THE HERA RF-DRIVEN MULTICUSP H^- ION SOURCE

J. Peters, DESY, Hamburg, Germany

Abstract

The HERA RF-Volume Source is the only source that delivered routinely a H^- current of 40 mA without Cs. This current has been improved to 60 mA. For HERA a pulse length of less than 200 µsec is necessary. It was possible to demonstrate a pulse length of 3 msec with the HERA source at DESY in a cooperation with SNS, FNAL and CERN. RF H^- sources are now in permanent use for accelerators like HERA or SNS. The reliability of these sources becomes very important. Special techniques for a reliable external RF coupling to the plasma, ignition, filter field, collar transition for extraction and electron dumping have been developed at DESY. The physics of the extraction plasma region was the subject of very detailed investigations with special sets of collars, cones and Langmuir probes.

A CESIUM FREE SOURCE FOR HERA

During the first years of the magnetron source at DESY several problems were caused by the use of caesium (Cs) in this source [1]. At that time in 1989 a Cs free source was under development at LBL [2]. It was impossible for DESY to get a copy of this source or plans directly from LBL. DESY was forced to buy the source from an American company [3] which had the right to work with the plans of LBL. The source delivered did not run for longer uninterrupted periods as it was necessary for HERA. There were many small and some big problems to solve within the given mechanical source frame [4,5]. Finally the source works now almost maintenance free. Several investigations of the physics of this source were made. We were able to produce the longest and highest pulse ever seen in a RF – volume source. The design details of this source can be found in [6].

As institutes and companies intend to copy our source several experiments for a new cost effective and improved design have been made.

AN IMPROVED RF-VOLUME SOURCE DESIGN

A maintenance free coupling of RF into the plasma with an internal antenna is not possible until today. This problem was solved for DESY by moving the antenna coil behind a ceramic wall [7]. The rest of the chamber was still out of metal and the filter field magnets were inside of the plasma. Successful tests were now made to move also the filter magnets behind the ceramic and achieve a full insulated plasma chamber in order to get a simpler chamber and a more effective design (see Fig.1).

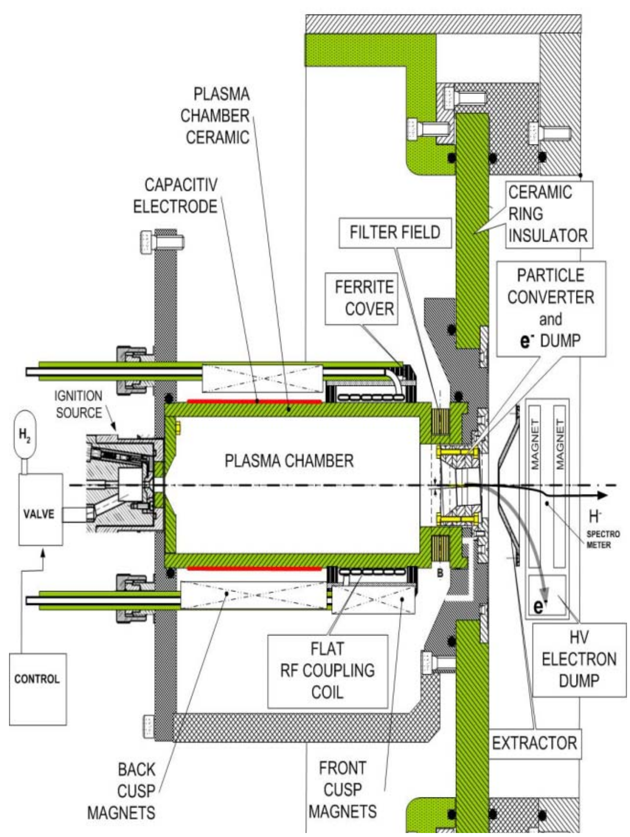

Figure 1: The NEW HERA RF-Driven Multi cusp H^- Ion Source.

The necessary plasma volume was tested by using a smaller length of the chamber. It turned out that a bigger volume is better. Changing the diameter was so far not possible.

As the chamber is isolated particles which hit the wall are not lost or directly neutralized by wall currents.

Tests were made without confinement and a multi cusp magnet system surrounding the chamber. Calculations and measurements were pursued [8,9] with different configurations. A multi cusp confinement with not too strong magnets even in the range of the RF coupling gave the best results.

The RF coupling was improved by using ferrites to guide the RF field into the plasma. In addition a capacitive electrode was introduced to determine the electric field coming from the coil (see Fig.1).

A segmented funnel particle converter is situated at the output of the chamber. It deneutralizes the Plasma, converts H^+ to H^*_2 and reduces the electrons flowing to the extractor.

The ceramic HV insulator was a special problem in the old design. It replaced a plastic ring which worked only for a very short time. After years of operation spots of copper were found on its surface leading to sparking. This very expensive piece will be replaced by a ceramic friendly design which costs less than 10 % of the present ceramic. In addition to the long HV insulation path it does not attract and accumulate the positive ions of the vacuum. These accumulations lead to a sparking of the HV.

As the external antenna design which was pioneered by DESY was patented by a source group this time a patent is pending for the new DESY design.

Ignition Source

The ignition of the H^- source is done by electrons which are injected into the plasma chamber by a special ignition source. This technique was invented at DESY in 1999 [10]. It uses the high pressure of the gas feeder in a small cell to utilize a spark gap. This type of ignition is not possible in the plasma chamber due to the necessary low pressure in this part. An ignition with high RF fields was not as reliable, filaments and UV-flash lamps make short maintenance periods necessary.

When this electron injection technique started at DESY it was also tested as a method to increase the H^- production. However the use of more energetic electrons will increase the plasma temperature, the emittance will rise, the lifetime of the ignition system will be reduced and better ways to increase the H^- current were found.

Insulated Plasma Chamber

An insulated plasma chamber makes the plasma potential free. This has the advantage that the potential profile of the plasma can be manipulated by electrodes which can be freely set at any place in the chamber. It is possible to determine and manipulate the plasma.

The loss of particles is reduced. For this reason less RF power is necessary for equal extracted currents. As it is necessary to insulate a part of the chamber for external coupling it is simpler to build a full insulated chamber.

The filter field magnets

- need no plasma protection
- are outside the vacuum
- do not influence the potential at the collar entrance
- do not draw a high electron current in front of the collar.

The ferrites can be used more effective

The design of the chamber is done in such a way that it can move freely in longitudinal direction. The transversal expansion is not so critical. The radial seals can be cooled efficiently.

As an alternative it is also possible to metallize the ceramic and solder it to a bellow

Design Alternatives

Table 1 lists the alternatives to the HERA RF volume source design. Characteristic for HERA are external antenna, ignition source, external filter magnets, a collar in a segmented tilted insulated construction, adjustable extractor, magnetic spectrometer with a dump and beam correction behind extractor, a ceramic ring insulator holding the source and no use of Cs.

The Longest H^- Pulse

The DESY RF transmitter works only for a pulse length of 200 µsec. There were doubts if the Cs free volume production process used at DESY would work also for longer pulses. For a test a SNS transmitter was shipped to DESY the freight was paid by FNAL. At DESY a new RF pulsing and triggering and a new gas pulsing was built. In addition a new HV power supply was built with an increased capacity of 1.5 µF. Investigations were made to reduce this capacity with a droop compensation technique [11]. There was not enough time to prepare the DESY source for additional cooling. This limited the repetition to 0.25 Hz. Fig. 2 shows an oscillogram of the longest and highest H^- beam pulse extracted from any volume source. The droop from 40 mA to 30 mA after 3 msec was also caused by a HV and and RF droop.

The power supplies of both units were not able to sustain the voltage for such a long time.

Table 1: Design Alternatives

HERA H^- SOURCE		**OTHER SOLUTIONS**	
+	-	+	-
EXTERNAL ANTENNA		**INTERNAL ANTENNA**	
No deterioration			**short lifetime, punctured**
IGNITION SOURCE		**FILAMENT, UV FLASH,RF [CONTINIOUS MODE]**	
long lifetime		**simpler**	**short lifetime,[vacuum load]**
EXTERNAL FILTER MAGNETS		**internal FILTERMAGNETS**	
no vacuum necessary		**strong magnetic field in front of the collar**	**has to be vacuum tight**
COLLAR		**NO COLLAR**	
highest currents are reached, improved e/H^- ratio		**simpler**	**High electron currents**
SEGMENTED TILTED INSULATED COLLAR		**FIXED COLLAR no bias,(moving the source)**	
higher current, adjustment of beam position, bias stabilizes	**complicated**	**simpler collar**	**less optimizing (complicated construction)**
EXTRACTOR ADJUSTABLE in X,Y and Z		**FIXED EXTRACTOR,(moving the source)**	
higher current adjustment of beam position		**simpler extractor**	**less optimizing (complicated construction)**
MAGN. SPECTROMETER with a DUMP behind extractor		**MAGN. SPECTROMETER, with DUMP ELECTRODE.**	
save, no H^+ or other secondary particles that interfere		**simpler**	**not secure when the beam energy changes**
MAGN. SPECTROMETER w. BEAM CORR.		**MAGN. SPECTROMETER no BEAM CORR.**	
simple			**additional beam steering**
RING INSULATOR ALUMINUM OXYD		**PLASTIC INSULATOR**	
cheap ,save & small			**huge& vulnerable**

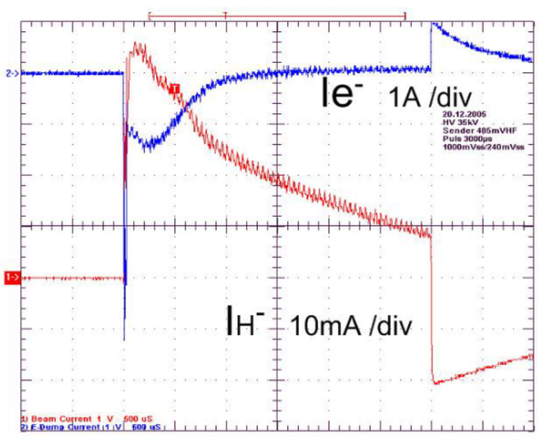

Figure 2: Oscillogram of the longest and highest H^- beam puls extracted from any volume source.

ACKNOWLEDGEMENTS

The author wants to thank M. Stockli (SNS), D. Moehs (FNAL), T. Meinschad (CERN) for their support and their participation in the long pulse test. The author is grateful for the contribution of the following colleagues at DESY: M. Marx, I. Hansen, H. Sahling, and R. Subke. The author also wishes to thank H. Weise and the technical groups at DESY for their support. The support of EEC (Contract HPRI-CT-2001-50021) is gratefully acknowledged.

REFERENCES

[1] J. Peters, Rev. Sci. Instruments, 65 (4), April 1994, pp. 1237-1239.
[2] K.N. Leung, G.J. DeVries, W.F. DiVergilio and R.W. Hamm, Rev. Sci. Instrum. 62(1), 100 (1991).
[3] AccSys, Pleasanton , California 94566.
[4] J. Peters, Rev. Sci. Instruments, **67** (3), March 1996, pp. 1046-1047.
[5] J. Peters, Rev. Sci. Instrum.69 (2) February 1998.
[6] J. Peters, Proceedings of the 2005 Particle Accelerator Conference (May 2005).
[7] J. Peters, Proceedings of the EPAC 02, Paris June 2002.
[8] Private communication with R. Becker, University Frankfurt.
[9] Private communication with M. Marx, DESY.
[10] J. Peters, Proceedings of the XX International Linear Accelerator Conference (August 2000).
[11] K. Müller and J. Peter, “Improving the H^- pulse quality with an active HV droop compensation,” DESY HERA 06-02, January 2006.