The AC-MOT Cold Atom Electron Source (CAES)

Michael Jones*[1], Matthew Harvey*, William Bertsche*†, Guoxing Xia*†, Swapan Chattopadhyay‡, Andrew James Murray*[2] and Robert Appleby*†

* Photon Science Institute, School of Physics & Astronomy, University of Manchester, Manchester M13 9PL, UK.
† The Cockcroft Institute, Daresbury Laboratory, Sci-Tech Daresbury, Daresbury, Warrington, WA4 4AD UK.
‡ Department of Physics, Northern Illinois University, 1425 W. Lincoln Hwy DeKalb, IL, USA 60115.

Synopsis. A new cold atom electron source based on an AC-driven magneto-optical trap (AC-MOT) is described for electron diffraction studies. The advantages of the new source which uses an AC-MOT are detailed.

Progress towards observing ultra-fast dynamics on atomic length scales is limited by the achievable brightness, or current per unit solid angle, of available electron beams. The brightness of an electron beam is related to its characteristic temperature [1], and hence by reducing the temperature of the electron beam, higher brightness beams can be produced.

In a cold atom electron source (CAES), cold atoms held in a magneto-optical trap (MOT) are photo-ionized near threshold by a laser. This process yields electrons with an energy spread on the order of 1 meV, corresponding to a characteristic temperature of ~10 K [2]. Electrostatic fields are then used to extract the electrons into a bunched beam for delivery to experiments.

The magnetic **B**-fields found in a conventional MOT perturb the electron beam trajectory and its quality. The new source described here uses an AC-MOT [3] to ensure the trapping fields are zero at the time of electron extraction. This allows field-free electron extraction whilst retaining a high source density. In the AC-MOT, the trapping laser polarization is switched synchronously with an alternating **B**-field. Once the **B**-fields are zero, the atoms are ionized using pulsed, two colour photo-ionisation, and an electron beam is extracted.

To determine the brightness B of the CAES electron beam, its beam current $\mathbf{J}$ and characteristic temperature T are measured, since

$$B = \frac{\mathbf{J}}{4\pi}\frac{mc^2}{k_B T}.$$

The charge and temporal profile of the CAES electron bunches are measured using a charge pick-off circuit from a multi-channel plate (MCP). Figure 1 shows the cold atom source and the electrostatic extraction and acceleration optics. These consist of trapping coils, acceleration and focusing electrostatic optics, and an MCP and phosphor screen. The temperature of the beam is measured by the expansion of the electron bunch over the ~500 mm flight path, as determined from the spot size imaged using the MCP relative to the initial ionization volume. This expansion is linearly dependent on the initial divergence of the beam. When combined with the beam energy, the temperature can hence be estimated [1].

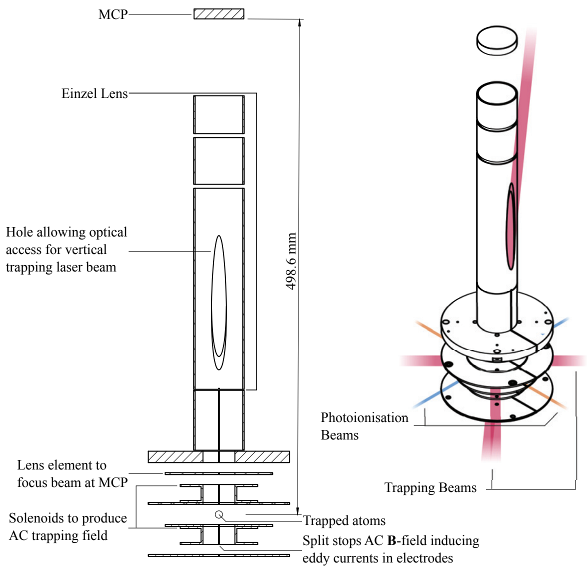

Figure 1. (Main): Cross-section of the CAES apparatus. Electrons are extracted upwards by biasing the MOT plates. (Insert): 3-D render showing the trapping (red) and ionization (blue, orange) laser beams.

A description of the source, temperature measurements, and the progress towards initial electron diffraction studies will be presented at the conference.

References

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[1] E-mail: Michael.Jones@manchester.ac.uk
[2] E-mail: Andrew.Murray@manchester.ac.uk