University of Groningen

Can a Hexapole Magnet of an ECR Ion be too Strong?

Drentje, A.G.; Kremers, H.R.; Sijbring, J.; Barzangy, F.

Published in:
Proceedings of the 14th International Workshop on ECR sources ECRIS99

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Final author's version (accepted by publisher, after peer review)

Publication date:
1999

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):
Drentje, A. G., Kremers, H. R., Sijbring, J., & Barzangy, F. (1999). Can a Hexapole Magnet of an ECR Ion be too Strong? In B. W. Allardyce, H. Haseroth, C. Hill, & K. Langbein (editors), *Proceedings of the 14th International Workshop on ECR sources ECRIS99* (Vol. PS-99-052-HP, blz. 94 - 97). [EXT-2000-093] CERN. https://cds.cern.ch/record/427298?ln=en

Copyright
Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment.

Take-down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): http://www.rug.nl/research/portal. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Download date: 11-10-2022

University of Groningen

Can a Hexapole magnet of an ECR Ion Source be too strong?

Drentje, A. G.; Barzangy, F.; Kremers, H. R.; Meyer, D.; Mulder, J.; Sijbring, J.

Published in:
Default journal

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
1999

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):
Drentje, A. G., Barzangy, F., Kremers, H. R., Meyer, D., Mulder, J., & Sijbring, J. (1999). Can a Hexapole magnet of an ECR Ion Source be too strong? *Default journal*.

Copyright
Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

Take-down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): http://www.rug.nl/research/portal. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Download date: 30-03-2020

Can a Hexapole magnet of an ECR Ion Source be too strong?

A. G. Drentje, F. Barzangy, H. R. Kremers, D. Meyer, J. Mulder, J. Sijbring
K.V.I. University Groningen
Zernikelaan 25, 9747AA Groningen, The Netherlands

Introduction.

Experience of many ECRIS designers and users during more than a decade has given a few experimental rules or “scaling laws”. Many of these have been discussed at the ECRIS workshops. After the 1993 workshop it was concluded [1] that the properties of the magnetic trap, in particular the strength of the radial component, determine to a great deal the confinement characteristics.

For that reason it was decided at the KVI to choose a strong magnet for the new 14 GHz ECRIS4 to be used in the Atomic Physics experiments. The hexapole magnet designed by the Giessen group [2] is a good example. There the higher field strengths were obtained in a so-called Halbach configuration with 24 wedge shaped pieces of two special kinds of permanent magnetic material (Vacodym), where the inside diameter was reduced to 65 mm as compared to the usual 70 – 75 mm). The field, measured 2.5 mm inside the pole tips (i.e. at the wall of the plasma chamber) is more than 1.2 T.
Whether or not the choice of this particular magnet was a good choice will be discussed in this contribution.

Operation of ECRIS3 with moderate hexapole magnet.

For ECRIS3 - in operation since 1994 - the ion beam currents for a few oxygen and argon charge states are given in the table. These values were reported earlier [3]; they were obtained after an extensive series of optimization experiments for oxygen, and a few for argon. For the oxygen beams, helium has been used as a mixing gas; for the argon beams, oxygen was used. The best results for the $Ar^{14, 16+}$ beams were obtained using ^{18}O as a mixing gas [4], [5]. The hexapole magnet properties are shown in the figure, marked “ECRIS 3”. The quality of the magnetic trap can be given by the “radial mirror ratio”, which is usually defined as R = B_{max}/ B_{reson}, with B_{reson} equals 0.5 T for a 14 GHz ECRIS. In the present source is R = 1.86. The measured radial field strength of this hexapole magnet obeys closely the expression $B_r = 0.00080\, r^2$ T (with r in mm).

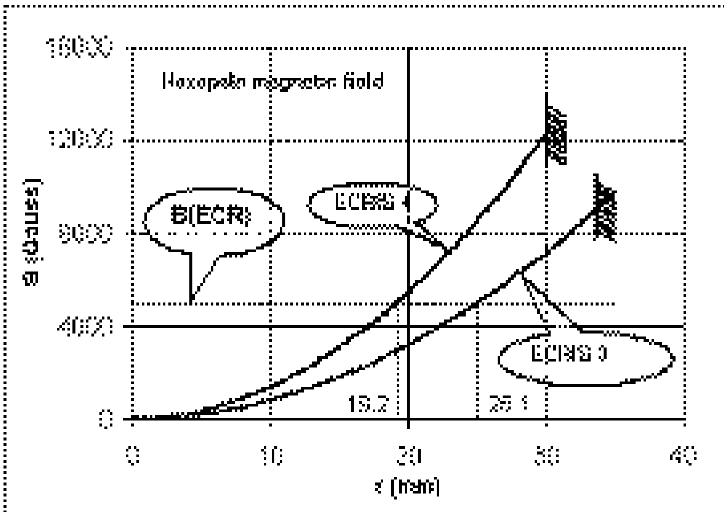

Fig. 1 Properties of the hexapole magnets of the two KVI ECR ion sources.

Operation of ECRIS4 with strong hexapole magnet.

The *strong* hexapole magnet was installed in ECRIS4, which is in operation since 1995. ECRIS4 is to a large extent a copy of ECRIS3 at KVI; the main difference is the hexapole magnet.

The measured radial field component B_r obeys closely the expression $B_r= 0.00136\ r^2$ (with B in T, r in mm); see the curve marked “ECRIS 4” in the figure. For the strong hexapole magnet in ECRIS4 the radial mirror ratio R= 2.4.

For ECRIS4, the optimization procedure was essentially similar as was applied for other sources, but it took much longer because the source was used intensively before being commissioned. In order to improve the beam transmission to the experimental stations, it was tried to reduce the beam emittance by reducing the size of the hole in the plasma electrode from ϕ =5.7 to 3.7 mm. The argument was that aberrations could easily be picked up during beam formation in the fringing field of the narrow and strong hexapole magnet (See the discussion given in a separate contribution [6] to this workshop). For ECRIS4, four sets of currents are given, marked 1995, 1997 (with two values of ϕ) and 1998. Without giving details it is remarked here that the corresponding configurations of the coils, with respect to each other and with respect to the hexapole magnet were substantially different.

		ECRIS 3	.	ECRIS4	ECRIS4	ECRIS4	ECRIS4	ECRIS4	ECRIS4
								$=E_{downstairs}$	$E_{downstairs}$
hexapole magnet		Moderate		Strong	Strong	Strong	Strong	Strong	Strong
axial configuration				"3"	"5"	"5"	"8"		
coil distance				65	58	58	52	52	52
intermediate coil		No		No	No	No	No	Yes	Yes
extr hole diam. (mm)		7		5.7	5.7	3.7	3.7	3.7	6.1
		1995-98		1995	1997	1998	1998	Jan-99	Feb-99
O^{6+}	μA	220			110	90	93		
O^{7+}	μA	55		13	13	13	12	16	
Ar^{8+}	μA	70				55	55	60	64
Ar^{9+}	μA	74				25	25	41	
Ar^{11+}	μA	52				8	12	26	
Ar^{13+}	μA	15				1.7	2.5	8	
Ar^{14+}	μA	4.7				0.6	0.7	3.9	4.1
Ar^{16+}	μA	0.27				0.003	0.014	0.22	0.21

Table 1. Best results obtained (in μA) with ECRIS3, and at various stages with ECRIS4.

In reality even more changes than the ones mentioned above were made. One conclusion could be that some basic parameter was limiting the output to a large extent, as the O^{7+} beam current was at best 12 – 13 μA in all these cases. A second conclusion is that the same O^{7+} beam current is obtained with different sizes of the extraction hole ϕ. This could be consistent with the general observation that the emittance becomes smaller at high charge states.

A considerable step forward was made when a "intermediate" coil with reversed current was installed between the main axial coils. In that situation, in particular the argon charge state distribution improved substantially. The Ar^{14+} and Ar^{16+} currents reached a value of about 80% of the ECRIS3 records, see column marked "Jan- 99" in the table. After that, the exit hole was increased from ϕ=3.7 to 6.1 mm. As can be seen in column "Feb-99" of the table, the effect on the high charge state was zero, but the effect on the Ar^{8+} current was surprisingly small too. Surprising, because similar experiments on other sources had given for these beams an intensity increase with increasing hole size.

Recently, further improvements have been made; this is reported in a separate contribution to this workshop [6].

The order of magnitude of the beam emittance was estimated from the transmission to a given set of diaphragms. This gives (at 12 kV) an emittance of the order of 40π mm.mrad. This is an advantage in cases that the beam acceptance of the user's set – up is also small, which is the case in the particular application of ECRIS4.

Discussion

The observations described above may give rise to the following questions:

- Is the stronger hexapole magnet in this particular application limiting the performance of the source?
- Is the apparently smaller emittance related to the stronger hexapole magnet?

From the properties of hexapole magnets it obviously follows that the radial size of the ECR volume is smaller for a stronger magnet. For the given situation, the difference in radial size is 20%. Therefore, the radial size of the high-density core of the plasma is substantially smaller as well. By making this "plasma size" smaller the charge state distribution inside will certainly shift to higher charge states, but at the same time the extracted fluxes (i.e. the losses) will decrease.
This might be true in the present situation, which then leads to the observed "limitation".

The effect on the beam formation could be as follows. The high-density core of the plasma maps onto a small part of the extraction area where the axial field lines are highly concentrated. That part will become even smaller for the reduced "plasma size" due to the stronger hexapole magnet. If that part of the extraction area coincides with the actual extraction hole, a further increase of the size of the extraction hole will not lead to higher currents. It might be that due to this effect even the beam emittance becomes smaller. The observations mentioned above are consistent with this model, but are certainly not accurate enough to prove it.

Conclusion.

- When the output of ECRIS4 is compared to that of ECRIS 3, it is clear that the source with the *stronger* magnet (i.e. ECRIS4) produces *lower* currents of highly charged ions.
- By changing various parameters, including major alterations of the (axial) magnet configuration it seems that the stronger hexapole magnet is *limiting* (in terms of O^{7+} and Ar^{14+} currents) the output in this particular source.
- The limits could be upgraded by further changing the axial field profile and increasing the axial mirror ratios to values substantially higher than those of ECRIS3.
- The beam emittance of the source with strong hexapole magnet is smaller.
- A higher RF frequency, e.g. 18 GHz might result in a more effective use of this strong hexapole magnet.

1. A.G. Drentje Rev. Sci. Instrum. 65(1994) 1045 (Review ECRIS workshop 1993)
2. M. Schlapp, R.Trassl, M.Liehr, E. Salzborn, Report ECRIS workshop Groningen (1993), p 226
3. A.G. Drentje, H.R. Kremers, J. Sijbring, Report 12th ECRIS workshop Tokyo (1995), p 148.
4. A. G. Drentje, H. R. Kremers, J. Mulder, J. Sijbring, Rev. Sci. Instrum. 69(1998)728
5. A. G. Drentje, A. Girard, D. Hitz, G. Melin, contributed paper to this workshop.
6. A.G. Drentje, F. Barzangy, H.R. Kremers, D. Meyer, J. Mulder, J. Sijbring, "Status report of the ECR ion sources at the KVI", contributed paper to this workshop.

agd:CoE99b.doc; 280499