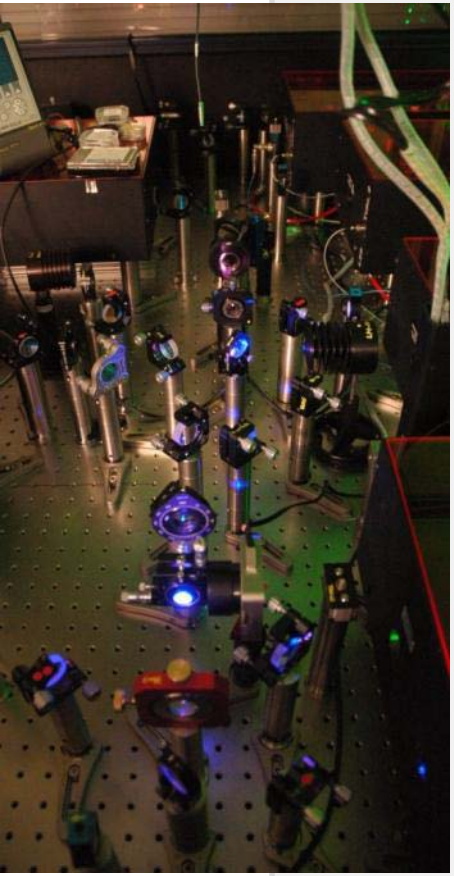


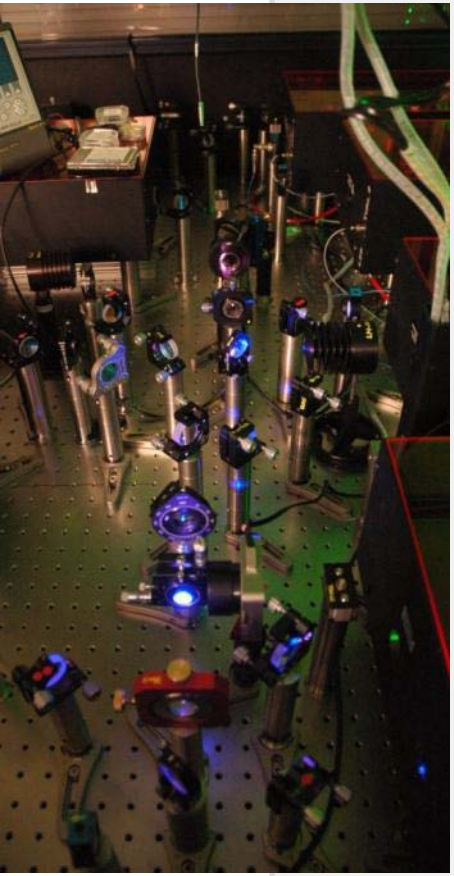
Actinium
Laser Ionization and Spectroscopy

TRILIS / TRIUMF

S. Raeder, H. Heggen, J. Lassen, P. Levy,
M. Sjodin, A. Teihelhöfer, K. Wendt

1.2.2012 - Science Forum

Outline



- Motivation for Ac spectroscopy
- Ti:Sa Laser system
- Development of ionization scheme
- Laser ionization of Ac @ TRIUMF
- Laser spectroscopy

General remarks

TABLE 6. *Terms in the Ac I spectrum*

Configuration	Designation	J	Level	Interval
$6d\ 7s^2$	$a\ ^2D$	1½	0. 00	2231. 43
		2½	2231. 43	
$6d^2\ 7s$	$a\ ^4F$	1½	9217. 28	646. 31
		2½	9863. 59	1042. 43
		3½	10906. 02	1172. 05
		4½	12078. 07	
$7s^2(a\ ^1S)7p$	$z\ ^2P^\circ$	½	?	
		1½	?	
$6d\ 7s(a\ ^3D)7p$	$z\ ^4F^\circ$	1½	*13712. 90*	1227. 82
		2½	*14940. 72*	2743. 15
		3½	*17683. 87*	
		4½	?	
$6d\ 7s(a\ ^3D)7p$	$z\ ^2D^\circ$	1½	*17736. 26*	214. 45
		2½	*17950. 71*	
$6d\ 7s(a\ ^3D)7p$	$z\ ^4D^\circ$	½	*17199. 71*	1812. 75
		1½	*19012. 46*	2183. 41
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		1½	*22801. 10*	1097. 76
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		5½	*33429. 76*	
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		1½	*32918. 40*	
		1½	*33673. 66*	
		3½	*33756. 43*	
		3½	*34360. 25*	
		2½	*34658. 47*	
		4½	*34788. 12*	
		4½	*35870. 00*	

Meggers et al. J. Res. Nat. Bur. Stand, **58**,6, pp297 (1957)

Laser spectroscopy for

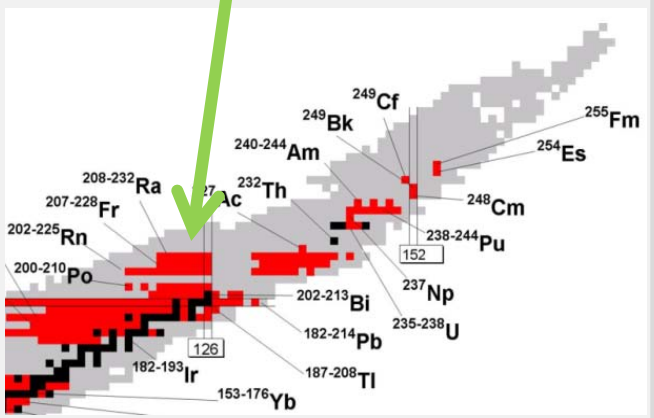
- nuclear properties
  - Isotope shift
    - Δr^2
  - Hyperfine splitting
    - μ, Q, I
- Atomic properties
  - Atomic energy levels
  - Ionization potentials
  - Ionization schemes

^{212,213}Ac

Gascell (IGISOL)

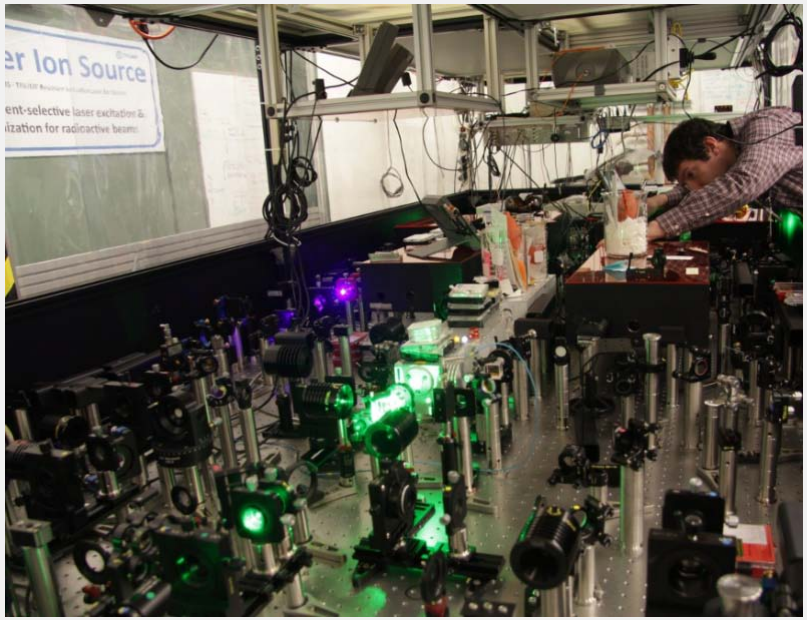
^{197}Au(^{20}Ne-145 MeV,4-5n)^{212,213}Ac

σ: 2.3 mb for ^{212,213}Ac



http://www.gsi.de/forschung/ap/projects/laser/survey.html

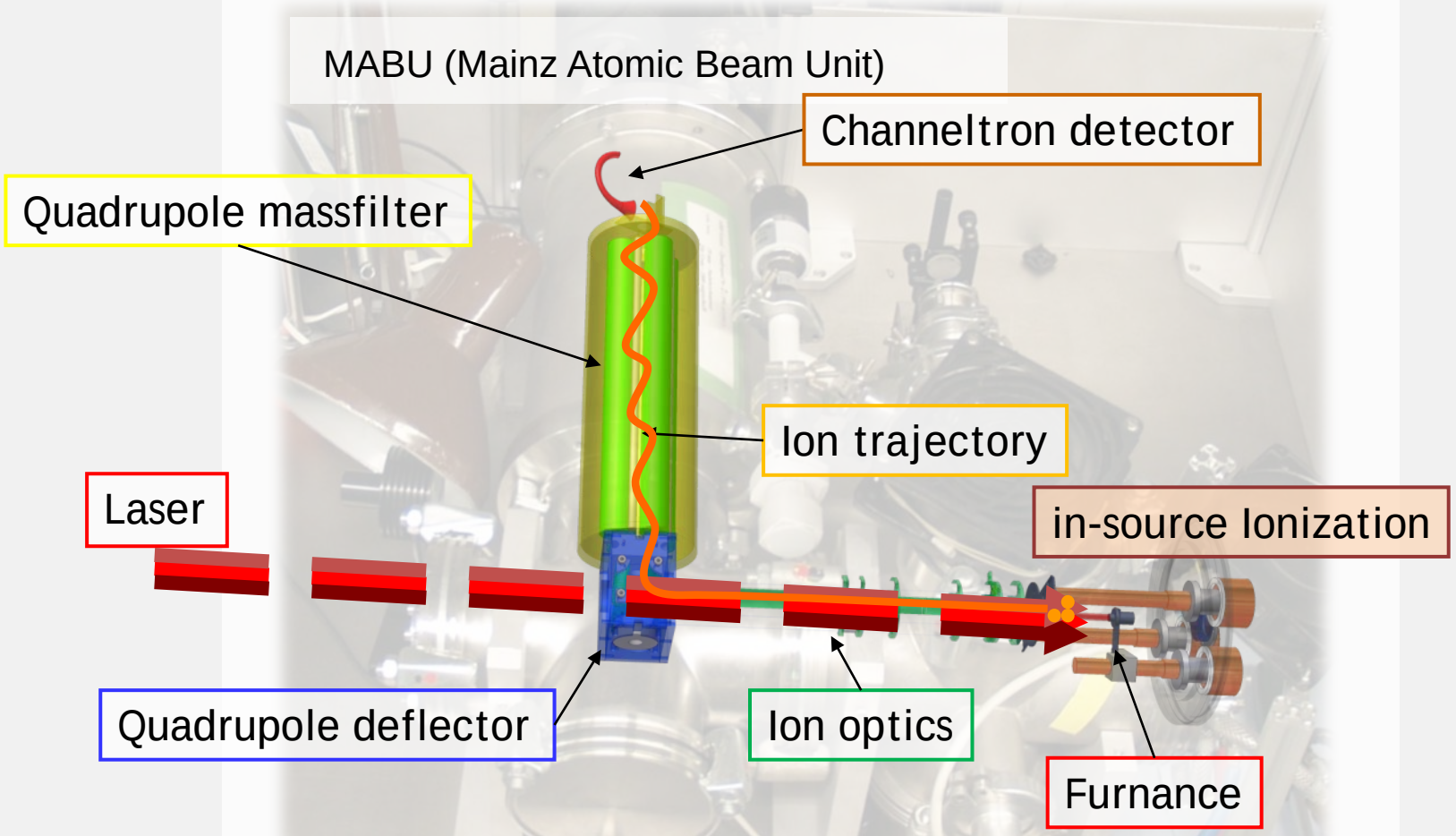
Pulsed Ti:Sa-Laser System



Specifications	
Repetition rate	10 kHz
Wavelength range fundamental	690 – 960 nm
doubled (2v)	350 – 480 nm
trippled (3v)	233 – 320 nm
quadrupled (4v)	205 – 232 nm
Tuning range conventional	300 GHz
grating-Resonator	135 THz
Intensity	3 W
doubled (2v)	0.5 W
trippled (3v)	100 mW
quadrupled (4v)	100 mW
Spatial beam quality, M^2	< 1.2
Spectral bandwidth	3 – 5 GHz (→20MHz)
Temporal pulse duration	30 – 50 ns

Good coverage of **infra-red to visible-red** & **blue to ultra-violet** range

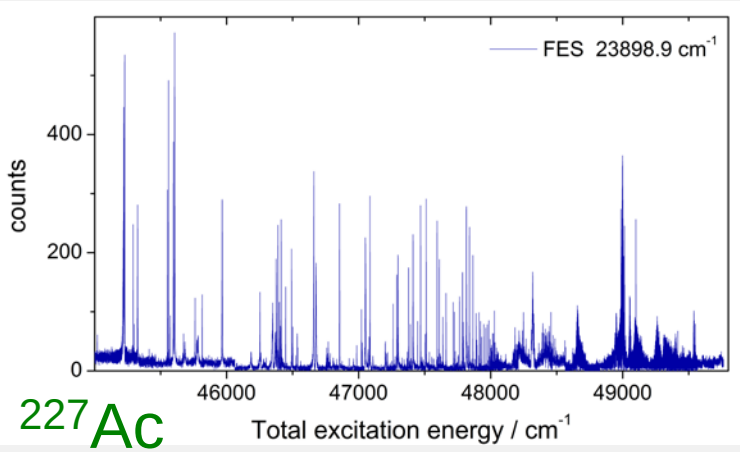
In-Source Ionization

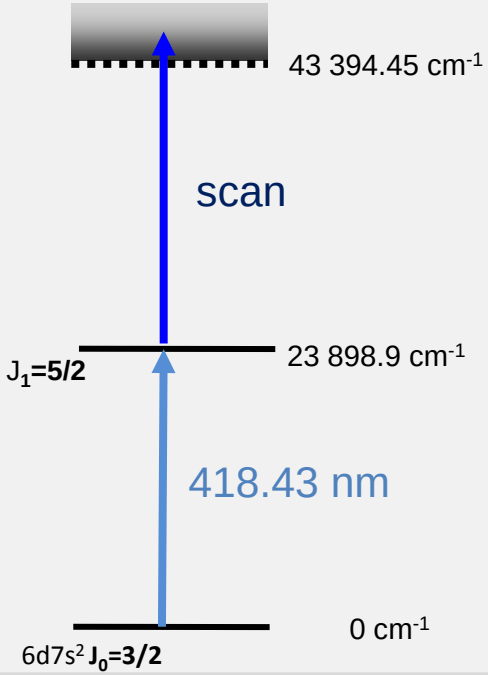


Laser ion source & laser in-source spectroscopy

resolution limited to Doppler broadening and laser bandwidth

Ionisation scheme



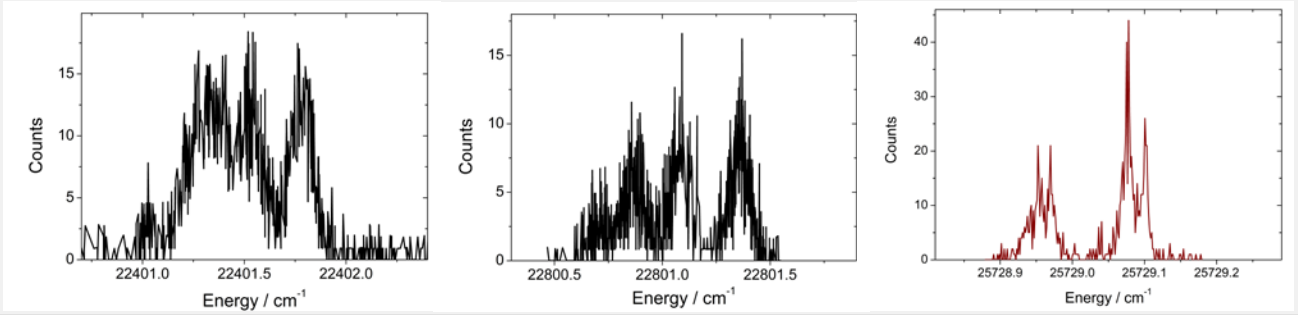


- In-Source spectroscopy in Mainz - ^{227}Ac ($T_{1/2}$ = 21.8 a)
  - Ionization scheme:

    spectra of

    Auto-ionizing (AI) resonances

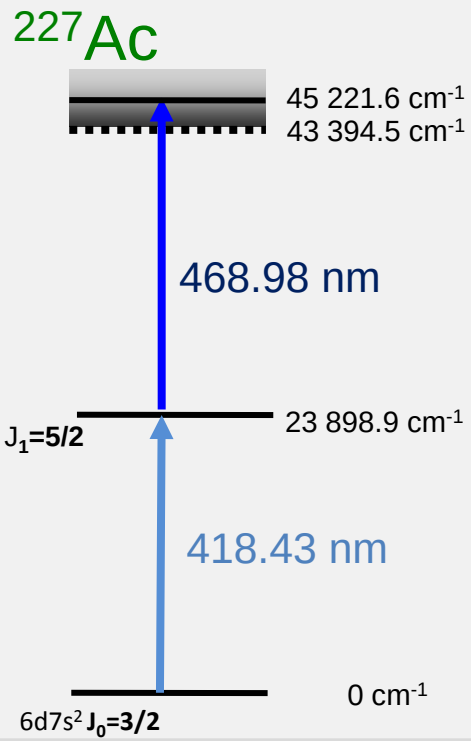
    Rydberg levels, **Phys. Rev. A 85, 012525 (2012)**
  - First hyperfine structure

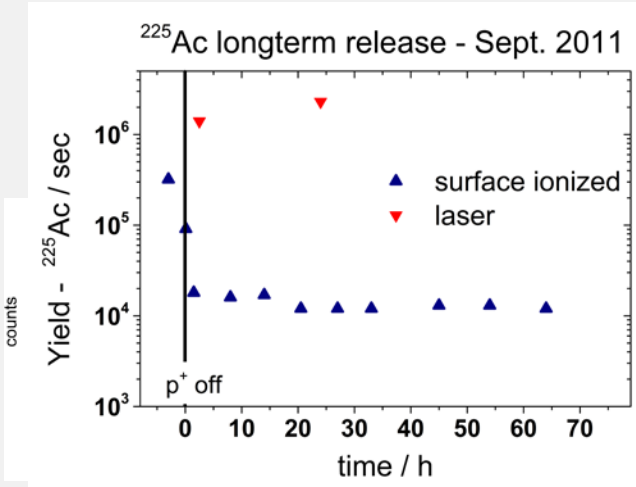


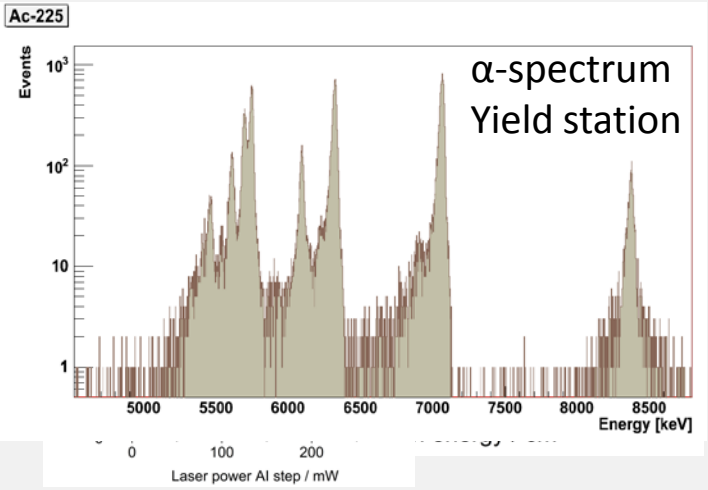
Ionisation of Ac @ ISAC

Sept. 2011: Test of ionization scheme on irradiated UC_x target without p^+

^{225}Ac ($T_{1/2}$ = 10 d) requested for ^{221}Fr experiments







- Yield: up to 10^7 ions / sec (Dec. 2011)
- Factor 100 laser enhancement
  higher than expected - IP of Ac: 5.4 eV similar to Li
- Stable signal over days

Ionisation of Ac @ ISAC

Sept. 2011: Test of ionization scheme on irradiated UC_x target without p^+

^{225}Ac ($T_{1/2}$ = 10 d) requested for ^{221}Fr experiments

$^{212,213}Ac$

Gascell (IGISOL)

$^{197}Au(^{20}Ne\text{-}145\ MeV,4\text{-}5n)^{212,213}Ac$

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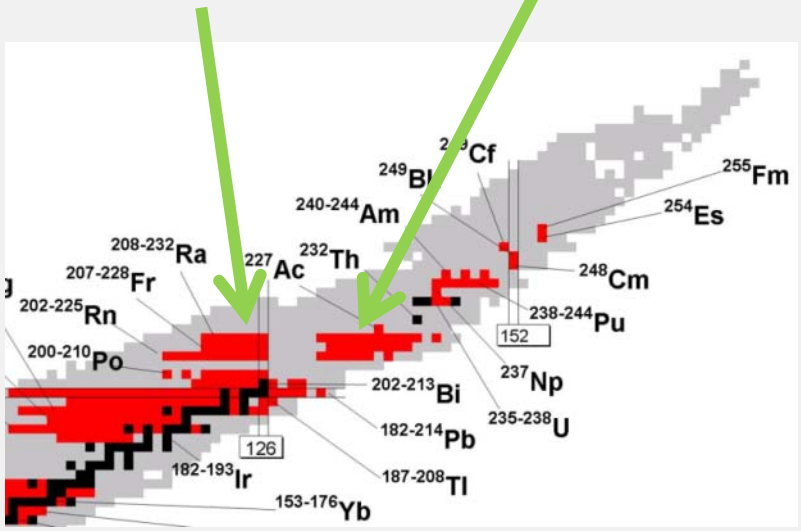
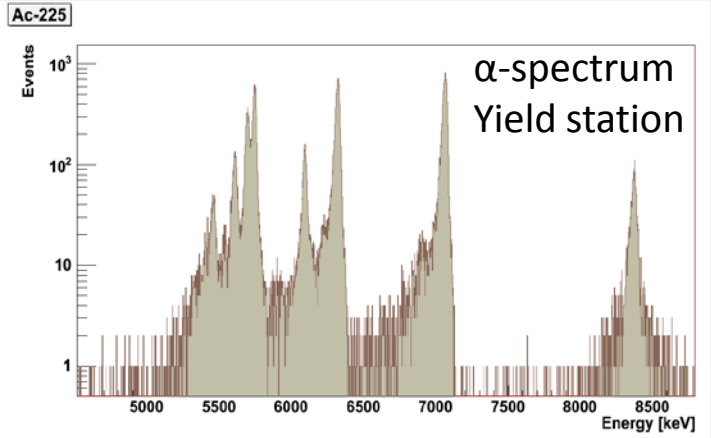
…225…Ac

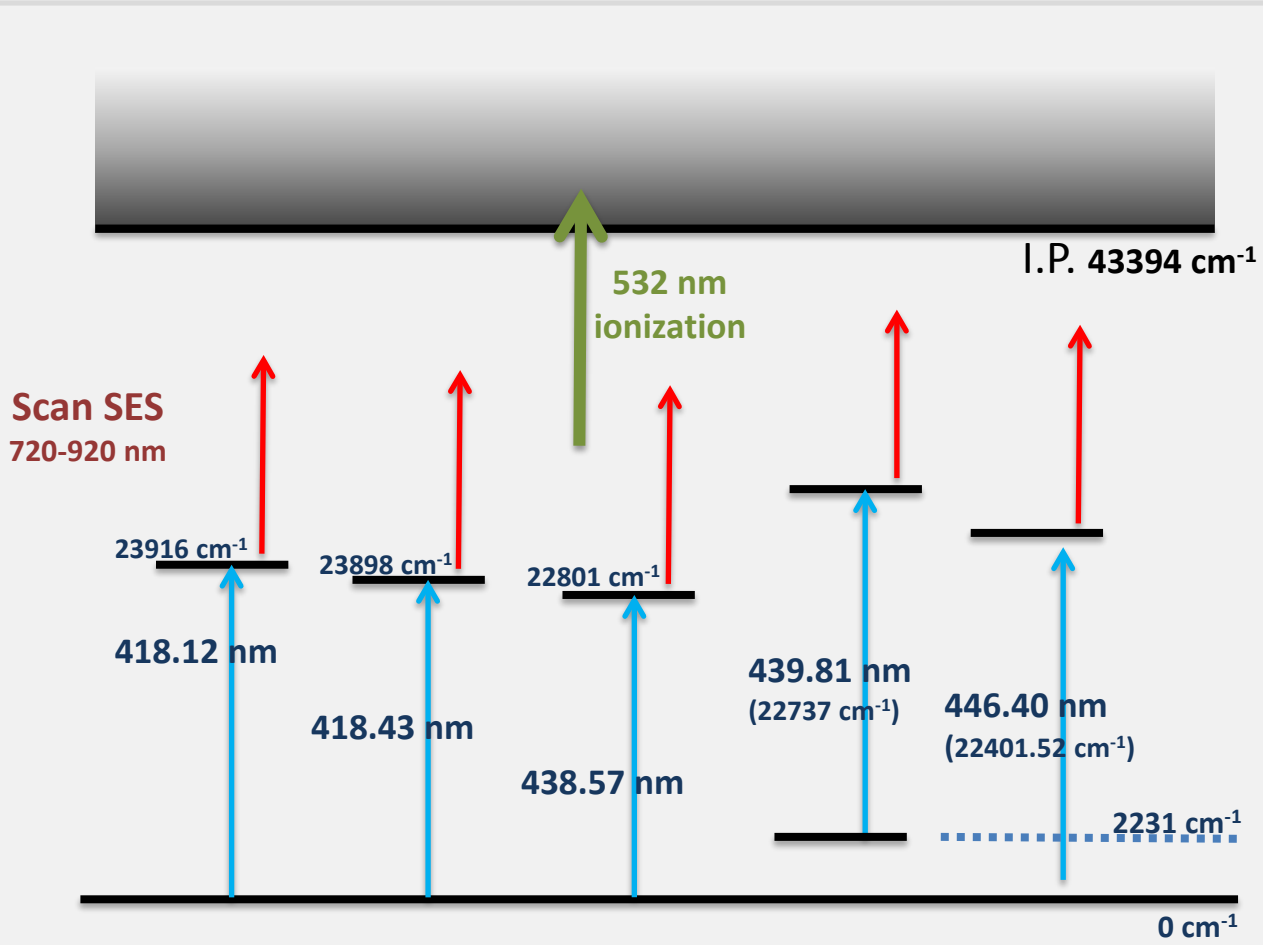
ISOL !!



http://www.gsi.de/forschung/ap/projects/laser/survey.html



Ac spectroscopy



- Signal from ISAC Channeltron detector
- Attenuated beam

TABLE 6. *Terms in the Ac I spectrum*

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		4½	32867. 39	561. 37
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		1½	32918. 40	
		1½	33673. 66	
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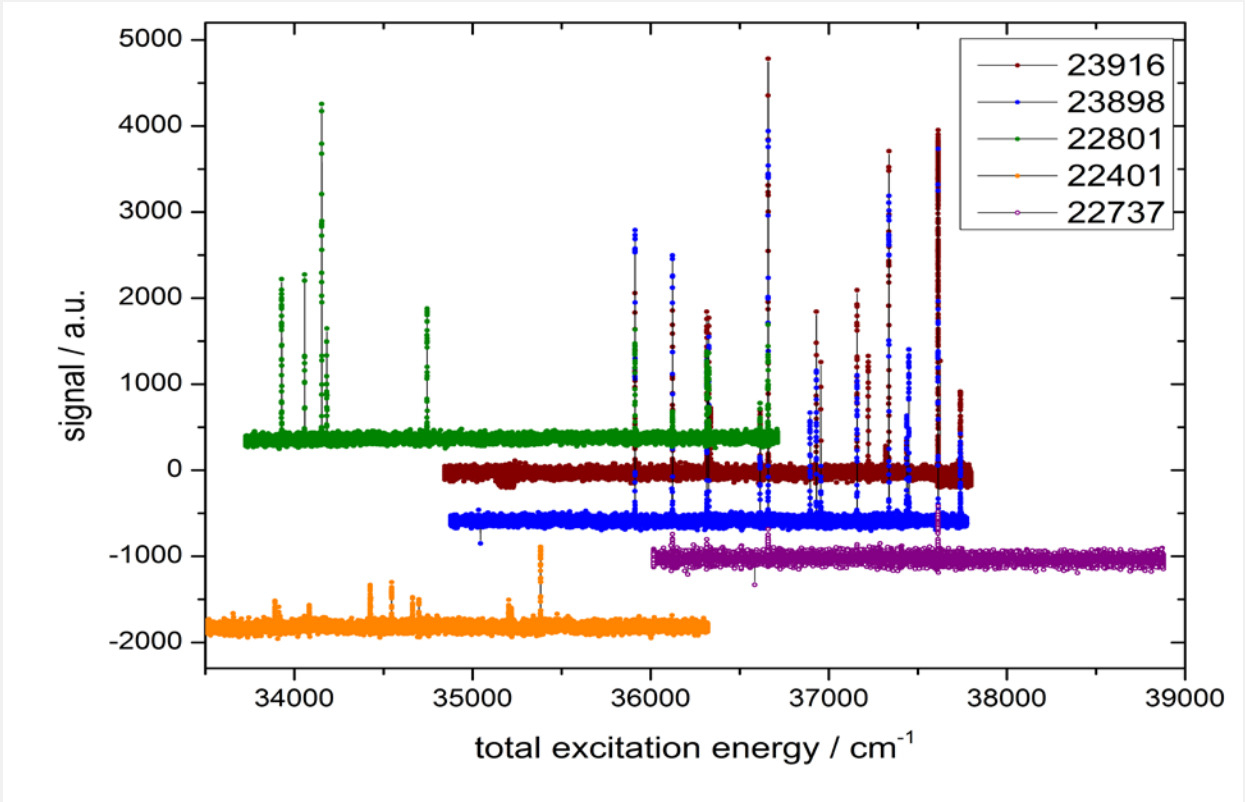
		2½	34658. 47	
		4½	34788. 12	
		4½	35870. 00	

Meggers et al. J. Res. Nat. Bur. Stand, **58**,6, pp297 (1957)

High lying atomic levels in Ac



- 20 high lying atomic levels identified
- 22401 cm^{-1} transition does not fit

TABLE 6. *Terms in the Ac I spectrum*

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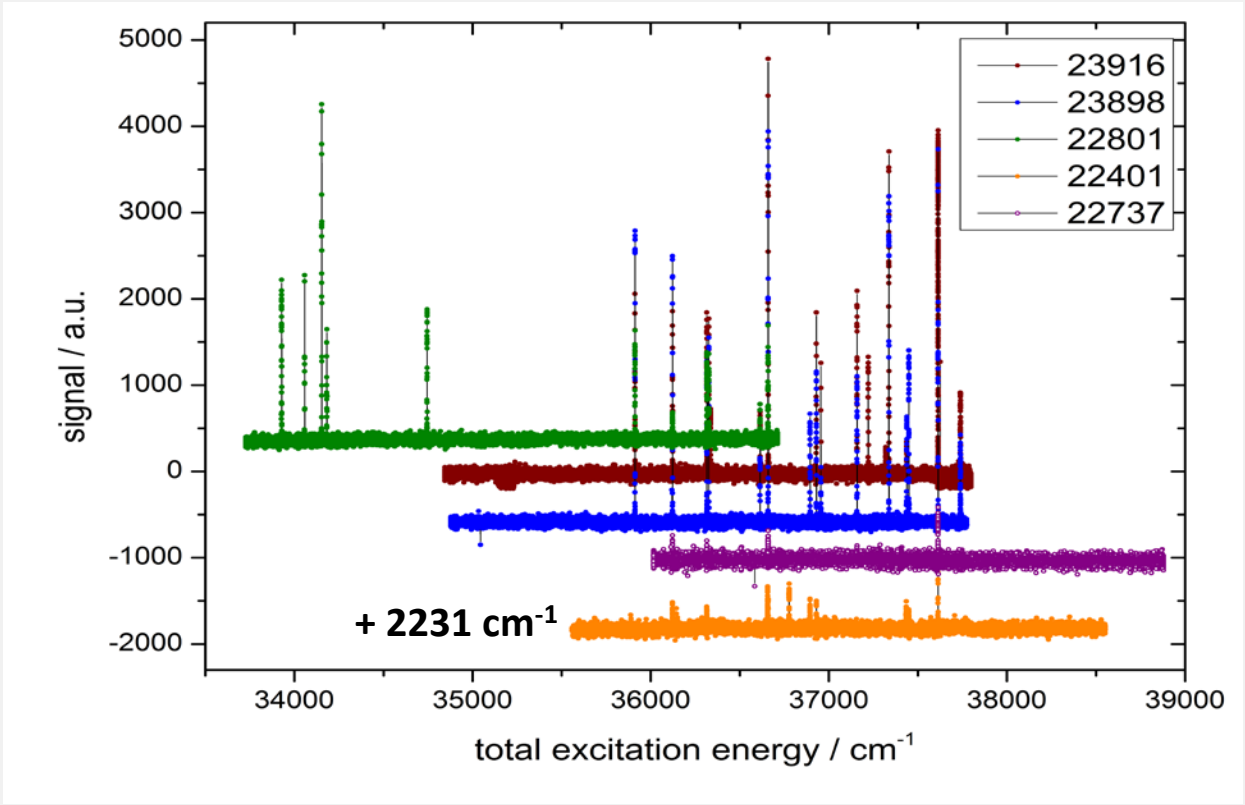
Meggers et al. J. Res. Nat. Bur. Stand, **58**,6, pp297 (1957)

High lying atomic levels in Ac



- 20 high lying atomic levels identified
- 22401 cm^{-1} transition does not fit

  Transitions starts from thermal 2231 cm^{-1} level

  → Reliability of atomic data ?

TABLE 6. *Terms in the Ac I spectrum*

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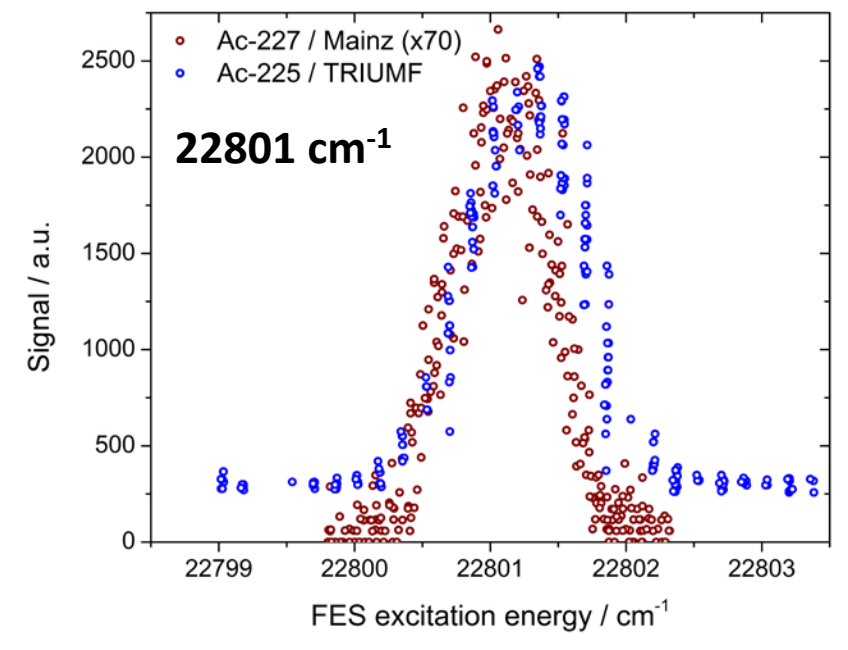
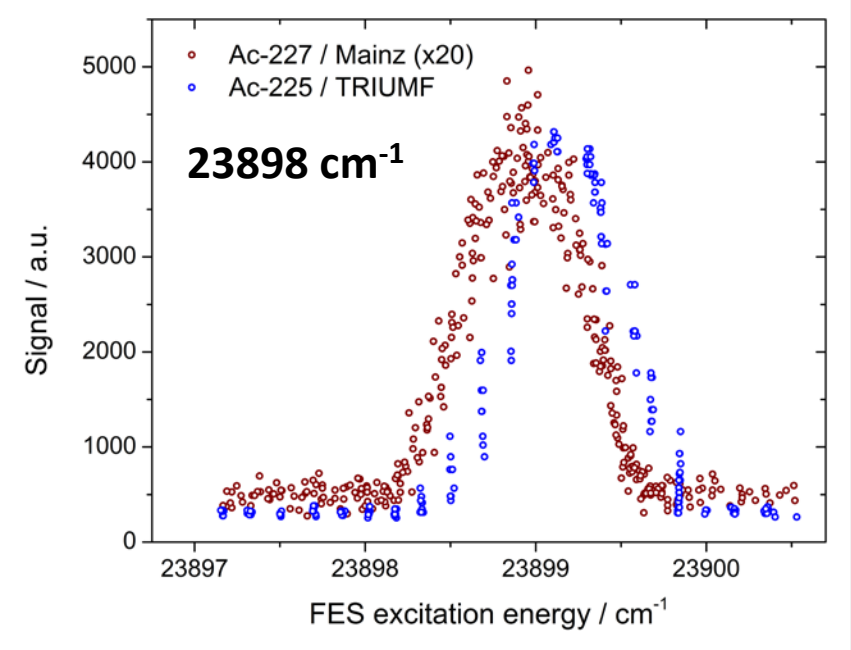
Meggers et al. J. Res. Nat. Bur. Stand, **58**,6, pp297 (1957)

Isotope Shifts

First rough measurement of isotope shifts

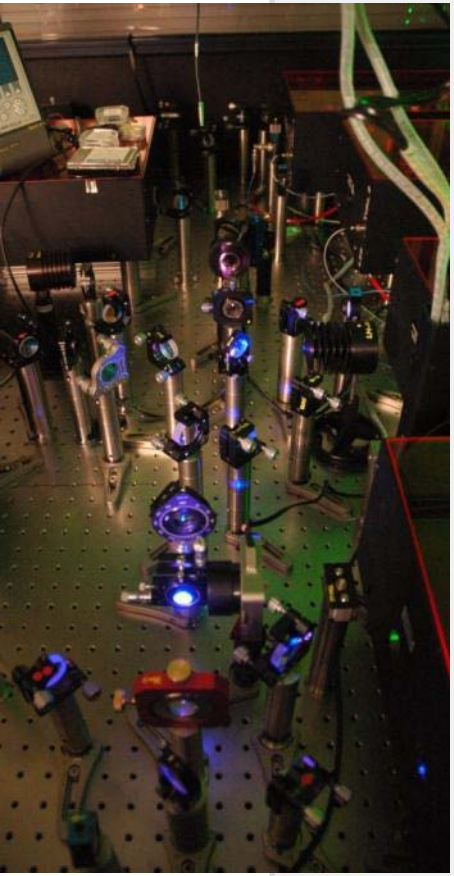




About 0.2 cm^{-1} (6 GHz) isotope shift ^{227}Ac-^{225}Ac measured

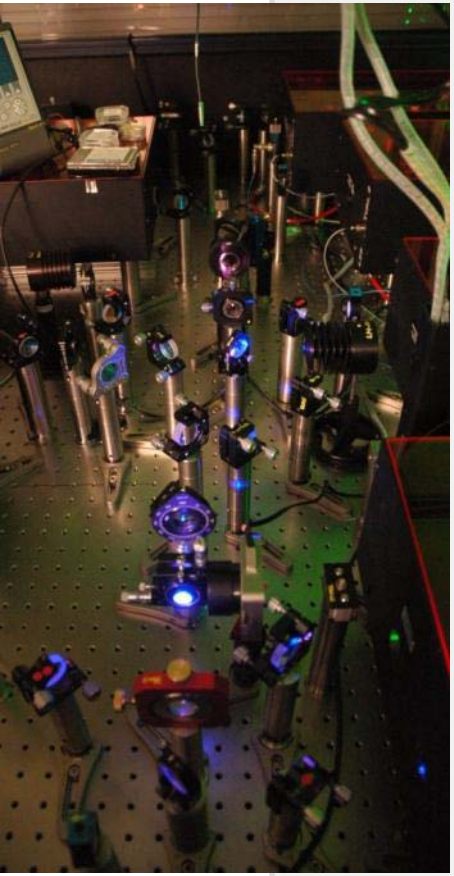
laser optimized for spectroscopy - high power and spectral broadband

Outlook



- Atomic lines still under evaluation
  - More data from Jan. 2012
- Atomic spectroscopy mostly done
  - Few spectra missing due to break of target
- HFS & IS Spectroscopy
  - Has to be measured precisely
  - Which isotopes are feasible

Thanks



- J. Grüneisen (B. Eng.)
  Thesis on *Grating laser control*
- Th. Quenzel (B. Eng.)
  Thesis on *Automated doubling crystal tracking*

- Special thanks to
  - ISAC Operators
  - Yield station support
  - Joe Mildenberger - Safety
  - John Behr

Thanks for your attention