Commonly used building blocks for photonic NNs

Photonic components in neuromorphic computing

1 Focus areas

Application:

The components presented here contribute to the development of neuromorphic computing hardware by providing high-speed, energy-efficient processing capabilities. They address scaling challenges such as parallel processing of complex computations, reducing latency, and handling large volumes of data. Applications real-time signal processing, image recognition, and other fields requiring fast and efficient computation.

2 Photonic activation functions

Optical amplifiers like SOAs.

Semiconductor optical amplifiers (SOAs) operate by amplifying incoming optical signals through stimulated emission. Their gain saturation and carrier dynamics introduce the necessary nonlinearity, mimicking activation functions in neural networks.
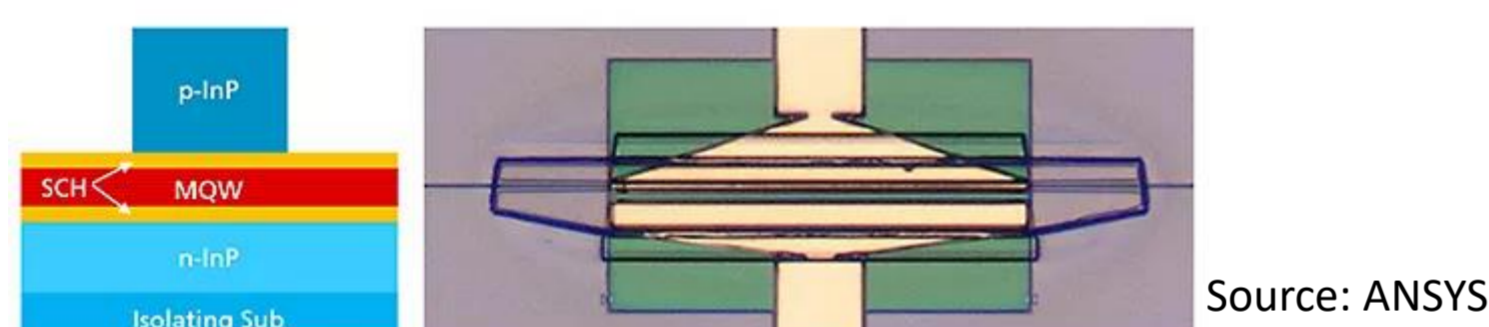

Source: ANSYS

3 Photonic neurons

Optical Ring Resonators & MMIs:

Optical ring resonators and MMIs can be used to create photonics neurons. They rely on resonance and interference effects. Ring resonators trap light at specific wavelengths, enabling signal processing functions like filtering and delaying. MMIs split and combine multiple optical signals, facilitating the interaction between different signal paths.


Source: University of Viena
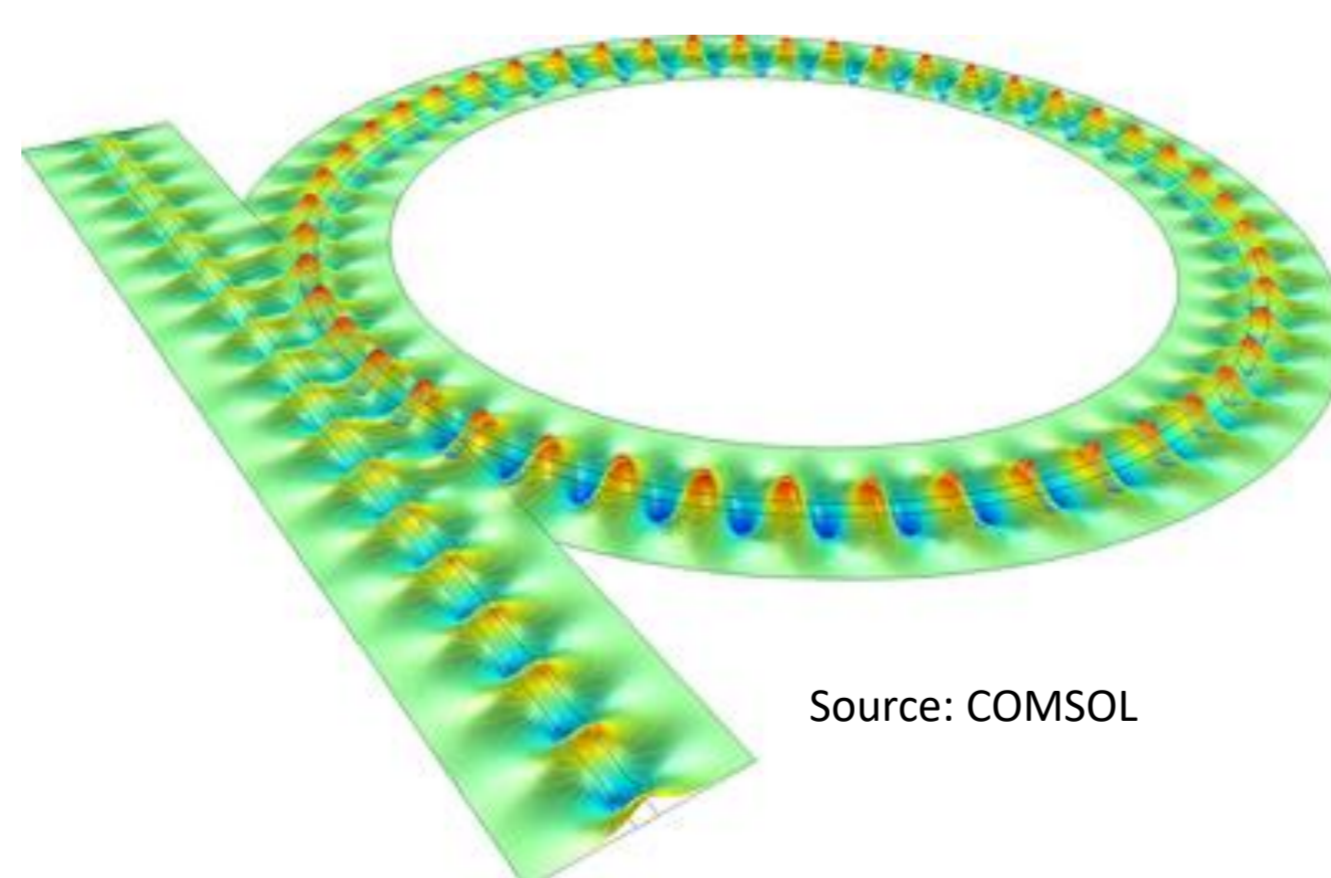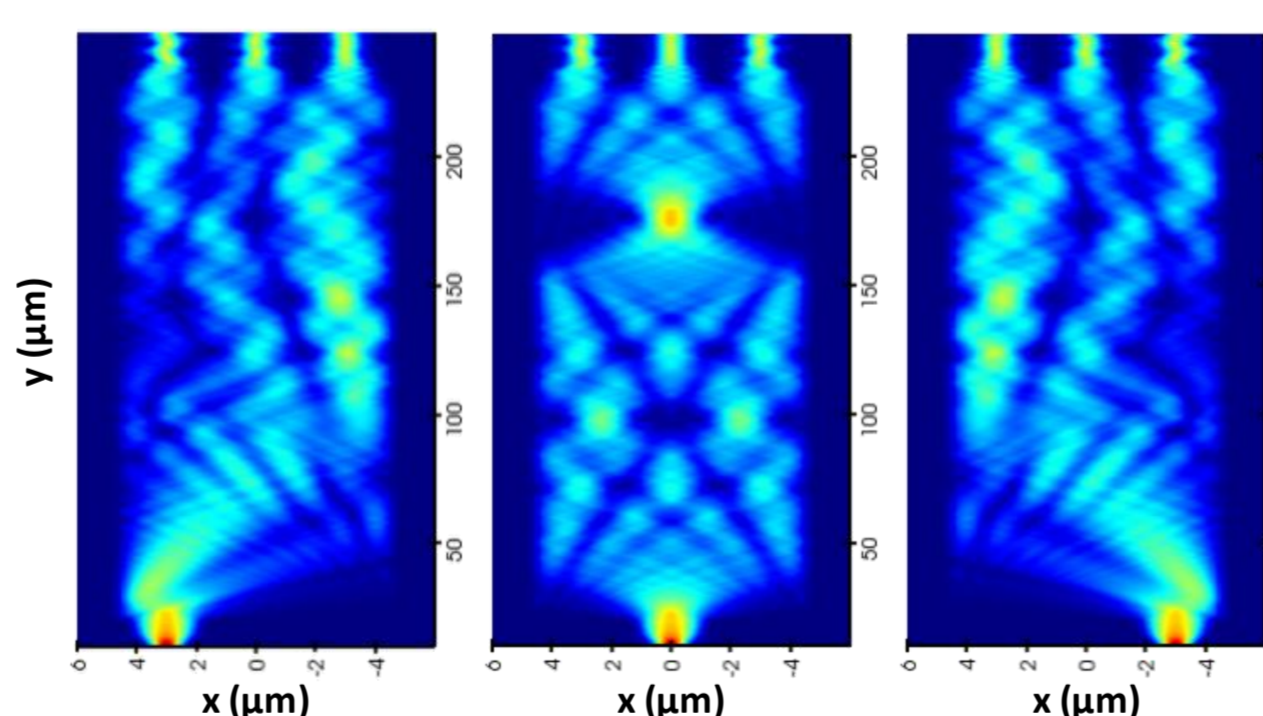
Source: COMSOL

4 Photonic processors

MZI Meshes (Mach-Zender Interforomenter Meshes)

These enable Linear Optical Processors (LOPs) capable of implementing arbitrary complex matrices in the optical domain. By manipulating the interference of light within a mesh network, they perform matrix operations essential for neural network computations at the speed of light.
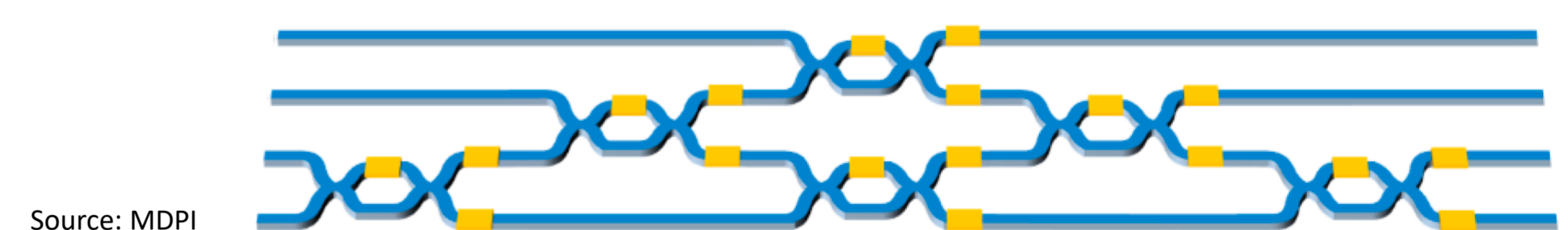
Source: MDPI

Photonic Reservoirs

Photonic reservoirs are used in reservoir computing architectures to extract time interdependencies in optical signals. They process temporal information through complex, nonlinear dynamical systems, allowing for efficient real-time signal processing without the need for extensive training.
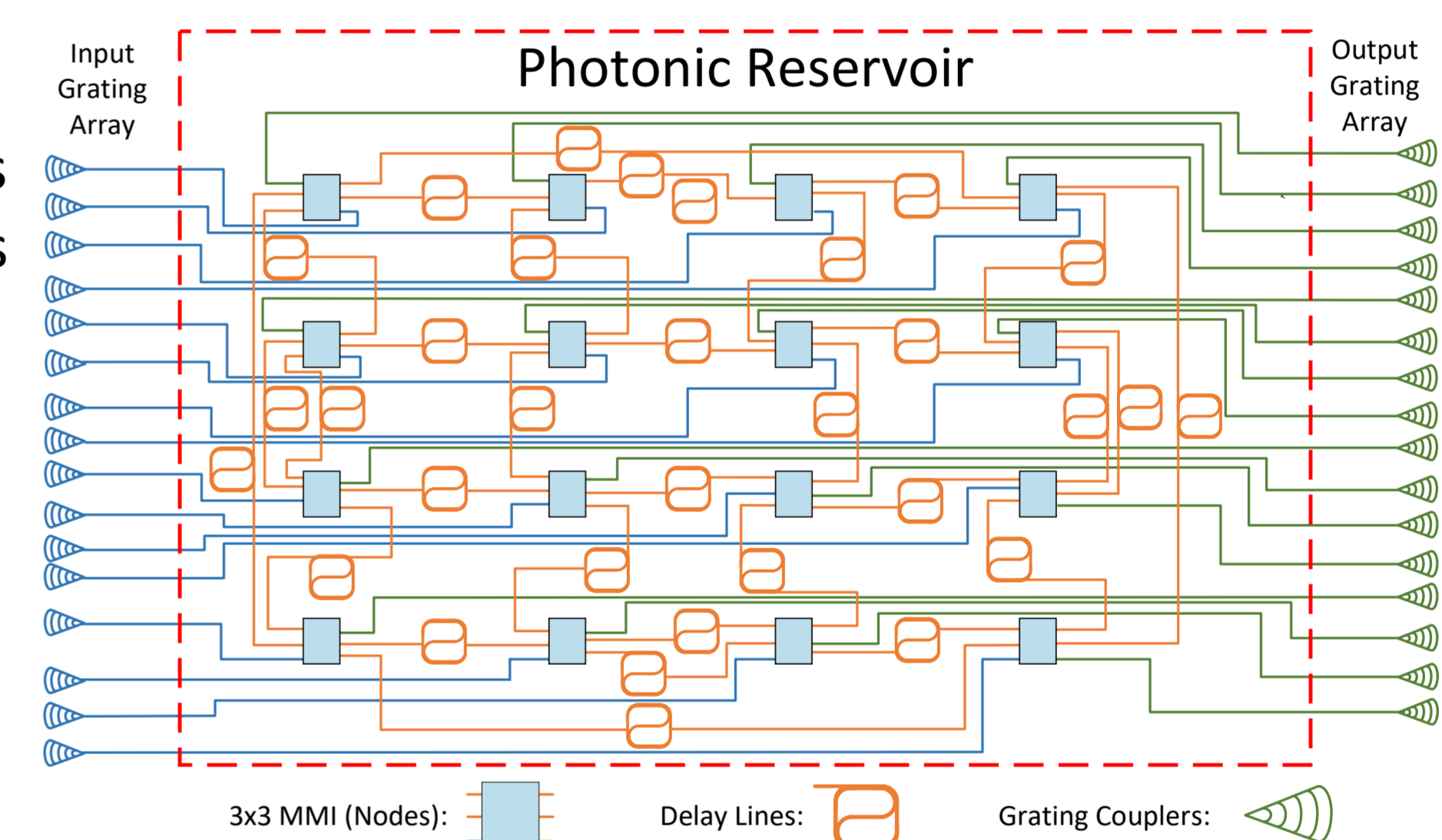
5 Integration

The integration of photonic components like MZI meshes, photonic reservoirs, optical ring resonators, MMIs, and SOAs revolutionizes neuromorphic computing. By harnessing optical phenomena, these technologies enable ultra-fast, energy-efficient processing capabilities, addressing key scaling challenges in modern computing systems. They pave the way for advanced applications in AI and real-time data processing.

6 Outlook

Future developments may include enhanced integration techniques for photonic components, the use of novel materials to improve performance, and the creation of hybrid photonic-electronic systems.