Report of the visit by Luka Pravica to CNR IMIP

The visit to CNR IMIP involved working on three different projects:

1. Measurements of triple differential cross-sections in magnesium,
2. Automatic digitising of the spectra from the mass spectrometer,
3. Development of data acquisition software to allow direct collection of the coincidence data from the time-to-amplitude converter.

1. Measurements of triple differential cross-sections in magnesium

Electron impact ionisation of atoms plays an important role in the study of atomic processes and helps to explain a variety of physical phenomena related to areas such as astrophysics, discharge and plasma physics. In particular the (e,2e) process involves the ionisation of the target atom by the incident electron and the detection of the scattered and the ejected electron in coincidence, i.e. coming from the same scattering event. In this relatively difficult measurement of the triple-differential cross-section (TDCS) the energies and momenta of all three electrons are uniquely determined. This allows the most complete information on the ionisation process to be obtained.

The TDCS of simple target atoms such as hydrogen and helium has been extensively studied in the past and very good theoretical models have been developed using the distorted-wave Born approximation (DWBA) approach. However, the real test of the theory comes, for example, from the studies of the experimentally difficult metal atoms which require vaporisation of the metal in vacuum by heating to a high temperature. Further challenges to the theory can be achieved by a careful selection of the experimental conditions such as the choice of incident electron energy and detection angles. Such experiments have being carried out on magnesium atoms during the visit. This includes the measurements of the TDCS of the outer-shell states (*3s, 4s, 3p*) and the inner-shell *2p* state which is shown, for example, in figure 1a). The energy of the incident electrons was 427.5V while the 20V scattered electrons were detected at 12° scattering angle. The 400V ejected electrons were detected in the binary region between 40° and 130° and in the recoil region between 220° and 310°. The possible angular range was determined by the physical size and location of the electron analysers. The results from the outer-shell measurements have been compared with the DWBA calculations by Klaus Bartschat, one of the leading theoreticians in the field, and excellent agreement between the theory and the experiment has been obtained, as shown for the binary region of the *3s* state in figure 1b). The experimental data have been put on an absolute scale by normalising to the theory to give the best visual fit.

Further studies of magnesium atoms are in progress for the same states at 7° angle of the scattered electrons. This angle has been chosen to test an interesting oscillatory behaviour predicted by the DWBA theory for small scattering angles. The TDCS at 7° is about two orders of magnitude smaller than that at 12° which makes this particular experiment extremely difficult requiring long measurement times. The measurements for the *3s* state are in progress and the preliminary results have indicated possible structures.

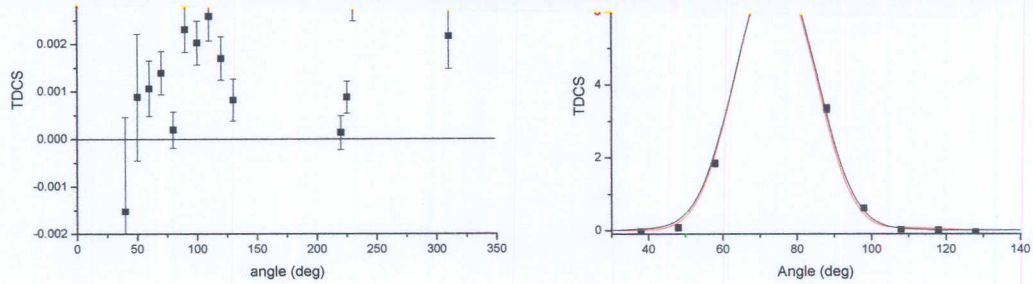

Figure 1: a) TDCS for magnesium inner-shell *2p* state for 400V ejected electrons and 20V scattered electrons at 12°; b) TDCS for magnesium outer-shell *3s* state for 400V ejected electrons and 20V scattered electrons at 12°.

2. Automatic digitising of the spectra from mass spectrometer

The existing mass-spectrometer on the scattering chamber of the magnesium experiment has been connected to a National Instruments 6024E card in the data acquisition computer and software has been developed using Labview 7.1. The software allows acquisition of the mass-spectrum scans on the computer. This will significantly simplify and speed up the recording of the mass spectrum which was previously done manually. The software was fully tested and the mass spectrum of the vacuum in the scattering chamber of the magnesium experiment was recorded successfully. The planned future application of the mass spectrometer is the detection and analysis of the fragmentation of molecules after electron impact.

3. Development of data acquisition software to allow direct collection of the coincidence data from the time-to-amplitude converter

The third part of the project included optimising of the data acquisition system. The existing data acquisition system uses a complicated arrangement of two single-channel analysers, two counters, a data acquisition card and two computers to digitise and record pulses from the time-to-amplitude converter (TAC). The new data acquisition system software has been developed using Labview 7.1 to digitise the pulses from the TAC directly. This has been achieved using an existing National Instruments 6024E card and will simplify the data acquisition and hence reduce the number of the required equipment. The software has been extensively tested using two random pulse generators with adjustable delay generator and it is ready to be integrated into the existing data acquisition software.

Summary:

The results of the short visit were very productive. The magnesium experiment has provided new tests of the theory modelling the ionisation process in magnesium atom. The results will be published in a scientific journal. The newly developed system for a direct acquisition of the mass spectra by a computer will save lots of time for the future experiments and will allow automatic detection of elements present in the vacuum system. Additionally, the new data acquisition system software is ready to be tested on a real experiment and then integrated into the existing data acquisition software.