Topic specifications for MSc students					
Name of the subject (topic)	**Supervisor's name, e-mail address and department**	**Type of graduation** (diploma work, thesis) More types can be given!	**Short description (max. 1000 characters, including space)**	**Expected prior knowledge, language**	**Assumed number of students**
Simulation of strong-field high-average-power THz sources	**Vineet Gupta, József Fülöp,** Vineet.Gupta@eli-alps.hu Jozsef.Fulop@eli-alps.hu	MSc	The work focuses on the development of numerical simulation tools for the investigation of various effects influencing the performance of strong-field high-average-power terahertz (THz) sources, as well as performing simulations to optimize such sources.	basic optics, electrodynamics, programming	1
THz-driven electron source	**Ashutosh Sharma, József Fülöp,** Ashutosh.Sharma@eli-alps.hu; Jozsef.Fulop@eli-alps.hu	MSc	Terahertz (THz) radiation is considered as nonionizing because of photon energies orders of magnitude smaller than typical ionization energies. However, for extremely strong fields, the interaction with matter can be dramatically different. Terahertz-frequency fields with MV/cm field strengths can liberate bound electrons from materials. The work aims at the characterization of the emitted electron bunches and can include experimental and simulation work.	basic optics, electromagnetism	1
Theory and simulation of atoms and molecules interacting with strong laser fields	**Attila Czirják,** attila.czirjak@eli-alps.hu	MSc thesis	Our research group works on various projects in attosecond and strong-field physics. The MSc student is expected to have a strong background and interest in quantum physics, mathematics or numerical simulations. He/she will first receive a broad perspective and introduction into the research area and then choose to participate in one of our ongoing projects supported by a supervisor. Some of the current hot topics: supercomputer simulation of high-order harmonic generation with advenced atomic model potentials; theory of high-order harmonic generation with quantized field modes; quantum entanglement in strong-field physics; quantum tunneling in strong-field ionization.	Strong background in quantum physics, mathematics or numerical simulations.	1
Synthesis and optimization of B-C-N based 2D materials by NanoESCA endstation	**Dr. Óvári László** laszlo.ovari@eli-alps.hu ELI-ALPS	MSc (3 semesters)	Graphene, hexagonal boron-nitride and the BCN-based atomic layers are versatile two-dimensional (2D) materials uniquely combining electronic and structural properties. Due to their tunable band structures, BCN materials have potential applications in nanoelectronics, optoelectronics, and catalysis. The momentum microscope is based on a NanoESCA photoemission microscope comprising a PEEM column and a double hemispherical imaging energy analyzer. The relevant scientific fields include interfacial charge transfer, ultrafast demagnetisation, orbital tomography, (ultrafast) molecule-substrate interactions, ultrafast processes in topological insulators, band structure evolution, and phase transition dynamics.	Basic knowledge of Physics and/or Chemistry.	1
Quantized field description of high-field phenomena	**Péter Földi,** peter.foldi@eli-alps.hu, ELI ALPS	MSc	Recent experiments demonstrated that the quantized nature of the electromagnetic radiation („photon picture") has significance also in strong-field regime of laser-matter interaction. During the planned theoretical project the students will learn the fundamentals of quantum optics, and will apply the related methods to study simple model systems first, and more realistic problems later. Our approach is a combination of analytic and numerical techniques.	Quantum mechanics, Optics. English, Hungarian	1
Exploring High-Harmonic Generation in Semiconductors: An ab-initio Simulation and Machine Learning driven optimization	**Mousumi Upadhyay Kahaly,** mousumi.upadhyaykahaly@eli-alps.hu	Masters level thesis – duration 6-9 months	High-harmonic spectroscopy in semiconductors presents intriguing opportunities and challenges within the realm of ultrafast solid-state physics. Addressing hurdles like low high harmonic conversion efficiency, phase matching complexities, and material-related effects is essential and is highly relevant for experiments. In this work, we construct an efficient TDSE-based model for rapid simulation of high harmonic generation (HHG) in bulk semiconductors with experimental relevance. Utilizing this model, we pioneer an innovative machine learning-driven approach to optimize laser and material parameters within a multivariable space. This project, with sincere efforts from the student for a tentative duration of 6-9 months, guarantees a research publication in scientific journal for the participating student.	This workflow will be implemented mainly in Python. English skills are required for seamless comunication within our multinational team.	1
Advanced Glucose Detection and Monitoring in Blood: Innovative 2D Materials-Based Sensor Design and Ultrafast Electron Dynamics	**Mousumi Upadhyay Kahaly,** mousumi.upadhyaykahaly@eli-alps.hu	Masters level thesis – duration 6-9 months	Glucose monitoring is a critical aspect of managing diabetes and other metabolic disorders. Traditional methods for glucose detection often lack the required sensitivity and rapid response necessary for effective real-time monitoring. Considering emerging applications of two-dimensional (2D) materials in recent past as promising candidates for sensor applications, this project aims to develop a highly sensitive and fast-responding glucose sensor using novel 2D materials. Leveraging ab initio density functional theory (DFT), we will investigate the electronic properties, of selected 2D materials to understand their suitability for glucose detection. Associated ultrafast electron dynamics and charge transfer processes upon glucose binding will be investigated with time dependent density functional theory, providing critical insights into the operational mechanisms of the sensor. This approach aims to optimize the sensor's design for enhanced performance in terms of sensitivity, selectivity, and response time. Over the course of six months, the project will involve a comprehensive literature review, selection of suitable 2D materials, and detailed DFT and TDDFT simulations. In the final month, the sensor design will be optimized based on simulation results, and its performance metrics will be validated. The expected outcome includes the identification of optimal 2D material for glocose sensing, a detailed understanding of the underlying mechanisms, and an optimized sensor design, setting the stage for experimental validation and a useful publication. This project, with sincere efforts from the student for a tentative duration of 6-9 months, guarantees a research publication in scientific journal for the participating student.	This workflow will use open source quantum chemistry simulation codes (which we will help you to quickly learn and use). Some coding experience with Python and/or some knowledge of Machine Learning approaches is preferred, but not mandatory; Communication language is mainly English.	1

Strong field photoionization of noble gases: going beyond the dipole approximation	**Mousumi Upadhyay Kahaly,** mousumi.upadhyaykahaly@eli-alps.hu	Masters level thesis – duration 6-9 months	Photoionization represents a fundamental phenomenon that occurs when matter absorbs electromagnetic radiation with a sufficiently high frequency. An electron is liberated into the continuum via different ionization channels corresponding to different initial or final angular momenta, giving insight into this intricate process. Within the framework of this project we would like to give an overview of the quantum mechanical description of the photoionization process (e.g wavefunctions, overlap integrals, cross sections) to the applicant/trainee, with special consideration given to the effect of strong fields. The project provides a first-hand experience of understanding the photoionization dynamics theoretically and correlating to modern experiments, immensely important in many fields from environmental chemistry to fundamental physics. Furthermore we plan to attempt the inclusion of time dependence in the model, depending on the available time/duration of the internship and interest of the candidate. The results obtained during this project could be helpful in interpreting ultrafast experiments performed here and broaden our theoretical understanding of basic physics phenomena. This project, with sincere efforts from the student for a tentative duration of 6-9 months, guarantees a research publication in scientific journal for the participating student.	some coding experience with Python, Fortran or C is preferred, but not mandatory; communication language is English; curiosity towards physics.	1