Implementation of neuromorphic activation function within Surface Plasmon Polariton circuits

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This research deals with simulation of a neuromorphic structure by implementation of a nonlinear medium as a control gate of Surface Plasmon Polariton propagation. Intensity of the input light is the key parameter for the gate control.

Keywords: Neuromorphic, surface-plasmon-polariton, saturable-absorber, artificial intelligence, phase change material, nanophotonics

1. Introduction

Recently the availability of large amounts of data and the necessity of processing it efficiently has led to the rapid development of machine-learning techniques. But unlike real neural tissue, traditional computing architectures physically separate the core computing functions of memory and processing, making fast, efficient and low-energy computing difficult to achieve. In order to overcome these limitations, the investigation toward the design of new fundamental building blocks of brain tissue has been triggered. In this way the analysis and the processing of data can be made directly on small units (chips). The electronic neuromorphic implementations suffer from considerable losses and they are not adaptable to different situations of learning. For this reason, optical and photonic hardware seem to be a good candidate for neuromorphic models. Considering this fact, current research benefits the advantages of working with surface Plasmon Polariton (SPP), which are the high speed of the photons and impressive interaction of electron at the same time.

2. Surface Plasmon Polariton

To excite the SPP there are three different procedures such as Otto, Kretschmann and grating configurations to couple the light into Polariton. Unlike the two former methods, the grating configuration is more preferred from designing point of view. By defining precisely, the angle of incidence and the grating periodicity we can couple the wave number of the light and Polariton, starting the propagation of SPP on the surface of the metal and dielectric interface. To control the propagation of the SPP, we use a gap filled by PCM, which acts as a saturable absorber.

3. PCM Nonlinear control gate

Neuron is characterized by three fundamental parts: the dendrites (input), the soma (computing entity), axon and postsynaptic terminals (outputs).

In order to mimic the neuronal activation process, we use the PCM (*phase change material*) with non-linear saturable absorption. Depending to the temperature, this medium can be in two states (crystalline or amorphous) with different optical properties, which allows to implement the input intensity threshold to let the SPP to propagate or suppress it completely.

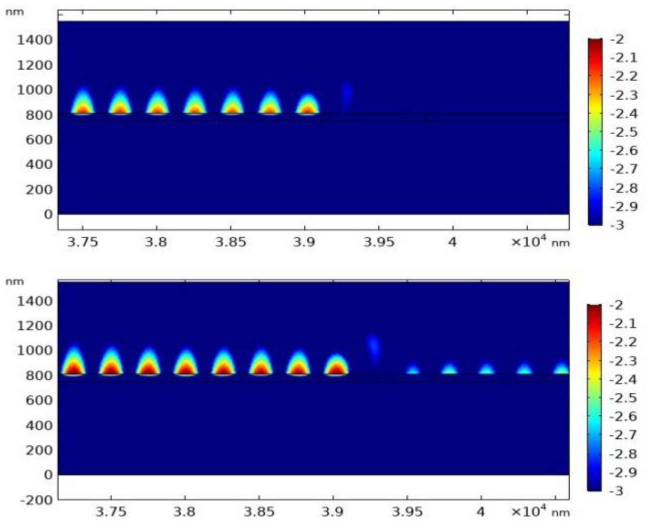

Fig. 2 Surface Plasmon Polariton propagation below and above the threshold with respect to input intensity.

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