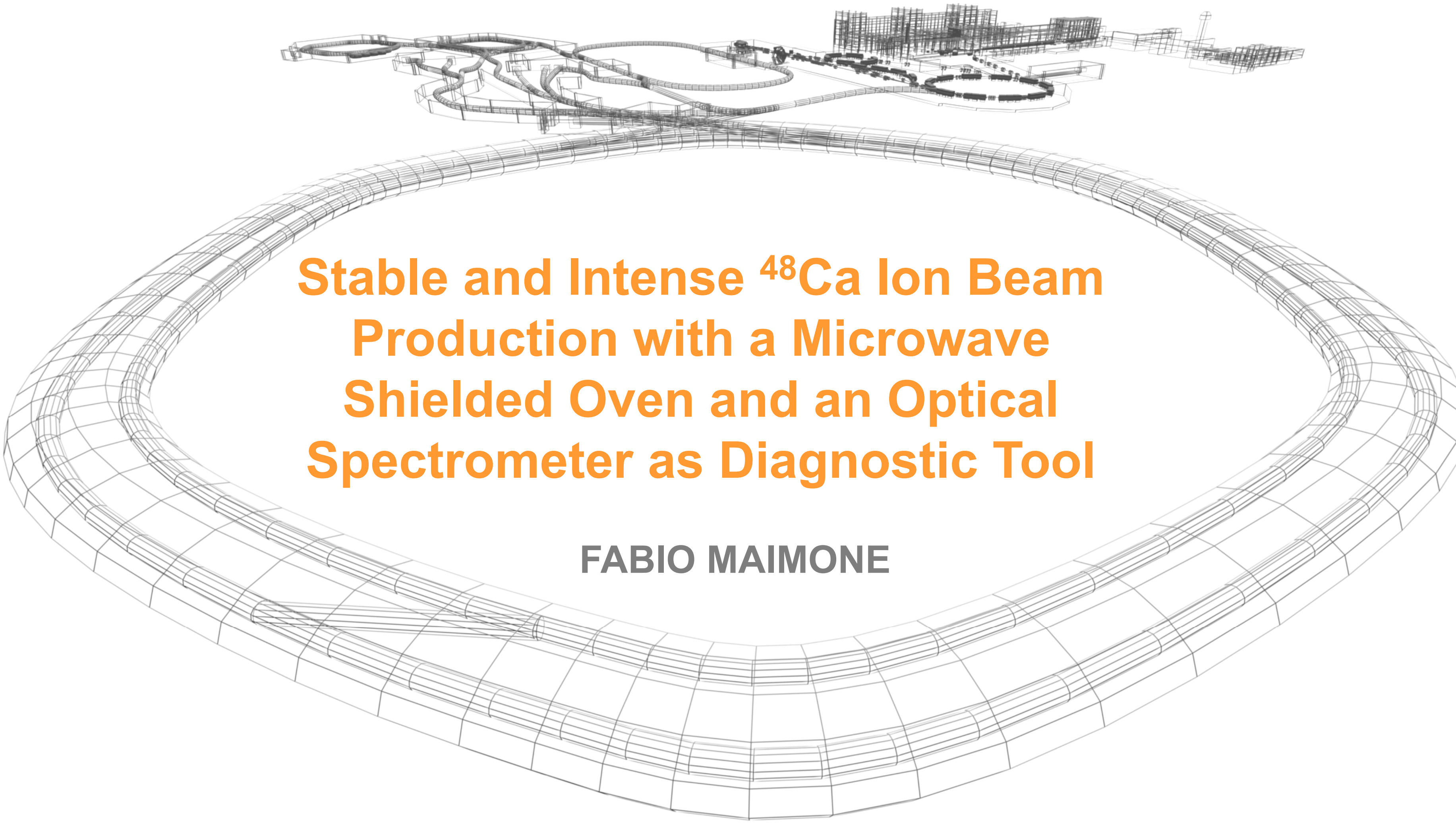


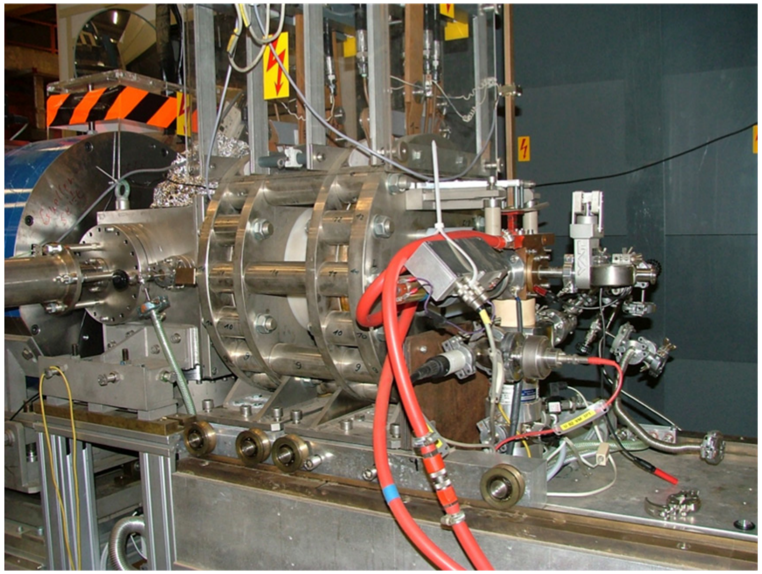
Stable and Intense ^{48}Ca Ion Beam Production with a Microwave Shielded Oven and an Optical Spectrometer as Diagnostic Tool

FABIO MAIMONE

„Poster“ Outline

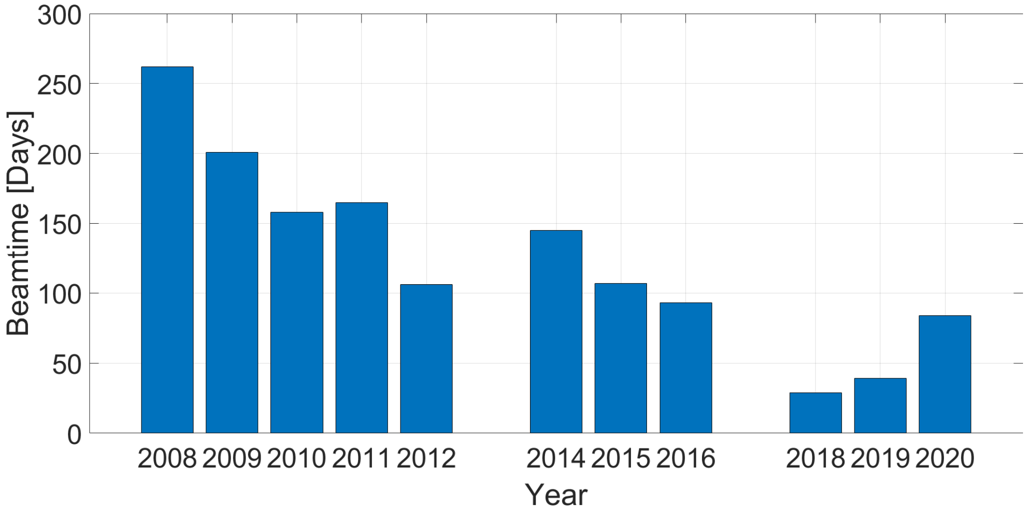
- Optical emission spectroscopy diagnostics implemented at the high charge states injector of GSI
- Microwave shielding of Standard Evaporation Oven for stable metal ion beam production and operation
- Achievements in Ca ions beams production

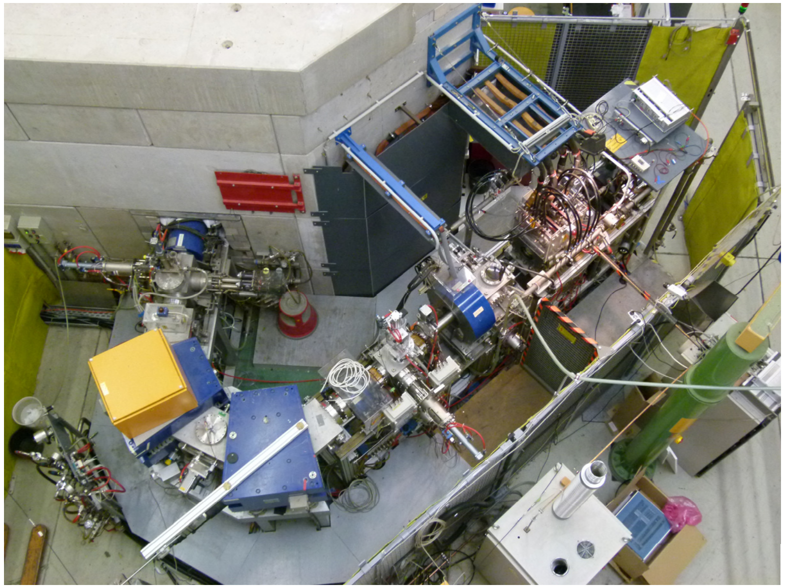
High Charge States Injector (HLI)



CAPRICE ECRIS MAIN PARAMETERS

Hexapole field	1...1,2 T
Solenoid field	0,8...1,5 T
µW-power	10...800 W (CW mode)
µW-frequency	14.5 (12,4...16) GHz
Extraction Voltage [kV]	≤ 22
Ion Species	Gas + Metal
Mode	CW or Pulsed





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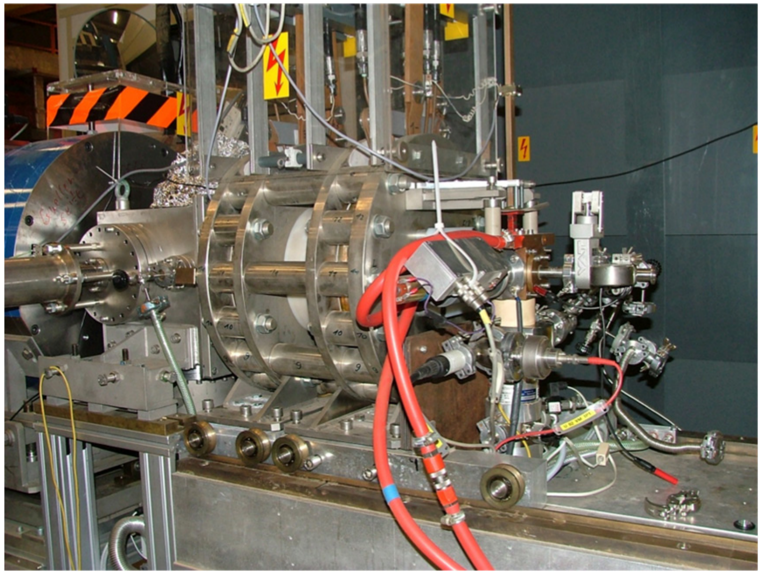

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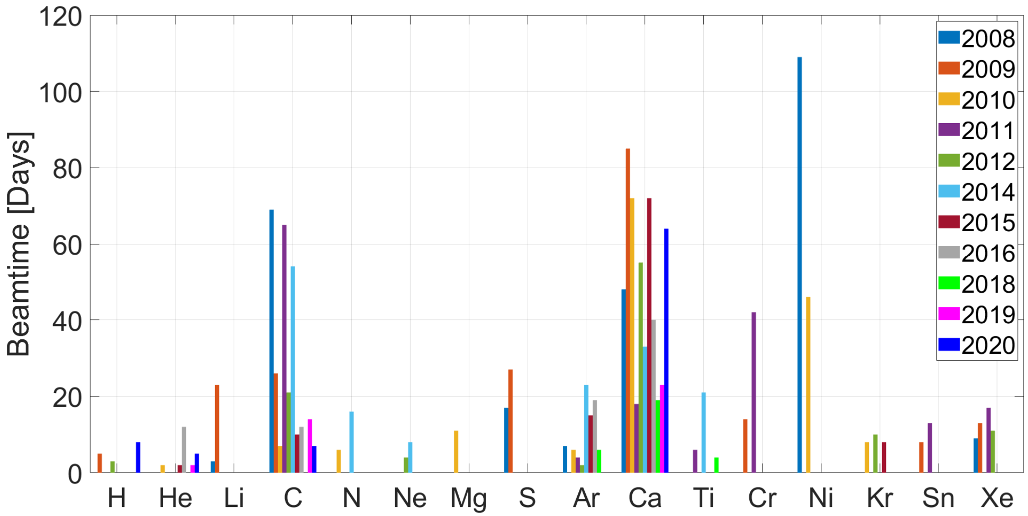
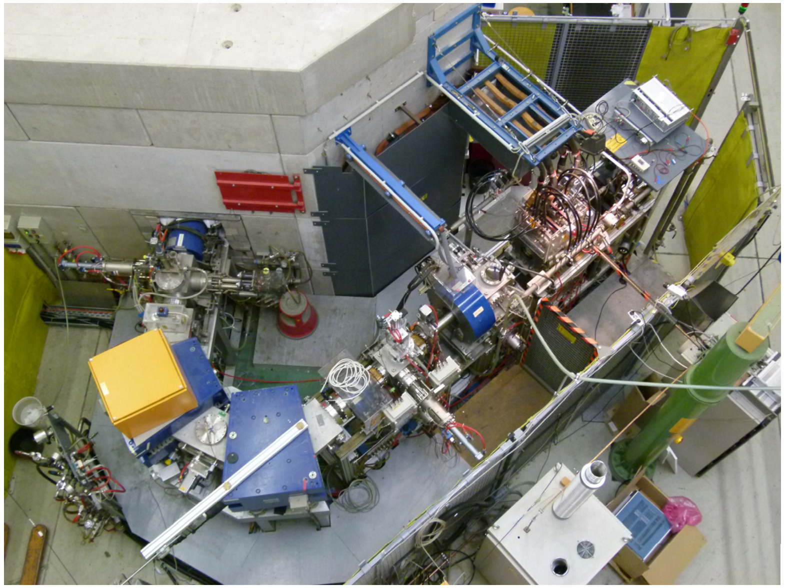
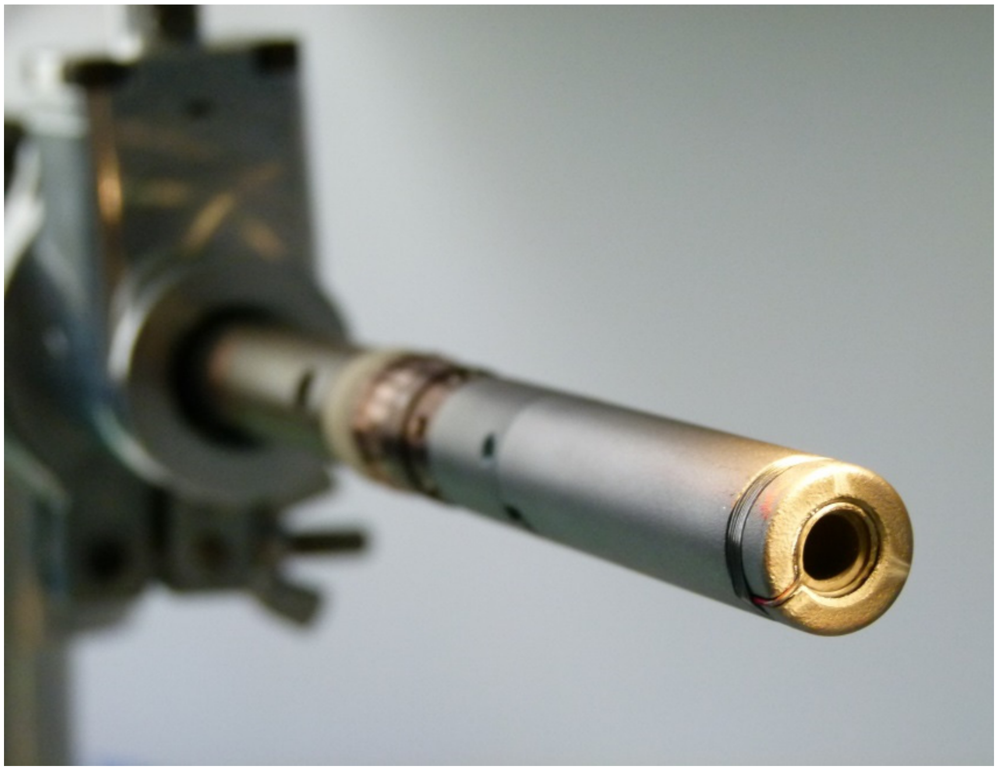




Evaporation technique for metal ion beam production

Standard Temperature Oven (STO)

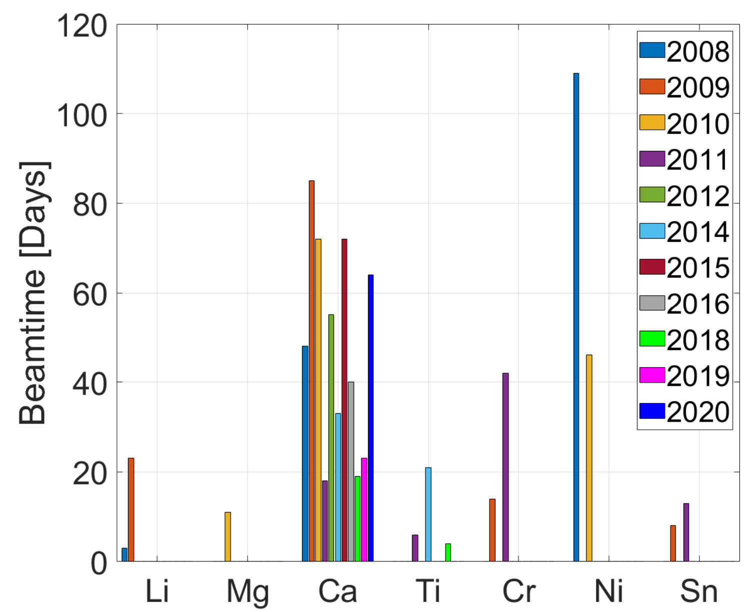


LAYOUT

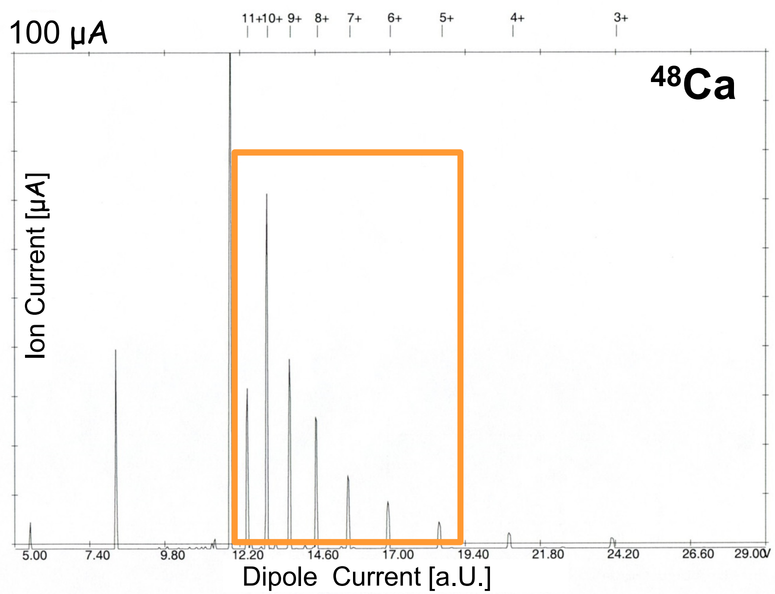
- Central current entry
- Heating helix on ceramic body
- Water cooled support tube
- Crucible or aperture ring

OPERATING PARAMETERS

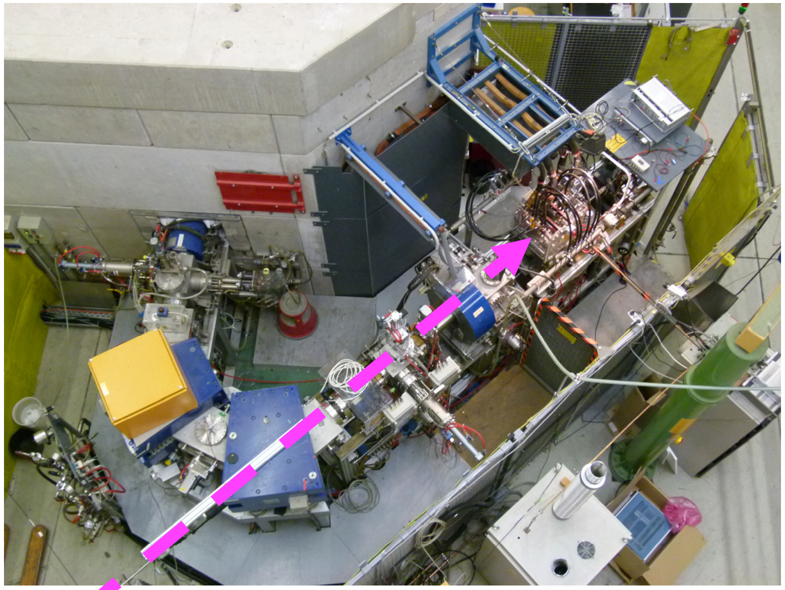
- Power: 2-120W
- Temperature: 400 -1550°C
- Consumption: 0,2 – 5 mg/h
- Lifetimes days: ^{48}Ca $\leq$ 30, ^{64}Ni $\leq$ 6



^{48}Ca charge states distributions and plasma images

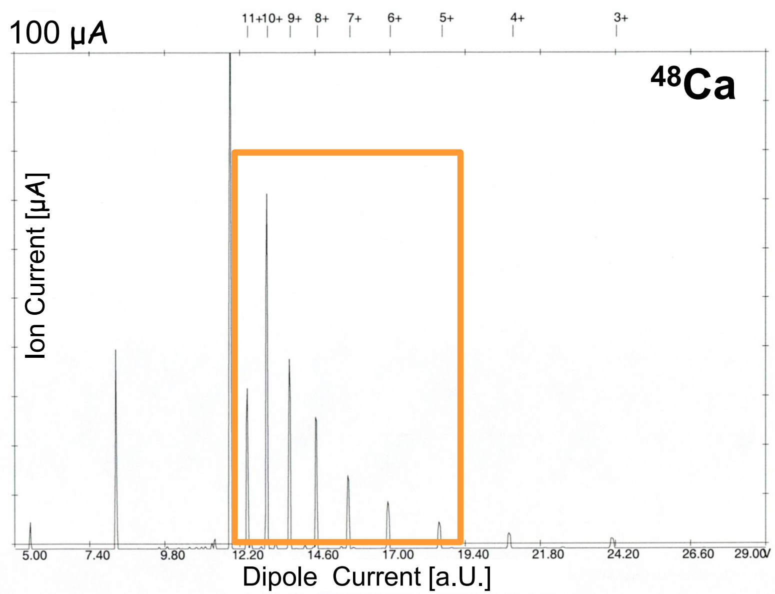


Spectrum of ^{48}Ca + He optimized on $^{48}Ca^{10+}$



A CCD camera looks through the straight beam line and the extraction aperture into the plasma chamber.

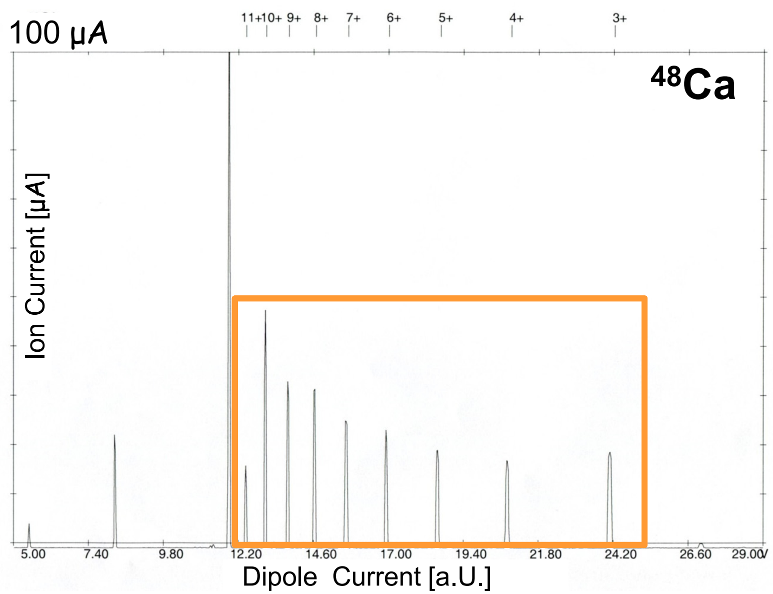
^{48}Ca charge states distributions and plasma images



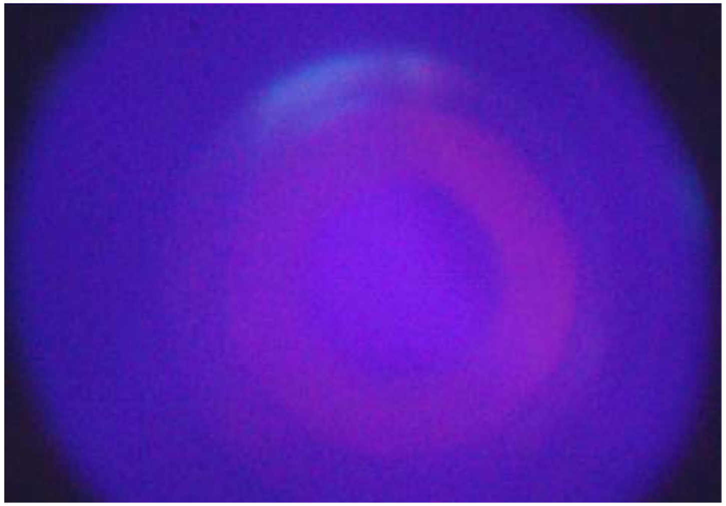
Spectrum of ^{48}Ca + He optimized on $^{48}Ca^{10+}$

Plasma image recorded with the CCD camera

^{48}Ca charge states distributions and plasma images

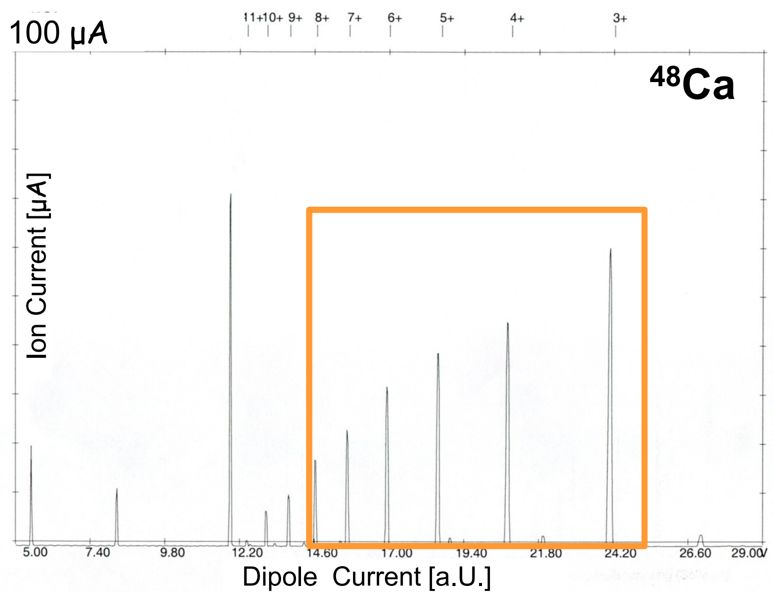


Spectrum of ^{48}Ca + He optimized on $^{48}Ca^{10+}$ after an excessive oven power increase

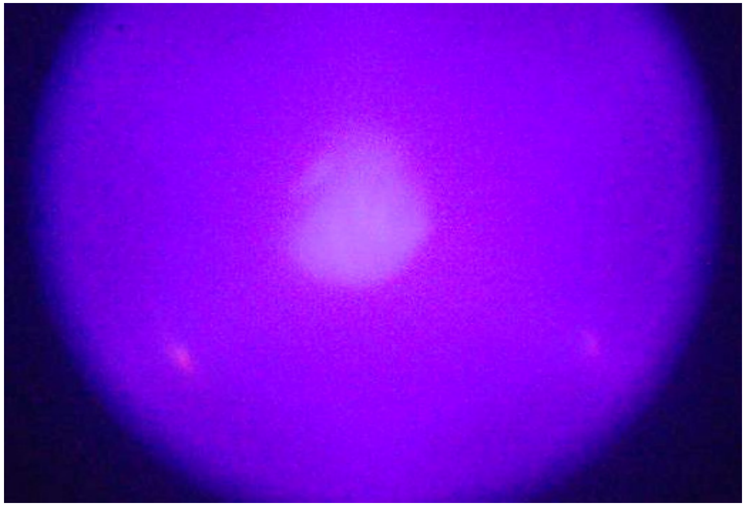


Plasma image recorded with the CCD camera

^{48}Ca charge states distributions and plasma images

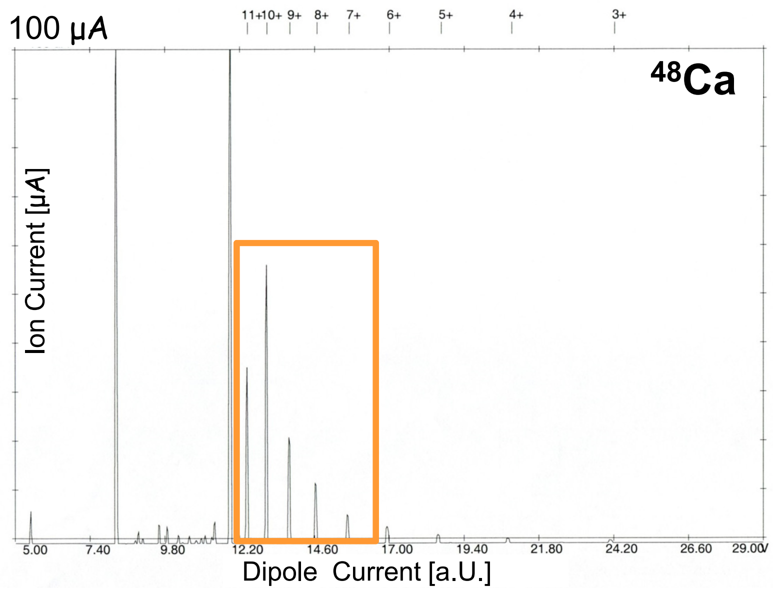


Spectrum of ^{48}Ca + He optimized on $^{48}Ca^{10+}$ during an over heating of the oven

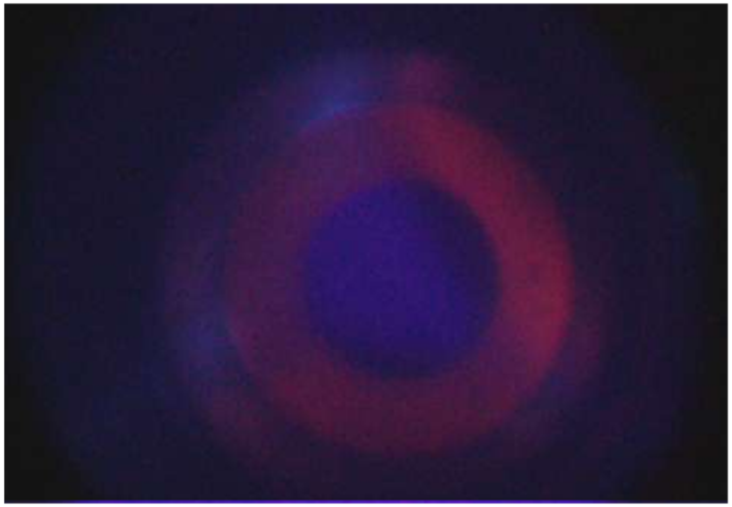


Plasma image recorded with the CCD camera

^{48}Ca charge states distributions and plasma images

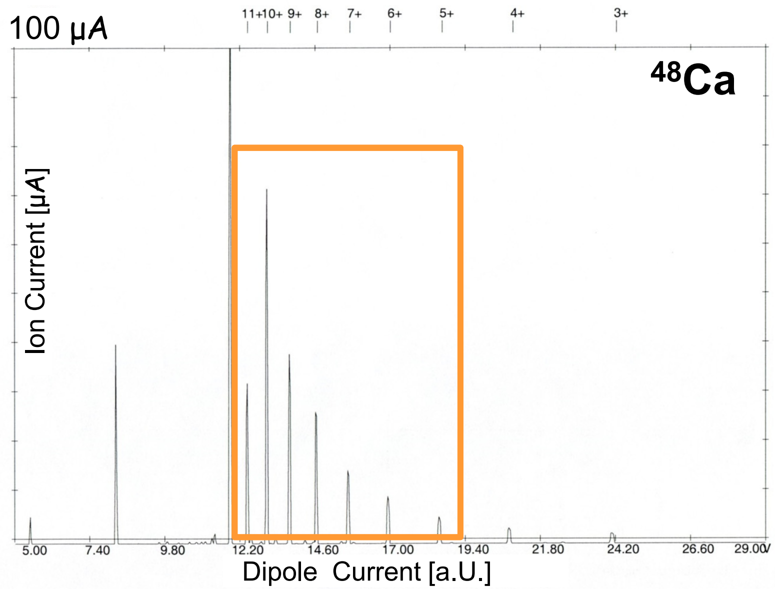


Spectrum of ^{48}Ca + He optimized on $^{48}Ca^{10+}$ after a power reduction of the oven



Plasma image recorded with the CCD camera

^{48}Ca charge states distributions and plasma images



Spectrum of ^{48}Ca + He re-optimized on $^{48}Ca^{10+}$

Plasma image recorded with the CCD camera

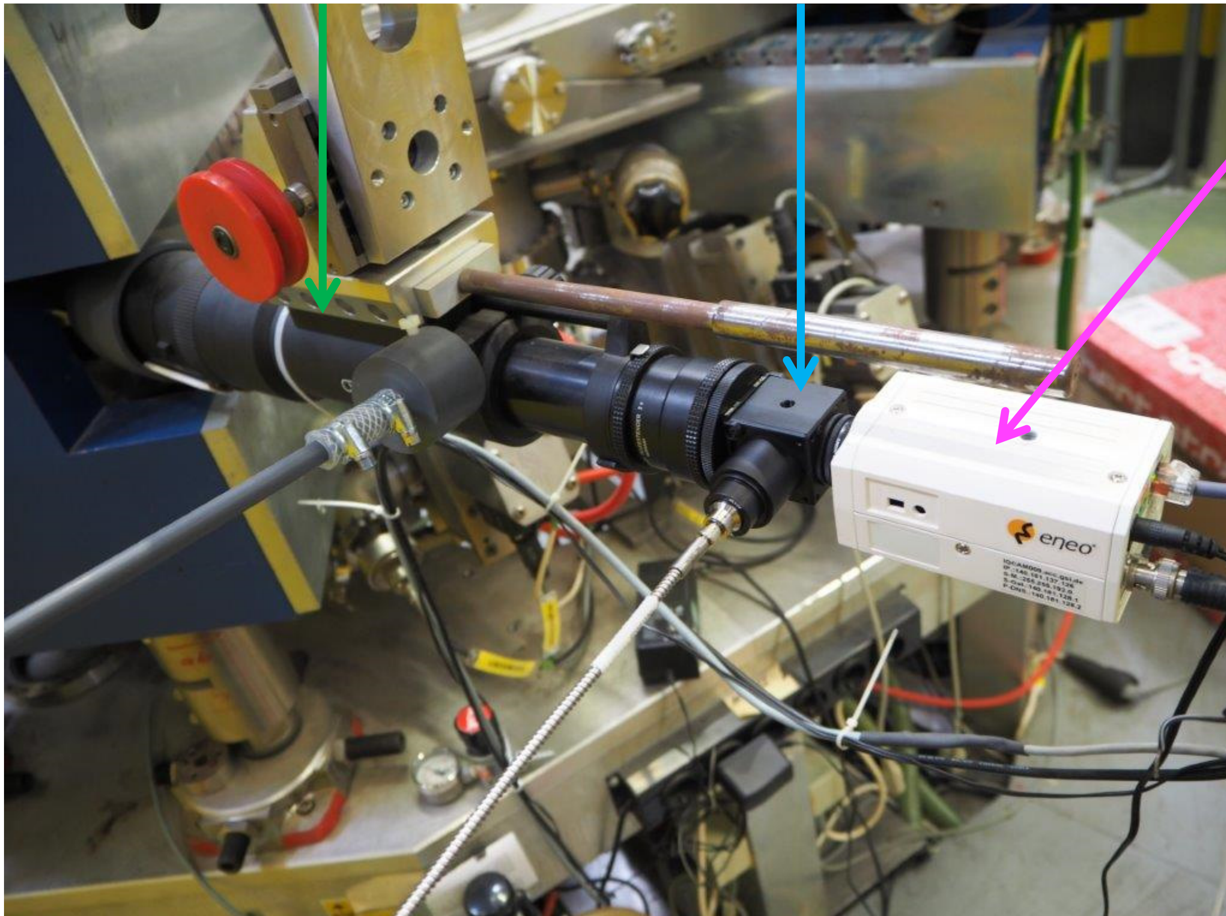
Hours of beam time wasted, consumption increase of expensive material and experimentalist disappointment.

Optical diagnostic devices at HLI

Telephoto Lens

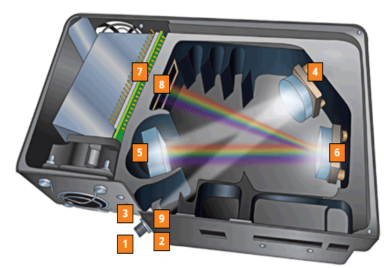
Optical Beam Splitter and Glass Fiber

CCD Camera



OCEAN OPTICS QE Pro

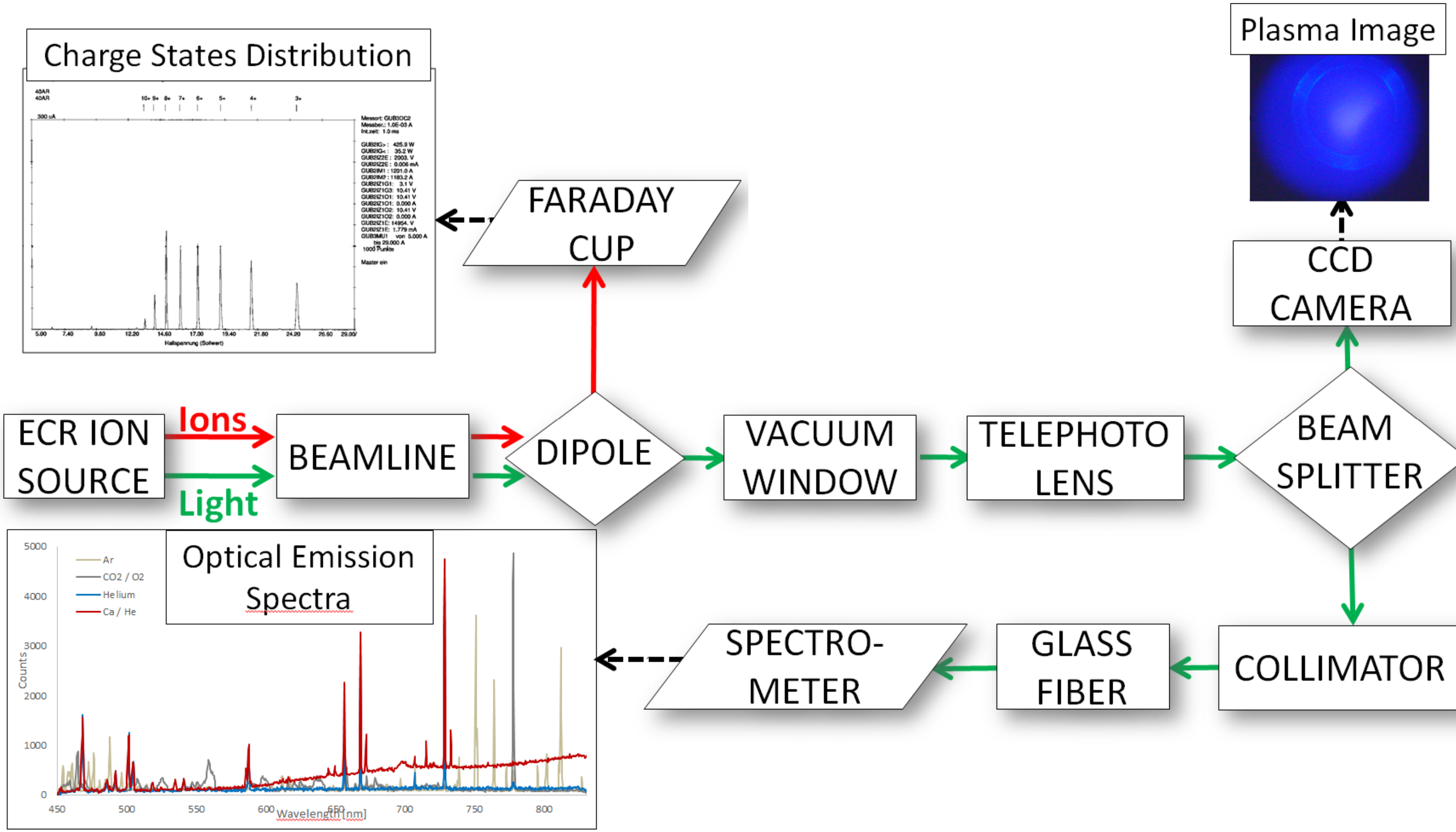
Entrance slits: 25 µm
Wavelenght Range 449-833 nm
Resolution 0.95 nm



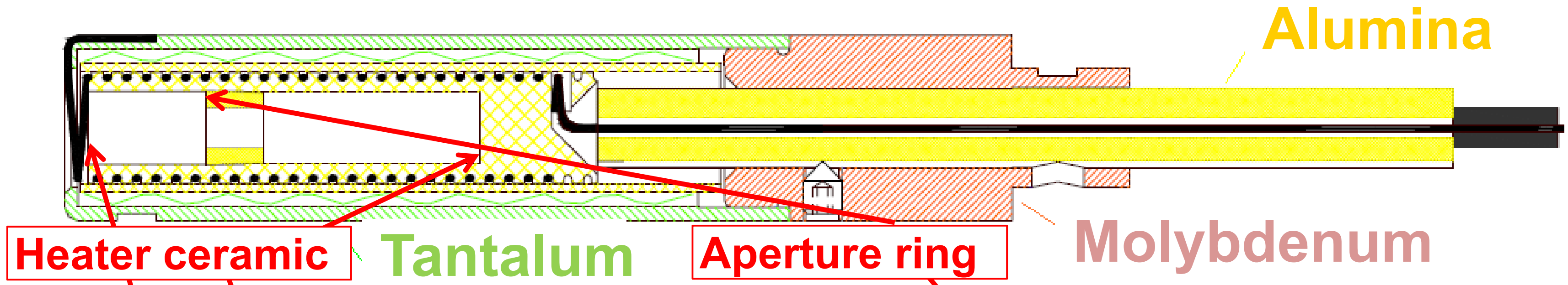
https://www.oceaninsight.com

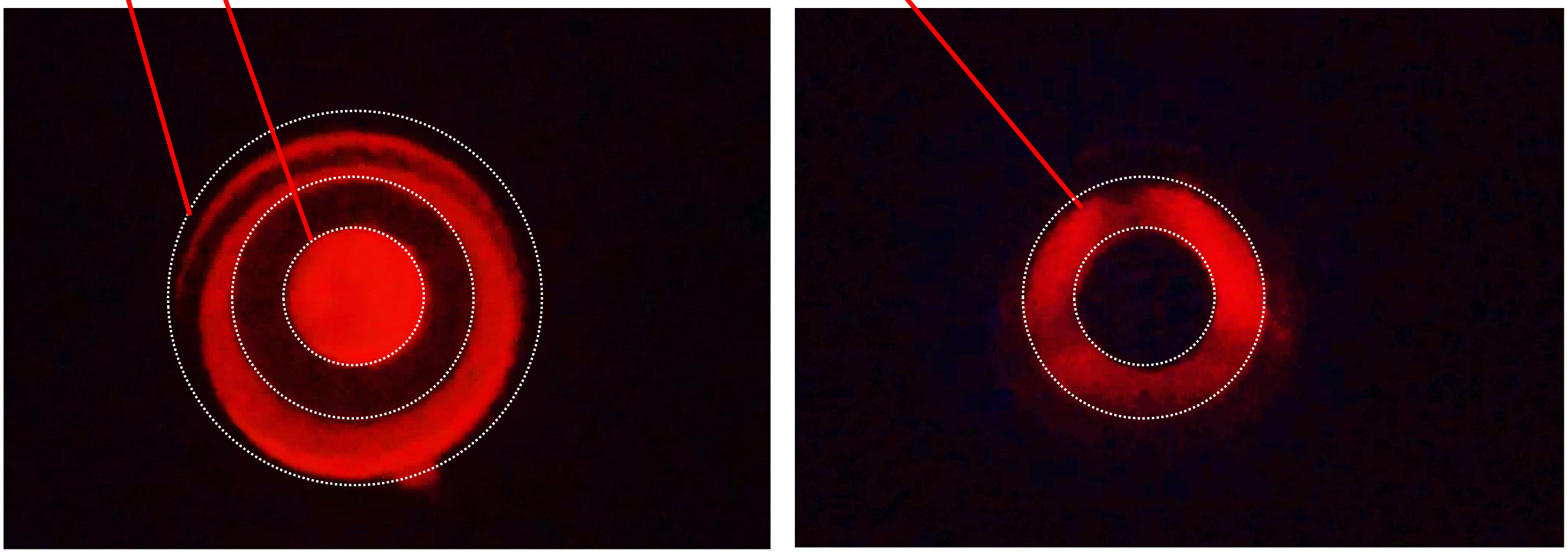
..to the Optical Emission Spectrometer

HLI diagnostic devices set-up



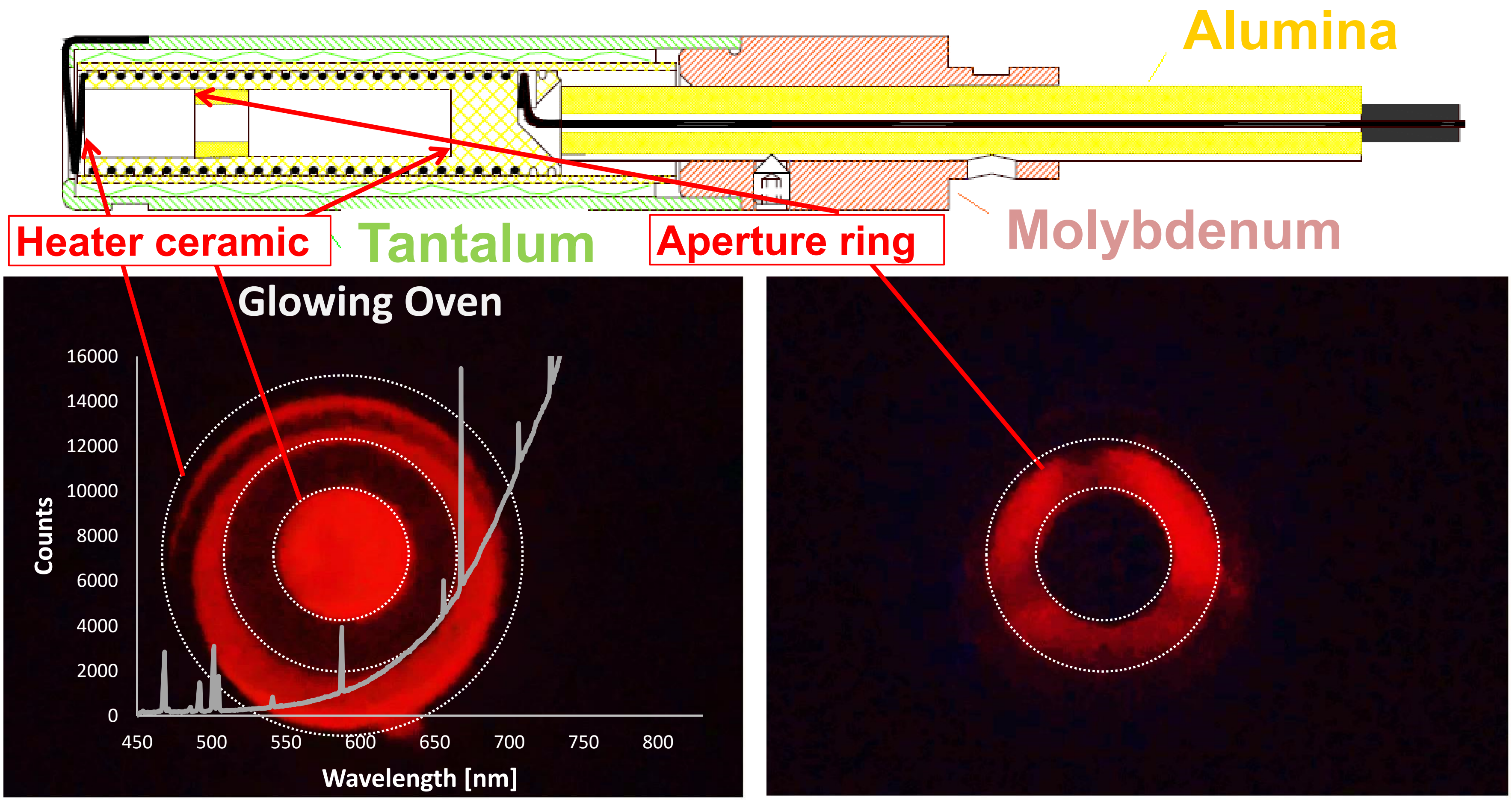
Optical Emission Spectroscopy on a Standard Temperature Oven





Oven heating: CCD Camera images and Optical Emitted Spectrum

Optical Emission Spectroscopy on a Standard Temperature Oven



Oven heating: CCD Camera images and Optical Emitted Spectrum

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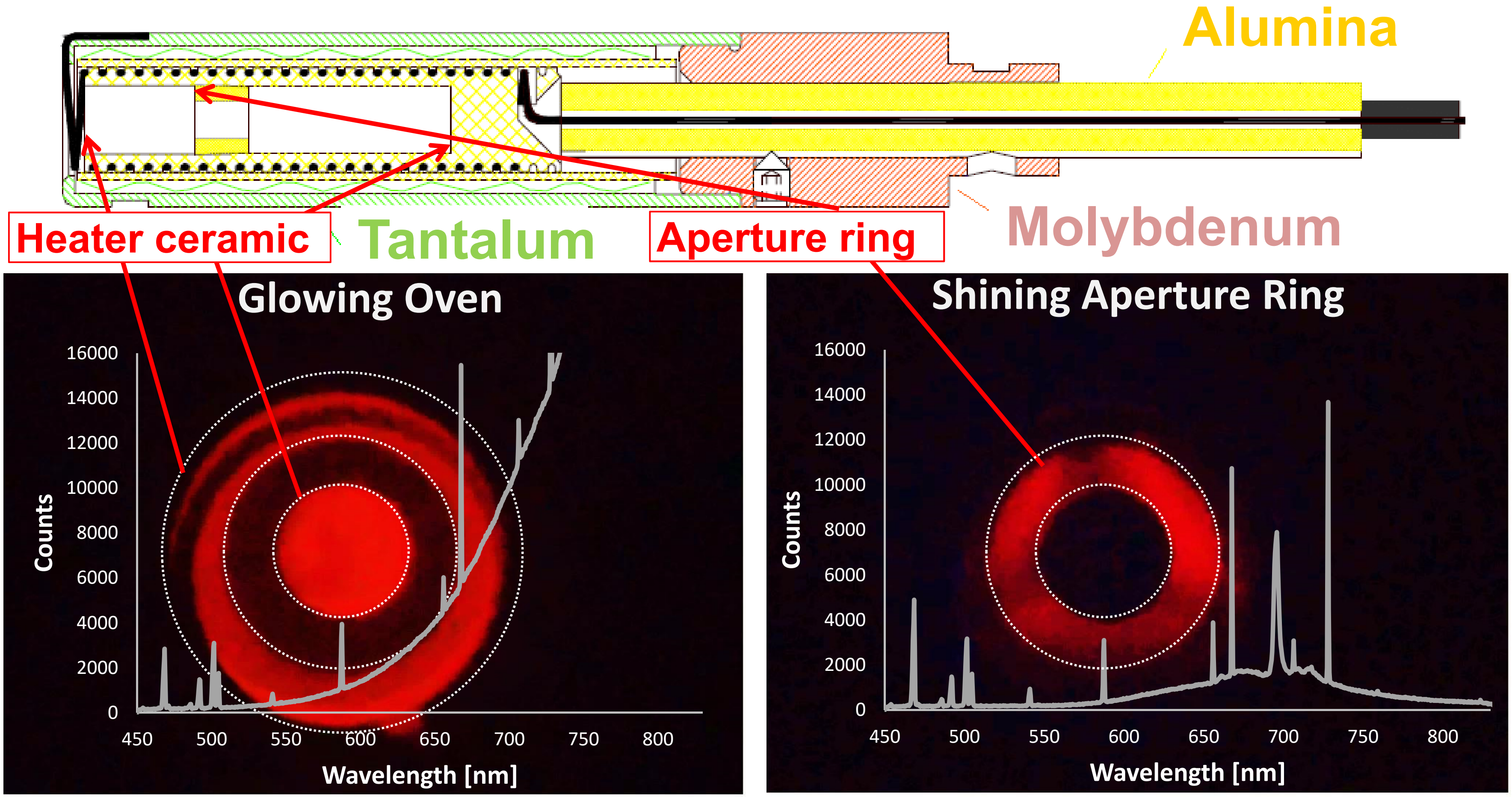


Oven heating: CCD Camera images and Optical Emitted Spectrum

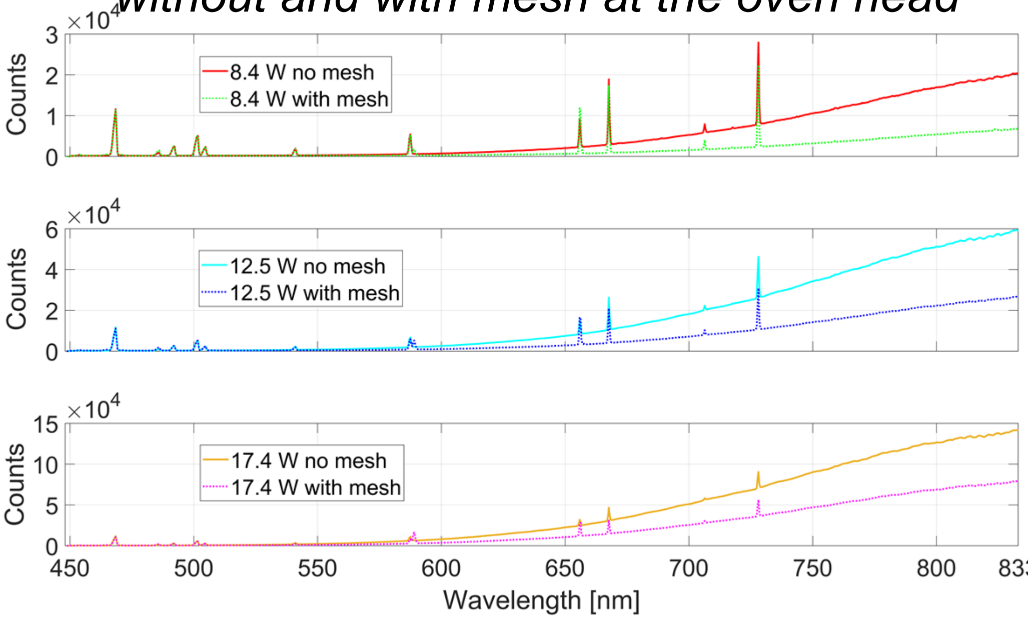
Microwave shielding of the oven orifice

MICROWAVE SHIELDING

- Material: Tungsten
- Mesh 18 (1 mm) - 50 µm wire

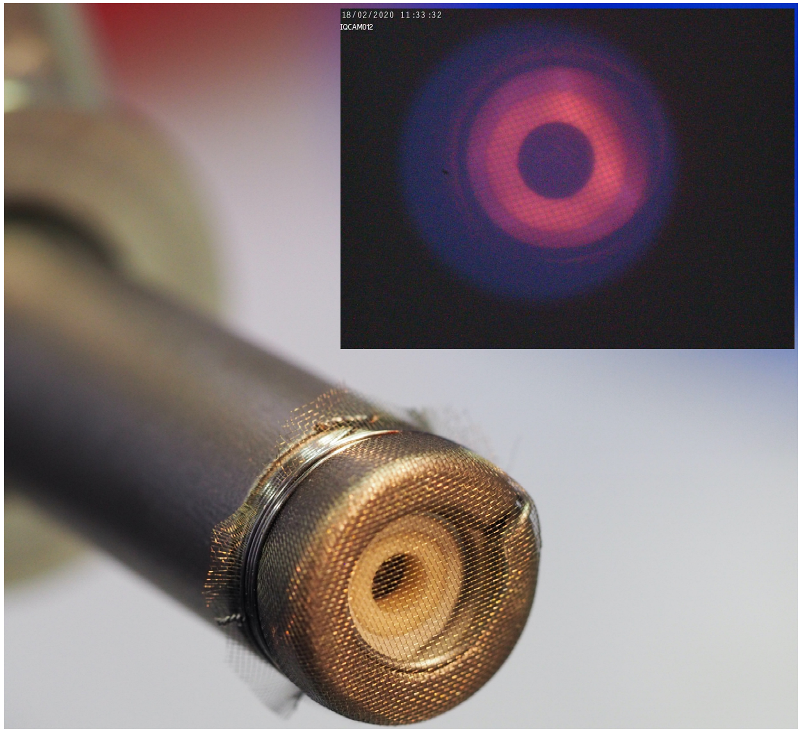
Optical spectroscopy as a diagnostic tool for metal ion beam production with an ECRIS
F.*Maimone, J.Mäder, R.Lang, P.T.Patchakui, K.Tinschert R.Hollinger* , Rev. Sci. Instrum. 90, 123108, 2019

OES measurements for different oven powers without and with mesh at the oven head



- Measurements carried out with the shielded empty oven inserted inside the ECRIS.
- Helium plasma generated by coupling up to 650 W microwave power.
- Oven power settings: 8.4, 12.5, 17.4 W.
- Up to 69% shielding due to the mesh.

Microwave shielding of the oven orifice



MICROWAVE SHIELDING

- Material: Tungsten
- Mesh 100 (149 µm) – 25.4 µm wire

Optical spectroscopy as a diagnostic tool for metal ion beam production with an ECRIS
F.*Maimone, J.Mäder, R.Lang, P.T.Patchakui, K.Tinschert R.Hollinger* , Rev. Sci. Instrum. 90, 123108, 2019

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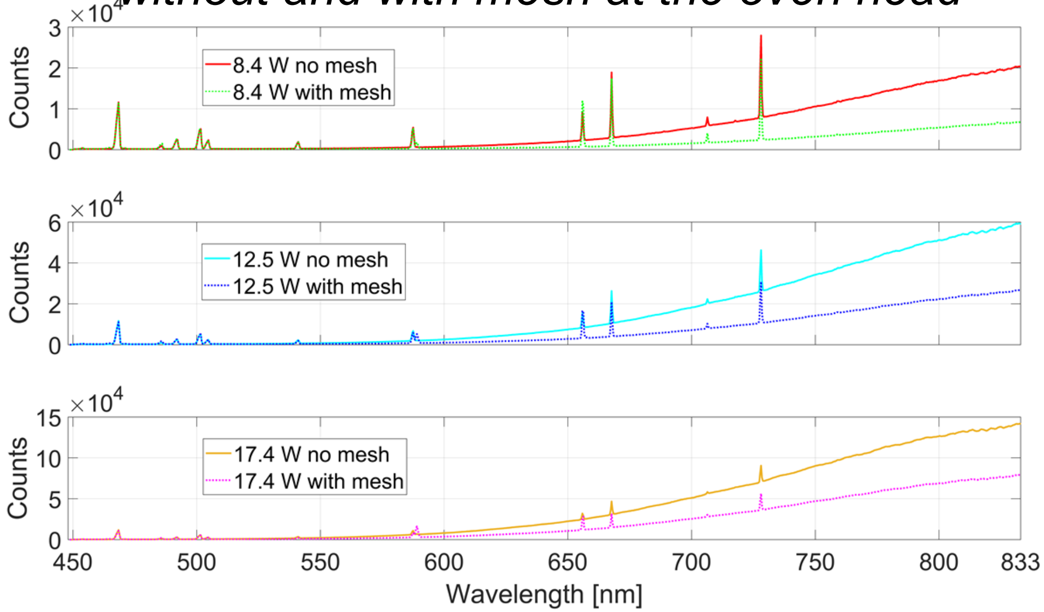

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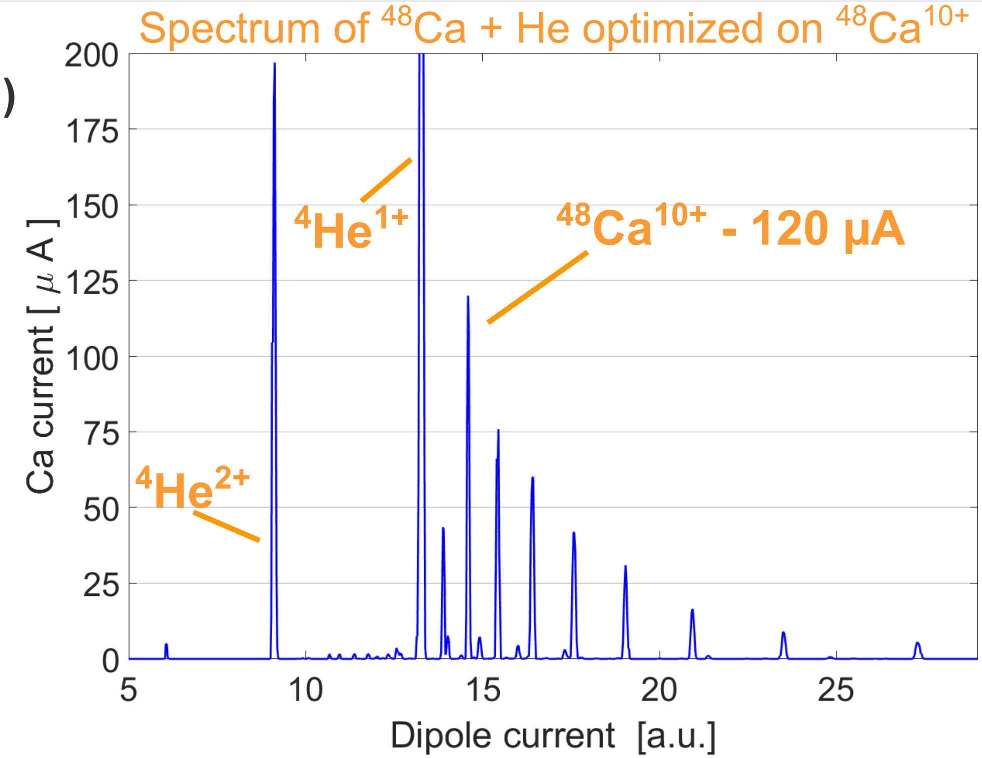
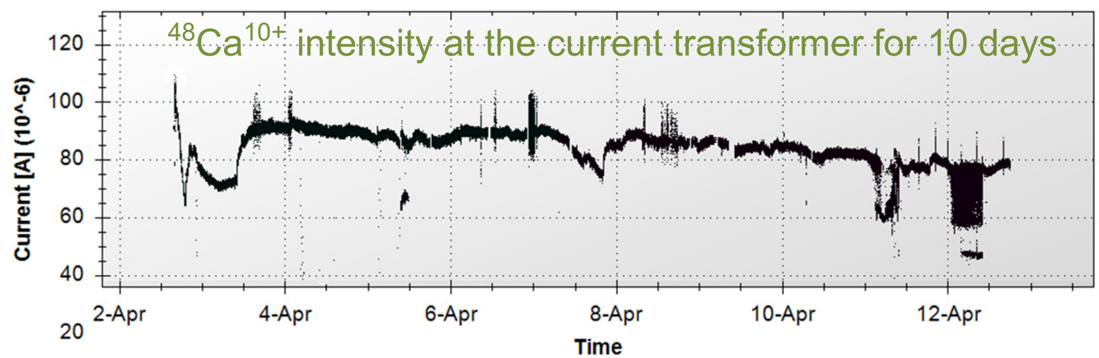
- Oven power settings: 8.4, 12.5, 17.4 W.
- Up to 69% shielding due to the mesh.
- **Succesfull test at EIS testbench with ^{40}Ca**

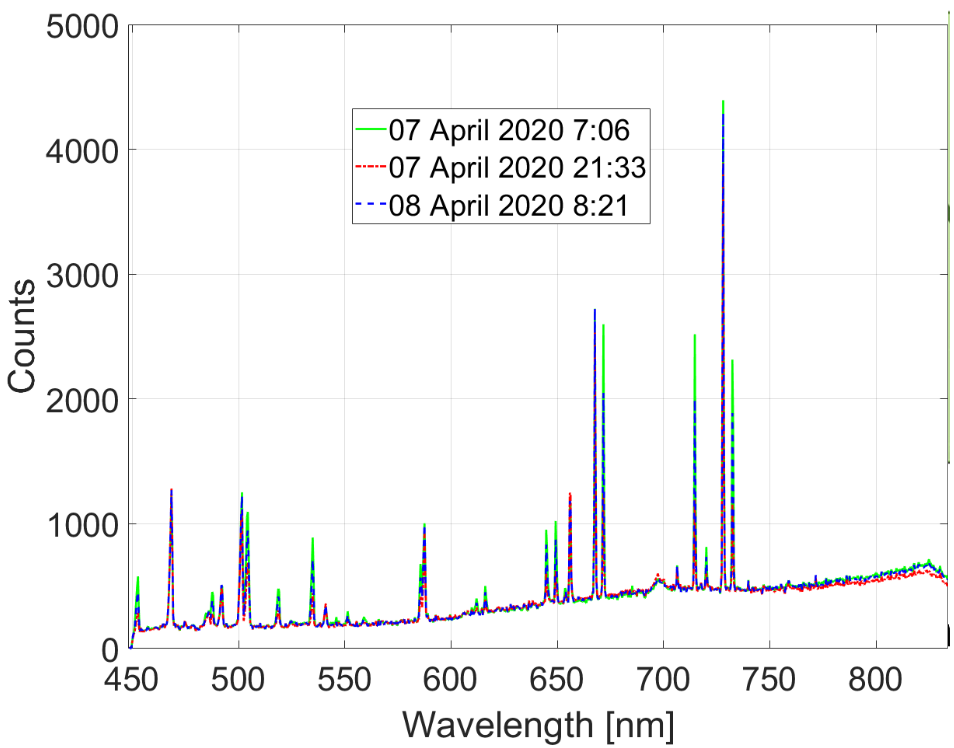
^{48}Ca Beam Times in 2020
(With microwave shielded oven)

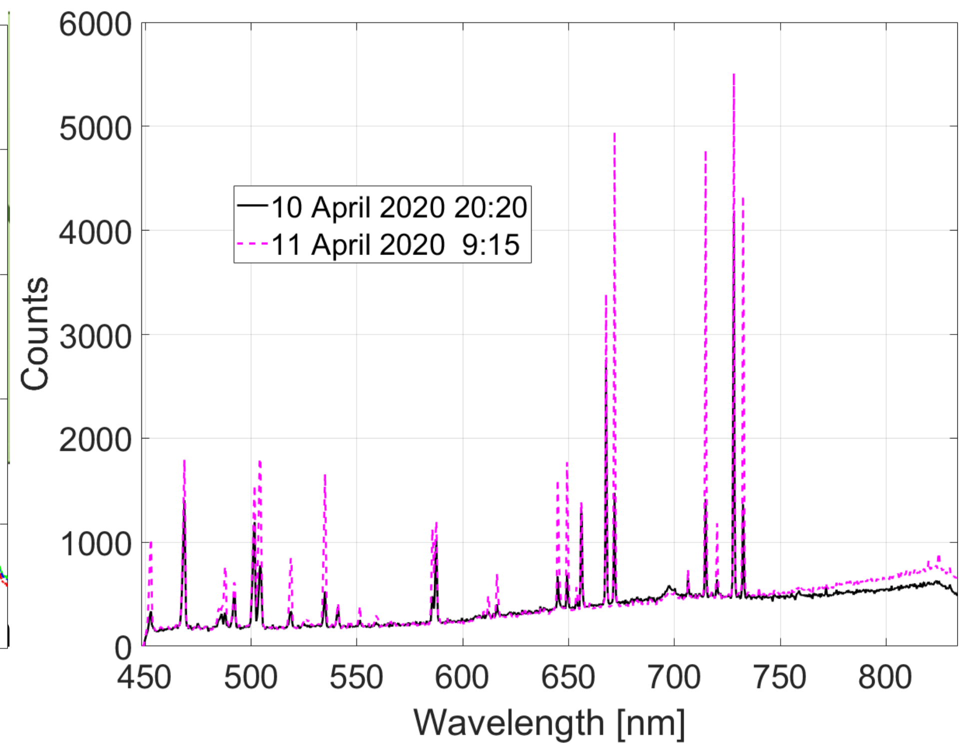
- **$^{48}Ca^{10+}$ beam (19 February – 04 March)**
  - Beam intensity: 90-120 µA
  - Stable beam for the entire beam time and no on–call or intervention necessary
- **$^{48}Ca^{10+}$ beam (17-31 March)**
  - Beam intensity: 70-90 µA
  - Two on–call intervention necessary
- **$^{48}Ca^{10+}$ beam (02-15 April)**
  - Beam intensity 90-100 µA
  - Two on–call intervention necessary
  - Beam unstable after source recovery due to software reset (12.04.20)
- **$^{48}Ca^{10+}$ beam (19 April -15 May)**
  - Beam intensity 100-110 µA
  - Non on-call intervention necessary



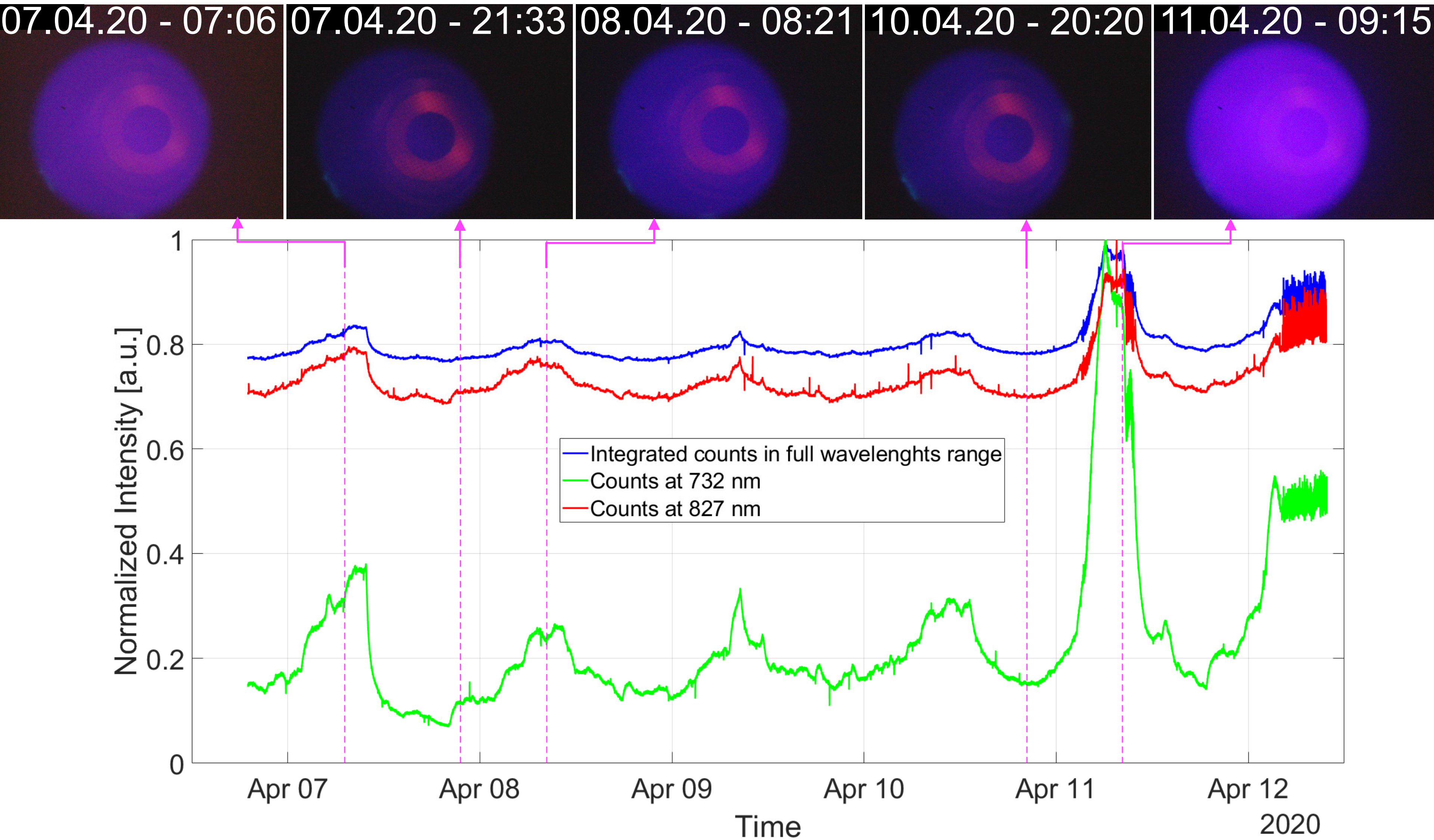


OES diagnostic during the ^{48}Ca beam-run 02-15 April 2020





OES diagnostic during the ^{48}Ca beam-run 02-15 April 2020



Conclusions

- For ^{48}Ca operation it is difficult to find a working point to guarantee a long-term stability as the oven response time and the ECRIS reaction are relatively slow.

- The use of an optical spectrometer as a diagnostic tool for routine operation helps to recover the source performances much faster during the metallic ion beam production whenever optimizations are required or instabilities occur.

- The grid shielding of the oven head improved the Ca ion beam production in terms of stability, intensity and material consumption since the parasitic heating of the ceramic insulating material inside the oven head is strongly reduced.

THANK YOU FOR YOUR KIND ATTENTION

THE ECRIS TEAM

R. Hollinger (dpt. Leader)
Klaus Tinschert
Ralf Lang
Jan Mäder
Patrick Tedit Patchakui
Aleksandr Andreev
Me

SPARES SLIDES

Selection of provided ion species

Gaseous Elements and Compounds				
Element	Isotope	Charge States	Main Gas	Aux Gas
H	$^{1}H_2$	1	H_2	-
C	^{12}C	2	CO_2	O_2
O	^{16}O	3	O_2	He
	^{18}O	3	O_2, *	He
Ne	^{20}Ne	4	Ne	He
	^{22}Ne	4	Ne, *	He
S	^{32}S	5	SO_2	O_2
	^{34}S	6	SO_2, *	O_2
	^{36}S	5	SO_2, *	O_2
Ar	^{36}Ar	5, 6, 7	Ar, *	O_2
	^{40}Ar	6, 7, 8	Ar	O_2
Kr	^{84}Kr	12	Kr	He
	^{86}Kr	12	Kr, *	He
Xe	^{124}Xe	15, 16	Xe, *	O_2
	^{129}Xe	18	Xe, *	O_2
	^{136}Xe	18, 19	Xe, *	O_2

Solid Elements and Compounds				
Element	Isotope	Charge States	Sample Material	Aux Gas
Li	^{6}Li	1	LiF, *	He
	^{7}Li	1	LiF	He
Mg	^{24}Mg	5	Mg	He
	^{25}Mg	4	Mg, *	He
	^{26}Mg	4, 5	Mg, *	He
Si	^{28}Si	5	SiO	He
	^{30}Si	6	SiO, *	He
Ca	^{40}Ca	6, 7	Ca	He
	^{48}Ca	7, 10	Ca, *	He
Ti	^{48}Ti	7	Ti	He
	^{50}Ti	7, 8	Ti, *	He
V	^{51}V	8	V	He
Cr	^{50}Cr	8	Cr, *	He
	^{52}Cr	7	Cr	He
	^{54}Cr	8	Cr, *	He

Solid Elements and Compounds				
Element	Isotope	Charge States	Sample Material	Aux Gas
Fe	^{58}Fe	8, 9	Fe	He
Ni	^{58}Ni	8, 9	Ni	He
	^{62}Ni	9	Ni, *	He
	^{64}Ni	9	Ni, *	He
Zn	^{64}Zn	10, 11	ZnO	O_2
	^{68}Zn	10	ZnO, *	O_2
	^{70}Zn	10	ZnO, *	O_2
Ag	^{107}Ag	15	Ag	O_2
Sn	^{112}Sn	15, 17	Sn, *	O_2
	^{114}Sn	16, 17	Sn, *	O_2
	^{118}Sn	16	Sn, *	O_2
	^{122}Sn	17	Sn, *	O_2
	^{124}Sn	16	Sn, *	O_2
Au	^{197}Au	24	Au	O_2
Pb	^{208}Pb	27	Pb, *	O_2

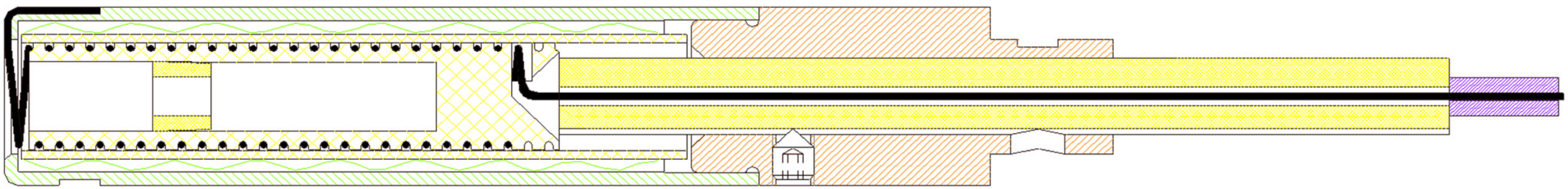
*** enriched elements**

*** enriched compounds**

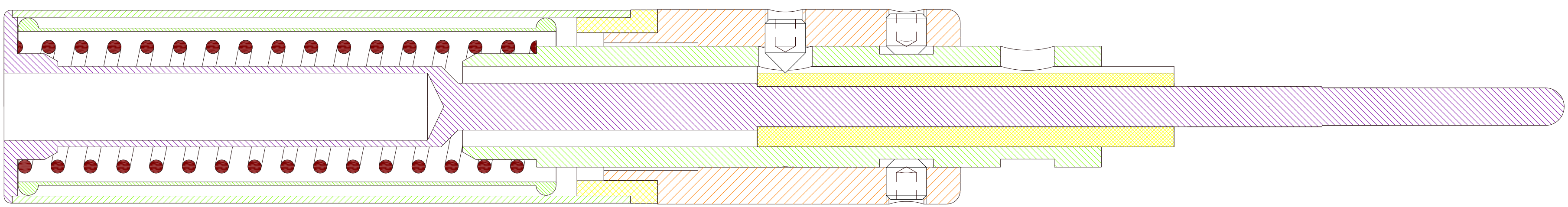
➔ Evaporable solids (metals) – vapor pressure of $\approx 10^{-2}$ mbar at T < 1600°C for Standard-Oven (STO), and at T < 2000°C for High-Temperature-Oven (HTO)

GSI Oven Types: STO and HTO

Oven models used at GSI – length 70 mm, diameter 14.5 mm



Standard Temperature Oven (STO): yellow = Al_2O_3; green = Ta; orange = Mo; violet = $CuBe_2$; black = WRe(26%)



High Temperature Oven (HTO): yellow = Al_2O_3; green = Ta; orange = Mo; violet = WL20

Hot screen for Ca, Mg (, Sr)

- Made of Tantalum
- Screen thickness: 0,1 mm
- Length= 165 mm
- Diameter= 62 mm
- Plasma chamber diameter= 64 mm
- Gap to cold plasma chamber: 1 mm
- Ca consumption without hot screen: ~ 10 mg/h
- Ca consumption with hot screen: ~ 0,2–0,5 mg/h
- Crucible filling: ~ 300 mg
- Material costs: ~ 50.000 €
- Screen used only once
- Caps are cleaned and reused