PROJECT SOLITER (English)

Development of a bright ion source based on ionic liquids containing rare earth elements.

Context and objectives: This project is part of the CICLOP joint laboratory, involving CIMAP in Caen and Orsay Physics TESCAN in Fuveau. It aims to produce a high-brilliance source of rare-earth ions (La3+, Nd3+, Er3+) for focusing beams to nanometer points. The source will implant RE ions in crystals like LiF or YAG, creating color centers from interactions with crystal defects [1]. These centers can be optimized for optical sensors, solid-state lasers, nanostructures like phosphors and LEDs, optical waveguides, and quantum computing applications (Qbits) [3].

State of the art: Liquid Alloy Ion Sources (LAIS) achieve 10 nm implantation accuracy but struggle with rare-earth ions due to low solubility, ionization efficiency, and oxidation [4]. Alternatives like laser ablation and confined plasma (ECRIS) have a modest resolution of several micrometers, requiring nanometric masks for precision [2], complicating CC production.

Positioning: LAIS sources utilize a metal needle wet by a liquid metal as the emitting tip. Sources employing similar principles but using ionic liquids (LI) or molten salts (SF) instead of liquid metal, have been previously studied and validated [5,6]. The innovation involves using LI or SF containing rare earths to generate a TR ion beam. Additionally, the metal tip is substituted with a hand-stretched conical glass capillary. The liquid fills the capillary tip up to its micro-metric orifice, ensuring good electrical conductance and enhanced brilliance.

Thesis Work: The first objective is to provide a proof-of-concept for a source capable of producing a stable TR ion beam over several hours, with a V/I curve characteristic of a LAIS, using at least one of the two configurations (LI/SF).

The first part of the thesis will focus on the bibliographic and experimental study of LI and SF containing TR to identify promising candidates. Specifically, the physical properties (conductivity, viscosity, wetting character, etc.) of LI and SF containing TR under secondary vacuum conditions will be measured, as there is no existing data available in the literature. Concurrently, the phenomenon of ion emission from an electrified liquid will be examined. The process of ion evaporation by electric field will be modeled and simulated using the SIMUL team's numerical codes.

A conical capillary will then be attached to the source body filled with salt or LI. The body will be mounted on the source head, which controls the imposed potential and heating current, and then the head will be screwed onto the vacuum chamber. A slight overpressure will inject the SF or LI into the capillary until a droplet forms at its tip, observed in real time by camera. An electric field will transform this droplet into a Taylor cone with a half-angle of 49°, emitting TR ions by field evaporation from the nanoscale meniscus. A slight overpressure will prevent the salt from retracting. Subsequently, the extraction system will be configured, the capillary tip geometry optimized, the SF or LI temperature adjusted, and the correct overpressure found for stable emission. Furthermore, the TR source will be installed and mounted on a filtered Focused Ion Beam (FIB) column from Orsay-Physics to determine the beam composition (emitted species) as well as the lateral resolution of the TR beam by imaging a sample.

Previous experience: The thesis topic is an original and innovative project with controlled risks, since the existing experimental set-up has already been validated by a preliminary study. Subject in collaboration with Orsay Physics TESCAN

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Références :

[1] Kolesov, R., Xia, K., Reuter, R. *et al.* « Optical detection of a single rare-earth ion in a crystal.” *Nat Commun* **3**, 1029 (2012). https://doi.org/10.1038/ncomms2034

[2] T. Kornher *et al.*, “Production yield of rare-earth ions implanted into an optical”, *Appl. Phys. Lett.* 108, 053108 (2016), https://doi.org/10.1063/1.4941403

[3] Siyushev, P., Xia, K., Reuter, R. *et al.* « Coherent properties of single rare-earth spin qubits”. *Nat Commun* **5**, 3895 (2014). https://doi.org/10.1038/ncomms4895

[4] Th. Ganetsos et al., “Characteristics of erbium-ions-producing liquid metal ions sources”, Physica B: Condensed Matter, Vol 340–342 (2003), p. 1166-1170

[5] Paulo Lozano, Manuel Martínez-Sánchez, Journal of Colloid and Interface Science 282 (2005) 415–421 , “Ionic liquid ion sources: characterization of externally wetted emitters”

[6] M. Léger, E. Giglio, S. Guillous et A. Houel, “Molten salt ion source using glass capillaries as emitter”, submitted to Journal of vacuum science and technology B, ArXiv:2412.09374v1