Secondary-Electron-Enhanced Plasma as an Alternative to Double/Variable-Frequency Heating in ECRIS

K. E. Stiebing, L. Schachter #, and S. Dobrescu #,

Institut für Kernphysik der Goethe-Universität, Frankfurt/Main, Germany

National Institute for Physics and Nuclear Engineering, Bucharest, Romania

(supported by European Union 7th Framework Program FP7/2007-2013-Grant Agreement No. 262010-ENSAR)

Content:
- Introduction
- the MD- method
- the IKF 14GHz ECRIS
- the experiment
- results

HBFG- Grant No: III P 2-3772-116-246

Introduction

Double Frequency Heating (DHF):

injection of two RF-waves into the ECRIS plasma chamber
(typically 10GHz+14GHz, 14GHz+18GHz; 18GHz+24GHz)

Frequency Tuning (FT)-mode:

injection of two RF-waves with neighboring frequencies,
with an option to sweep one of the frequencies

→ two RF-transmitters required (for FT-mode one has to be broadband)

→ generally works via an increase of the resonance volume of the source leading to higher electron energies (electron temperature)

→ does normally not enhance confinement significantly

Metal Dielectric (MD) configuration:

thin liners with a *metal-dielectric(MD) structure* on one side are introduced in to the ECRIS plasma chamber to cover the radial walls and the extraction electrode, with *MD structure facing towards the plasma*. MD structures (e.g. Al_2O_3) are produced to possess high coefficients of secondary electron emission.

generally works via two effects:

→ enhances the *plasma-electron-density* n_e by supplying cold electrons (secodary emission)

→ enhances the *confinement* significantly by blocking wall currents (Simon short circuits)

The MD-method

Ar^{8+}, P_{RF}= 1000 Watt

MD-effect:

→ ejection of cold electrons into the plasma.

→ blocking of wall currents (short circuits over the walls)

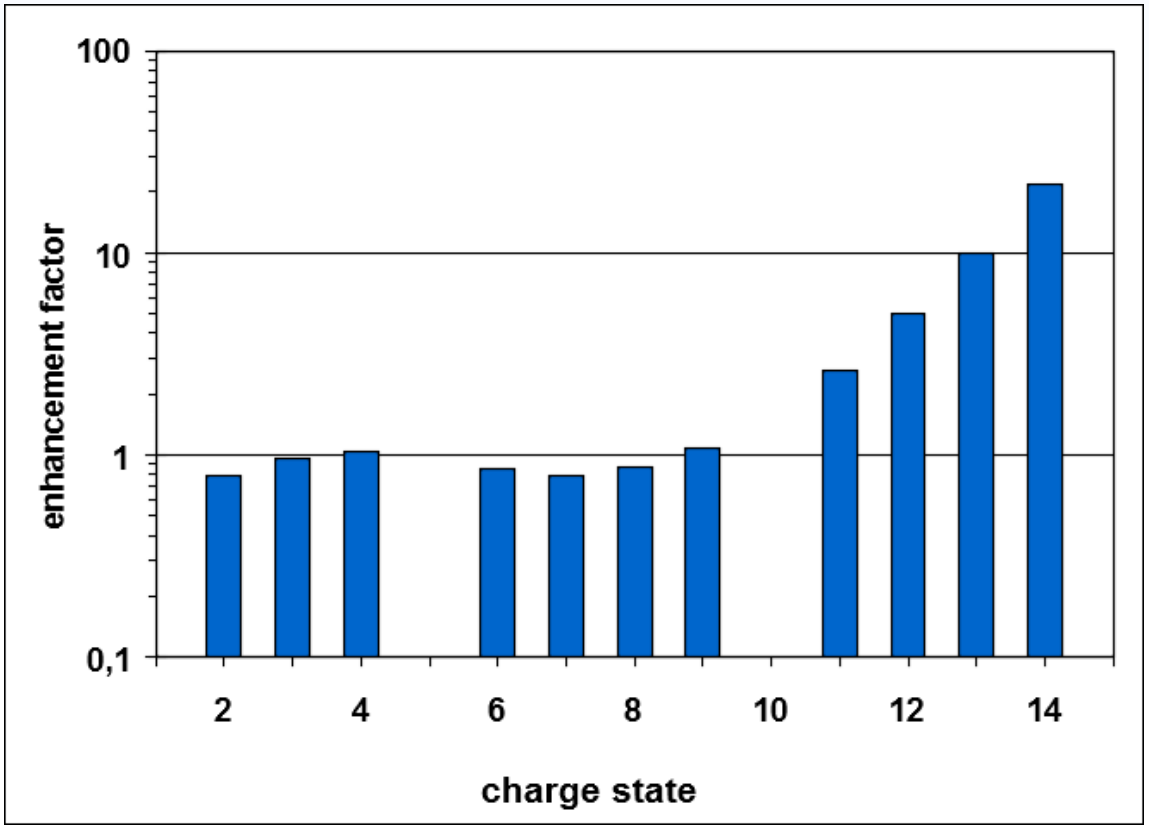
→ the emission of all charge states is enhanced by 30-90% compared to the reference (all stainless steel) source.

[1] L.Sch

The MD-method

Analysis in terms of an *enhancement factor:*

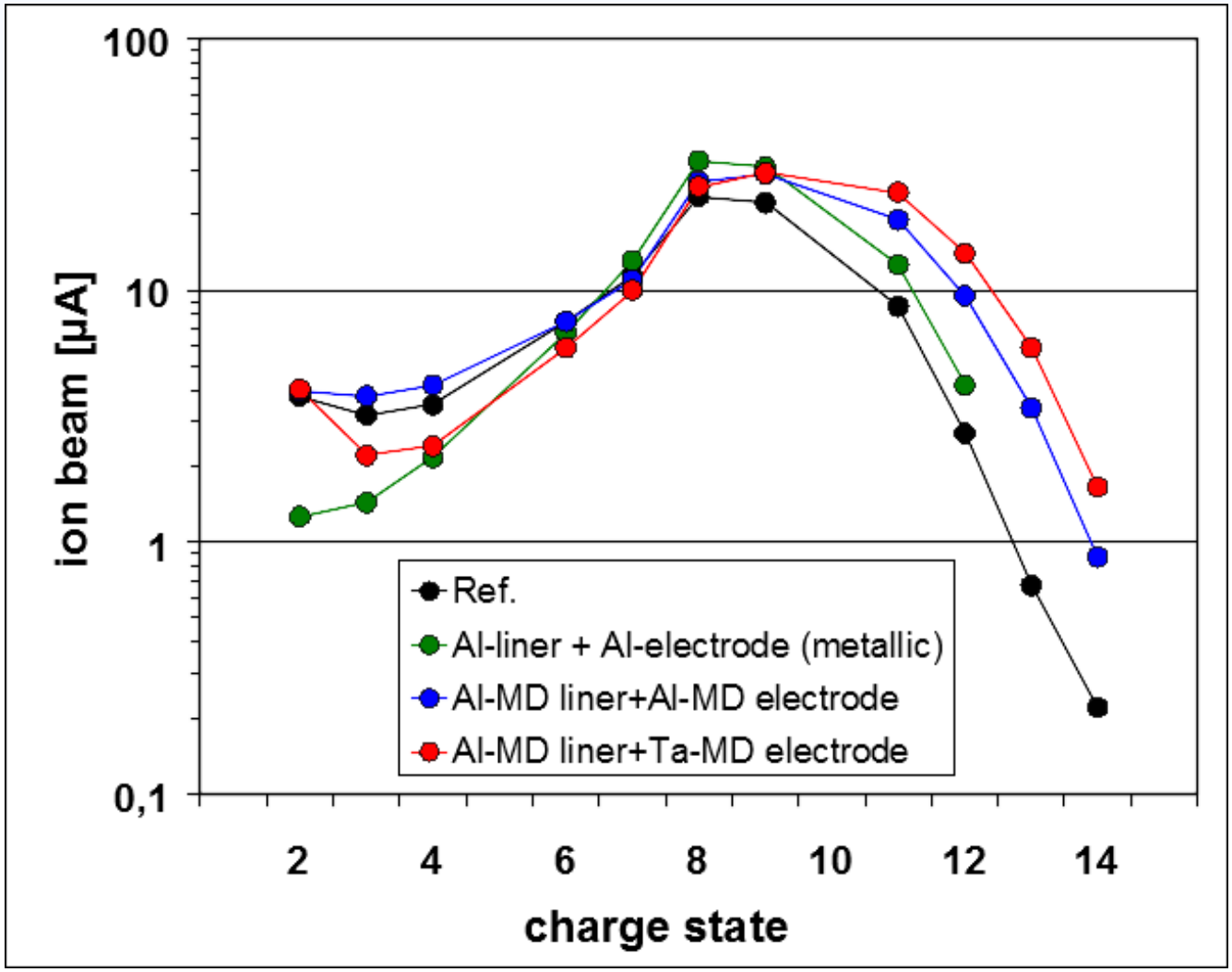
$$\varepsilon = I_{ion}n^{+}_{(Al\text{-}MD)} \;/\; I_{ion}n^{+}_{(stainless\ steel)}$$



ε higher than 20 for Ar^{14+} !

The MD-method

comparing Al-liner with Al_2O_3 -MD-structure



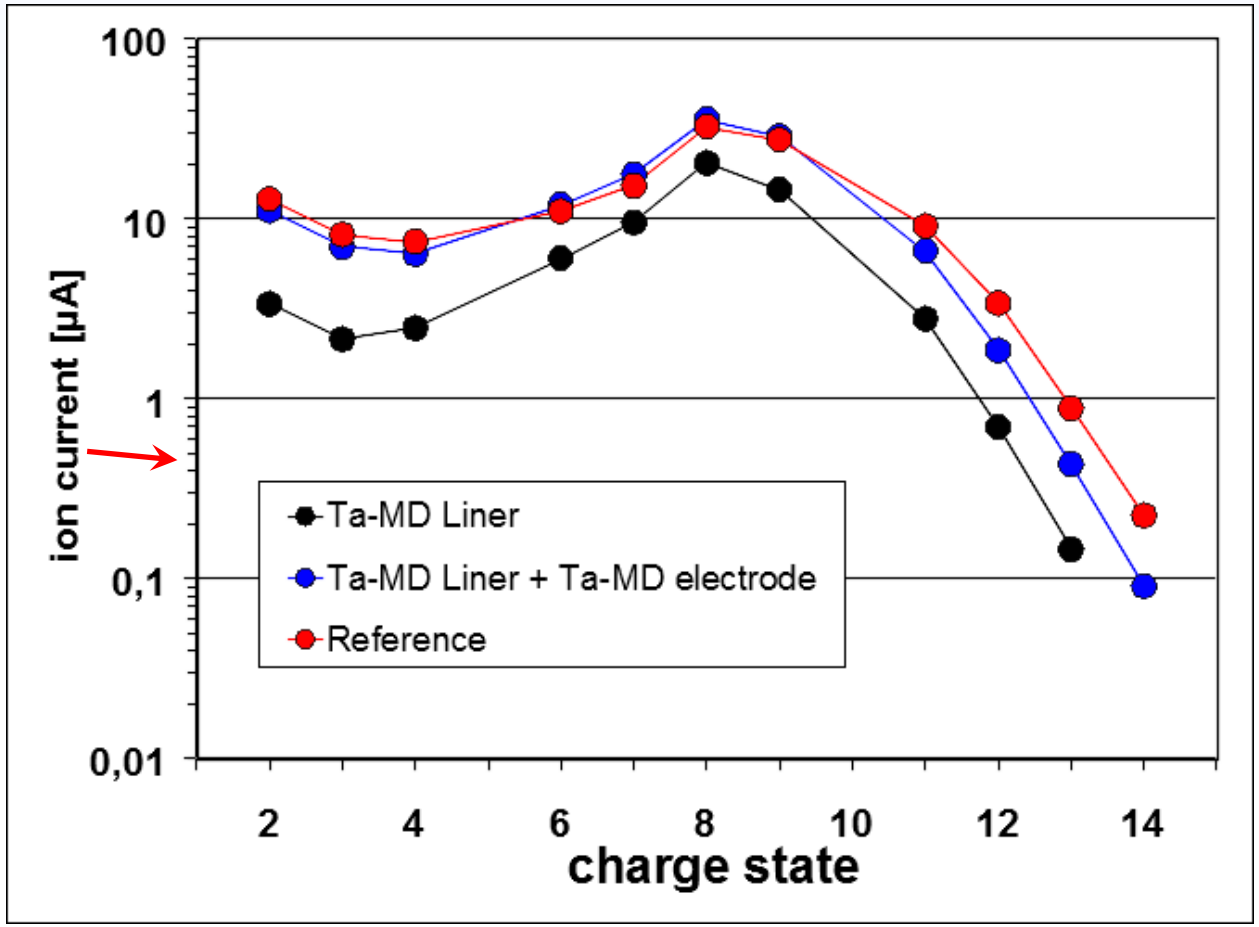
→ Al-liner doesn't change the shape of CSD significantly towards higher charge states

→ Ta-MD electrode allows for extraction of higher currents of highly-charged ions as Al-MD electrode!

Ar^{14+}, P_{RF}= 1000 Watt

The MD-method

Using a MD-structure without significant secondary electron emission



Ta-MD-structure:

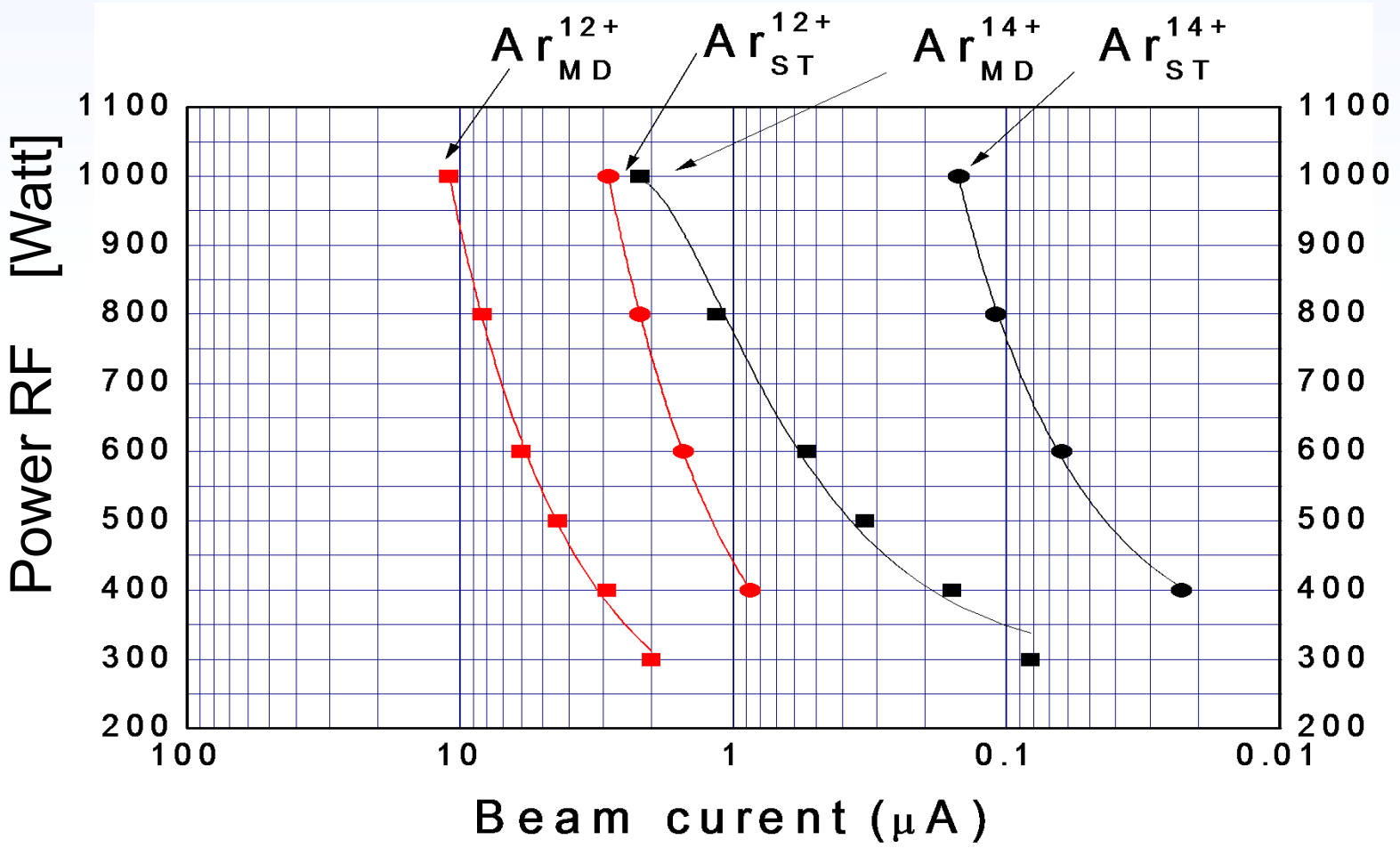
→ strongly reduced output from the source. The Ta-MD liner is just an insulator without markable emission of secondary electrons and obviously

→ does not change the shape of the CSD.

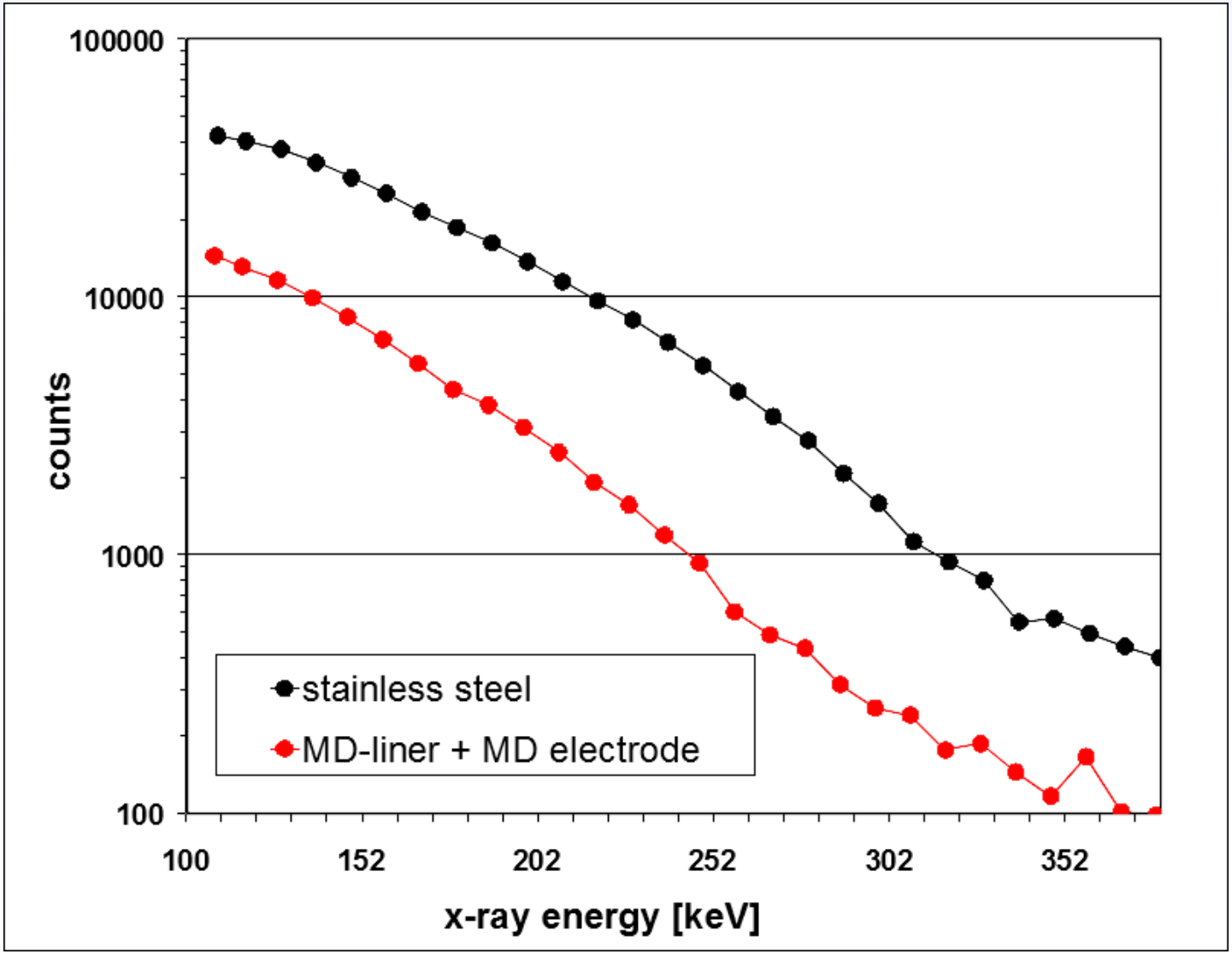
→ Also in this scenario, the Ta-MD electrode considerably improves the extraction of ions by suppressing ion losses to the wall at the extraction hole.

Ar^{14+}, P_{RF}= 1000 Watt

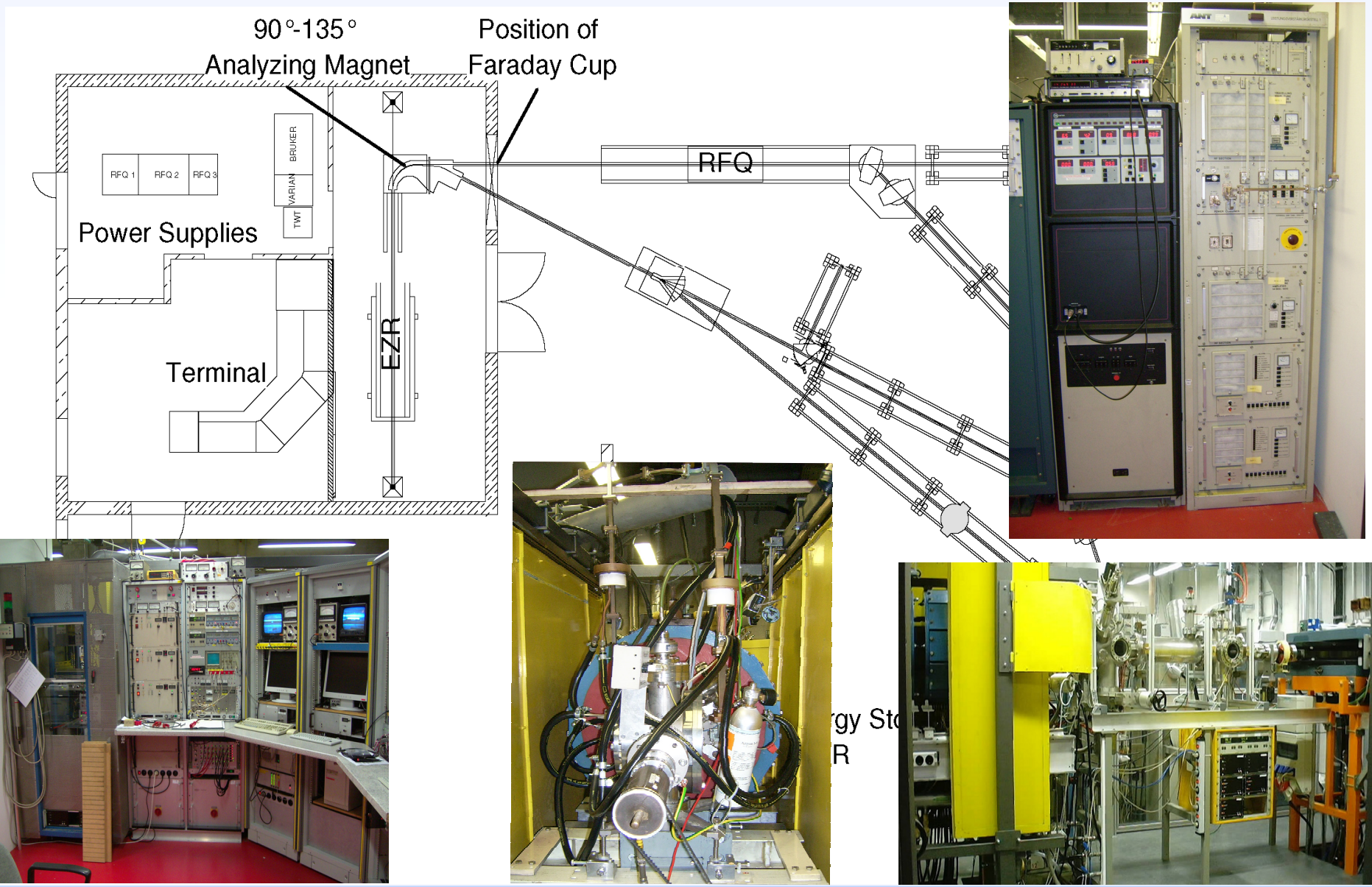
The MD-method



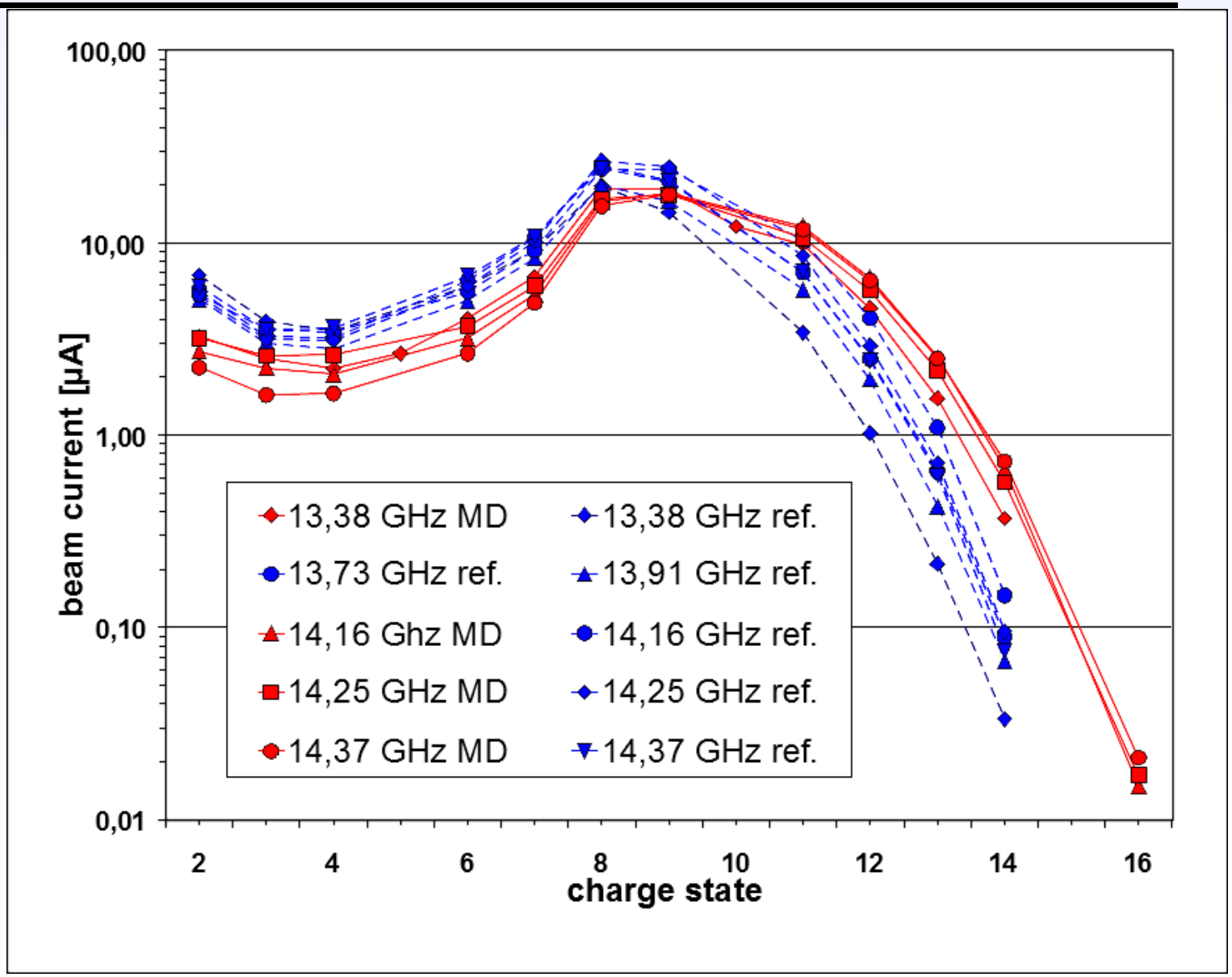
The MD-method



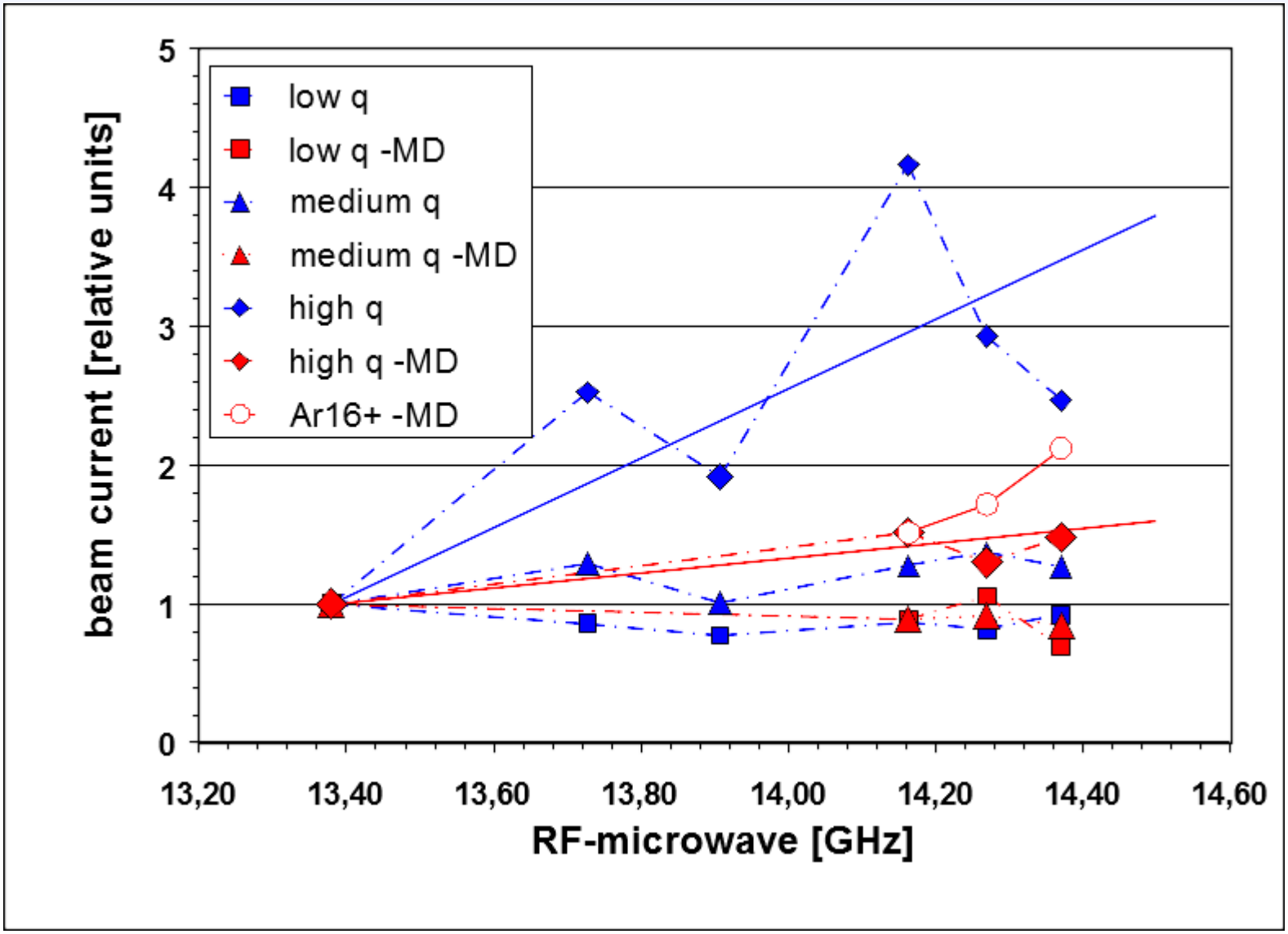
The IKF-14GHz ECRIS Installation



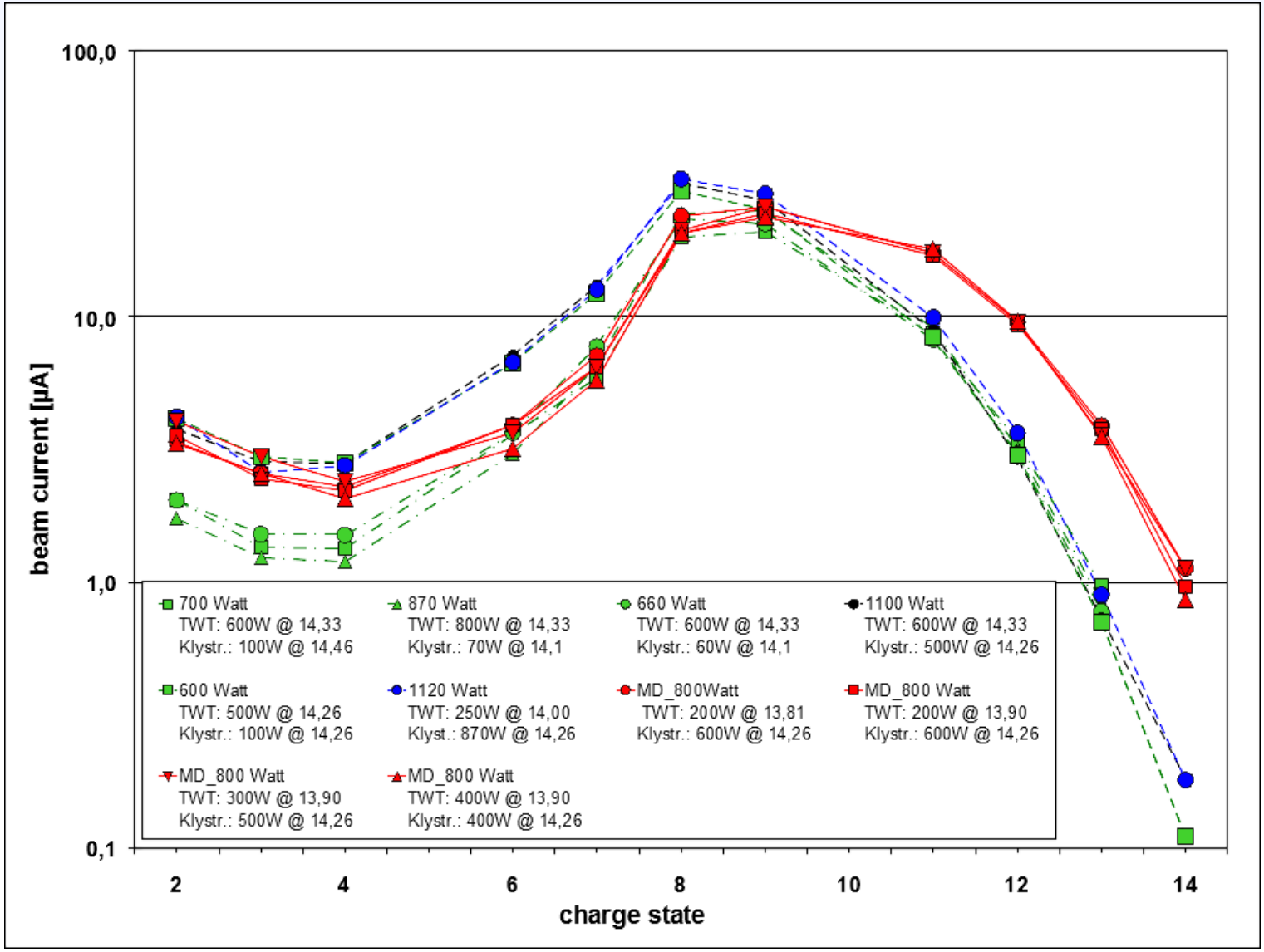
Results


100,00
10,00
1,00
0,10
0,01
beam current [µA]
2
4
6
8
10
12
14
16
charge state
13,38 GHz MD
13,38 GHz ref.
13,73 GHz ref.
13,91 GHz ref.
14,16 Ghz MD
14,16 GHz ref.
14,25 GHz MD
14,25 GHz ref.
14,37 GHz MD
14,37 GHz ref.

Results


beam current [relative units]
RF-microwave [GHz]
low q
low q -MD
medium q
medium q -MD
high q
high q -MD
Ar16+ -MD
0
1
2
3
4
5
13,20
13,40
13,60
13,80
14,00
14,20
14,40
14,60

Results


100,0
10,0
1,0
0,1
beam current [µA]
2
4
6
8
10
12
14
charge state
700 Watt
TWT: 600W @ 14,33
Klystr.: 100W @ 14,46
870 Watt
TWT: 800W @ 14,33
Klystr.: 70W @ 14,1
660 Watt
TWT: 600W @ 14,33
Klystr.: 60W @ 14,1
1100 Watt
TWT: 600W @ 14,33
Klystr.: 500W @ 14,26
600 Watt
TWT: 500W @ 14,26
Klystr.: 100W @ 14,26
1120 Watt
TWT: 250W @ 14,00
Klyst.: 870W @ 14,26
MD_800Watt
TWT: 200W @ 13,81
Klystr.: 600W @ 14,26
MD_800 Watt
TWT: 200W @ 13,90
Klystr.: 600W @ 14,26
MD_800 Watt
TWT: 300W @ 13,90
Klystr.: 500W @ 14,26
MD_800 Watt
TWT: 400W @ 13,90
Klystr.: 400W @ 14,26

Summary

METHOD	INTENSITY GAIN				REFERENCE
	Ar^{12+}	Ar^{13+}	Ar^{14+}	Ar^{16+}	
DFH/SFH	-	1.13	1.38	1.6	[1] (10+14.5) GHz / 14.5 GHz
DFH/SFH	1.74	2.02	1.07	-	[2] (10+14.5) GHz/ 14.6 GHz
FT(MD)/SFH(MD)	1.04	1.06	1.0	-	IKF this experiment
FT(MD)/standard	5	10	20	-	IKF best results for good MD performance
DFH/SFH	Xe^{30+}	Xe^{31+}	Xe^{35+}	Xe^{38+}	[3] (24+18) GHz/ 24 GHz
	1.55	2.44	1.42	1.33	

[1] Z. Q. Xie, C. M. Lyneis, *Rev. Sci. Instrum.*, ***66***, *8, 1995*

[2] R. C. Vondrasek, R. Scott, R. C. Pardo, *Rev. Sci. Instrum.* ***77***, *03A337, 2006*

[3] H. W. Zhao, W. Lu, X. Z. Zhang, Y. C. Feng, J. W. Guo, Y. Cao, J. Y. Li, X. H. Guo, S. Sha, L. T. Sun and D. Z. Xie *Rev. Sci. Instrum.* ***83***, *02A320 (2012)*