Thesis proposal

Electrical gating of reconfigurable integrated nonlinear plasmonic devices

Scientific context: Plasmonic components are a novel class of functional integrated optical devices providing ultra-compact footprint and superior performances [1]. The technology is now entering the ultimate length with active areas driven at the atomic scale [2,3]. The Werner-Siemens foundation has recently sponsored a multimillion research program to foster opto-electronic blocks for logic and memories at the level of a few atoms. The elaboration of complex and versatile systems for optical information processing is however limited by the available plasmons states given by the geometry of the prototypes. This is especially detrimental for computing functions requiring cascaded Boolean operations because plasmon-based devices are notoriously difficult to scale up due to their inherent losses. New paradigms are thus required to develop alternative functional platforms.

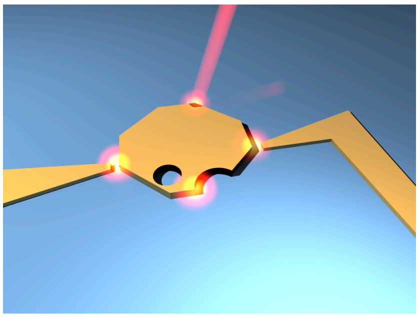

Figure 1: Electrical control of the outputs of a modal plasmonic logic gate. The overall length of the device is ca. 1-5 μm.

Methodology: Figure 1 is describing the essence of such an alternative approach whereby an integrated single plasmonic gate performing logic operations can be reconfigured on-demand electrostatically. The central element is a designed two-dimensional plasmonic logic gate with laser-activated (pulsed) *n*-inputs and *n*-outputs. The device reacts to the pulse by locally creating a nonlinear response (photoluminescence) routed across the unit via the underlying plasmonic landscape. A series of static Boolean operations may be derived by designing the appropriate modal landscape linking the *n*-input signals to the *n*-outputs [4]. The reconfigurability is insured by the in the integration of a set of control electrodes placed in the vicinity of the gate's outputs. Upon applying a voltage, the local electron density is modified and the logic level of the output nonlinear response maybe changed on demand to reconfigure the device's table of truth. Preliminary experiments recently performed in the laboratory on simple modal patterns confirmed the voltage control of the output level routed by the plasmonic landscape. The research plan for this doctoral work will consist at providing a clear understanding the electrical control of device's outputs on a simple test platform and to transpose the concept to functional reconfigurable logic gate architecture. The dynamics of the reconfiguration will also be quantified. The work is experimental in nature, but will be accompanied by numerical simulations for designing the appropriate plasmon local density of modes as well as the control static electric field landscape.

Dr. Alexandre BOUHELIER– Research director (CNRS)
9 Avenue Alain Savary, B.P. 47870 - 21078 DIJON Cedex – France
Tél (+33) 3 80 39 60 22 - Fax (+33) 3 60 24 alexandre.bouhelier@u-bourgogne.fr
Secrétariat : Tél. (+33) 3 80 39 60 20– Fax (+33) 3 80 39 60 24

Facilities: The research will be conducted at ICB's photonic department in the OSNC-P group (Submicron Optics and Nanosensor). The thesis will be supervised by Dr. Alexandre Bouhelier. The candidate will work in a lively environment composed of four permanent researchers supervising 4 to 5 PhD students and a couple of postodocs. The candidate will have full access to the characterization tool including nonlinear confocal microscopy retrofitted for simultaneous optical and electrical investigations. The laboratory hosts the technological platform ARCEN Carnot. The platform operates a user nanofabrication facility in a clean-room environment including electron-beam lithography, thin film depositions and ion etching apparatus. The candidate will receive an exhaustive training on the nanofabrication line. Such know-how is nowadays a valuable asset for prospecting jobs in academia and in nanotechnology related industries.

This thesis proposal is in line with the main research topics developed in the department (light-mediated control processes, advanced nonlinear optical dynamic and plasmonics). The nonlinear responses of the plasmonic devices are subject to collaborative research between two groups of the department and this doctoral work will benefit from such combined efforts.

[1] *Low-loss plasmon-assisted electro-optic modulator,* C. Haffner *et al., Nature* **556**, 483–486 (2018)
[2] *Optical wireless link between a nanoscale antenna and a transducing rectenna*, A. Dasgupta et al. Nature Commun. *9*, 1992 (2018)
[3] *Atomic Scale Photodetection Enabled by a Memristive Junction,* A. Emboras, ACS Nano, 12, 6706 (2018)
[4] *Tailoring and imaging the plasmonic local density of states in crystalline nanoprisms.* S. Viarbitskaya *et al.* Nature Mater. 12, 426-432 (2013).

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