Topic specifications for PhD 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**	**Expected prior knowledge, language**	**Assumed number of students**
THz emission and control of light-harvesting proteins	**József Fülöp** Jozsef.Fulop@eli-alps.hu ELI ALPS, **Zimányi László** HUN-REN Biological Research Centre	PhD	One of the most important processes for the biosphere is the utilization of solar light energy (in plants by photosynthesis), which some archea are capable of with the help of the bacteriorhodopsin protein. In this project, we study thin films of micron thickness, produced using bacteriorhodopsin, which have very strong optical nonlinearity and respond to light excitation with ultrafast polarization and THz radiation emission. We will investigate the THz radiation generated in such protein-based microstructures. We also aim to investigate whether a modulated THz field can induce or influence a response corresponding to the biological function, the photocycle accompanied by proton transport.	MSc in physics, biophysics, chemistry, or related fields	1
Measuring the tunnel exit momentum in strong-field ionization	**Attila Czirják,** attila.czirjak@eli-alps.hu	PhD thesis	Quantum tunneling is an important ingredient in the strong-field ionization of atoms with suitably strong few-cycle near-infrared laser pulses, enabling e.g. high-order harmonic generation, attosecond XUV pulses and attosecond metrology. Fundamental open questions include the tunnel exit time and momentum. Based on our recent results, we plan to measure the tunnel exit momentum in a Reaction Microscope. The main tasks of the PhD student are the numerical simulation of the quantum dynamics and the processing and interpretation of the measured data.	Strong background in quantum physics, mathematics and numerical simulations., data processing.	1
Investigation of band structure of 2D materials by condensed matter endstation	**Prof. Dr. Kónya Zoltán** konya@chem.u-szeged.hu SZTE & **Dr. Óvári László** laszlo.ovari@eli-alps.hu ELI-ALPS	PhD	Photoemission is a frequently applied method to study solid materials and surfaces. The aim is to gain insight and a deeper understanding of its methods, including sample preparation, characterization and an in-depth analysis of electronic structure using the NanoESCA end station of ELI-ALPS. The NanoESCA is a photoemission electron microscope (PEEM) with different imaging and energy filtering options. In this electron microscope, the sample under study is the electron source. It is illuminated by ultraviolet (UV) or extreme ultraviolet (XUV) light, which creates photoelectrons. These photoelectrons carry the information to build up and visualize the whole band structure of the investigated materials.	Hold a Master's degree in Physics or chemistry. English as a communication language	1
High-order harmonic generation with quantized fields	**Péter Földi,** peter.foldi@eli-alps.hu, ELI ALPS	PhD	The project considers the theoretical description of strong-field light-matter interaction using the „photon picture" of the electromagnetic field. As a specific example, the focus will be on the generation of high-order harmonics. We aim to calculate the photon statistics and entanglement properties of both the exciting laser pulse and the high harmonic modes. High harmonic spectra and intensity correlations will be compared to experimental findings. The planned research is based on analytic calculations but will strongly involve numerical techniques as well.	Quantum mechanics, Optics. English, Hungarian	1
PhD position on liquid phase attosecond spectroscopy	**Zsolt Divéki,** diveki.zsolt@eli-alps.hu ELI ALPS	PhD	A PhD position is open to develop and construct a liquid jet station with the option of photon and electron spectroscopy. The setup would be a portable end station between various beamlines at ELI-ALPS. The applicant would apply both XUV-IR pump-probe experiments and high order harmonic generation in liquids, depending on the need of the scientific project, to study water solution structures and charge migration in liquids on the attosecond time scale. These techniques within the liquid phase are important to understand and control the electronic interactions within molecules.		
PhD position on MIR-HE ATTO beamline	**Zsolt Divéki,** diveki.zsolt@eli-alps.hu ELI ALPS	PhD	ELI-ALPS has a High Energy mid-infrared laser (20 mJ, sub 100 fs, 1 kHz) equipped with a dedicated attosecond pulse generating beamline. The task of the applicant would be to optimize and operate the beamline, demonstrate soft X-ray generation and/or implement an attosecond pulse duration measurement technique (like streaking or PROOF). Furthermore, electronic interaction studies in the water window spectral regime could be performed.		
Machine Learning-Driven Optimization of Lead-Free Perovskite-Inspired Materials for Indoor Photovoltaic Applications	**Mousumi Upadhyay Kahaly,** mousumi.upadhyaykahaly@eli-alps.hu	PhD	Recently, with the emergence of Big Data and the Internet of Things (IoT), the demand for self-powered wireless electronics is growing rapidly, with a focus on affordability and ecofriendliness, sparking a rising interest in indoor photovoltaic solutions. While Lead-halide perovskites have demonstrated high power conversion efficiency in photovoltaics, the toxicity of lead and its ready solubility in water are concerns for widespread implementation. Within this project, we will explore through quantum chemistry simulations, some newly designed alternative perovskite-inspired materials, towards theoretical predictions of relevant material properties and structure, alongside validation of stability/synthesizability and expected performance. Furthermore, by employing machine learning algorithms, our study will predict and synthesize novel material compositions, focusing on enhancing optoelectronic properties and stability under artificial illumination. Starting from ab initio simulations and experimental results, a comprehensive dataset of existing lead-free perovskite-inspired materials, including their structural, electronic, and photovoltaic properties will be compiled. Next supervised machine learning techniques will be used to identify patterns and predict promising new material compositions with desired bandgaps and stability profiles. Our proposed models will be further refines with experimental validation/new training, to understand the feasibility of these materials in indoor photovoltaic architecture. This PhD topic is expected to be concluded within 3 years, with sincere efforts from the student, with last 6 months planned to be dedicated for thesis preparation and final examination. On my part, I assure you of multiple significant research publication in the course of PhD.	This workflow will use open source quantum chemistry simulation codes (which we will help you to quickly learn and use). Basic programming skills in python or C++ required. English communication is required to collaborate with our multinational colleagues.	

Nonequilibrium Order Parameter Dynamics in Quantum Materials	**Mousumi Upadhyay Kahaly,** mousumi.upadhyaykahaly@eli-alps.hu	PhD	How do collective modes like amplitude modes evolve under ultrafast excitation? Can light be used to switch between competing ordered phases? It is extremely relevant to simulate time-dependent order parameters in quantum materials undergoing ultrafast transitions (e.g., charge density waves, superconductivity, ferroelectricity). Within the PhD topic, mainly based on simulation techniques, we use use time-dependent Ginzburg-Landau theory, nonequilibrium path integrals, and mean-field approaches, to understand how strong fields modify the band structure and induce transient phases, and possibly lead to phase transition. This PhD topic is expected to be concluded within 3 years, with sincere efforts from the student, with last 6 months planned to be dedicated for thesis preparation and final examination. Multiple significant research publication in the course of PhD is assured.	Coding experience with Python, Fortran or C, communication language is English.	
Photoelectron Interference in Strong-Field Ionization of Rare Gas Mixtures: Probing Coherent Wave Packet Dynamics	**Mousumi Upadhyay Kahaly,** mousumi.upadhyaykahaly@eli-alps.hu	PhD	Insights into alternative phase-sensitive probing techniques for ultrafast physics without traditional interferometric setup is a much needed in current attoscience. This thesis aims to investigate the fundamental quantum interference effects that emerge in the strong-field ionization of mixed noble gas systems under well-defined harmonic spectra. By ionizing a carefully chosen gas mixture with ultrafast laser harmonics, we seek to analyze the resulting photoelectron angular distributions and extract phase-sensitive information encoded in the interference between electron wave packets originating from different atomic species. The relative ionization probabilities, ionization potential differences, and fine-structure effects contribute to the observed interference contrast, providing insights into the temporal delays and coherence properties of the emitted electrons. Unlike conventional interferometric techniques, this approach leverages the natural coherent superposition of electron wave packets to extract ultrafast ionization dynamics without the need for external reference beams.These findings will provide a deeper understanding of attosecond electron dynamics in complex multi-electron environments and contribute to the development of novel probing techniques in ultrafast physics. This PhD topic is expected to be concluded within 3 years, with sincere efforts from the student, with last 6 months planned to be dedicated for thesis preparation and final examination. Multiple significant research publication in the course of PhD is assured.	Coding experience with Python, Fortran or C, communication language is English.	
Beyond-Dipole Corrections in Attosecond Time-Resolved Photoionization.	**Mousumi Upadhyay Kahaly,** mousumi.upadhyaykahaly@eli-alps.hu	PhD	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. Majority of existing work relies on the dipole approximation, which assumes that the laser's wavelength is significantly larger than the atomic or molecular dimensions, and the magnetic component of the electromagnetic field can be neglected. While this approximation simplifies calculations and has been remarkably successful in describing phenomena like high harmonic generation (HHG) and above-threshold ionization (ATI), it becomes inadequate for ultrahigh intensities, short wavelengths, and attosecond temporal resolutions where relativistic and non-dipole effects become significant. Within the framework of this project we would start from TDSE as foundation, and will develop and implement numerical simulation approaches that will allow beyond-dipole corrections and will let us access key aspects like electron momentum shifts, asymmetric angular distributions etc in strong field ionization of atoms, molecules. Successful code development and comparison with experimental data will help to understand, predict and design new experiments at relativistic intensities and attosecond temporal scales developing precise control over ultrafast electron motion in atoms and molecules. This PhD topic is expected to be concluded within 3 years, with sincere efforts from the student, with last 6 months planned to be dedicated for thesis preparation and final examination. On my part, I assure you of multiple significant research publication in the course of PhD.	Coding experience with Python, Fortran or C, communication language is English.	