H^- DISTRIBUTION IN THE HERA RF-VOLUME SOURCE

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Abstract

The HERA RF-Volume Source is the only source that delivers routinely a H^- current of 40 mA without Cs. The production mechanism for H^- ions in this type of source is still under discussion. Laser photodetachment measurements have been started at DESY in order to measure the H^- distribution in the source. The measurements were done also under extraction conditions at high voltage. Measurements with and without extraction are contributions for the H^- sheath theory. Knowing how the H^- are distributed and where they are produced makes further source improvements possible.

INTRODUCTION

Photodetachment measurements in order to measure the density of negative ions have been done as early as 1969 [1]. First density measurements of H^- are reported in 1979 [2]. In the HERA source a modification of a technique with a cylindrical metal probe (langmuir probe) aligned parallel to a laser axis [3] was used. The HERA volume H^- source is a RF source with an antenna outside of the plasma chamber. The antenna is shielded by a ceramic. For HERA a current pulse of 40 mA, 120 µsec long is extracted at 35 kV. The details of the source are given in several papers [4],[5],[6].

MEASUREMENT SET UP

The power applied at the RF coil of the HERA H^- source is pulsed. With a positive bias (U_{LP}) of 5V close to saturation one draws an electron current to the tip of the probe. This current (I_{LP}) is measured with a toroid (see Fig.1). The current signal is shown in Fig.2a. The affinity of the electron attached to the hydrogen atom is with 0.75eV very low [1]. By photodetachment $H^- + h\nu = H + e^-$ an increase in electron density is produced.

To clearly interpret the signals it has to be made sure that no other photon processes like photoionisation take place. Fig. 2b shows the increase in electrons detected when a 9 nsec, 1064 nm puls of a Nd: YAG laser travels on the axis of the source. The maximum pulse energy of our laser was 650 mJ per pulse. The 8 mm ∅ laser beam was compressed to 3mm ∅ with an optical system.

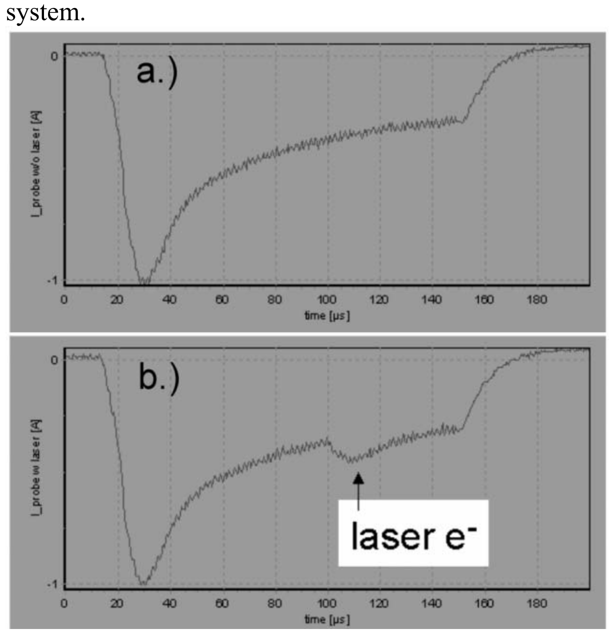

Figure 2: Current pulse of the Langmuir probe (I_{LP}) without laser beam (a) and with photo detached electrons (b).

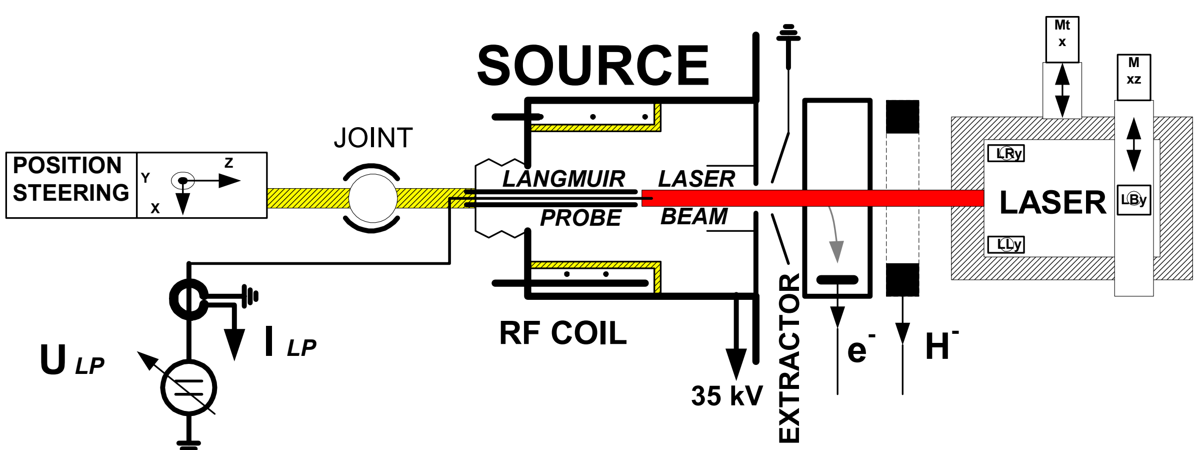

Figure 1: HERA RF source with mounted langmuir probe on the back side and a laser beam shooting through the extractor hole.

The beam was dumped on the probe or on a ceramic dump surrounding the end of the probe. A set up where the laser beam is dumped outside of the source is given in [7]. The probe tip and inner conductor are a molybdenum wire of 0.4 mm ∅. The center wire is shielded by a metal tube which is completely isolated from the plasma with sealed ceramic tubes (see Fig. 3).

Due to the environment there is noise on the signals in Fig.2. By averaging over many pulses it was possible to get very stable values.

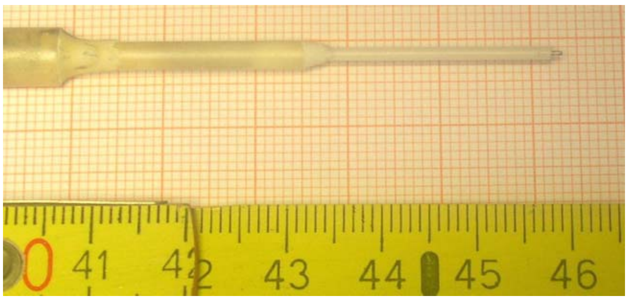

Figure 3: Ceramic shielded probe with tip

We tried different ways [8] to detect the increase in the number of electrons due to the laser beam. First the signal without laser beam was subtracted from the signal with laser beam. It turned out that detecting in the same pulse the difference between maximum and the minimum before the laser starts delivers the same results.

The laser beam was fixed on axis of the source. The probe tip was moved step by step in rectangular planes perpendicular to the beam axis (see Fig. 1). The x and y movement is done by turning the probe in a joint the z motion by pulling the probe in and out. The movements in x, y and z are done with a three table system. A long bellow is used for transforming the movements into the vacuum.

The size of the planes over which measurements were done varied from 4mm x 4mm in the collar area to 10mm x 10mm in the RF coil range and had in the final part of the source a size of 6mm x 6mm. All measurements were done with a 0.5 mm step size. The z planes were measured in 5mm steps.

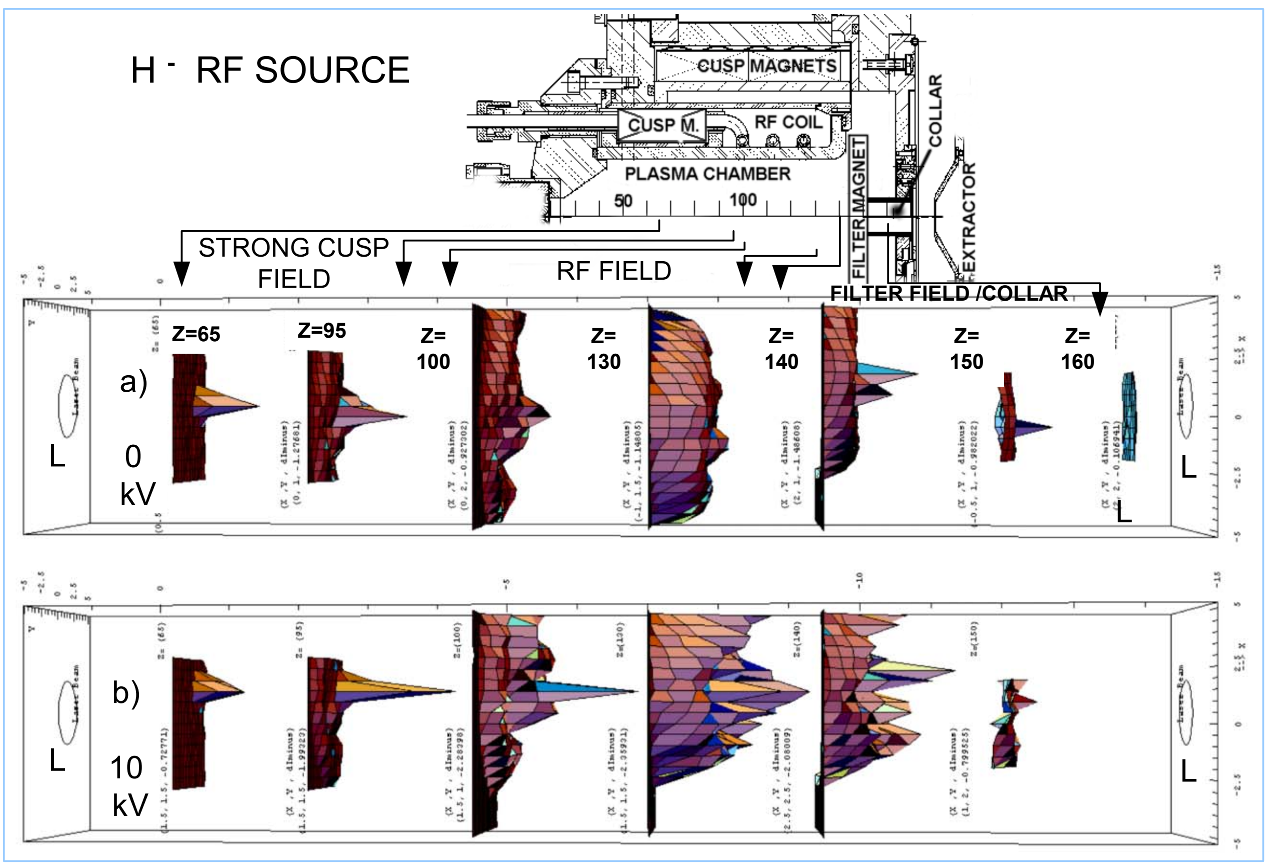

Figure 4: H⁻ intensities along the source axis without extractor gap voltage (a.) and with 10 kV applied (b.). L marks the laser beam diameter.

RESULTS

Fig. 4 gives a 3D sample presentation of typical H^- intensities measured on selected rectangular areas along the source. It was possible to associate measurement patterns to different zones of the source. The H^- intensity (Nh^-) is proportional to the additional electron current delivered due to the laser pulse . The Nh^- measurements were taken along the central axis of the source in arbitrary units. Measurements were taken at 0 V and at 10 kV extractor gap voltage.

Strong Cusp Magnet Field Area

In the range between z=65mm and 95mm a strong multicusp field is present in the source. Only a small maximum was detected in an area of about 1.5mm times 1.5mm which is a factor 2 smaller than the laser beam diameter. Significant peaks with a Nh^- value around 1 were measured.

RF Field Area

Between z=100 mm and 130-140 mm a strong RF field is applied to the plasma. The cusp field is reduced and the dipole filter field starts only at the end of the range. One finds now laser produced electrons in a circle with 10mm diameter. A plateau is formed and in addition there are spikes. The spikes become more numerous when the acceleration voltage is applied. Apparently the freed electrons are accelerated by the RF field and this movement is modulated by the acceleration voltage. In this range a maximum Nh^- value of 2.28 was found.

Filter Field Area (in front of the collar)

A dipole field is applied which has a maximum of about 20 mT at z= 157 mm and goes to zero in the middle of the acceleration gap. The plateau becomes lower which could be due to a reduced RF field. Just in front of the collar the size of the measurement plane was reduced in order to avoid damage. Here the H^- densities were less than half the maximum values.

Collar Area

In this region only one measurement was done without acceleration voltage due to sparking which occurred under high voltage. With the 6.5 mm plasma aperture the plasma density is here reduced. The H^- density (Nh^-) is only about 5% of the maximum values detected. In case of an applied acceleration field there would be a competition between the field from the probe tip and the accelerating field.

Acceleration Voltage (On/Off)

Contrary to expectations a large intensity change was found when an extraction voltage of 10 kV was applied. This difference is most obvious in the RF field area. The voltage was applied in the usual operation mode with extractor at ground and the source at high voltage. The mechanic for the probe was grounded and isolated from the probe and source bucket.

Alignment

In the strong cusp magnet field area the position of the maximum intensity varies only 0.5 mm, the step size. In the RF field area the variation is bigger and with HV applied many peaks occur. In case of the filter field range without HV the adjustment was lost due to a power failure.

CONCLUSIONS

Photodetachment measurements of the H^- ions show that the extraction voltage has an unexpected effect on the H^- distribution in the plasma. The photodetached electrons are strongly influenced by the different magnetic fields and the RF which is coupled into the source plasma. It will be interesting to change these fields and study the change in the H^- distribution not only on axis but in the whole source. The magnetic and RF fields together with the laser light should be carefully measured. Varying the filter field and observing the change in the plasma transition (sheath) will be of special interest.

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