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A BRIGHT ULTRACOLD ATOMS - BASED ELECTRON SOURCE

G. Taban, M.P. Reijnders, S.B. van der Geer, O.J. Luiten, and E.J.D. Vredenbregt

Department of Applied Physics, Eindhoven University of Technology,
PO Box 513, 5600 MB Eindhoven, The Netherlands

An important application of pulsed electron sources is Ultrafast Electron Diffraction [1]. In this technique, used e.g. in chemistry, biology and condensed matter physics, one can observe processes that take place at the microscopic level with sub-ps resolution. To reach the holy grail of UED, single-shot diffraction images of biologically relevant molecules, electron bunches of 1pC charge, 100fs length and 10nm coherence length are required. Conventional pulsed electron sources cannot fulfil these requirements, but according to the simulations reported in [2] and [3] a new type of source can.
The new source combines the use of magneto-optical atom trapping with fast high voltage technology. We start by cooling and trapping rubidium atoms, followed by ionisation just above threshold, leading to an ultracold plasma. Another possibility is to excite the atoms into a high Rydberg level, from which they spontaneously evolve into an ultracold plasma. Applying a fast high voltage pulse, electron bunches can be extracted. In an initial study [2] it has been shown that this type of source can provide a very high brightness. Depending on the initial particle distribution, the reduced brightness can be in the order of $1x10^9$ A/(rad^2m^2V), which is orders of magnitude higher than what established technology such as an electron photogun can provide.
Here we report the first experiments toward realisation of the source. A simple accelerator structure consists of four bars surrounding a MOT, on which an 800V pulsed voltage with a rise time of 1μs is applied. An MCP together with a phosphor screen and a CCD camera are used as detection system. The bunch size obtained from the phosphor screen is fitted with a Gaussian distribution, from which the electron temperature is extracted. For small extracted charges, the electron temperature is found to have an upper limit of 500K, the measurement being limited by stray magnetic fields due to the low electron energy (10eV). We have also extracted a pulsed ion beam by reversing the sign of the accelerating voltage. Since ions are heavier, they obtain higher energy and are less influenced by the magnetic fields. The temperature in this case is found to be <60K, indeed orders of magnitude lower than 50,000K found in conventional sources.
To improve this setup, namely to reduce the stray magnetic fields influence, minimize the influence of the space-charge, and create a cylindrically symmetric electric field, a new fast high voltage switch and a new accelerating structure were developed and installed. They will provide a 30kV pulse in 30ns, which is closer to our goal.
Because the properties of the electron beams depend on the initial properties of the ultracold plasma, in particular its temperature, understanding the plasma dynamics is very valuable. The new setup also allows for fundamental studies of such properties.

[1] B. Siwick et al., Science **302**, 1382 (2003)
[2] B.J. Claessens et al., Phys. Rev. Lett. **95**, 164801 (2005)
[3] T. van Oudheusden et al., Phys. Rev. Lett. (2007) (submitted)