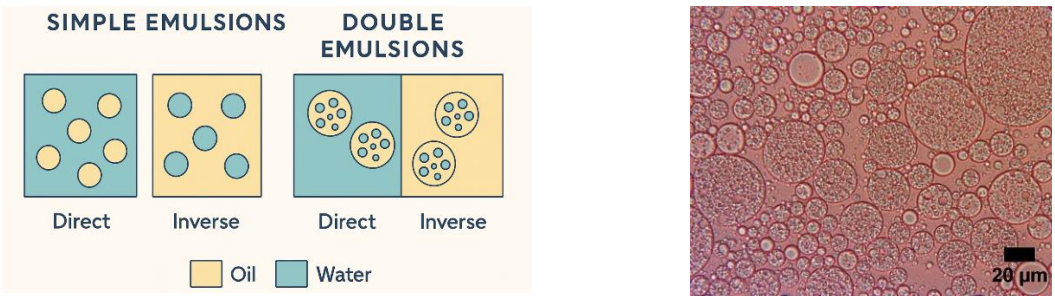
Master Internship

Advanced NMR and MRI methods for the characterization of emulsions

A multiple emulsion is a colloidal system where droplets of a primary emulsion (such as water-in-oil) are dispersed in another continuous phase, forming water-in-oil-in-water (W/O/W) or oil-in-water-in-oil (O/W/O) structures, Fig. 1. These emulsions are used in controlled drug delivery, the food industry (for encapsulating flavors and nutrients), and industrial applications such as pesticide release and alternative fuel formulation. However, large-scale development requires improvements to ensure long-term stability and controlled release of active ingredients. Stability depends on droplet size and the manufacturing process, and NMR techniques, particularly pulsed field gradient NMR, offer a non-invasive method to characterize emulsions, measuring droplet size distribution and molecular transfer between phases.



(a) (b)

Fig. 1 – (a) Simple and double emulsions. (b) Microscopic picture of a multiple emulsion, Stasse *et al.* 2020.

Double emulsions, such as water-in-oil-in-water, are produced in two stages, with the second stage—dispersing the primary emulsion into the external phase—being the most challenging, as it requires controlled shear to form stable droplets without leakage, making both formulation and processing critical for stability and encapsulation efficiency.

The long-term objective of the present project is to develop, instrument and parameterize a device and a methodology for monitoring the multiple emulsion manufacturing process by MRI, in particular the second stage of the process.

Encouraging preliminary results have recently been obtained for simple direct emulsions, showing qualitative agreement on average droplet sizes. However, detailed comparison of size distributions has revealed the need to continue working on improving the NMR measurement methodology.

The internship will continue the work, focusing on the methodology for NMR and MRI measurements:

- First, reverse water in oil emulsions with varying compositions and droplet sizes will be prepared at LRGP, then multiple emulsions will be fabricated. These emulsions will then be characterized using multiple techniques, including conductimetry, microscopy, laser granolumetry (LDS), and rheometry, on LRGP's experimental platforms.
- Next, the emulsions will be analyzed under static conditions at LEMTA using NMR techniques described in the literature, particularly pulsed field gradient (PFG) NMR, to accurately measure droplet size and identify key measurable parameters. The NMR results will be compared with data from other characterization techniques to ensure reliability.
- Finally, the methods will be extended to flowing emulsions using MRI velocimetry, aiming to determine the same representative parameters as in static conditions.

The internship will take place at the University of Lorraine (60,000 students) in Nancy, within two research laboratories LEMTA and LRGP.

The LEMTA (Laboratoire Énergies & Mécanique Théorique et Appliquée) has about 200 staff, including 80 professors and researchers, and specializes in heat transfer, fluid mechanics, and materials science, with applications in energy and complex systems engineering. The internship will take place within the "MRI for Engineering" team of LEMTA.

The LRGP (Laboratoire Réactions et Génie des Procédés) specializes in chemical and biological reaction engineering, as well as the modelling and optimization of processes for energy, environment, and industry, with over 300 staff members, including 100 professors and researchers. The intern will join the Product Engineering team, which focuses on the formulation, characterization, and modelling of complex fluids, such as emulsions.

The internship will start between January and March 2026 and last 6 months with a gratification of €670 per month. The estimated cost of living in Nancy (including accommodation, food, and social security) is around €900 per month.

Nancy (population 300,000, including 40,000 students) is a vibrant university city in eastern France, renowned for its Art Nouveau heritage and located just 1 hour 30 minutes from Paris by train.

To apply for the internship, send your CV and cover letter to

jean-christophe.perrin@univ-lorraine.fr

cecile.lemaitre@univ-lorraine.fr

Candidates will be good students of engineering or basic science (chemical engineering, energy, physics, fluid mechanics, chemistry, biology, etc.) with an interest in spectroscopic methods such as NMR and image analysis. The candidate should be comfortable both with experiments and modelling. Skills of signal processing and programming would be highly appreciated.