LITHUANIAN ENERGY INSTITUTE

ADMISSION TO PHD STUDIES FOR THE YEAR 2026

DOCTORAL RESEARCH TOPIC:

Analysis and control of hydrodynamic flow structures for microfluidic device applications

RESEARCH FIELD:

Energetics and Power Engineering (T 006)

BRIEF DESCRIPTION OF RESEARCH TOPIC:

Microfluidic systems are innovative devices that enable the manipulation of extremely small quantities of liquids or particles using networks of narrow channels and flow-control components at the micro- or nanoscale. The design and practical application of devices such as microreactors, lab-on-a-chip, organ-on-a-chip, and microelectromechanical systems spans physics, biochemistry, and microsystems engineering. Application areas include analytical and diagnostic solutions that require precise reagent mixing, dosing, and flow control.

In these fields, the creation of integrated processes is significant, allowing reactions and product separation, as well as particle sorting and separation, to occur within the same microsystem—thereby optimizing workflows and increasing the level of automation. These technologies accelerate processes, reduce costs, and enable the development of low-volume, high-precision instruments used in the life sciences, pharmaceuticals, chemical engineering, analytical chemistry, environmental protection, and energy.

One of the key challenges in designing microfluidic systems is the accurate selection of operating parameters to achieve the desired flow effects. Because these systems are used for a wide range of tasks, it is essential to understand the fundamental relationships that link flow structure and control strategies with channel geometry and the rheological and interfacial properties of the fluid (or mixture). It is also important to assess how these factors influence particle motion, multiphase interactions, and their dependence on the principal dimensionless parameters and the specific geometry.

This work aims to reveal the regularities of flow dynamics at the microscale, to quantitatively relate geometric, rheological, and flow-control parameters to the resulting flow structures; to develop general regime and stability maps; and to prepare design guidelines for such systems applicable to a variety of microfluidic solutions. The focus will be on single-phase and two-phase systems with immiscible fluids, in which interfacial area and interactions between phases and with channel walls are critical. Particular attention will be paid to the behaviour of non-Newtonian fluids and suspensions, as their rheological properties often determine the efficiency of mixing, droplet formation, and particle manipulation.

The research will employ experimental and numerical methods. Microfluidic systems will be fabricated using advanced photolithography and soft-lithography techniques. An experimental analysis of flow structures will be conducted using a micro-flow visualization system and computational fluid dynamics software. Droplet formation and particle behaviour will be analysed using a high-speed camera and ImageJ software. Using these methods, studies will be conducted on the prediction of single- and two-phase flow dynamics, the evolution of mixing indices, pressure losses, droplet size and generation frequency stability, and transitions between regimes as a function of fluid properties and microfluidic system architecture, among other topics.

Within this theme, several topics may be selected, including but not limited to: (i) investigation of fluid mixing and separation of different phases efficiency in microreactor systems; (ii) investigation of the influence of fluid rheology on suspension formation and stability; (iii) investigation of parameters governing droplet formation and dynamics; and (iv) investigation of hydrodynamic particle control in microfluidic systems.

SCIENTIFIC SUPERVISOR:

Dr. Paulius Vilkinis
Laboratory of Heat-Equipment Research and Testing

Lithuanian Energy Institute
Breslaujos 3, 44403 Kaunas
Lithuania

Paulius.Vilkinis@lei.lt

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