Title: A novel needle-free injection method based on controlling interfacial flows of complex fluids

Keywords: Interfacial flows, Complex flows, Fluid mechanics, Non-Newtonian fluids, Multiphase flows

Main tasks and skills required:

- The student needs to be familiar with fluid mechanics concepts.
- The student needs to be willing to perform laboratory experiments.
- The student needs to be hard-working person and be passionate about research.

Abstract of the research project: While needles and syringes are among the common methods to administer vaccines and dermatological medications, they suffer from numerous disadvantages, including unsafe practices, exposure to infections, needle phobia, lack of reusability, and disposal and environmental problems. A safe alternative to deliver vaccines and other immunological products is the needle-free injection method (NFIM), using a high-velocity liquid jet created via a laser pulse exciting the injection drug fluid. Major limitations of this method are severe pain, penetration depth variability, skin hole size variability, skin irritation, etc. Many of these limitations have roots in the jet flow dynamics and they are caused by undesirable jet dispersion, jet widening, jet flow instabilities (e.g. droplet formation), atomization or spray, jet tip deformation, splash, inhomogeneous penetration into skin, etc. In this context, our interdisciplinary research project proposes to remove the aforementioned limitations of the NFIMs, via immersing the high-velocity liquid jet into a complex fluid, filling the space between the liquid drug and the skin (known as the stand-off). This high-risk approach may allow us to use a complex fluid to properly surround the jet, confining it to a stable cylindrical form that precisely/controllably penetrates into the skin target area, while reducing the jet widening and jet instabilities (break-ups); subsequently, the jet can reach the desired penetration depth, with a precise penetration width/shape. Our specific research objectives, achieved via an interdisciplinary approach, include: (i) examining the effects of filling the stand-off distance with complex fluids on the jet flow development, possibly stabilizing and controlling the jet; (ii) examining the subsequent penetration of the submerged jet into the skin multilayers; and (iii) analyzing the skin response to the jet penetration. These objectives will be achieved via novel experiments and mathematical modeling approaches, relying on the state-of-the-art research methods, while combining interdisciplinary knowledge from a wide range of disciplines, such as fluid mechanics, rheology, complex fluid mechanics, dermatology, drug delivery, etc.