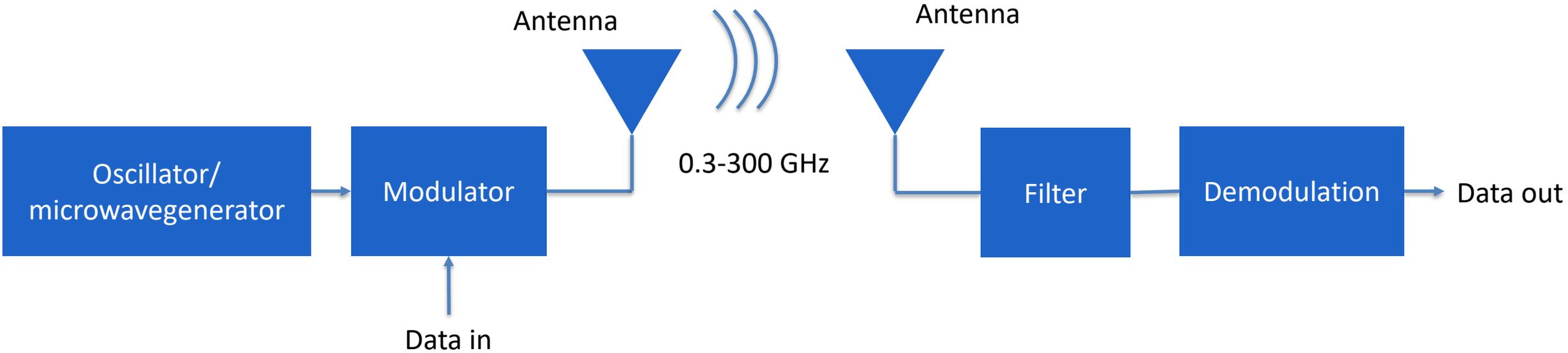


MICROWAVE PHOTONICS

Kasper Van Gasse

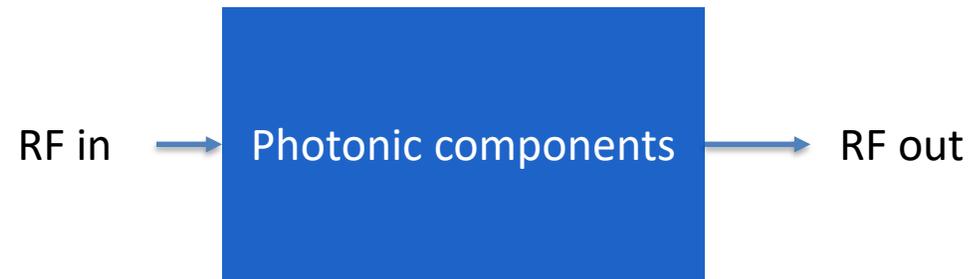
MICROWAVE SYSTEMS



Applications:



MICROWAVE PHOTONIC SYSTEMS

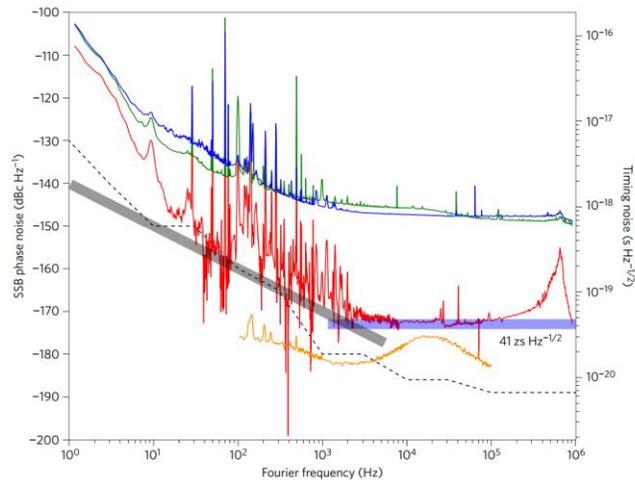


A microwave system where the functionality is provided by a photonic system.

LETTERS
PUBLISHED ONLINE: 21 NOVEMBER 2016 | DOI: 10.1038/NPHOTON.2016.215

nature
photonics

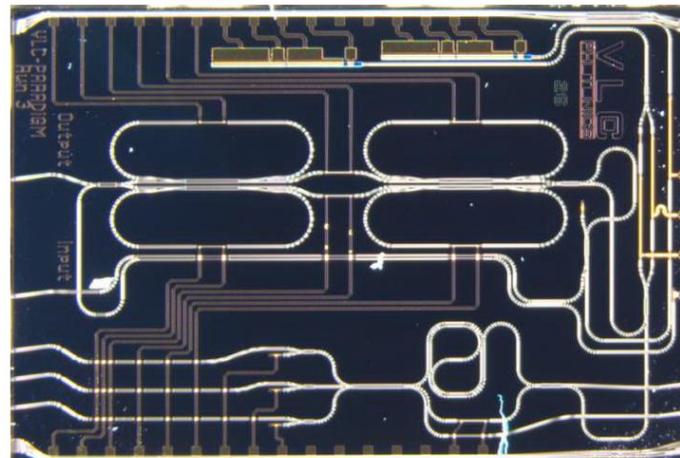
Photonic microwave signals with zeptosecond-level absolute timing noise



ARTICLES
PUBLISHED ONLINE: 5 DECEMBER 2016 | DOI: 10.1038/NPHOTON.2016.233

nature
photonics

A monolithic integrated photonic microwave filter

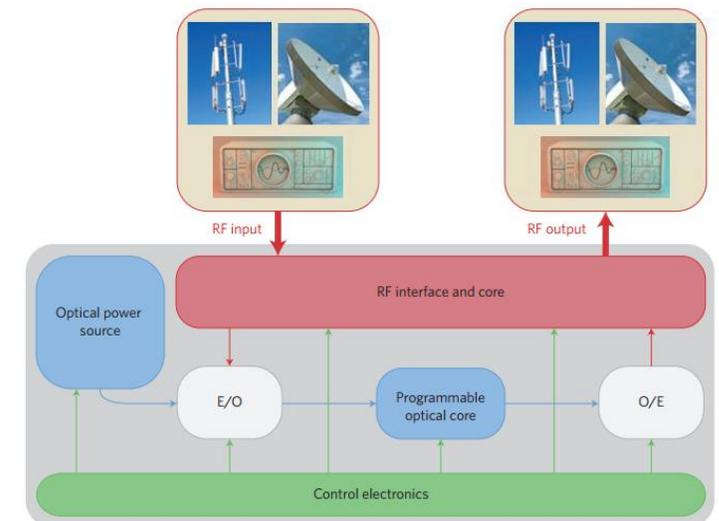


MICROWAVE PHOTONICS

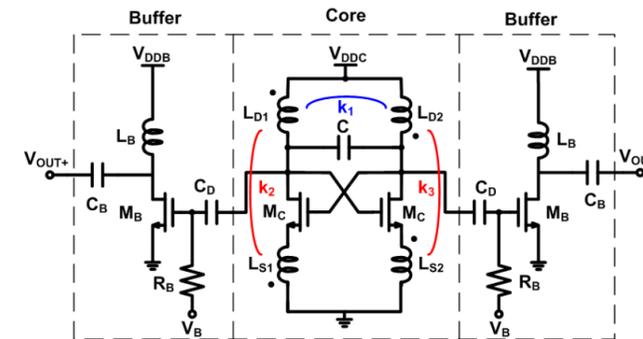
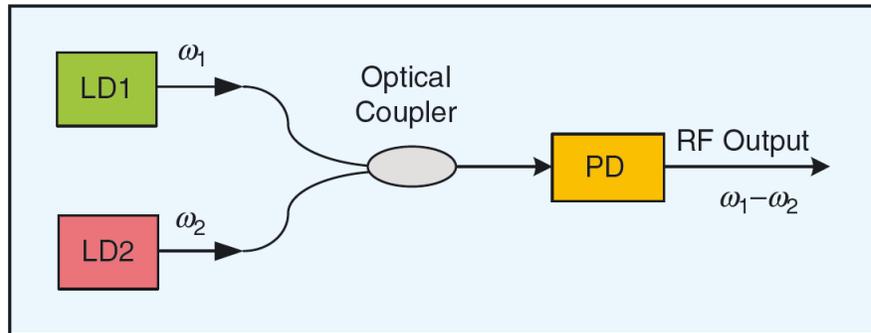
The programmable processor

Reconfigurable optical chips made from 2D meshes of connected waveguides could pave the way for programmable, general purpose microwave photonics processors.

José Capmany, Ivana Gasulla and Daniel Pérez



MICROWAVE GENERATION: PHOTONICS VS ELECTRONICS

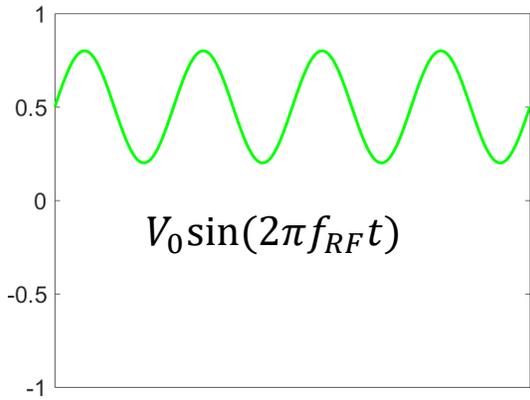


	Photonic	Electronic
Bandwidth	Bandwidth limited to UTC-PD 1 nm tuning is 120 GHz	200 GHz bandwidth and 10 percent tuning
Size	Determined by wavelength: 1 μm	Wavelength: 1-5 mm
Losses	0.3 dB/km in optical fiber	6000 dB/km @ 60 GHz No transmission above 100 GHz

OVERVIEW

- **Introduction to microwave photonics**
- Ongoing research
 - Silicon photonic Radio-over-Fiber links for 5G
 - Photonic frequency conversion
- Summary

MICROWAVE PHOTONICS PROCESSING



RF or data in

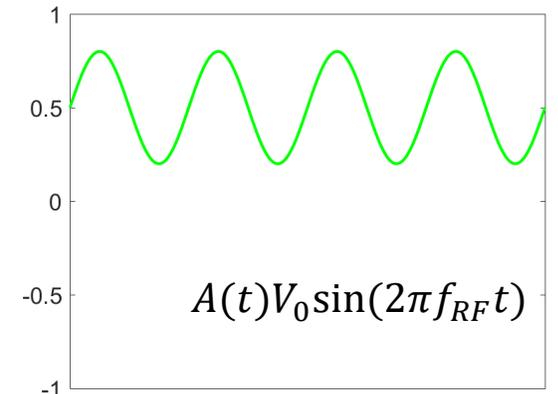
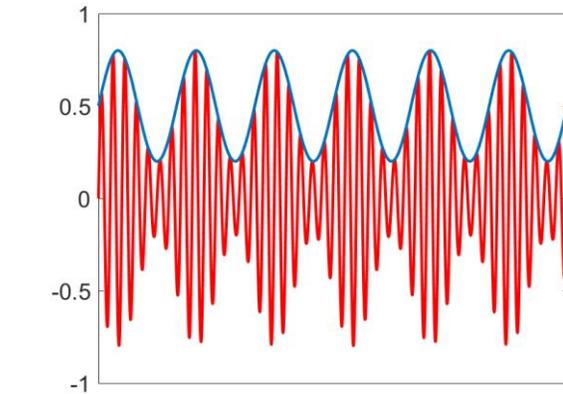
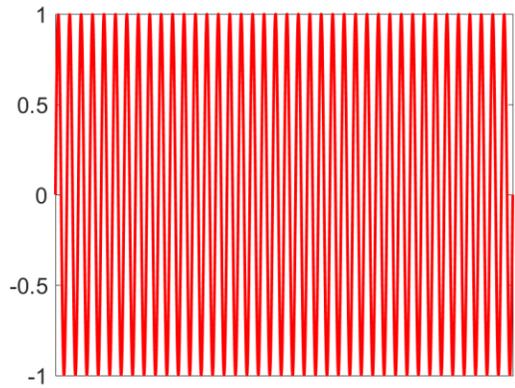
Laser

Modulator

RF functionality in optical domain

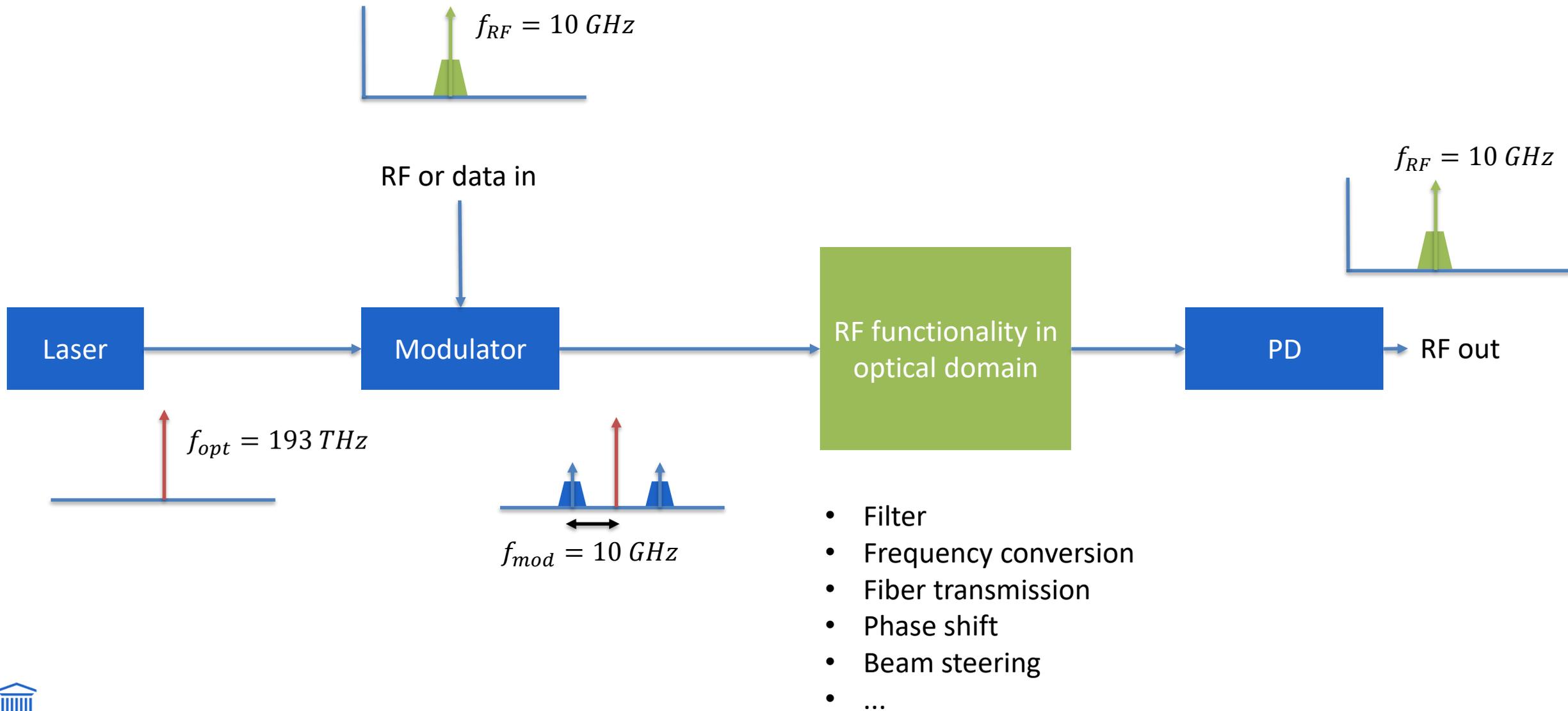
PD

RF out

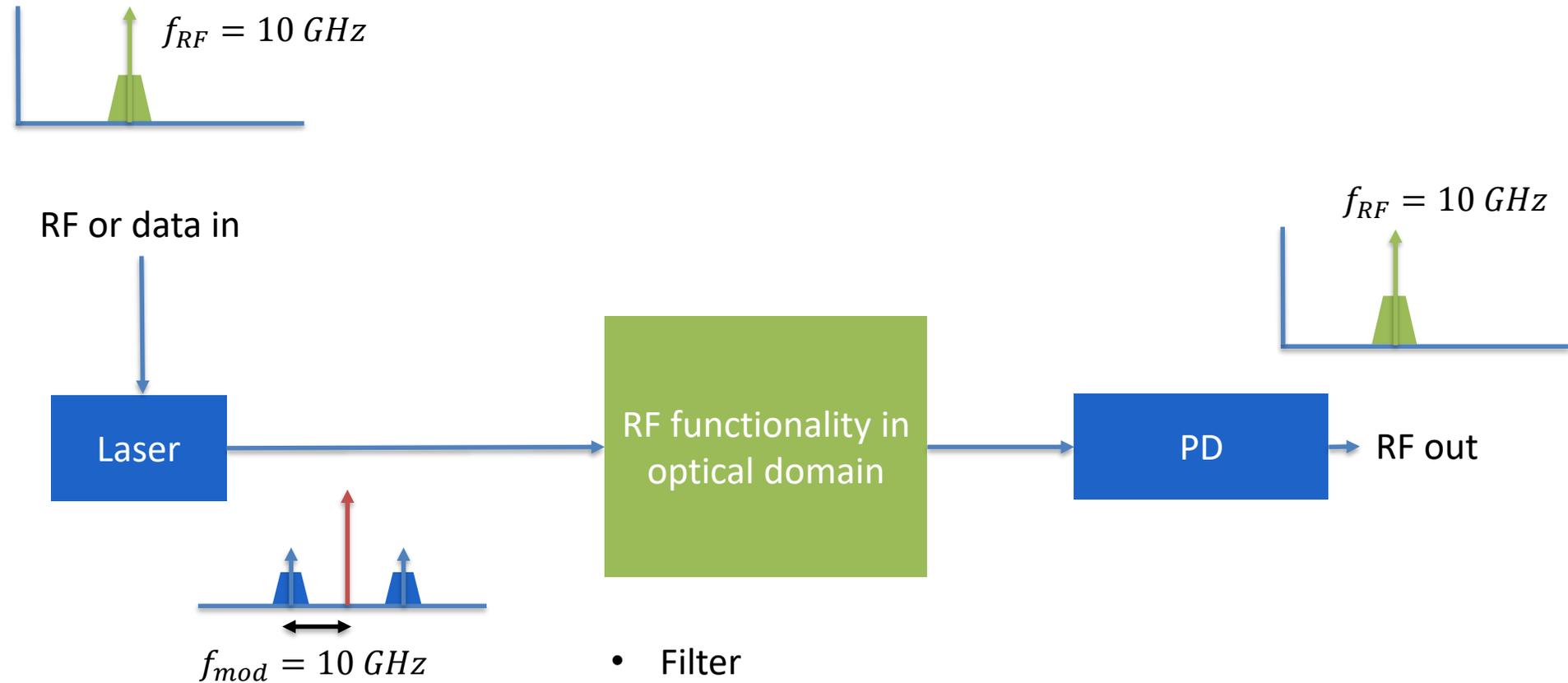


- Filter
- Frequency conversion
- Fiber transmission
- Phase shift
- Beam steering
- ...

MICROWAVE PHOTONIC PROCESSING

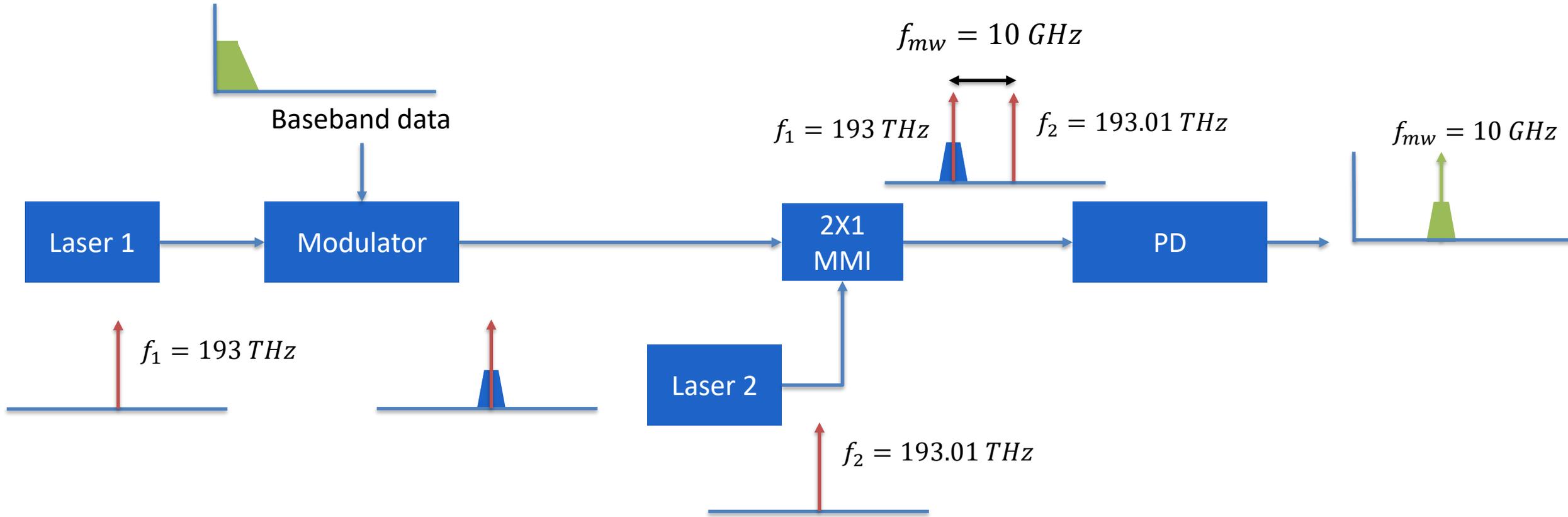


MICROWAVE PHOTONICS PROCESSING



- Filter
- Frequency conversion
- Fiber transmission
- Phase shift
- Beam steering
- ...

MICROWAVE PHOTONIC UPCONVERSION



Integrated InP Heterodyne Millimeter Wave Transmitter

Frederic van Dijk, Gaël Kervella, Marco Lamponi, Mourad Chtioui, François Lelarge, Eric Vinet, Yannick Robert, Martyn J. Fice, Cyril C. Renaud, Alvaro Jimenez, and Guillermo Carpintero

Fully integrated heterodyne microwave generation on heterogeneous silicon-III/V

Jared C. Hulme,^{1*} Jin-Wei Shi,³ MJ Kennedy,¹ Tin Komljenovic,¹ Bogdan Szafraniec,² Doug Baney,² and John E. Bowers¹

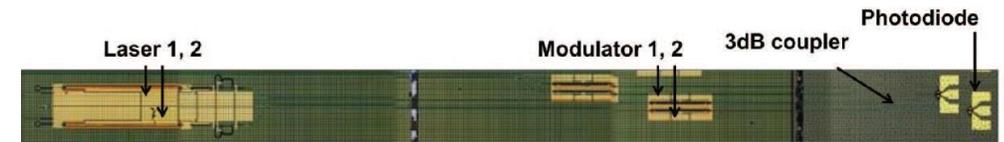
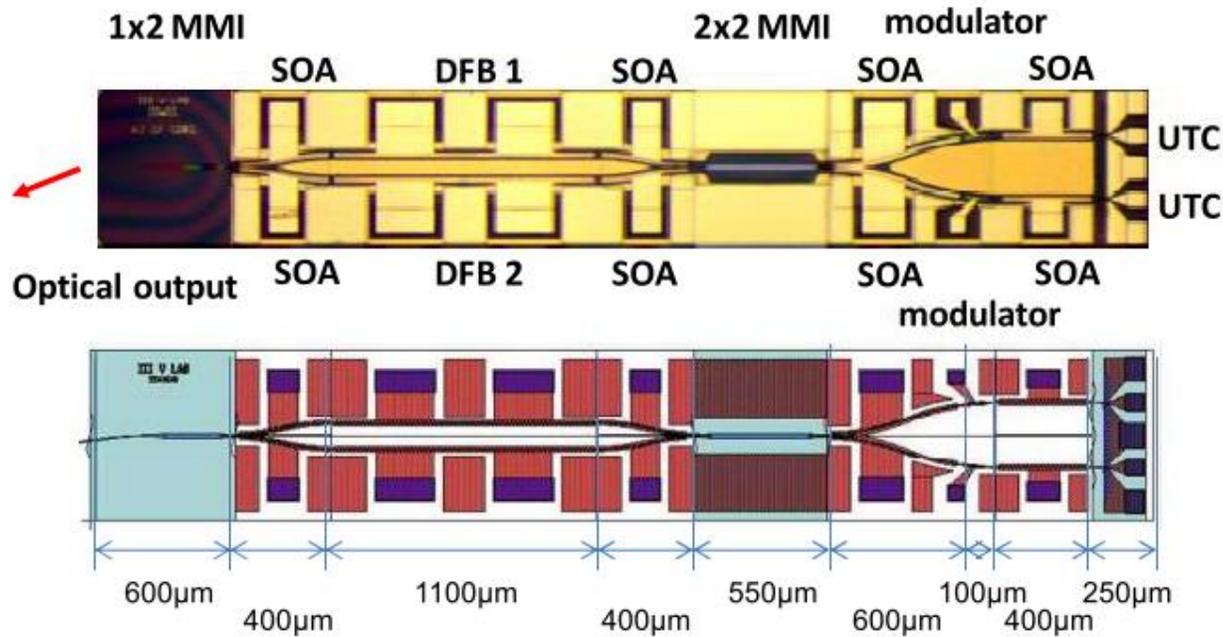
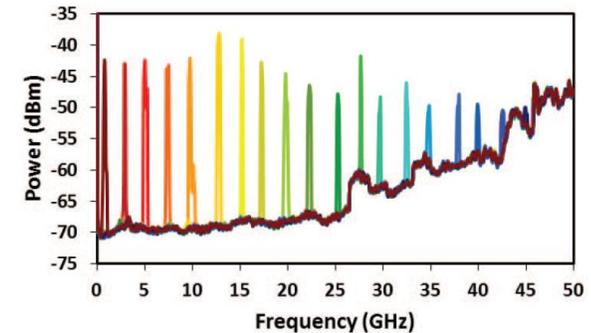
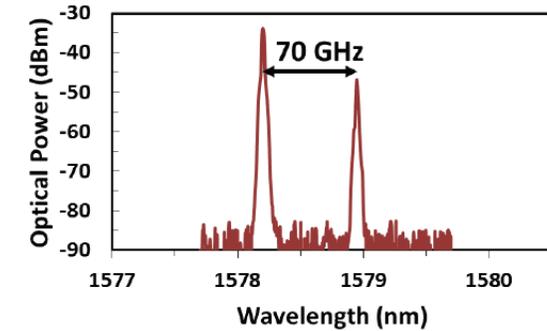
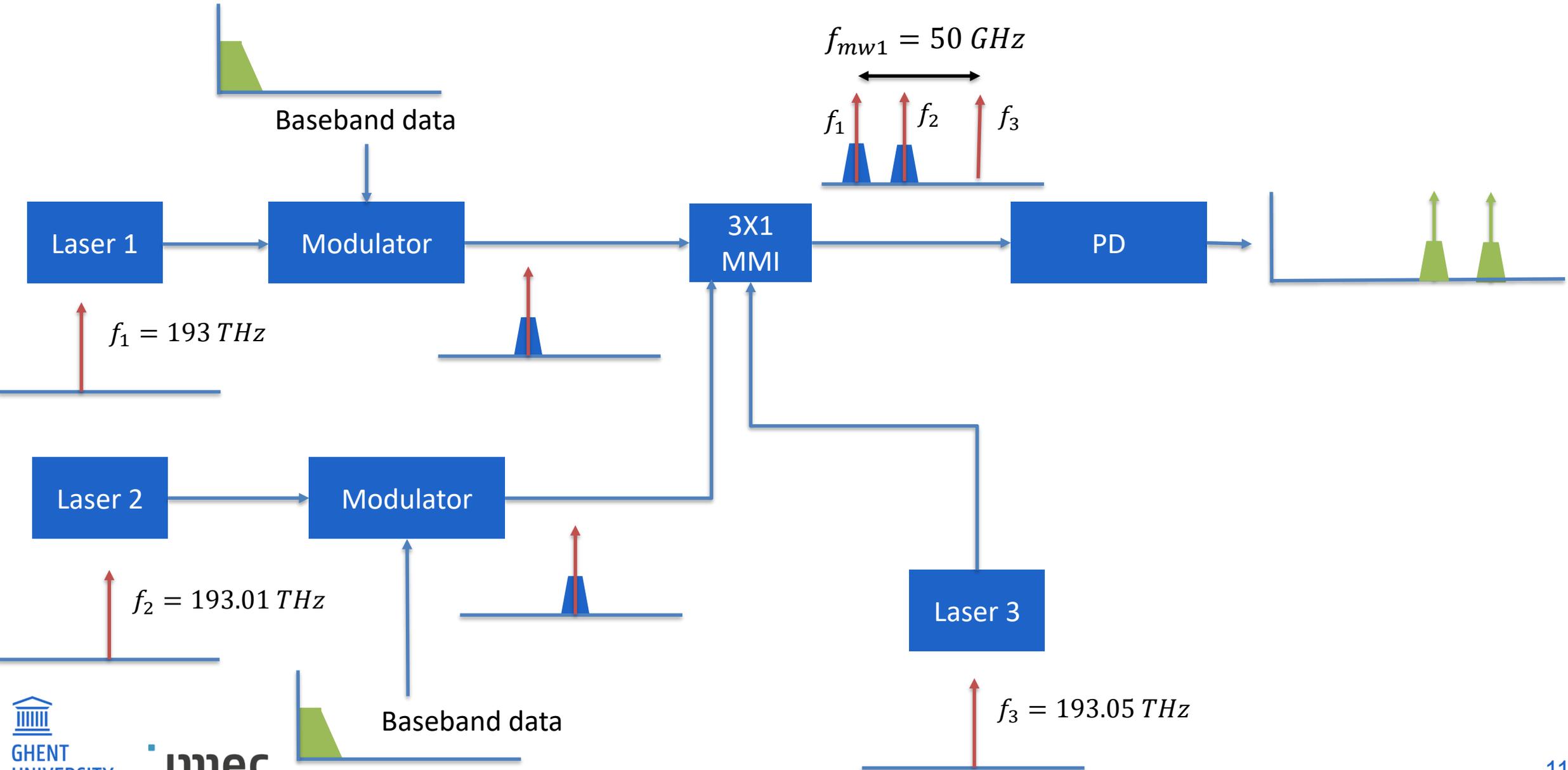


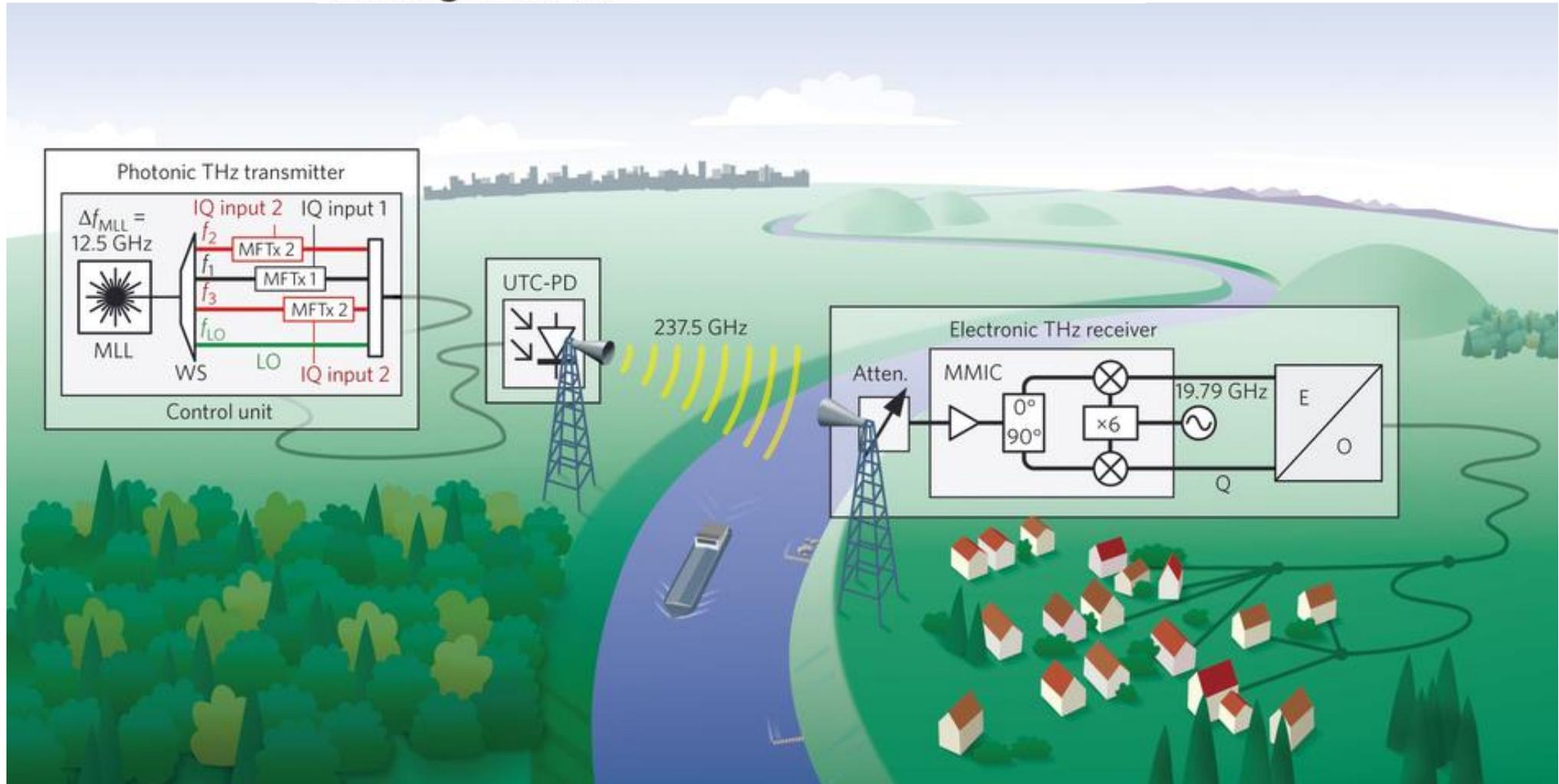
Fig. 7. Optical microscope photo of completed integrated microwave generator including two 1x2CRR lasers, phase modulators, a 3dB directional coupler, and on-chip photodiode.



MICROWAVE PHOTONICS UPCONVERSION: MULTICHANNEL



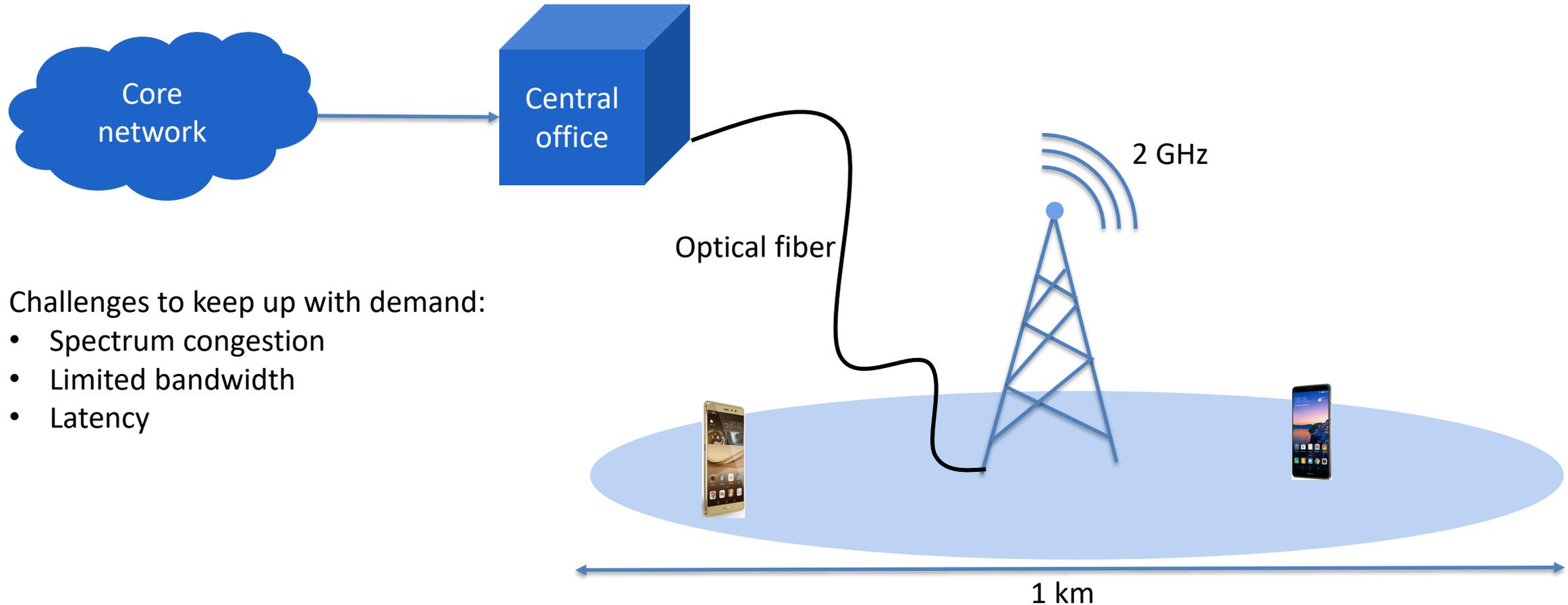
Wireless sub-THz communication system with high data rate



OVERVIEW

- Introduction to microwave photonics
- Ongoing research
 - **Silicon photonic Radio-over-Fiber links for 5G**
 - Photonic frequency conversion
- Conclusion

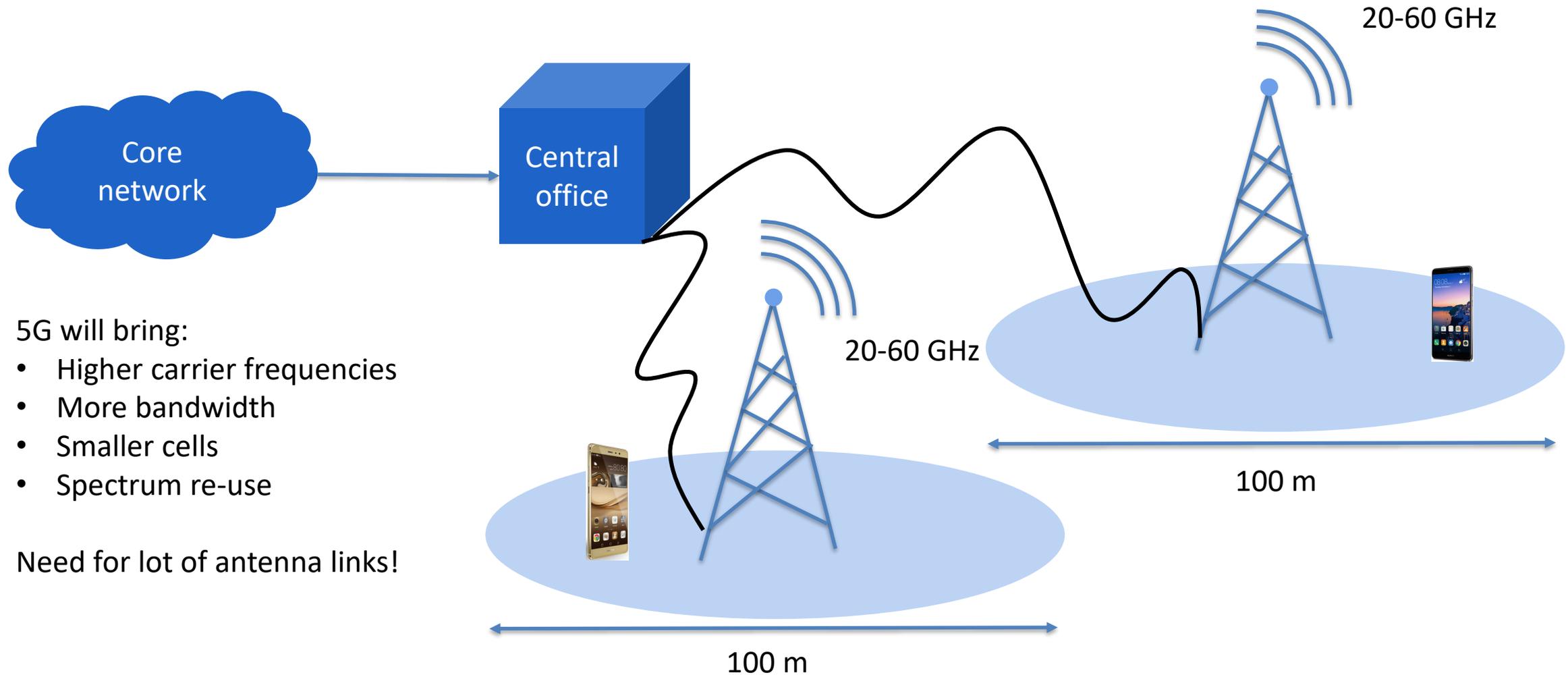
WIRELESS COMMUNICATION – 4G LTE



Challenges to keep up with demand:

- Spectrum congestion
- Limited bandwidth
- Latency

WIRELESS COMMUNICATION – 5G



5G will bring:

- Higher carrier frequencies
- More bandwidth
- Smaller cells
- Spectrum re-use

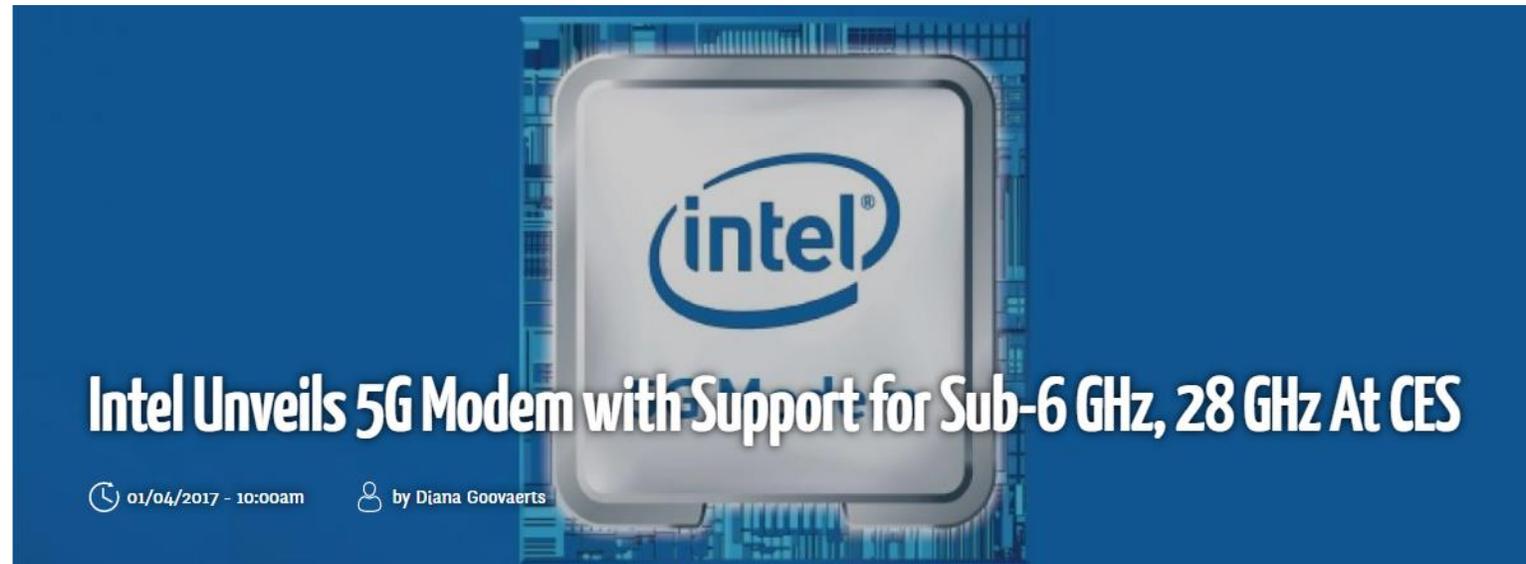
Need for lot of antenna links!

WIRELESS COMMUNICATION – 5G

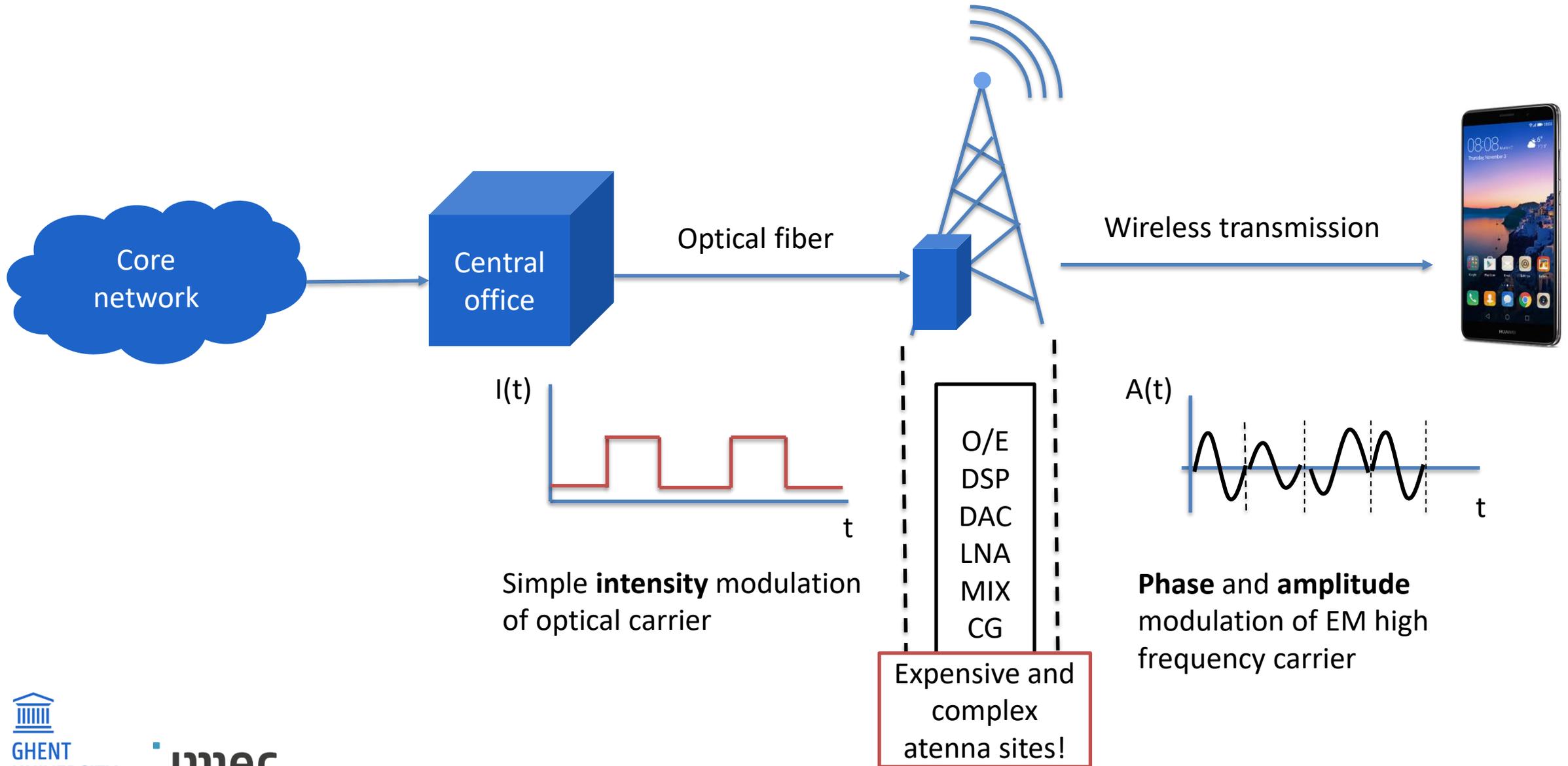
FierceWireless

WIRELESS TECH EUROPE DEVELOPER 5G IOT

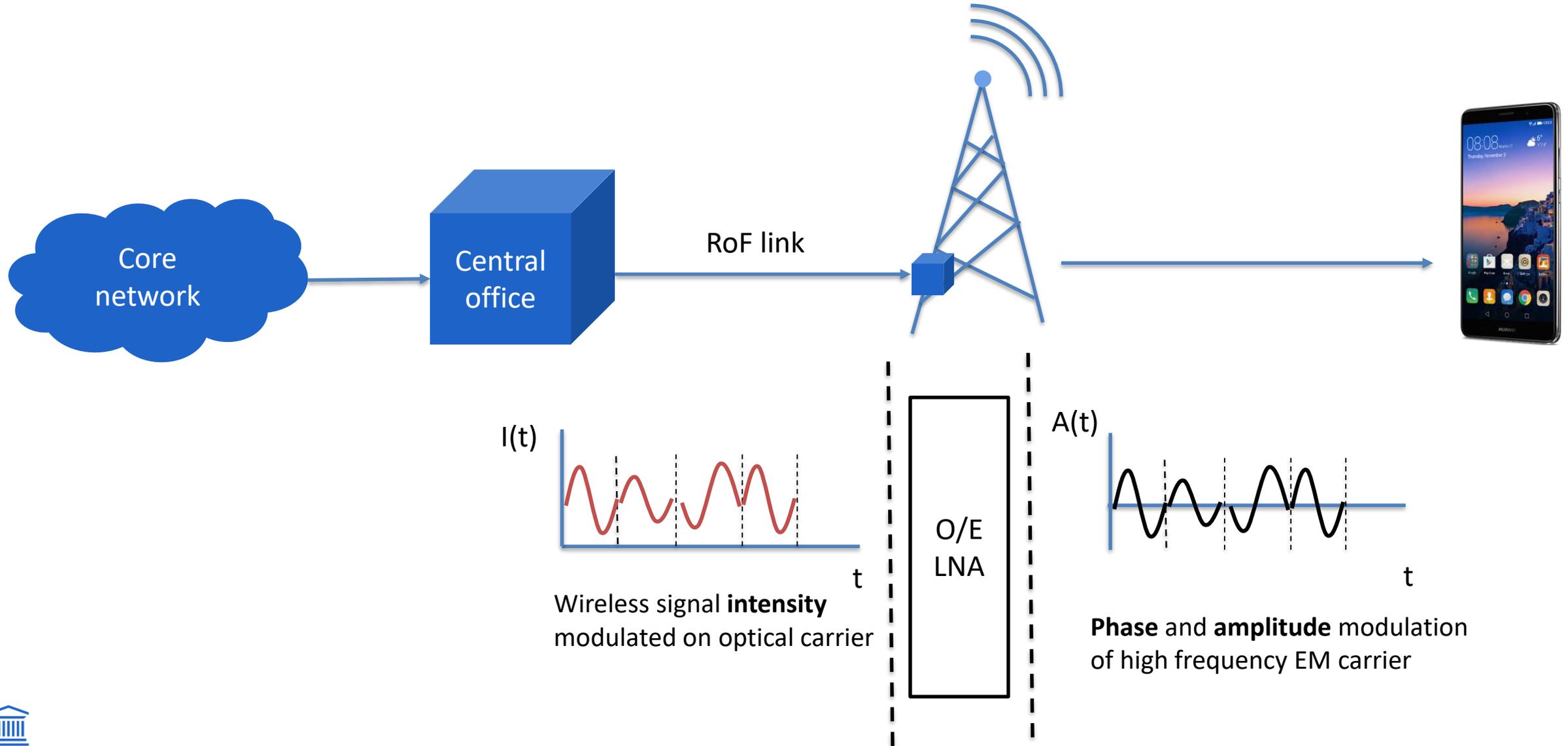
Verizon tells FCC to move fast on 28 GHz and 37-40 GHz bands to promote 5G



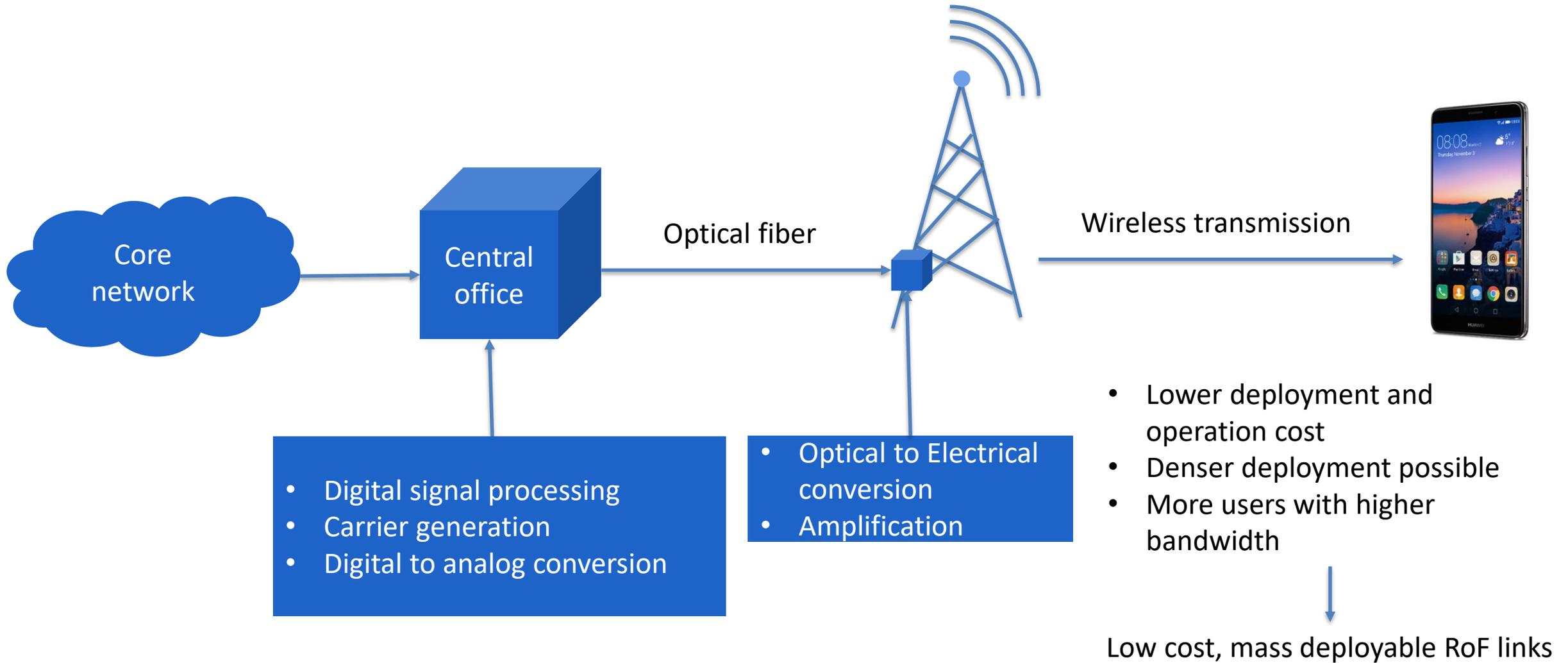
WIRELESS COMMUNICATION – CLASSIC TRANSMISSION



WIRELESS COMMUNICATION – RADIO OVER FIBER



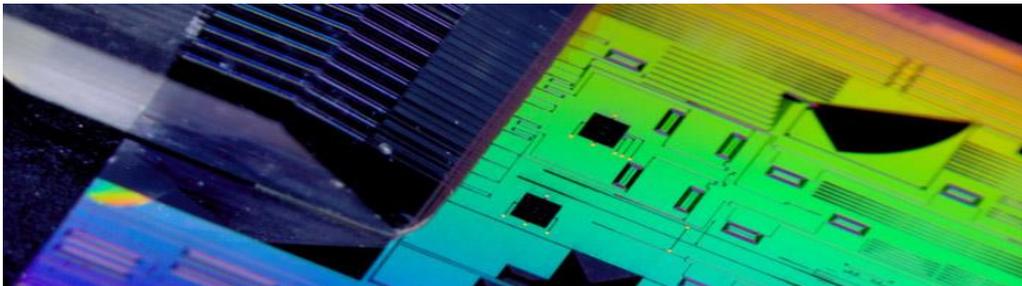
WIRELESS COMMUNICATION – RADIO OVER FIBER



INTEGRATED PHOTONIC TECHNOLOGY: SILICON PHOTONICS

Silicon photonic integrated circuit:

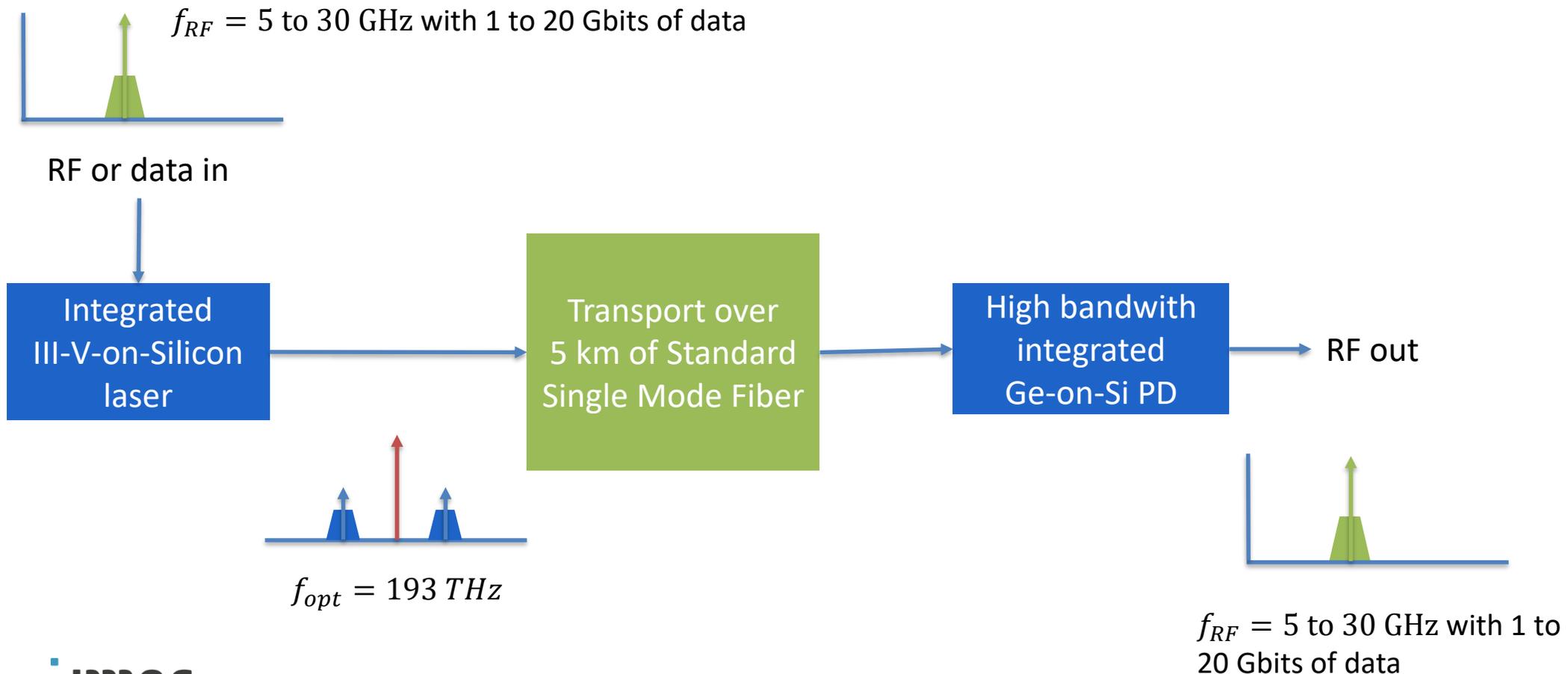
- 200mm/300mm CMOS fabrication for PIC realization
- Very compact PICs because of high index contrast
- Low loss waveguides



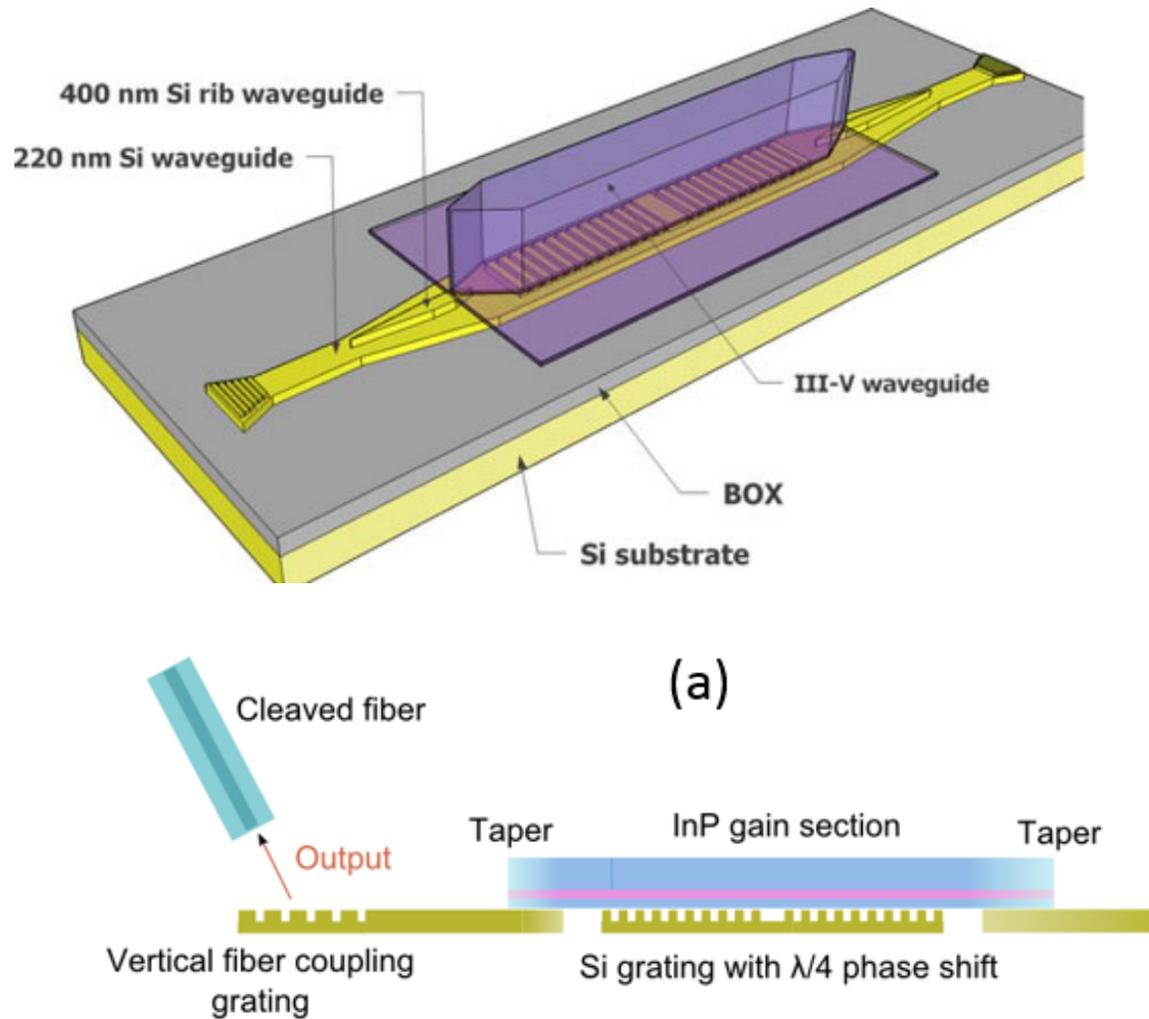
IMEC silicon photonic PIC

SILICON PHOTONIC RADIO-OVER-FIBER LINK

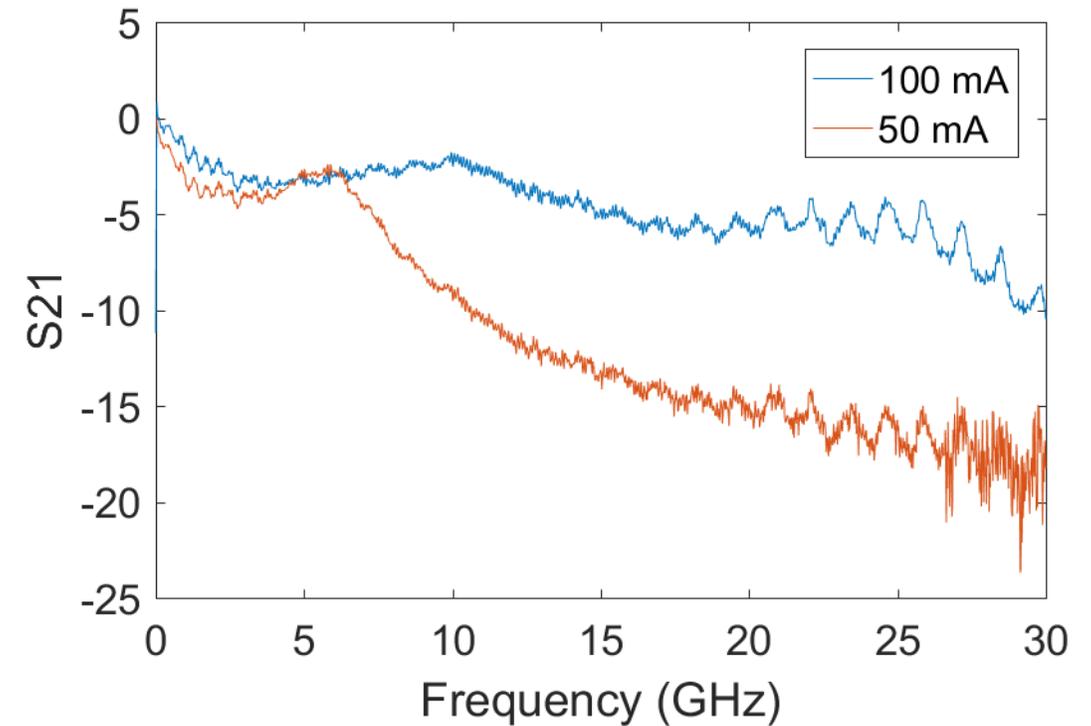
Use silicon photonic components to manufacture low-cost, large-volume integrated solution



III-V-ON-SILICON LASER



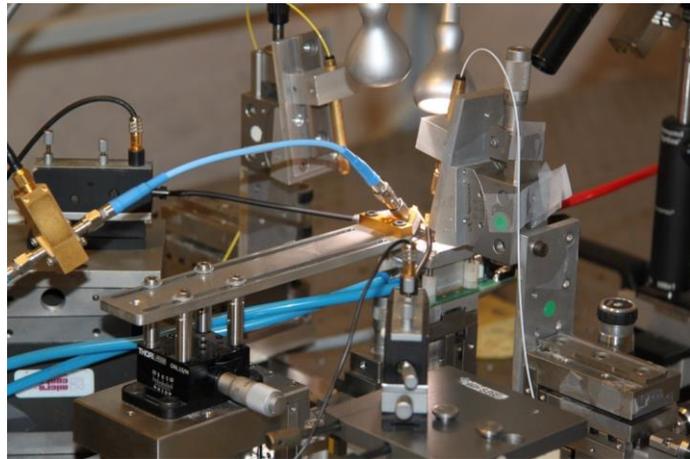
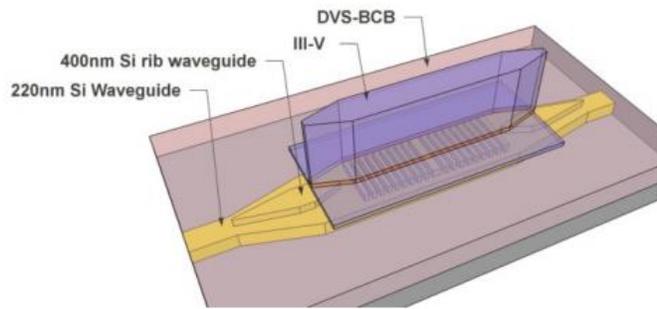
Small signal measurement



SILICON PHOTONIC RADIO-OVER-FIBER LINK

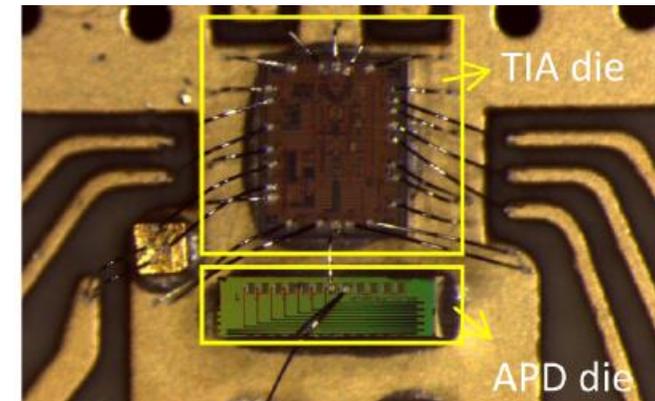
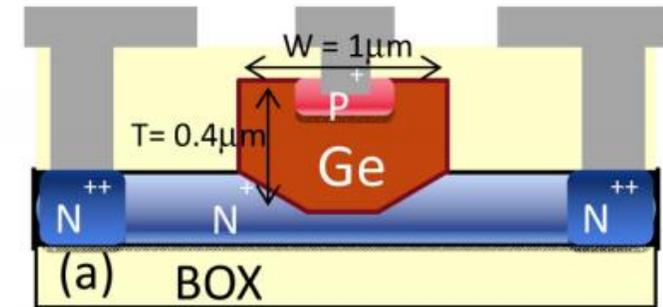
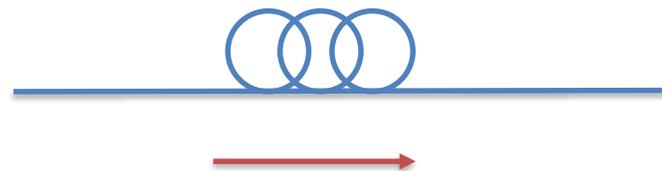
Enhanced Modulation Bandwidth of Heterogeneously Integrated III-V-on-silicon DFB Laser for 40 Gb/s NRZ-OOK Direct Modulation

A. Abbasi^{1,2}, J. Verbist^{1,2,3}, X. Yin^{2,3}, F. Lelarge⁴, G-H Duan⁴, J. Bauwelinck^{2,3}, G. Roelkens^{1,2}, G. Morthier^{1,2}

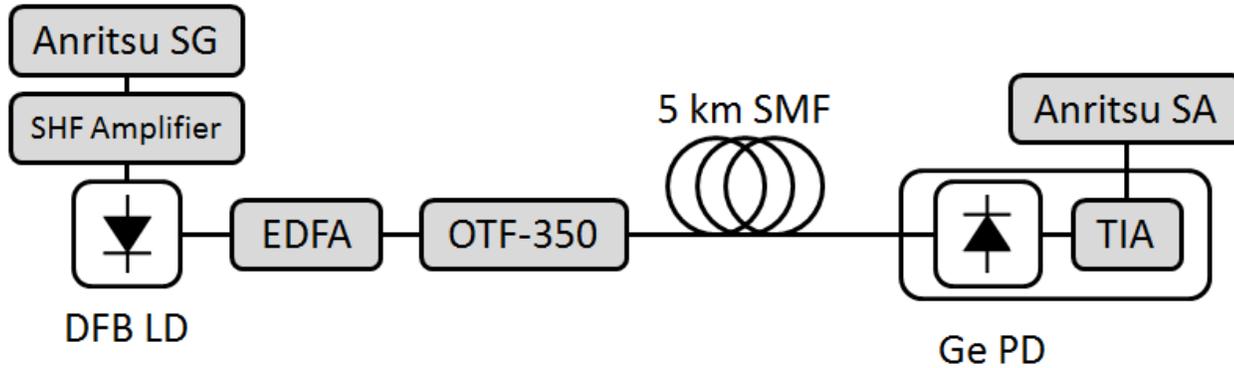


High sensitivity 10Gb/s Si photonic receiver based on a low-voltage waveguide-coupled Ge avalanche photodetector

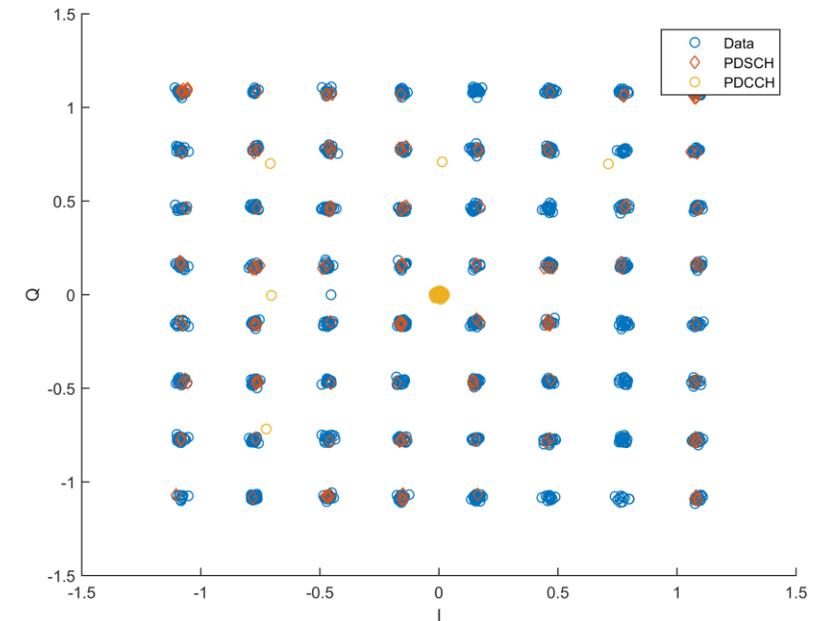
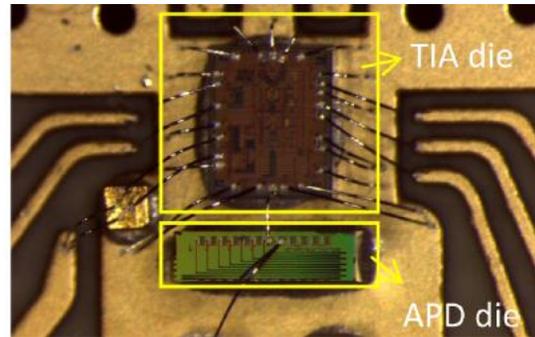
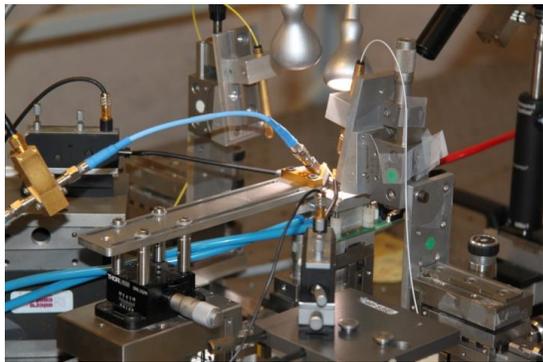
H. T. Chen,^{1,2,*} J. Verbist,³ P. Verheyen,¹ P. De Heyn,¹ G. Lepage,¹ J. De Coster,¹ P. Absil,¹ X. Yin,³ J. Bauwelinck,³ J. Van Campenhout,¹ and G. Roelkens²



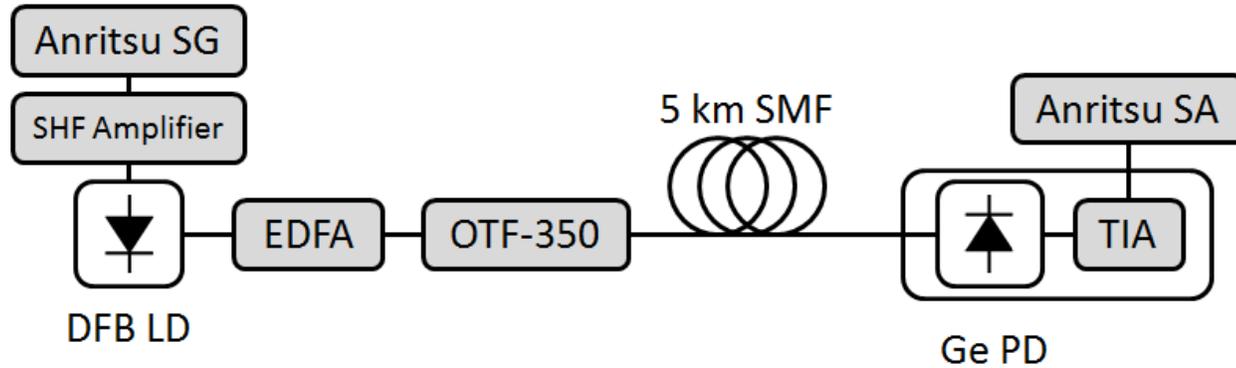
MEASUREMENT RESULTS: SILICON PHOTONIC ROF LINK



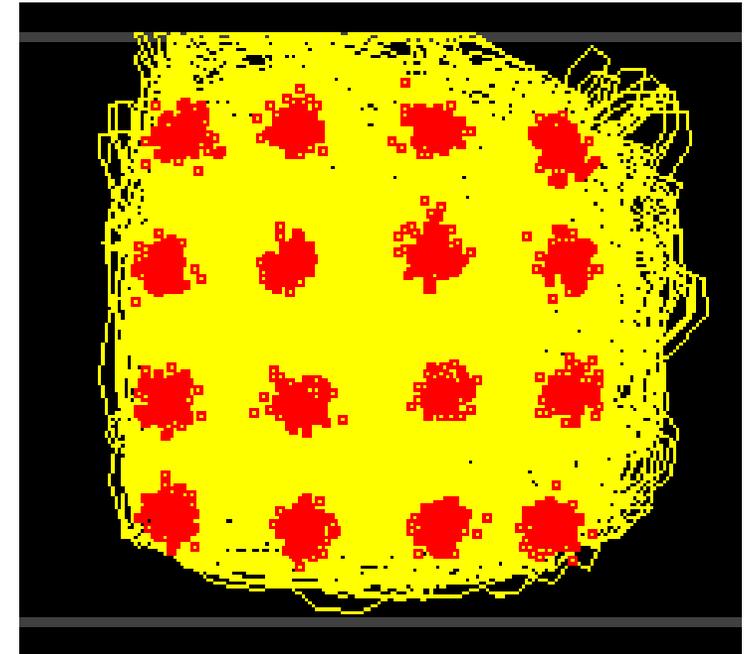
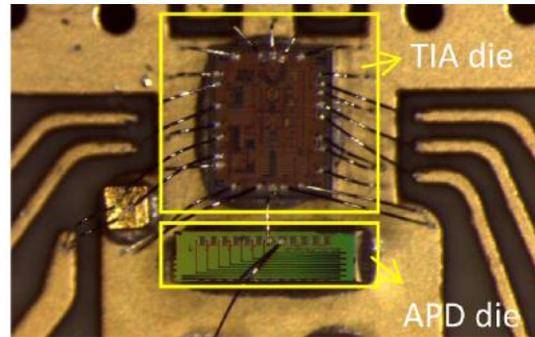
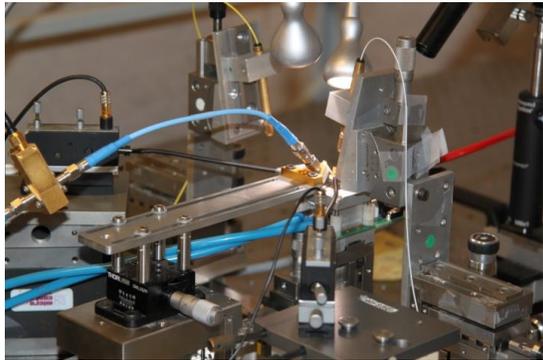
54 Mbps
64-QAM OFDM
5 GHz carrier
error free



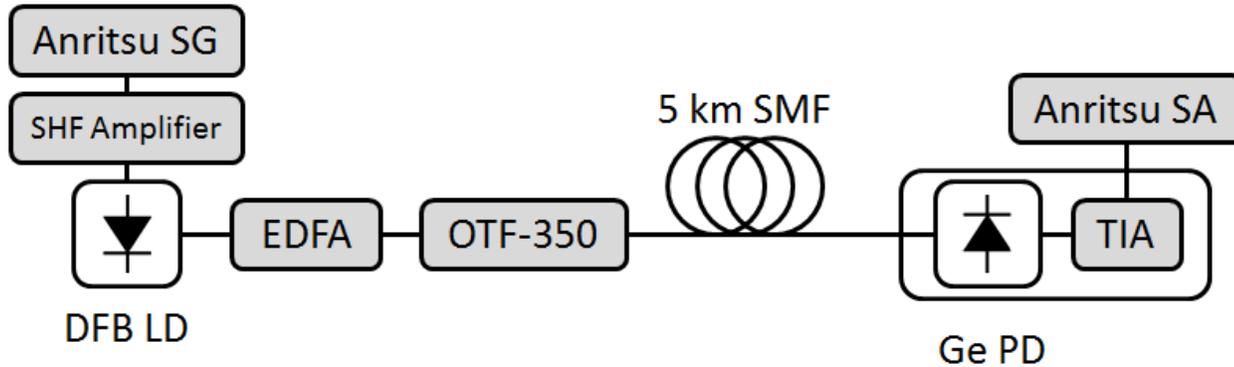
MEASUREMENT RESULTS: SILICON PHOTONIC ROF LINK



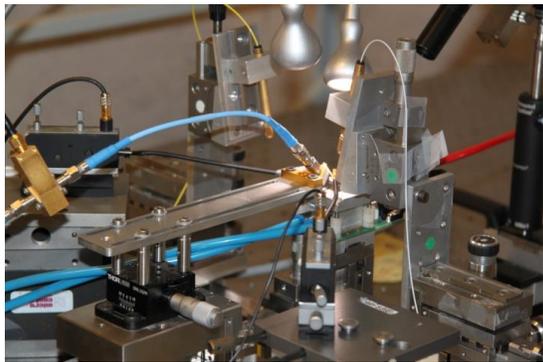
16 Gbps
16-QAM
20 GHz carrier
BER = 10^{-5}



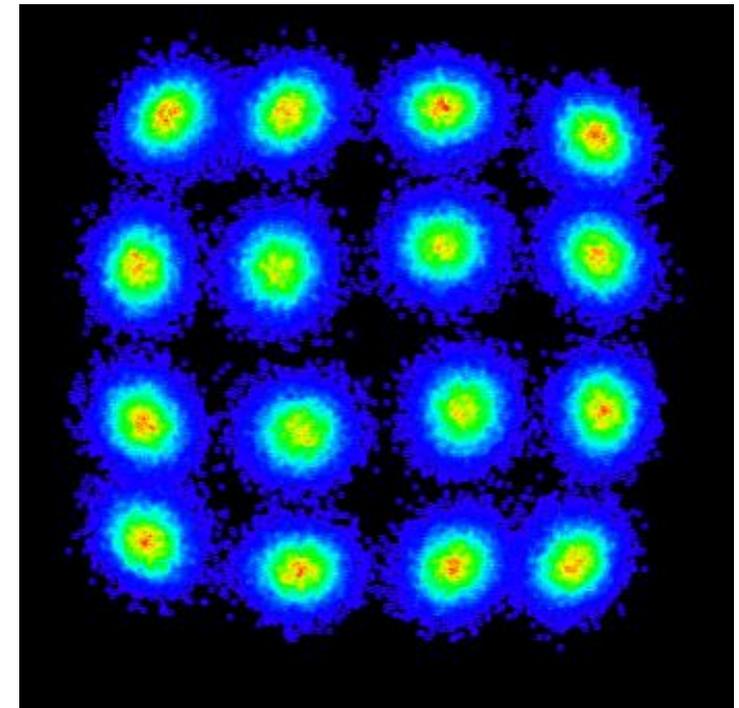
MEASUREMENT RESULTS: SILICON PHOTONIC ROF LINK



10 Gbps
16-QAM
26 GHz carrier
BER = 10^{-5}



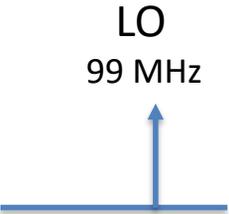
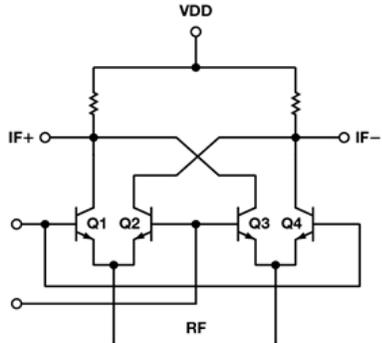
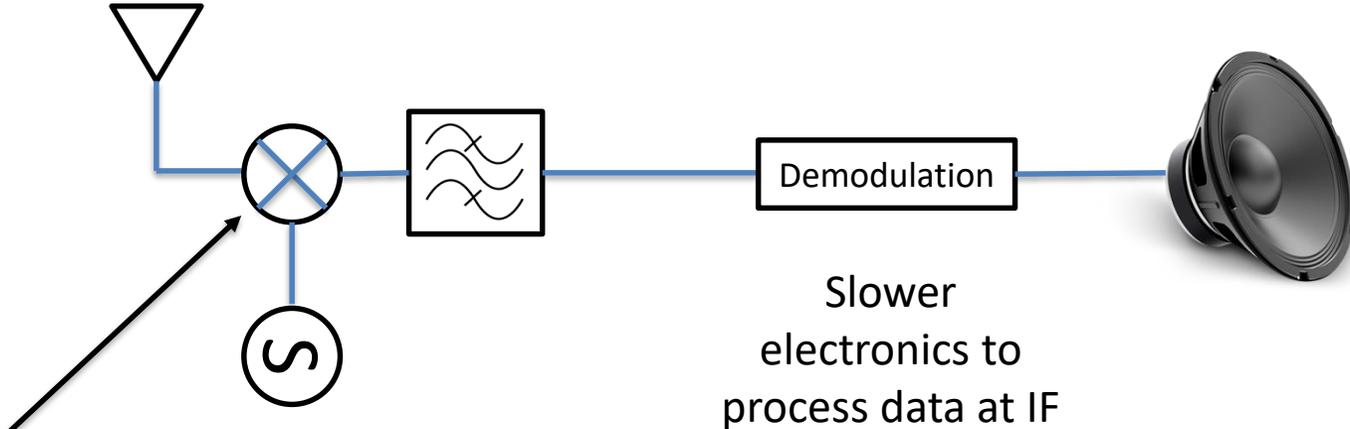
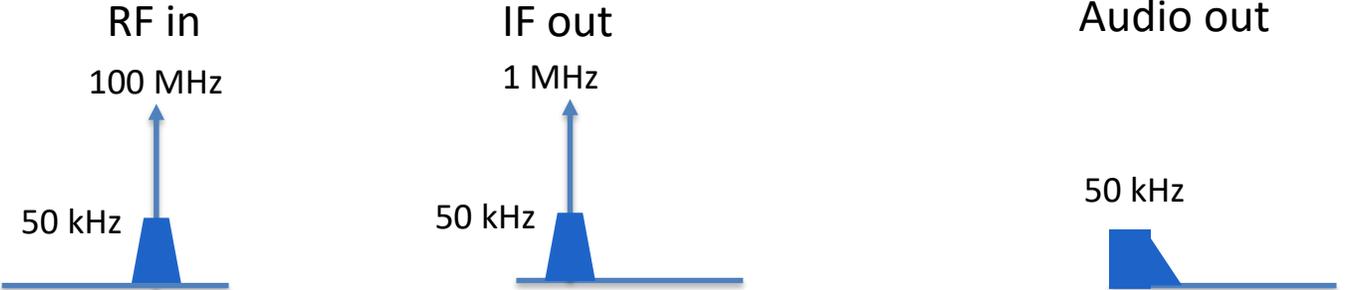
5G peak data rate



OVERVIEW

- Introduction to microwave photonics
- Ongoing research
 - Silicon photonic Radio-over-Fiber links for 5G
 - **Photonic frequency conversion**
- Conclusion

FREQUENCY CONVERSION - INTRODUCTION



FREQUENCY CONVERSION - INTRODUCTION



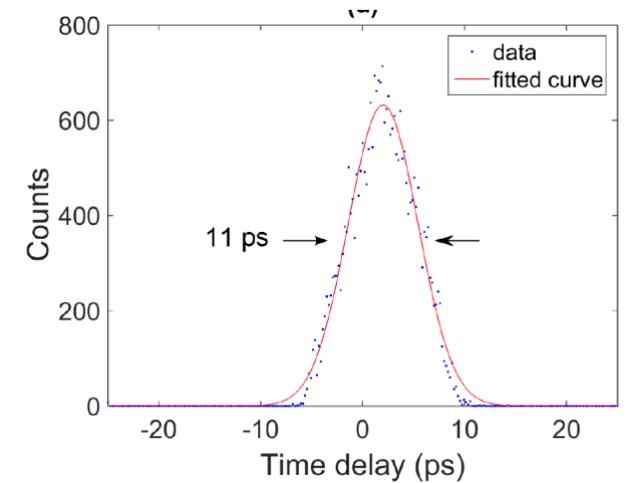
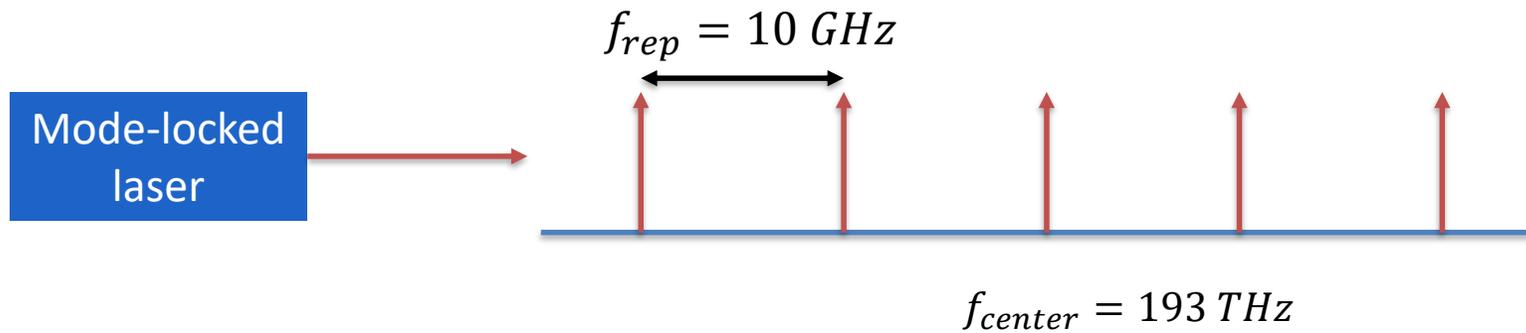
MICROWAVE PHOTONIC FREQUENCY CONVERSION



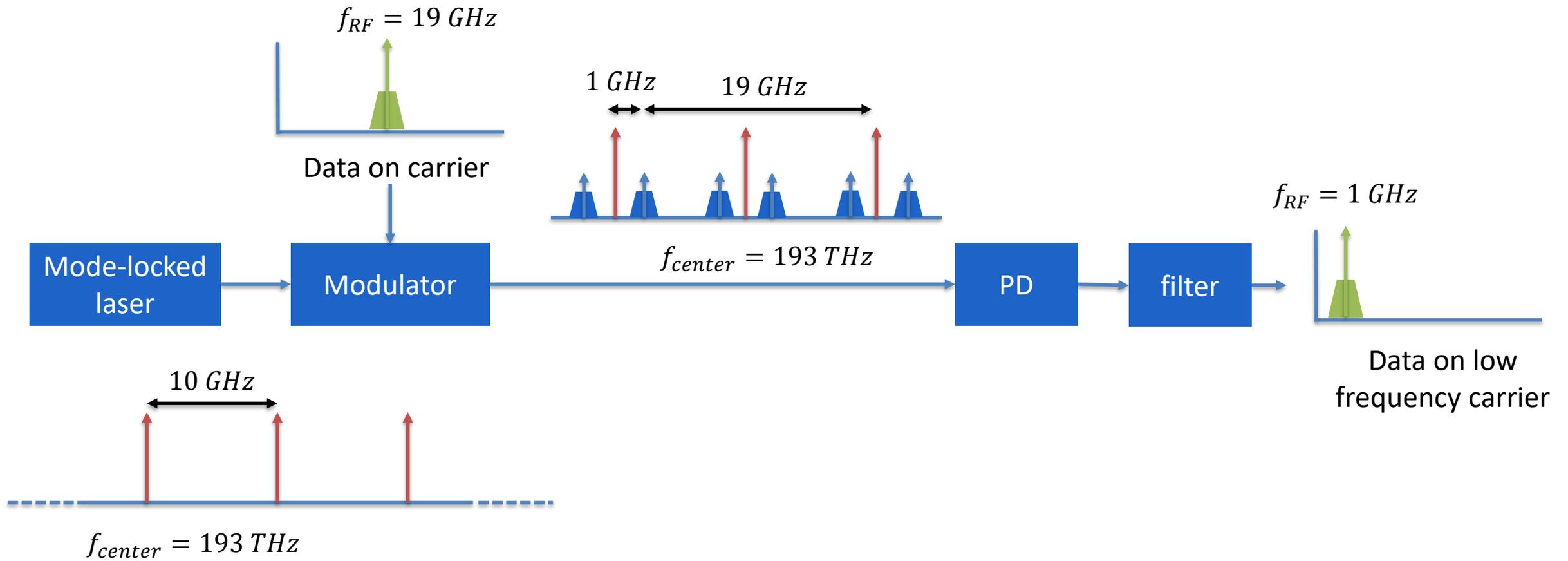
- Large bandwidth
- Input frequency independent response
- MLL works as local oscillator

MICROWAVE PHOTONIC FREQUENCY CONVERSION

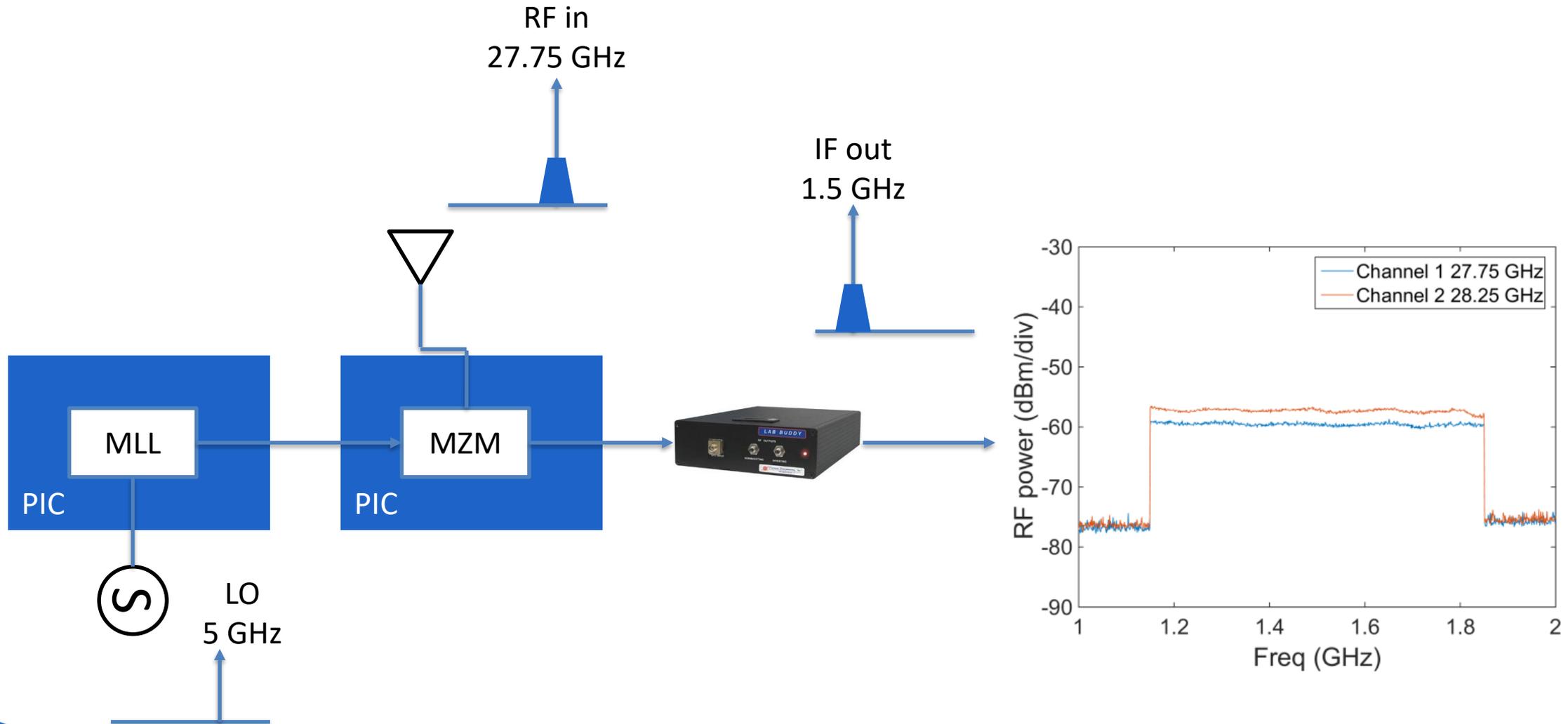
Mode-locked laser creates optical frequency comb



MICROWAVE PHOTONIC FREQUENCY CONVERSION

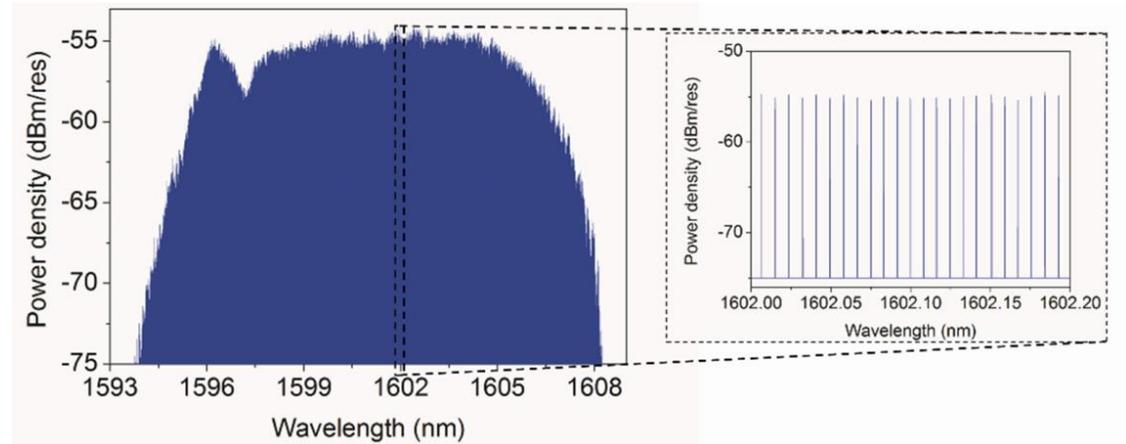
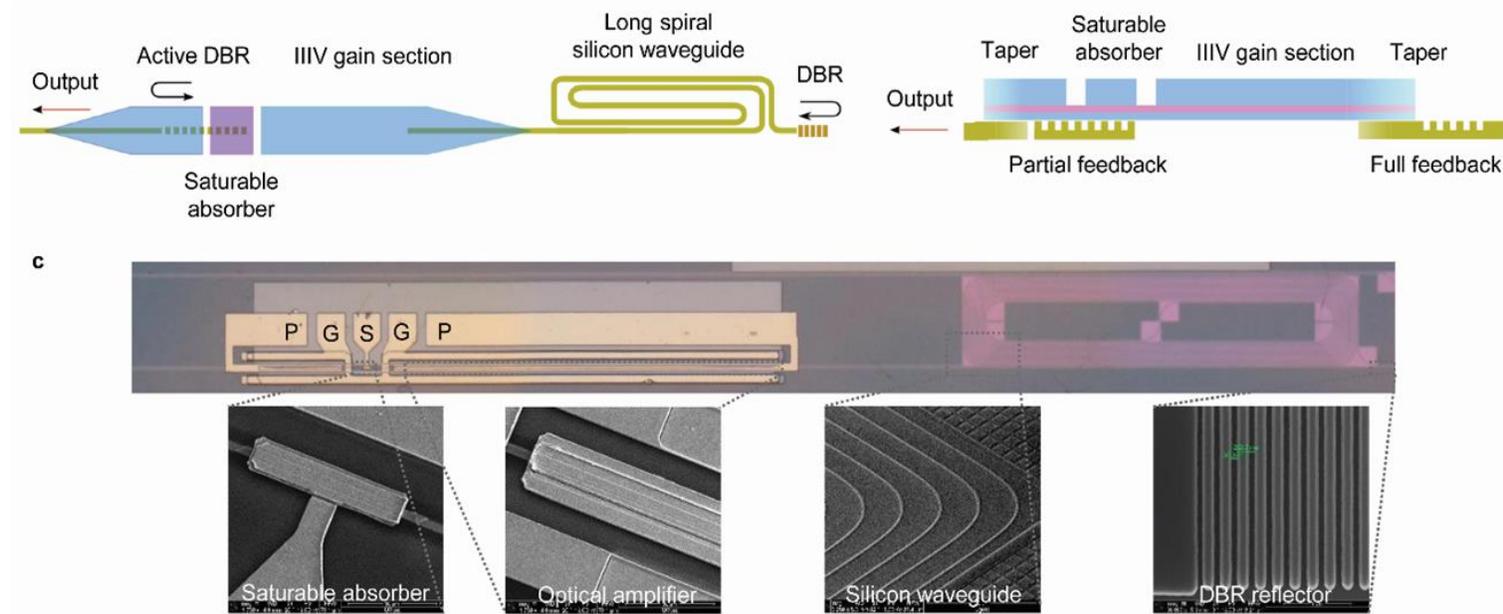
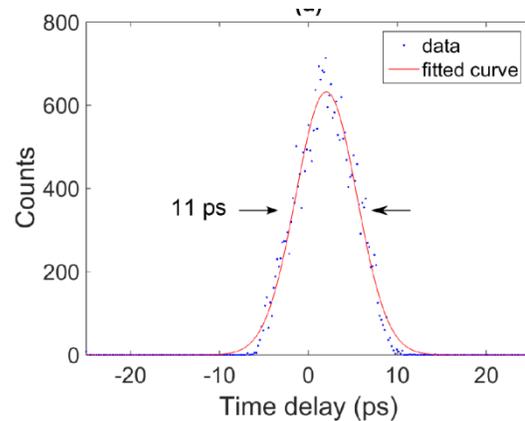
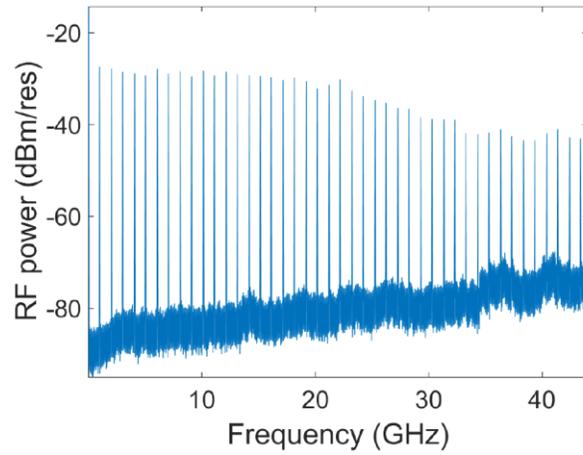


PHOTONICS MICROWAVE DOWN-CONVERSION DEMONSTRATION



K. Van Gasse, Z. Wang, S. Uvin, J. Marien, L. Thomassen, G. Roelkens, **Ka-to-L-band frequency down-conversion using a micro-photonic III-V-on-silicon mode-locked laser and Mach-Zehnder modulator**, International Conference on Space Optics, France, (2016)

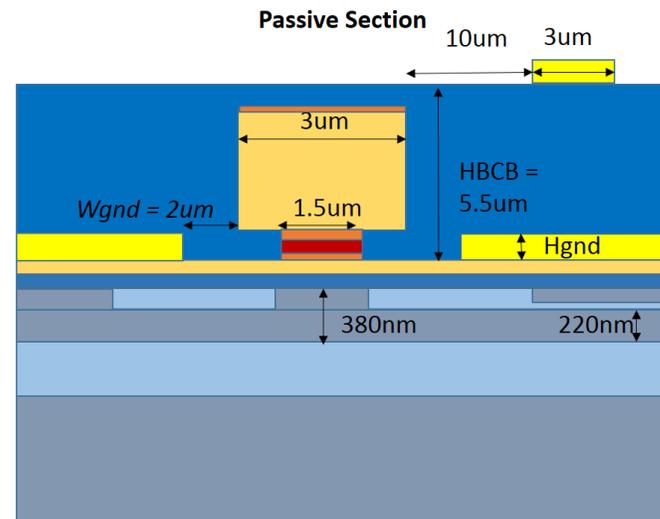
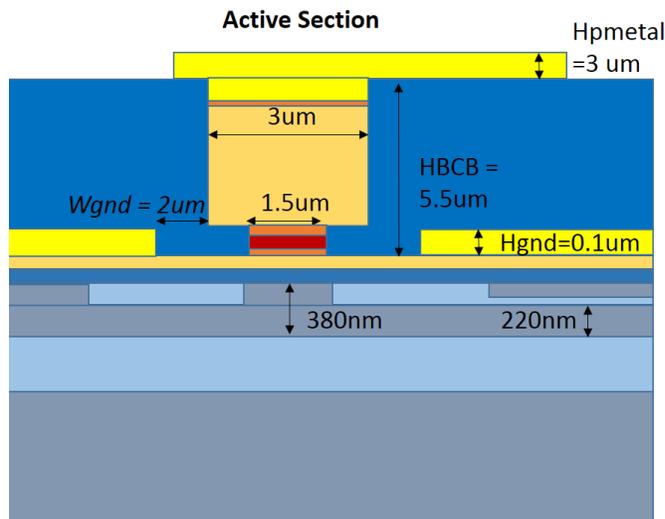
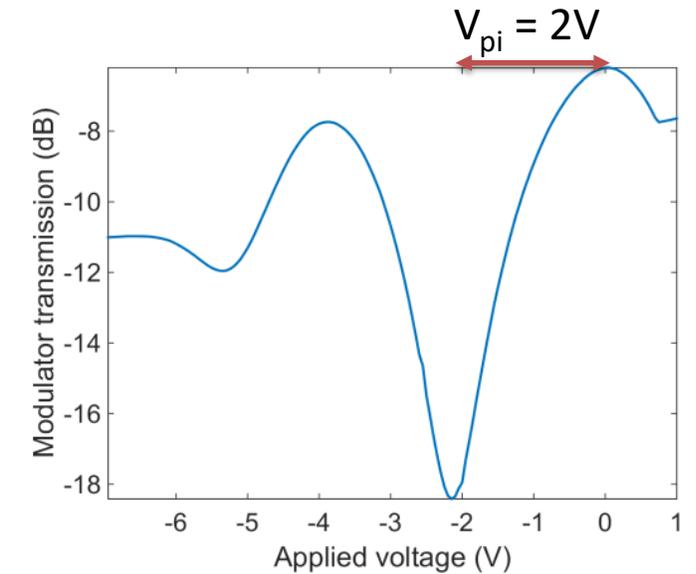
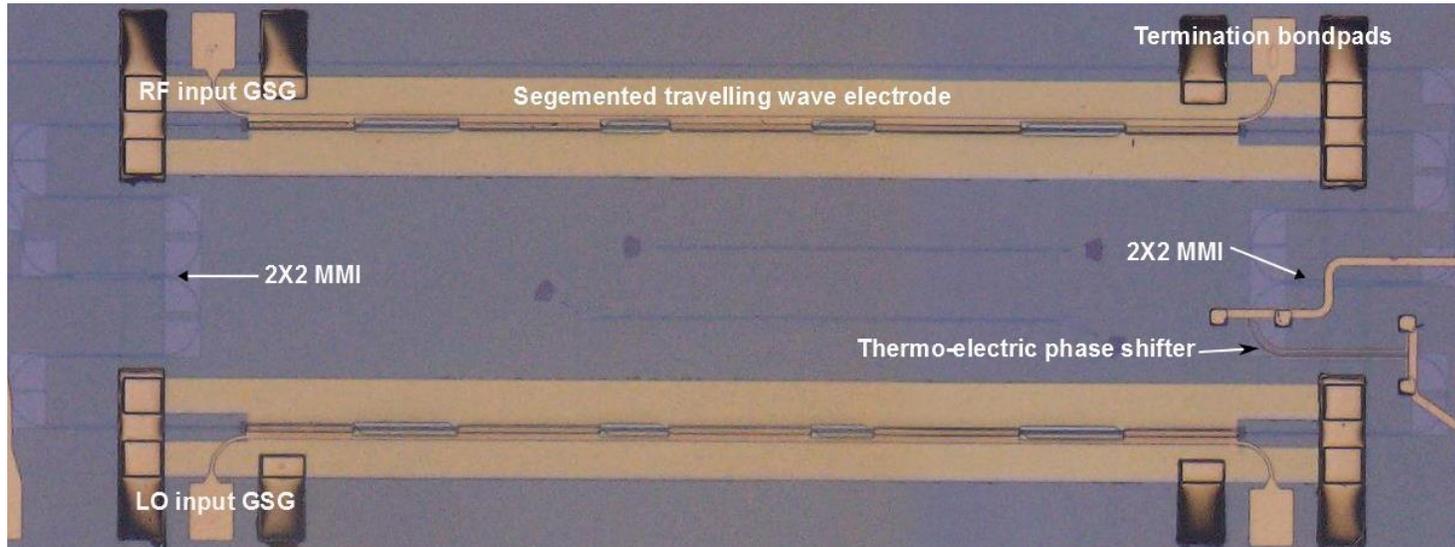
MODE LOCKED LASER



Z. Wang, K. Van Gasse, Valentina Moskalenko, Sylwester Latkowski, Erwin Bente, B. Kuyken, G. Roelkens, **A III-V-on-Si ultra dense comb laser**, Light: Science and Application

K. Van Gasse, Z. Wang, V. Moskalenko, S. Latkowski, B. Kuyken, E. Bente, G. Roelkens, **Passively mode-locked III-V-on-silicon laser with 1 GHz repetition rate**, The 25th International conference Semiconductor Laser Conference (ISLC 2016)

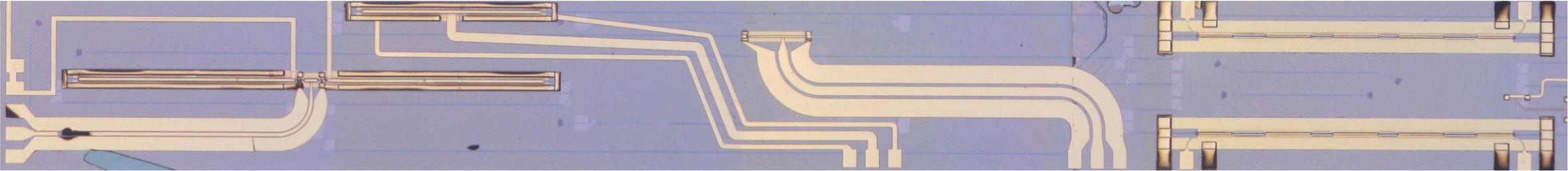
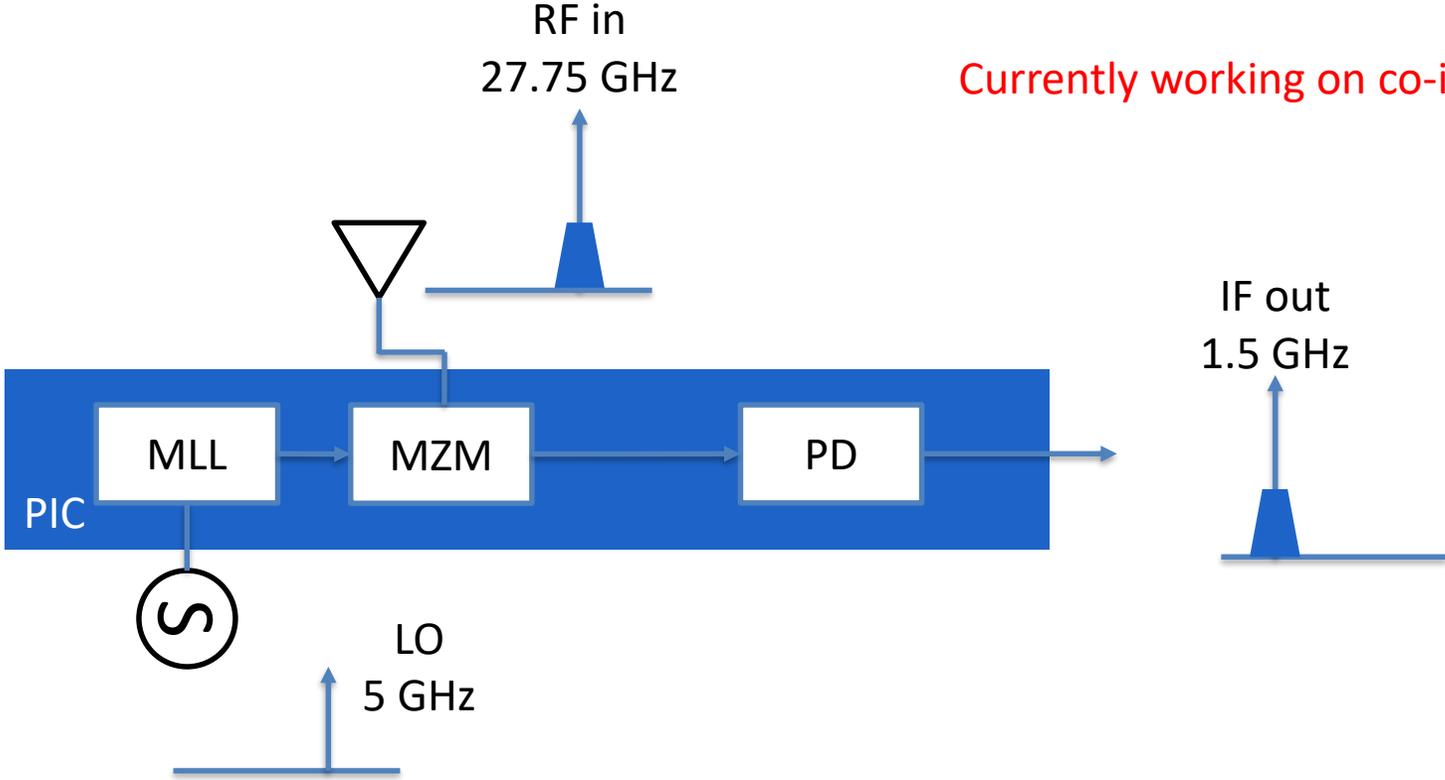
MACH-ZEHNDER MODULATOR



- InP MQW phase shifter
- Combines Pockels and carrier depletion
- Very low V_{π} compared to Silicon MZM
- Segemented electrode design

PHOTONICS MICROWAVE DOWN-CONVERSION

Currently working on co-integrating all components on a single chip



SUMMARY

- Integrated microwave photonics is a field with many applications such as wireless communication
- Next generation wireless network (5G) is a strong driver for integrated microwave photonic solutions
- Silicon photonic RoF links aimed at 5G in development
- Photonic frequency conversion for satellite communication under development

PHOTONICS RESEARCH GROUP

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PhD student

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T



@PhotonicsUGent

www.photonics.intec.ugent.be