M2 Internship offer:

Electrically-driven Phase Change Materials Devices for Reconfigurable Nanophotonics

Research team: i-Lum, light engineering and conversion

Main location: Ecole Centrale de Lyon

Keywords: Photonic integrated circuits, Multiphysics modelling and design, Electrical engineering
Profile: Physics, Optics

Duration: 4-6 month.

Context:
Nanophotonics is a mature field of research enabling the control of light via the nanostructuration of matter, with industrial applications ranging from telecoms to sensors as well as clean energy. Many optical components require local control of the direction, magnitude or phase of the electromagnetic field. This is particularly the case for programmable circuits, LIDARs or spatial light modulators (SLMs), which allow, among other things, optical computing, remote sensing and beam shaping. Most of these devices rely on thermo-optical effects, mechanically operated mirrors or liquid crystals, which fundamentally limits their operating speeds, sizes and integrability. As these components become crucial for self-driving cars, head-up displays or adaptive optics, it is necessary to transform them towards on-chip integration and mass production, which means finding new integrated optical modulation strategies.

Goals:
In this internship position, we propose to use the potential of phase change materials (PCMs) to dynamically control the optoelectronic response of photonic devices. More specifically, we will use chalcogenide-type materials such as GeSbTe, Sb_2S_3 and Sb_2Se_3, whose atomic arrangement can be changed in a controlled manner by an optical or electrical signal. This reversible amorphous-crystalline transition results in a very wide modulation of the refractive index, especially at near infrared wavelengths.
Our overall goal is to develop the selective electrical addressing of individual pixel elements of a nanophotonic device to actively write, erase and reconfigure integrated nano-devices in real time. For this it is necessary to develop a functional low-loss integrated PCM platform for photonics, with potential applications for optical computing, beam shaping and holographic display.

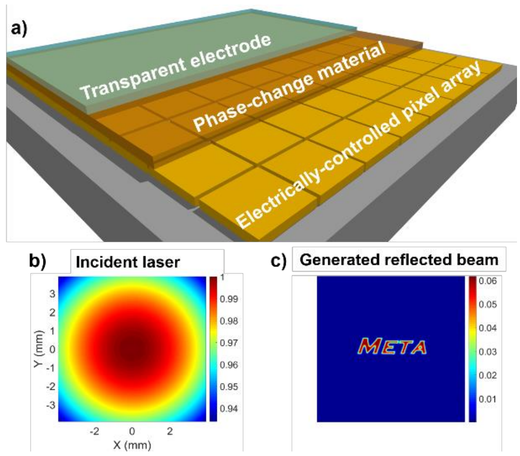

***Figure 1**: a) a PCM-based pixel array can transform an incident Gaussian beam, (b) to an arbitrary reflected wavefront; c) Here, each PCM-pixel is encoded to reflect the word 'META' in the far-field.*

This internship therefore aims to unlock the following scientific roadblocks: (i) design efficient integrated micro-heaters on-chip using multiphysics modelling; (ii) Fabricate and characterize PCM-based devices whose phase is electrically-controlled via integrated micro-heaters

Expected original contributions:

Controlling the individual state of each PCM-based pixels will enable real-time programmable photonic circuits or on-demand writing of metasurfaces for applications ranging from holographic displays to adaptive optics. Unlike existing solutions at the micrometric scale (liquid crystals, micro-mirrors, etc.), phase change materials will allow working at the nanometric scale with a much higher speed. Integrated reconfiguration techniques based on the selective control of PCM-based elements via electrical pulses may lead to a breakthrough in the field of reconfigurable photonics, promising innovative devices such as compact LiDARs for autonomous vehicles, components for beam shaping for biological analysis or even new types of displays for the augmented / virtual reality.

The candidate will take advantage of the stimulating scientific environment of INL, as well as of the scientific and technological facilities available in the lab, hosted in particular by the Nanolyon technology platform.

Profile

The candidate must have a strong background in Materials science, electrical engineering and photonics, with a strong motivation for Multiphysics designs, technological and experimental work as well as good social skills to carry out her/his researches in a dense collaborative context. The candidate will receive a solid training in nanofabrication in a clean room environment. Likewise, he / she will develop skills in electro-optical characterizations of nanophotonic devices.

Possible perspective

This internship can be followed by a PhD via an already funded ANR grant.

References:

- "Programming multilevel crystallization states in phase-change materials thin film"
A. Taute, S. Al-Jibouri, C. Laprais, S. Monfray, X. Letartre, N. Baboux, G. Saint-Girons, L. Berguiga, and S. Cueff, *Optical Materials Express* 13, 3113 (2023)

- "Dynamic control of light emission faster than the lifetime limit using VO_2 phase-change",
S. Cueff, D. Li, Y. Zhou, F. J. Wong, J. A. Kurvits, S. Ramanathan, and R. Zia.
Nature communications **6** (2015)

- "Reconfigurable Flat Optics with Programmable Reflection Amplitude Using Lithography-Free Phase-Change Materials Ultra-Thin Films",
S. Cueff, A. Taute, A. Bourgade, J. Lumeau, S. Monfray, Q. Song, P. Genevet, B. Devif, X. Letartre and L. Berguiga
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- "Tunable Mie-resonant dielectric metasurfaces based on VO2 phase-transition materials"
A. Tripathi, J. John, S. Kruk, Z. Zhang, H.S. Nguyen, L. Berguiga, P. Rojo Romeo, R. Orobtchouk, S. Ramanathan, Y. Kivshar, S. Cueff, *ACS Photonics* 8 (4), 1206-1213 (2021)

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