Job offer – PhD in Photonics

Research Project Short Title as Submitted to CEFIPRA: "Whispering gallery modes microsphere visible light sources based on single quantum emitters (MASALA-Q)"
Principal Investigator contact: "Prof. Stéphane Trebaol, stephane.trebaol@univ-rennes.fr**",** University of Rennes
Reference Number of the Job Offer: IFI_CEF_24_03

Project description

- **Keywords :** High-Q microresonator, rare-earth ions, single photon source, laser, visible light, cavity quantum electrodynamics

- **Context:**

  Nowadays, lasers are essential elements for the development of compact photonic devices. They offer the opportunity of combining good performances in terms of linewidth, optical power and frequency noise. The implementation of such lasers with low-frequency noise at visible wavelengths covering the near-ultraviolet to infrared spectral range is a technological challenge recently addressed by several research groups. The objective is to provide lasers capable of meeting several application requirements in the fields of classical and quantum sensors and the metrology of optical frequencies for the production of compact optical clocks. Indeed, such clocks require the use of narrow-spectrum and low-frequency noise lasers at visible wavelengths for cooling, capturing and manipulating atoms or ions.

  The objective of the project is to follow up the early stage of lab-to-market technology transfer of integrated atomic clock and quantum optics for which, compact room temperature coherent photonic sources is still lacking.

  - **Abstract of the Research Project:**

  Footprint reduction of quantum photonic components relies on the availability of integrated narrow-linewidth lasers and efficient room temperature single photon sources.
  An ideal quantum system should address simultaneously narrow optical transitions and long spin coherence time. Various solid-state qubits optically addressable have been studied within the last decade; such as semiconductor quantum dots, colour centres and rare-earth ions. The main difficulties to reach robust room temperature single photon sources lies in the weak fluorescence emission for quantum emitters. To overcome this, one solution consists in introducing quantum emitters in a high finesse optical resonator to enhance the spontaneous emission rate. Microresonators, thanks to their high-Q factor and small mode volume, have been identified as model systems to study cavity quantum electrodynamics (CQED) phenomena and narrow-linewidth and low threshold laser emission. Microsphere resonators are simple photonics objects easy to fabricate and customable in term of doping medium, host matrix, size and shape. This makes microspheres a model system to study various light emission configurations. Rare earth doped microsphere resonators have demonstrated their ability to produce optical memories and laser emission in the visible range by using the up conversion effect. Meanwhile, the recent availability of efficient GaN laser diodes has pushed forward the development of rare-earth doped lasers at visible wavelengths. To date such direct in band-pumping scheme has not been reported yet in microresonators either for laser emission observation nor single photon source demonstration at visible wavelengths.

[Maurice2020] Maurice et al., Optics Express 28 (17), 24708-24720 (2020) **[Xia2022]** Xia et al., Optica 9 (4), 445-450 (2022)
[Atature2018] Atature et al., Nature Reviews Materials 3, 38-51 (2018) **[Zhong2018]** Zhong et al., Phys. Rev. Lett., 121 183603 (2018) **[Huet2016]** Huet et al., Phys. Rev. Lett. 16 (13), 133902 (2016)

- **Scientific Objectives of the Project:**

  We propose to develop **compact whispering gallery modes (WGM) microsphere visible light sources based on single quantum emitters.** In particular, the PhD student will contribute to study the optical properties at visible wavelengths of rare earth ions incorporated into high-Q and high finesse microsphere resonators. Fluorescence measurement and laser emission will be implemented in WGM microspheres doped with rare earth ions emitting at visible wavelengths like Erbium, Praseodymium, Dysprosium to only name a few. Various materials will be involved like polymer, silicate and fluoride glasses to determine the optimal host matrix.

  The Masala-Q project is unique opportunity to bring together complementary skills and know-hows of the two partners, International School of Photonics (CUSAT-India) and Foton Institute (CNRS-France), to reach the demonstration of **targeted milestones: (i) a sub-kHz linewidth and tens of mW visible light fiber laser (ii) a kHz linewidth visible light microsphere laser with sub µW threshold and (ii) a room temperature single photon source.**

- **Methodology and Timeline of the Project:**

  The partners have well-balanced contributions to the project. Indeed, CUSAT will mainly contribute to the fabrication and characterization of doped fibers with various doping concentrations to address both lasing and single photon emission. Foton Institute will be mainly devoted to the fabrication, the design and the characterization of optical microresonators based on fiber samples develop by CUSAT. Foton Institute will focus on the optical cavity and gain properties characterization of fabricated resonators to demonstrate lasing effect. The PhD will have the opportunity to visit Indian partners (CUSAT) to share knowledges in particular on the fiber sample fabrication.

  The project is organized in 3 workpackages, the PhD student will be involved on the tasks listed below:

  1/ Visible light sources design (T0 at T0+36)

  2/ Microsphere fabrication (T0 at T0+36)

  3/ Microsphere characterization (T0 at T0+36)
  Q-factor, coupling regime and finesse characterization in passive and active resonators

  4/ Narrow linewidth and low threshold microsphere laser (T0+12 at T0+24)

  5/ Room temperature single photon source (T0+24 at T0+36)

  6/ Results disseminations: articles in peer-reviewed journals, communications in international conferences, PhD thesis (T0+12 at T0+36)

FOTON Institute will collaborate through this project with national (Exail, Le Verre fluoré, Photonics Bretagne) and international partners (University of Kochi – CUSAT-, India).

Candidate profile

- Only Indian candidates or candidates with a research experience in India are eligible; French candidates are not eligible
- Applicants for PhD must have a master's degree (or be in the process of obtaining one) or have a University degree equivalent to a European Master's (5-year duration) to be eligible at the time of the deadline of the call;
- No competences in French language is required

- Candidate competences: Laser physics, optical fibers, optical resonators, non-linear optics, numerical simulations. Good communication skills in English are required.
- Candidate know-how: Laser characterization, instrumentation (relative intensity noise and frequency noise measurements), control or servo-loop. The ideal profile would combine interest for experimental work and, in a second place, for modelling and simulation work.
- Expected starting date: **Between 01-09-2024 and 01-11-2024**

How to candidate ?

Documents to be provided :

i. A cover letter (reasons for the candidature, professional project …) max 2 pages
ii. A copy of the master's degree or a proof of the program followed (and expected date of end) OR A copy of the PhD degree or a proof of the PhD program followed (and expected date of defense) max 1 page
iii. A copy of results for previous scholarship (max 3 pages)
iv. International curriculum vitae (max 2 pages)
v. Two letters of recommendation: one from any Indian institution and one from the French institution planned to host the candidate –mandatory- (max 2 pages)
vi. All should be submitted within 1 pdf file of no more than 10 pages.

Applications should be submitted to the following email address: msi@ifindia.in mentioning the reference number of the Job offer clearly.

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Candidates are requested to contact the French scientific principal investigator of the project before submission. A recommendation letter from the scientific principal investigator is mandatory.

Benefits:

- Monthly allowance of 1710 euros for PhD
- Travel allowance
- University fee
- Carte de séjour fee
- Campus France management fee
- Registration to the French social security scheme
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Selection process:

Selection is made by a dedicated selection committee of at least 4 persons. Decisions will be transmitted by the Embassy of France to CEFIPRA. **No consideration will be given for candidates with no recommendation letter from the French institution.**

Criteria for applicants' selection:

Academic excellence

- Excellence of the Academic background, Academic records, Honors, Letters of support, Participation to international research projects, exchange programmes and conferences.

Motivation and qualities

- Academic maturity: appropriation of the thesis project (stakes and contexts) • Quality of the presentation (oral expression, skills for synthesis, English level) • Maturity of the professional project: capacity to project her/himself within five years in terms of career development.

About CEFIPRA:
Indo-French Center for the Promotion of Advanced Research (CEFIPRA/IFCPAR) is an Indian body which promotes scientific cooperation between France and India in advanced fields of Science and Technology. It is supported by the Department of Science and Technology, Government of India and the Ministry of Europe and Foreign Affairs of the French government.