THE STATUS OF DESY H^- – SOURCES

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Abstract

Two different types of H^- sources are operated at DESY, a magnetron source and an rf- driven volume source.
H^- sources for HERA have to run for long uninterrupted periods with a low duty factor and a high reliability.
Several necessary improvements are under construction for our rf - driven volume source.
The status of both our magnetron and our volume source will be discussed and the first LINAC III experiment with the rf-driven volume source will be presented.

Introduction

The H^- source is a component of LINAC III, the injector for DESY III. The H^- ions are converted to protons using a thin stripping foil. Multiturn injection then allows particle accumulation in the synchrotron, as described in Ref. [1].

At present an 18 kV magnetron source [2] is operated as the H^- source for LINAC III, with the matching of the source to the 750 kV RFQ (Radio Frequency Quadrupole) done by a LEBT (Low Energy Beam Transport) consisting of two solenoids.
A magnetron source has to be operated with cesium in order to reduce the work function for electrons.
The availability of the source is limited by the delay due to cesium [3].
A cesium free source became even more desirable for use on LINAC III when a glow discharge was seen in the four vane RFQ and multipactoring occurred in the first section of the Alvarez tank of LINAC III.
Although it was not possible to detect cesium in the RFQ or the Alvarez tank nevertheless measurements showed traces of cesium leaving the source [3].
A volume source can be operated without cesium. It has a lower emittance, but if uncesiated it produces a lower output current than a magnetron source.

Status of the magnetron source

The DESY magnetron has been operating since 1985. It is based on the design of FNAL [2] and was modified according to the DESY requirements [3]. Since 1993 the magnetron has been operated from one HERA maintenance period to the next for 152, 301 and 291 days without breaking the vacuum. There were only minutes of interruption due to failures of the electronics. Figure 1 shows the run periods since 1993. Until now the source has run in 1996 for 171 days.

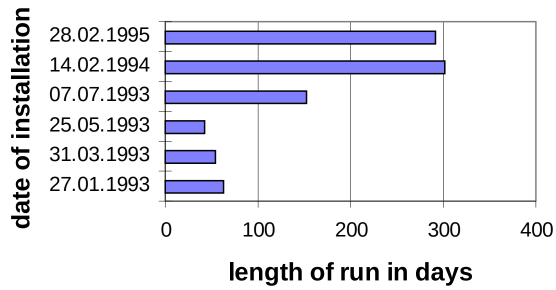

Fig. 1 Uninterrupted operation period of the magnetron vacuum unit.

Operation periods of more than 300 days are possible due to the low duty cycle of 75 µsec/6 sec = 12×10^{-6}.
Data from the magnetron source are summarized in Table 1.

Table 1: Data of the magnetron H^- source.

beam energy	18 keV
H^- beam current	60 mA
emittance	
$\varepsilon_{x\ rms,norm}$ ($\varepsilon_{x\ 90\%,norm}$) (35mA beam)	0.28(1.35) π mm mrad
$\varepsilon_{y\ rms,norm}$ ($\varepsilon_{y\ 90\%,norm}$) (35mA beam)	0.25(0.81) π mm mrad
arc voltage	140 V
arc current	47 A
arc pulse width	75 µsec
extraction repetition rate	1/6 Hz
magnetron repetition rate	1/6 Hz/ 6 Hz
cathode temperature	249 °C
anode temperature	147 °C
Cs boiler temperature	100 °C
Cs consumption 6 Hz magnetron repetition	3mg/day

The emittance in the vertical plane, is reduced due to aperture limitations of the magnet gap. A beam of up to 100 mA can be produced.

Status of the rf - driven volume source

The rf - driven volume source was originally built by AccSys [12] using plans from LBL [4]. The source was redesigned by DESY in order to gain a better reliability, higher currents and a beam energy of 35 keV.

A DESY designed piezo valve is now used which has successfully operated in the DESY magnetron source for many years. As the pulser of the piezo valve has to be rack mounted we had to build a new high voltage deck (see Fig. 2). The filament was replaced by a flash light which is directly mounted to the source bucket. It has a UV window Ref. [5].
The source is connected to a computer control system which delivers histograms and programmed diagrams of parameter dependencies.

Fig. 2 rf driven volume source at DESY R&D laboratory.

A 2000 l/s vacuum pump and a water cooling system for the multi cusp bucket are necessary.

Figure 2 shows the rf driven volume source at DESY R&D laboratory with the new 35 kV box connected to the bucket.
The extraction system is an electrode with a 60 mm wide spectrometer similar to the LBL design [4].
An electron current of about 1A is dumped on a grooved graphite plate. The magnets are encapsulated in vacuum tight steel boxes in order to protect them against hydrogen (see Ref. [6]).
The beam position is corrected with a horizontal and vertical adjustable collar and plasma electrode.
The adjustments were measured with a multi faraday cup [6] which was inserted into the beam pipe. The beam current was measured in the 35 mm beam pipe with a current transformer.
For several weeks it was possible to run the source above 23 kV with a current of 33 mA. Details are given in [9].
Measurements of the emittance are done after the beam is collimated by a 35 mm ∅ beam pipe which is more than 80 mm long.
The emittance was measured with a slit and grid system. Table 2 summarizes the data of this configuration.

LINAC 3 - DESY 3 test with the rf driven volume source

During January 1996 the magnetron source of LINAC 3 was replaced by the rf driven volume source.
The extraction system shown in Fig. 3 was connected to a LEBT consisting out of two solenoids.

Table 2: Data of the rf H^- source with a spectrometer.

beam energy	18–35 keV
beam current	16–33 mA
emittance	
$\varepsilon_{x\ rms,norm}$ ($\varepsilon_{x\ 90\%,norm}$) (16mA,18 keV beam)	0.18 (0.81) π mm mrad
$\varepsilon_{y\ rms,norm}$ ($\varepsilon_{y\ 90\%,norm}$) (16mA, 18 keV beam)	0.16 (0.72) π mm mrad
source voltage	–18 to –35 kV
extraction voltage	0 V
electron current	0.8–1.8 A
rf output power	25–45 kW
pulse width	100 μsec
repetition rate	1–6 Hz

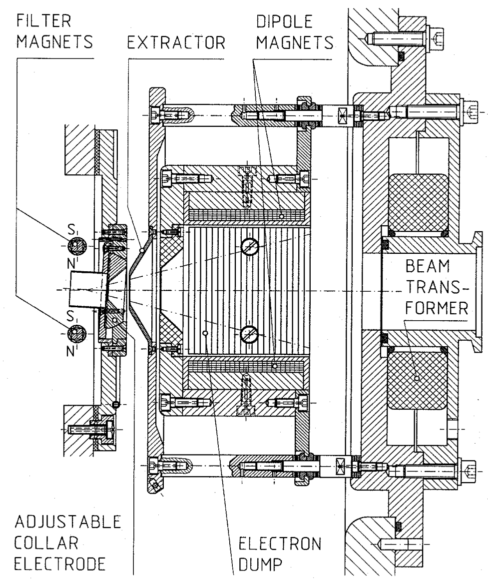

Fig. 3 rf driven volume source with a wide spectrometer and an adjustable collar electrode.

At the beginning the source delivered a 18 keV, 20 mA H^- current and about 39% of the beam was measured behind the RFQ.
Emittance measurements were made in the HEBT (High Energy Beam Transport) line. Table 3 summarizes the measurements with the magnetron and the volume source done at LINAC 3 [7].
There is almost no beam loss between tank 1 and tank 3 of the alvarez .
At DESY 3 after accumulation and acceleration to 7.5 GeV/c a proton current of 60–70 mA was measured [8].

Future source plans

The rf driven volume source of DESY has delivered a H^- beam of 15–33 mA for more than a year.

The long term experience shows that the graphite dump for the electron current deteriorates. It will be replaced by a multi faraday cup which makes it also possible to check the position of the electron beam.

Table 3: LINAC 3 measurements

	magnetron		volume source	
	current	trans-mission	current	transmission
source	60 mA		16.9 mA	
		0.33		.34 (.39)
RFQ	20 mA		5.8 mA	
		0.64		0.75
alvarez	14 mA	0.78	4.4 mA	0.9
HEBT	11 mA		4.3 mA	
$\varepsilon_{x\ rms,norm}$	0.68 π mm mrad		0.43π mm mrad	
$\varepsilon_{y\ rms,norm}$	0.6 π mm mrad		0.46 π mm mrad	

The reliability of the source depends very much on the quality of the antenna coating.
The H^- current will not only depend on the insulation of the antenna but also on sputtering of antenna insulation to critical parts of the bucket surface.
This insulation will limit the recombination of H^+ ions to H_2 and the production of excited H^*_2 on the walls.

Reliable tests were developed which make it possible to check the antenna insulation outside and inside of the source bucket. Before installation a power test in salt water detects even small defects in the coating.
After installation in the bucket the antenna insulation can be checked by applying HV during gas pulsing and measuring the antenna current. This makes a change of the driving circuitry necessary.
During operation of the source it was checked if critical parts of the antenna are not isolated by measuring the antenna bias voltage.
The transition during sparking damages the antenna significantly. Even with well designed HV circuitry it can not completely avoided. It happens mainly at the gap between extractor and plasma electrode.

Successful test were done with a small insulated plasma electrode. It is situated on the main plasma electrode opposite to the extraction electrode and is directly connected to the HV power supply.
If sparking occurs in the gap the current can flow directly to the HV supply.
Besides the insulation and sputter problem of the antenna there is also a limitation due to the different expansion of the coating and the copper material in a source pulsed with 50 kW rf .

These problems can be easily solved by separating insulation and antenna. Al_2O_3 has similar sputtering coefficients to the TiO_2 coating presently used .
With new methods [10] extremely smooth surfaces can be produced. The disadvantage is that only simple geometries can be improved.
Mafia calculations [11] show that rectangular antennas have similar fields to the present antenna. They can be built out of Al_2O_3 bends and straight pipes with a copper pipe inside.
A flat circular antenna behind a Al_2O_3 window has a different field but would be mechanically less complicated. Both antenna types are under production.

Conclusion

The magnetron source was successfully adapted to the HERA environment. Further test and development ofthe volume source is necessary to improve its reliability and performance.

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