Research platforms for optical communications and networks

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TELECOMMUNICATIONS,
COMPUTER
ENGINEERING,
AND PHOTONICS
INSTITUTE

Sant'Anna
School of Advanced Studies – Pisa

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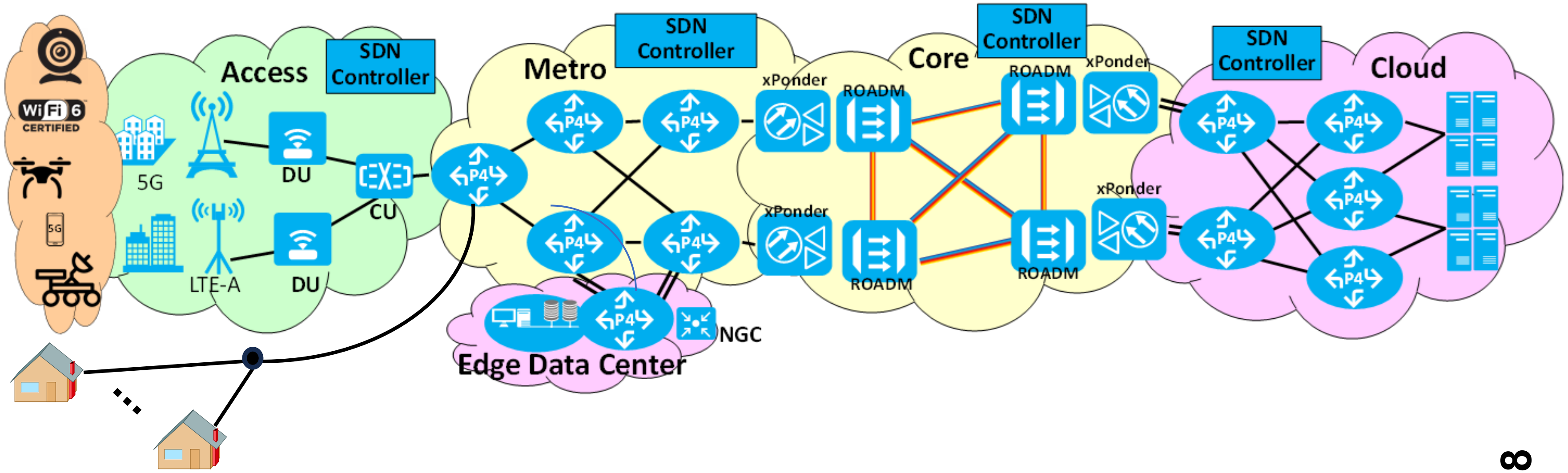
EngIneeRInG photOnic devices and systems towards a green opticaL nETwork infrasTructure for 6G



RESTART RIGOLETTO

GOALS

- Architecture for energy efficient optical networks
- Novel Photonic Integrated Circuits for switching and transmission (including design, fabrication, packaging and characterization)
- Fiber and wireless data plane capacity enhancement via MB/SDM/HCF/LiFi
- Data plane telemetry/monitoring platforms
- AI-assisted autonomic optical network for zero-touch operation

→ GRAND CHALLENGE 18

Synergic EU Projects

DESIRE6G

Allegro

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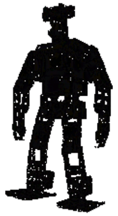
RESTART PHONET LAB

Optical Networks, Systems and Devices Lab

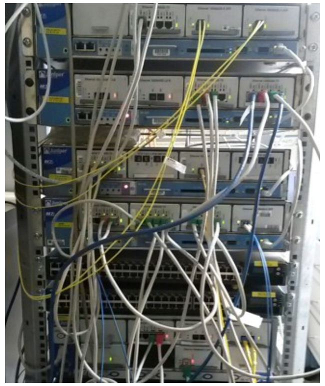
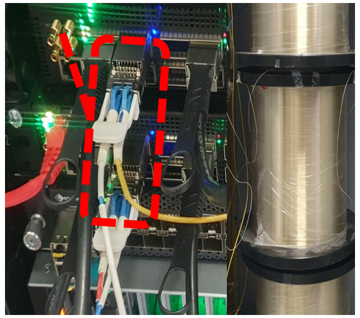
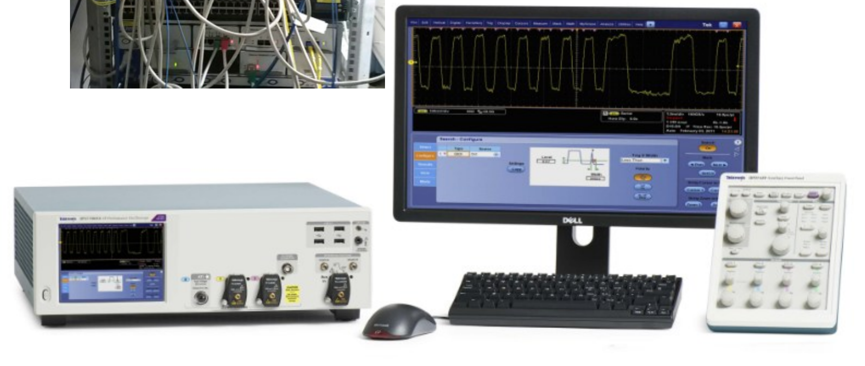
Connecting value chain of photonics

Terminals

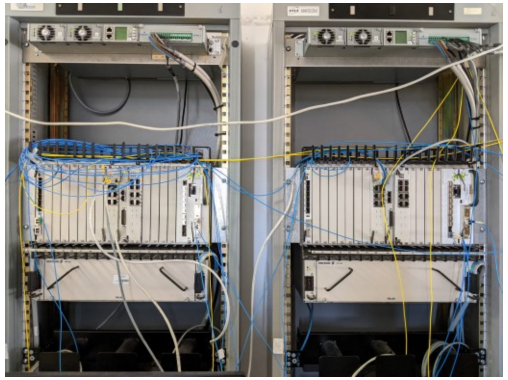




Disaggregated access


Legacy and disaggregated metro

Core network



Cloud/edge continuum

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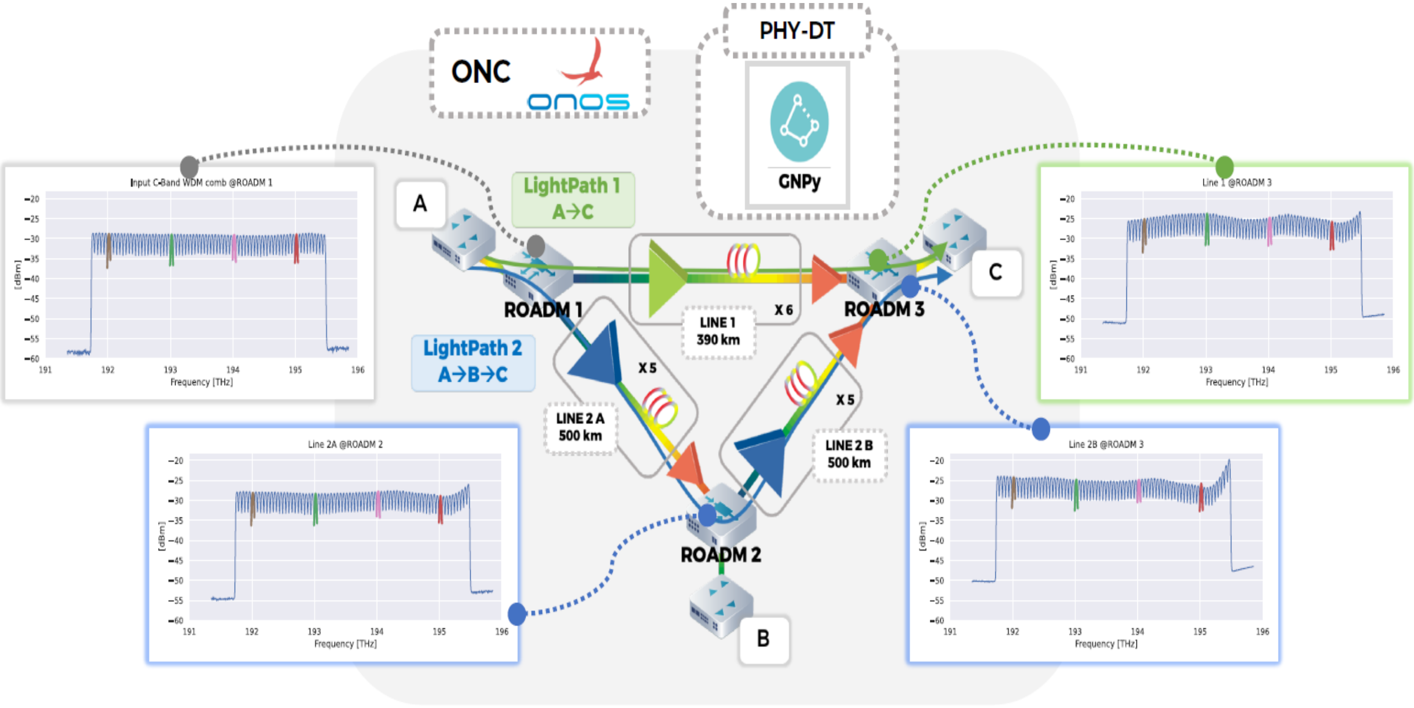
MISSION

Design, prototype and demonstrate solutions for an end-to-end optical transport network with an innovative focus on the optical network segments that will support the future 6G infrastructure



Involved Areas

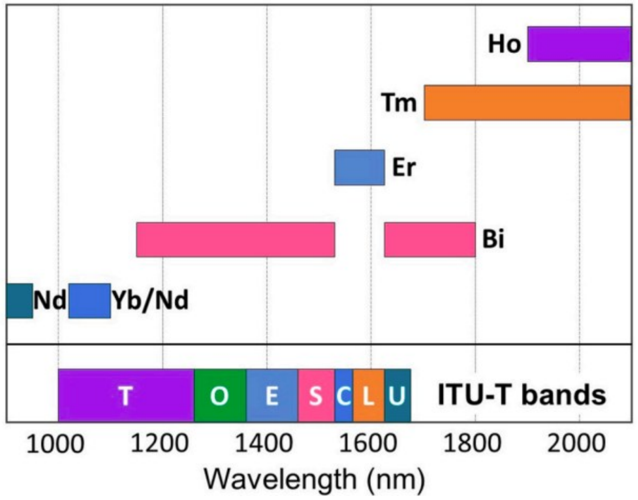
- Advanced Optical systems
- Optical plane Monitoring platforms

Innovation

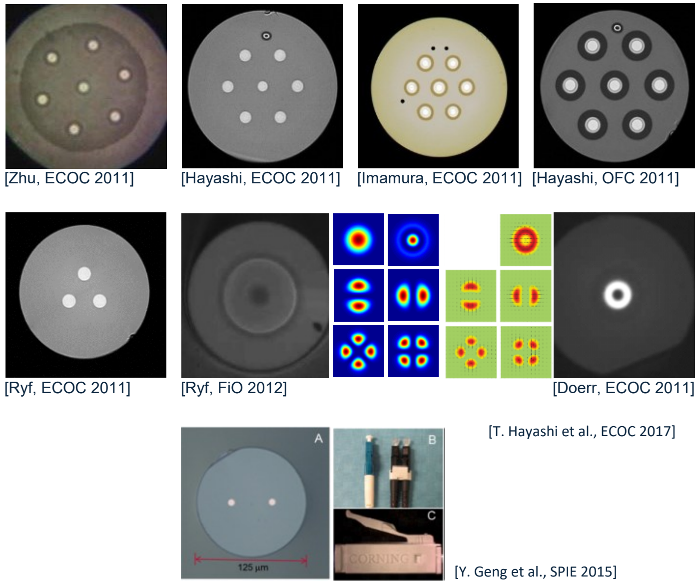
- Advanced optical communication systems for capacity scaling
- Suite for disaggregated optical networks validation
- Zero touch optical network validation

Boosting optical bandwidth

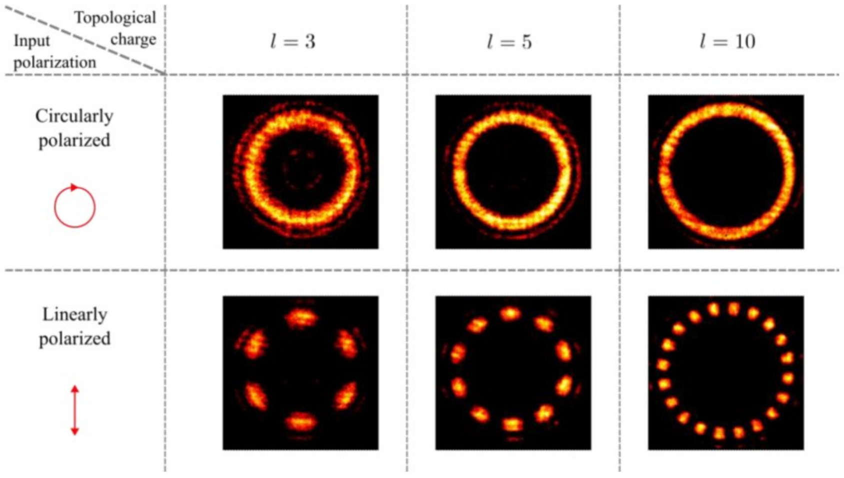
- innovative data plane of an optical transport infrastructure supporting capacity enhancement via MB, SDM, (+ hollow-core fibers) and optical wireless access



Multiband transmission



Multicore SDM fiber network



Metalenses for SDM coupling

Hollow-Core Fiber networks for low-latency applications

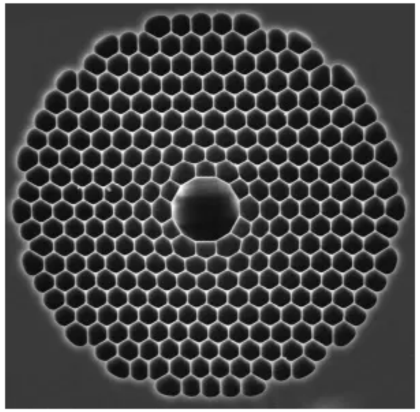
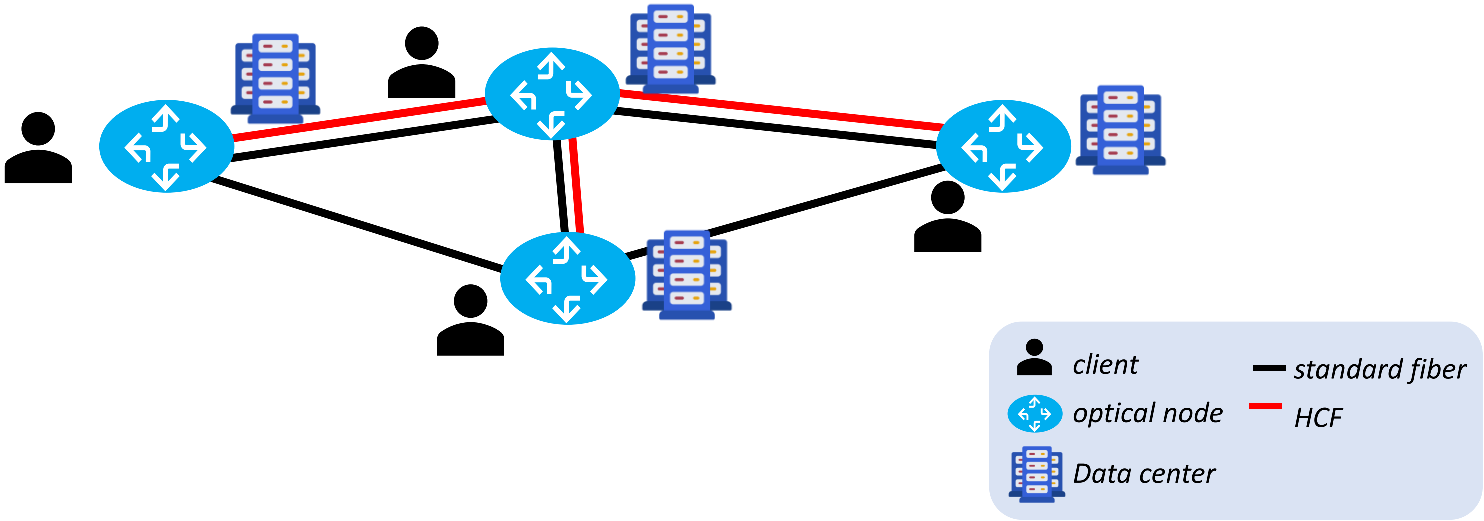


Figure 2: Microscope picture of the end of a hollow-core fiber. The photograph has been kindly provided by NKT Photonics.



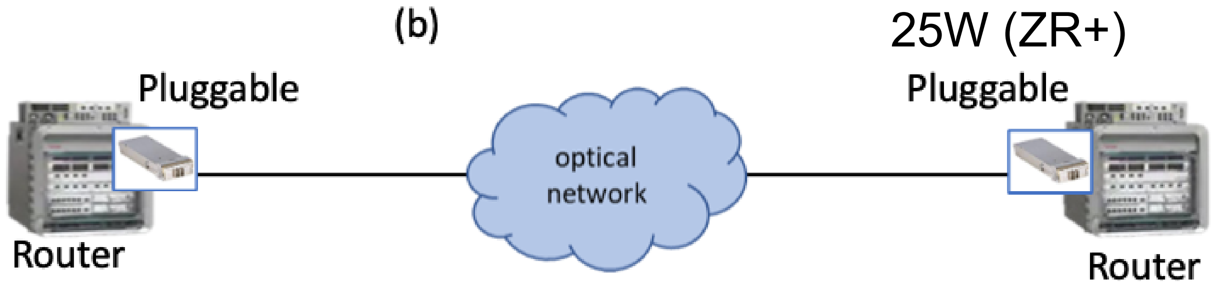
- 30% lower propagation latency
  → Reduction in number of edgeDCs
- Lower attenuation and non-linear effects
  → Higher SNR and spectral efficiency, lower transponder cost

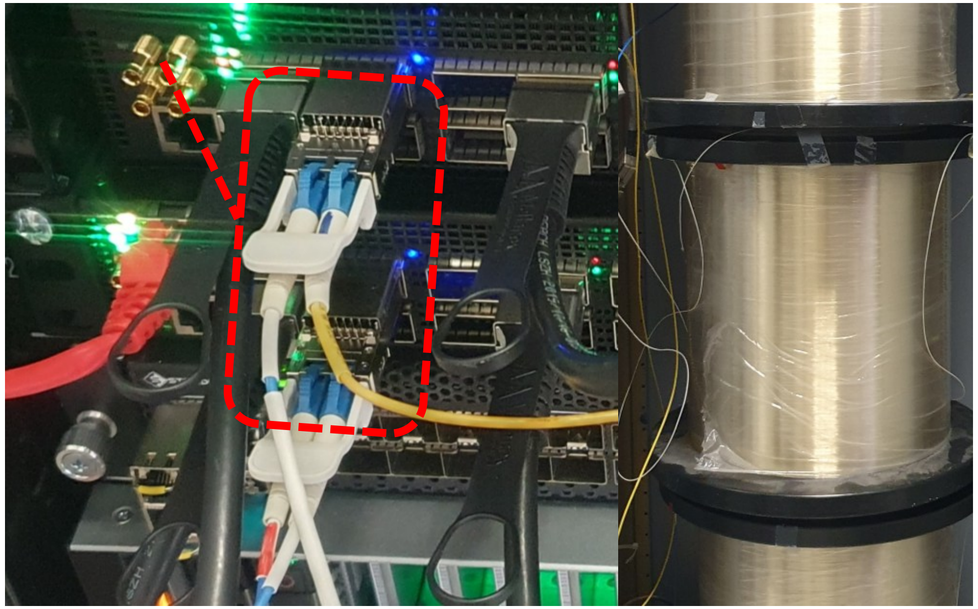
Pluggable Transceivers

- The IP-over-WDM architecture is based on the integration of the coherent optical transceivers (**Digital Coherent Optics, DCO**) into the IP router equipment:
  - Pt-to-pt ZR (80 Km) and ZR+ (< 400 Km)
  - Pt-to-mtpt XR with carrier multiplexing (e.g 16ch)

Benefits of **pluggable transceivers**

- **Removal of transponders** as standalone network elements
- **Savings in power consumption** and space in central office

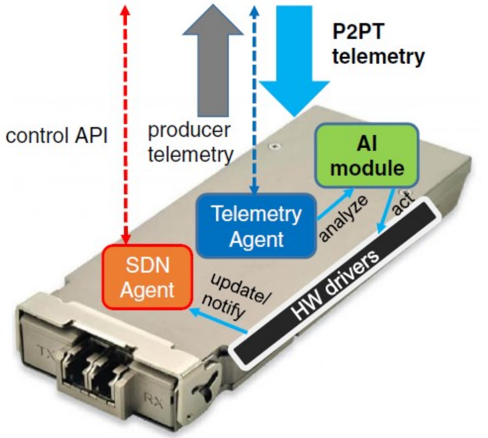


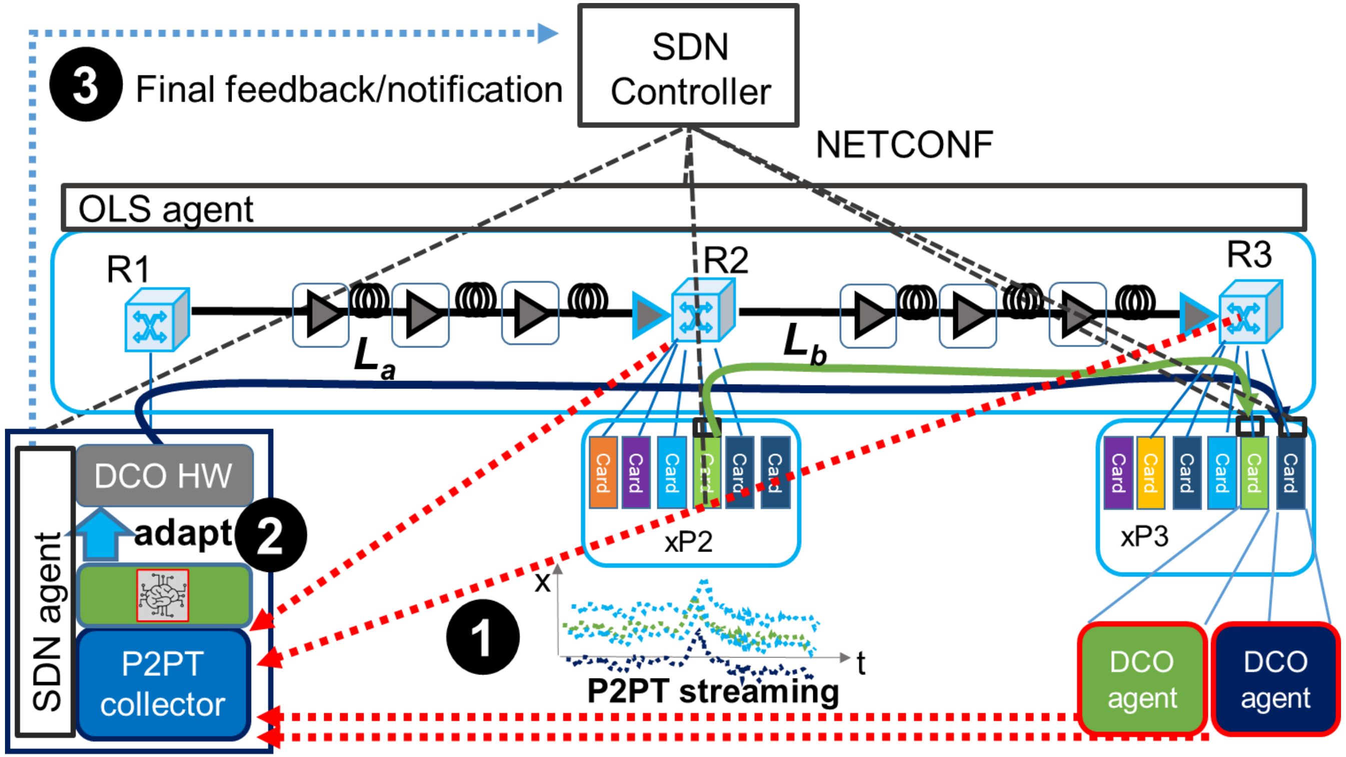


Peer-to-peer telemetry (P2PT)

where one card analyzes the health of "its" lightpath

- To **selected disaggregated components,** make lightpath re-adjustment
  - No controller intervention
  - **AI available at cards**, in future*





* F. Paolucci et al, "Peer- to-peer disaggregated telemetry for autonomic machine- learning-driven transceiver operation", JOCN, vol. 14, no. 8, pp. 606– 620, 2022.

RESTART Inphotec
AFFILIATED LAB

Integrated Photonic Technology center

A fabrication and packaging facility for prototyping

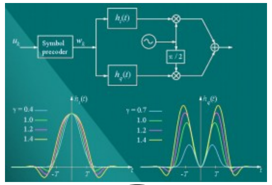
MISSION

The INPHOTEC High Technology Center enables the fabrication of circuits, sensors, material deposition, packaging of devices with reproducible processes for prototyping and small-scale production (< 1000 pieces) in selected fabrication platforms

Organization

- All the assets (building and equipment) CAPEX of the Inphotec Center are owned by Scuola Sant'Anna
- Inphotec Center is run by the company Camgraphic srl, responsible for the OPEX aspects

Innovation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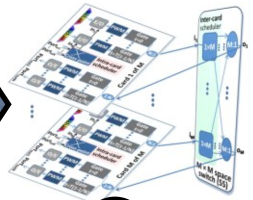
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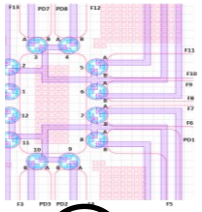
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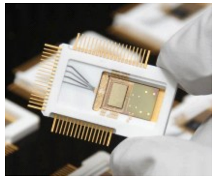
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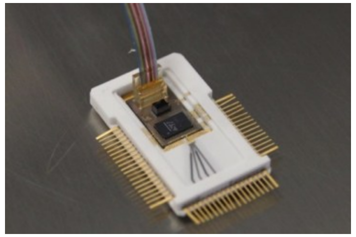
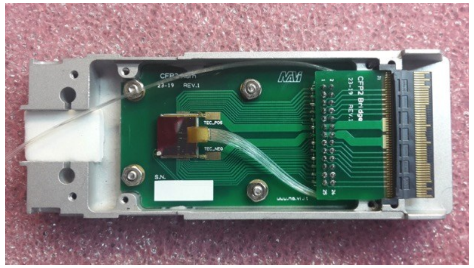
6

Die Bonder and Flip Chip Bonder

Offered services

- Testing platform for disaggregated optical networks
- Packaging and characterization platform for PIC
- Optical systems test



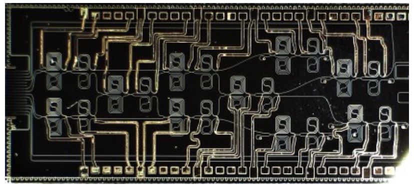


Involved RESTART projects

- RIGOLETTO (+ Cascade TRIBOLETTO)
- HePIC
- Others will come …

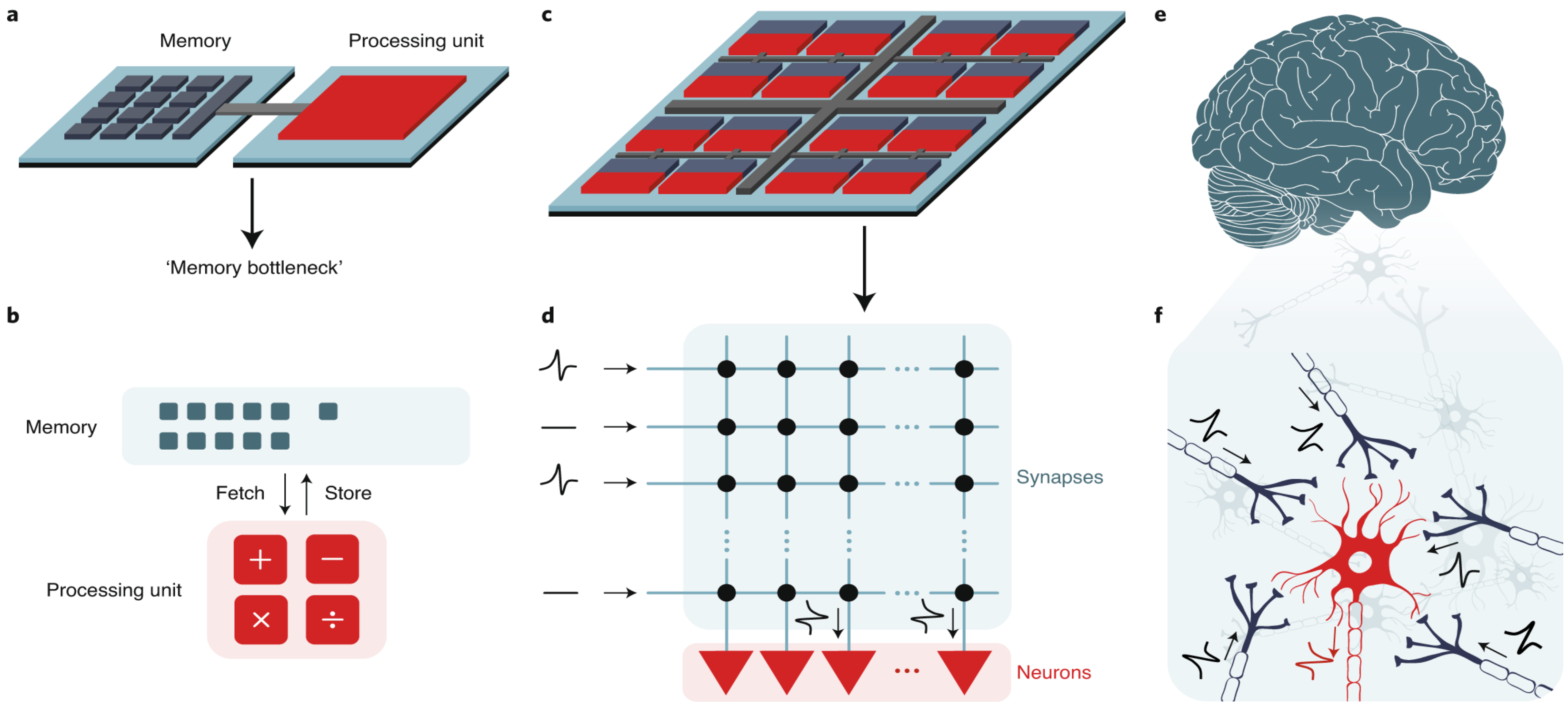
Synergic Labs

- Department of Excellence in ICT and Robotics 2023-2027, SSSA, Pisa
- Inphotec Affilated Lab, Quantum-x Nanoscribe SSSA
- PoliFab facility (through HePIC)



Neuromorphic photonics (1)

Analog Computing: exploit physics for processing

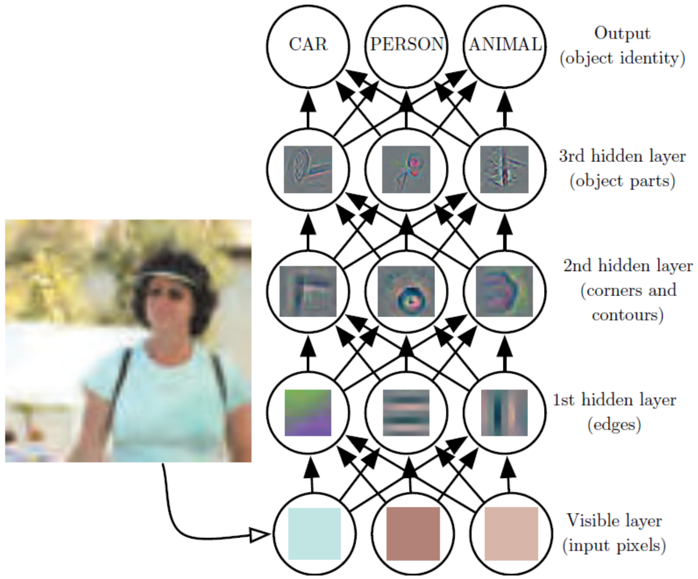


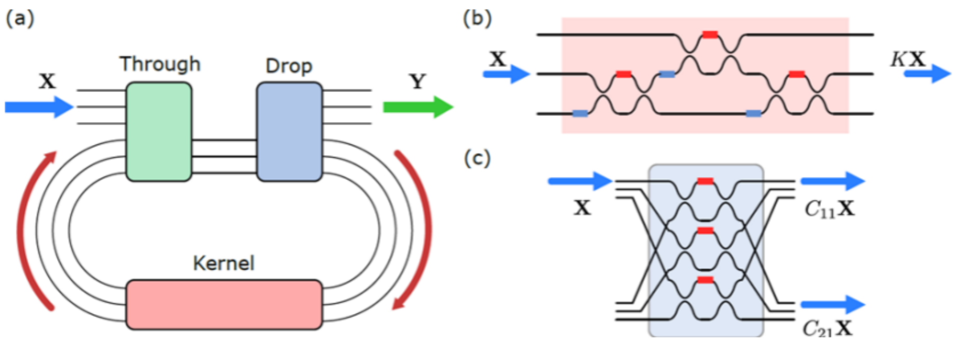
Zhang, Wenqiang, et al. "Neuro-inspired computing chips." Nature electronics 3.7 (2020): 371-382.

Photonic Neural Networks*: implements neural networks (NN) in photonic integrated circuits (PICs) re-creating the linear operations of NNs through optical elements such as lasers, switching matrices, and optical modulators

*L. De Marinis, M Cococcioni, P Castoldi, N Andriolli – "Photonic neural networks: A survey" - IEEE Access, December 2019

Neuromorphic photonics (2)

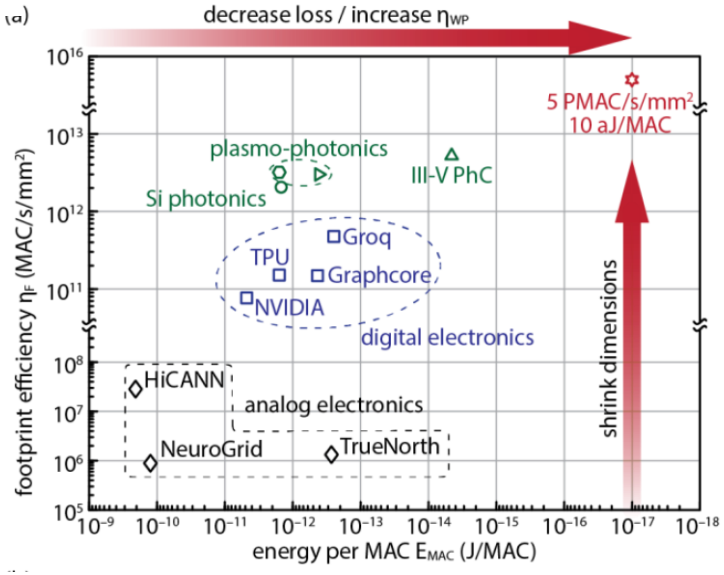




X input
Y = K • X (matrix-vector multiplication)
(Kernel K can be e.g. microrings o MZI)
Can be nested as in deep neural network

Photonic integrated processors

- **Speed:** Light travels faster and allows for **massively parallel processing**.
- **Energy Efficiency:** No need for clocked switching or charge movement, reducing energy per operation.
- **Scalability:** With proper integration (e.g., silicon photonics), thousands of operations can be packed into small chip areas.



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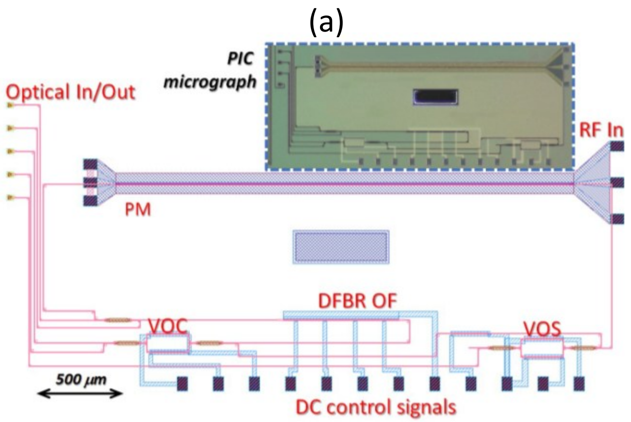
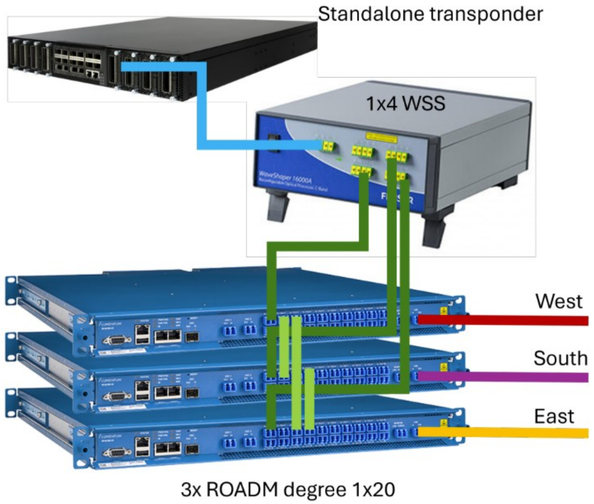
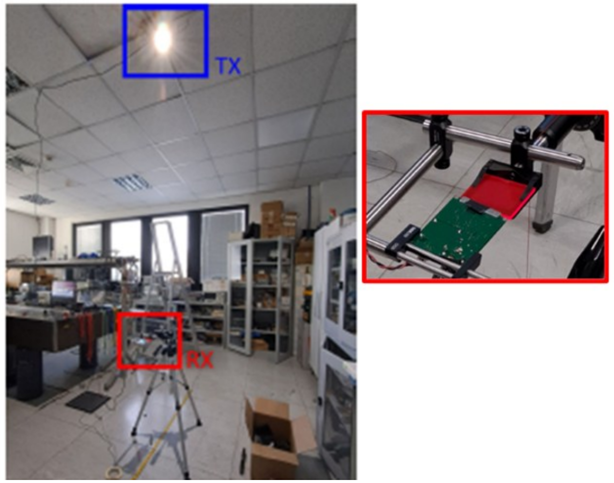
PoCs from RIGOLETTO (1)



Architecture for reconfigurable LO frequency synthetizer up to mm-Wave

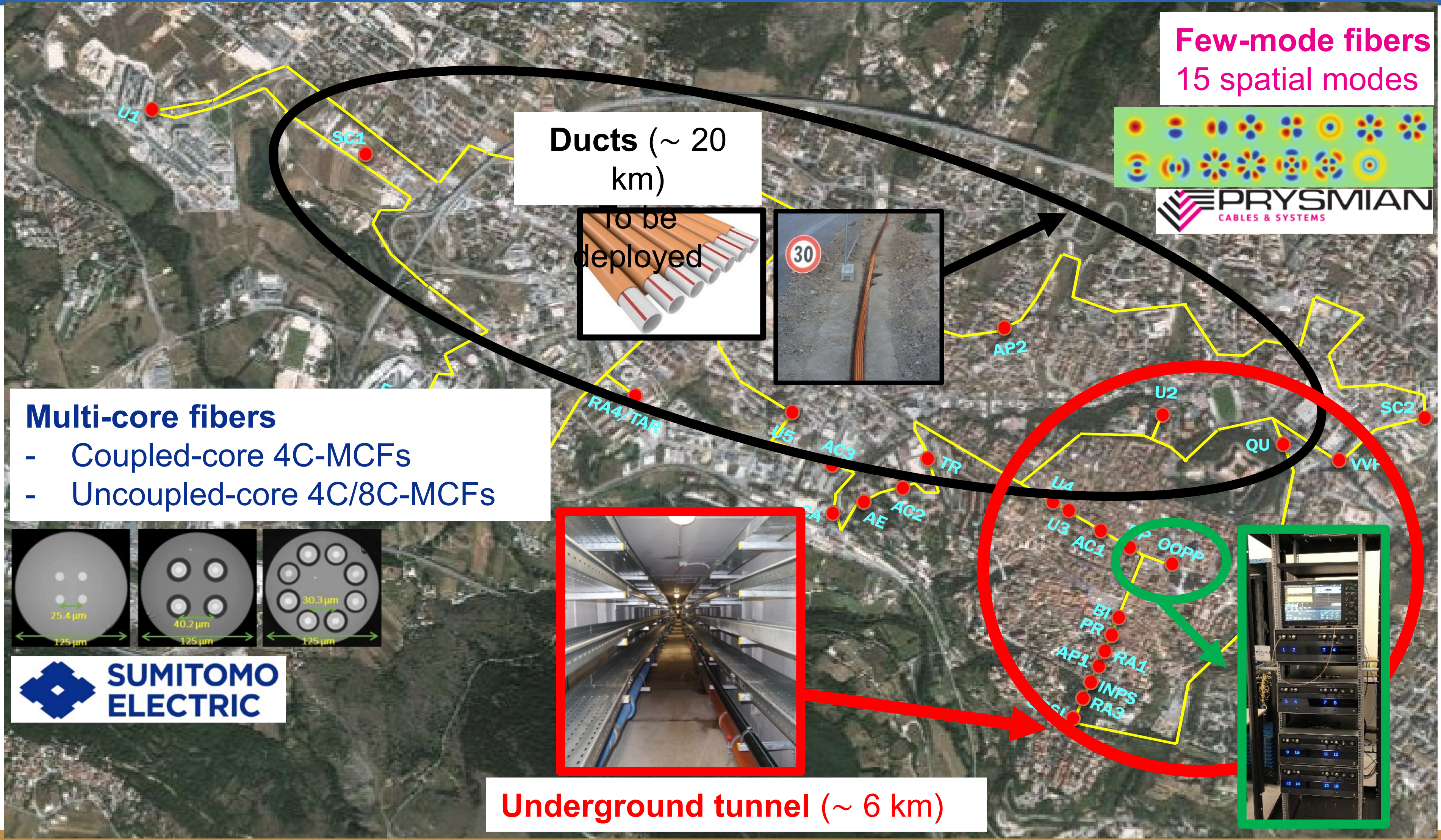


Open and disaggregated optical nodes/networks



Low cost LIFi experiment

City PoC from RIGOLETTO



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Thank you for the attention!
Q & A

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RESTART

Credits to RESTART projects RIGOLETTO, HePIC, and to RESTART research colleagues at Scuola Superiore Sant'Anna, Consiglio Nazionale delle Ricerche, Politecnico di Bari, Politecnico di Torino, Politecnico di Milano, Università di Roma «La Sapienza», Università degli Studi di Padova, Università di Bologna, Università di Napoli «Federico II», Università dell'Aquila, CNIT, OpenFiber, Ericsson