PhD offer
Phononic Skyrmions for Waves Structuration

PhD project

Skyrmion, a topologically stable three-component vector field, was initially developed in elementary particles and has since been demonstrated in condensed-matter systems [1] and helimagnetic materials [2]. Characterized by a real-space nontrivial topological number, the skyrmions were considered as a promising route toward high-density magnetic materials for information storage and transfer [2], due to their defect immunity and low driven energy. Such topological skyrmions have been recently extended to photonics based on dynamic electromagnetic fields with axial evanescent waves [3] and spin-orbit coupling in the evanescent fields. In 2023, our group in Institut Jean Lamour (University of Lorraine and CNRS), who is proposing the PhD project, demonstrated, for the first time, theoretically and experimentally the existence of phononic skyrmions [4]. This remarkable scientific breakthrough is extremely promising on both fundamental and engineering aspects. Indeed, phononic skyrmions could lead to transformative phononic applications, especially in a generally concise configuration that can be scaled accordingly for future integrated on-chip, acoustofluidics and lab-on chip technologies.

The main objective of this PhD project is to structure acoustic and elastic waves in an unprecedented way. To do that, we will use the spin of elastic and acoustic waves and the generation of related skyrmions as an extra degree of freedom. The methodology will consist in exploring, conceiving, simulating and realizing a new class of multiphysical metamaterial capable of extreme manipulation and structuration of acoustic and elastic waves using their spin angular momentum.

More in details, we would like to explore the underlying physics of these topological structures, phononic skyrmions, and how they can introduce a transformative approach for some specific applications. More specifically we aim to:

1. Tackle the three-dimensional spin states for manipulation of topological phonons and the exploration of new (high) topological orders.
2. Realize novel topological phononic materials in different scales from macro to micro.
3. Generate controllable dynamic skymions.
4. Put forward the use of phononic skyrmions for acoustofluidics to deal, for example, with particles/cells manipulation applications, advanced acoustic tweezers, and biomedical testing.

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Constraints and risks

The position you are applying for is located in a sector relating to the protection of scientific and technical potential. It therefore requires, in accordance with the regulations, that your arrival be authorized by the competent authority of the Ministry of Higher Education, Research and Innovation.

About Institut Jean Lamour

The Institute Jean Lamour (IJL) is a joint research unit of CNRS and University of Lorraine. Focused on materials and processes science and engineering, it covers: materials, metallurgy, plasmas, surfaces, metamaterials, nanomaterials and electronics. It regroups 183 researchers/lecturers, 91 engineers/technicians/administrative staff, 150 doctoral students and 25 post-doctoral fellows. Partnerships exist with 150 companies and our research groups collaborate with more than 30 countries throughout the world. Its exceptional instrumental platforms are spread over 4 sites; the main one is located on Artem campus in Nancy.

Requirement and candidate profile

We are looking for a brilliant PhD candidate for a PhD project on phononics and metamaterials, and specifically on Phononic Skyrmions. Our group at the Institut Jean Lamour (IJL), Institution belonging to the University of Lorraine and CNRS, develops since many years state of the art researches on acoustic and elastic metamaterials, metasurfaces and phononics. If you like scientific challenges, working and evolving in very dynamic group and institute, having a solid background in wave physics and engineering, this position is for you. The applicants should have:

- Master degree in one of these specialties: acoustics, applied physics, material physics, wave physics, mechanical engineering …

Application

To apply and to get more information and details about this position, please email **Prof. Badreddine Assouar** (badreddine.assouar@univ-lorraine.fr) and **Dr. Aurélien Merkel** (aurélien.merkel@univ-lorraine.fr) with the following documents:

- **CV, motivation letter, the marks of the Master and a copy of your ID.**
- Deadline of application: April 30, 2024. Thesis to start on October 2024.

References

1. U. AlKawaja et al, Skyrmions in a ferromagnetic Bose–Einstein condensate. Nature 411, 918-920 (2001).
2. N. Romming, C. Hanneken, M. Menzel, J. E. Bickel, B. Wolter, K. v. Bergmann, A. Kubetzka, R. Wiesendanger, Writing and Deleting Single Magnetic Skyrmions. Science 341, 636-639 (2013).
3. L. Du, A. Yang, A. V. Zayats, X. Yuan, Deep-subwavelength features of photonic skyrmions in a confined electromagnetic field with orbital angular momentum. Nature Physics 15, 650-654 (2019).
4. L. Cao, S. Wan, Y. Zeng, Y. Zhu & M. B. Assouar. Observation of Phononic Skyrmions based on Hybrid Spin of Elastic Waves. Science Advances 9, eadf3652 (2023).