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

Project title:

Electron impact ionisation cross-sections studies of atoms and ions using ion traps

1.1. Project goals

- Optimisation of experimental set-up for precise measurement of electron impact ionisation cross-section for atoms and ions,
- Measurements of electron impact ionisation-cross section for chosen atoms and ions using an ion trap,
- Comparison obtained results with theoretical data (prof. Fursa and prof. Bray, Curtin University, Australia)

1.2. Outline

Experiments involving electron collisions with various targets provide very important information on structure of the bombarded objects such as atoms or molecules. The information on scattering amplitudes is complement for data obtained using optical spectroscopy methods. Such amplitudes in numerous cases are determined as cross sections of various kind. They can be determined both numerically or experimentally. In the case of experiment, the measurement usually involves bombardment of the selected target with a beam of electrons and detection of the electrons. Such approaches typically is used in case of neutral target.

The situation becomes more complicated, if one considers electron impact on ions. It is generally difficult task to provide a beam of ions of sufficiently well-defined geometry and the density allowing to detect scattered electrons with good statistics. In the case of plasma scattering experiments, this is also difficult to provide good purity of the target ensemble. Due to these facts, there are only few experiments on electron collisions with singly charged ions. To overcome such difficulties, an ion trap can be used as a container for target ions. As typical numbers of ions in trapped ensembles are well below 10^5 pieces, the statistics for scattered electrons would be also insufficient. Fortunately, in the case of trapped ions, the target can be detected instead of the projectile, which can be achieved using optical detection. Thus the electron impact ionisation cross sections can be determined analysing images of the ion cloud recorded during electron

bombardment. This methodology can be used for neutral atoms and ions. In both cases the results strongly depend on electron current, which should be precisely determined. It can be achieved using custom made Faraday's Cup and/or pulsed-voltage-supply system for an ion trap. All those optimisation of the experimental set-up will enable to obtain cross sections with high accuracy. The main task of the PhD will be to optimise the apparatus for such studies and conduct cross section measurements for chosen atoms and ions.

1.3. Work plan

1. Introduction into techniques and methodology used in ion trap experiments,
2. Rearrangement, optimisation and testing experimental set-up,
3. Measurement of cross sections for electron impact ionization of atoms and ions,

1.4. Literature

- F.G. Major et al., Charged Particle Traps, Physics and Techniques of Charged Particle Field Confinement, Springer, (2005)
- 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)
- Ł. Kłosowski et al., Attraction between trapped ions and beams of electrons, AIP Advances 10, 015028 (2020)

1.5. 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,

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

The PhD student will gain knowledge of:

- Ultra High Vacuum system,
- Ion traps,
- Electron spectroscopy,
- Laser systems,
- Ultra-sensitive imaging systems.