INTERNAL VERSUS EXTERNAL RF COUPLING INTO A VOLUME SOURCE

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Abstract

RF sources have the advantage of a cleaner plasma and a longer lifetime compared to filament sources. Hminus Ions can be produced by RF driven volume sources. These sources are often designed with an internal antenna. A present example is the RF Hminus source for the spallation accelerator SNS. A similar source is considered for the European spallation source ESS.

At DESY a new development took place. The internal antenna of the HERA RF Hminus source was replaced by an external RF coupling. This system has been running for more than 25 000 h without any degradation. This is a significant improvement compared to the 980 h average lifetime of internal antenna systems.

In recent publications [1], [2] the RF coupling problem has been raised again. Six basic reasons are given why external RF coupling is superior to internal coupling.

1 EXPERIENCE WITH INTERNAL COUPLING

In 1994 a RF volume source with internal coupling was installed at DESY. After solving some technical problems [3], [4] a test was carried out with HERA LINAC III and DESY III as accelerators. It turned out that the source was not reliable enough for a continuous accelerator service. The main reason was the unpredictable antenna lifetime (see Fig. 1).

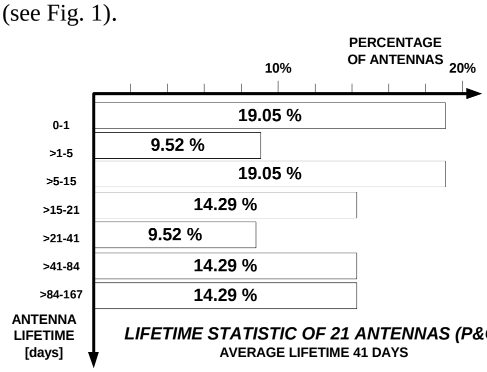

Figure 1: Lifetime statistic of the coated antennas.

The statistic shows that there is a high probability for failure at any time. For this reason it does not help to change the antenna as a precaution after some time.

In Fig.2 the antenna coil surface area is presented as a stretched surface. An analysis of the bad spot pattern showed that there is not only one reason for failure of this design.

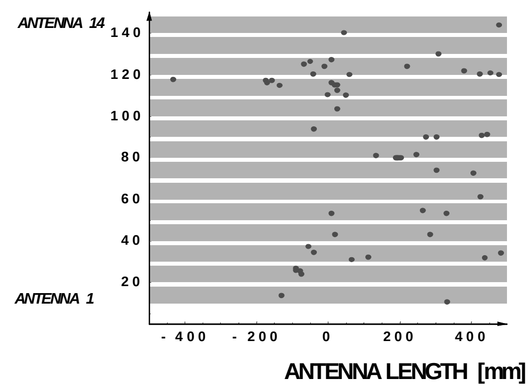

Figure 2: Bad spots on the antenna surface.

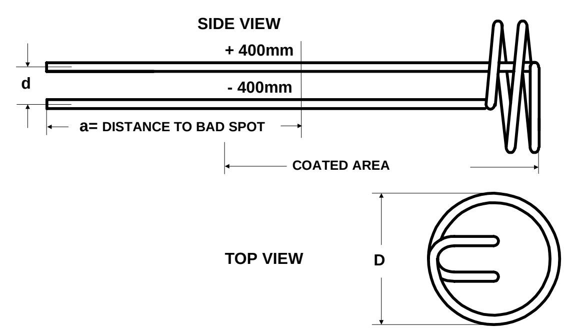

Figure 3: Antenna shape and bad spots on the antenna surface.

A sketch of the antenna shape is given in Fig. 3.

2 ANTENNA INSULATION

The antenna has to deliver some kW to the plasma. Due to the resistance of the coil there is a voltage drop in the kV range along the antenna tube. This voltage modulates the plasma potential if the antenna is not insulated. The H^- current is reduced by a factor of about two due to the modulation.

In addition the metal surface of the antenna will be sputtered to the surface of the chamber. Even if a metal with a low sputter rate is used one has to protect insulated areas like the antenna feed through.

If the antenna coil is insulated the plasma modulation is reduced but the antenna surface potential becomes negative [5]. A measurement of the voltage in the plasma of a perfect insulated internal antenna is shown in Fig. 4. It demonstrates how the voltage drops following the ignition of the plasma.

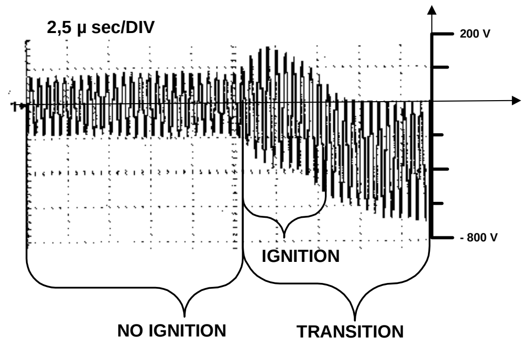

Figure 4: Langmuir Measurement of the Transition at Plasma Ignition.

3 SIX REASONS TO CHANGE FROM THE INTERNAL ANTENNA TO EXTERNAL RF COUPLING

3.1 Sputtering of the internal antenna coating

As the antenna is on a negative voltage of several hundred volts it is bombarded by positive ions and sputters its coating. In the case of the enamel coating these insulating particles form an insulating SiO_2 layer on the surface of the plasma bucket. This layer reduces the production of H^- .

The same happens with a glass antenna. The cleaning of the surface is very time consuming. If any SiO_2 is left it redistributes on the surface and forms an insulating coating again. It is important to monitor the surface of the source. In particular the collar surface has to be out of metal.

3.2 Reaccelerated positive ions (Fe and H)

It is a well known fact that the accelerating field grinds away the surface of the extractor (see Fig. 6). This way positive Fe ions are produced and accelerated into the source bucket (see Fig. 5). The same happens to positive H ions which are generated in the gap.

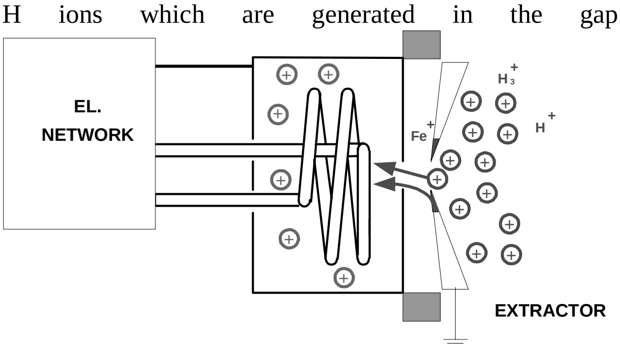

Figure 5: Source set up for internal antenna coupling. Shown is the reacceleration of ions back into the bucket.

Once in the bucket, they are attracted by the negative potential of the antenna and bombard it.

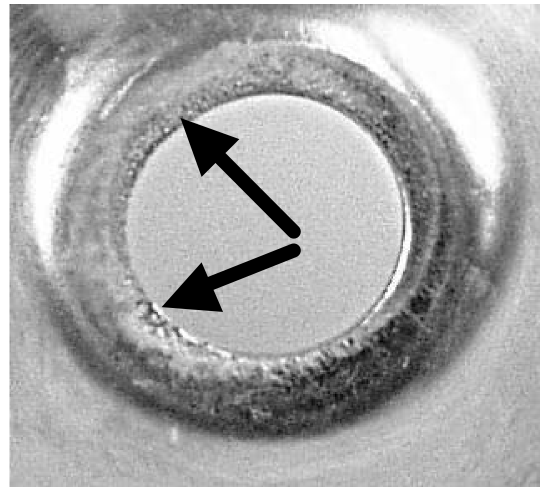

Figure 6: Metal pulled out of a Ti extractor.

3.3 Chamber ions

Due to the negative voltage of the antenna its surface will be bombarded by positive chamber ions.

3.4 Breakdown between windings

When the voltage between the windings is too high a plasma arc can formand destroy the antenna. This can be avoided by using a thicker coating. However the transients due to high voltage (HV) breakdowns can become very high.

3.5 HV sparking transients

In case of the breakdown of the high voltage transients can occur which may reach twice the level of the supply HV. Such transients are possible between the antenna and the surface of the bucket (see Fig. 5). An arc can then destroy the antenna. As the bucket is negatively biased to ground and many positive ions are produced near the source this type of breakdown seems unavoidable.

3.6 Mechanical stresses between the coating and metal tubing

Changing temperatures between the water cooled tubing of the antenna and the plasma lead to mechanical stresses between the coating and metal tubing. The coated surface develops fissures, becomes brittle and cracks (see Fig.7).

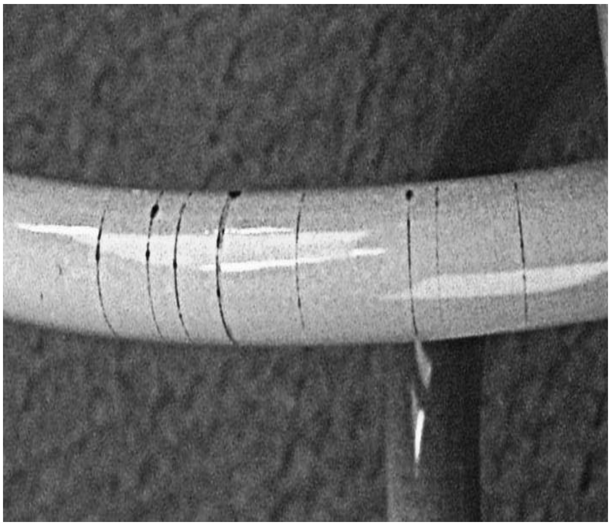

Figure 7: Antenna surface fissures .

So far no insulating material has been found which can survive these stresses for an extended period of time.

At DESY the tubing and the Al_3 O_2 ceramic insulation were separated in order to allow a free movement of these two parts which have different temperature coefficients. Two antennae of this type were developed. These designs were abandoned when it was found that external coupling has no disadvantages.

4 EXTERNAL COUPLING (THE SOLUTION)

Fig.8 shows the DESY HERA source with external coupling.

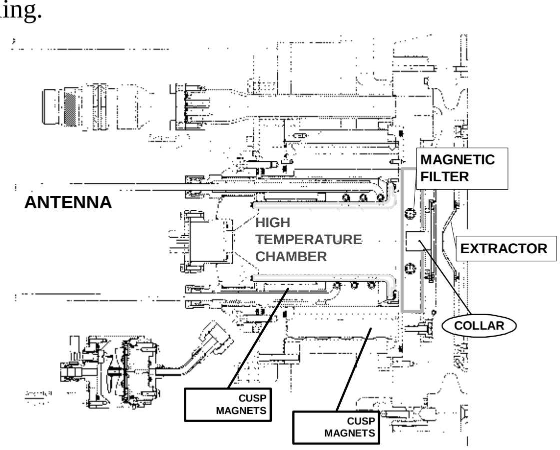

Figure 8: The DESY HERA source with external coupling.

The RF coil and Al_2 O_3 ceramic insulation are separated as one can see in Fig. 9. There are multi cusp magnets above and behind the coil. The source is Cs free, it is operated with the data shown in table 1.

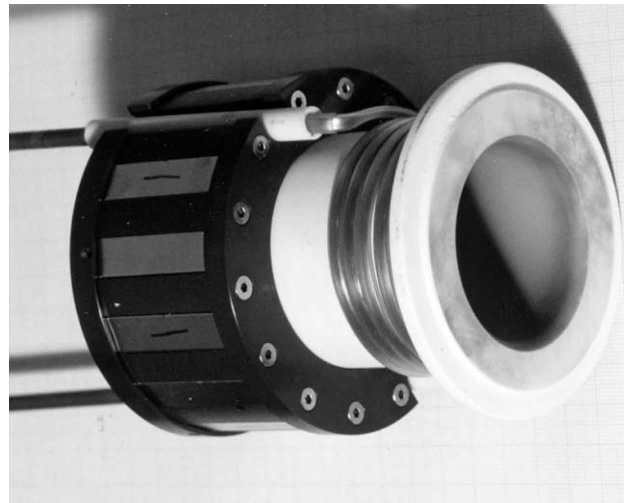

Figure 9: External coupling: coil, Al_2 O_3 ceramic and multi cusp magnet.

Table 1: Source data

H^- current	40 mA
P_{RF}	10-45 kW
Power/current	0.46 kW/mA
Pulse length	100 – 200 µsec
Repetition	1-6 Hz
Duty cycle	0.1 %

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6 REFERENCES

[1] M. P. Stockli et al, Rev. Sci. Instrum., Vol. 73 (1007), No. 2, February 2002

[2] R. F. Welton et al, Rev. Sci. Instrum., Vol. 73 (1008), No. 2, February 2002

[3] J. Peters, Rev. Sci. Instrum., Vol. 67, No. 3, March 1996

[4] J. Peters, Proceedings of the XVIII International Linear Accelerator Conference (August 1996).

[5] J.Peters, Ph.D. thesis, Universität Frankfurt, 2001