COST – Short-Term Scientific Missions

Scientific Report

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The scientific mission reported on here comprised a one month stay of Dr. Lutz Lammich, affiliated at the Max-Planck-Institute for nuclear physics in Heidelberg, Germany, with the Molecular Dynamics group headed by Prof. Lars H. Andersen at Aarhus University, Denmark. The aim of the visit was an exchange of experiences in the fields of electrostatic storage rings, electron-molecular ion interactions and imaging detector techniques.

At the host institution in Aarhus, the electrostatic storage ring ELISA is in operation since 1997. One of its main applications are experiments on heavy molecular ions in the gas phase. Due to the purely electrostatic confinement of the ion beam, this apparatus offers the unique possibility to study biologically relevant species of virtually unlimited mass. In particular reactions of biomolecules with light and with electrons are studied at ELISA. For this purpose, facilities to overlap the stored ion beam with a tunable laser beam or to cross it with an electron beam are available. The biological background of these experiments is amongst others an investigation of the basic mechanisms of radiation damage to living tissue, as well as systematic studies of the light absorption of various chromophores aiming at an understanding of processes like color vision.

At the applicants home institution in Heidelberg, the cryogenic storage ring CSR is currently being developed. The most important innovation of this facility will be the possibility to keep the entire storage ring at a temperature as low as a few Kelvin. While this device will incorporate a considerable amount of new technologies, in several aspects it will be comparable to existing electrostatic storage rings like ELISA. Thus, one purpose of the visit was to enable the applicant to become familiar with the operation of an electrostatic storage ring, and to strengthen the collaboration between the two institutions in the development and advancement of such techniques. On the other hand, the visit aimed at further enhancing the scientific potential of ELISA with the help of the applicants experience in molecular ion-electron interactions and imaging techniques gained at the magnetic heavy-ion storage ring TSR in Heidelberg.

During the four-week visit, ELISA was available to the molecular dynamics group for three weeks. In this time, several important steps were taken towards establishing a new class of experiments, namely the study of reactions between biomolecules and *trapped* electrons. A technique well established at ELISA is the observation of interactions between molecular ions and electrons in a *crossed-beam* configuration, where a beam of electrons intersects the stored ion beam at a 90º angle. However, this type of experiments bears the disadvantage that a certain minimum energy of the electrons is needed to ensure a controlled production and steering of the electron beam. To overcome this limitation, the electron gun at ELISA was designed in a way that allows trapping of a bunch of electrons in a configuration of electric and magnetic fields similar to that of a Penning trap. The kinetic energy of the trapped electrons can then be reduced in an evaporative cooling process, leading to an electron target which is basically at rest in the laboratory frame of reference. For reactions with heavy molecular ions, this results in a collision energy well below 1 eV, which is out of reach of crossed-beams experiments.

To explore the possibilities of the new technique, a beam of NO^+ ions was produced in a standard RF ion source and stored in ELISA. This species was chosen firstly because it can easily be produced in quantities sufficient for a detection by the various beam diagnostic devices in use at ELISA. Secondly, this molecule exhibits a relatively high cross section for dissociative recombination (DR) reactions with low-energy electrons. For a diatomic ion, these DR reactions produce two neutral atomic fragments which leave the storage ring and can in principle be used as a signature of those electron-induced reactions, as opposed to collisions of the stored molecular ions with residual gas in the vacuum system which in general produce only one neutral fragment. A drawback of the use of NO^+ is the relatively small mass of this ion, which results in a considerable influence of the magnetic fields needed for operation of the electron trap on the orbit of the ion beam.

With the help of two different neutral fragment detectors and eight pickup electrodes mounted along the ion beam orbit, the influence of both the magnetic and electric fields of the electron trap and the trapped electrons themselves on the ion beam could be studied. Various strategies of operating the electron trap were tested, and the performance of several diagnostic devices was optimized, thus also enabling the applicant to gain a detailed overview of the operation of an electrostatic storage ring.

In addition, an imaging data acquisition system for the analysis of neutral fragments emerging from molecular breakup reactions was set up. To this end, an existing MCP-phosphor screen detector combination mounted straight ahead of the electron-ion interaction region was equipped with a switchable high voltage power supply and the logic circuits necessary for the desired data acquisition on a molecule-by-molecule basis. A photomultiplier tube for detection of molecular breakup events and a CCD camera recording the fragmentation patterns were installed. Finally, an algorithm performing basic data analysis (e.g., extracting fragment distances from the recorded images) was developed. The new detection scheme was tested using again the beam of NO^+ molecules in combination with trapped electrons.

From the development work and test experiments described here, no new scientific results on the physics of the molecular system under study were expected or could be obtained. However, important steps were taken towards the technical realization of experiments studying reactions of biomolecules and low-energy electrons. The operation of ELISA together with the electron trap was explored, and a detection system for analyzing molecular fragmentation patterns was put to operation. Besides these concrete results, the project carried out during the visit proved to be well suited to serve the overall aim of exchanging knowledge and fostering the collaboration between the two institutions involved.

This collaboration is planned to be continued through a post-doctoral stay of the applicant at the host institution in the near future.

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