University of Ljubljana
Faculty of Mechanical Engineering

Slovenian Research and Innovation Agency

Two-dimensional materials-based piezophotonic composites for tailor-made ultrasounds stimulation in biological systems (2D-UltraS)

❖ About the project and what we offer

Light-to-sound conversion has shed light on opportunities to integrate miniaturized photoacoustic (PA) devices, developing minimally invasive tools with high spatial precision for applications in life science. The PA process relies on an exceptionally fast thermoelastic effect, determined by absorbed laser fluence and material properties. We propose a **PhD project to extend photoacoustic research to emerging 2D layered materials beyond graphene**, known as transition metal dichalcogenides (**TMDCs**). This project aims to create innovative piezophotonic polymer composites with precise control over geometry, optical, and mechanical properties, enhancing photoacoustic responses. Monolayer TMDCs, such as MoS_2, exhibit strong excitonic absorption cross sections of about 10% compared to graphene's 2%, indicating exceptional light-matter interaction. This makes TMDCs a natural 2D candidate for photoacoustic applications, offering greater flexibility in realizing piezophotonic polymer composites and opening new perspectives in the field.

The PhD student will investigate the PA response of TMDCs-based polymer composites, learning experimental techniques to characterize ultrasound waves using **nanosecond and picosecond lasers, high-frequency sensors, and a fast pump-probe photography system**. The experimental work will be supported by a multiscale theoretical approach to optimize PA emitter design and unveil the interplay in the PA response between electronic, optical, and thermal properties. Subsequently, we aim to **implement high spatial precision piezophotonic tools (e.g. integrated on a lens or onto an optical fiber)** intended for novel biomedical applications. These applications encompass photoacoustic light modulation in imaging, manipulation of bioink or cells embedded in bioink, and in-vitro and in-vivo investigations on the effect of high-frequency PA waves on protein aggregates associated with neurological diseases.

To achieve these objectives, the student will benefit from a combination of complementary research expertise. At the **Faculty of Mechanical Engineering**, the activities of the principal investigator and project coordinator, Dr. Daniele Vella (Laboratory for Laser Techniques), will merge with those of another Slovenian research group at **Josef Stefan Institute**, specializing in synthesis (chemical and liquid phase exfoliation), characterization of 2D materials (optical absorption, Raman, photoluminescence and AFM) and integrated biophotonics. Additionally, a foreign collaborating group from Coimbra University, with expertise in photochemistry, biochemistry, and photoacoustic studies, will be involved. The candidate will work in a

multidisciplinary and dynamic environment at the Faculty of Mechanical Engineering and Jozef Stefan Institute, developing skills in **2D nanoflake synthesis, polymer composite realization, biomedical ultrasound characterization, and the creation of novel photoacoustic experimental platforms, including ultrasound interaction with biological systems**. The candidate will also have the opportunity to spend **three to six months at the Department of Chemistry at Coimbra University (prof. Carlos Serpa)** for in-depth studies on biological system interactions and in-vivo experiments.
In summary, we propose a challenging yet feasible PhD project considering the expertise of the scientific team involved. We expect the candidate to attain research maturity, capable of influencing decisions with mid-and long-term implications for their future.

For further information about the project please contact the project lead **Dr. Daniele Vella** (Daniele.Vella@fs.uni-lj.si) and the head of the laboratory **Prof. Matija Jezeršek** (Matija.Jezersek@fs.uni-lj.si).

❖ Applicant's requirements

***Position profile**:*

- *Master in applied physics, electrical/mechanical/biomedical engineering, nanotechnology, nanoscience, lasers, or a related field.*
- *Good English level, both written and spoken.*
- *Team working skills (highly important).*

***In addition, the following items are interesting**:*

- *Programming skills (Matlab, C++, Labview)*
- *Design and simulation (SolidWorks, Comsol, or Ansys).*
- *Experience with any of the above-mentioned characterization and experimental techniques.*
- *Experience with 2D materials.*
- *Experience in nanoscience/nanotechnology.*

❖ How to apply

The project is funded by the Slovenian and Innovation Research Agency. Interested candidates must submit their application in January-February (flexible date) 2024 to the email Daniele.Vella@fs.uni-lj.si and Matija.Jezersek@fs.uni-lj.si, including a presentation letter and a CV. Two recommendation letters are desirable. Candidates will be called for an online interview.

❖ Salary

The salary has been fixed in agreement with national standards for researchers with the experience requirements for the position. The salary in Slovenia includes basic health insurance, social security, and a pension plan. **Duration of the contract: 4 years.**