Laser Ionisation and Spectroscopy of Actinides
Overview of the innovative training network

Bruce Marsh, CERN

ISOLDE Workshop and User Meeting - 5th December 2019

“YOU CANNOT HOPE TO BUILD A BETTER WORLD WITHOUT IMPROVING THE INDIVIDUALS.”
MARIE SKŁODOWSKA-CURIE
“Aim to train a new generation of creative, entrepreneurial and innovative early-stage researchers, able to face current and future challenges and to convert knowledge and ideas into products and services for economic and social benefit.”
RESIST aimed to refine the highly successful Resonance Ionization Laser Ion Source (RILIS), the In-Gas Laser Ionization and Spectroscopy (IGLIS) and Laser Ion Source Trap (LIST) technologies. The goal was to provide RIBs of the highest purity for both ISOL and In-Flight facilities. The JRA proceeds according to plan, with milestones achieved ahead of time. *Articles have been published within the ENSAR2 period by individual participants and further are planned combining several RESIST institutes. Innovation links have been provided to NUPIA (Nuclear Physics InnovAtion). No deviations have occurred from the proposed plan.
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LIONESS (Lasers, IOns and Nuclei for Environmental Science and Society) was a proposed JRA focused on the development of state-of-the-art laser-based techniques and their application in environmental-based science in the actinide and lanthanide elements. These activities will strengthen the links between basic radioactive ion beam research and societal applications at the Transnational Access Facilities, and beyond. 9 scientific partners, 5 tasks.
Marie Skłodowska-Curie Actions

Laser Ionisation and Spectroscopy of Actinides

- **CERN**-hosted Marie-Curie ITN
- **12** beneficiaries
- **13** partner organisations
- **15** Early Stage Researchers (PhD positions)
- Starting in **November 2019**
- Duration of **48 Months**

LISA ITN Kick-off Meeting

- **Monday 2 Dec 2019, 10:00 → 22:00** Europe/Zurich
- **513/1-024 (CERN)**
- **Bruce Marsh (CERN)**, **Thomas Elias Cocolios (KU Leuven - IKS)**

[https://indico.cern.ch/event/851894/](https://indico.cern.ch/event/851894/)
Training Office

Prepare the community for the operation and use of the next generation of ISOL facilities that are on the horizon. Contribute to the future-proofing of nuclear and atomic physics expertise.

**NUPECC Long range plan Recommendations:**

“Exploitation of European Facilities for the training of the next generation nuclear scientists Preference for inter-sectorial aspects and exploitation of nuclear applications”
Research objectives

What? Increase our understanding of the atomic and nuclear properties of the chemical elements known as the actinides

What are the limits of stability and what is the heaviest element?
How does nuclear structure evolve across the nuclear landscape?

Why?

- Effective production, identification and handling of these elements
- Exploiting the potential for practical applications of the actinides in the fields of medical physics, nuclear applications and environmental monitoring
- Prerequisite for unravelling the structure of the superheavy elements

Who? World-leading experts in radioactive ion beam research and applications, laser spectroscopy, scientific laser technologies (industrial partners) and nuclear and atomic theorists

How? 4 Scientific Work Packages

- Novel techniques and technologies
- Medical & societal benefits
- Actinide atomic structure
- Exploring the limits of nuclear existence
Table 1.1: The technical WPs (2 training objectives of LISA, as shown in LISA will be structured into Research methodology and approach for extraction of their atomic and nuclear structure. Our research objectives are This will be supported by improvements to our theoretical and computational approaches for the understanding and continue the recent momentum in this novel methods and instrumentation to overcome the various technical challenges for actinide research, LISA will research facilities and most interdisciplinary training network hosting Led by several of the most accomplished researchers in this field, LISA aims to build upon this existing expertise, intensify the collaborative efforts, and focus our attention on the actin elements and beyond. Figure 1.2 shows the extent of the existing knowledge and what could be achieved by combining activity, within ENSAR2, Horizon2020, and the LA3NET and IGLIS international networks. The LISA consortium EU framework programs, for example the RESIST (RESonance Ionization techniques) developing the aforementioned methodologies Traditionally, European scienti...
Beneficiaries + Partners
The 15 Researchers

<table>
<thead>
<tr>
<th>ESR #</th>
<th>Recruiting Participant</th>
<th>PhD awarding entity / Doctoral School</th>
<th>Start</th>
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## The ESR Projects

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New techniques and production methods

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## Atomic and nuclear theory

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Practical applications

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Each ESR will perform a secondment to stimulate both their research and mobility. They will be involved in projects at a partner organisation, either an academic, industrial, or research organisation. The specific details are given for each ESR in Table 3.1d and a global overview is provided in Section 2.4.

The network has been extensive in terms of the number of participating organisations and the duration of the mobility periods. Half of the secondments are within the LISA consortium, but the others have been either within the broader community or to other ETNs. The secondments are also the opportunity to explore new, critical research areas and to build new research partnerships.

The beneficiaries and partners include those from the LISA consortium, as well as many other organisations. They will greatly benefit from the ESRs and Visiting Researchers through their contributions to the R&D program. The network has been crucial in providing new synergies between participating organisations, with many of the references provided in this document.

Figure 1.6 shows the many interactions crossing each other within the network. The secondments have been made during General Training and will benefit both the researchers and the host organisations. They will share this experience with the other ESRs and the wider community.

The secondments are also the opportunity to explore new research areas and to build new research partnerships. They will contribute to the R&D program of their respective organisations and will greatly benefit from the ESRs and Visiting Researchers through their contribution. The network has been crucial in providing new synergies between participating organisations, with many of the references provided in this document. To a wide extent they lead the way to new and exciting research areas, and they will greatly benefit from the ESRs and Visiting Researchers through their contribution to the R&D program.
Industrial participation for state of the art laser development

ADVANCED RESEARCH PLATFORMS

SOLSTIS
MODULAR DESIGN
210 nm - 4 μm
C-WAVE | THE TUNABLE CW LASER LIGHT SOURCE
Tunable frequency-converted cw optical parametric oscillator (OPO)

LISA-ITN | ESR (#15) PROJECT
Development of a solid-state tunable CW laser based on HUB’s existing C-WAVE concept with customized linewidth options and enhanced output power levels, optimized for actinide research.

- Comparison and investigation of different linewidth customization concepts for tunable CW lasers
- Production & validation of customized linewidth OPO prototype
- Investigation of cavity designs for enhanced power levels
- Test C-WAVE system with pulsed dye amplifier by Liop-Tec (Dr. Jürgen Lindener-Roenneke, Liop-Tec GmbH)
- Production & validation of a high power OPO prototype with customized linewidth option
- Implementation and validation of the outcomes at the CERN-ISOLDE facility (Bruce A. Marsh, CERN)
Part B

3.2. It is organized in different modules as listed in Table 1.2b. The network overview and how documentary students are described in Table 3.1d. A general table of recruitments in the network is shown in Table 1.2a whilst the individual research projects for the 15 partners have been defined as having high quality standards in their research fields in the past as evidenced by the high reference publications. The partners are at the forefront of the study of the actinide elements and have a long-standing collaboration with many beneficiaries and partner organisations in academia, world leading universities, and large industries, all of whom already share a fruitful and amicable joint working relationship. We expect that the LISA network will solidify the team spirit and increase its impact, and therefore ideally equipped for the task of delivering doctorates, with high level of employability as we focus our activities world wide. Our fundamental atomic and nuclear physics research on the actinide elements is not only an essential technological challenge related to laser spectroscopy and the actinides for societal benefit, but also has implications in the study or understanding of the region of superheavy elements under the current NuclearAssigned Limit (NAL). The LISA network provides the trainees a unique opportunity to work in a high quality training environment, with access to a full range of cutting edge research and industry facilities, thus making it a key feature of the LISA network and will be implemented across many beneficiaries and partner organisations. The LISA ITN will offer a training environment closely aligned with the work and topics covered within the LISA research objectives necessitating a close collaboration of the various concerned sectors. From the perspective of an ESR trainee joining this collaboration, this will be a highly motivational and supportive environment for the completion of their PhD enrolment and as such a substantial part of the European expertise on actinide spectroscopy methods for studying rare isotopes. The consortium is envisaged to build upon the existing collaboration structure whilst being able to guarantee comprehensive and high impact cooperation

Outreach, dissemination, and communication

Secondments

Originality and innovative aspects of the research program

Secondments

Quality and innovative aspects of the training programme

Figure 1.4: The LISA consortium beneficiary network (ETN) for example, to the aforementioned references 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23.
Address the lack of fundamental nuclear structure data in the actinide region

Research interplay example

Theory

Introduce and adapt the Hubner 'C-Wave' laser to improve the spectral coverage

Develop the pulse-amplified Ti:Sapphire laser into a commercial-grade product

Experiment

Laser technologies

New techniques

Applications
Research interplay example

Address the lack of fundamental nuclear structure data in the actinide region
Probe Octopole deformation in Th and U

direct impact on the validation and further development of atomic and nuclear models

High resolution laser spectroscopy of actinides

Introduce and adapt the Hubner 'C-Wave' laser to improve the spectral coverage
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Gas jet spectroscopy development
High resolution In-source RIS
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High resolution In-source RIS
Recruitment starts next week!
https://lisa-itn.web.cern.ch (coming soon)