Offline commissioning of S^3-LEB

LISA ITN Academic Day 17/06/2022

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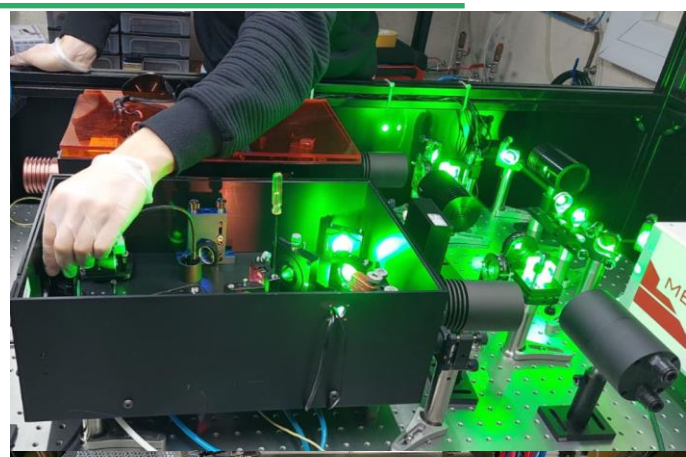
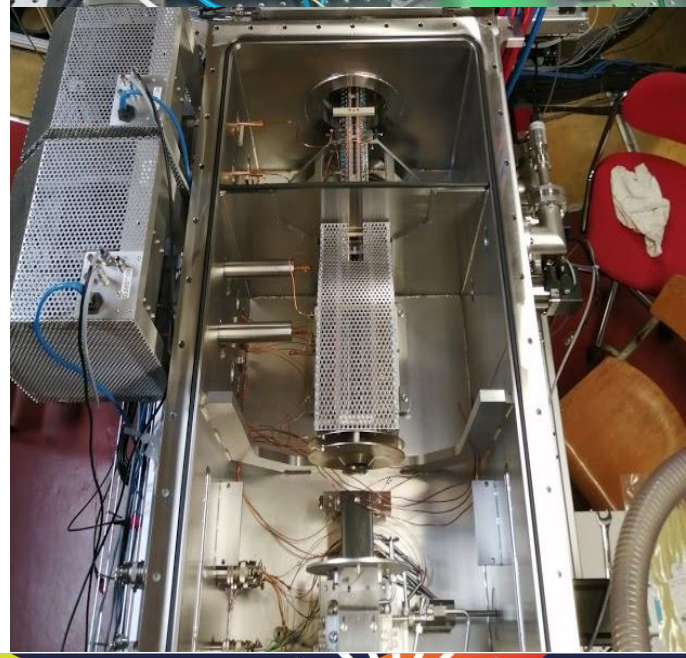
OUTLINE

- S3-LEB set up
- S3-LEB offline commissioning
- Gas cell spectroscopy tests
- Preparation to In-gas jet
- Outlook

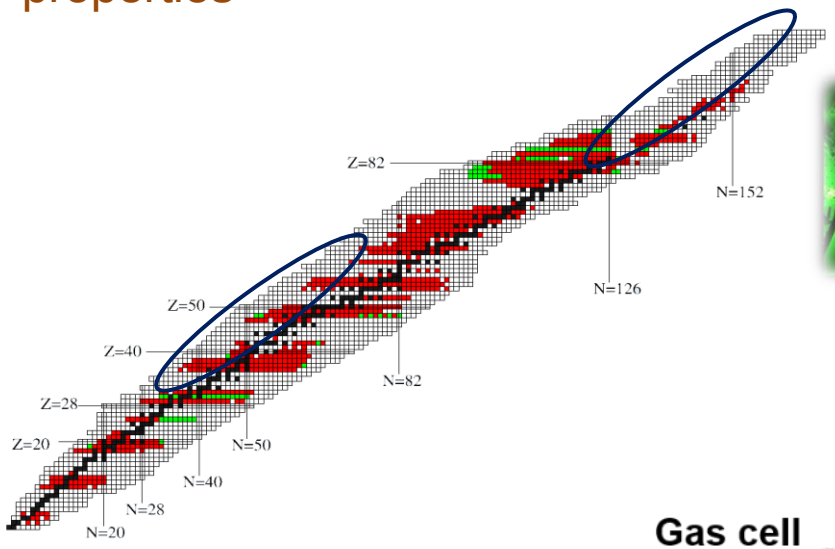




S³-LEB

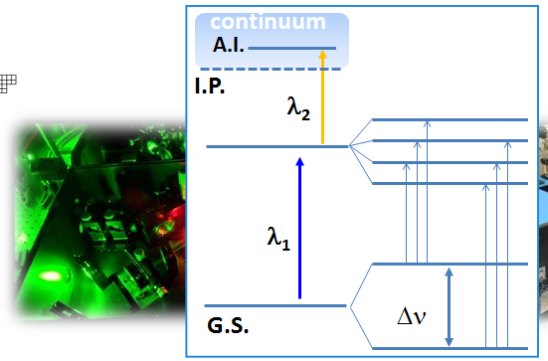
- Day-1 experiments

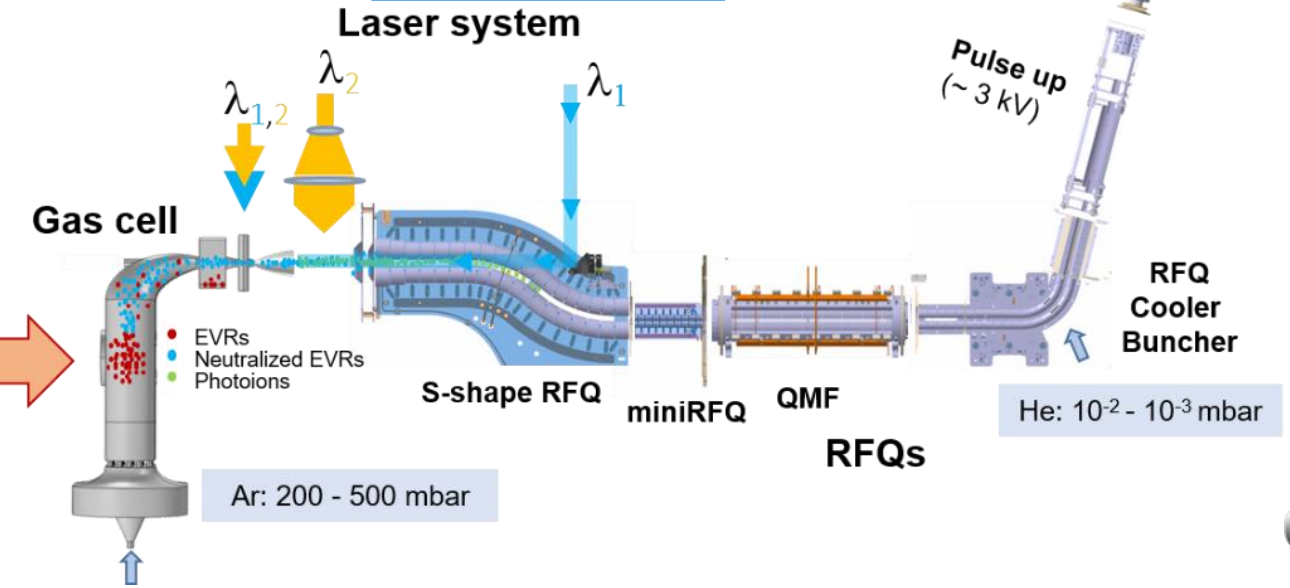
- study nuclear and atomic properties



- Medium resolution laser spectroscopy
  -Gas cell/ Gas jet
- Mass measurement
- Decay spectroscopy

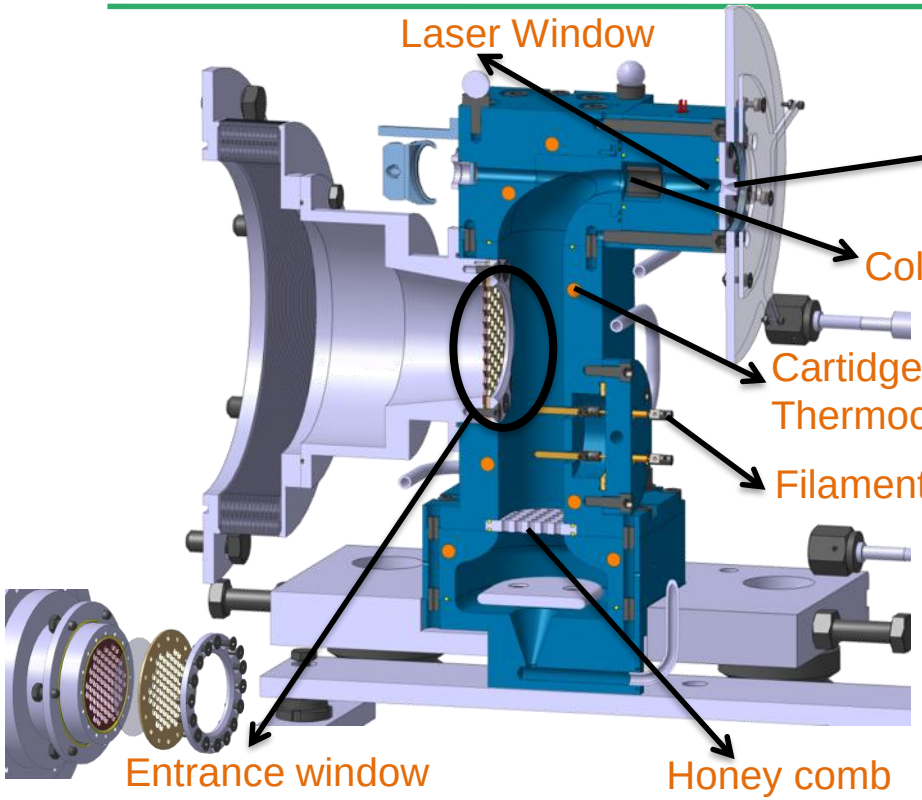
Laser Ionisation Spectroscopy

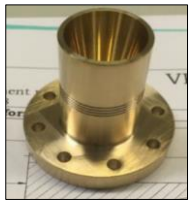


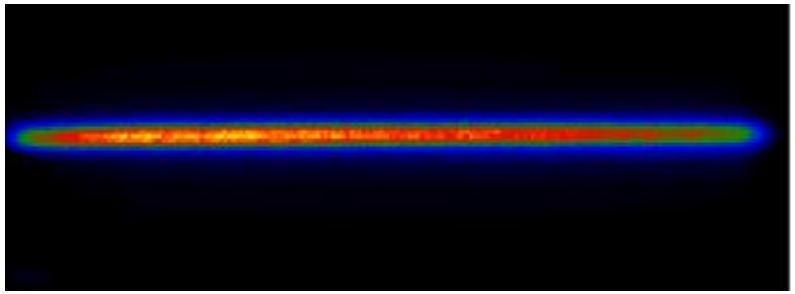


Decay station

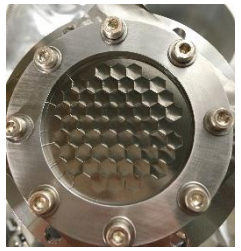
In-gas cell/jet spectroscopy





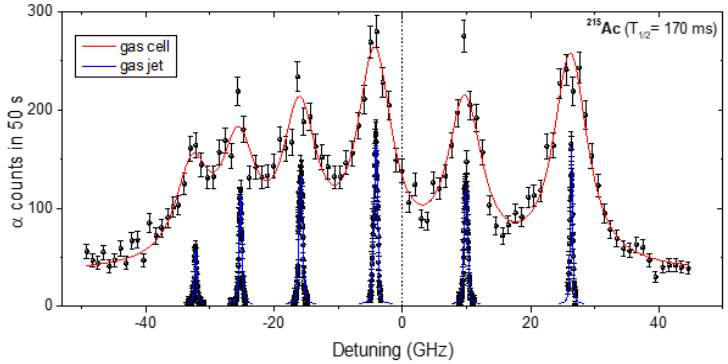


Fluorescence spectrum of gas jet



Ti or Mylar foils
5 – 1.5 µm

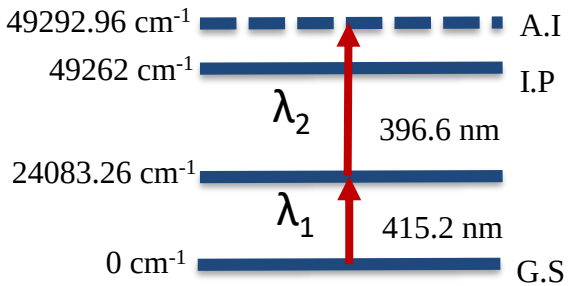
- Gas cell
  - broadening effects
  - Broad band laser (GHz)
- de Laval Nozzle
  - Hypersonic gas jet
    ρ ↓ T ↓
  - Narrow band laser (MHz)



[2] R.Ferrer et al. Nature Communications.8.14520 .doi: 10.1038/ncomms14520

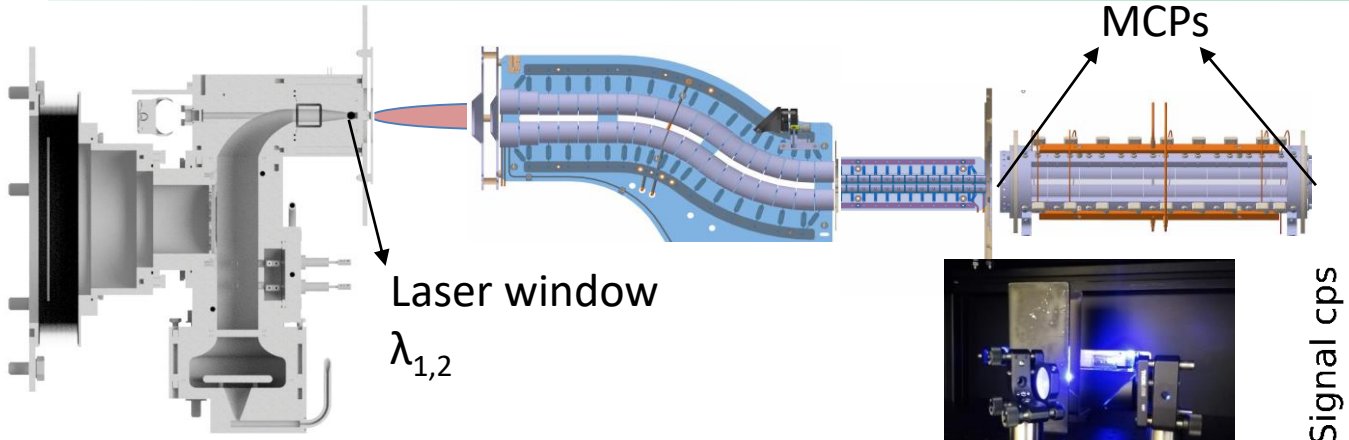
S³-LEB offline commissioning

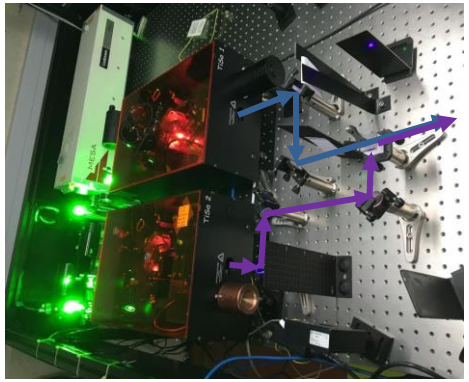
- Er for commissioning tests
- Two step Ti:sa laser scheme

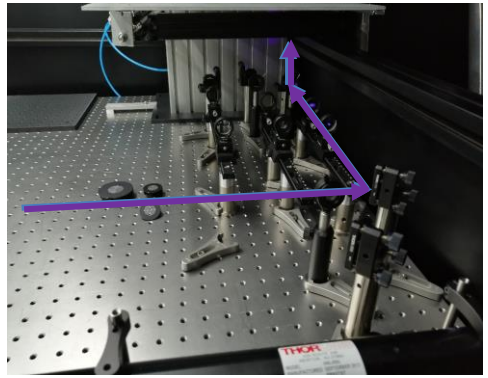


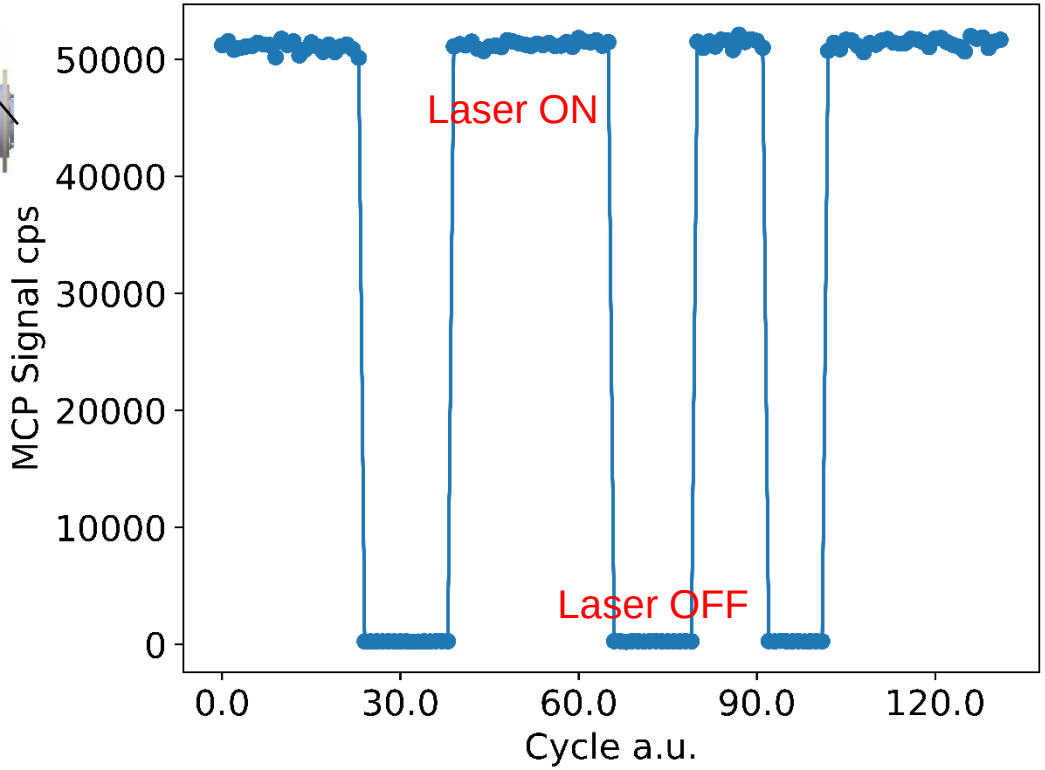
[3] J.Romans et al., Atoms,10,21 URL:https://doi.org/10.3390/atoms10010021

In-gas cell laser ionization of Er



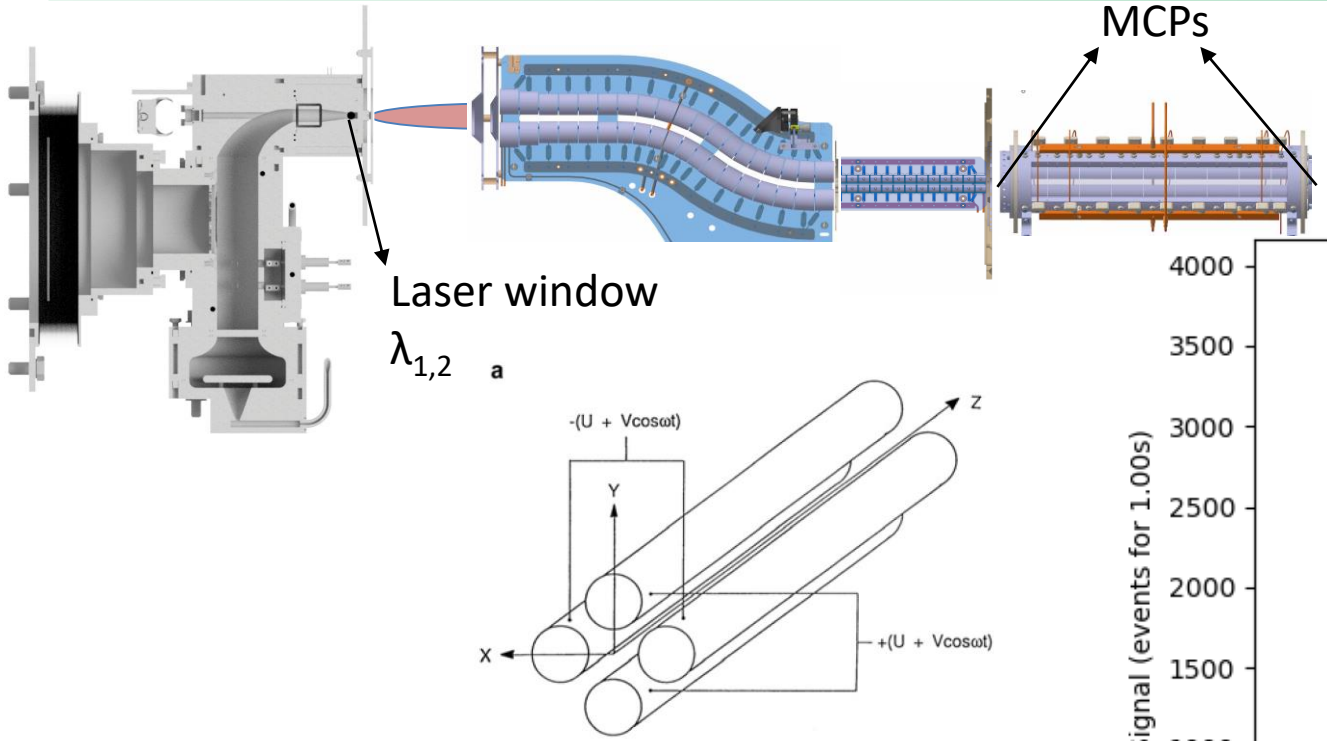


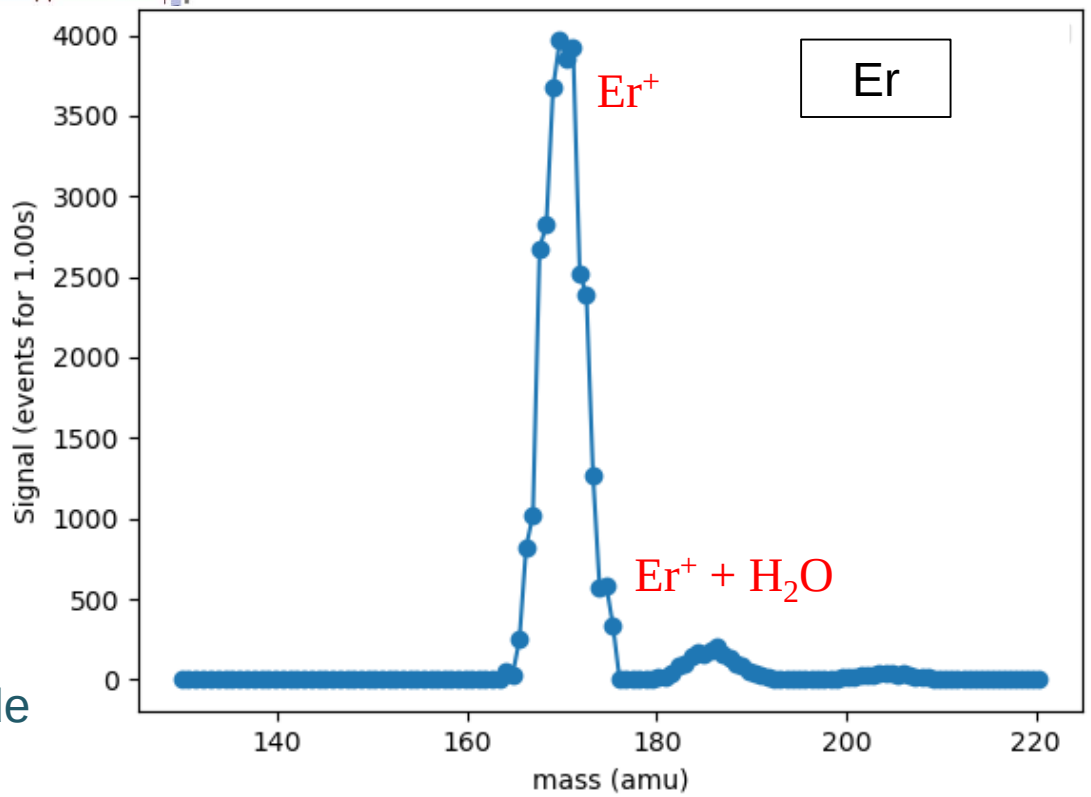




- Broad band lasers installed
- First Er^+ ions in the gas cell

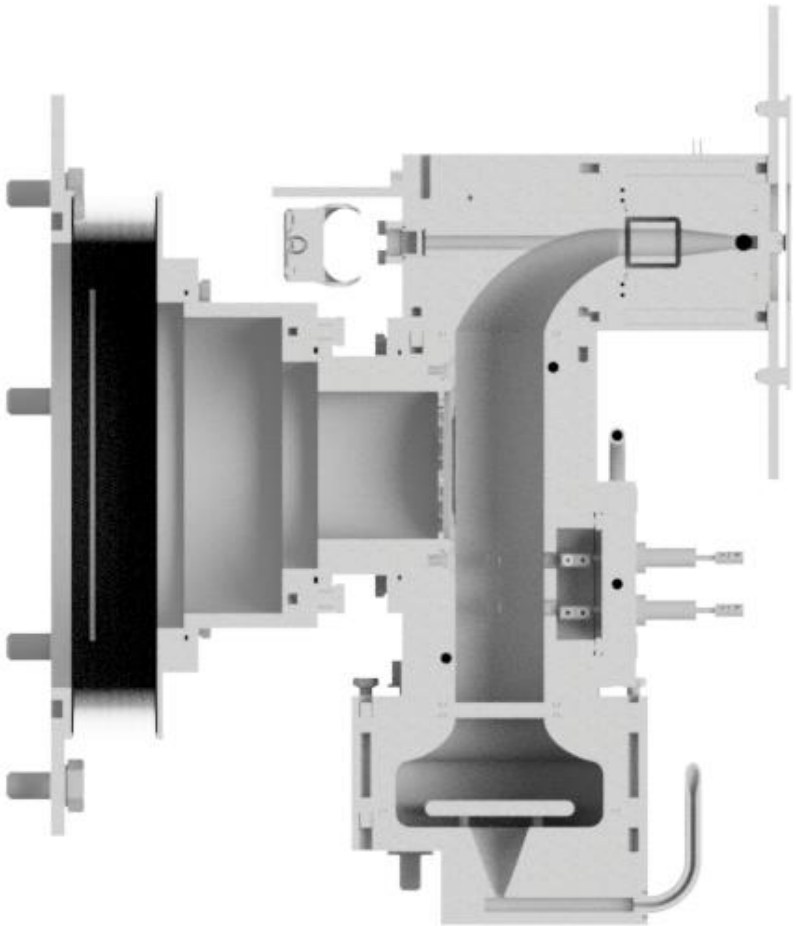
Er mass scan with QMF

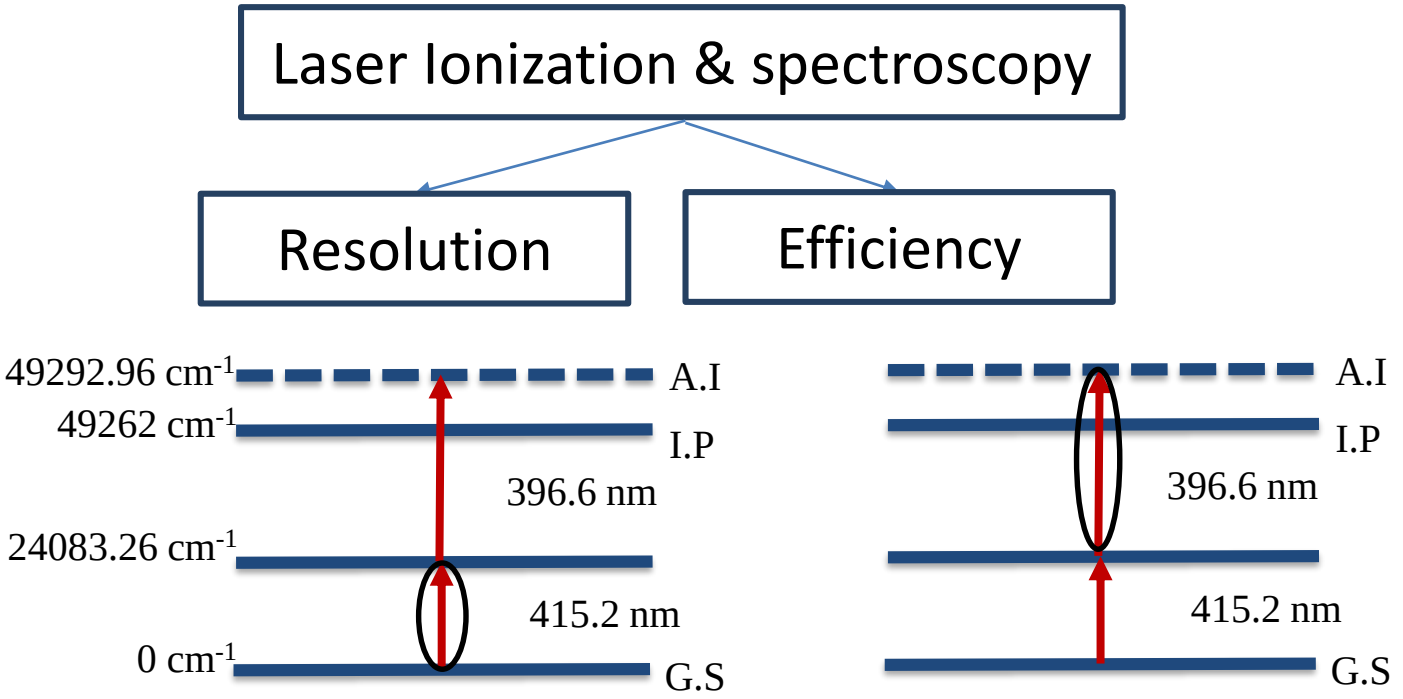




- Mass scan done at constant DC/RF ratios
- 60 % transmission efficiency at high resolution mode
- 100% efficiency at transmission mode

Er ions in the gas cell





- Pressure broadening
- Power broadening
- Doppler broadening

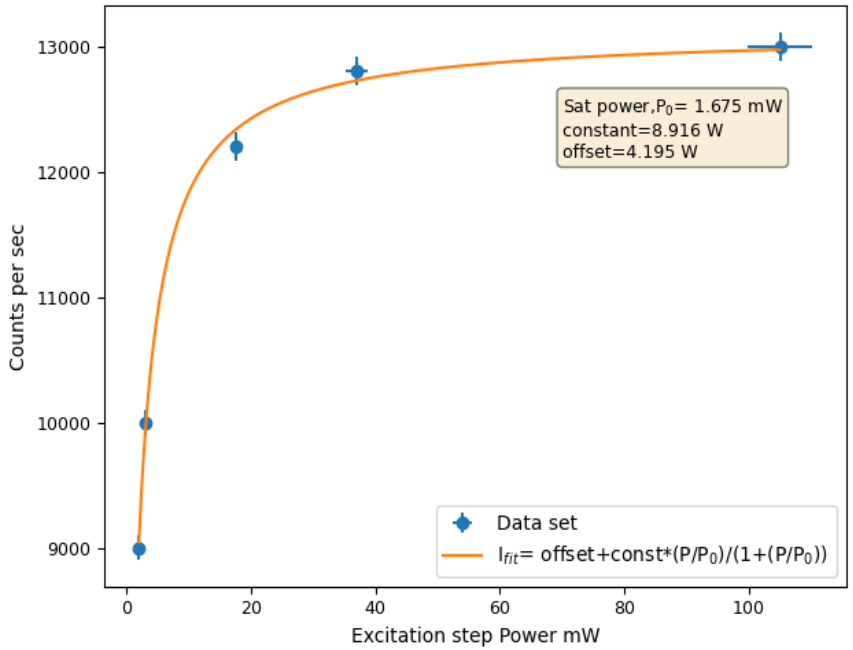
Test on Er ions in the gas cell

Power/Pressure broadening↓ Resolution↑

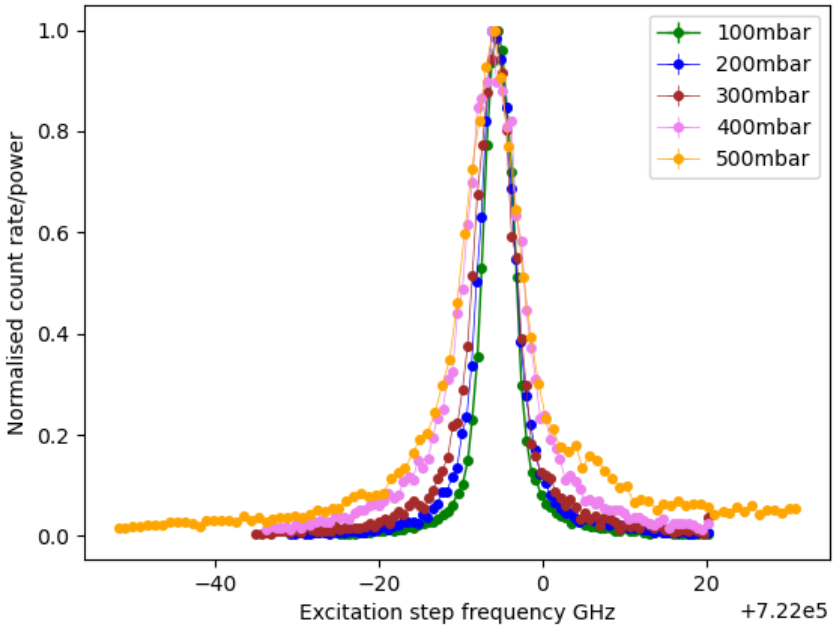
Excitation laser power: linear regime

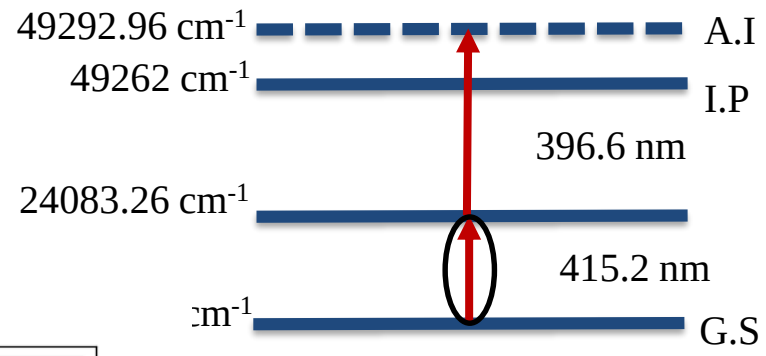
Pressure broadening: γ_{coll}

γ_{sh}



Excitation step laser scan





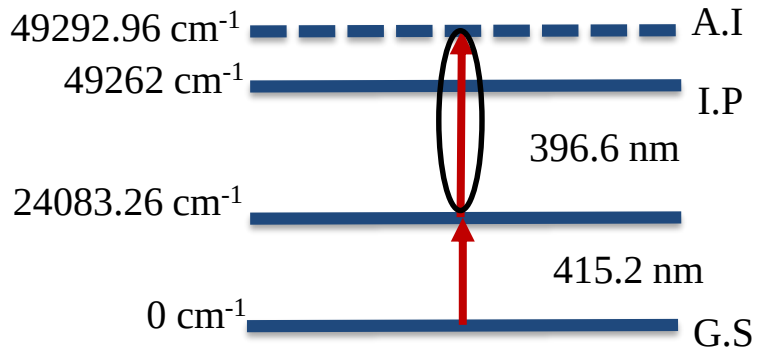
[4]I. Pohjalainen, Ph.D. Thesis,2018

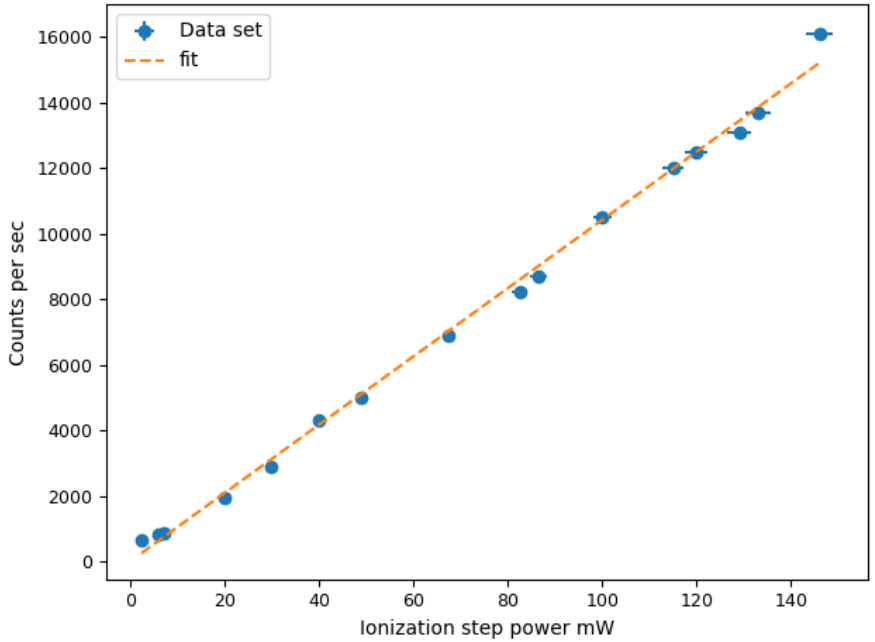
.Ferrer et al. Nucl. Instrum. Methods Phys. Res. 7 doi:https://doi.org/10.1016/j.nimb.2013.07.028

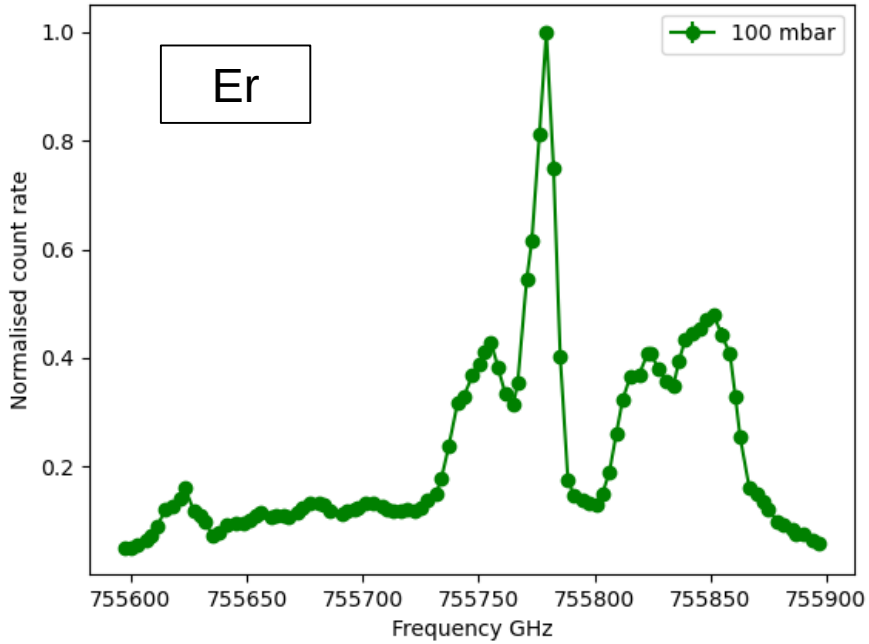
Test on Er ions in the gas cell

- Ionization step power in linear regime

  Ionization Efficiency↓

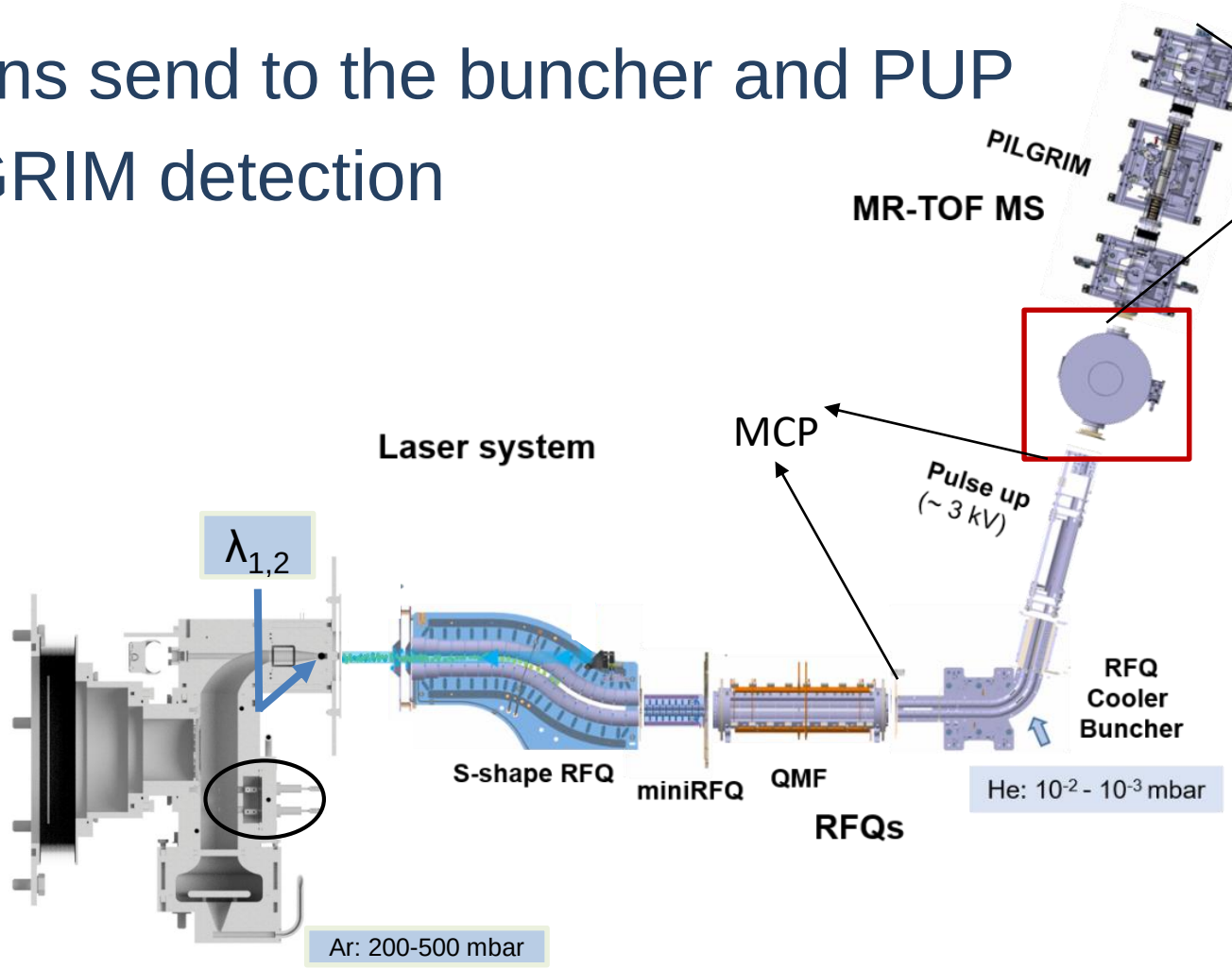


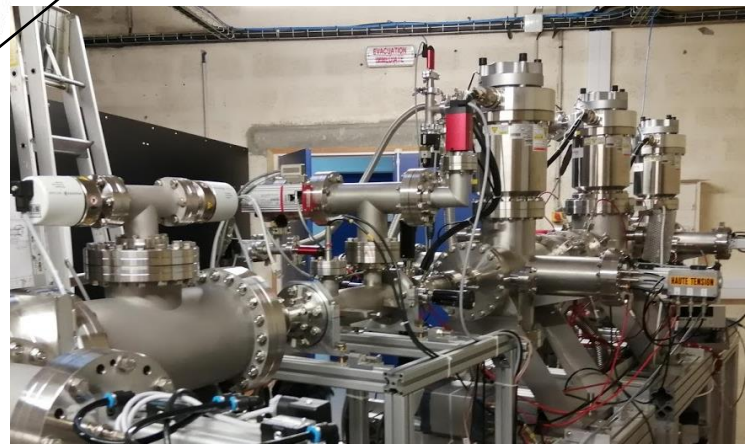




S^3-LEB offline commissioning

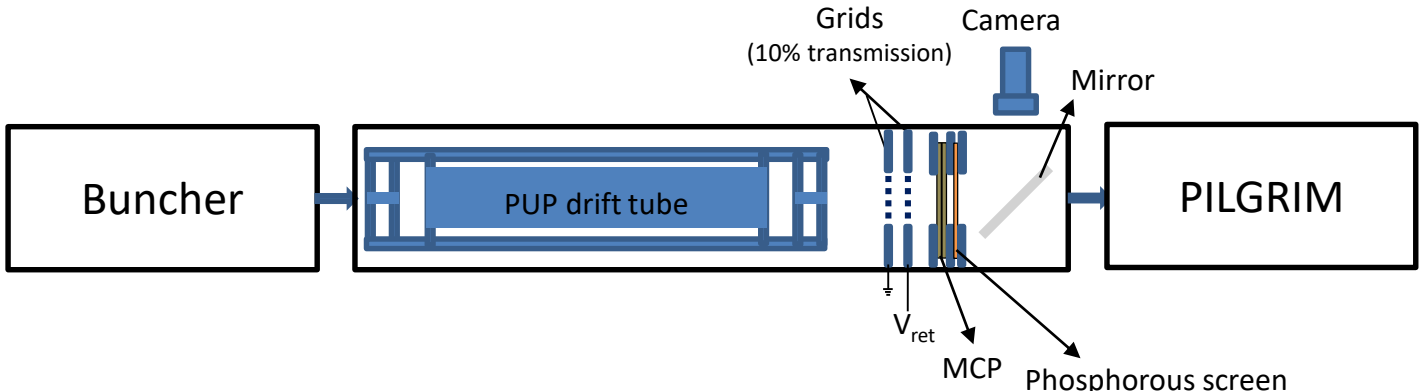
- Er ions send to the buncher and PUP
- PILGRIM detection





Buncher transmission

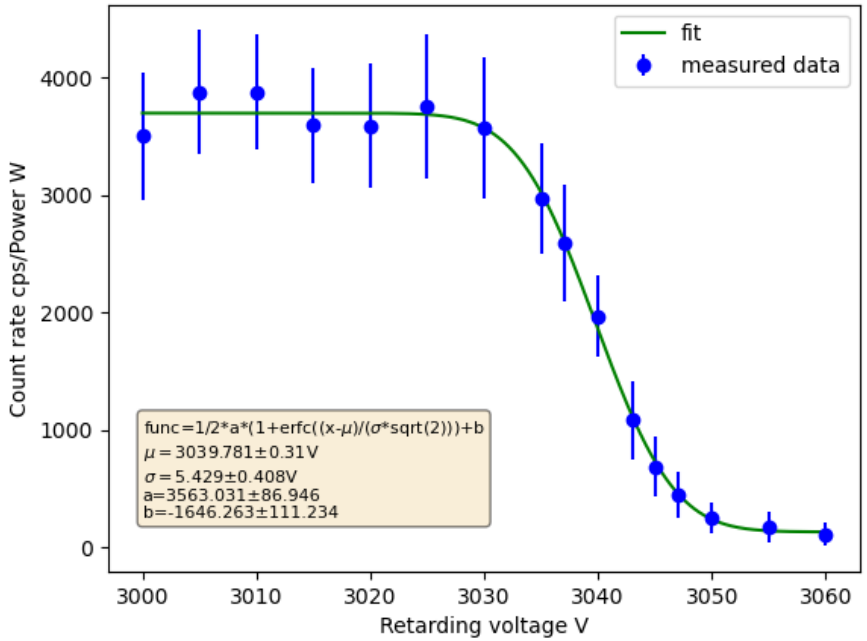
- Ions cooled by He gas
- Potential well for bunching
- Re-acceleration with PUP drift tube



- Systematic study of buncher parameters
  - He gas pressure
  - Energy spread
  - Bunch duration
  - Spatial spread
  - RF amplitude
  - Transmission

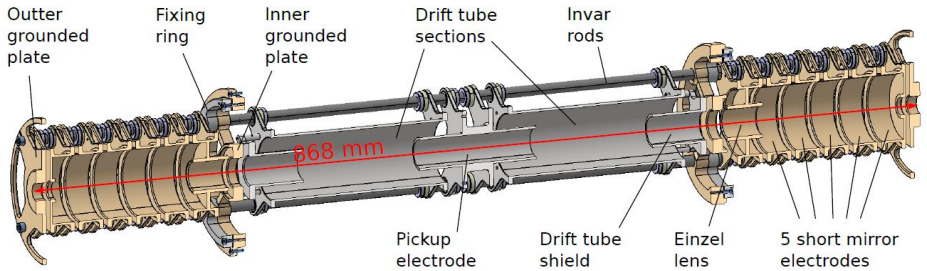
- Spatial spread, Xdisp= 1.5(1) mm
  Ydisp= 1.5(3)mm

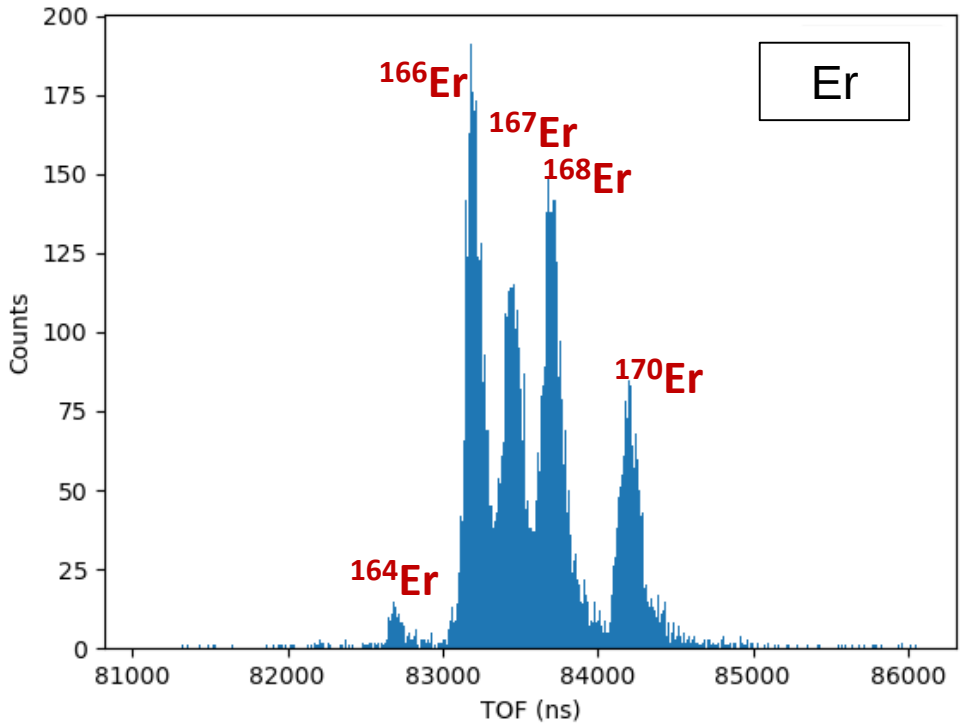
- Energy spread, FWHM < 12.7(1)V
- After optimization, Eff_{Bun}~ 30 %



Mass spectrum at PILGRIM

- Transmission to PILGRIM optimization in process
- Mass spectrum recorded at PILGRIM shoot through: Eff ~ 20% from buncher
- RMS width,FWHM (^{170}Er) < 122(4) ns

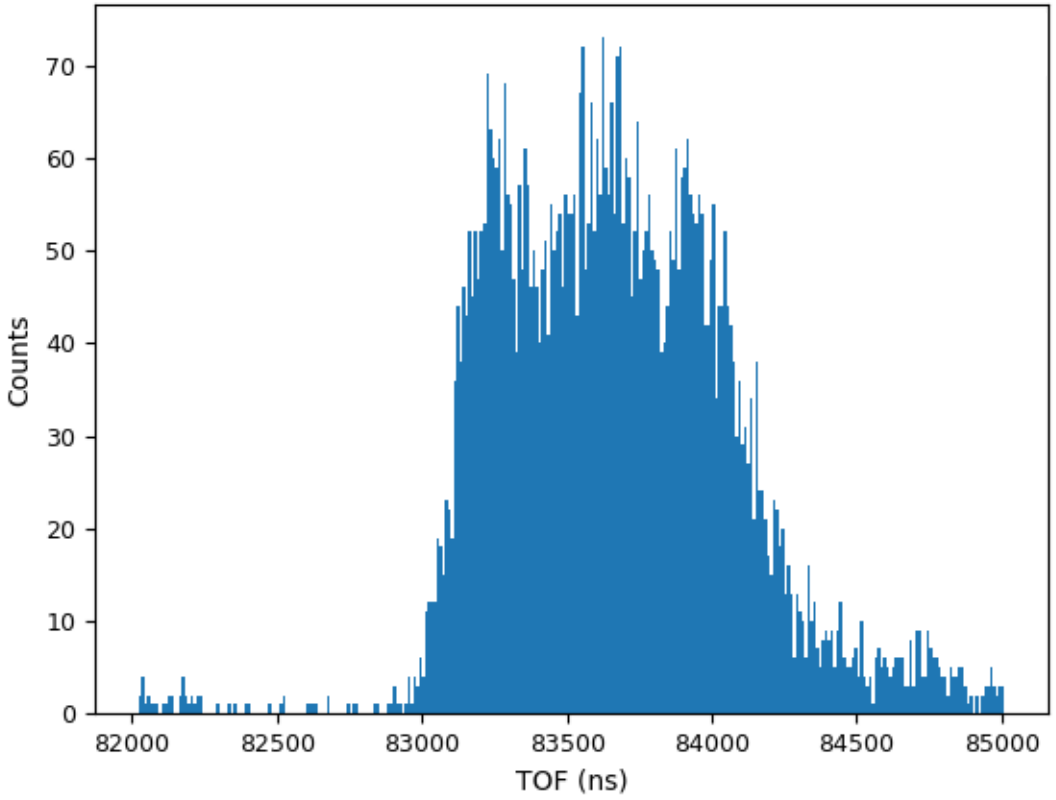




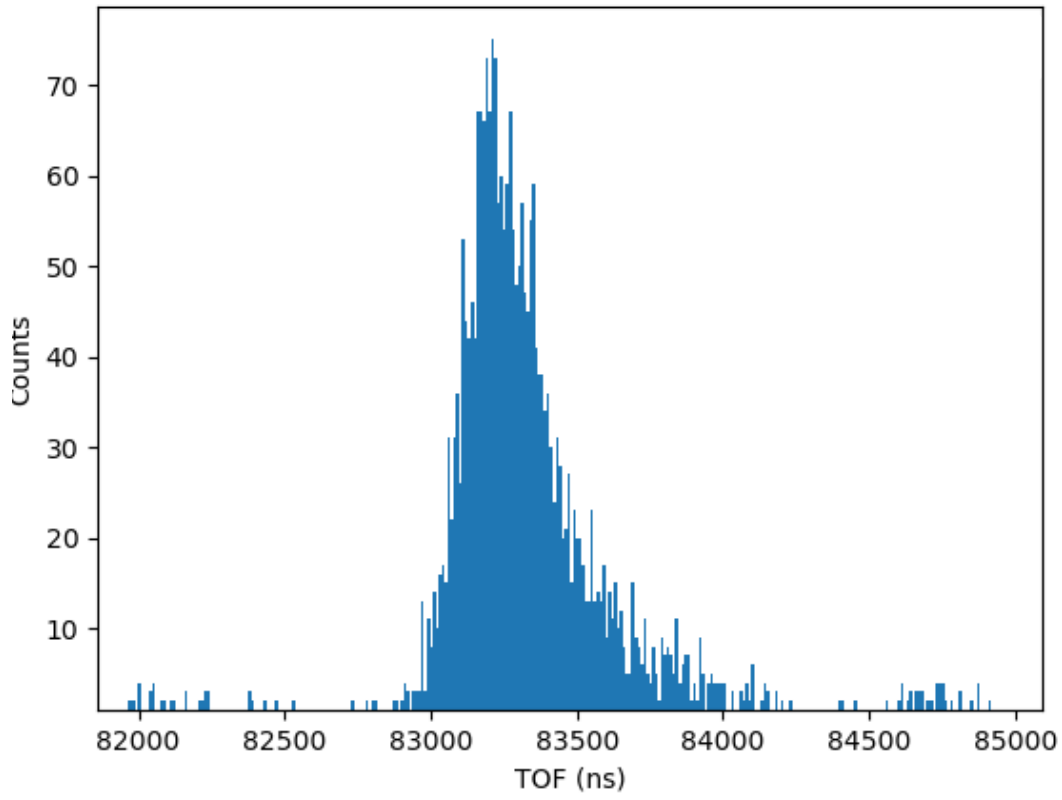
Trapping of Er ions

- Trap at 1000 turns – several isotopic masses of Er
- Extraction of contaminants before the ions of interest

Without suppression

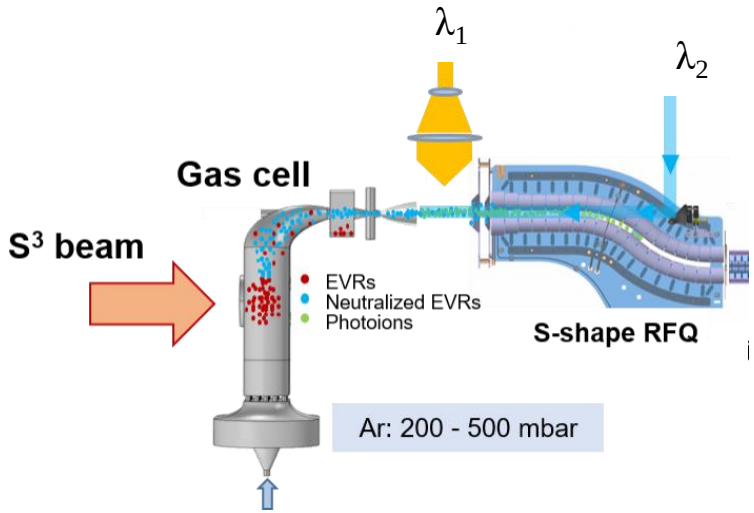


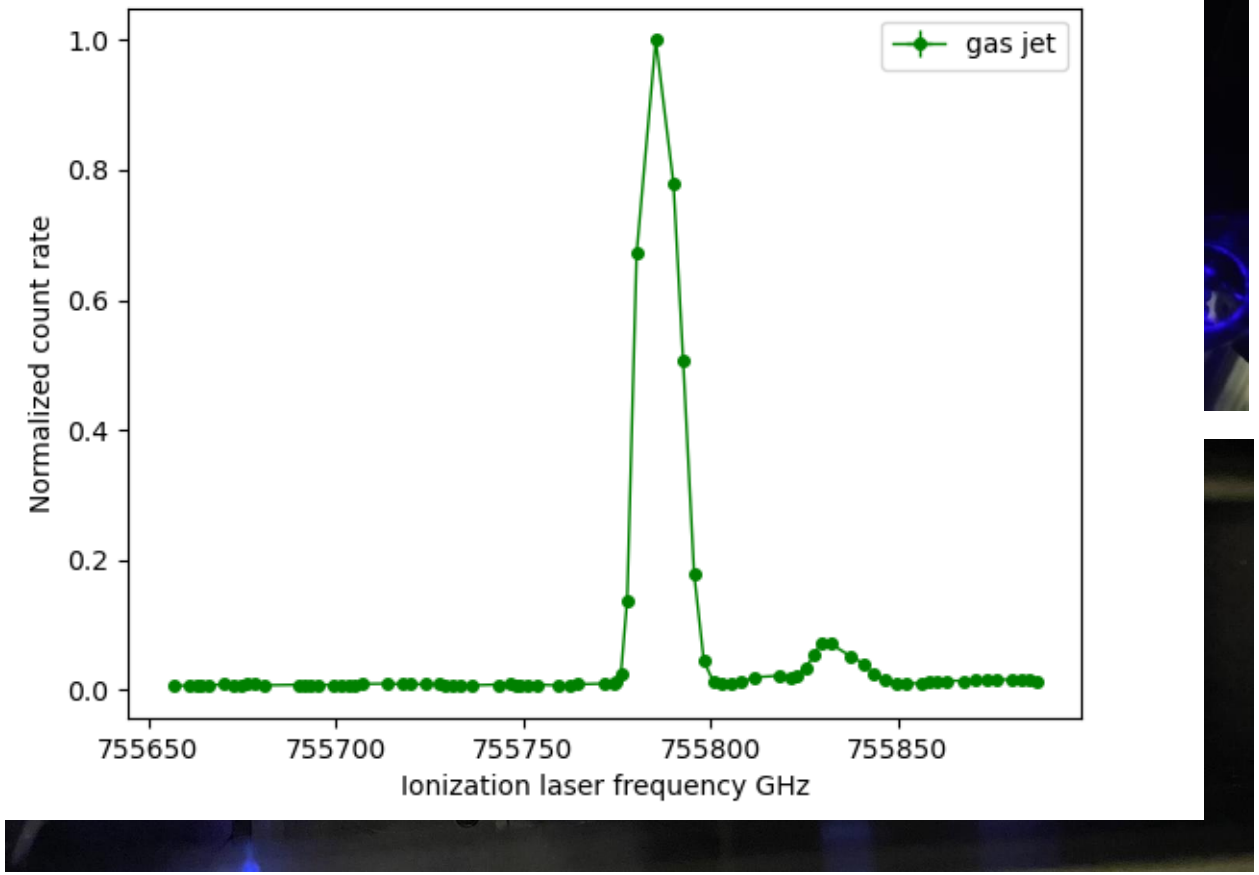
$^{167}Er^{+}$ suppression



Preparation for In- gas jet spectroscopy

- De-Laval nozzle M=7
- Gas jet path
  - -Second step Ti:sa :collinear
  - -First step Ti:sa : Transversal
- Ionization in gas-jet

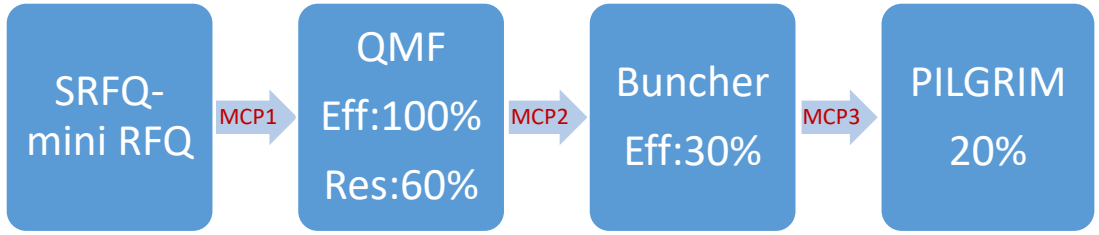


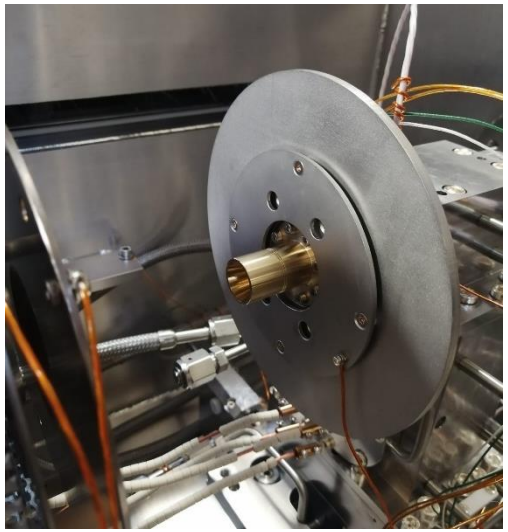


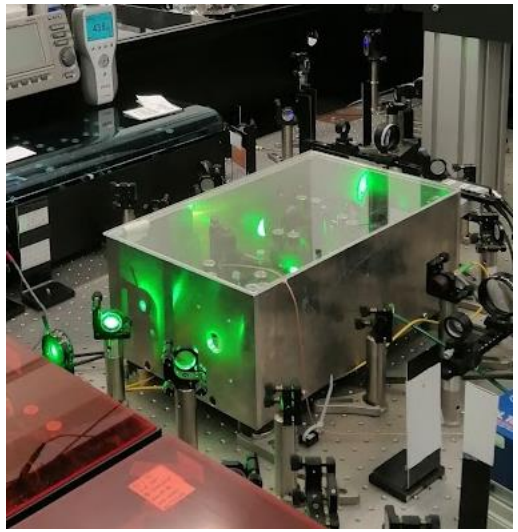
Outlook

Summary:

- Relative transmission of laser ions till PILGRIM tested
- Characterisation of laser ions in the gas cell
- De-Laval nozzle installed
- Trapping of ions in PILGRIM







Future Steps:

- Preparation for In- gas jet high resolution spectroscopy

Acknowledgement

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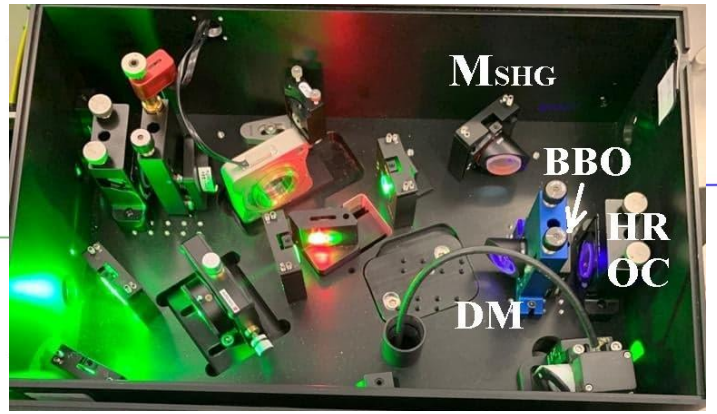
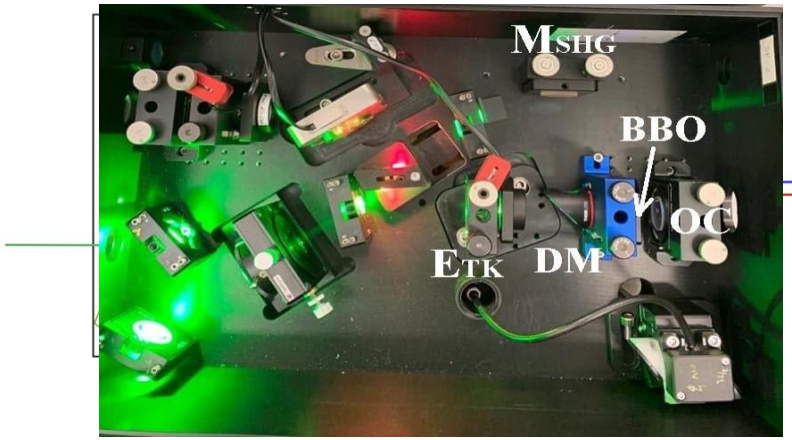
Thank you

Er Resonance Ionisation spectroscopy

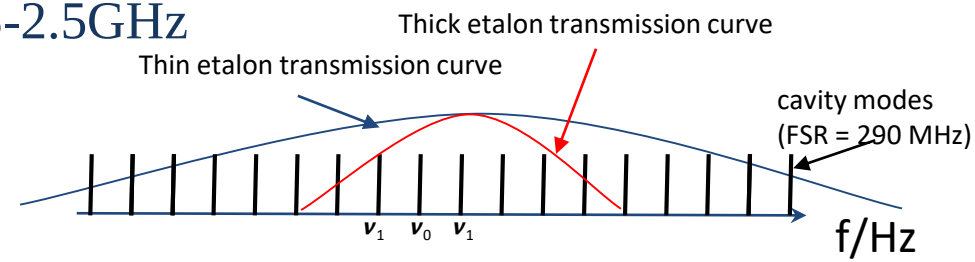
- Training with broad band Z-cavities



Ti:sa #3
Ionisation step



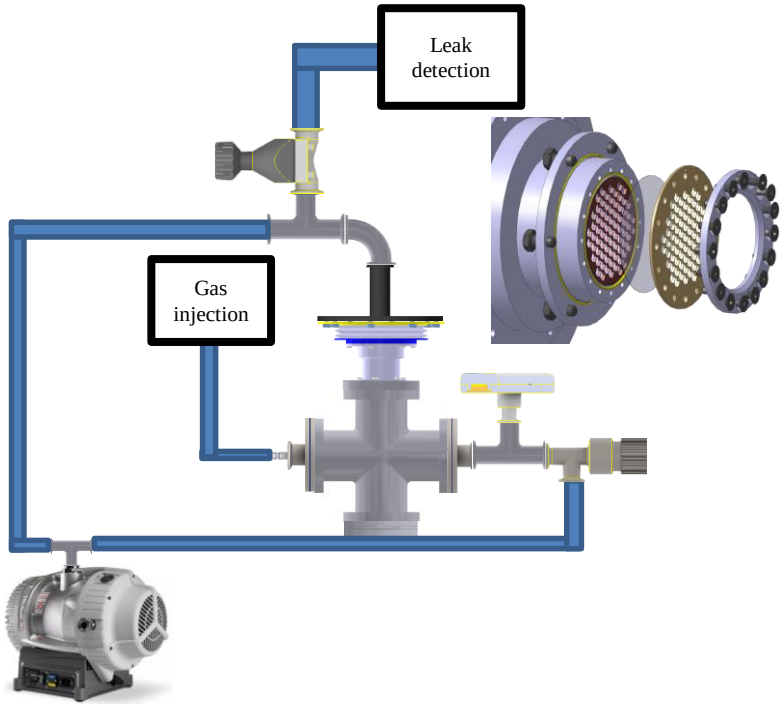
Ti:sa#2
Excitation step
Linewidth:1.5-2.5GHz

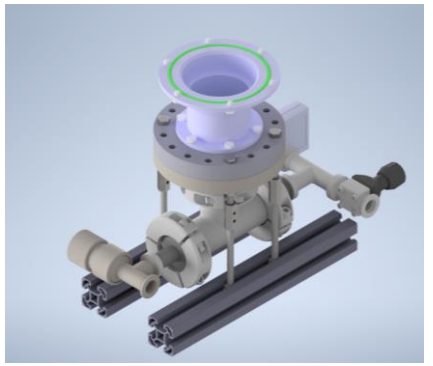


New entrance window test bench

- New test bench design in Inventor
- Allows measurement of absolute pressure
- Implementation of design and leak test performed

  Leak rate > 10^{-11} mbar l/s
- Thin foils ordered for start of tests





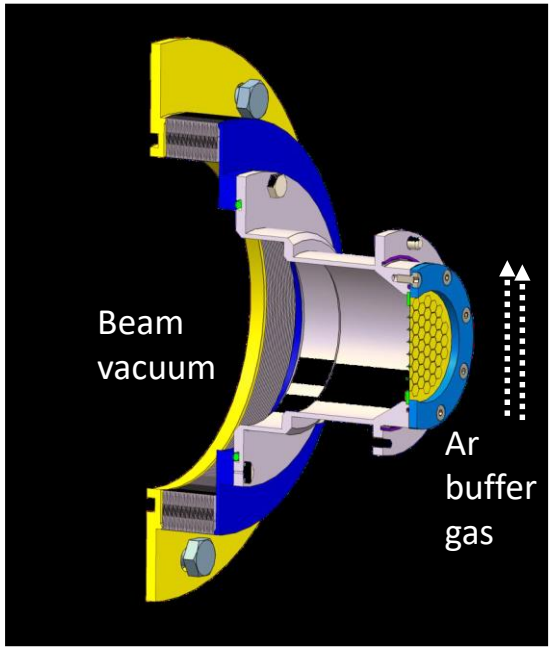
3D design of the new test bench adapter

Entrance window tests for the gas cell

- Test bench prepared for entrance window
- Initial tests with Aluminium 20µm: leak test with He leak detetctor > 10^{-9}mbar l/s
- Integral leak rate also calculated for the setup >10^{-7} mbar l/s
- Ti film:1st test: leak >10^{-5} mbar l/s

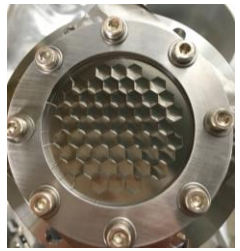
2µm Ti			3µm Ti			4µm Ti		
Range (mm)	P (mbar)	sigma (mm)	Range (mm)	P (mbar)	Sigma (mm)	Range (mm)	P (mbar)	Sigma (mm)
7,5	1013,25	0,49	5,33	1013,25	0,48	3,1	1013,25	0,50
15	500	1,00	10,7	500	0,98	6,3	500	1,02
21,6	350	1,43	15,4	350	1,40	9	350	1,45
-	200	-	26,9	200	2,47	15,8	200	2,55

Stopping range for a 152Er with Ar as buffer in the gas cell(Courtesy:Lucia)

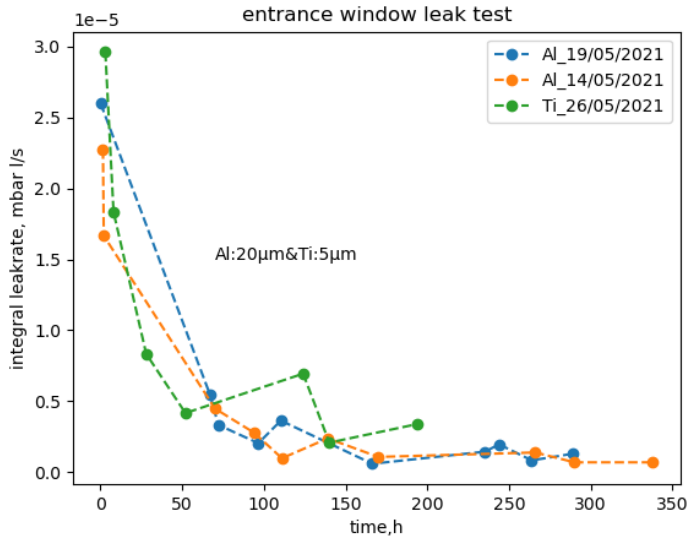


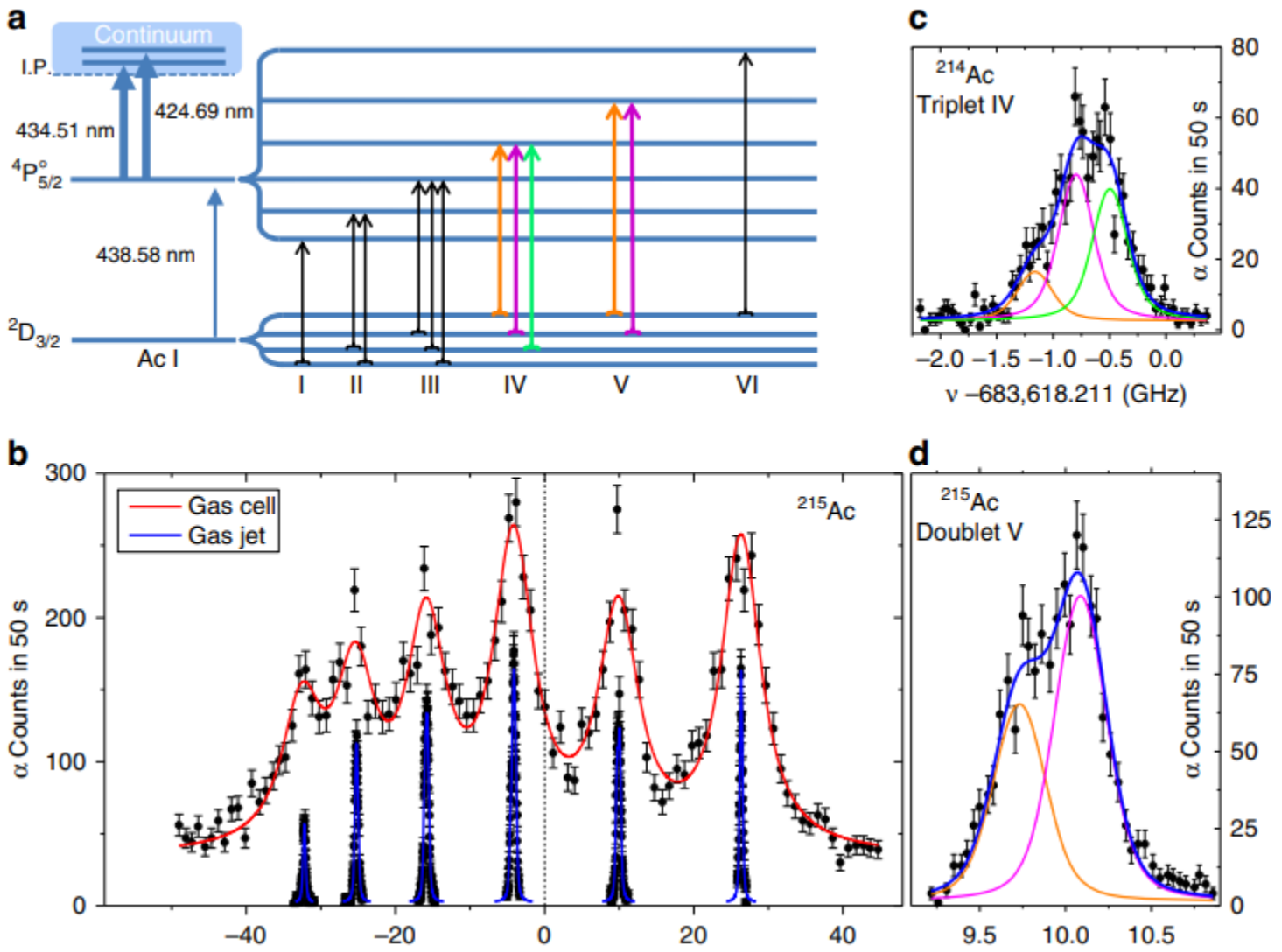
Window design


Window test bench


Ti 5 µm window

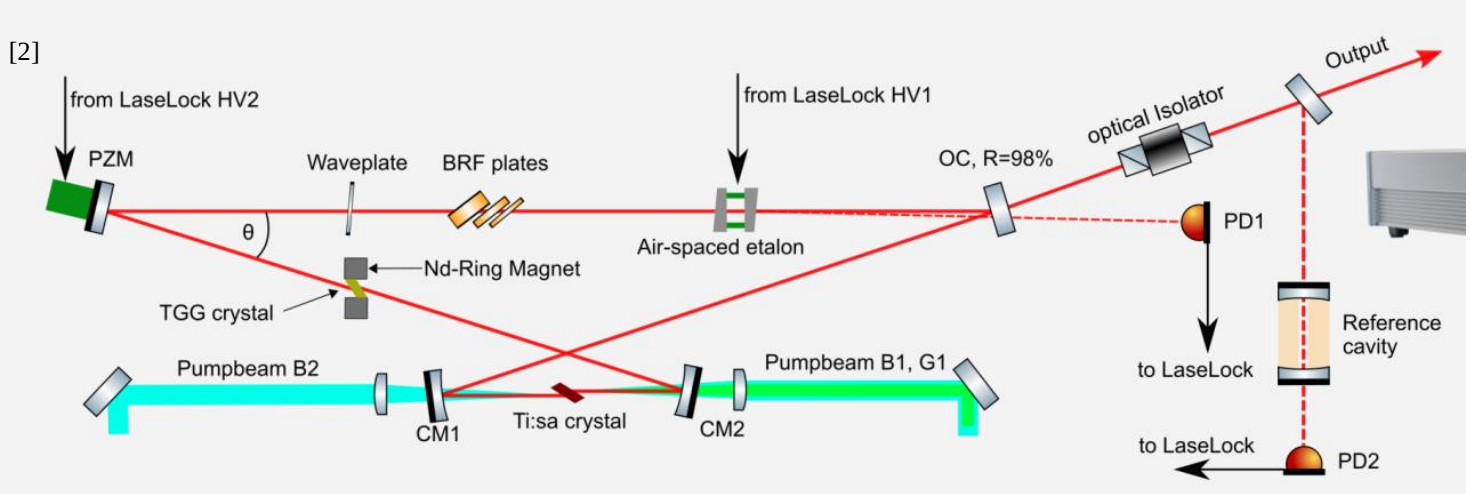

Al:20 µm window




a
Continuum
I.P.
434.51 nm
424.69 nm
$^4P^\circ_{5/2}$
438.58 nm
$^2D_{3/2}$
Ac I
I
II
III
IV
V
VI
c
^{214}Ac
Triplet IV
α Counts in 50 s
80
60
40
20
0
−2.0 −1.5 −1.0 −0.5 0.0
ν −683,618.211 (GHz)
b
Gas cell
Gas jet
^{215}Ac
α Counts in 50 s
300
200
100
0
−40
−20
0
20
40
d
^{215}Ac
Doublet V
α Counts in 50 s
125
100
75
50
25
0
9.5
10.0
10.5

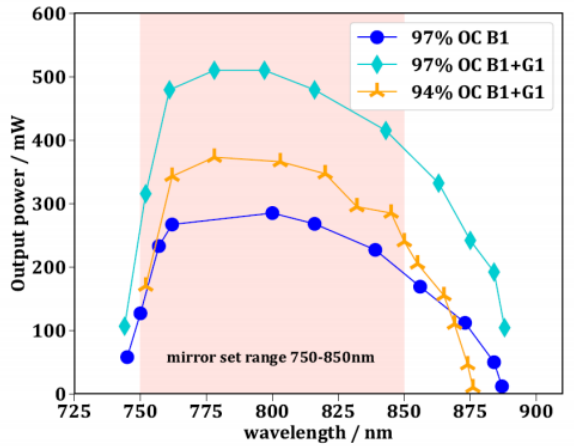
Diode pumped CW Ti:sa as seed source

[2]



[2]Volker Sonnenschein et al.Hyperfine Interactions.241:32.(2020). https://doi.org/10.1007/s10751-020-1706-4

[3]

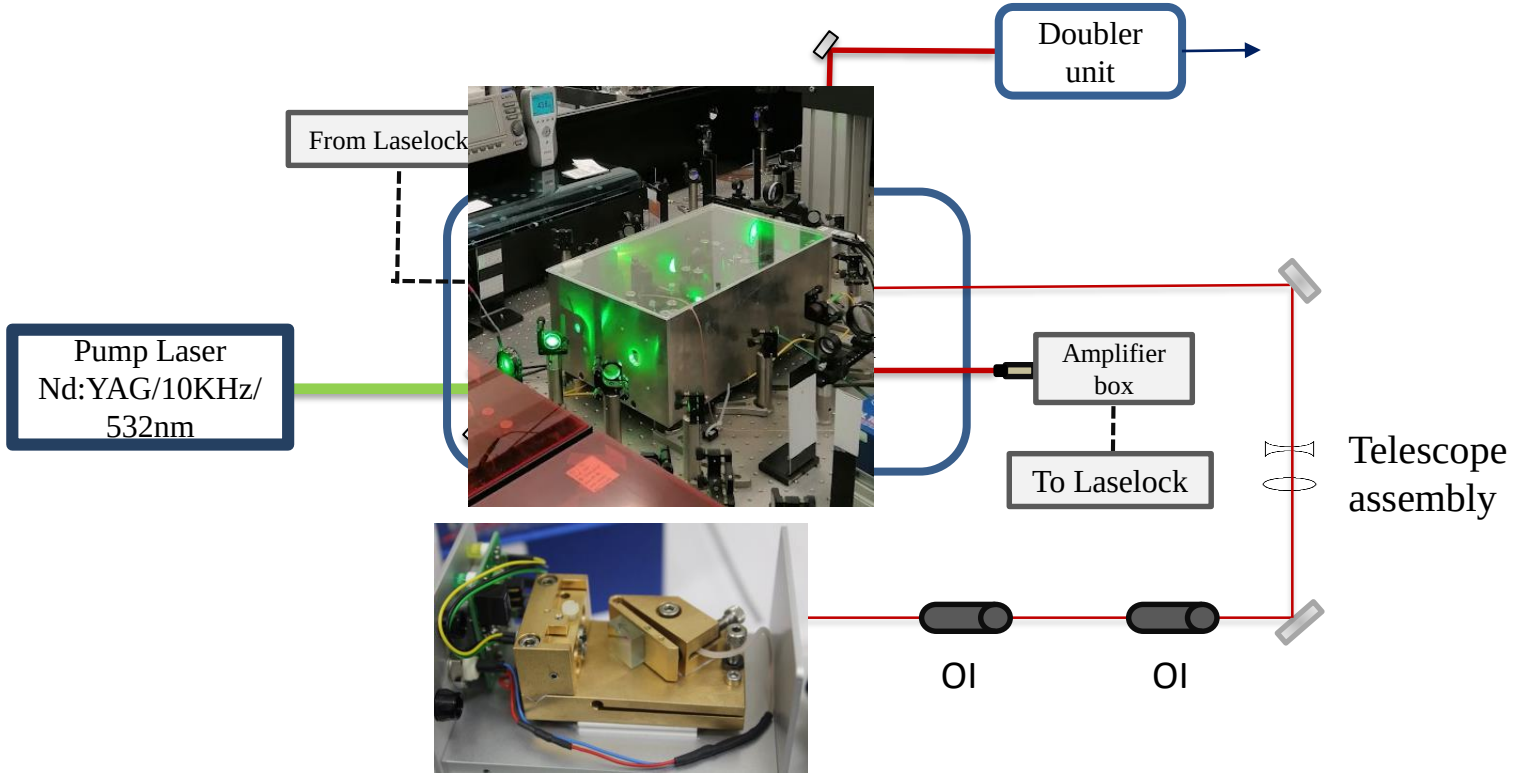


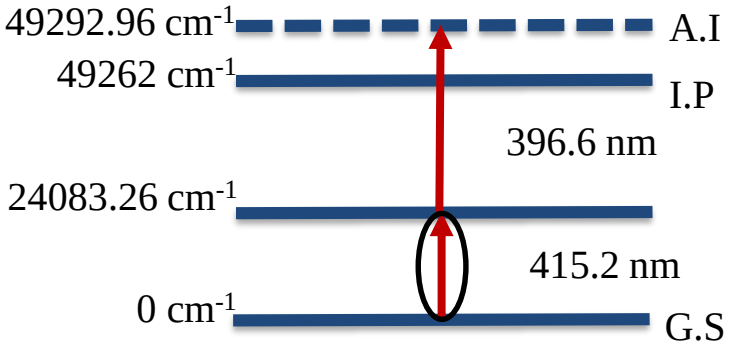
[3]Volker Snnenschein et al.Nuclear Inst. And Methiods in Physics ResearchB.463(2020) .doi.org/10.1016/j.nimb.2019.03.017

- Compact setup
- Replaces expensive commercial pump sources
- Dichroic combination of diode lasers used
- Wavelength selection by Birefringent filter and etalons
- Stabilized cavity

Narrowband laser system

- Participation in the offline commissioning of NB laser system





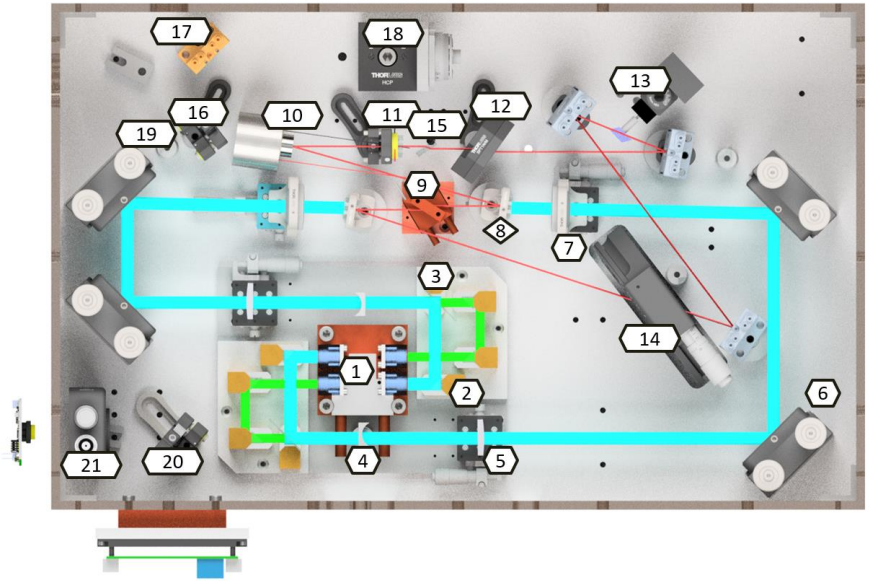
- Wavelength tuning range 10 nm - 50 nm
- Offset voltage +/- 10V for grating control

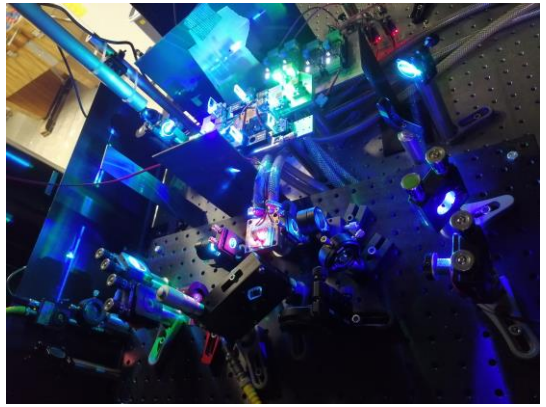
CW laser system as seed source

- Green/blue diode lasers as pump
- Power required: few mW
- Output wavelength range: 150 nm

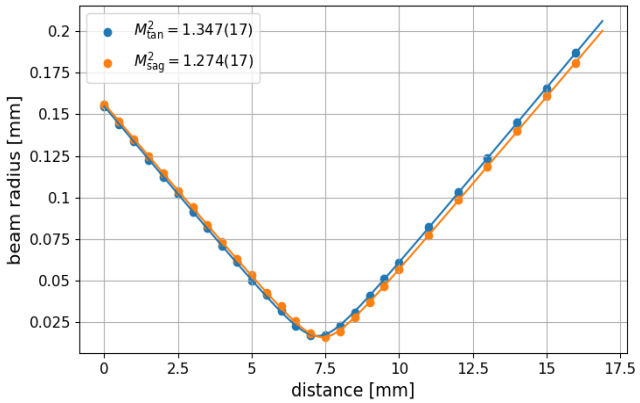
Requirements

- Narrow linewidth < 10 MHz
- Stability: Electronics
- Wavelength scanning by FPI
- Wavelength selection: BRF and etalon
- One direction operator: Faraday rotator



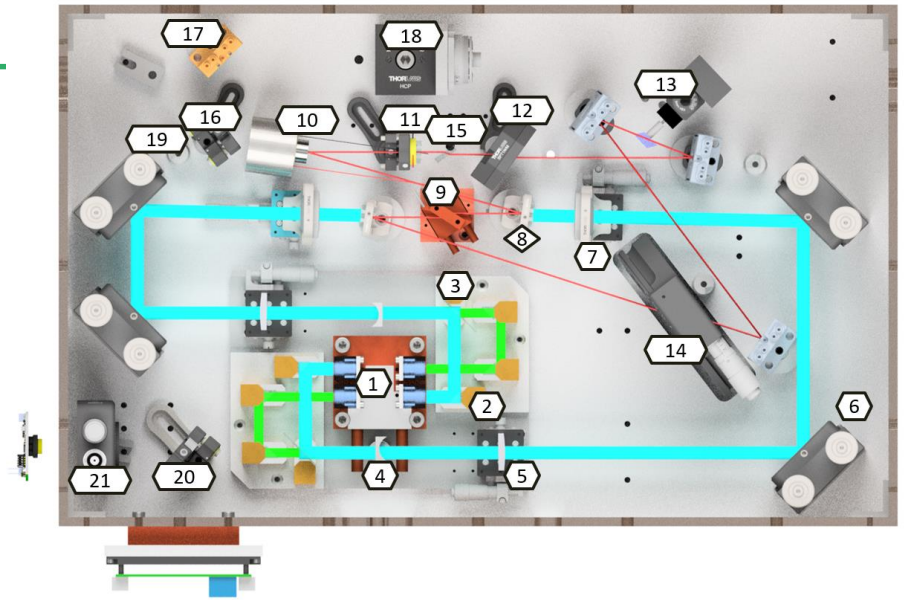


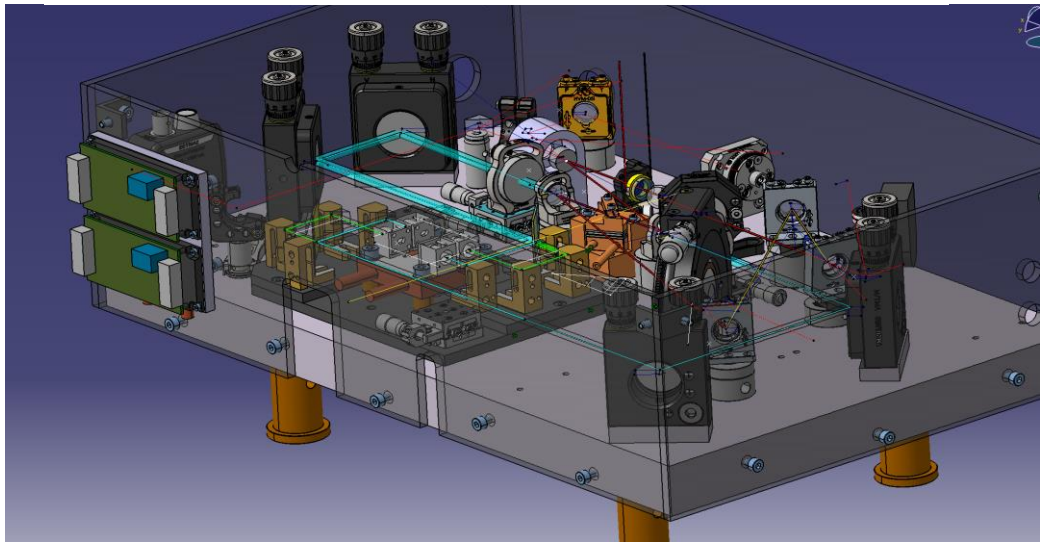
CW laser at Mainz



CW laser system as seed source

- Final design obtained from V.Sonnenschein
- Design verified in detail (Inventor Professional software)
- Update of design with machining team
- Launch of machining in progress
- Components listed and ordered, most of them delivered
- Test of components in progress
- Design of a home built FPI for wide range scanning of wavelength

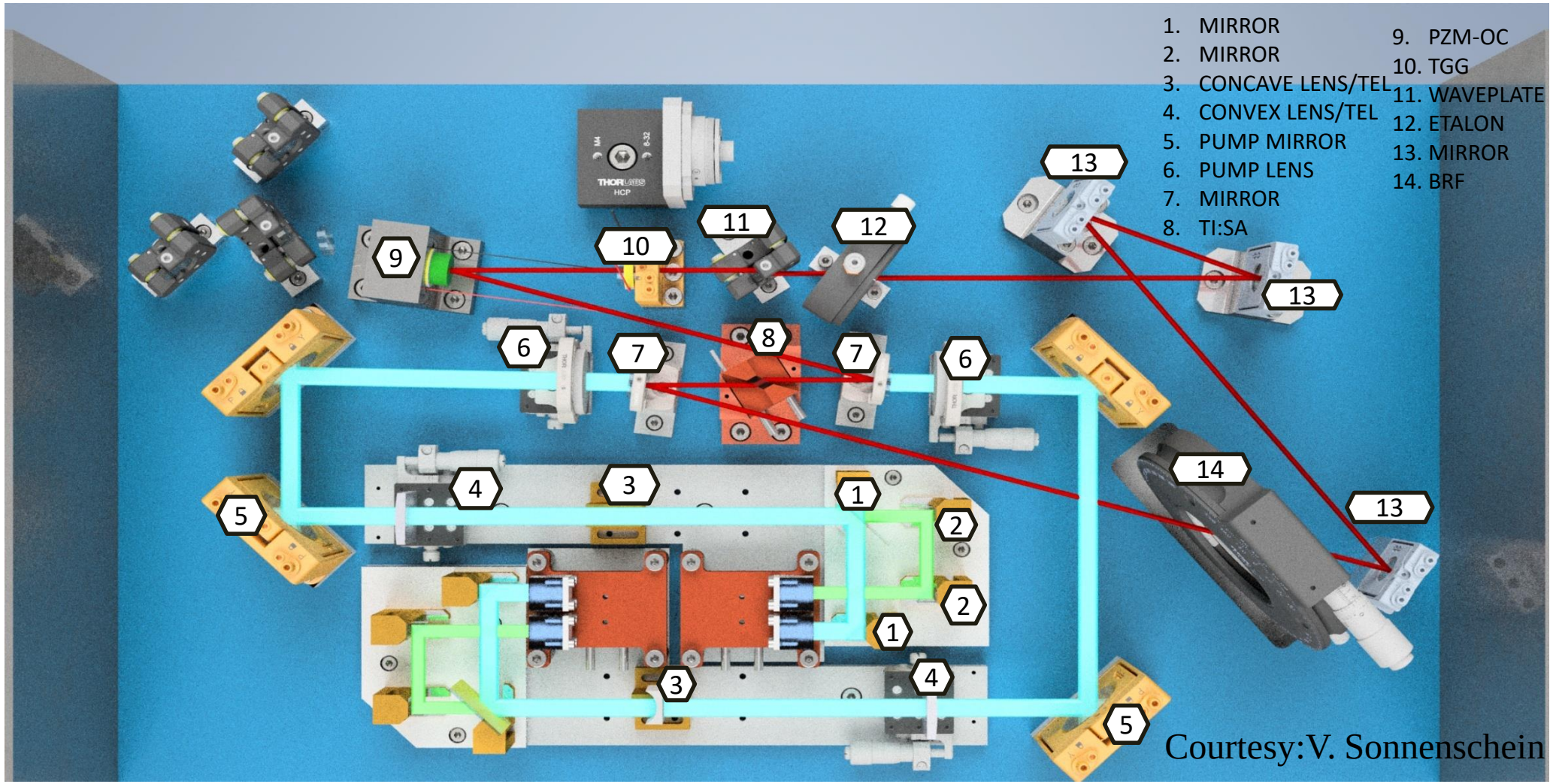




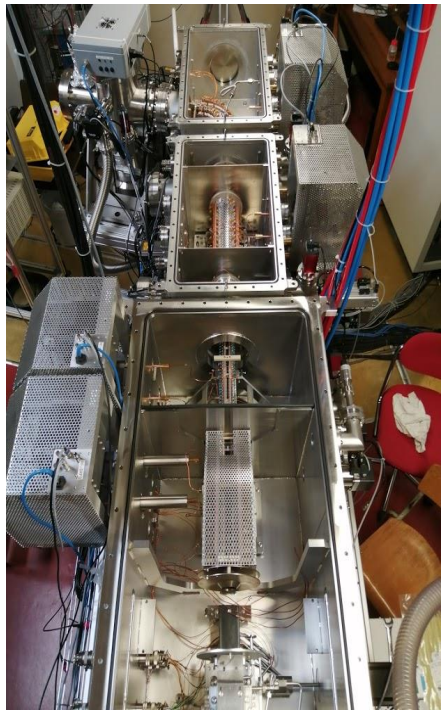
Updates

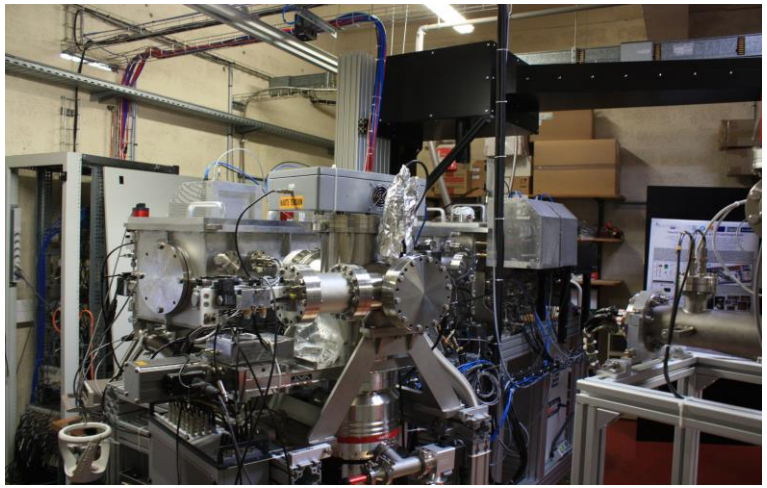
- Option to use with an Nd:YAG pump laser
- Cooling system for the Ti:sa crystal, diodes and diode controller

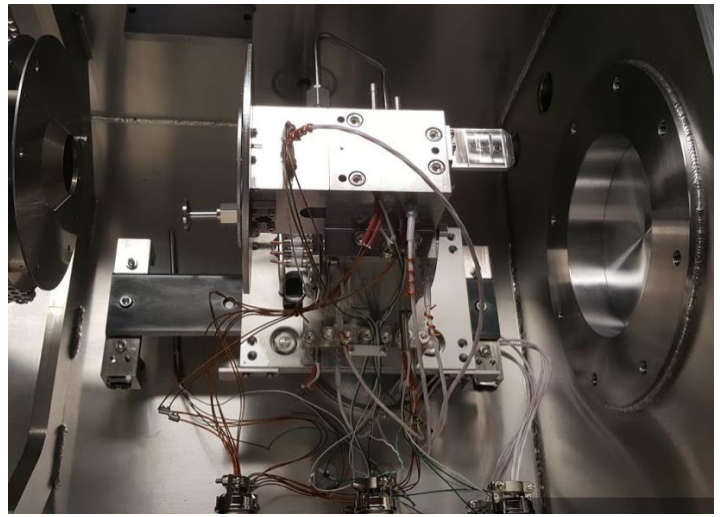
Diode Pumped CW Ti:sa cavity as the seed source



LPC



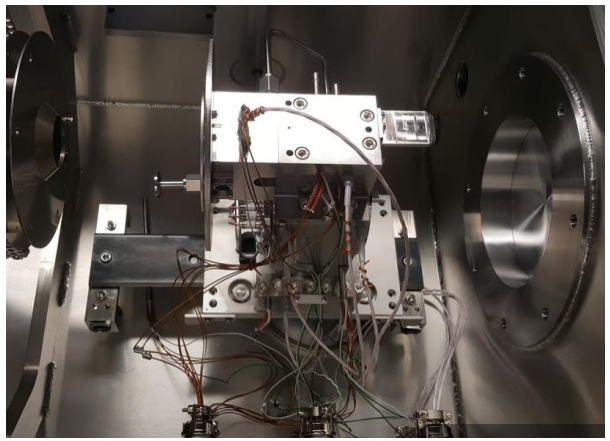


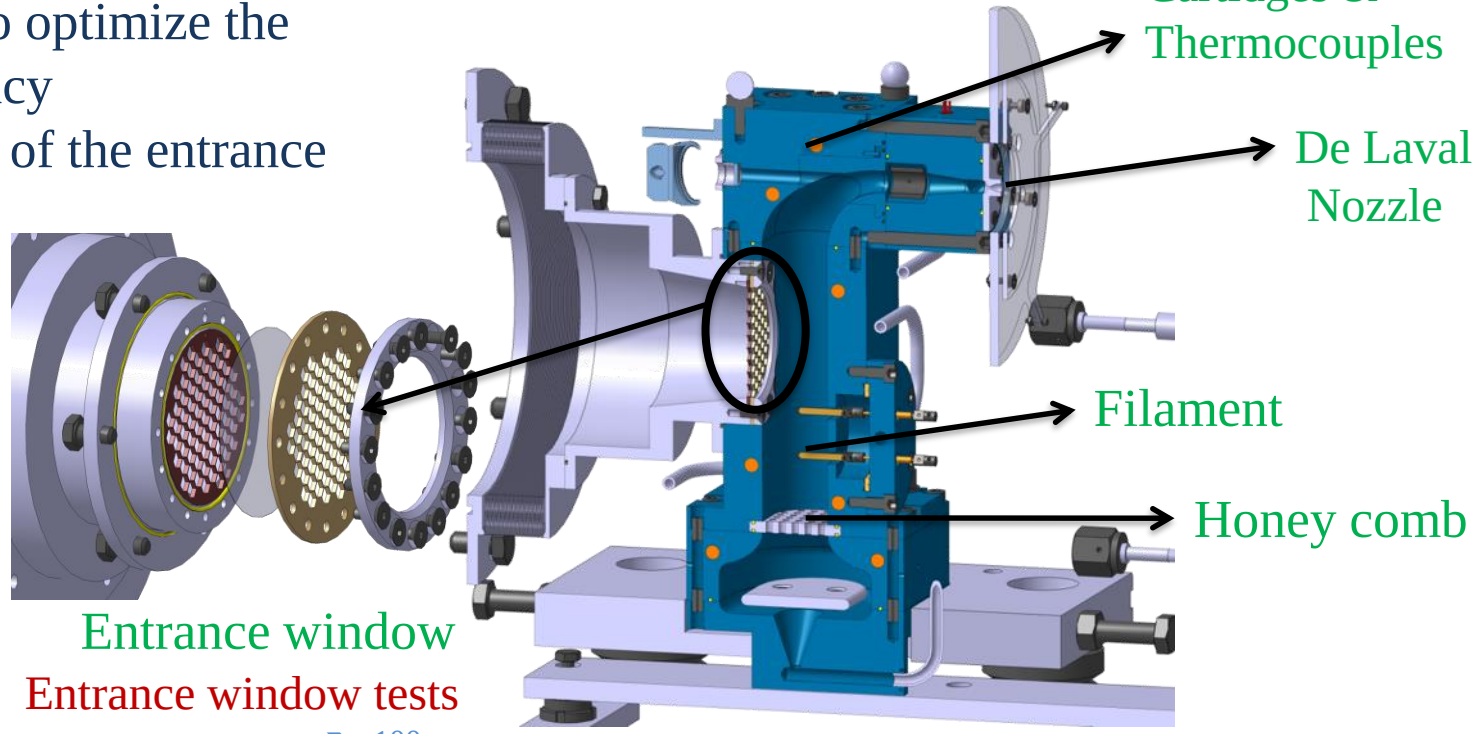


Gas cell efficiency optimisation

Optimization of the gas cell geometry

- Study gas flow inside gas cell to optimize the parameters for increased efficiency
- Simulation: Optimize geometry of the entrance window(COMSOL)
- Entrance window tests





Entrance window tests

Titanium 5µm ➔ ^{100}Sn

Titanium 3µm ➔ ^{152}Er

Titanium 3µm ➔ ^{254}No

Mylar 1,5µm ➔ ^{215}Ac