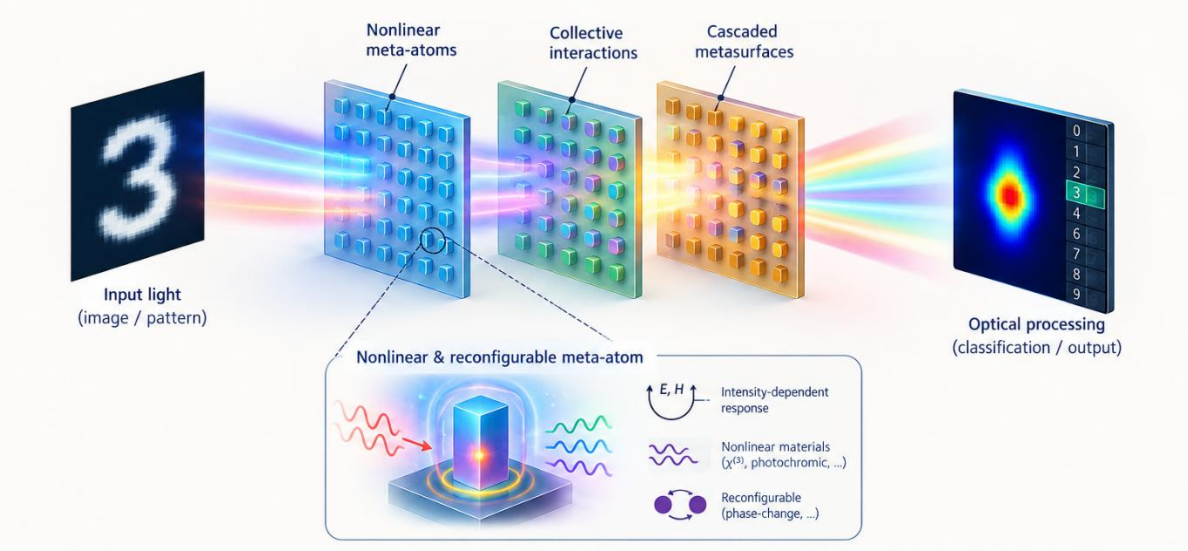
## *NEUROMORPHIC METAOPTICS*

Artificially structured optical materials, such as metasurfaces, provide unprecedented opportunities for controlling and processing light at the nanoscale. By engineering the amplitude, phase, polarization, and spectral response of light through subwavelength nanostructures, metasurfaces can perform complex optical functions in an ultrathin and highly compact fashion. Beyond conventional applications in imaging, sensing, and beam shaping, metasurfaces are emerging as promising building blocks for a new generation of optical information-processing systems, in which computation is performed directly by light.

The major aim of this PhD thesis project is to investigate theoretically the use of nonlinear and reconfigurable metasurfaces as neuromorphic optical processors. The project will explore how ensembles of nanoscale resonators can be engineered to mimic functionalities of biological neural networks, with individual meta-atoms acting as physical processing elements or optical synapses. The student will explore how these elementary building blocks can be combined into metasurfaces and cascaded meta-optical architectures capable of performing tasks such as image classification, feature extraction, pattern recognition, and decision making, as illustrated in the Figure.




Specifically, the project will investigate neuromorphic meta-atoms based on resonant nanostructures made of nonlinear or reconfigurable materials, whose optical polarizabilities can depend dynamically on the incident optical field and on the state of the surrounding nanostructures. This is in contrast to conventional metasurfaces, where each meta-atom provides a fixed linear response, and opens the possibility to encode optical analogues of synaptic weights, nonlinear activation functions, and memory-like functionalities, with the ultimate goal of implementing optical information processing directly within the material itself, at essentially zero-energy cost.

An important aspect of the project will be the connection between fundamental electromagnetic physics and machine learning. Rather than treating a metasurface simply as a black-box optical element, the emphasis will be placed on understanding how physically meaningful parameters, such as the excited optical resonances, the induced near- and far-field interactions, and the nonlinear and reconfigurable material responses can be exploited to introduce concepts analogous to learning, adaptation, and memory, directly into the photonic hardware.

Concerning Methodology, the student will be introduced to analytical and numerical approaches in Electrodynamics, including coupled-dipole theories, Green-function methods, effective polarizability models, and Fourier-space propagation techniques. These approaches will be combined with full-wave electromagnetic simulations and modern machine-learning and optimization methods. Moreover, the theoretical developments may be validated through our network of collaborations with experimental groups in Singapore, Eindhoven and Paris.

This project therefore lies at the interface between nanophotonics, nonlinear optics, electromagnetic theory, and artificial intelligence, with the broader goal of establishing new physical principles for neuromorphic computation using light, which may lead to radically compact and energy-efficient optical processors in which sensing, memory, and computation are intrinsically integrated.

***Requirements: eligible candidates are students with a good academic record and strong motivation for research, with a B.S. or M.S. degree enabling access to a doctorate program in (preferably) Physics, Electrical Engineering, Computer Engineering, or related fields, earned prior to the deadline of the application. Experience in electromagnetism, photonics/nanophotonics, nonlinear optics, numerical simulations, or machine learning will be considered an advantage.***

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