Slide 1

PHOTONICS RESEARCH GROUP

PHOTONIC NEUROMORPHIC COMPUTING USING SILICON CHIPS

Peter Bienstman, Joni Dambre, Alessio Lugnan, Stijn Sackesyn, Chonghuai Ma, Emmanuel Gooskens, Muhammed Gecide, Sarah Masaad

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WHAT IS RESERVOIR COMPUTING?

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WHAT IS RESERVOIR COMPUTING?

From field of machine learning (2002)

Addressing training issues in recurrent networks

Quite successful:

- Time series prediction
- Speech recognition
- Robot control
- ...

Originally mainly in software

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RESERVOIR COMPUTING

Don't train the neural network, only train the linear readout

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BOUNDARIES WITH MANY DEGREES OF FREEDOM ARE PRONE TO OVERFITTING

d = 2   d = 6 (over-fit)

house size   house size

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Slide 6

WHY DOES RC WORK?

To higher order space

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MEASUREMENT WITH RESERVOIR CHIP

EXPERIMENTS: RC IS BETTER AT EQUALISING THIS NL DISTORTED SIGNAL

Distorted signal | Linear equalizer | Reservoir 0 errors in 131072 bits

Same number of copies as the reservoir has nodes

SIMULATIONS: "BAD" NON-LINEAR DETECTOR EVEN BETTER

Distorted stream | Compensated stream using RC BER: 3 orders of magnitude better | compensated stream with extra non-linearity from TIA BER: 7 orders of magnitude better

RC EQUALISATION FOR KK RECEIVERS

MOTIVATION

Coherent transmission is the optimal choice for medium-long range communications

Coherent detection costs are too high for short links

KRAMERS-KRONIG RX

Kramers-Kronig (KK) Receiver is an alternative scheme for coherent receivers which uses direct detection (i.e., amplitude of the signal) to extract the phase information. Certain conditions must be respected for accurate reconstruction:

1. Single sideband signal: the spectrum of the signal must be located to one side of a subcarrier
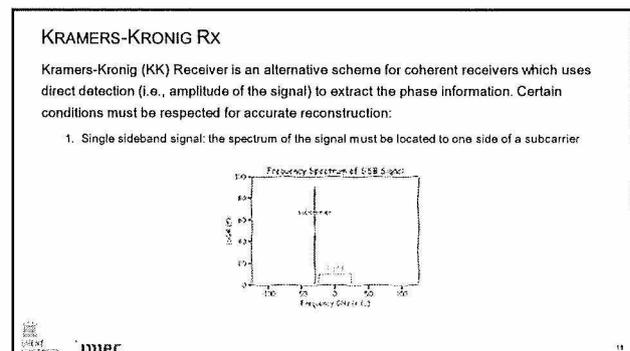
OTHER TELECOM TASKS

SOLVE A TASK SIMULTANEOUSLY ON 2 WDM CHANNELS
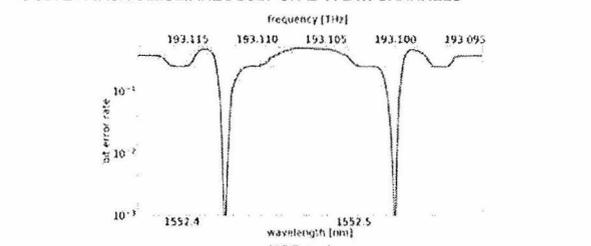
XOR task

Same readout for both channels!
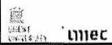
IMPROVE ROBUSTNESS AGAINST WAVELENGTH DRIFT
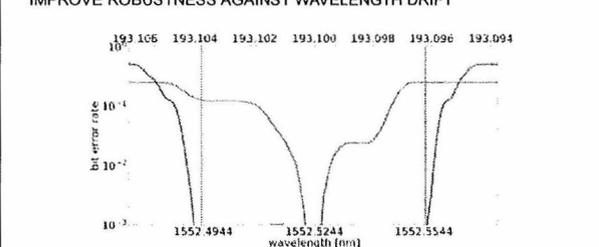
Multiwavelength training gives 8 GHz vs 3 GHz window
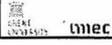
JAMMING DETECTION

Successful identification in real time of in-band and out-of-band jamming

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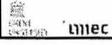
MODULATION FORMAT IDENTIFICATION: BPSK VS QPSK
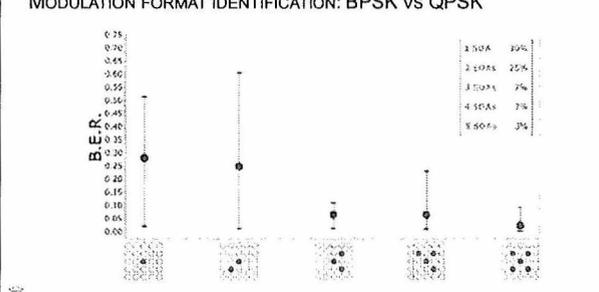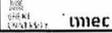
BIOLOGICAL CELL SORTING
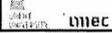
NEXT STEPS: EXPERIMENTS WITH AN EVENT CAMERA
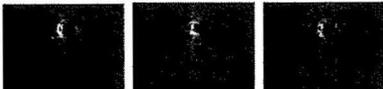
No need for background subtraction!
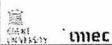
CONCLUSIONS

Reservoir computing
is interesting new paradigm
for all-optical information processing
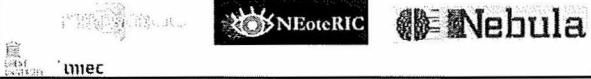
Invited Speakers

- Stephen Furber, *University of Manchester, United Kingdom*
  Neuromorphic Computing Plenary
- Hong Liu, *Google LLC, United States*
  The Evolving Role of Optics in the Hyperscale Data Centers Plenary
- Masaya Notomi, *Tokyo Institute of Technology, Japan*
  Attojoule Nanophotonics Towards Optoelectronic Accelerators Plenary
- Stefan Abel, *Lumiphase, Switzerland*
  Pockels-enhanced Ultra-efficient Silicon Photonics Keynote
- Juan Miguel Arrazola, *Xanadu Quantum Computing, Canada*
  Photonic Quantum Computing at Xanadu Keynote
- Fumio Koyama, *Tokyo Institute of Technology, Japan*
  Transverse Coupled Cavity VCSEL Array for CPO Applications Keynote
- Nicholas New, *Optalysys Ltd., United Kingdom*
  The Dawn of Energy Efficient Computing: Optically Accelerating the Fast Fourier Transform Core Keynote
- Bhavin Shastri, *Queen's University at Kingston, Canada*
  Photonics for Artificial Intelligence and Neuromorphic Computing Keynote
- Volker Sorger, *George Washington University, United States*
  Photonic Machine Intelligence Hardware: From Photonic Memory and Photonic TPU to Optical CNN Keynote
- Nicola Andriolli, *Consiglio Nazionale delle Ricerche, Italy*
  Photonic Integrated Neural Network Accelerators
- Piotr Antonik, *CentraleSupélec, France*
  Human Action Recognition with Photonic Reservoir Computing
- Farshid Ashtiani, *University of Pennsylvania, United States*
  Photonic-electronic Co-design: From Optical Phase Control to Signal Processing
- Keren Bergman, *Columbia University, United States*
  Energy Efficient Multi-terabit Photonic Connectivity for Disaggregated Computing
- Peter Bienstman, *Ghent University, INTEC, Belgium*
  Reservoir Computing for High-speed Photonic Information Processing
- Adonis Bogris, *University of West Attica, Greece*
  Neuromorphic Integrated Photonics as Hardware Accelerators for Ultra-high Speed Telecom and Imaging Applications
- Hugo Cable, *PsiQuantum, United States*
  Switch Networks for Photonic Fusion-based Quantum Computing
- Zizheng Cao, *Technische Universiteit Eindhoven, Netherlands*
  Non-line-of-sight Beam-steerable Infrared Wireless Communication
- Jose Capmany, *Universitat Politècnica de València, Spain*
  Integrated Photonic Analog Computing: Principles and Technologies
- Haoshuo Chen, *Nokia Bell Labs, United States*
  Phase Retrieval Receiver for Optical Coherent Communications
- Xi Chen, *Nokia Bell Labs, United States*
  High Capacity Short-reach Systems
- Qixiang Cheng, *University of Cambridge, United Kingdom*

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Photonics in Switching and Computing highlights the latest research activities in areas related to "Photonics in Switching" and to "Photonics in Computing". This year's conference will highlight the synergy between photonic technologies, systems and computing/networking architectures.

Research topics include optical computing, photonic neuromorphic computing, optical switching technologies for dense integration of photonic and electronic functionalities operating side-by-side; various aspects of photonics in computing systems such as photonics for AI and quantum photonics; optical subsystem technologies and architectures for 5G networks and beyond, and inter- and intra-datacenter interconnects; and optical networking and computing architectures including short-reach optical interconnects, optical packet/burst switching routers, rapidly reconfigurable networks, and next-generation protocols and architectures.

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Topics

Photonic Technologies for Computing, Switching and Interconnects

- Photonic-Electronic Integrated Circuits
- Photonic Switching and Routing Technologies
- Nanophotonic Lasers, Quantum-Scale Light Sources