THESIS TOPICS: 2025-2026

Title: Fast statistical sampling with photonic Ising machines for efficient neural network training

Description:
Recent years have seen a tremendous growth in the use of artificial neural networks (ANN) for different types of AI applications. This trend is expected to continue during the next decade(s), resulting in a substantial increase in the computing power and energy consumption needed to train and operate these AI systems. In this context, Ising machines present a promising solution, as neural networks can be mapped onto these Ising machines which are physical systems that implement a network of artificial spins. To harness the speed and efficiency of Ising machines for machine learning, we focus on a particular type of generative neural networks known as Boltzmann machines. Training these machines relies on Boltzmann sampling, a time-consuming process with current state-of-the-art statistical samplers. We conjecture that noise-induced Ising machines can greatly speed-up this sampling process.

The objective of this project is to investigate Boltzmann sampling with an opto-electronic Ising machines in which additional noise is injected as randomizing element. Based on numerical simulations, you will test if the samples obtained with this approach indeed correctly sample the Boltzmann distribution of the network. Next, these samples can then be used to train a Boltzmann machine as neural network. This will be done using well-established benchmark tasks such as the MNIST handwritten digit recognition and generation task. These numerical simulations can also be further validated in this project by comparing them with experiments done on a Ising machine demonstrator build around opto-electronic oscillators.

The work is a mixture between numerical simulations and experiments, where the main focus of the work will depend on the research interest of the student.

Link to current research project: aphy.research.vub.be/eos-project

Location: VUB - Etterbeek

Promotor 1
Name: Guy Van der Sande
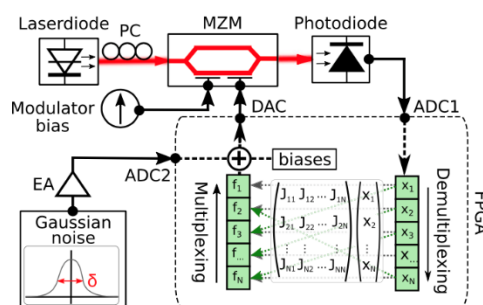**e-mail: Guy.Van.der.Sande@vub.be**

Promotor 2
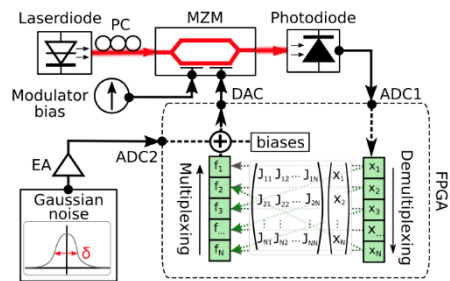**Name: Guy Verschaffelt**
e-mail: Guy.Verschaffelt@vub.be

Supervisor
Name: Leen Mys
e-mail: leen.mys@vub.be

Schematic setup of an opto-electronic Ising machine with noise injection. The light of a single-mode laser is sent through a Mach-Zehnder modulator. After detecting the optical power, the value of the time-multiplexed artificial spins is recorded using an FPGA. The electrical feedback signal is then calculated in the FPGA, combined with a controlled amount of noise and sent to the modulation signal port of the modulator, closing the electro-optical feedback loop. (right) Handwritten digits generated by a restricted Boltzmann machine's neural network that is trained with Boltzmann sampling from an Ising machine.