The complete ISOLDE RILIS upgrade programme.

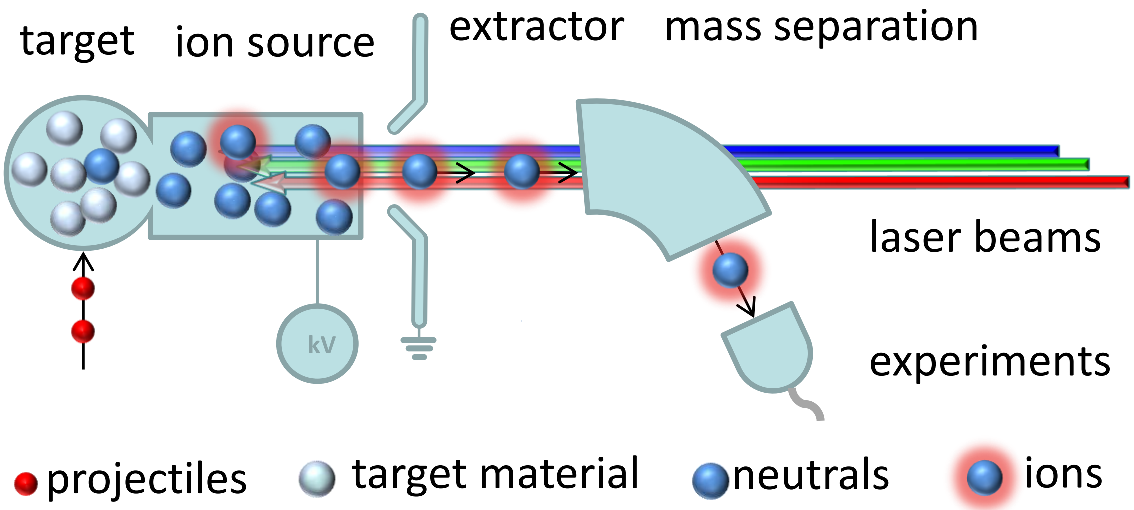
The benefits of the new Dual Dye and Ti:Sa RILIS

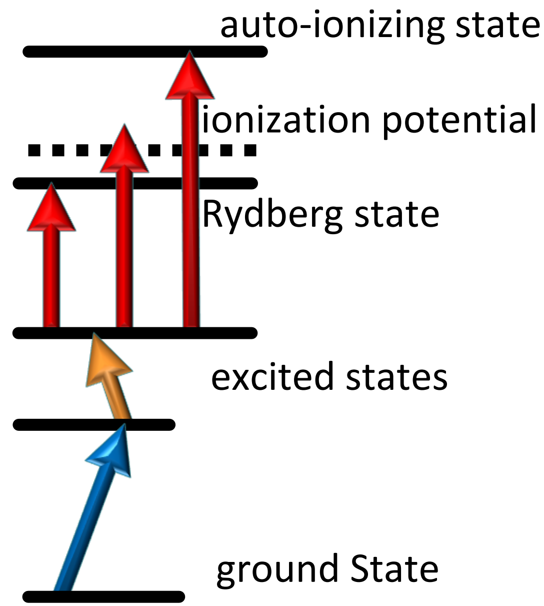
Bruce Marsh - CERN EN-STI-LP

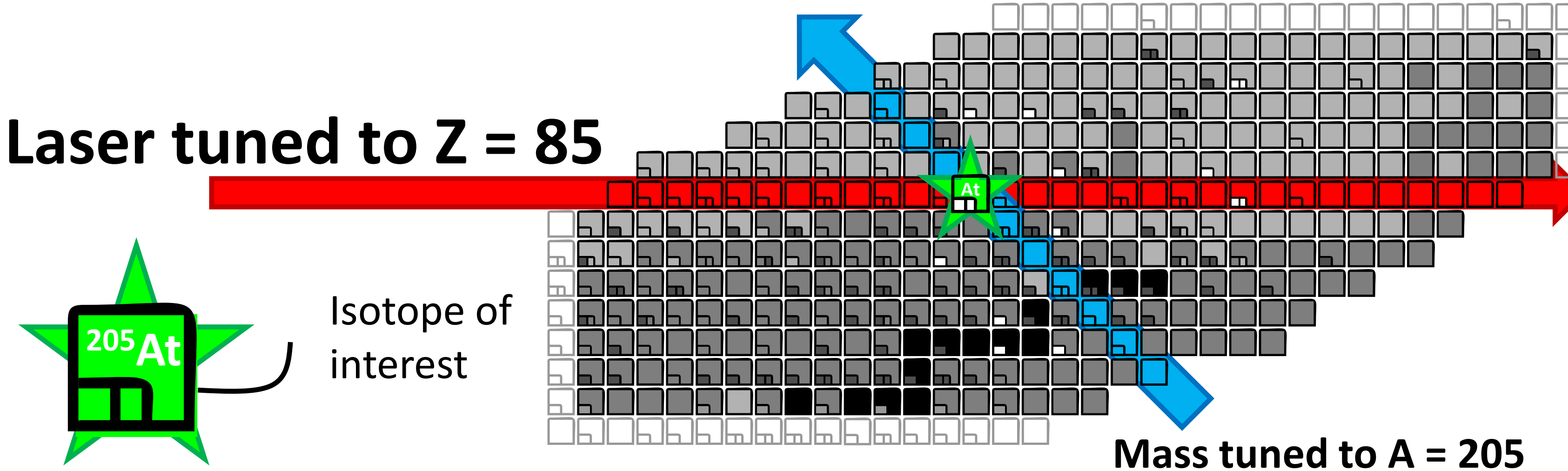
EURORIB '12 Padova, Italy

The ISOLDE Resonance Ionization Laser Ion Source

Z- selective ionization and extraction:







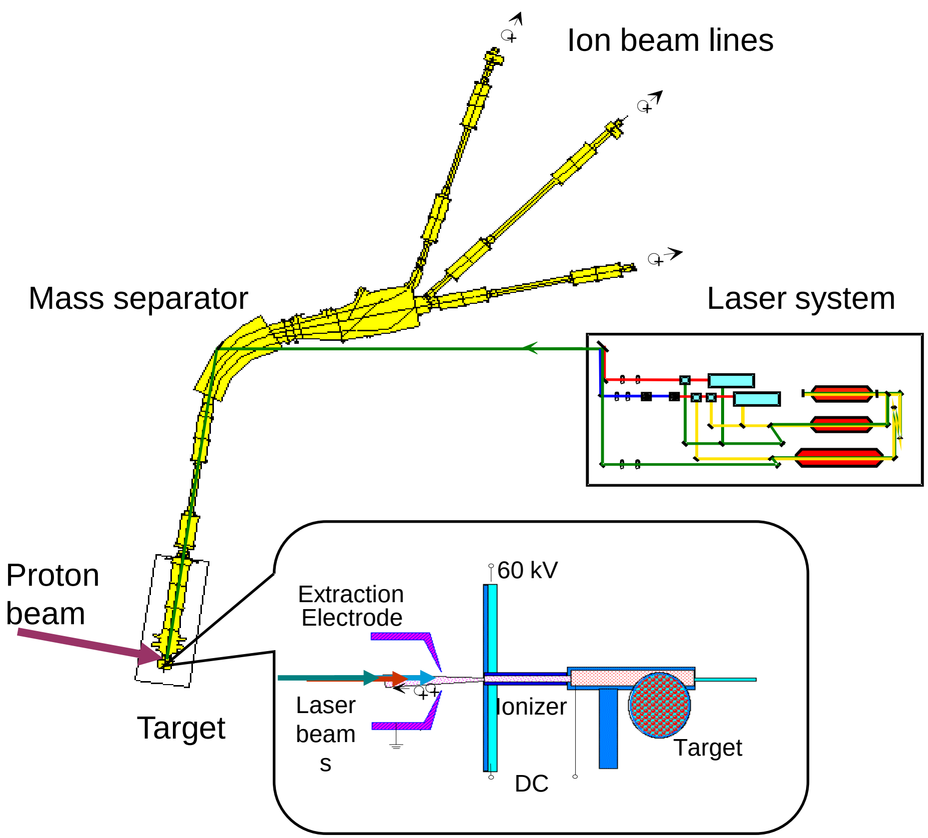
RILIS at ISOLDE PSB since 1994

Chemically selective laser ion-source for the CERN–ISOLDE on-line mass separator facility

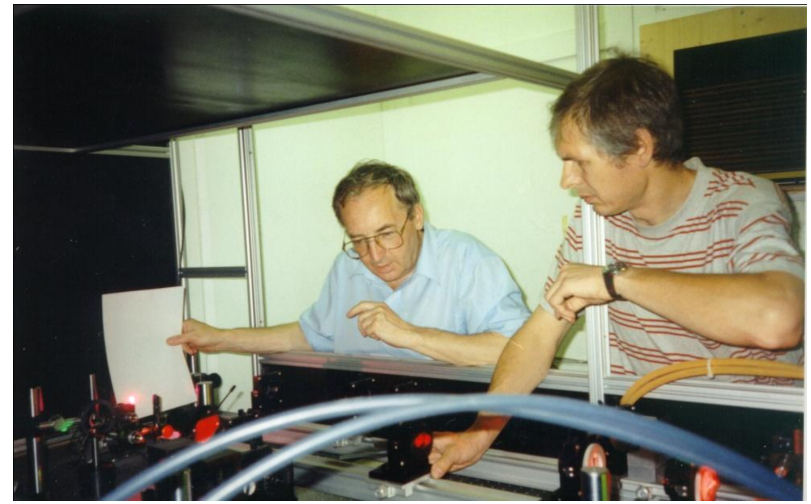
V.I. Mishin [1], V.N. Fedoseyev [1], H.-J. Kluge [2], V.S. Letokhov [1], H.L. Ravn [3], F. Scheerer [2], Y. Shirakabe [4], S. Sundell [3], O. Tengblad [3] and the ISOLDE Collaboration
PPE Division, CERN, Geneva, Switzerland

Received 26 November 1992

Nuclear Instruments and Methods in Physics Research B73 (1993) 550–560



Target - Ion Source Unit



CVL lasers: ν_{rep}=11.000 Hz
Oscillator + 2 amplifiers
2-3 dye lasers with amplifiers,
nonlinear crystals BBO:

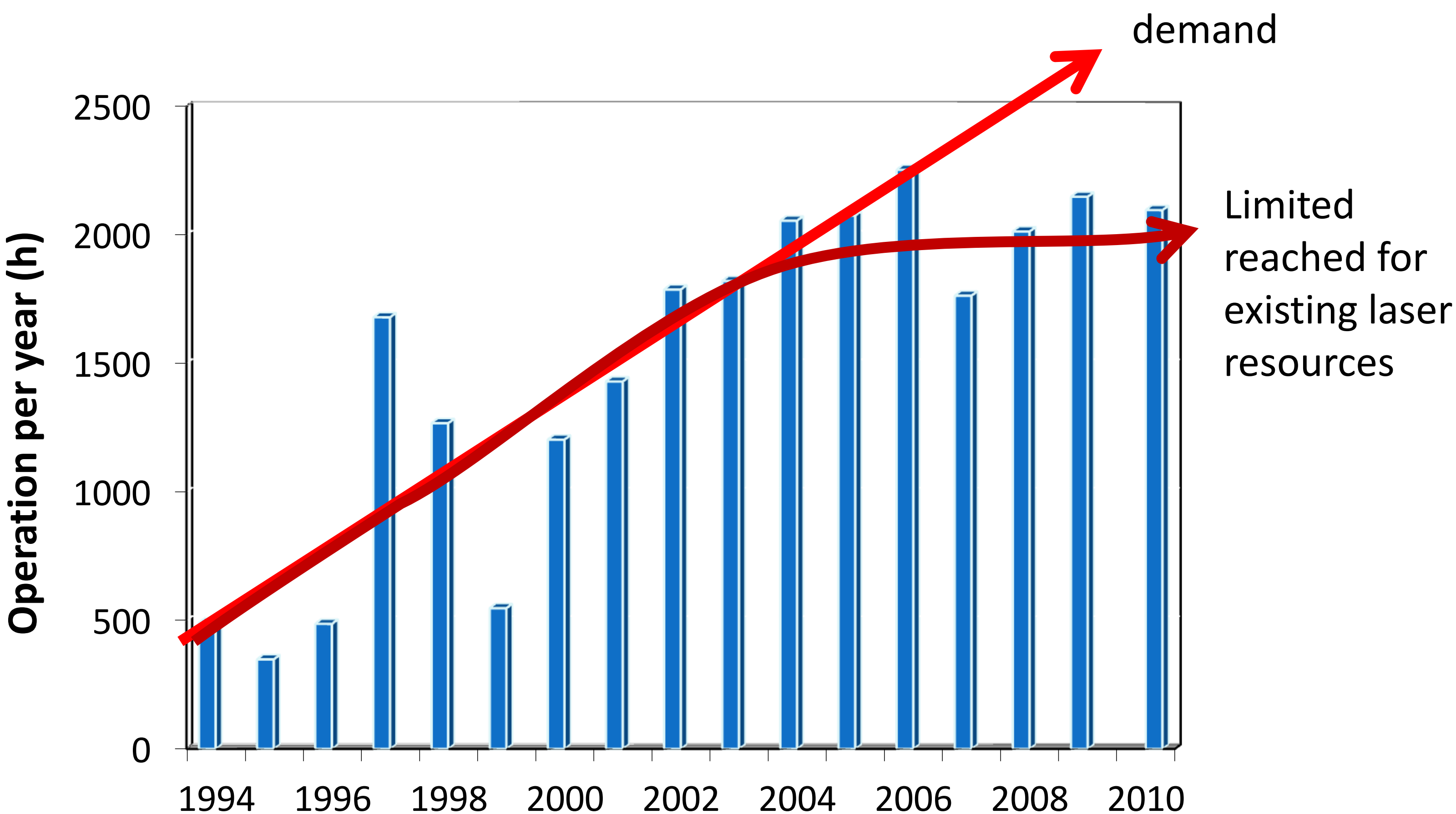
$$P_{Cu}^{total} \leq 75\,W$$

$$P_{dye} \leq 8\,W$$

$$P_{2\omega} \leq 2\,W \qquad P_{3\omega} \leq 0.2\,W$$

RILIS operation since 1994

- Annually increasing demand for RILIS beams
- Feasible 'hours of operation' limit reached in 2002
- Increase requires greater reliability and a larger laser installation – RILIS UPGRADE



The 3 stages of RILIS Upgrade

1 **The pump laser upgrade[1]:**

- ➢ Change from copper vapour laser (CVL) to commercial Nd:YAG laser

Aim: Maintain or improve the dye laser performance whilst increasing the **reliability** of the overall system.

2 **The dye laser upgrade:**

- ➢ 3 New state of the art dye lasers to replace the original dye lasers

Aim: Improve the dye laser **performance**, **ease of use and reliability**, make full use of the capabilities of the new pump laser.

3 **Install an independent and complementary Ti:Sa based RILIS laser setup[2,3] :**

- ➢ 2 pump lasers and 3 Ti:Sa lasers plus harmonic generation units

Aim: **Extend the tuning range** of the RILIS setup to enable access to the large number of ionization schemes developed for Ti:Sa lasers.

Reduce switching time between elements to allow for more condensed scheduling of RILIS runs.

2008

2009

2010

2011

2012

Additional on-going developments

- Improve **monitoring** and **automation** of the RILIS parameters
- Implement **machine protection** and alert systems to enable **on-call operation**
- Improve the **selectivity** of RILIS through ion source developments

[1] The ISOLDE RILIS pump laser upgrade and the LARIS Laboratory

B. Marsh et al: Hyperfine Interactions, Volume 196, Issue 1-3, pp. 129-141 (2010)

[2] A complementary laser system for ISOLDE RILIS

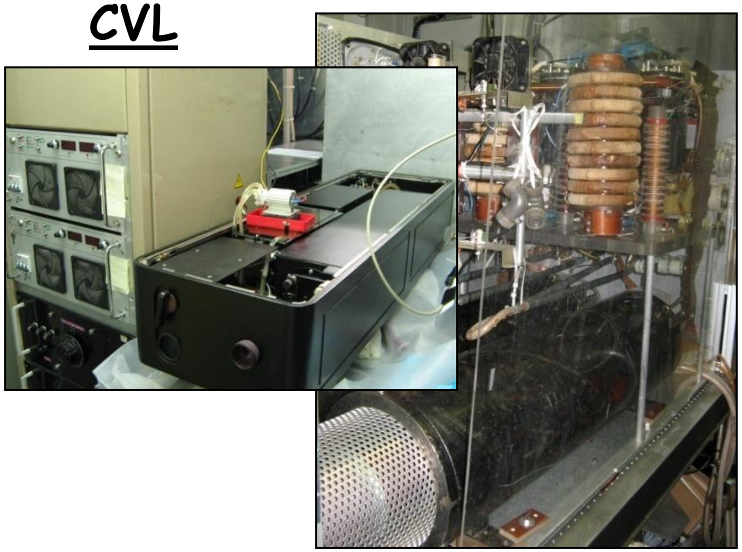
S Rothe et al: Journal of Physics: Conference Series 312 (2011) 052020

[3] Upgrade of the RILIS at ISOLDE: New lasers and new ion beams

V. Fedosseev et al: Rev. Sci. Instrum. 83, 02A903 (2012)

Solid-state pump laser parameters

CVL



15 ns @ 11 kHz

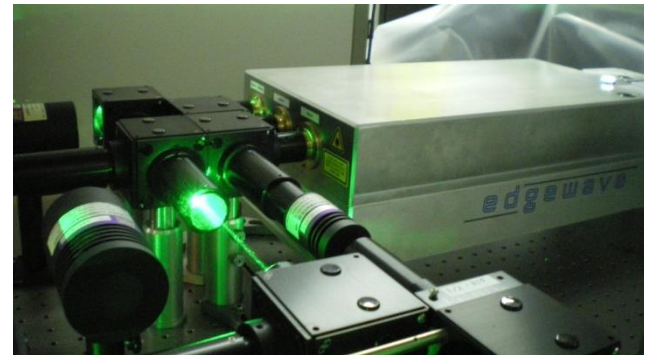
Green Beams
45 W @ 511 nm

Yellow Beams
35 W @ 578 nm

2 hr start up time

Varying power output over time

SSL



8 ns @ 10 kHz

Green Beams
85 W (+11 W)
@ 532 nm

UV Beam
18 W @ 355 nm

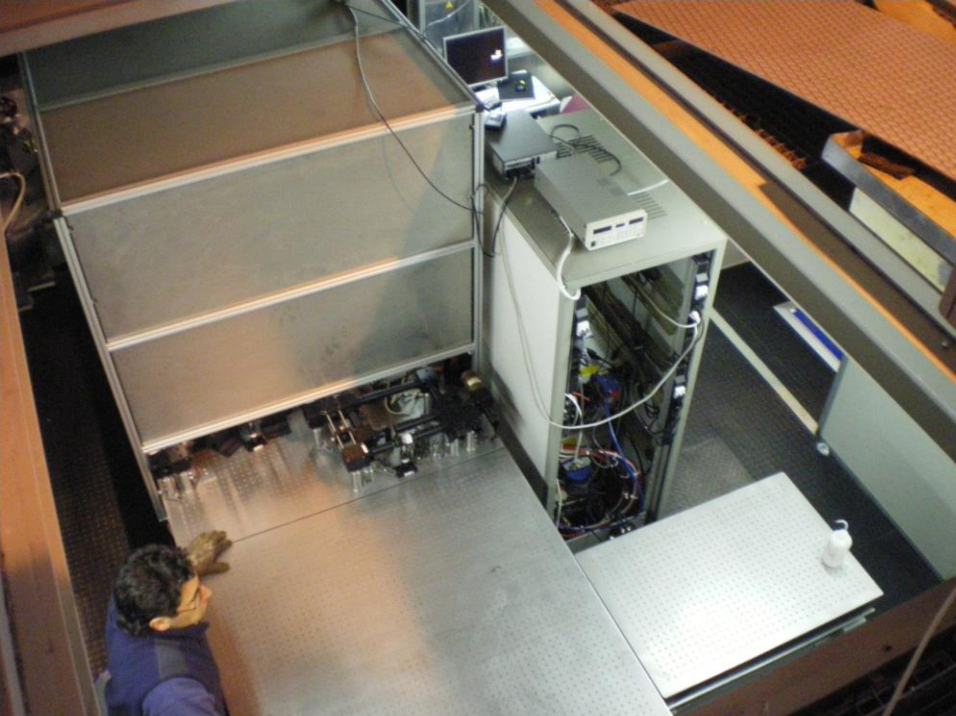
IR Beam
45 W @ 1064 nm

30 min start up time

Reliable long term power output

"The ISOLDE RILIS pump laser upgrade and the LARIS Laboratory"

B. Marsh et al: Hyperfine Interactions, Volume 196, Issue 1-3, pp. 129-141 (2010)

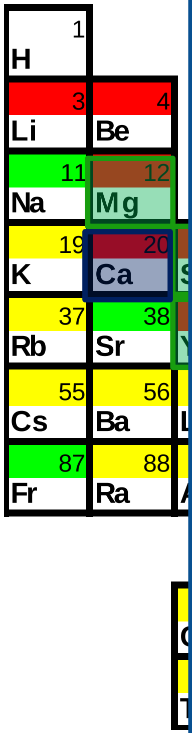


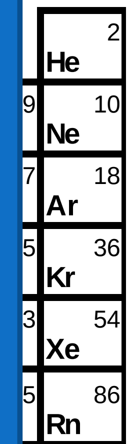
Benefits and issues that had to be to resolved

1 – Pump laser upgrade

+ More green power

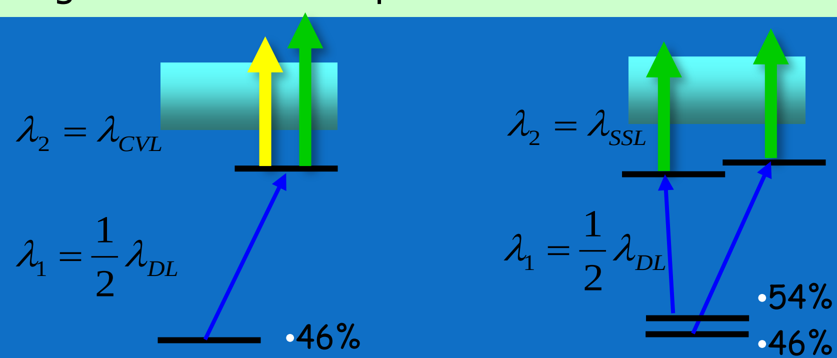
- 532 nm dye pumping instead of 511 or 578 nm





Good example: **Gallium**

- Two dye lasers were applied at 1st step of excitation - >2x improvement
- More power could be delivered to HRS target at the 2nd step of excitation

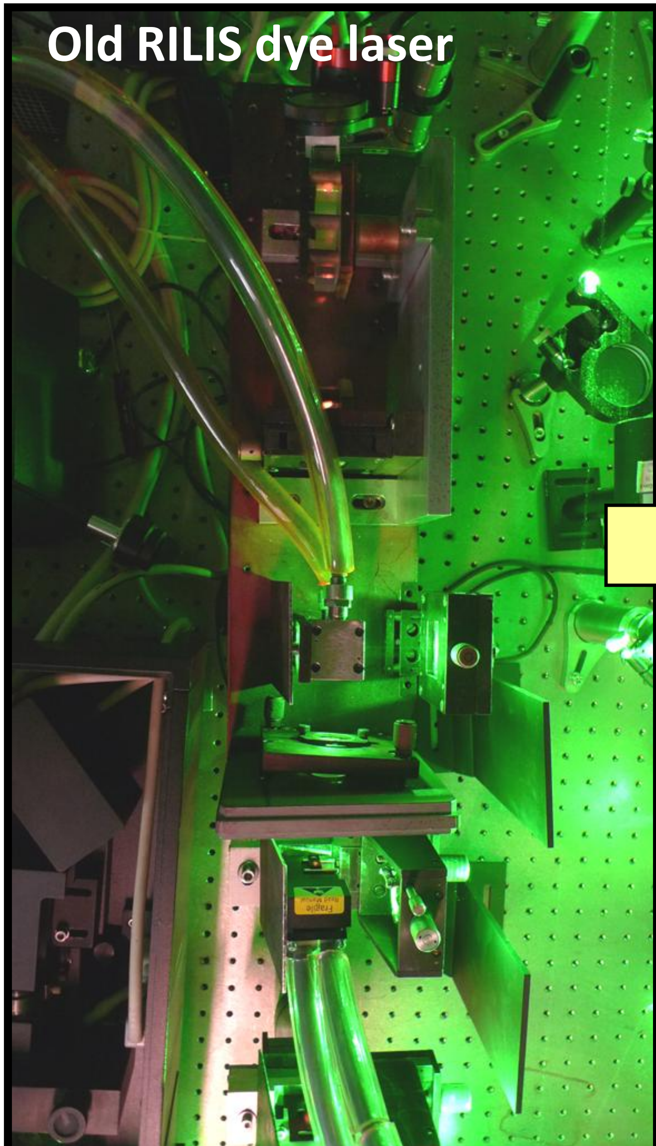


Most schem

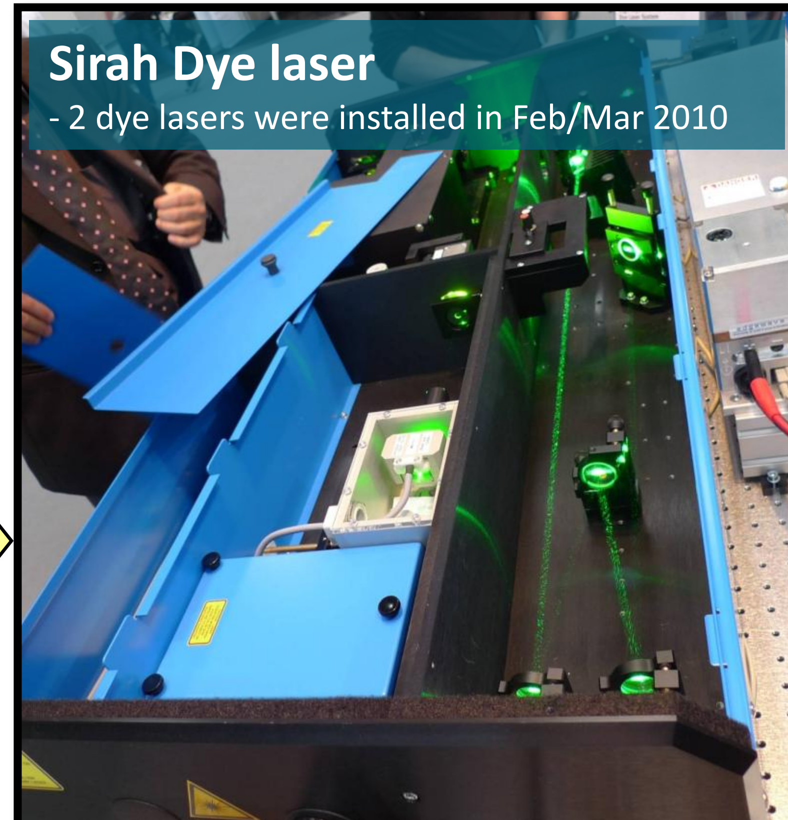
Some schemes are no longer useable due to the 532 nm pump beam

- lower final step efficiency or absorption cross section (Mn)
- Need for a < 540 nm fundamental wavelength.

Dye laser upgrade



Old RILIS dye laser



Sirah Dye laser

- 2 dye lasers were installed in Feb/Mar 2010

Benefits:

- Greater efficiency and stability.
- Higher UV power and better beam quality.
- Enable UV pumping to provide beams in the 380 – 540 nm range.

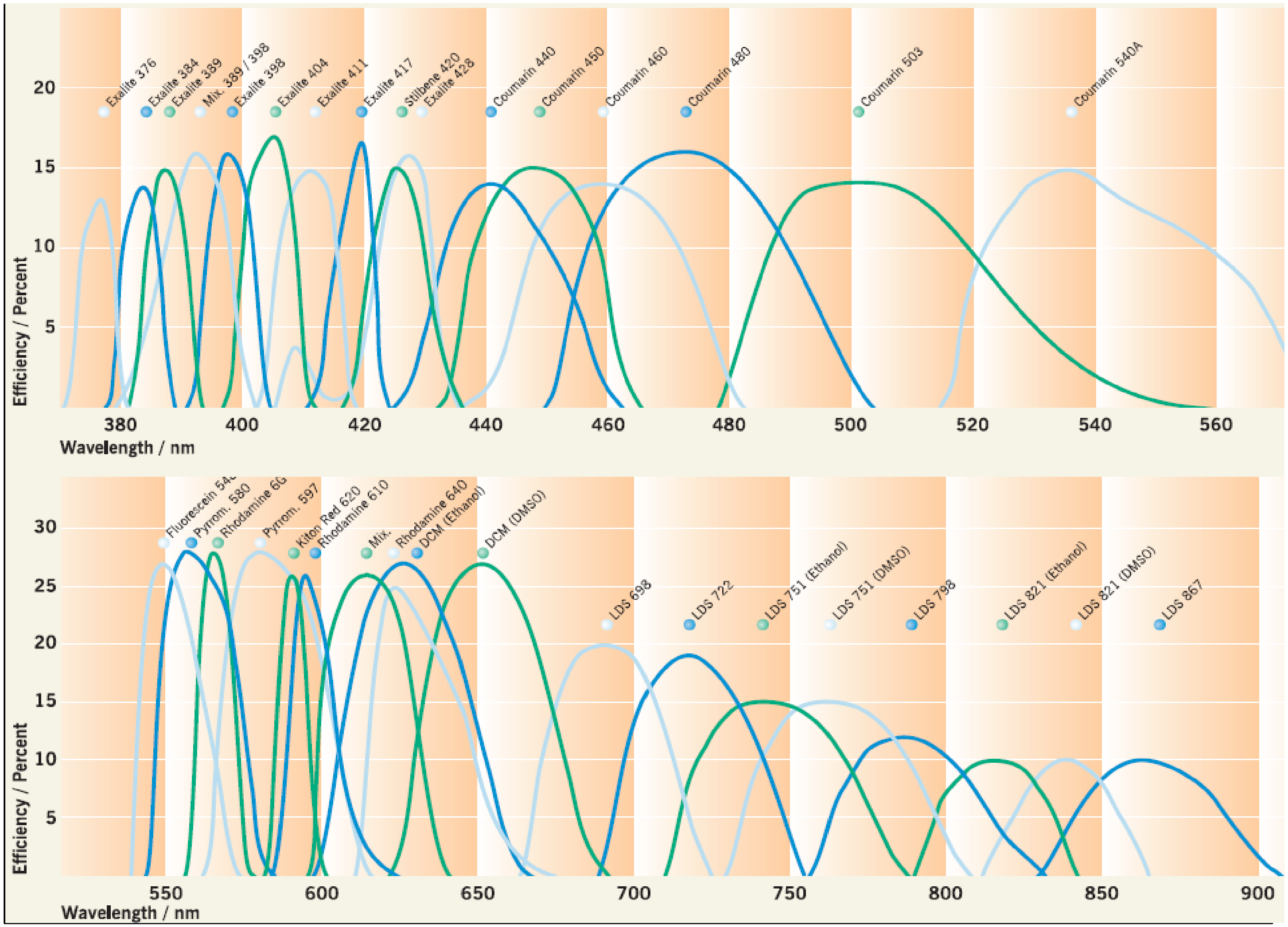
"Upgrade of the RILIS at ISOLDE: New lasers and new ion beams"

V. Fedosseev et al: Rev. Sci. Instrum. 83, 02A903 (2012)

New dye laser installation

CREDO dye lasers made by Sirah GmbH installed in Feb/Mar 2010

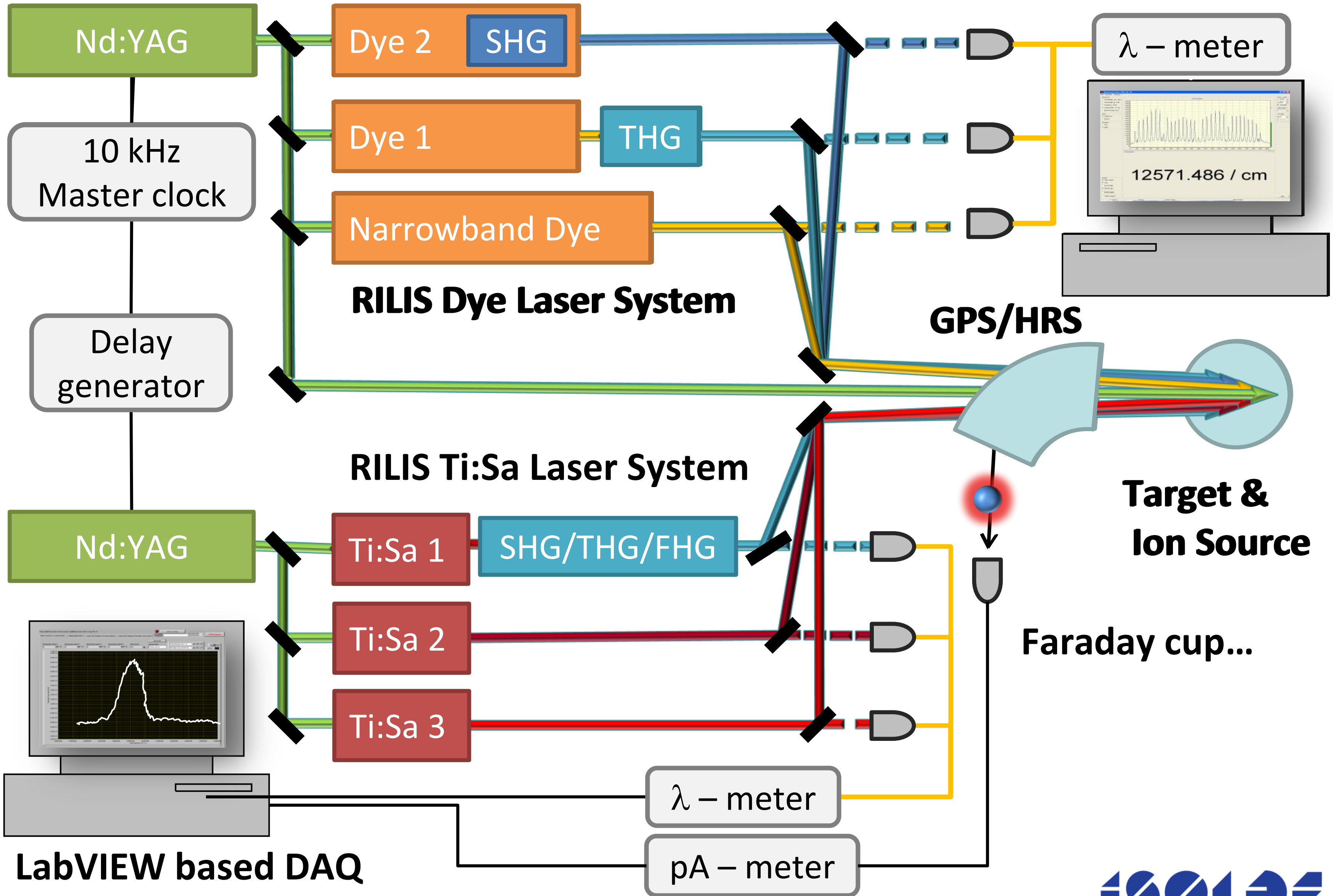
- **Optimized for 10 kHz EdgeWave pump**
- **Accept both 355 and 532 pumping beams**
- **Equipped with FCU (up to 2W of UV)**



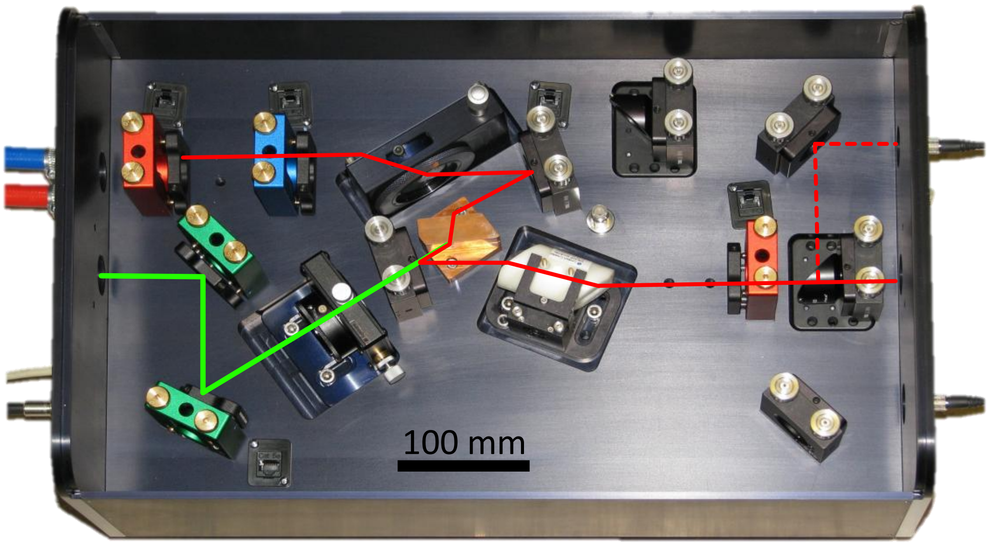
"Upgrade of the RILIS at ISOLDE: New lasers and new ion beams"

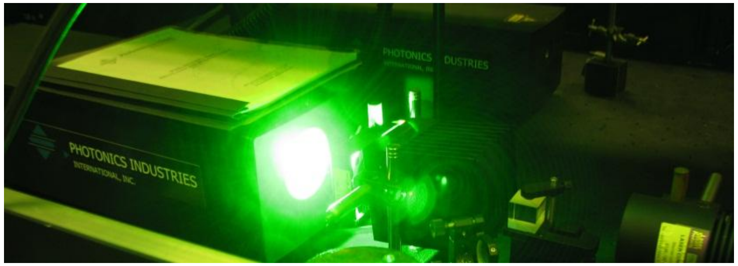
V. Fedosseev et al: Rev. Sci. Instrum. 83, 02A903 (2012)

Dual RILIS Concept



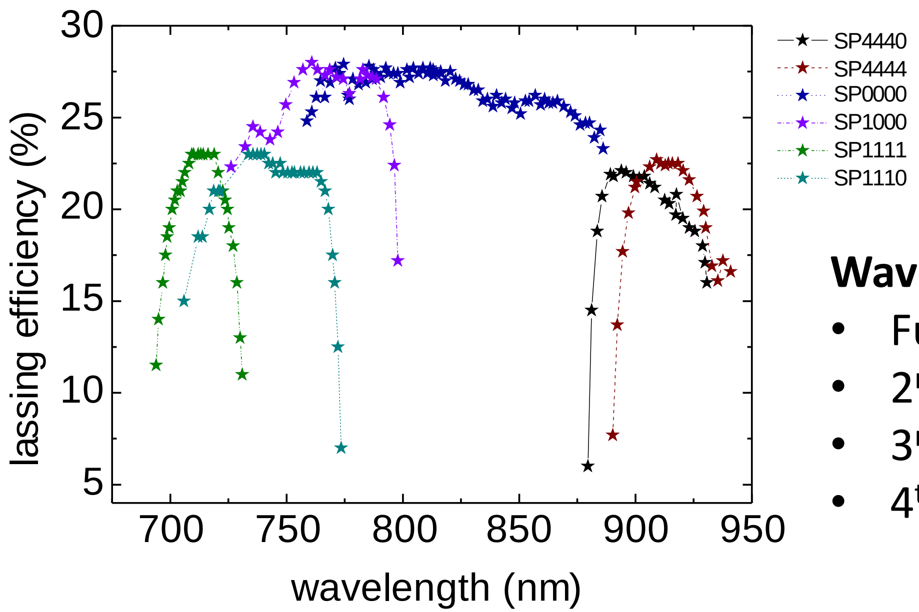
The RILIS Ti:Sa lasers





Pump laser: Nd:YAG (532 nm),
Photonics
Repetition rate: 10 kHz
Pulse length: 180 ns
Power: 60 W

Ti:Sa lasers:
Line width: 5 GHz
Pulse length: 30-50 ns



Wavelength tuning range (6 mirror sets):

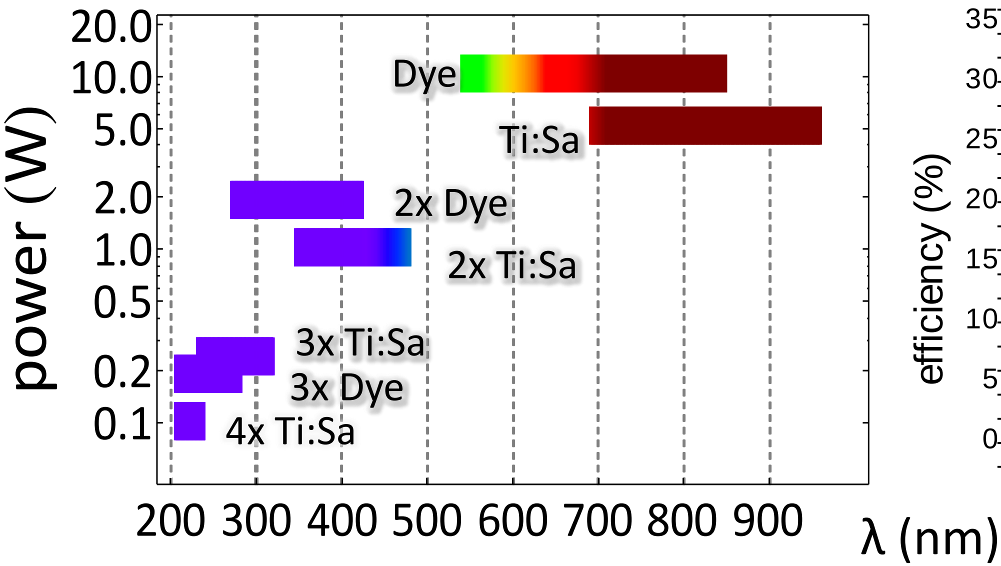
- Fundamental (ω) **690** - **940** nm (5 W)
- 2nd harmonic (2ω) **345** - **470** nm (1 W)
- 3rd harmonic (3ω) **230** - **310** nm (150 mW)
- 4th harmonic (4ω) **205** - **235** nm (50 mW)

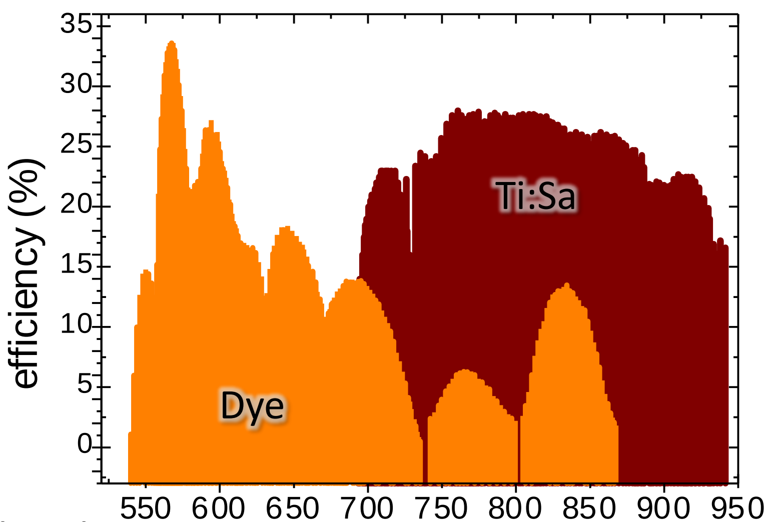
"A complementary laser system for ISOLDE RILIS"

S Rothe et al: Journal of Physics: Conference Series 312 (2011) 052020

Comparing the dye and Ti:Sa lasers

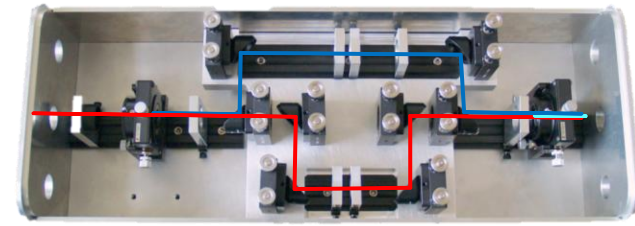
	Dye	Ti:Sa
Gain Medium:	> 10 different dyes	=1 Ti:sapphire crystal ☺
	liquid (org. solvents)	solid-state ☺
Tuning range	540 – 850 nm	680 – 980 nm
Power	< 12 W ☺	< 5 W
Pulse duration	~8 ns ☺	~50 ns
Synchronization	optical delay lines	q-switch, pump power ☺
# of schemes developed	47 ☺	37
Maintenance	renew dye solutions	~ none ☺



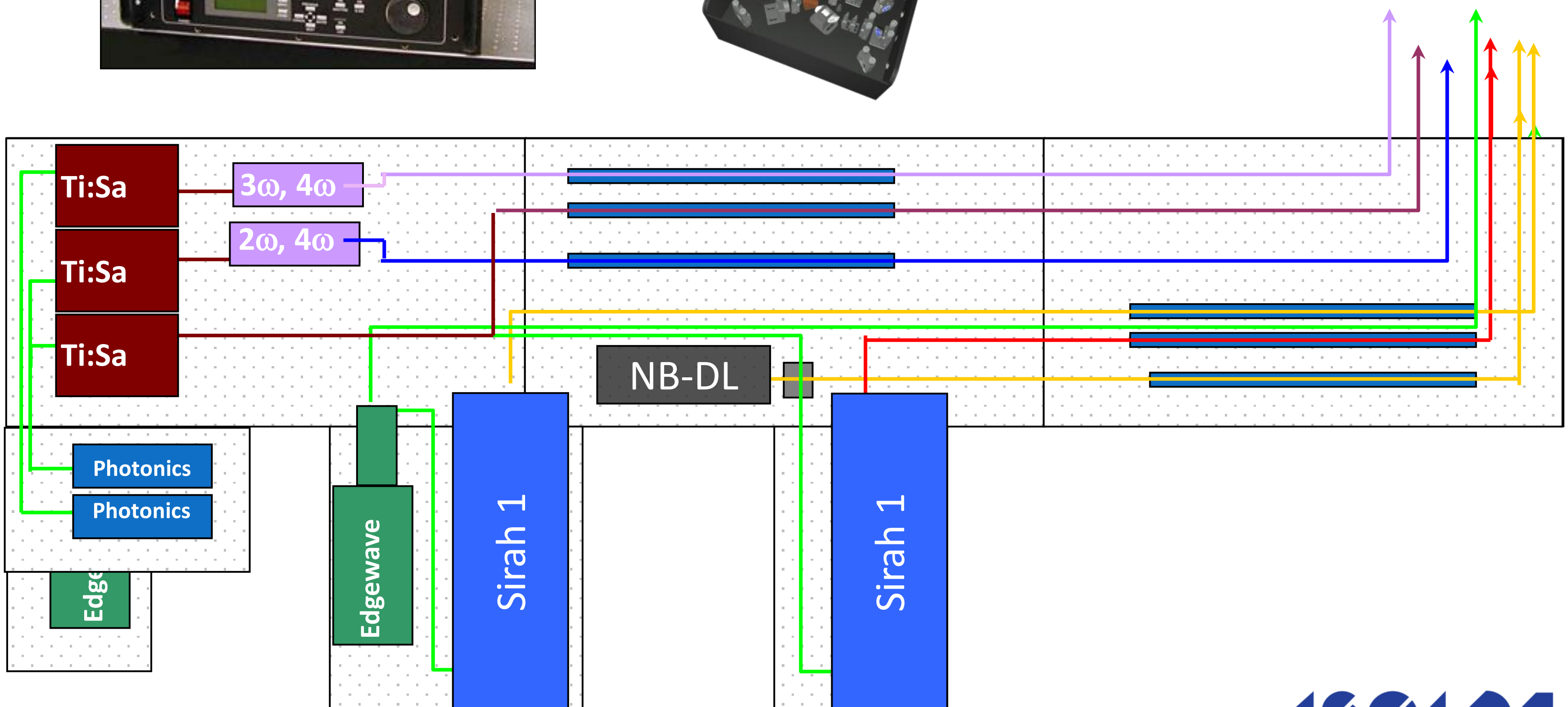


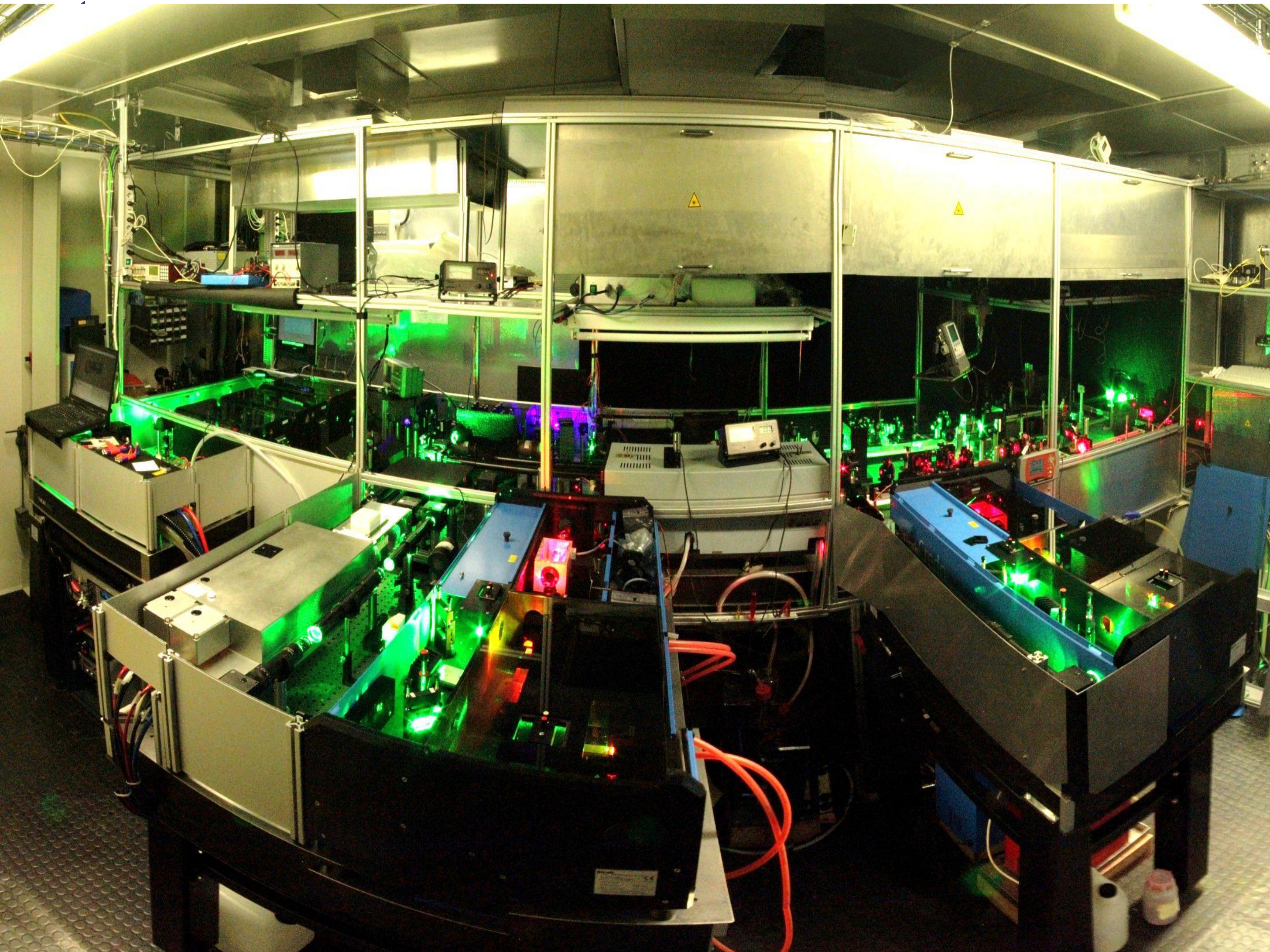
Installing the Ti:Sa alongside the dye lasers

Finding space for pump laser +
3 Ti:Sa + FCUs



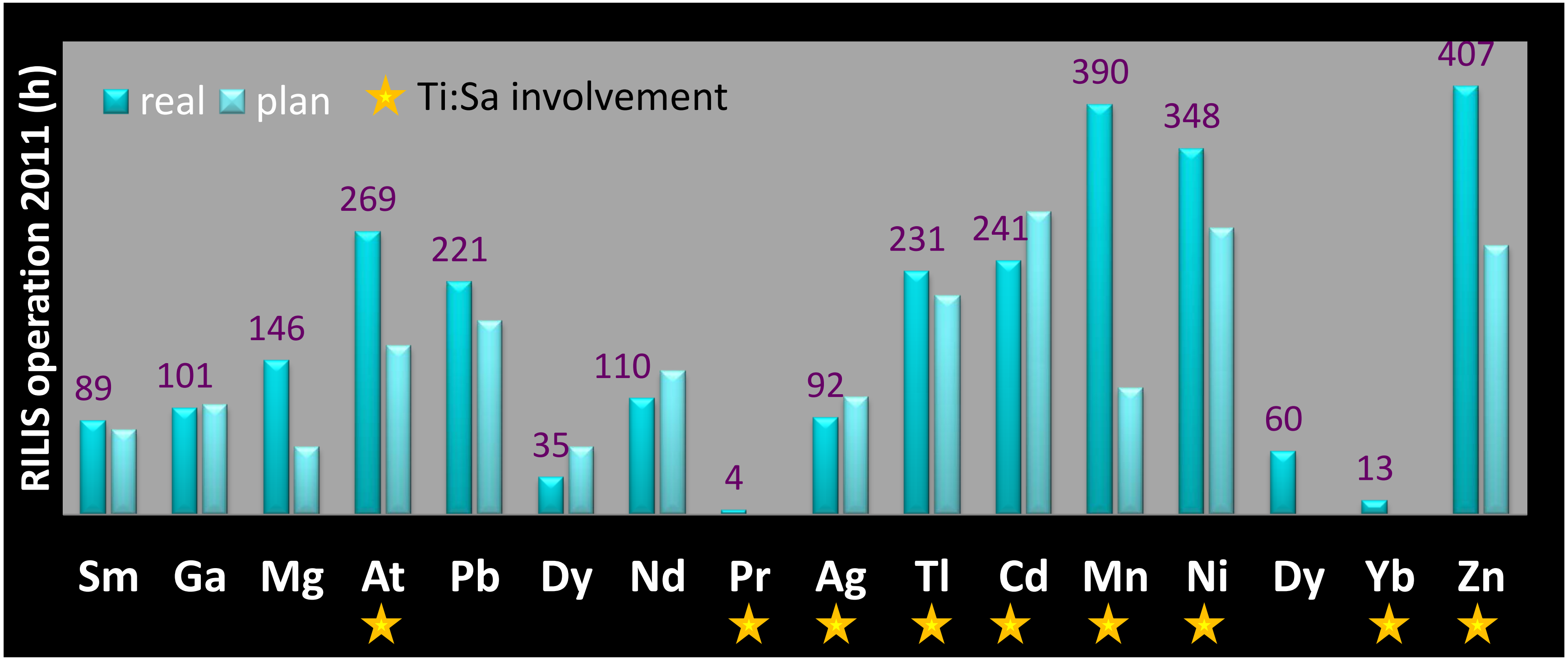
Frequency conversion unit






RILIS-screen 1
Shuttle
PHOTONICS INDUSTRIES

Ti:Sa involvement in RILIS operation



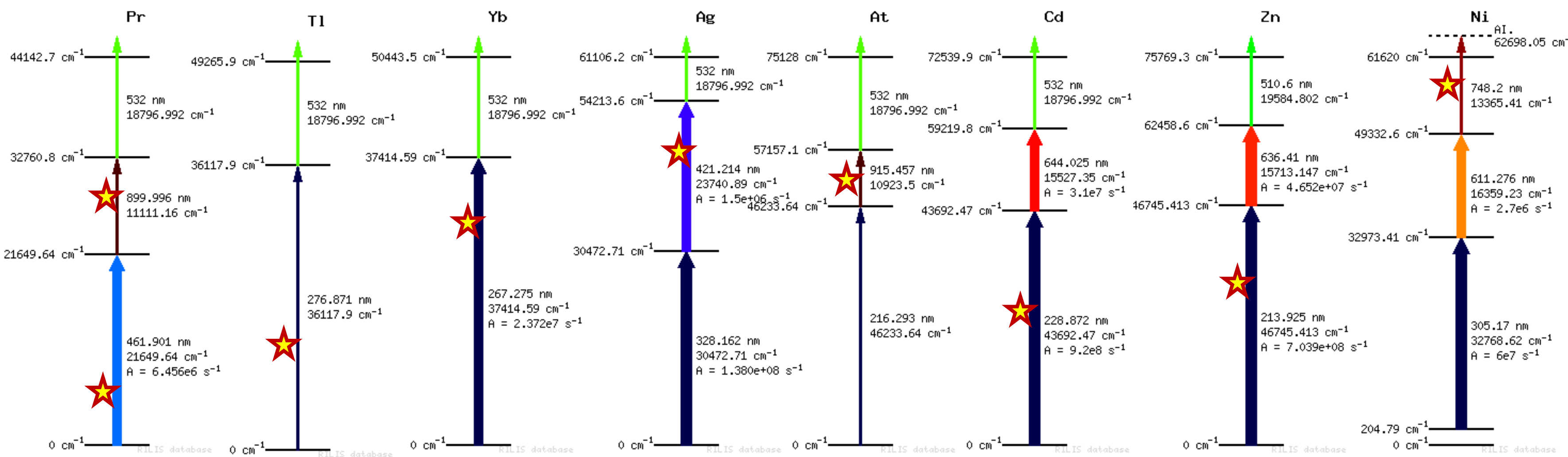
Ion beams of 16 elements were produced during 2011 :

- **2573 h for on-line experiments**
- Ti:Sa system used already with 9 elements
- Some additional tests only feasible because of the 'spare' laser system
- Significant Ti:Sa use despite 1st year of operation and still in 'implementation/testing phase'

New modes of RILIS operation: Dual RILIS

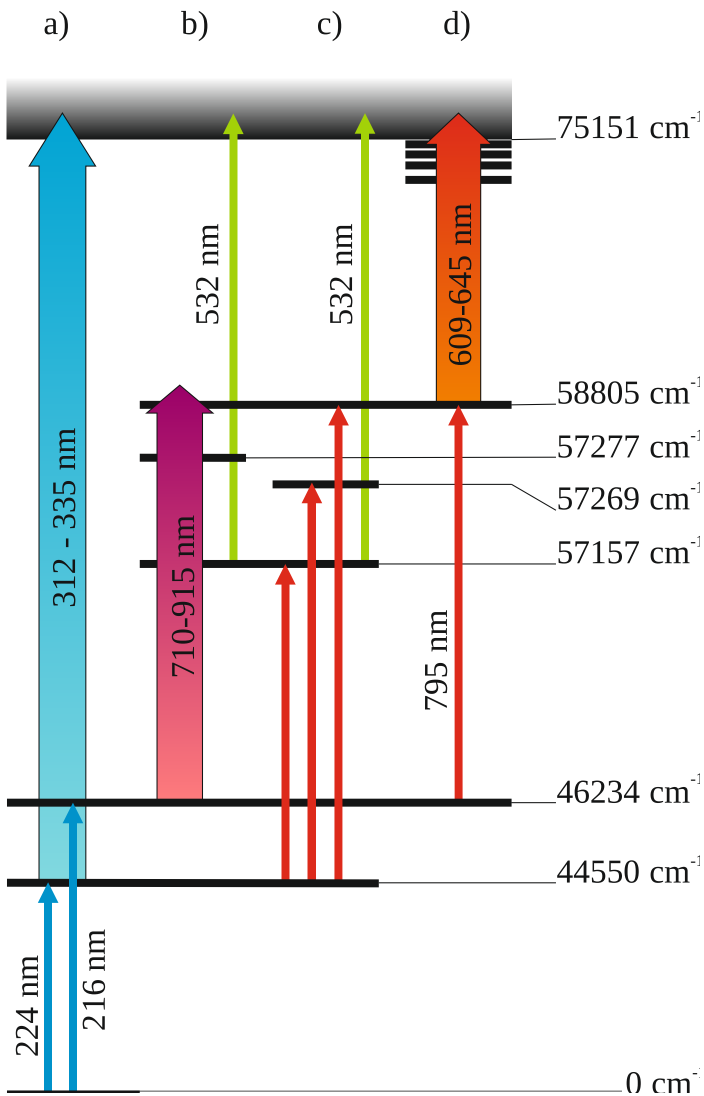
Condition for dual operation: **Temporal synchronization** of the two laser systems

Ti:Sa only mode	**Mixed mode**	**Backup mode**
50 W Nd:YAG laser available for non-resonant ionization	Combination of dye and Ti:Sa	dye and Ti:Sa are exchangeable



- Increased efficiency due to higher laser power or optimal scheme
- Improved reliability due to redundancy / backup
- More elements are accessible due to greater tuning range/scheme database

In-source spectroscopy of Astatine

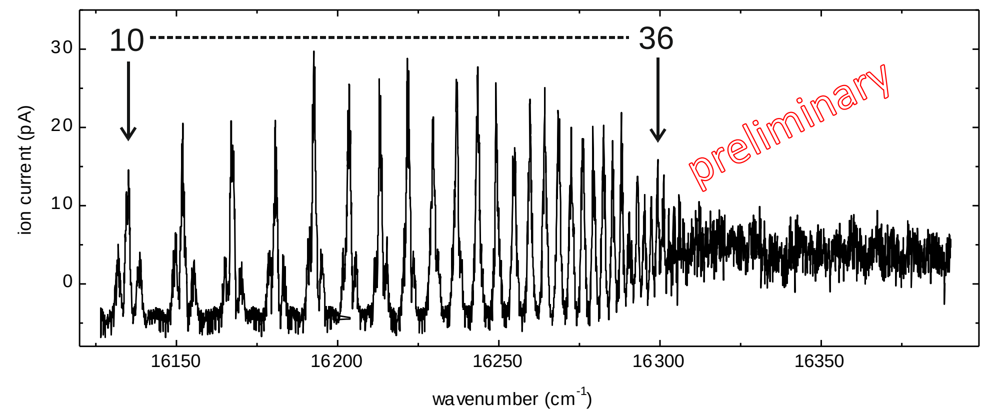


a) Photoionization threshold : 75129(95) cm^{-1}

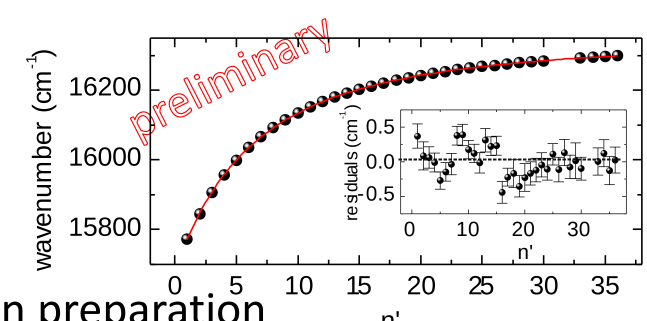
b) Scan for 2nd step transitions (at TRIUMF)

c) Verification of levels, yield measurements

d) Scan of ionizing laser: converging Rydberg levels allow precise determination of the IP



Rydberg-Ritz formula $E_n = \mathrm{IP} - \mathrm{R}_M /(n-\delta$

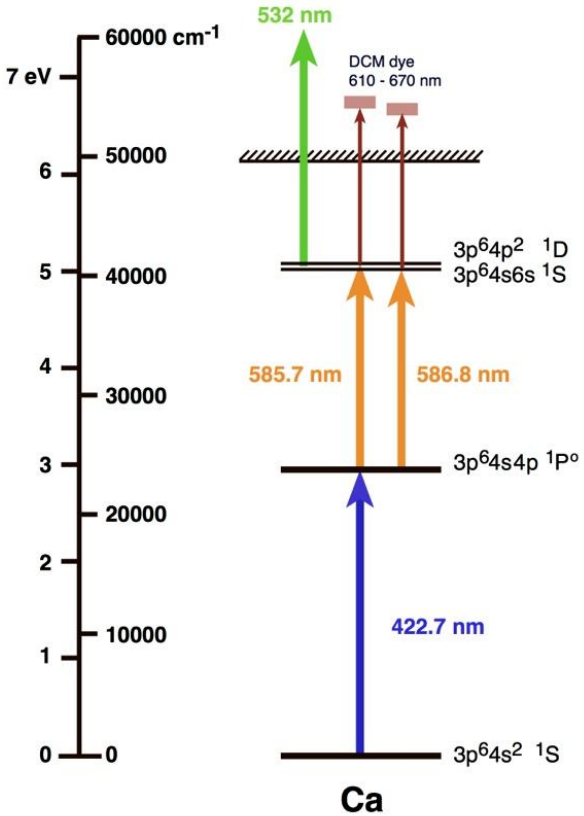


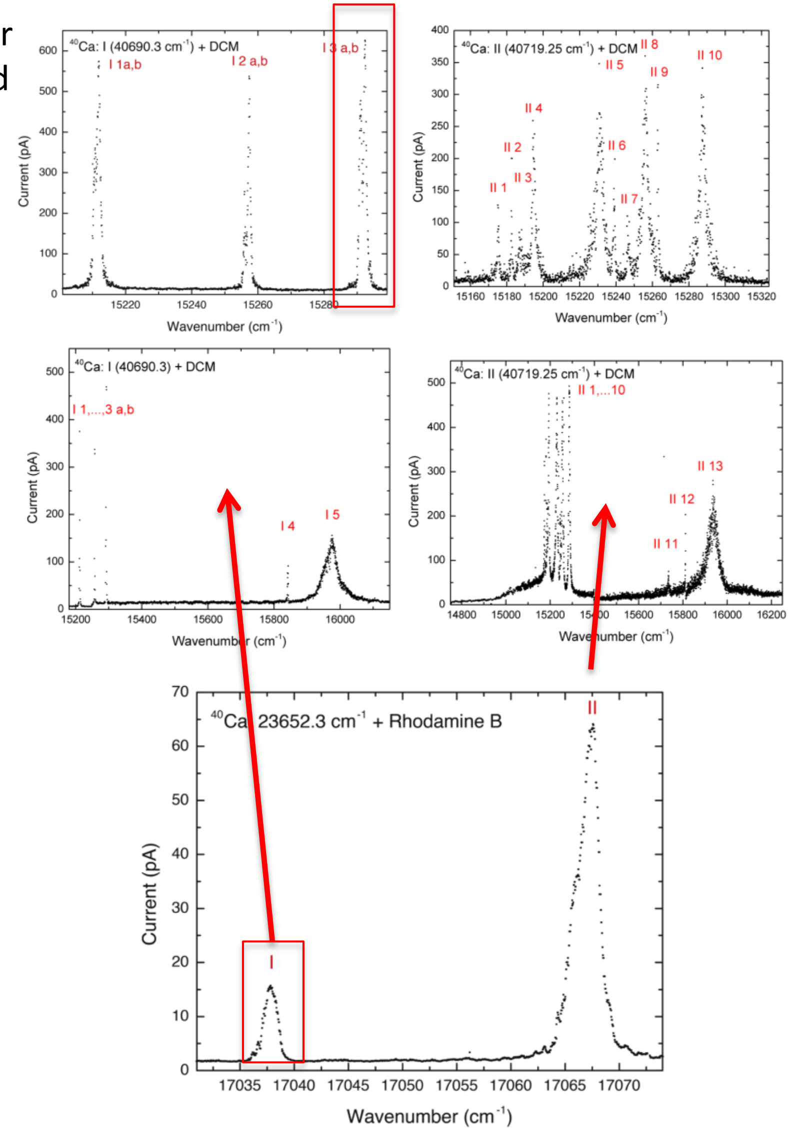
E_{IP}(At) = 75151(1) cm^{-1}

Poster #29 : *S Rothe et al.* Publication in preparation

Calcium scheme development

a) Scans for Auto-ionization states using spare Sirah Dye laser
b) AI Transitions from two intermediate levels were observed
c) Enhancement of ionization efficiency of a **factor of 4** w.r.t 50 W green beam for non resonant ionization!
d) Only possible due to the use of a TiSa for 1st step





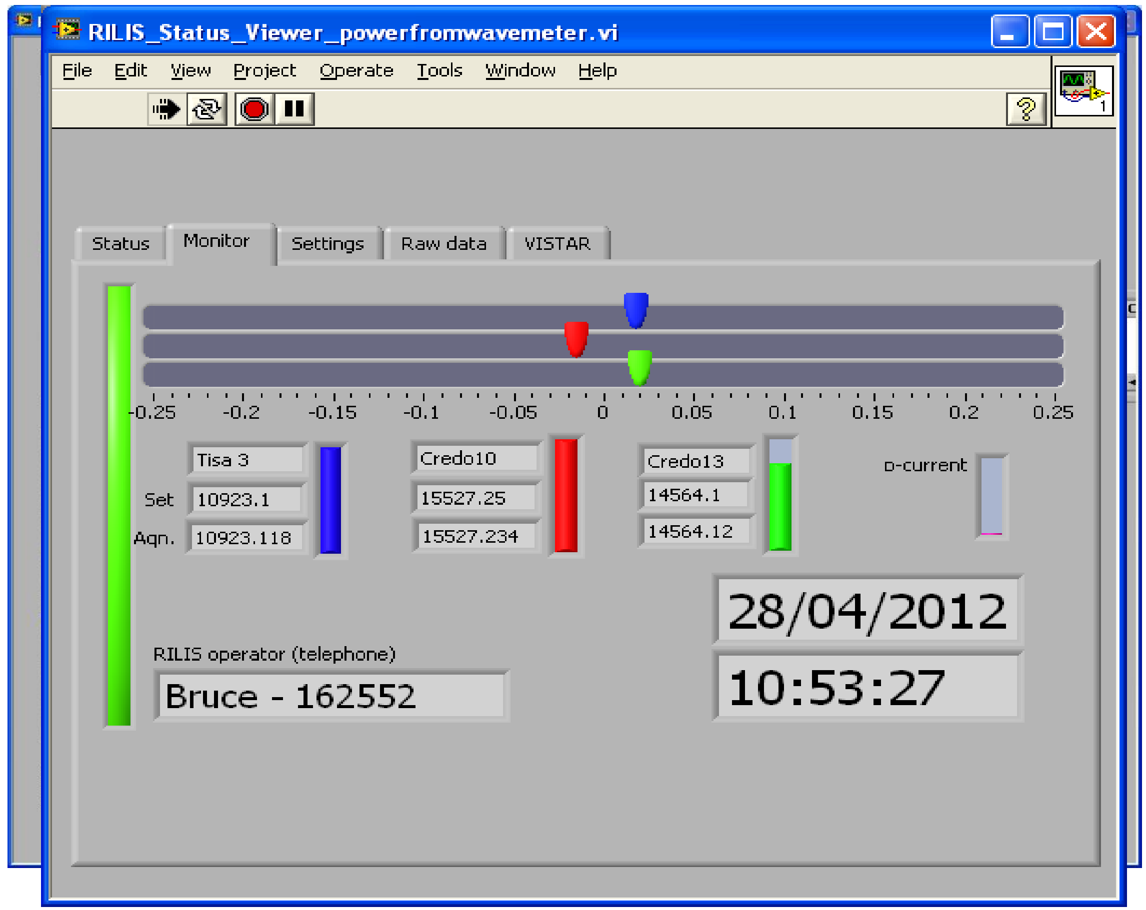
Daniel Fink: PhD work

RILIS status monitoring

Essential RILIS parameters are published to a Labview DSM.
All values are accessible from the CERN technical network
RILIS monitor display is published to a website for remote monitoring

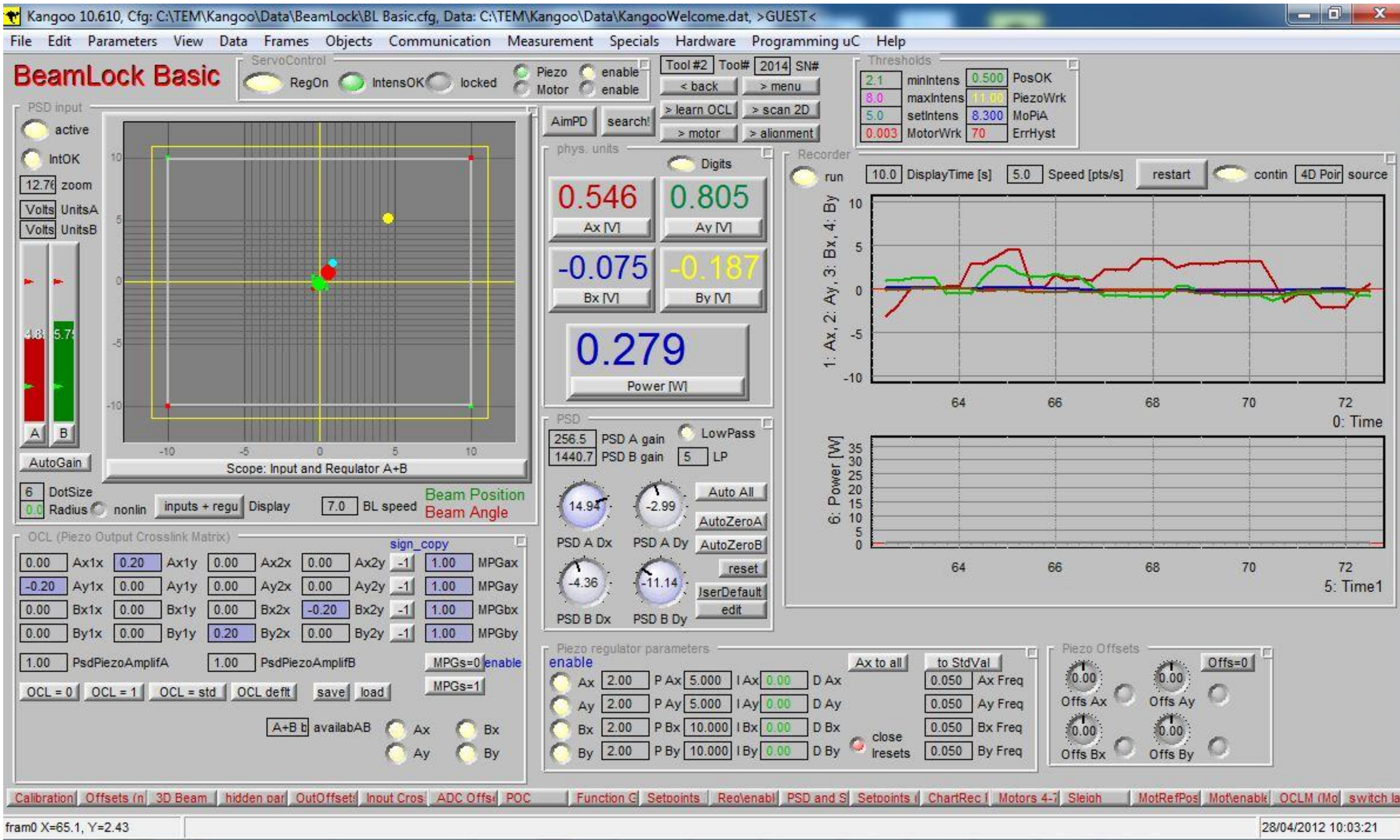
- Power
- Wavelength
- Proton current
- Reference beam images

https://riliselements.web.cern.ch/riliselements/LASERS/



Beam stabilization

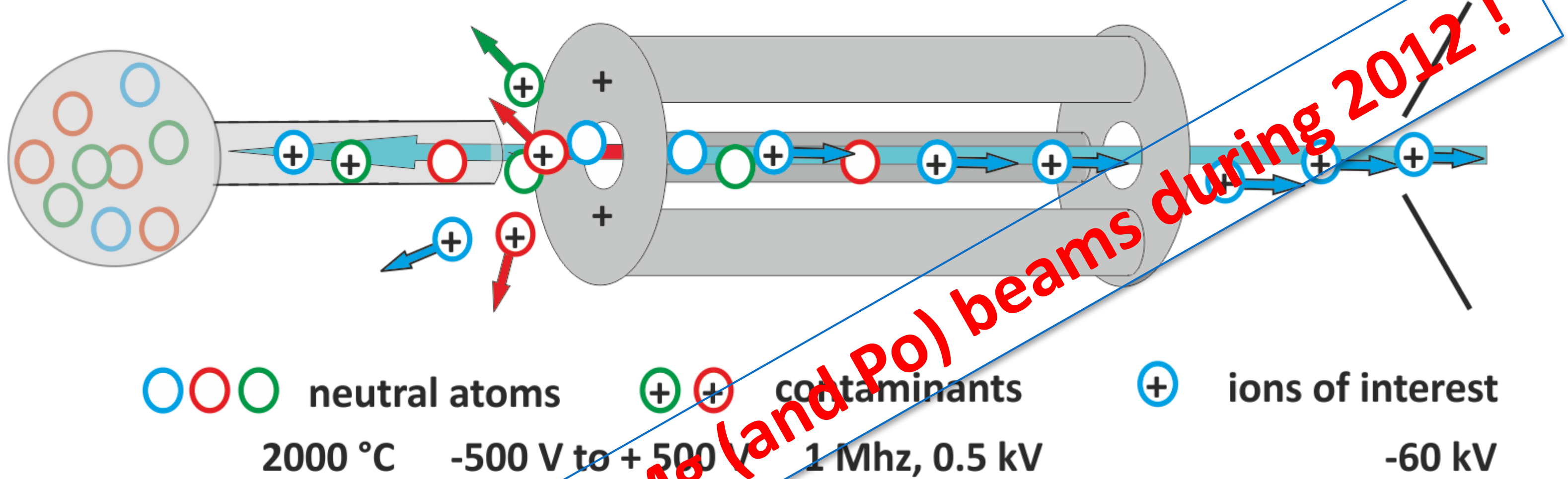
Stabilization of high and low frequency beam fluctuations, essential for ON-CALL RILIS



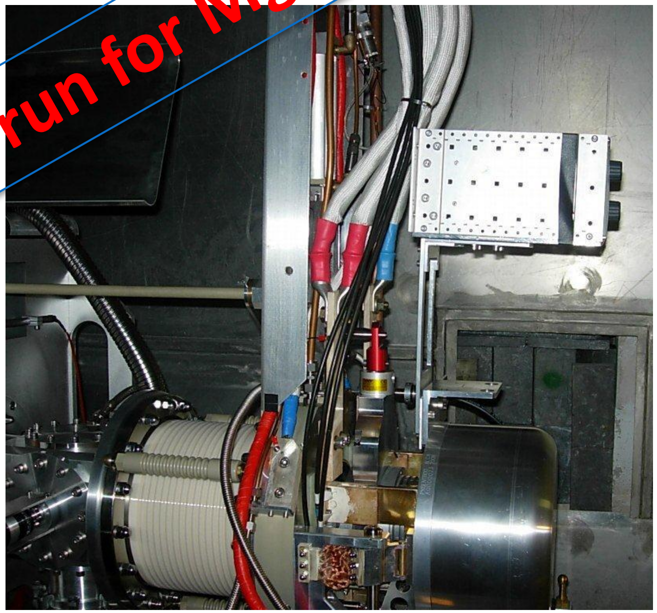
http://www.tem-messtechnik.de/MainPages/en/productsfs.htm

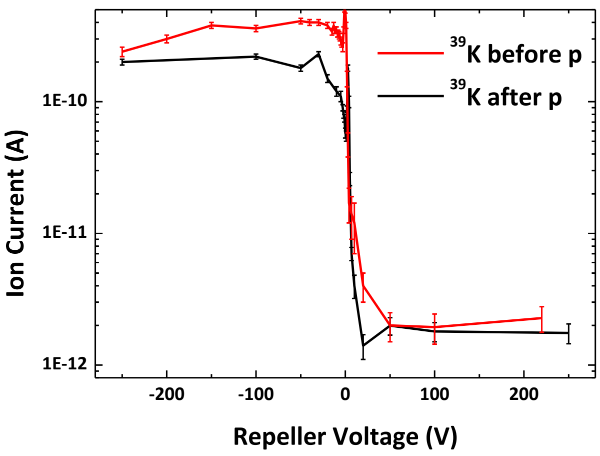
Laser Ion Source Trap

First On-Line test in 2011



On-line LIST run for Mg (and Po) beams during 2012 !





Daniel Fink - Poster presentation # 25

Summary and outlook

- The RILIS now comprises a dual laser system with state of the art Dye and TiSa lasers
- RILIS operated smoothly for over 2500 h in 2011
- Dual RILIS (Combined dye and Ti:Sa laser system) is in regular operation
- The reliability of the RILIS has been greatly improved through the use of solid state lasers and commercial dye lasers.
- The study of the optimal use of the full system is ongoing with being performed for almost every RILIS element that is scheduled!

Outlook / Comments

- Optimal Dye + TiSa combinations for each element need to be tested (many tests can be done in a parasitic/opportunistic way)
- Machine protection, monitoring and remote control of RILIS is being developed with a goal of ON-CALL operation, for completion in LS1.
- The LS1 will be used to extend the RILIS cabin for improved working conditions and to enable upgrades to the equipment setup.
- RILIS Marie Curie fellow will be recruited in summer 2012 http://www.liv.ac.uk/la3net/

Acknowledgements

RILIS – Team
http://isolde-project-rilis.web.cern.ch/isolde-project-rilis/

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https://en-sti-lp.web.cern.ch/en-sti-lp/

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