COLLEGE DOCTORAL PAYS DE LA LOIRE | ED MATIERE MOLECULES MATERIAUX & GEOSCIENCES

DESCRIPTION OF A THESIS PROJECT
DOCTORAL SCHOOL "Matter, Molecules, Materials & Geosciences"

Title of the thesis: Study of a TOF device coupled to a laser desorption source with laser resonant post-ionization for ultra-trace quantification of isotopes for environmental and medical applications.
Principal disciplinary field: Subatomic Physics and Instrumentation **Disciplinary field 2:**
Three keywords: isotopic separation; laser ionization; instrumentation
Research unit (specify if the research time is shared between several sites): SUBATECH laboratory (Joint Research Unit UMR 6457)
Indicate if the thesis will be subjected to a labeling by one of the Graduate Programmes of Nantes University: ☐ **Light, Molecules, Matter (LUMOMAT)** ☐ **Earth and Planetary Sciences (EPS)** ☐ **Innovative Materials and Energy systems (E-Mat)**

FUNDING OF THE THESIS

Origin(s) of the funding: ☐ **University** ☒ **CNRS** ☐ **ANR** ☐ **International co-supervision** ☐ **other:** *specify*
Funding status: ☒ **acquired** ☐ **demand in progress** *(indicate the expected date of answer)*
PhD employer: CNRS
Gross monthly salary: 2135 € *From 01/01/2024, the minimum gross salary set by the Ministry of Higher Education, Research and Innovation is €2100 per month.*
Starting date: October 01, 2024 *Funding for the thesis covers a period of 3 years starting from the date of the first registration.*

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SCIENTIFIC DESCRIPTION OF THE PROJECT

Context, objectives, methodology (1 page maximum)

The SMILES project (Mass Spectrometry Coupled with Laser Ionization for Applications in the Environment and Health) aims to develop instrumentation based on the coupling of laser ionization to mass separation in order to quantify, separate and purify isotopes for environmental and nuclear medicine applications. While laser ionization is selective according to atomic number, the application of an electromagnetic field separates isotopes according to their mass. This technique therefore makes it possible to isolate an isotope with a high degree of selectivity while avoiding its isobars. The experiments in the SUBATECH laboratory will involve stable isotopes or radioisotopes with very low activity at the ultra-trace scale.

An initial list of isotopes of interest was determined in order to constrain the design of the device. These include the isotopes of radium, uranium and plutonium, whose isotope ratios in the environment are important indicators of human activity in the nuclear industry. Copper is also considered, where the quantification or separation of its isotopes could be of interest for both environmental applications (pair of stable copper isotopes Cu 63 / Cu 65) and medical applications (via Cu 64 and Cu 67).

Two devices are to be designed: the first based on time-of-flight (TOF) separation using electrostatic acceleration, the second using an additional magnetic field to collect the isotopes separately. Neutral atoms may be extracted from the source either by thermal or laser desorption, depending on the case. A resonant laser post-ionization device achieves the desired elemental selectivity. An initial thesis work on this project has already studied, modelized and designed a prototype TOF device with a laser desorption and resonant post-ionization source. This prototype is under construction and will be used to carry out the first experiments, which will be cross-referenced with the simulation results in order to specify the operating conditions and optimize the performance of the instrument on an ultra-trace scale. These initial experiments will be based on identified isotopes of interest.

The thesis work will therefore involve setting up mass separation experiments coupled to laser ionization on the isotopes of interest and studying the possible applications regarding the obtained instrument performance. These experiments will also be simulated using models already developed under SIMION ion optics software coupled with Matlab programs to optimize the parameters of the ion source and the beam line. These results will be used to define, design and build a reflectron type TOF, more selective, on which experiments will be continued.

The main activities of the PhD student will therefore be:

- Simulate the transport of particles and the detection or collection of ions for the various devices using the SIMION software to obtain configurations that enable optimum experimental conditions to be achieved for ultra-trace quantification (detection efficiency, spatial and temporal resolutions, …).
- Participate to the construction of the devices, including acquisition systems.
- Carry out comparative tests on devices in the laboratory by defining and conducting experiments on copper isotopes for applications in the environment and nuclear medicine.
- Analyse data to interpret results and compare with simulations.
- Write articles and give presentations.

The PhD student will work in the PRISMA (Physics of Radiation Interaction with Matter and Applications) team, which carries out fundamental and applied research into the interaction of radiation and particles with matter. This interdisciplinary research focuses on 3 areas with a high societal impact: the production of innovative radionuclides for diagnosis and therapy, the elementary and non-destructive analysis of materials and structures and dosimetry studies for radiobiology and unconventional radiotherapy. The PhD student will benefit from a rich environment where several R&D projects are underway in these different areas, including the SMILES project.

Application, including names and email addresses of referees who can be contacted, should be submitted on https://emploi.cnrs.fr/Offres/Doctorant/UMR6457-ISAOLL-003/Default.aspx

Scientific and technical skills required:

- Master's degree in subatomic physics with an instrumental component or in laser physics
- Good knowledge of electromagnetism, laser physics or detector physics
- Knowledge of scientific programming language (Python and/or Matlab)
- Level of scientific and technical English B2 according to the Common European Framework of Reference for Languages
- Liking in test bench set-up and data analysis
- Thoroughness, good interpersonal skills at all levels, ability to listen and cooperate, ability to work as part of a team.

Language requirements:

- **English:**

  ☐ **N/A** ☐ **Basic** ☒ **Good** ☐ **Excellent** ☐ **Native language**

- **French:**

  ☐ **N/A** ☒ **Basic** ☐ **Good** ☐ **Excellent** ☐ **Native language**

MANAGEMENT OF THE THESIS PROJECT

A minimum supervision percentage of 40% must be allocated to the director of the thesis. A minimum supervision percentage of 30% must be allocated to the co-directors and/or co-supervisors. For more information, please consult the internal regulation of the doctoral school.

Name of the home research unit:	**Name of the research team:**
SUBATECH (UMR 6457)	PRISMA

Name of the research unit director:

MARTINEZ, Ginès, gines.martinez@subatech.in2p3.fr

Director of the thesis

Name, first name: METIVIER, Vincent

Function: Professor, IMT Atlantique

Date of obtaining HDR*: 2016

Research unit: SUBATECH

Supervision percentage in the project: 40%

Number of current directions, co-directions and co-supervisions: 3

Current total thesis supervisions percentage (directions, co-directions and co-supervisions): 120%

**HDR = French Ability to Supervise a PhD*

Co-supervisor 1 ***(if applicable)***

Name, first name: MICHEL, Nathalie

Function: Research Engineer at Nantes Univerity

HDR holder: ☐yes ☒ no If yes, date of obtaining:

Research unit (or private company): SUBATECH

Supervision percentage in the project: 30%

Number of current directions, co-directions and co-supervisions: 1

Current total thesis supervisions percentage (directions, co-directions and co-supervisions): 30%

Co-supervisor 2

Name, first name: PISCITELLI, Anne

Function: Research Engineer at CNRS

HDR holder: ☐yes ☒ no If yes, date of obtaining:

Research unit and location (or private company): SUBATECH

Supervision percentage in the project: 30%

Number of current directions, co-directions and co-supervisions in belonging ED: 0

Current total thesis supervisions percentage (directions, co-directions and co-supervisions): 0