ERC Project BACKUP

Unveiling the relationship between brain connectivity and function by integrated photonics

Neuromorphic Photonics

UNIVERSITÀ DI TRENTO
Dipartimento di Fisica

"BACKUP" Project

The BACKUP Project aims at studying the neural activity from a bottom-up perspective, with the help of artificial neural networks. BACKUP will tackle important problems spacing from neurological disorders to the comprehension of novel computation mechanisms. It is a multidisciplinary activity in which biology, informatics, and physics come together.

Artificial Neural Network

Artificial Neural Networks (ANNs) are computing systems that vaguely imitate mechanisms of biological neural networks. They are a collection of units that, connected together, elaborate the inputs and generate the outputs.

ANNs can perform complex tasks, such as:

- Pattern Recognition
- Clustering
- Time-Series Prediction

Network Training
In order to work properly, Neural Networks must learn to generate the correct output. For this reason they must go through the *training process*. During training, the internal parameters (weights) of the network are modified to improve the accuracy of the predictions.

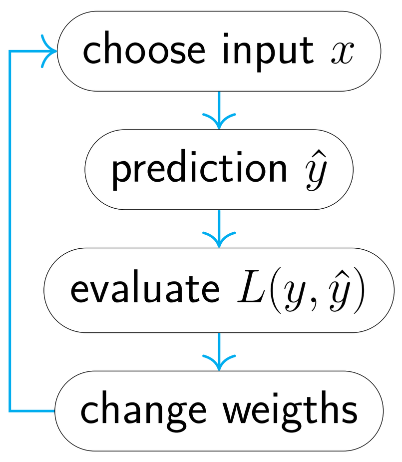


Fig. 1: Training steps.

Topologies

Nodes/neurons in neural networks can be connected together in several ways. Different topologies have pros and cons, depending on the task they have to carry out.

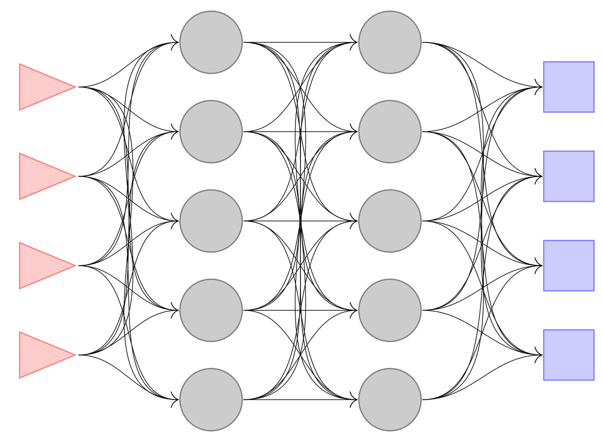


Fig. 2: Feedforward neural network

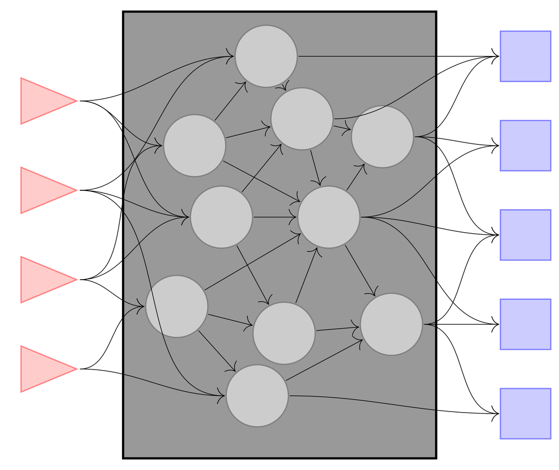


Fig. 3: Reservoir neural network

Integrated photonics

Silicon photonics exploits the low loss properties of the material to create integrated optical circuits. We make use of those structures to create optical neural networks.

We developed several ANNs with both feed forward and RC layouts, based on the nonlinear response of a singular *MicroRing Resonator* node or several in SCISSOR configuration.

The speed and bandwdith of integrated photonics are great advantages for high performance computation.

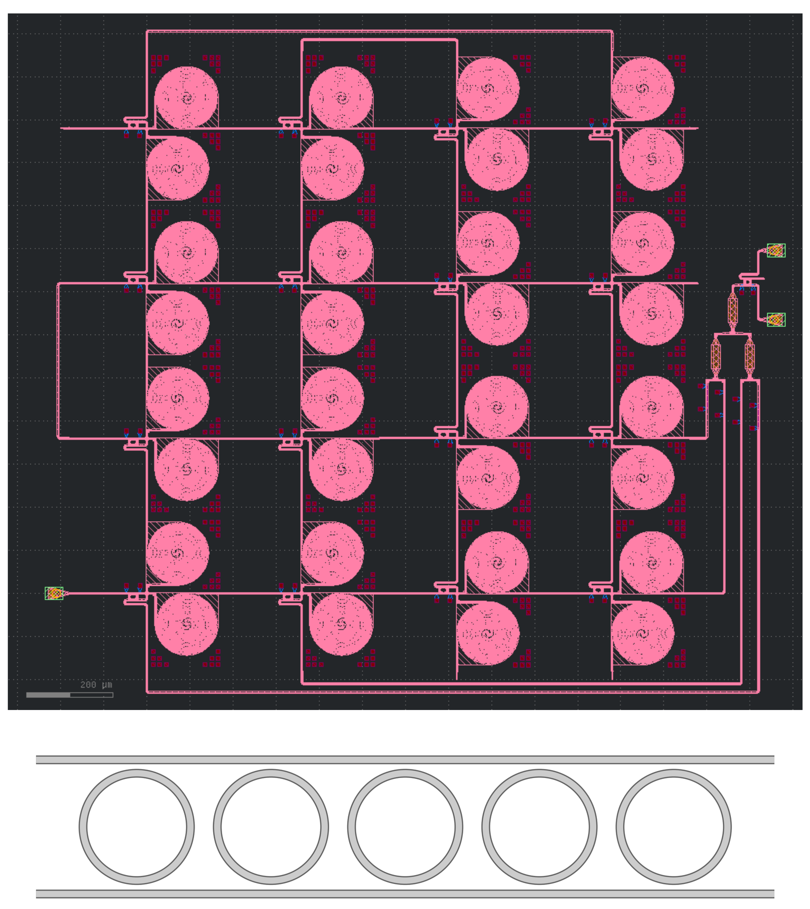


Fig. 4: (Above) Swirl RC ANN. (Below) SCISSOR.

ANNs are developed for signal processing and pattern recognition tasks (e.g. for telecom networks) and because they can be interfaced with biological networks.

Optical node

Our optical neuron is based on a *MicroRing Resonator* (MRR), whose transmittance (amplitude and phase) is wavelength dependent and strongly nonlinear in input power. Its complex nonlinear response is due to the interaction between optical, free carrier, and thermal effects.

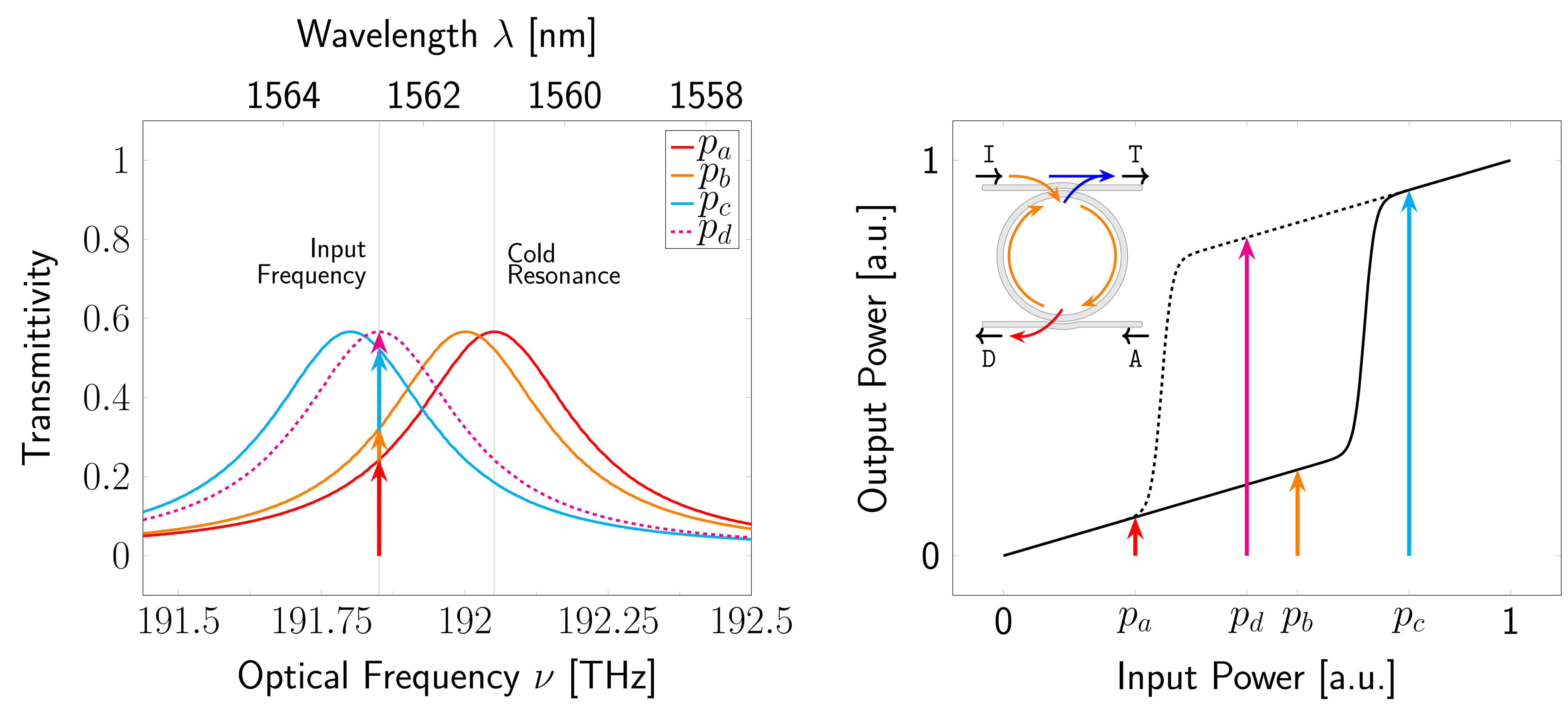
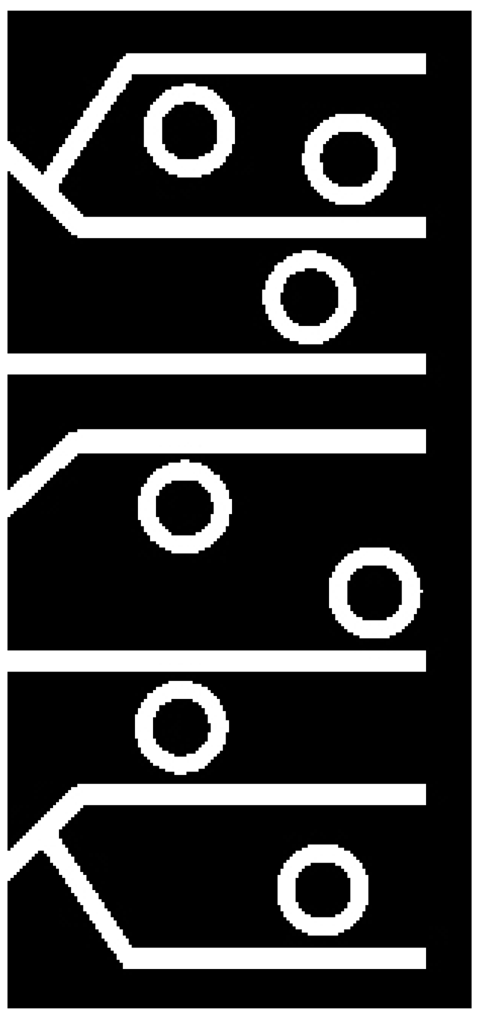


Fig. 5: (Left) Drop spectra for different input powers. (Right) Sketch of the bistable behaviour of the drop signal vs the input power.



Optical Characterization at 40 Gbps

The experimental setup to test the ANNs developed with arbitrary input signals and to characterize their output at 40 Gbps.

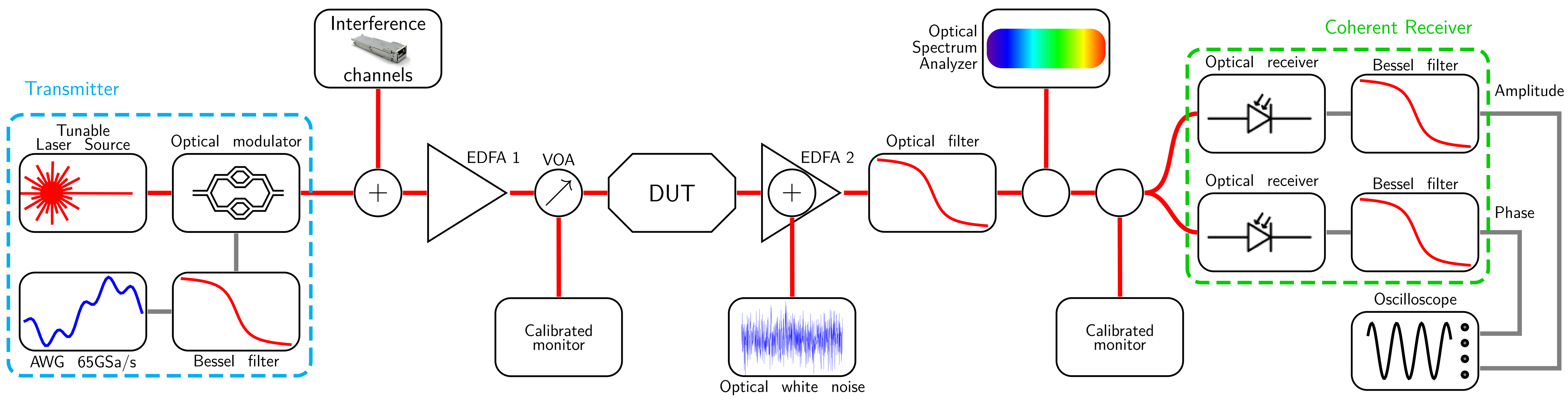


Fig. 6: Measurement setup for the optical characterization of microring resonators

The Neuromorphic BACKUP Team

(which is actually the regular team and not the *backup* team)