Engineering Department

Recent operation and outlook for the ISOLDE Resonance Ionization Laser Ion Source (RILIS)

Bruce Marsh - EN-STI-LP

LA^{3}NET Topical Workshop: Laser based particle sources

20-22nd February 2013

Outline of Talk

- Introduction to ISOLDE and the RILIS installation
  - The original CVL pumped dye laser system
  - The new Dual TiSa and Dye laser RILIS
- Operation of the RILIS in 2012
  - Total operating time
  - Specifics of Dual RILIS operation
  - Highlights and new developments
- Outlook and development work for 2013 and CERN LS1
  - Practical changes to the RILIS installation
  - Scheme development
  - Laser system upgrades / changes
  - Improved laser beam transport system

Part 1

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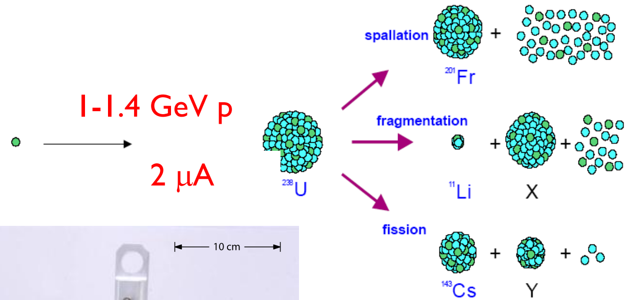
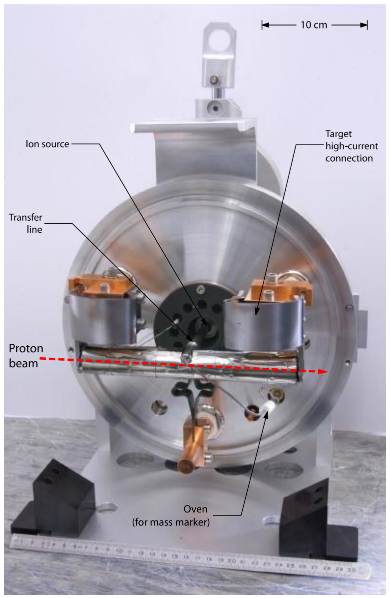
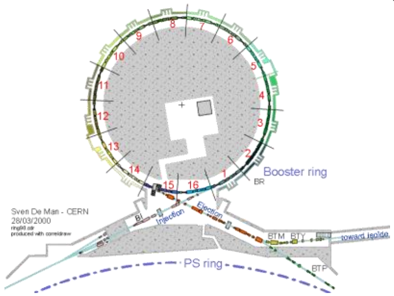
ISOLDE isotope separator on-line

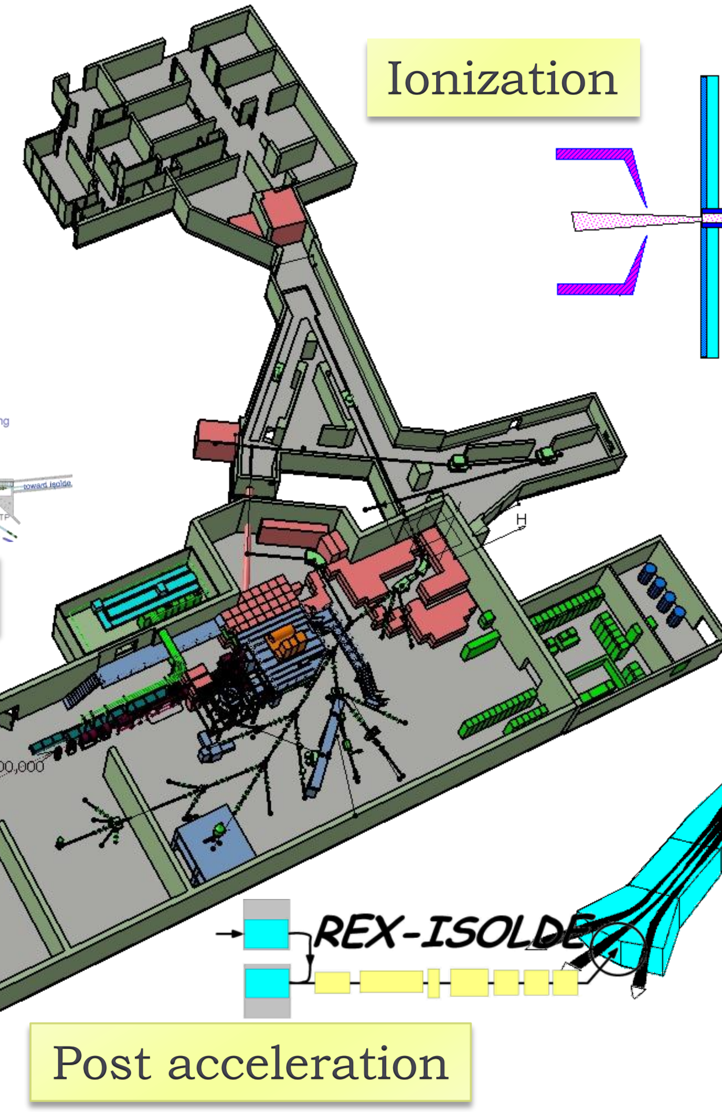
RILIS



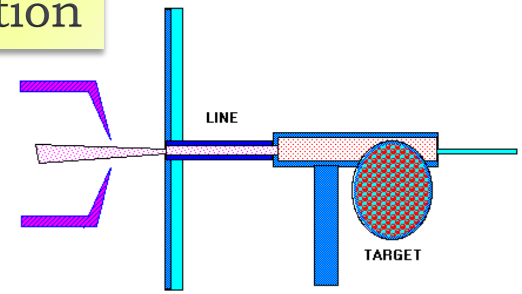




Production



Ionization



Single charge:

- Surface
- Plasma
- RILIS
- ECR

Mass separation

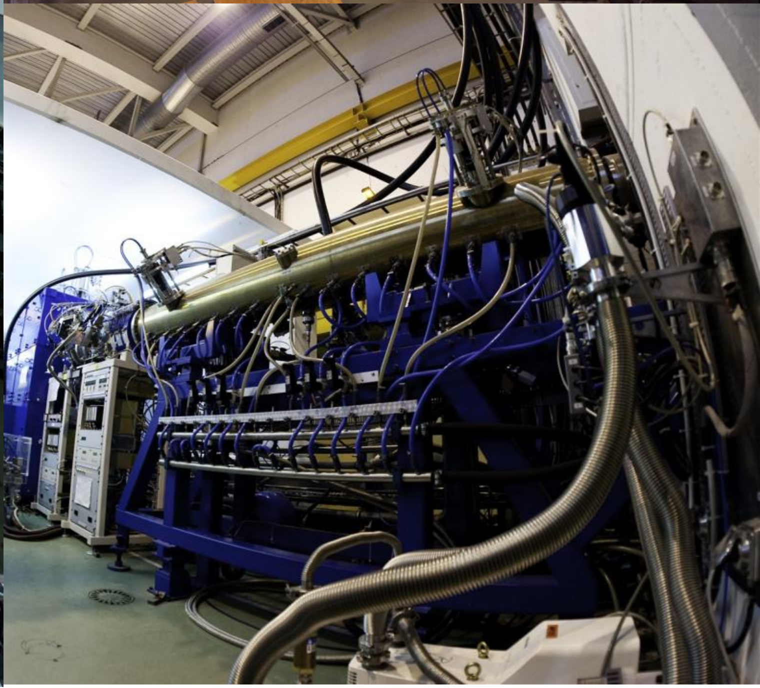
Delivers yearly 3200 h of radioactive ion-beams to 30 experiments by means of two target stations

Post acceleration

Jonson, B., & Richter, A. (2000). *More than three decades of ISOLDE physics. Hyperfine Interactions, 129*, 1–22. doi:10.1023/A:1012689128103

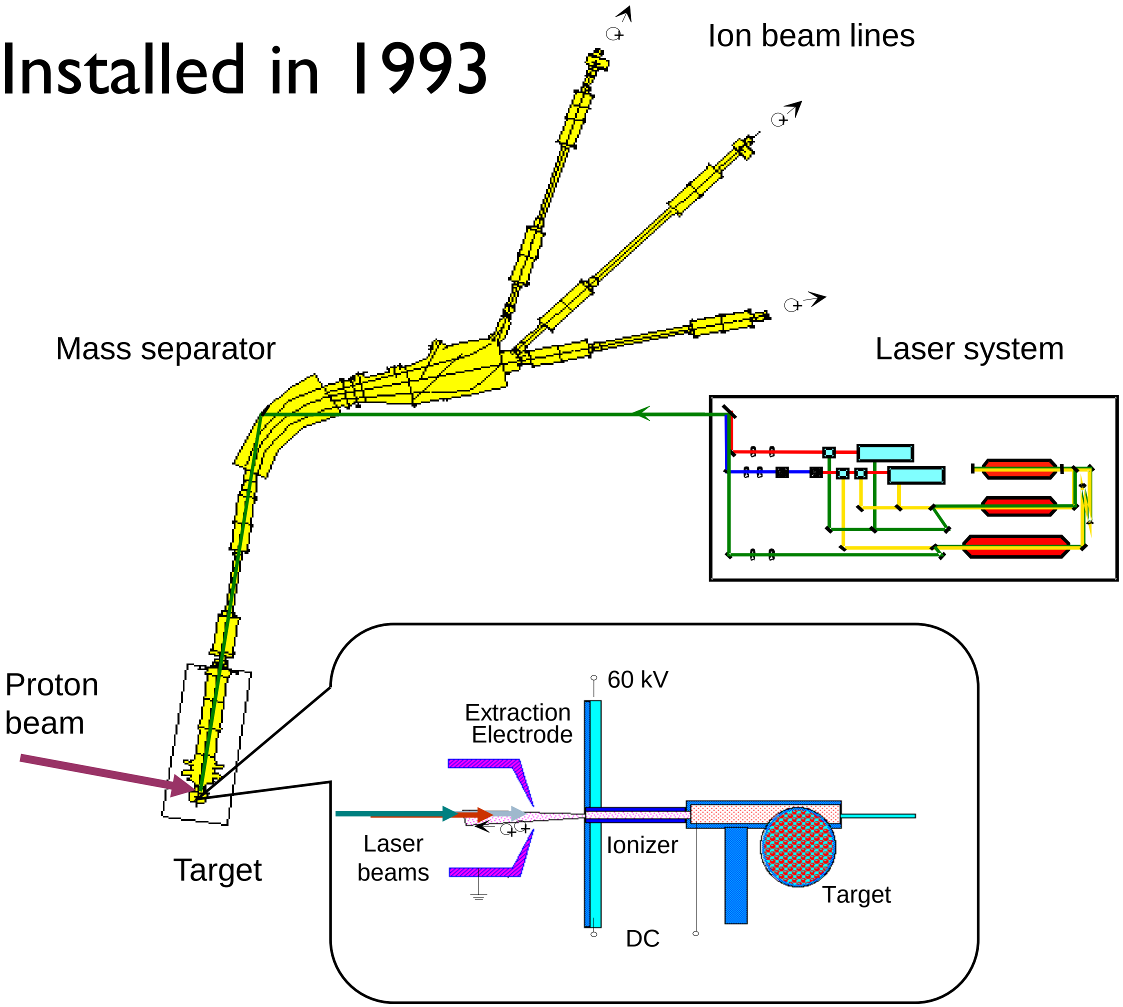
http://isolde.web.cern.ch/ISOLDE/





RILIS at ISOLDE-PSB

Installed in 1993



Target - Ion Source Unit

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

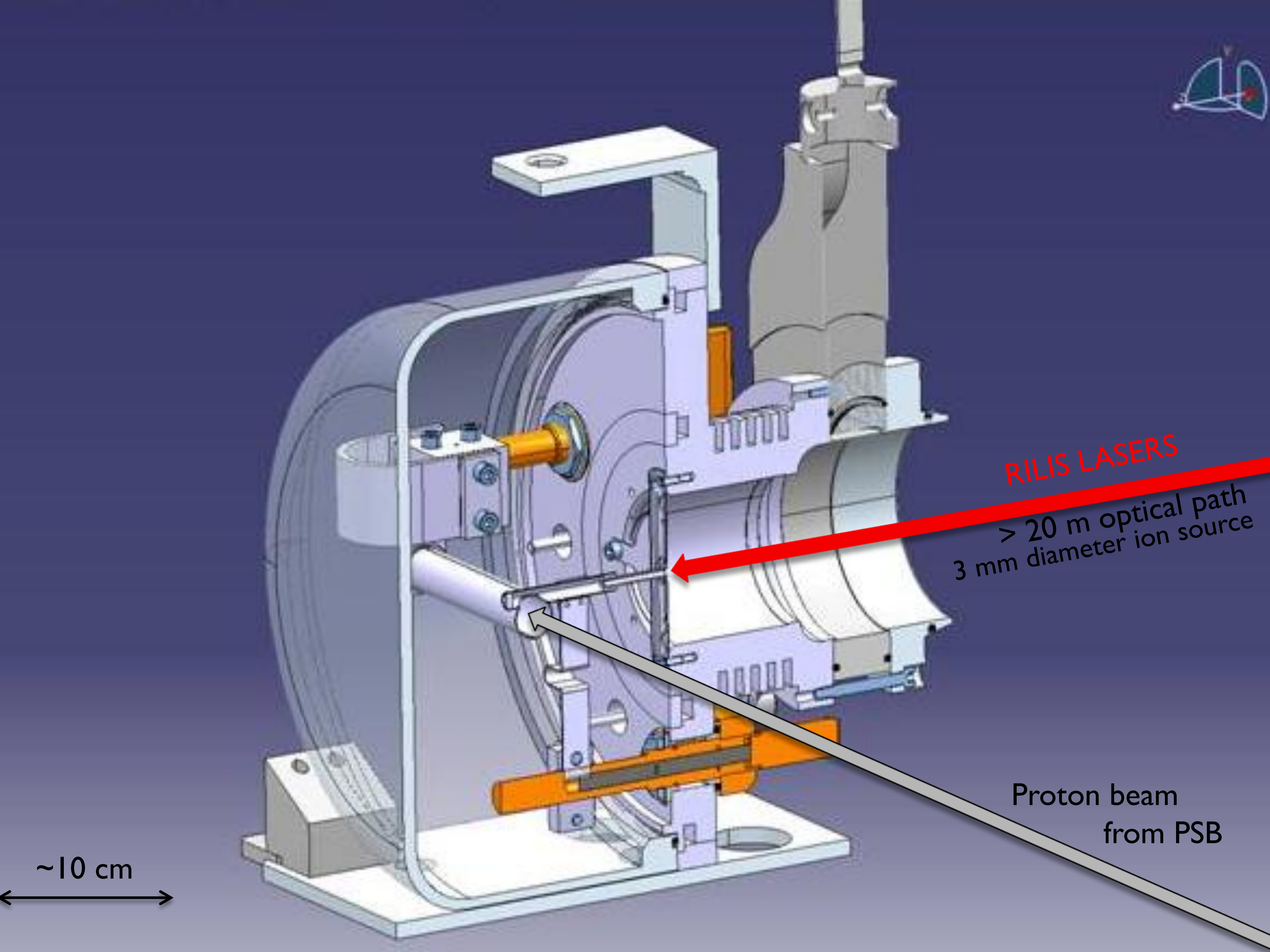
$P_{Cu}^{total} \leq 75\,W$

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

$P_{2\omega} \leq 2\,W$

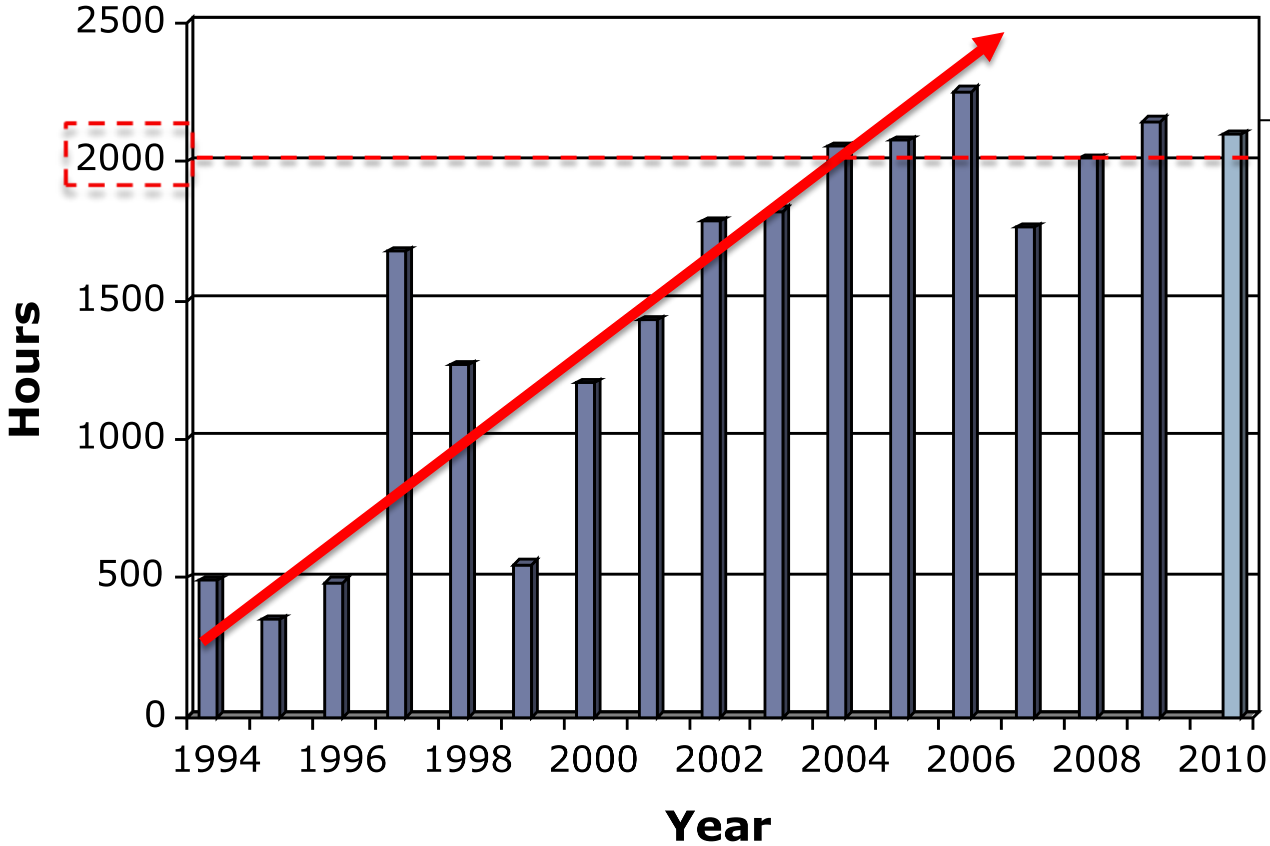
$P_{3\omega} \leq 0.2\,W$

Mishin, V., Fedoseyev, V. , Kluge, H., Letokhov, V., Ravn, H., Scheerer, F., Shirakabe, Y. et al. (1993). *Chemically selective laser ion-source for the CERN-ISOLDE on-line mass separator facility. NIM B: 73(4), 550–560.*



RILIS LASERS
> 20 m optical path
3 mm diameter ion source
Proton beam
from PSB
~10 cm

RILIS operation: **1994-2010**



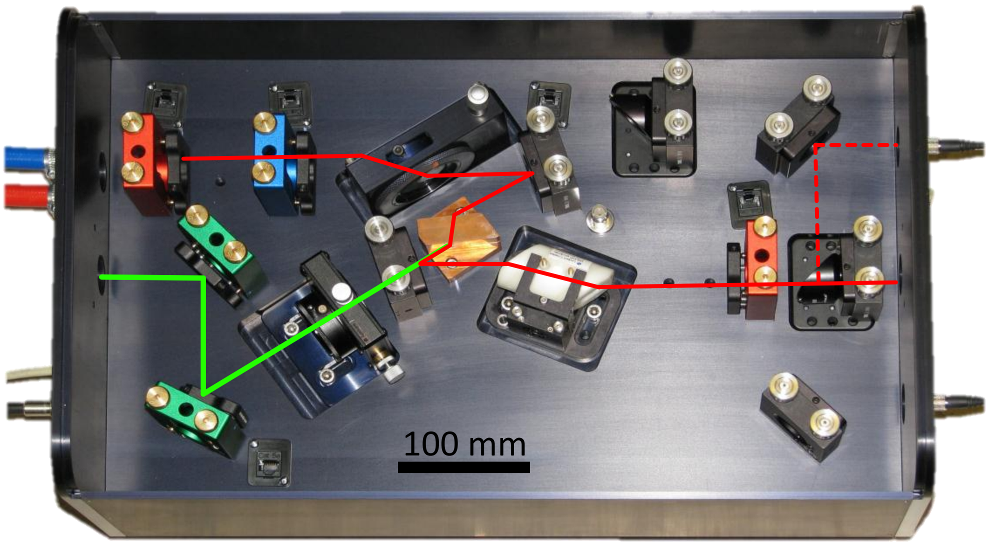
Laser ON time in 2010:

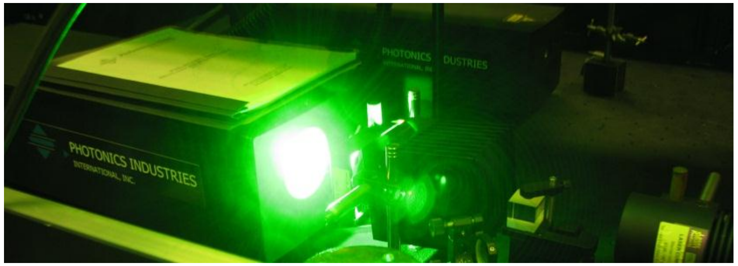
2096 h – total
2000 h - on-line

Laser time per beam for the **2010**

Sm	Mg	Cu	Ga	Tl	Be	Pb	Mn	Au	Be	Zn	Ag	At
52	154	183	52	184	54	123	228	114	344	299	140	74

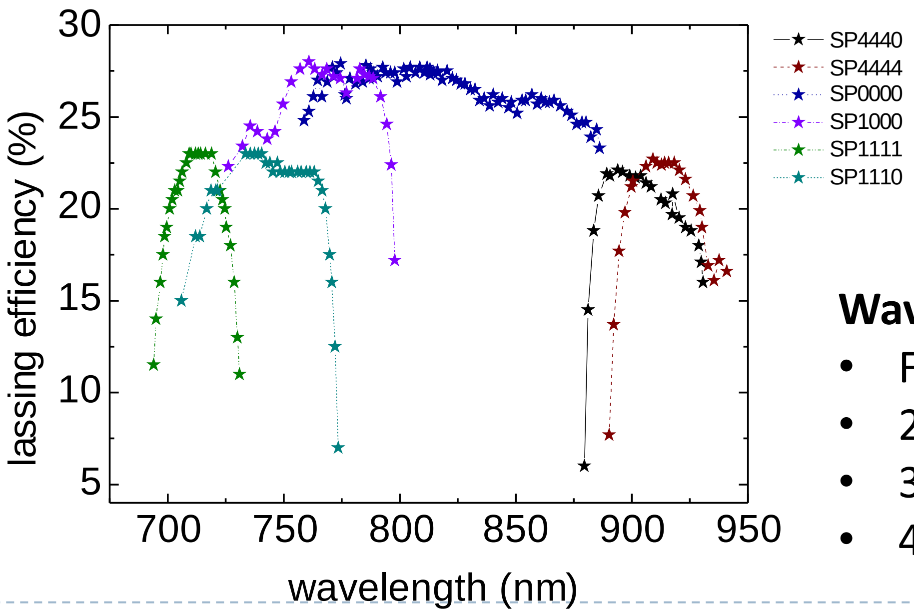
The RILIS Ti:Sa lasers





Pump laser: Nd:YAG (532 nm),
Photonics Industries Ltd. DM60
Repetition rate: 10 kHz
Pulse length: 180 ns
Power: 60 W

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

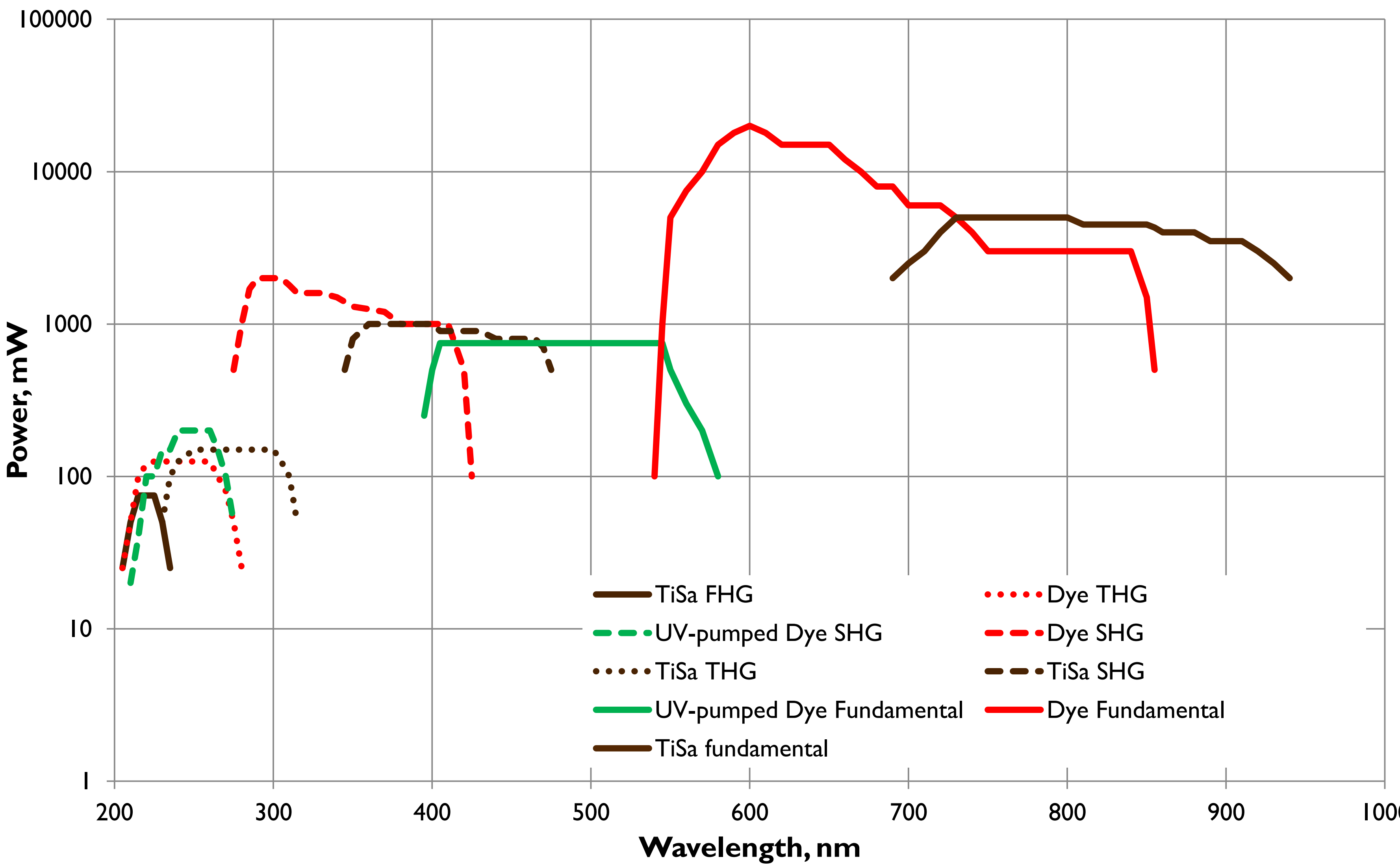


Wavelength tuning range (6 mirror sets):

- 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)

Featured in the next talk by ***Sebastian Rothe***
"A complementary laser system for ISOLDE RILIS" ***S Rothe et al:*** *Journal of Physics: Conference Series 312 (2011) 052020*

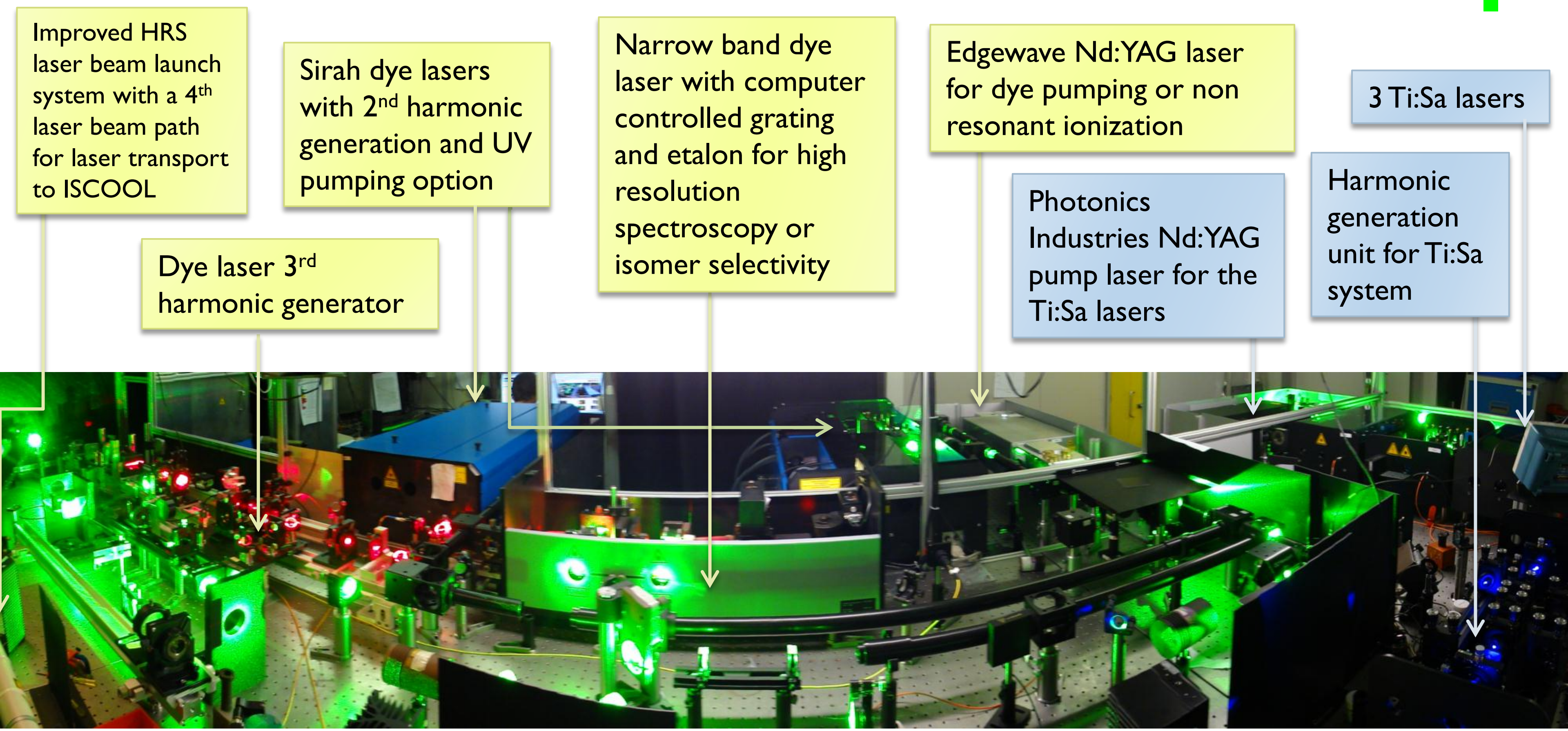
Dual RILIS tuning range



- **Fedosseev, V. N., Fedorov, D.V, Fink, D., Losito, R., Marsh, B.A., S.Rothe et al. (2012).** *Upgrade of the RILIS at ISOLDE; Rev. Sci. Inst 83*(2), 02A903. doi:10.1063/1.3662206

The RILIS Dye + Ti:Sa system

RILIS



- RILIS cabin layout has been redesigned to accommodate the new lasers
- Dye and Ti:Sa synchronization → mixed ionization schemes are possible

- The laboratory is now at maximum capacity – extension is planned.

Fedosseev, V. N., Fedorov, D.V, Fink, D., Losito, R., Marsh, B.A., S.Rothe et al. (2012). *Upgrade of the RILIS at ISOLDE; Rev. Sci. Inst 83*(2), 02A903. doi:10.1063/1.3662206

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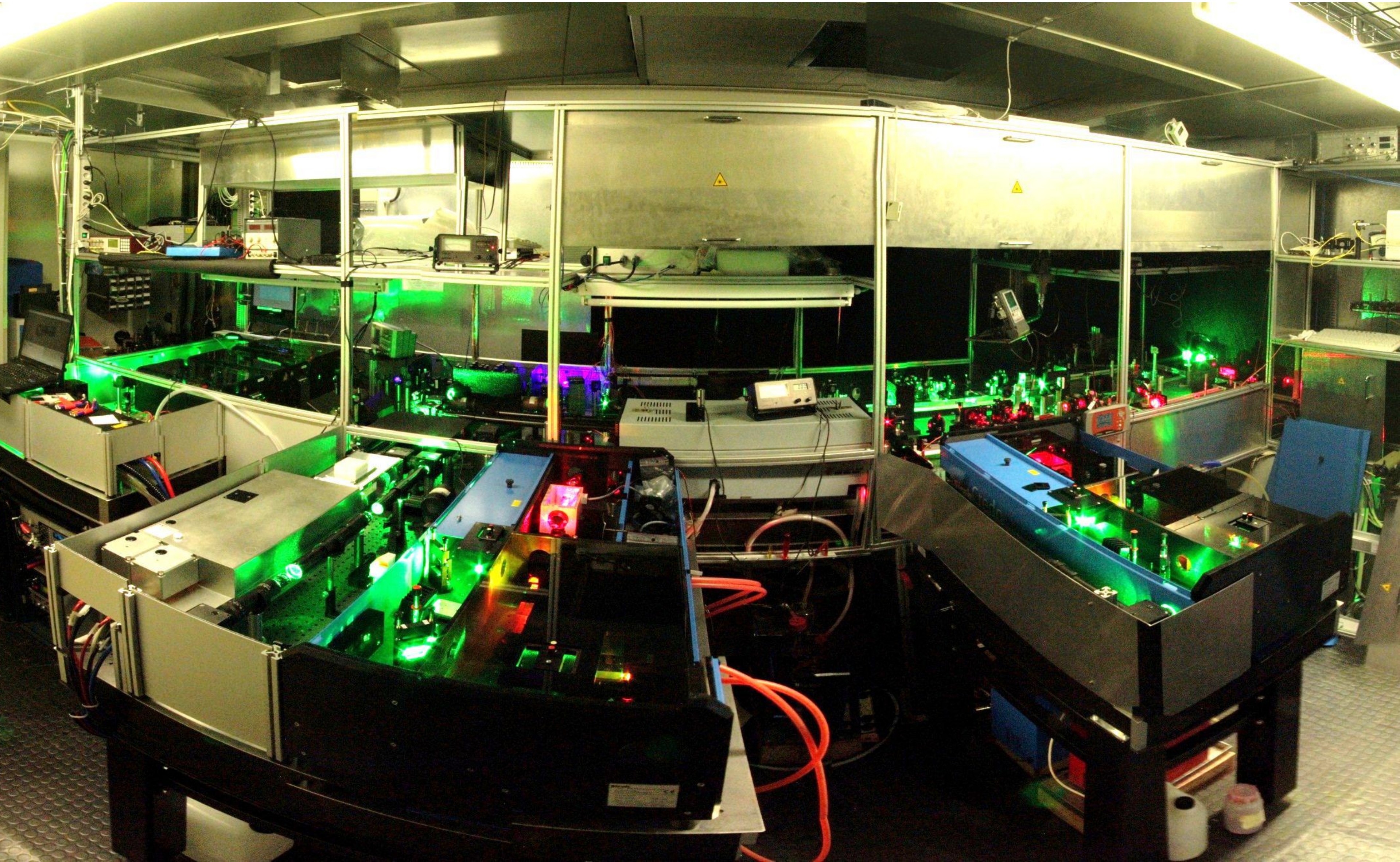
RILIS in action



RILIS in action

New modes of operation

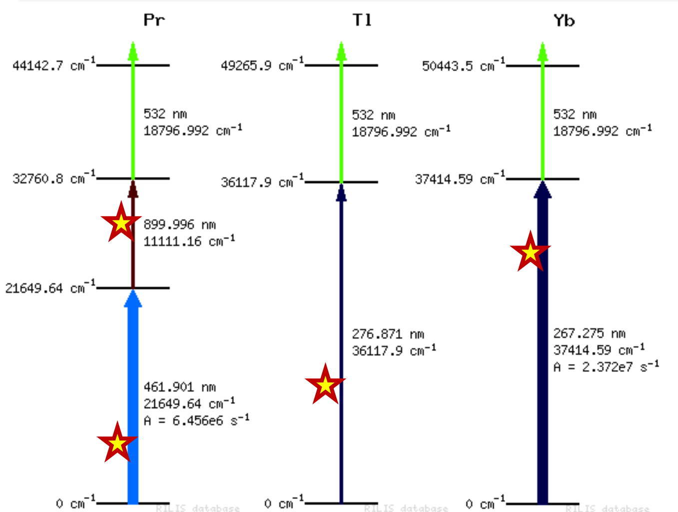
RILIS

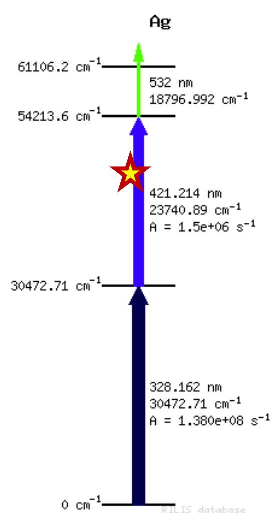
Prerequisite for dual operation: **Temporal synchronization** pulses of the two laser systems

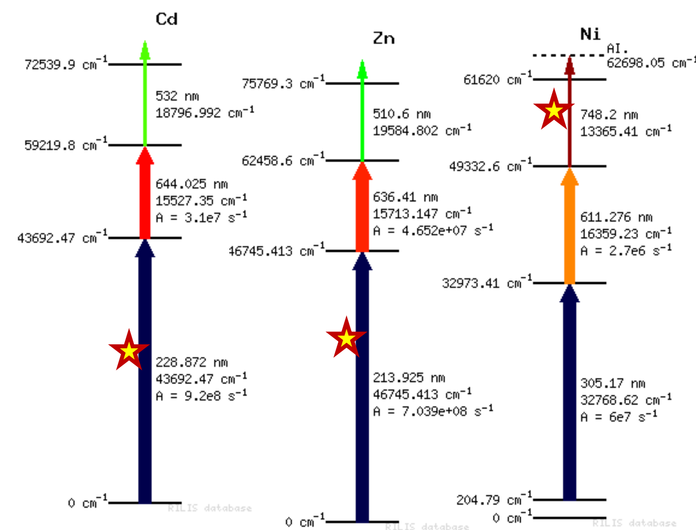
100W Nd:YAG laser is available for non-resonant ionization in **Ti:Sa only** schemes

Mixed schemes

Dye and Ti:Sa are **exchangeable**







Increased efficiencies

New elements

Backup solution

Keep one dye set up for future, use Ti:Sa instead

Reduction in down time

The Dual-RILIS is unique amongst laser ion sources

- http://isolde-project-rilis.web.cern.ch/isolde-project-rilis/

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  - The new Dual TiSa and Dye laser RILIS

- Operation of the RILIS in 2012
  - Total operating time
  - Specifics of Dual RILIS operation
  - Highlights and new developments

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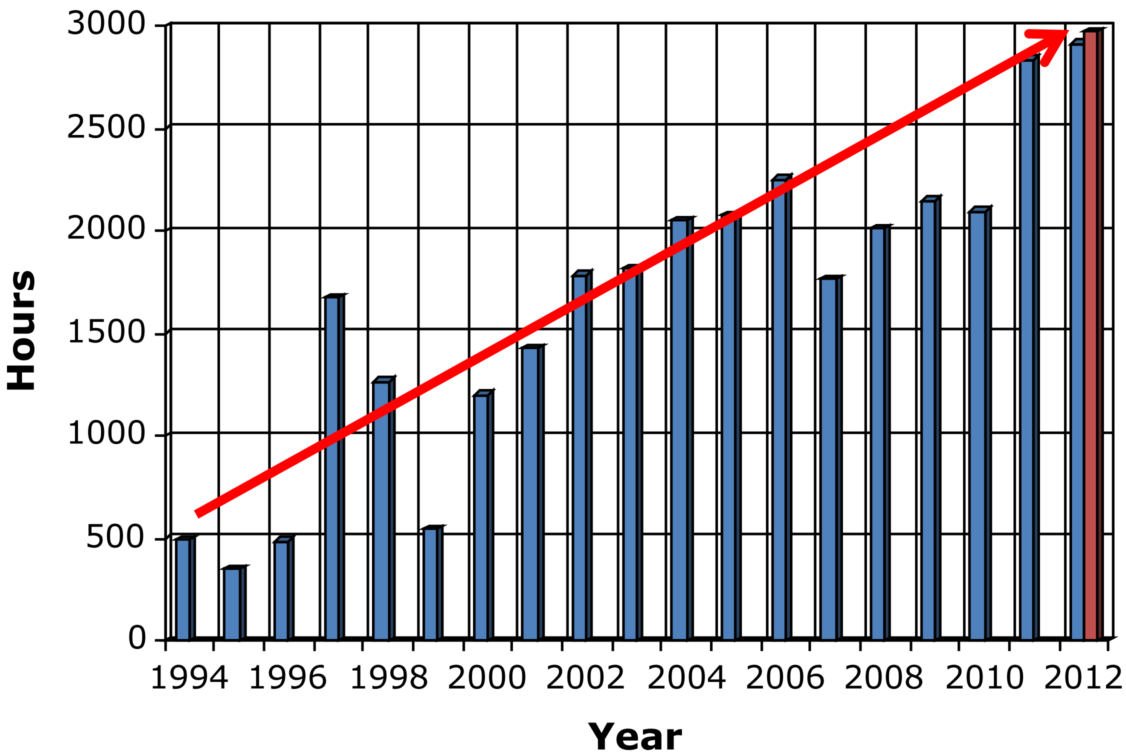
RILIS operation: 1994-2012

Ion beams of **13** elements were produced with RILIS in **2012**



Laser ON time in 2012:

3000 h in 2012

24 separate runs

344 RILIS operator shifts

Availability of two complementary laser systems (Dye and Ti:Sapphire) has ensured the increase of RILIS beam time in 2011-2012

Beam	Sm 2 runs	Ca 2 runs	Cd	At 2 runs	Au 2 runs	Be 3 runs	Dy	Mg 4 runs	Po 2 runs	Ag 2 runs	Zn	Cu	Mn
Planned	208	272	192	300	172	446	88	296	206	96	198	112	148
Real	212	359	253	345	262	278	111	378	206	113	124	69	208

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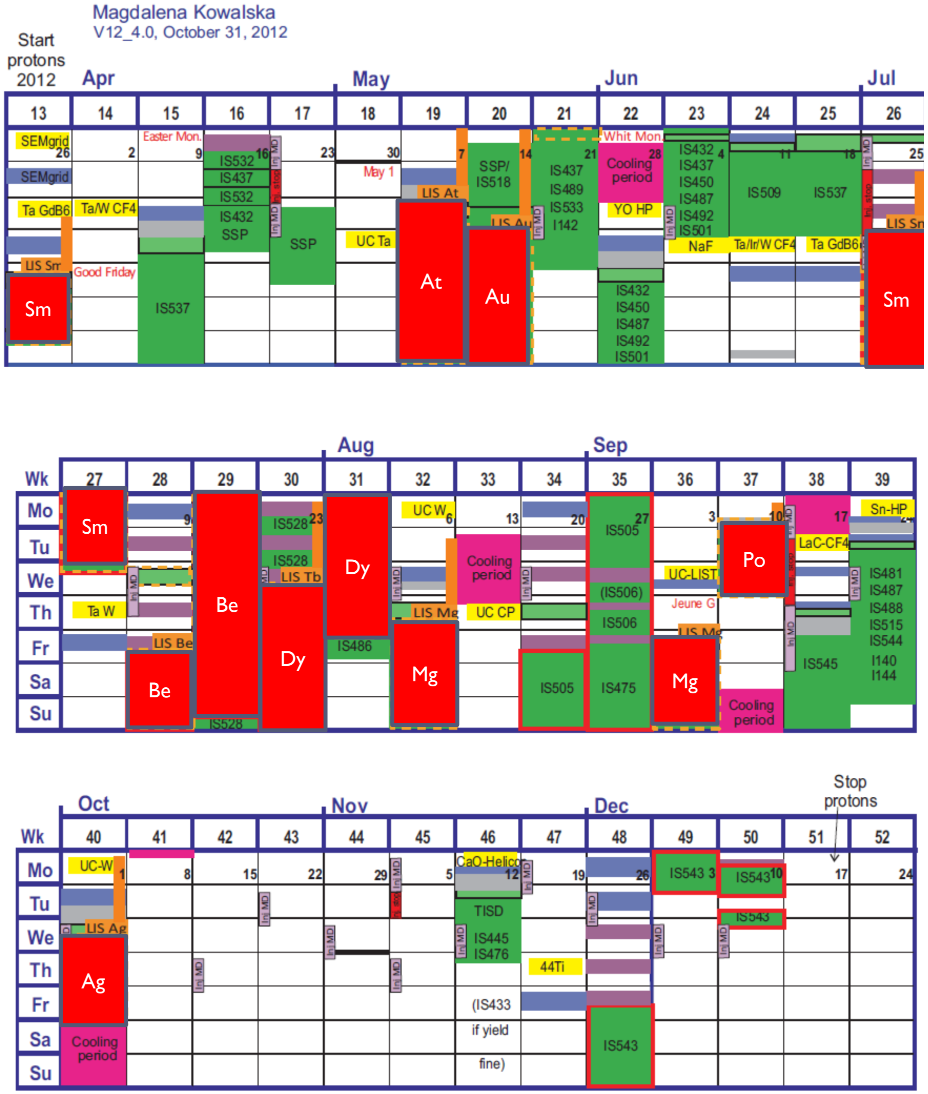
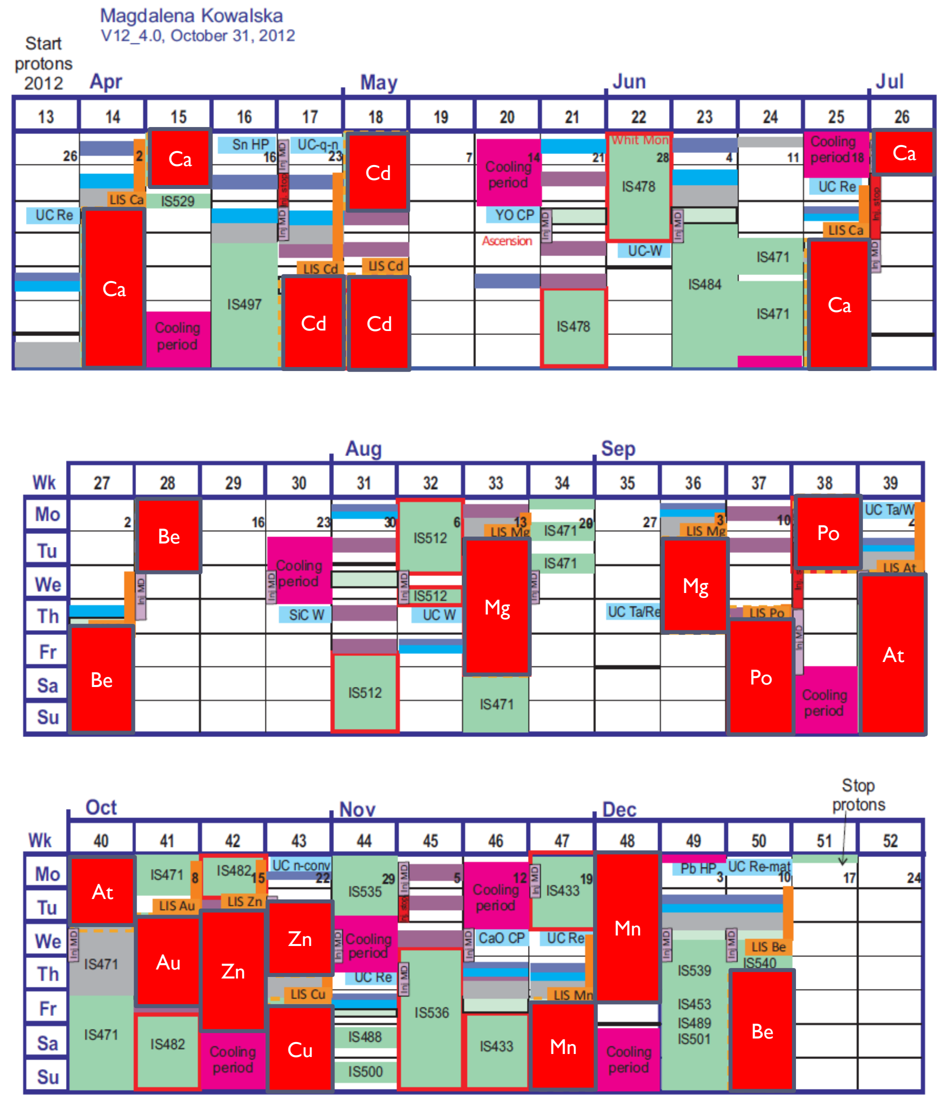
RILIS runs in 2012

RILIS

ISOLDE GPS SCHEDULE 2012



ISOLDE HRS SCHEDULE 2012

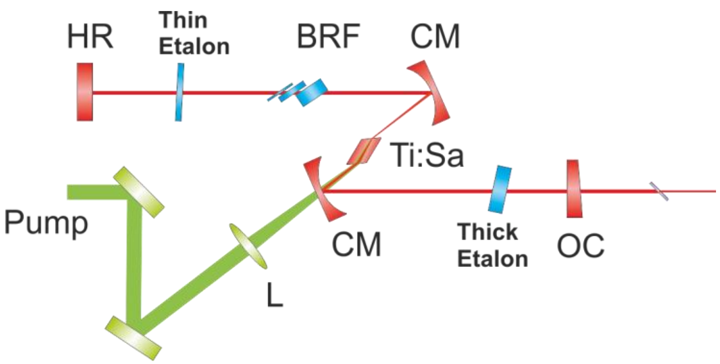


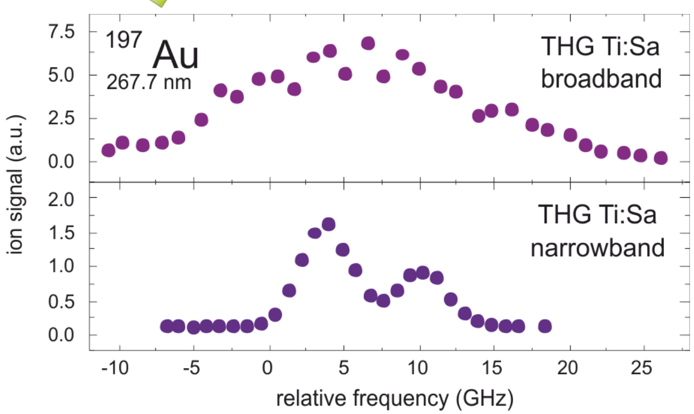
- http://isolde.web.cern.ch/ISOLDE/

Highlights 1 - In-source RIS

RILIS

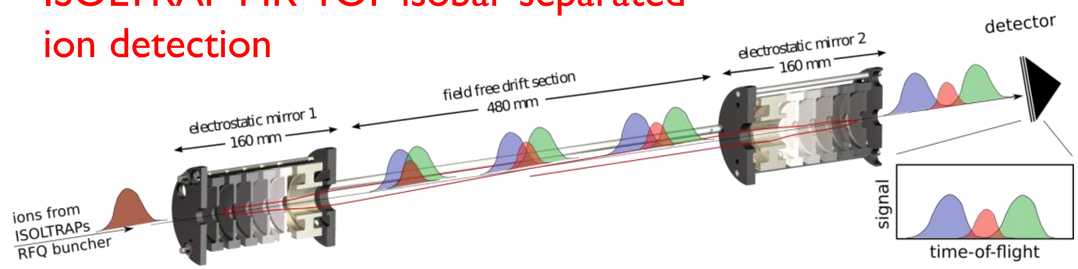
Dual etalon, narrow line-width Ti:Sa



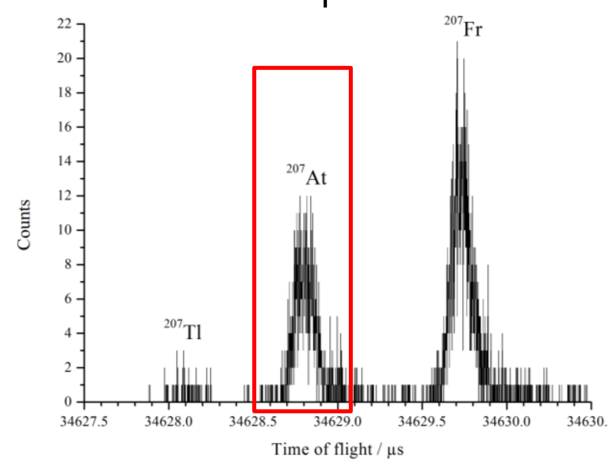


- Addition of a thick etalon to the TiSa cavity
- Reduction of linewidth from >5 GHz → <1GHz
- Remote dual etalon control, automatic optimization routine and feedback based frequency stabilization

ISOLTRAP MR-TOF isobar separated ion detection



- Mass resolution in the range of M/ΔM = 10^6
- MCP is used for direct ion detection with ~1% efficiency: No activity required for detection.
- Direct communication with RILIS for cycle triggering and shared data acquisition is established.



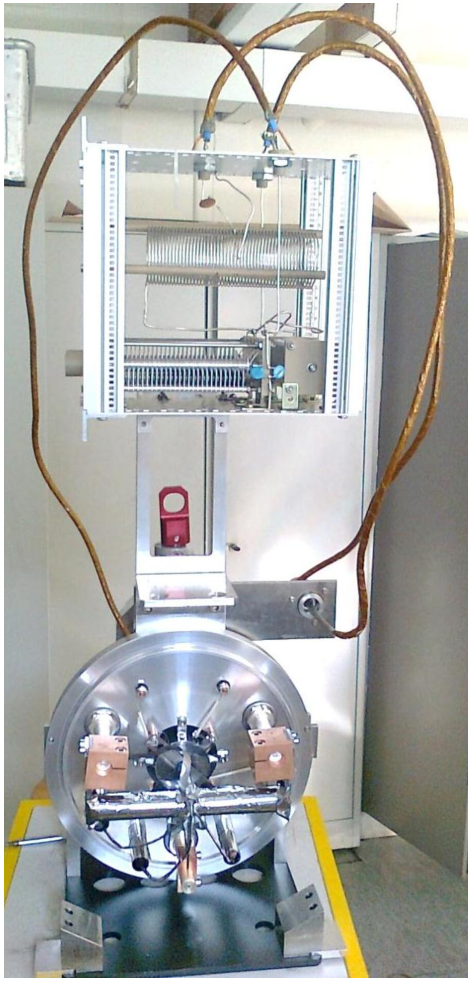
See talks of ***Anatoly Barzakh*** *and* ***Maxim Seliversov*** *on Friday*

R. N. Wolf *et al.*, Nucl. Instr. and Meth. A 686, 82-90 (2012), **(MR-TOF)**

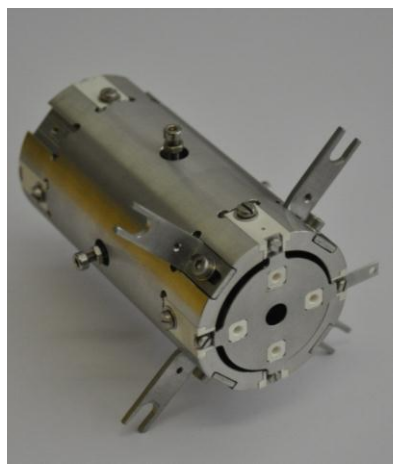
B.Marsh, V Fedosseev,, R. Rossel, S Rothe, D.Fink, M. Seliverstov, N. Imai et al, EMIS 2012 Proceedings, in preparation **(RILIS)**

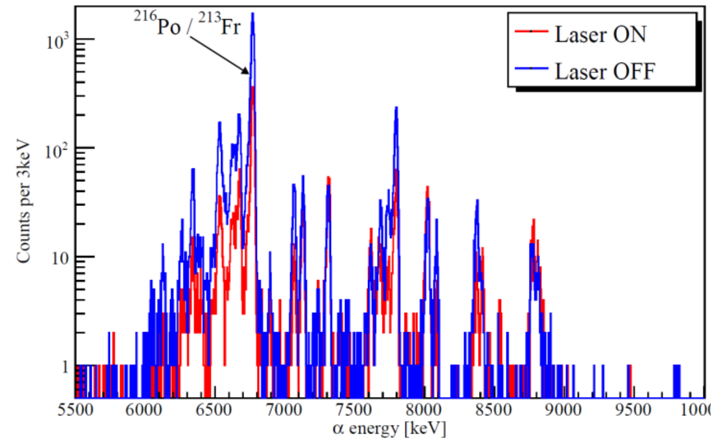
Highlights 2 – LIST operation

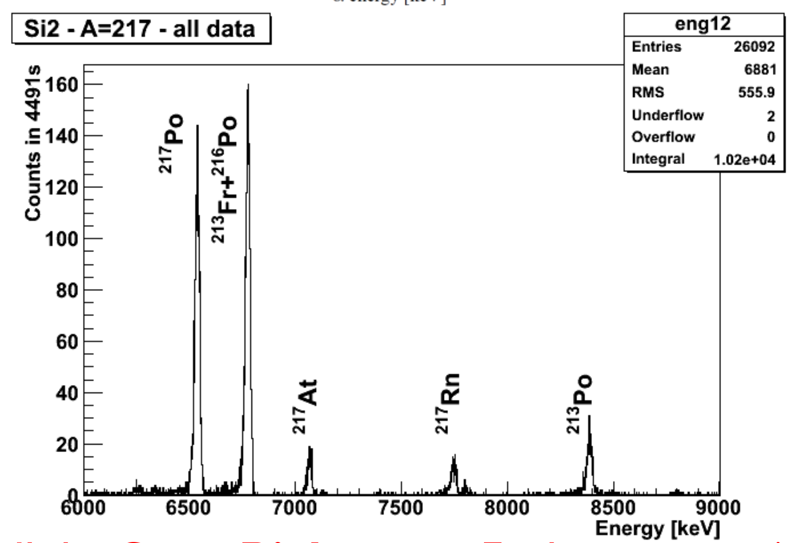
LIST + UCx run for Fr suppression for laser spectroscopy of Po



- **Suppression of >1000 for most surface ions**
- **Ionization efficiency reduction by ≈20x (Mg,Po)**







Talk by **Sven Richter** on Friday morning!

- **Daniel Fink** (CERN, Univ. Heidelberg) and **Sven Richter** (Univ. Mainz): **PhD work**

Part 3

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Future developments

GENERAL RILIS DEVELOPMENTS

- **Extension of RILIS cabin**
  - Enlarged entrance/storage and work area to maximize the useable laser laboratory space
- **Implement a dedicated, high power Nd:YVO_4 laser for non resonant ionization**
  - High beam quality industrial laser could significantly improve efficiency for many schemes.
  - Would simplify RILIS setup, increase reliability and reduce setup time.
- **On-call operation**
  - Installation of a machine protection and monitoring system to reduce reliance on shift-based operation
  - To be implemented during LS1

IONIZATION SCHEMES

- Investigate RILIS for refractory metals at ISOLDE
- Improved RILIS schemes for the Dual RILIS system

*See talk of **Tom Day Goodacre***

IN-SOURCE SPECTROSCOPY

- Installation of a reference cell at RILIS
- Pulsed amplification of CW seeded Dye laser or TiSa
- Improved motorization of Narrow-band TiSa

*See talk of **Anatoly Barzakh***

SELECTIVITY IMPROVEMENTS

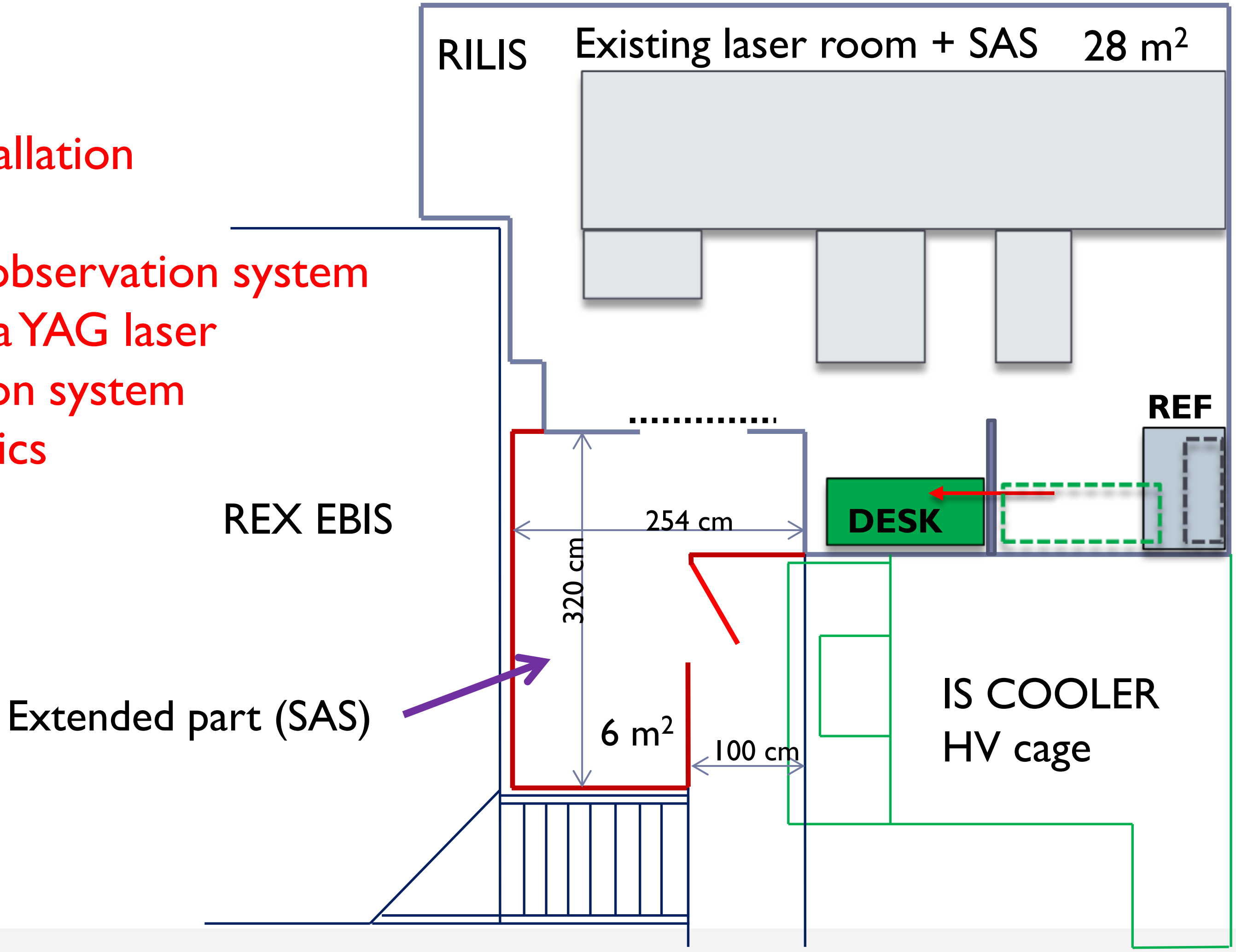
- Further optimization of LIST
- Improving the laser ion time structure or using a time focus for effective beam gating

*See talk of **Sven Richter***

RILIS room extension

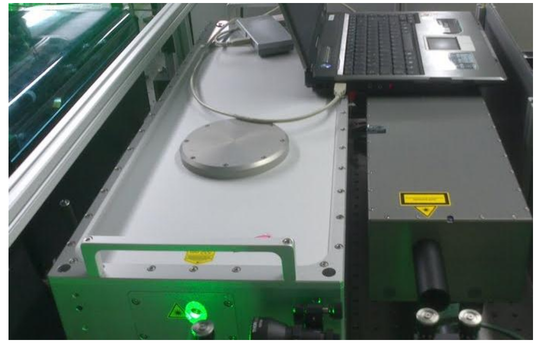
Required for:

- Safety
- Reference cell installation
- Dye handling
- Upgrade of beam observation system
- Installation of extra YAG laser
- Improved ventilation system
- Comfort/ergonomics



Independent laser for non resonant ionization

LUMERA LASER



- **40W at 10 kHz**
- **17ns Pulse**
- **Low Jitter**
- **Gaussian beam**
- **Much better transmission efficiency to ion source**

Blaze laser installed for a short test at RILIS in Dec 2012

Laser	Laser Power (on table)	Reference beam power in 3 mm aperture	Transport efficiency
Edgewave	43 W	370 mW	33 %
Blaze	15 W	350 mW	> 80%
Blaze	40 W	800 mW	~80 %

A similar efficiency improvement should be expected for the **18** RILIS elements that use non-resonant ionization for the final step!

Power dependent thermal lensing in the beam transport optics is to be eliminated

Can be used for Dye and Ti:Sa pumping as a back-up laser

- ***B. Marsh et al.**, Suitability test of a high quality Nd:YVO industrial laser for the ISOLDE RILIS installation. CERN-ATS-Note-2013-007 TECH*

Upgrade of HRS window

Problem with existing window

1) Window contamination:

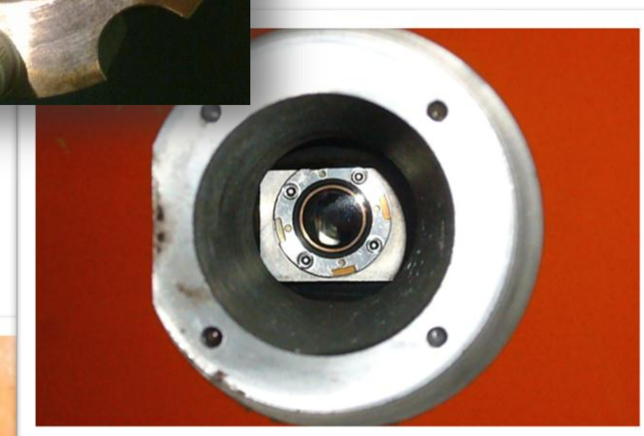
- Annual window change is required
- Difficult to access for change or inspection

2) Thermal lensing:

- Defocussing issue for high power beams must be measured and resolved

Solution

1. Extend the vacuum chamber and mount an adjustable window outside the magnet shielding
2. Use the internal and external reflections from the window for thermal lens and contamination diagnostics



Dye Leak: **Fire hazard; laser damage risk**

Up to 6 dye circulators each containing up to 3 L of ethanol flowing at 7 L/min.

Action required: Stop dye circulator, Stop or block pump laser, alert the laser operator.

Organic solvent detector (breathalyzer) **+**

NI CompactRIO MPS **+**

Laser beam shutter
or pump laser switch **OFF**
using interlock system
RELAY for circulator interlock

Dye flow interruption: **Fire hazard; laser damage risk**

Up to 40 W pump beam focused on dye cell. Almost immediate dye cell damage if dye flow stops.

Action required: Block pump beam to dye laser, alert the laser operator.

Solution to be tested:

Non invasive dye flow sensor (ULTRASONIC) **+**

NI CompactRIO MPS **+**

Remote controlled Laser beam shutter

Water leak: **Equipment damage risk; electrical safety hazard**

Water cooling for Ti:Sa crystals. Water cooling network for each dye circulator. Water cooled pump lasers

Action required: Stop pump lasers, alert the laser operator.

Install water leak sensor cables on laser table and RILIS cabin floor
Include sensor data logger in RILIS monitoring system

EN Engineering Department

On-call operation

RILIS

3 requirements for On-Call operation:

1) Machine protection / safety	2) Performance monitoring	3) Automation
This must be a ROBUST system (PC independent).	+ Alert system to request operator intervention.	To maintain RILIS performance therefore reducing the frequency of operator interventions.

ESSENTIAL

NON ESSENTIAL

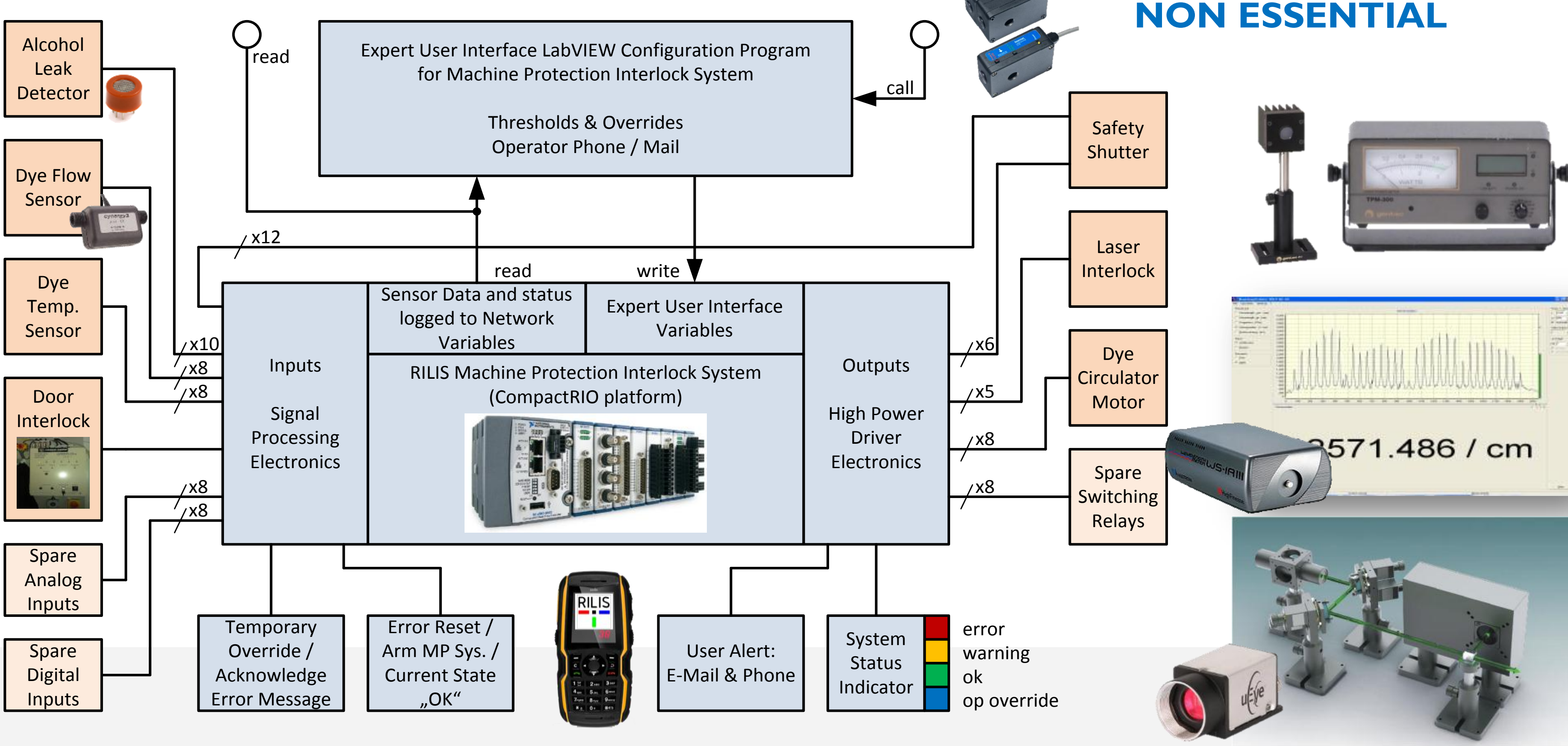


Diagram made by ***Ralf Rossel;*** *the project is being realized in collaboration with* ***EN-STI-ECE***

EN Engineering Department

Acknowledgements

RILIS

Valentine FEDOSSEEV[1], Bruce MARSH[1], Sebastian ROTHE[1], Daniel FINK[1,8], Maxim SELIVERSTOV[2], *Nobuaki IMAI[4], Ralf Erik ROSSEL[3], Dmitri FEDOROV[2], Anatoly BARZAKH[2], Pavel MOLKANOV[2], Marica Anna SJOEDIN[5], Daniele SCARPA[6], Sven RICHTER[7], Klaus WENDT[7]*

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[7]Johannes-Gutenberg-Universitaet Mainz
[8]University of Heidelberg
[9]University of Manchester

Spectroscopy with RILIS

IS511

Shape coexistence in the lightest Tl isotopes studied by laser spectroscopy
http://greybook.cern.ch/programmes/experiments/IS511.html

IS534

Beta-delayed fission, laser spectroscopy and shape-coexistence studies with radioactive At beams
http://greybook.cern.ch/programmes/experiments/IS534.html

IS456

Study of polonium isotopes ground state properties by simultaneous atomic- and nuclear-spectroscopy
http://greybook.cern.ch/programmes/experiments/IS456.html

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Spare slides

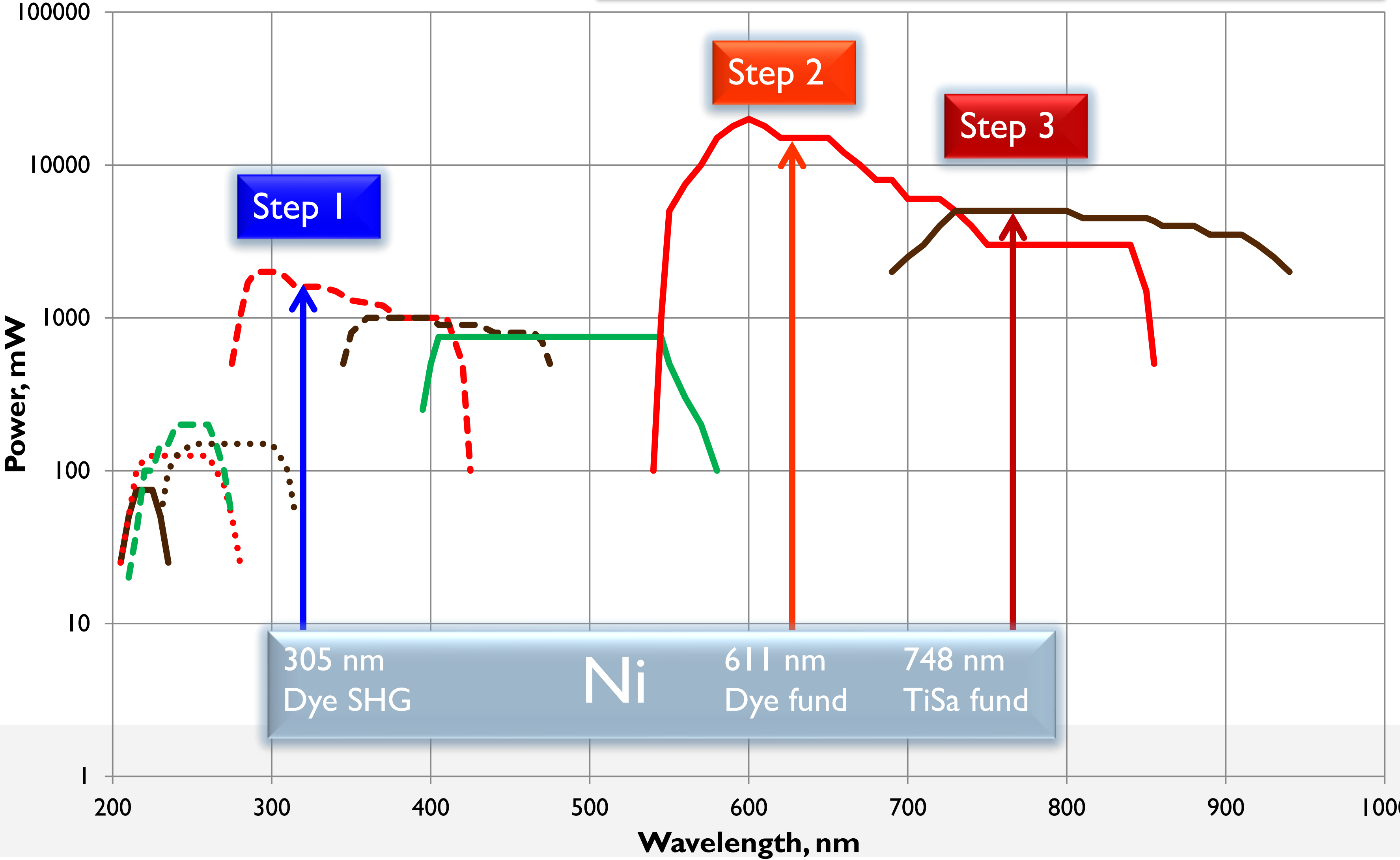
RILIS scheme setup requirements

	Dye laser schemes									Ti:Sa schemes					
Element	Setting time* days	Step 1 λ1, nm	Step 1 Dye	Step 2 λ2, nm	Step 2 Dye/YAG	Step 3 λ3, nm	Step 3 Dye/YAG	Efficiency off-line		Step 1 λ1, nm	Step 1 Fundamental	Step 2 λ2, nm	Step 2 Fundamental	Step 3 λ3, nm	Step 3 TiSa/YAG
$_{4}$Be	3	234.9	Pyridin 1	297.3	Rhod B	–		>7%		234.9	939.444				
$_{12}$Mg	2	285.2	Rhod 6G	552.8	Fluorescein 27	532.1	YAG	10%		285.2	855.639	552.8		532.1	YAG
$_{13}$Al	2	309.3 308.2	Rhod B Rhod B	532.1	YAG	–		20%		309.3 308.2		532.1		–	
$_{20}$Ca	2	272.2	?	532.1	YAG	–		0.50%		422.7	845.346		Rhod B		DCM
$_{21}$Sc	2	327.4	Phenox 9	719.8	Pyridin 2 ?	532.1	YAG	15%		327.4		719.8		532.1	YAG
$_{25}$Mn	3	279.8	Rhod 6G	628.3	DCM	635.8	DCM	19%		279.8		628.3		635.8	
$_{27}$Co	2	304.4	Rhod B	544.5	Fluorescein 27	532.1	YAG	>3.8%		304.4		544.5		532.1	YAG
$_{28}$Ni	3	305.1	Rhod B	611.1	Rhod B	748.2	Styr 8	>6%			Dye		Dye	748.2	TiSA
$_{29}$Cu	2	327.4	Phenox 9	287.9	Rhod 6G	–		>7%		327.4		287.9		–	
$_{30}$Zn	3	213.9	DCM	636.2	DCM	532.1	YAG	4.90%		213.9	855.428	636.2	Dye	532.1	YAG
$_{31}$Ga	2	287.4 294.4	Rhod 6G Pyrr 597	532.1	YAG	–		21%		287.4 294.4		532.1		–	
$_{39}$Y	2	414.3	Styr 9	662.4	Phenox 9	510.6	YAG			414.3		662.4		510.6	YAG
$_{47}$Ag	2	328.1	Phenox 9	546.6	Fluorescein 27	532.1	YAG	14%		328.1		546.6		532.1	YAG
$_{48}$Cd	3	228.8	Pyridin 1	643.8	DCM	532.1	YAG	10.40%		228.8	915.208	643.8	Dye	532.1	YAG
$_{49}$In	2	303.9 325.6	Rhod B Phenox 9	532.1	YAG	–				303.9 325.6		532.1		–	
$_{50}$Sn	4	286.3	Rhod 6G	811.4	Styr 9	823.5	Styr 9	9%		286.3	858.9	811.4	TiSA	823.5	TiSA
$_{51}$Sb	3	217.6	Phenox 9	560.2	Rhod 6G	532.1	YAG	2.70%		217.6		560.2		532.1	YAG
$_{60}$Nd	2	588.8	Rhod B or Pyrr 597	596.9	Rhod B	596.9				588.8		596.9		596.9	
$_{62}$Sm	3	600.4	Rhod B	675.2	Phenox 9	676.18	Phenox 9			600.4		675.2		676.18	
$_{65}$Tb	3	579.6	Pyrr 597	551.7	Fluorescein 27	618.3	Rhod B			579.6		551.7		618.3	
$_{66}$Dy	2	625.9	DCM	607.5	Rhod B	532.1	YAG	20%		625.9		607.5		532.1	YAG
$_{70}$Yb	2	555.6	Pyrr 567	581.0	Rhod 6G	581.0	Rhod 6G	15%		555.6		581.0		581.0	
$_{71}$Lu		*573.7*	*Rhod 6G*	*642.5*	*DCM*	*643.5*	*DCM*			*451.9*	*903.8*	*460.7*	*921.4*		
$_{79}$Au	5	267.6	Coum 540A	306.5	DCM	673.9	Phenox 9	>3%		267.6		306.5		673.9	
$_{80}$Hg	3	253.7	Styr 8	313.2	DCM	626	DCM			253.7		313.2		626	
$_{81}$Tl	2	276.8	Rhod 110	532.1	YAG	–		27%		276.8		532.1		–	
$_{82}$Pb	2	283.3	Rhod 6G	600.2	Rhod B	532.1	YAG	>3%		283.3		600.2		532.1	YAG
$_{83}$Bi	2	306.8	Rhod B	555.2	Fluorescein 27	532.1	YAG	6%		306.8		555.2		532.1	YAG
$_{84}$Po	4	255.8	Styr 8	843.4	Styr 9	532.1	YAG			255.8	767.403	843.4	TiSA	532.1	YAG
$_{85}$At	4	216.9 224.4	Phenox 9 Phenox 9	795.4 793.2 ?	Styr 9 Styr 9	532.1 532.1	YAG YAG			216.9 224.4	867.6 897.6	795.4 793.2 ?	TiSA TiSA	532.1 532.1	YAG YAG

Ni: Dye-Dye-TiSa

RILIS

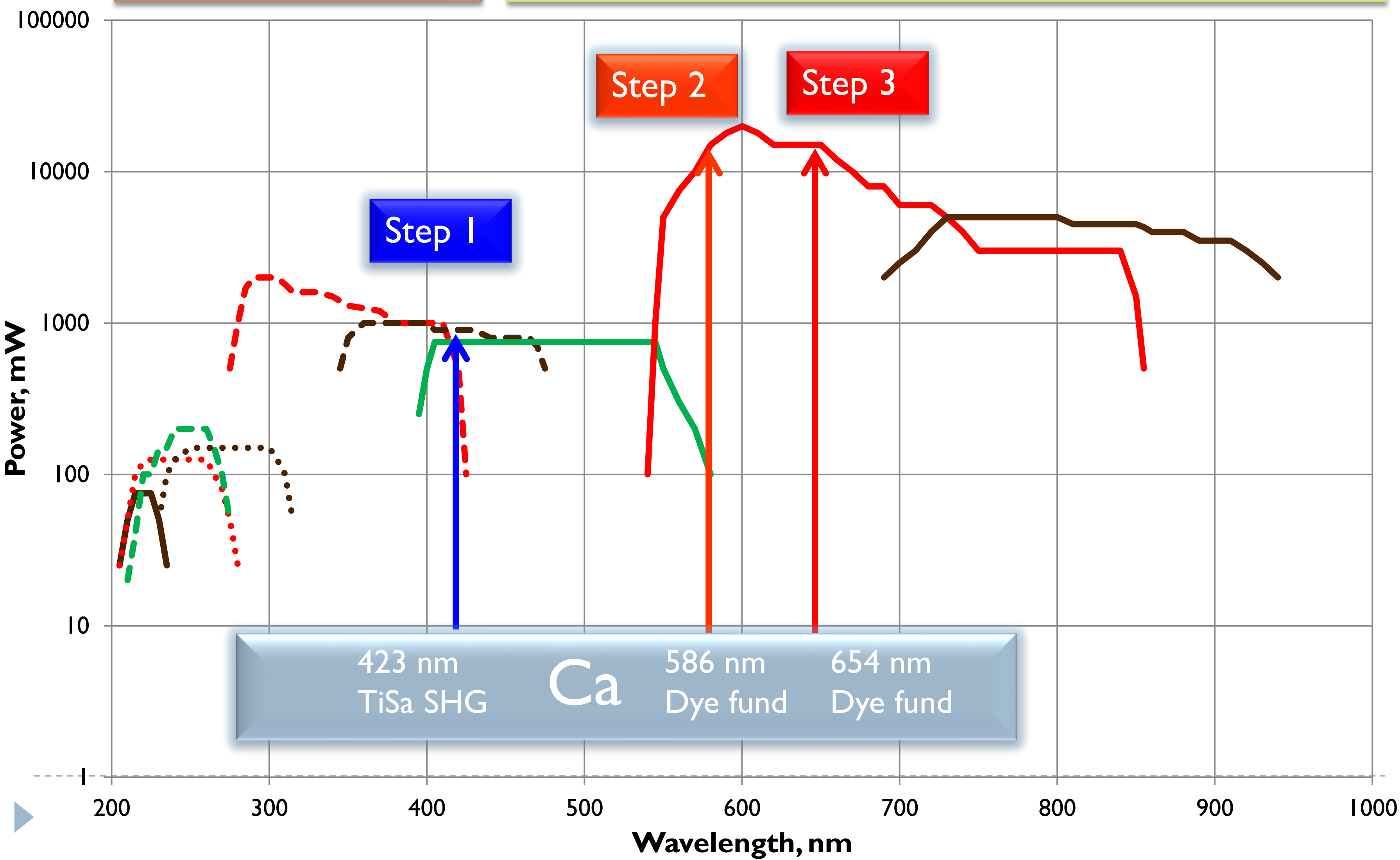
Higher power from TiSa for AIS transition



Ca: TiSa-dye-dye

Higher power from TiSa for Step 1

~50W @ 532 nm to pump dye laser for AIS search for step 3 – **new scheme found**



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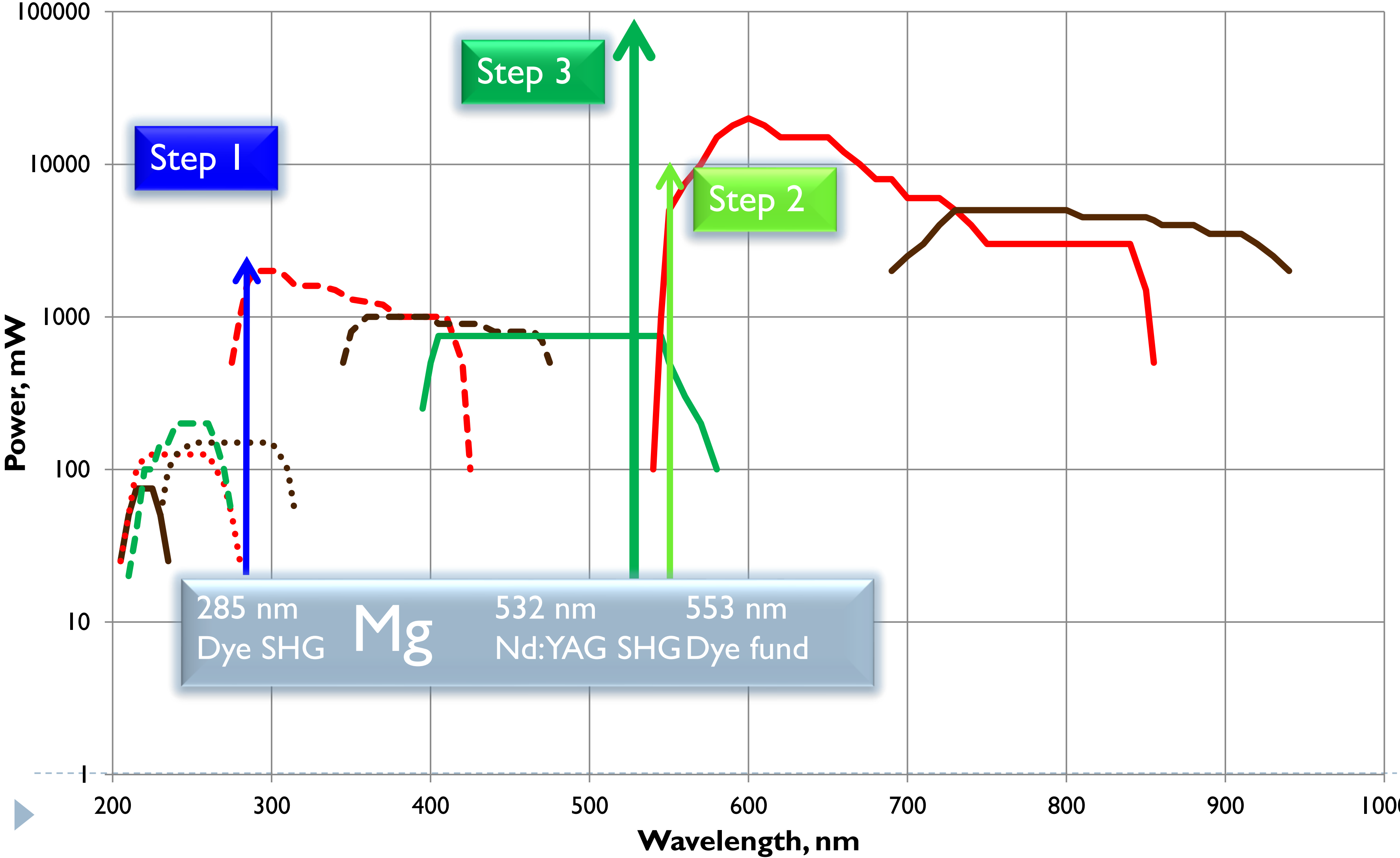
Mg: Dye-Dye-YAG

RILIS

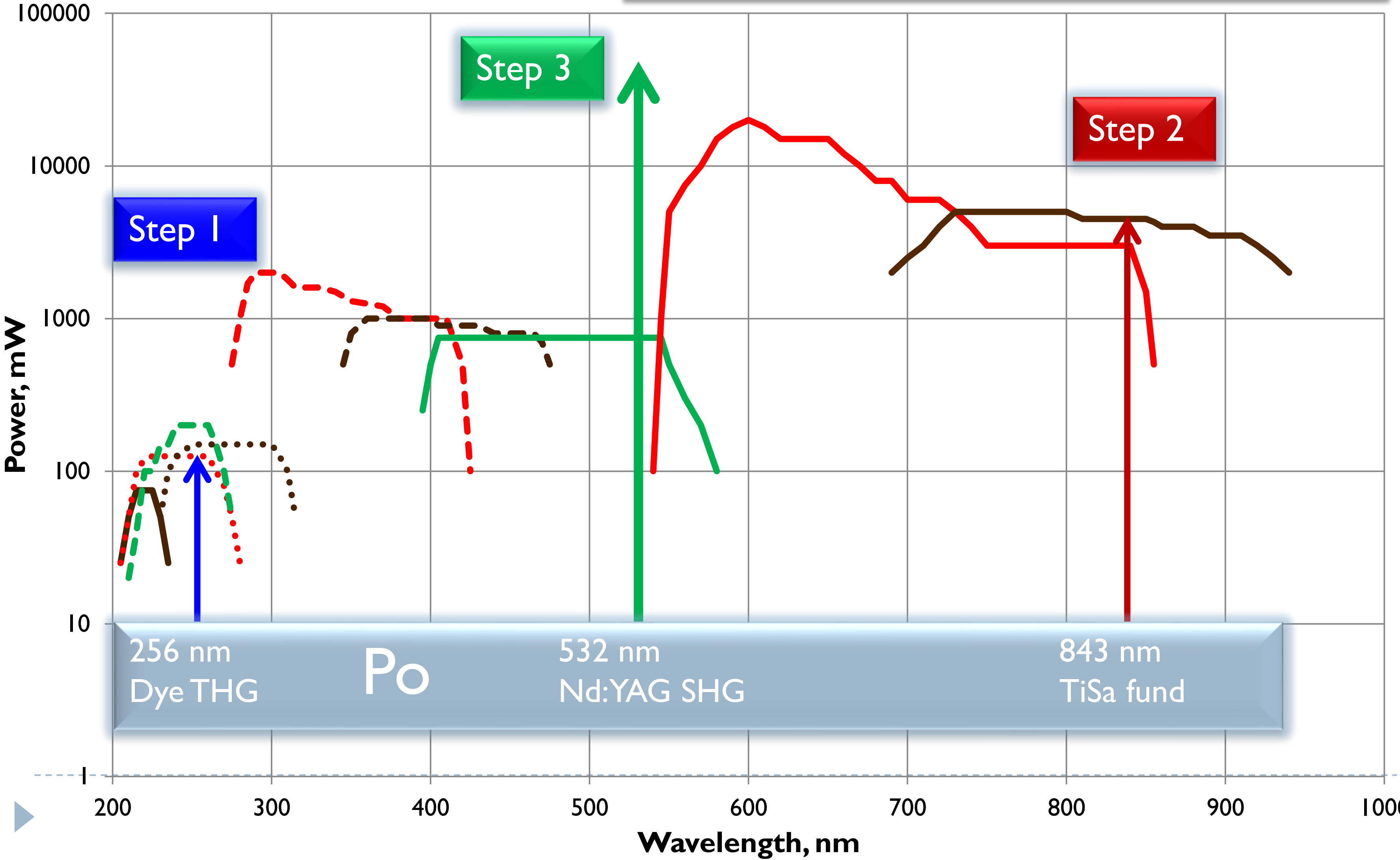
Dye only: TiSa is available for preparation for the next RILIS element



Po: Dye-TiSa-YAG

RILIS

Higher power from TiSa for Step 2, narrow line-width TiSa for spectroscopy



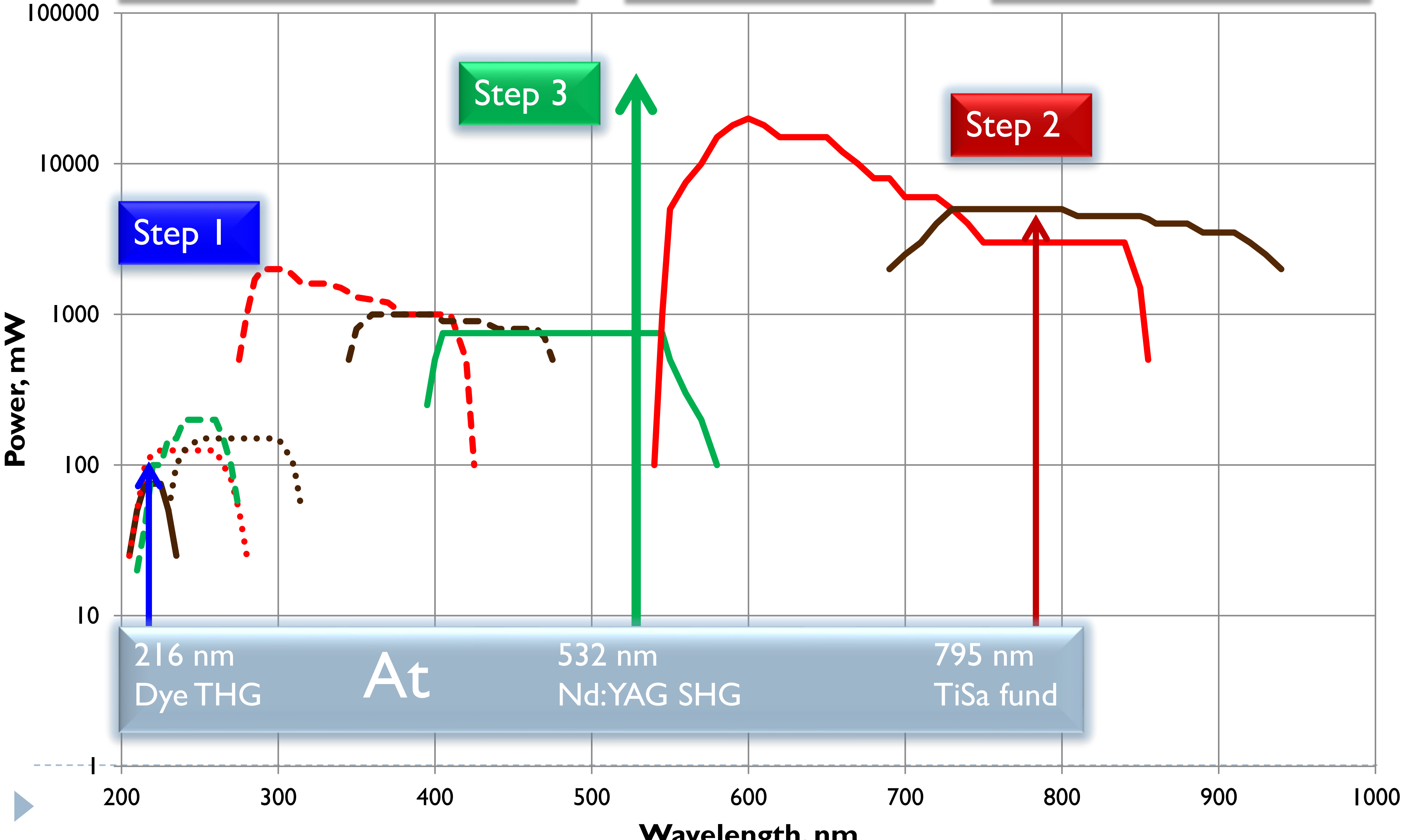
RILIS

At: Dye(TiSa)-TiSa-YAG

Dye and TiSa exchangeable for Step 1

~50W @ 532 nm for Step 3

Higher power from TiSa for Step 2



Au: TiSa-Dye-Dye

RILIS

Higher power from TiSa for Step 1

~50W @ 532 nm to pump dye laser for Step 3