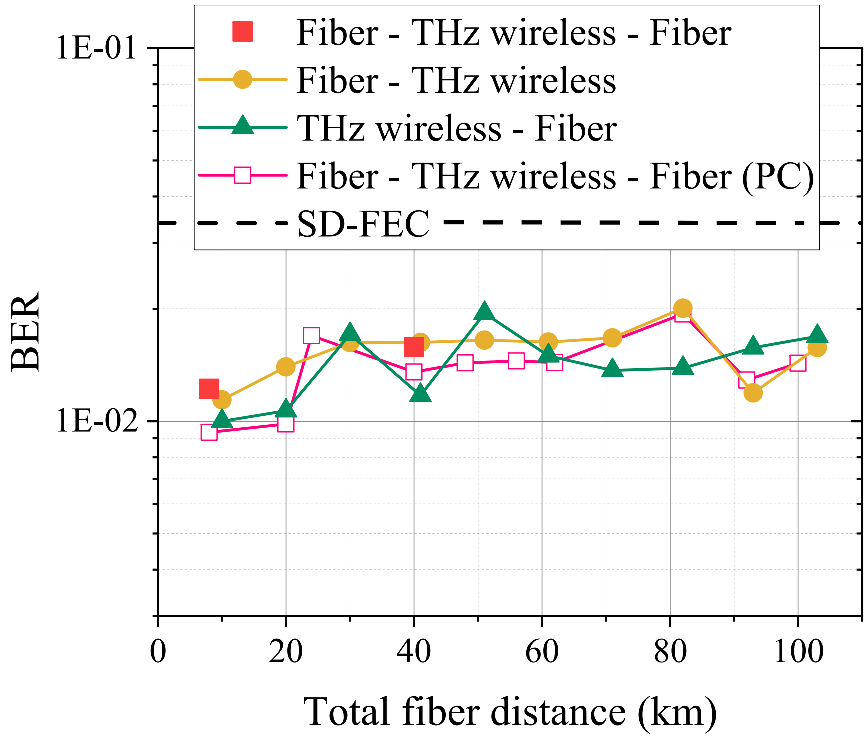
100 Gb/s real-time experiments – Optic/THz-wireless system

Physical layer performance of an optic/THz-wireless transmission system

- BER performance vs. total fiber distance for different link configurations
- Neither the fiber configuration nor the optical link distance seems to affect the overall performance
  - High OSNR: > 35 dB
  - THz-wireless link is the limiting factor



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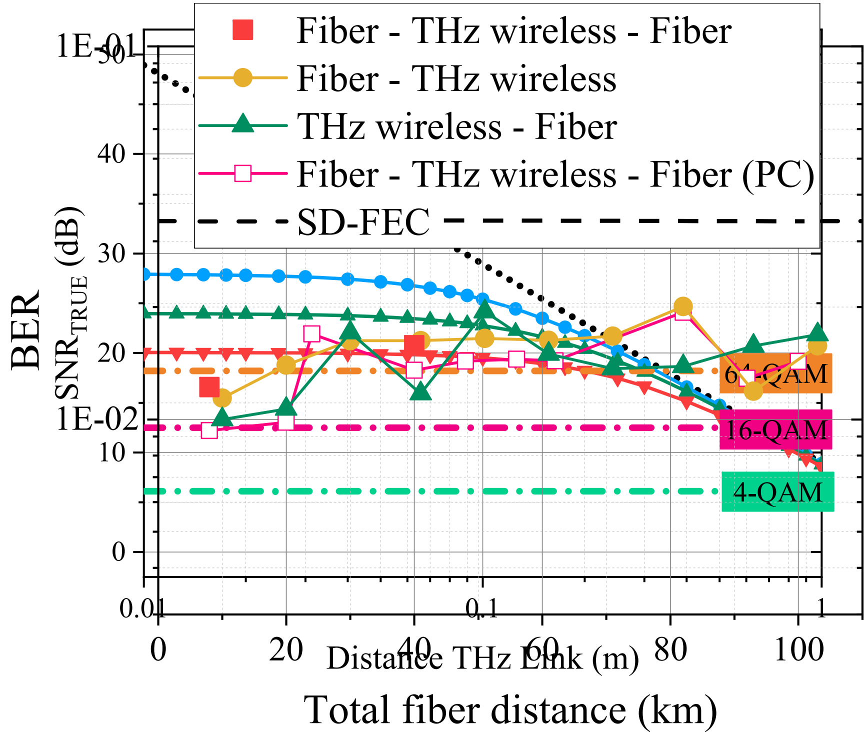
100 Gb/s real-time experiments – Optic/THz-wireless system

Physical layer performance of an optic/THz-wireless transmission system

- Comparison to simulation results
- Performance of a combined link is determined by the link with the worse SNR condition
  - Assuming there's a large SNR difference between them
- Evidence shows that the THz link operates in a low SNR condition



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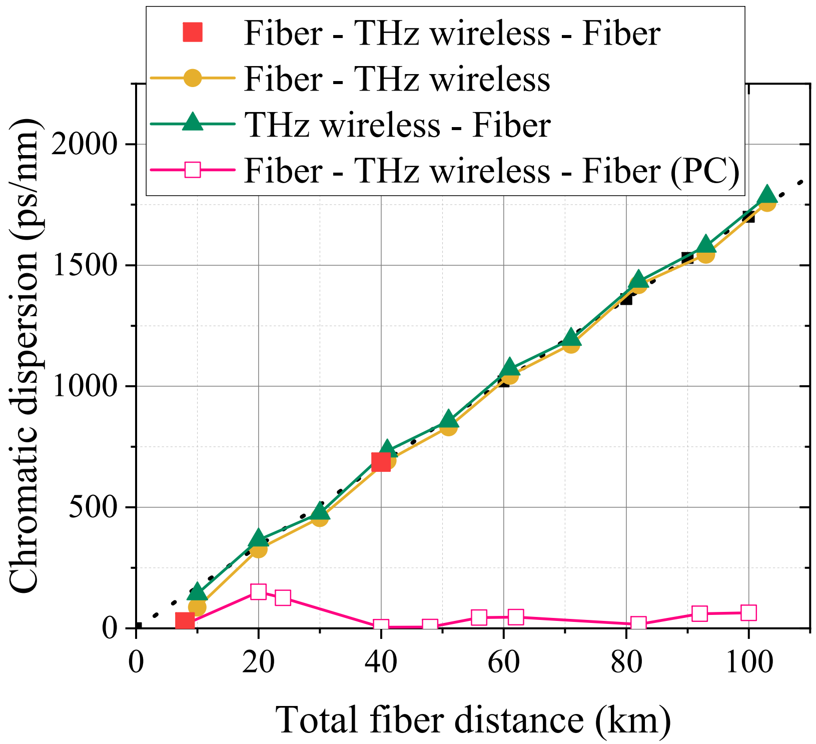
100 Gb/s real-time experiments – Optic/THz-wireless system

DSP techniques and their application to optic/THz-wireless links – Estimated total accumulated chromatic dispersion

- Chromatic dispersion is estimated as a function of the fiber distance
- The THz fiber extender is transparent to CD
  - A slope of ~17 ps/km·nm can be extracted (SSMF)
- Phase conjugator by inverting in-phase components at optic-THz interface



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Conclusions and future work

Towards integrated optic/THz-wireless connectivity for Beyond 5G

- Experimental demonstration: 100-Gb/s THz Wireless Transmission over 0.5 m
  - Stable BER performance over 96 hours of continuous operation
  - Validation of 100 Gb/s throughput (98.08 Gb/s)

- Experimental demonstration: Seamless interconnection between optical ransmission links and THz-wireless technologies
  - Real-time 100 Gb/s transmission over fiber + THz-wireless link
  - Demonstrated the linearity and transparency of the THz-wireless fiber extender

- Next steps: Increase range, capacity and flexibility
  - Extend range by using high-gain antennas (1 km-long THz-wireless transmission)
    - **28 GBd QPSK transmission over 1 km**
  - Improve linearity and output power of electronic front-ends (high-order modulation formats)
  - Adaptive PHY DSP to cope with channel dynamics (better suited DSP techniques)

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WE PUT SCIENCE INTO ACTION.

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