1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title:

1.1 Project goals

1. Construction and optimisation of highly efficient ion source using an ion trap.

2. Study of the ion interactions in the trap.

1.2 Outline

Experiments involving electron collisions with various targets provide essential information on the structure of the bombarded objects, such as atoms or molecules, and ionisation processes. The information on scattering processes is of great importance from the point of view of plasma research, matter and antimatter study and astrophysics.

In the proposed project, scattering processes involving negative ions will be studied experimentally. The experiment itself involves producing and detecting charged low-energy particle beams in high vacuum conditions, developing electronic control systems, etc. In this case, the ion traps will be used both as an ion detector and a storage device.

The project will be a part of cooperation with CERN's AEgIS project (aegis.web.cern.ch Antihydrogen Experiment: Gravity, Interferometry, Spectroscopy) and Polish Consortium AEgIS-PL (*www.cern-aegis.pl*). In particular, the experiment will involve the production of negative ions for the purpose of trapping antimatter particles, which will be further studied in gravitational experiments. The PhD student will actively participate in the research work of the team at NCU (Toruń) and at CERN (Geneva).

1.3 Work plan

1. Introduction to techniques and methodology used in ion trap experiments,
2. Development of experimental setup (ion source),
3. Characterisation, optimisation and testing of an ion source,
4. Study on ion interactions.

1.4 Literature *(max. 10 listed, as a suggestion for a PhD candidate)*

1. T. Glöggler *et al. „Positronium laser cooling via the 1^3S-2^3P transition with a broadband laser pulse"*, Phys. Rev. Lett. **132** 083402 (1-7), DOI: 10.1103/PhysRevLett.132.083402, (2024)

2. M. Volponi *et al.* "*CIRCUS: an autonomous control system for antimatter, atomic and quantum physics experiments*", EPJ Quantum Technol. **11**, 10 (1-28), https://doi.org/10.1140/epjqt/s40507-024-00220-6, (2024)

3. Ł. Kłosowski et al.„ Experimental method for determination of the integral cross-section for electron impact ionization of ions with optical control of the target's initial quantum state", J. Electron. Spectrosc. Relat. Vol. 260, 147239 p. 1-8, (2022)

4. Ł. Kłosowski et al., Attraction between trapped ions and beams of electrons, AIP Advances 10, 015028 (2020)

5. Ł. Kłosowski et al., Measurement of electron-calcium ionization integral cross section using an ion trap with a low-energy, pulsed electron gun, J. Electron Spectroscopy and Related Phenomena 228, 13–19, (2018)

6. AEgIS Collaboration, Exploring the WEP with a pulsed cold beam of antihydrogen, Class.Quant.Grav. 29, 184009 (2012)

7. AEgIS Collaboration, Proposed antimatter gravity measurement with an antihydrogen beam Nucl.Instrum.Meth.B 266, 351-356 (2008)

8. F.G. Major et al., Charged Particle Traps, Physics and Techniques of Charged Particle Field Confinement, Springer, (2005)

2.1. Required initial knowledge and skills of the PhD candidate

- MSc in physics, chemistry or related field,
- knowledge of optics, electronics, quantum mechanics, atomic and molecular physics, laser spectroscopy and numerical methods at the level equivalent to basic university courses,
- programming skills in at least one programming language,
- teamwork skills and high motivation for research work,

- good English, sufficient for reading literature and preparing publications.

2.2. Expected development of the PhD candidate's knowledge and skills

The PhD student will gain knowledge of:

- Ultra High Vacuum system,
- Ion traps,
- Electron-molecule/ion interactions,
- Electron spectroscopy,
- Mater - antimatter interactions.