Multilayer virtualization of integrated Photonic components for OON

Muhammad Umar Masood
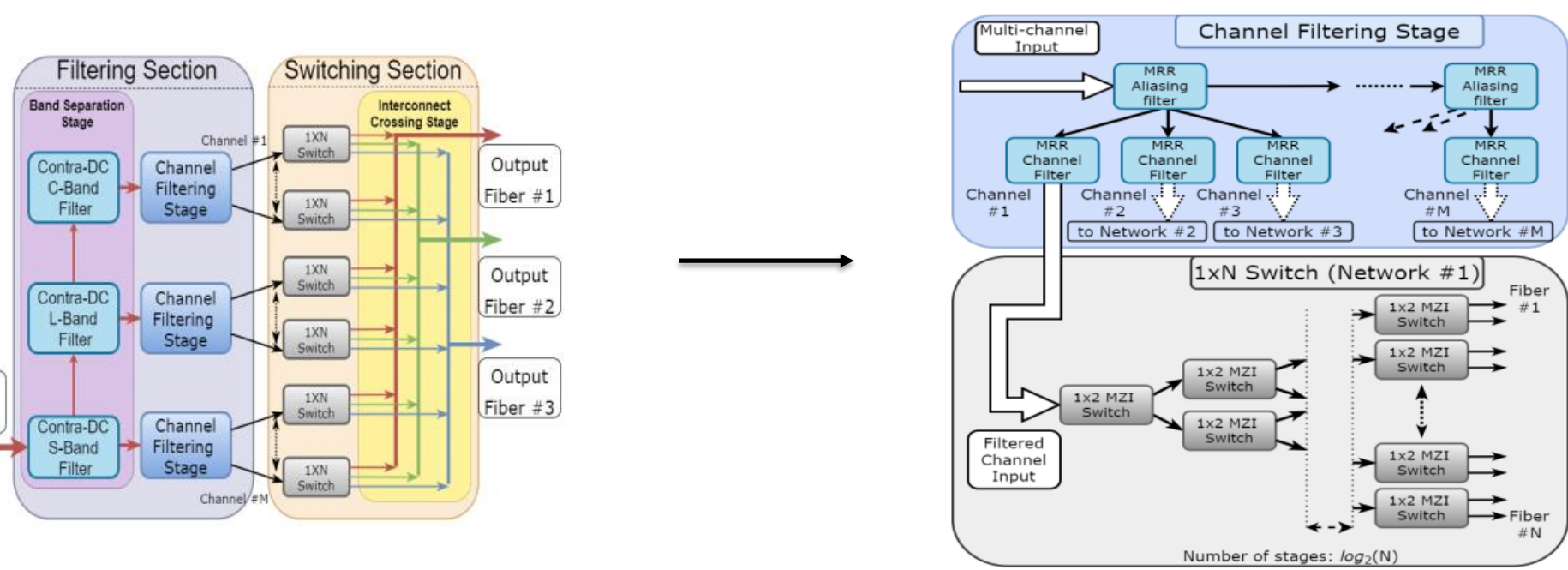## Supervisor: Prof. Vittorio Curri

Research context and motivation

- Nowadays, photonic integrated systems are widely used in optical transport and data center networks due to their large bandwidth and high reconfigurability. In addition to these features, photonically integrated systems offer overall low manufacturing cost, small footprint, and low power consumption.
- In this context, we designed a multi-band wavelength-selective modular photonic integrated switch (WSS). The three S+C+L bands can be managed by the proposed WSS, which is also potentially extendable to handle more output fibers and routed channels while yet having a compact physical footprint.
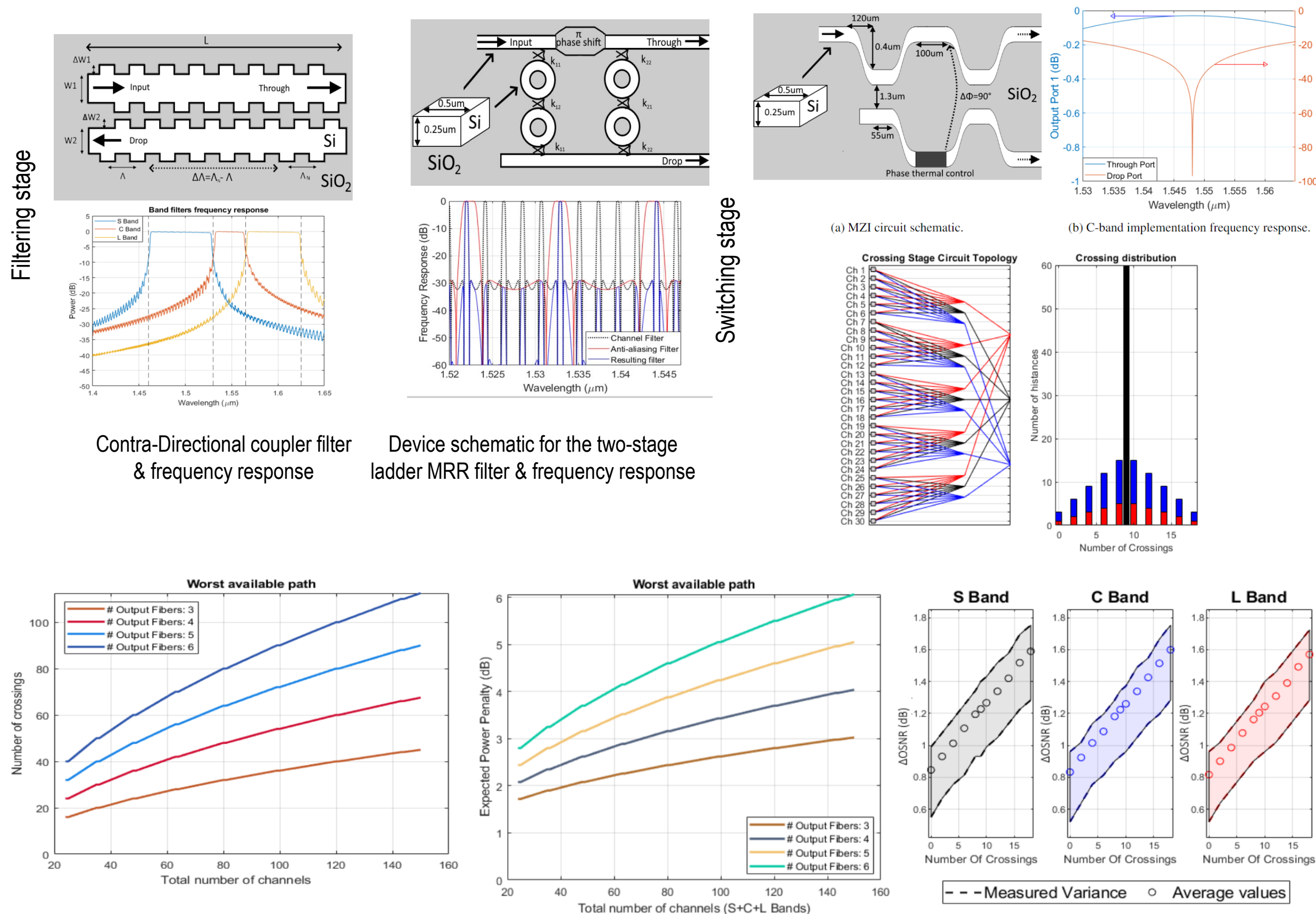
Addressed research problems

- At the device and transmission level, our work provides a complete abstraction of the proposed multi-band WSS in the context of software-defined optical networks by providing (QoT) degradation imposed by switching elements.
- At the network level, multiple networking analysis are done of the WSS device and its impact on the overall performance of the network are studied.
- The Wavelength Selective Switch architecture contains two stages: filtering stage and switching stage

Adopted Methodology

- The WSS device is designed using the OptSim software.

Contra-Directional coupler filter & frequency response

Device schematic for the two-stage ladder MRR filter & frequency response

- - – Measured Variance   ○   Average values

Submitted and published works

- Muhammad Umar Masood , Ihtesham Khan, and Lorenzo Tunesi, "Networking Analysis of Photonics Integrated Multiband WSS Based ROADM Architecture", SoftCOM, Croatia, 2022 (accepted)
- Muhammad Umar Masood , Ihtesham Khan, and Lorenzo Tunesi, "Network Performance of ROADM Architecture Enabled by Novel Wideband-integrated WSS", IEEE GLOBECOM, Brazil, 2022 (accepted)
- Muhammad Umar Masood , Ihtesham Khan, and Lorenzo Tunesi, "Network Traffic Analysis of Modular Multiband Integrated WSS based ROADMs",IEEE Photonics Conference (IPC), Vancouver, 2022 (accepted)
- Muhammad Umar Masood , Ihtesham Khan, and Bruno Correia, "Photonics Integrated Multiband WSS Based ROADM Architecture: A Networking Analysis", Asia Communications and Photonics Conference (ACP), Shenzen, 2022 (submitted)
- Lorenzo Tunesi, Ihtesham Khan, Muhammad Umar Masood, "Modular Photonic-Integrated Device for Multi-Band Wavelength-Selective Switching", International Conference on Photonics in Switching and Computing (PSC), Japan, 2022 (published)
- Lorenzo Tunesi, Ihtesham Khan, Muhammad Umar Masood, "Design and performance assessment\\of modular multi-band photonic-integrated WSS", OpticsExpress (submitted)
- Lorenzo Tunesi, Ihtesham Khan, Muhammad Umar Masood, "Novel Design and Operation of Photonic-integrated WSS for Ultra-wideband Applications", IEEE Summer Photonics Society Summer Topicals Meeting, Mexico, 2022
- ….

Novel Contributions

- Networking analysis is done for the three topologies (Spain-E, German and USA) for different traffic profiles (fixed vs. population based) and a detailed SDM vs. BDM comparison is also evaluated. SNAP tool is used for network simulation.
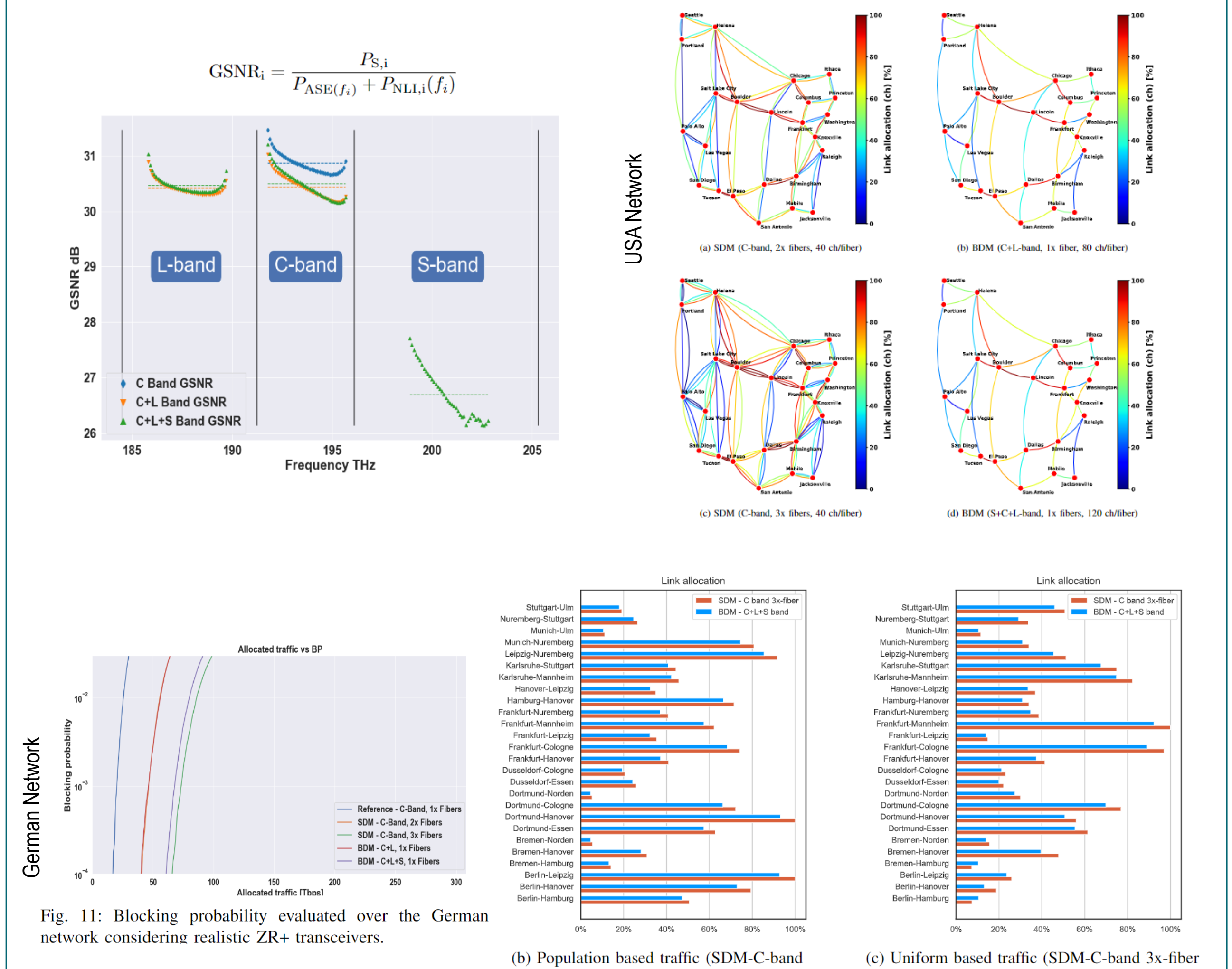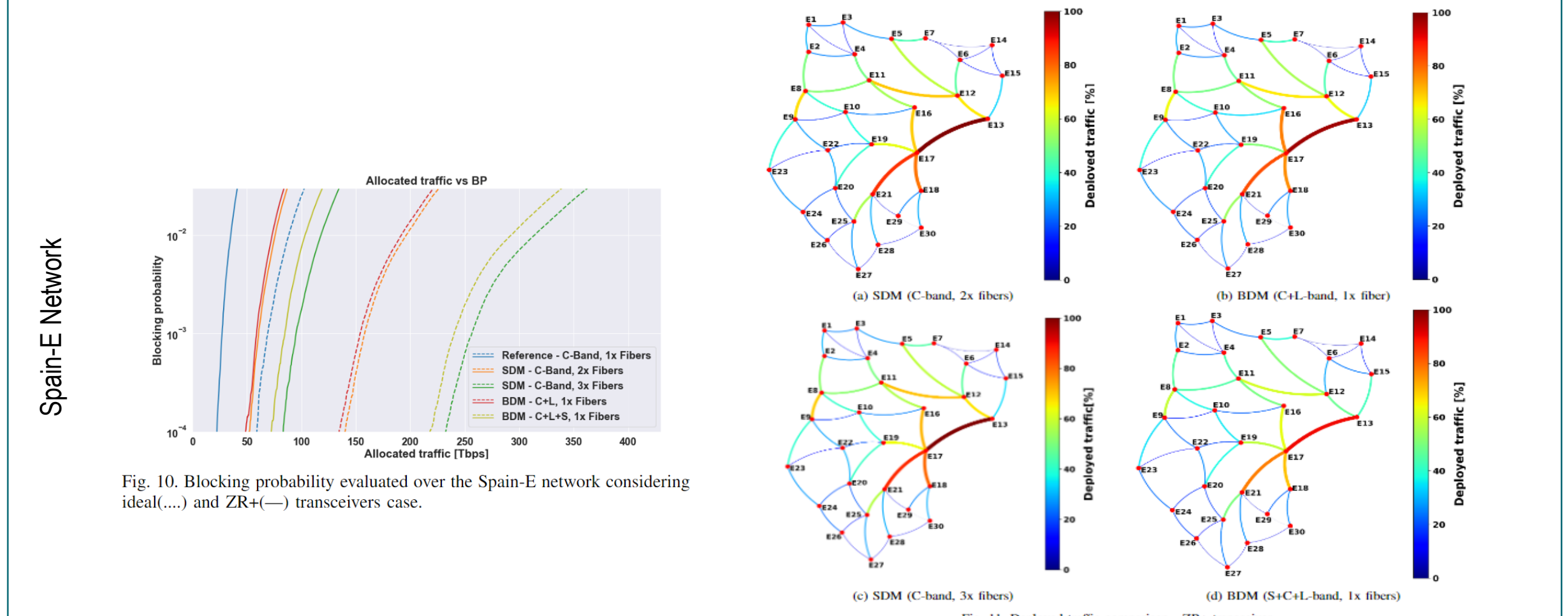
$$\text{GSNR}_i = \frac{P_{S,i}}{P_{ASE(f_i)} + P_{NLI,i}(f_i)}$$

Fig. 11: Blocking probability evaluated over the German network considering realistic ZR+ transceivers.

(b) Population based traffic (SDM-C-band 3x-fiber vs BDM-C+L+S band 1x-fiber)

(c) Uniform based traffic (SDM-C-band 3x-fiber vs BDM-C+L+S band 1x-fiber)

Fig. 10. Blocking probability evaluated over the Spain-E network considering ideal(....) and ZR+(—) transceivers case.

Fig. 11. Deployed traffic comparison - ZR+ transceiver.

- PIC based WSS device performance shows to be a potential solution for multi-band systems
- BDM proves to be a cost-effective solution with a slight compromise on the capacity as compared to SDM solution

Future work

- A detailed comparison is required in terms of techno-economic analysis for the traditional based ROADM devices and the PIC based ROADM (WSS module).
- Machine learning algorithms can be applied in the designing of device which will save time and computational power.

List of attended classes

- 01UMNRV – Advanced deep Learning (15/6/2021, 30 hours)
- 01UJBRV – Adversarial training of neural networks (3/6/2021, 15 hours)
- 01QTEIU – Data mining concepts and algorithms (1/2/2021, 20 hours)
- 01UJCRV – Spectral and machine learning methods for uncertainty quantification (23/6/2021, 21 hours)
- 01QFFRV – Innovative techniques for optimization (26/2/2021, 20 hours)
- External activity (OFC 2021) – Machine Learning in Optical Networks (07/06/2021)
- External activity (Lake Como school of advanced studies) – Machine Learning Photonics (22/04/2021)