Proposal of Master Thesis / Master Internship

Photonic Integrated Circuits: Integrated Electro-Optical Modulators for Magnetic Resonance Imaging.

Place of work: ENSEEIHT site of LAAS-CNRS/ INP Toulouse
Working language: French or English

Magnetic Resonance Imaging (MRI) Context:

MRI exploits hydrogen nuclear magnetic resonance (NMR) to reconstruct an image that characterizes the distribution and/or properties of water present in biological tissues. The NMR phenomenon occurs when an electromagnetic wave is emitted at a specific frequency that depends on the intensity of the magnetic field generated by the magnet of the MRI equipment (e.g. 300 MHz at 7Tesla). Under these conditions, part of the RF pulse energy emitted by the antenna is absorbed by the hydrogen nuclei (excitation phase), and the hydrogen nuclei return to equilibrium (relaxation phase), which is then detected and analyzed for image construction. **The relaxation signal is extremely weak**, so reception of the signal is usually achieved with a second antenna (receiving antenna) placed as close as possible to the signal source. This antenna is **only operational during the reception phase**, and **must be disconnected** (off resonance) **during the RF excitation pulse** (this operation is usually performed by a diode device that becomes conductive during the RF pulse).
Recent studies have focused on the use of an optical signal in MRI to overcome the electromagnetic interference caused by the use of galvanic cables:

1. Optical Control: Using photodiodes and optical beams (Fig. 2 (a)) to manage antenna switching (carried out during a previous internship)
2. Signal Conversion: Exploring the transformation of RF relaxation signals into optical format [1]

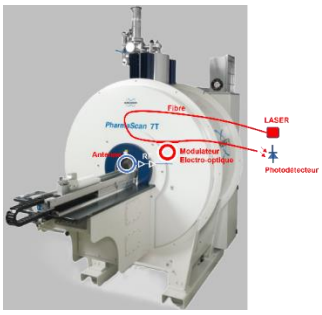

Figure 1: Schéma simplifié du dispositif RF/Optique proposé pour l'application IRM

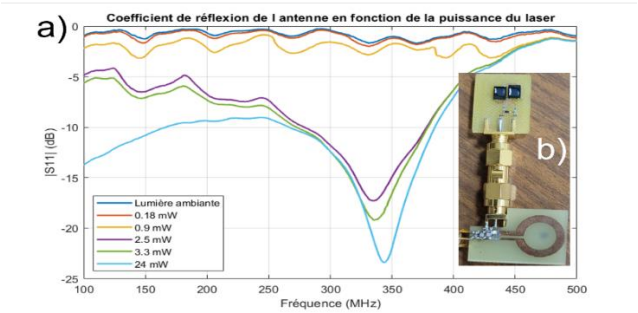

Figure 2: (a) Characterization of the antenna with its electro-optical circuit (b) by Julia Dillard during her internship.

Integrated Photonics Context:

Over the past two decades, integrated photonics have become a domain of intense research for the development of high-performance embedded sensors and telecommunication devices. **Photonic Integrated Circuits (PICS)** are in fact already driving communication and sensing performances in everyday mainstream applications. **Integrated Electro-Optical Modulators (IEOM)** ([2-4]) are micro-systems used to electrically control both amplitude and phase of optical signals in PICs. These devices combined with certain integrated optical components, are being developed on many PIC technologies for many different purposes.

Here, in the context of this project, we aim to develop an IEOM as a building block to convert the RF signal into an optical output signal.

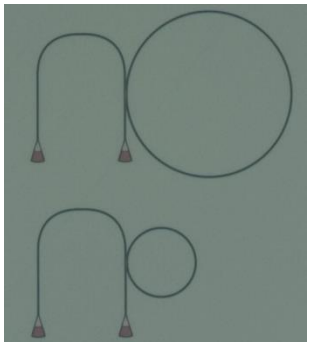

Figure 3: Ring resonator implemented in SiN technology at the LAAS cleanroom

Tasks and objectives of the internship:

1. **Literature Review:**
   - Conduct a comprehensive review of Integrated Electro-Opto-Mechanical (IEOM) theory.
   - Utilize foundational texts on optical principles and recent research publications to gain in-depth knowledge.
2. Design and Simulation:
   - Develop and simulate IEOM models using advanced multi-physical and optical simulation tools such as Lumerical and Klayout.
   - Focus on creating accurate and efficient models to predict system behavior.
3. Fabrication and Implementation (Optional):
   - Engage in the fabrication of micro-heaters or Kerr materials on Photonic Integrated Circuit (PIC) microchips.
   - Utilize LAAS cleanroom facilities and conventional lithographic techniques for precise implementation.
4. Characterization and Testing (Optional):
   - Perform detailed characterization and testing of fabricated IEOM components.
   - Use a well-established PIC testing platform to assess performance and validate design models.

Work environment:

The candidate will integrate the **OASIS research team** (optical Sensors and Smart Integrated Systems)t of **LAAS-CNRS** located at ENSEEIHT in Toulouse. He/She will also be working in close collaboration with the **LAAS TEAM** (Technique and Equipments Applied to Micro-nano technologies). He/She will also be working under the supervision of our postdoctoral research fellow who is at the forefront of the original SiN PIC technology developed within our research group.

Desired competences and personality :

-Knowledge in one or several of the following topics: Electrics, Optics or integrated photonics, Micro-Technologies and Instrumentation.
-Ability to work in a research team.
-Autonomy and a keen sense of problem solving.
-Experience in simulation and experimentation.
-Creative, conscientious and focused personality.
-A strong interest in research in physics and engineering, with good analytical and learning ability

Complementary information :

- ~640 €/month
- International and dynamic work environment
- Duration 5-6 months
- Expected start date between February 2025 - April 2025

Your application :

Send a CV and motivation letter as why this internship is made for you at mail addresses: olivier.bernal@toulouse-inp.fr and han-cheng.seat@toulouse-inp.fr

[1] Simonsen, A., Sánchez-Heredia, J.D., Saarinen, S.A. et al. Magnetic resonance imaging with optical preamplification and detection. Sci Rep 9, 18173 (2019)

[2] Densmore, Adam & Janz, S. & Ma, Rubin & Schmid, Jens & Xu, DanXia & Delâge, André & Lapointe, Jean & Vachon, Martin & Cheben, Pavel. (2009). Compact and low power thermo-optic switch using folded silicon waveguides. Optics express. 17. 10457-65. 10.1364/OE.17.010457.

[3] SungWon Chung, Makoto Nakai, and Hossein Hashemi, "Low-power thermo-optic silicon modulator for large-scale photonic integrated systems," Opt. Express 27, 13430-13459 (2019)

[4] Georgios Sinatkas, Thomas Christopoulos, Odysseas Tsilipakos, *and* Emmanouil E. Kriezis , "Electro-optic modulation in integrated photonics", Journal of Applied Physics 130, 010901 (2021) https://doi.org/10.1063/5.0048712