Applications of the AC Magneto-Optical Trap in Collision Experiments

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Synopsis In an alternating current magneto-optical trap (AC-MOT), the magnetic fields required for trapping and cooling can be rapidly switched off, allowing charged particle experiments to take place where they would otherwise be impossible. In Manchester this technique is used for the detection and study of cold Rydberg atoms in a field free environment, and for the creation of a cold atom electron source to be used in high resolution electron diffraction and collision studies. Details of these experiments will be presented.

A magneto-optical trap (MOT) uses six orthogonal damping laser fields in combination with a spatially varying magnetic field to cool and confine atomic and molecular targets. These traps have long been used as the basis of many atomic and condensed matter experiments, where the targets are cooled to ~ µK and below. This technique results in the targets having well defined momentum, and has further application in the preparation of laser-excited states.

Applying charged particle studies to cold atoms in a MOT has been a challenge due to the presence of the trap's inhomogeneous magnetic field. The alternating current MOT (AC-MOT) was invented in Manchester to overcome these limitations, by employing an oscillating magnetic field which can be rapidly switched off. In the AC-MOT, the trapping laser polarisation is switched synchronously with the alternating magnetic field. This allows the trapping magnetic fields to be eliminated in less than 20 µs, ~300 times faster than for a conventional MOT [1]. Field-free experiments can then take place without any loss of trapping efficiency.

Two AC-MOT experiments are currently in operation in Manchester. In the first, a new method for Rydberg atom detection is being exploited. ^{39}K atoms trapped in an AC-MOT are selectively laser excited to Rydberg states in a stepwise process. Ions or electrons from interactions between Rydberg atoms are then detected using a channel electron multiplier. The experiments take place in a field-free region set by six electrostatic deflector plates between the MOT coils. A pulsed laser beam is used to resonantly excite ground state atoms to the $4^2P_{1/2}$ state. These atoms are further excited to Rydberg states by a UV-pumped, tunable continuous wave dye laser ($\lambda \approx 418 \rightarrow 470$ nm) that is switched in by an acousto optical modulator. The laser beams are typically switched on for a few µs, after which a penetrating field is used to deflect ions or electrons into the detector. Using this technique, cold Rydberg atoms have been created and studied from n = 15D → n > 220S. Figure 1 shows an example of the spectrum for 15D to 196S, collected by scanning the dye laser.

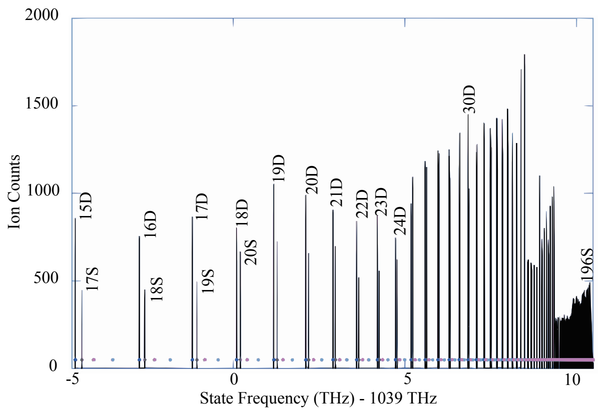

Figure 1. Excitation of Rydberg atoms from n = 15D to n = 196S using CW laser radiation, offset from 1039 THz.

In the second experiment, ^{85}Rb atoms are cooled and trapped in an AC-MOT. The atoms are then ionised at threshold in a pulsed, two colour photoionisation scheme. This yields electrons with an energy spread on the order of 1 meV, corresponding to a characteristic temperature of ~10 µK [2]. These electrons are then extracted by electrostatic fields to create a beam. The AC-MOT allows the electrons to be extracted without any **B**-field, with no appreciable reduction in trap density. This new source is currently being characterised in order to perform future electron diffraction and collision experiments.

The progress of these studies will be presented at the conference.

References

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