



# Upgrade of laser setup at ISOLDE RILIS

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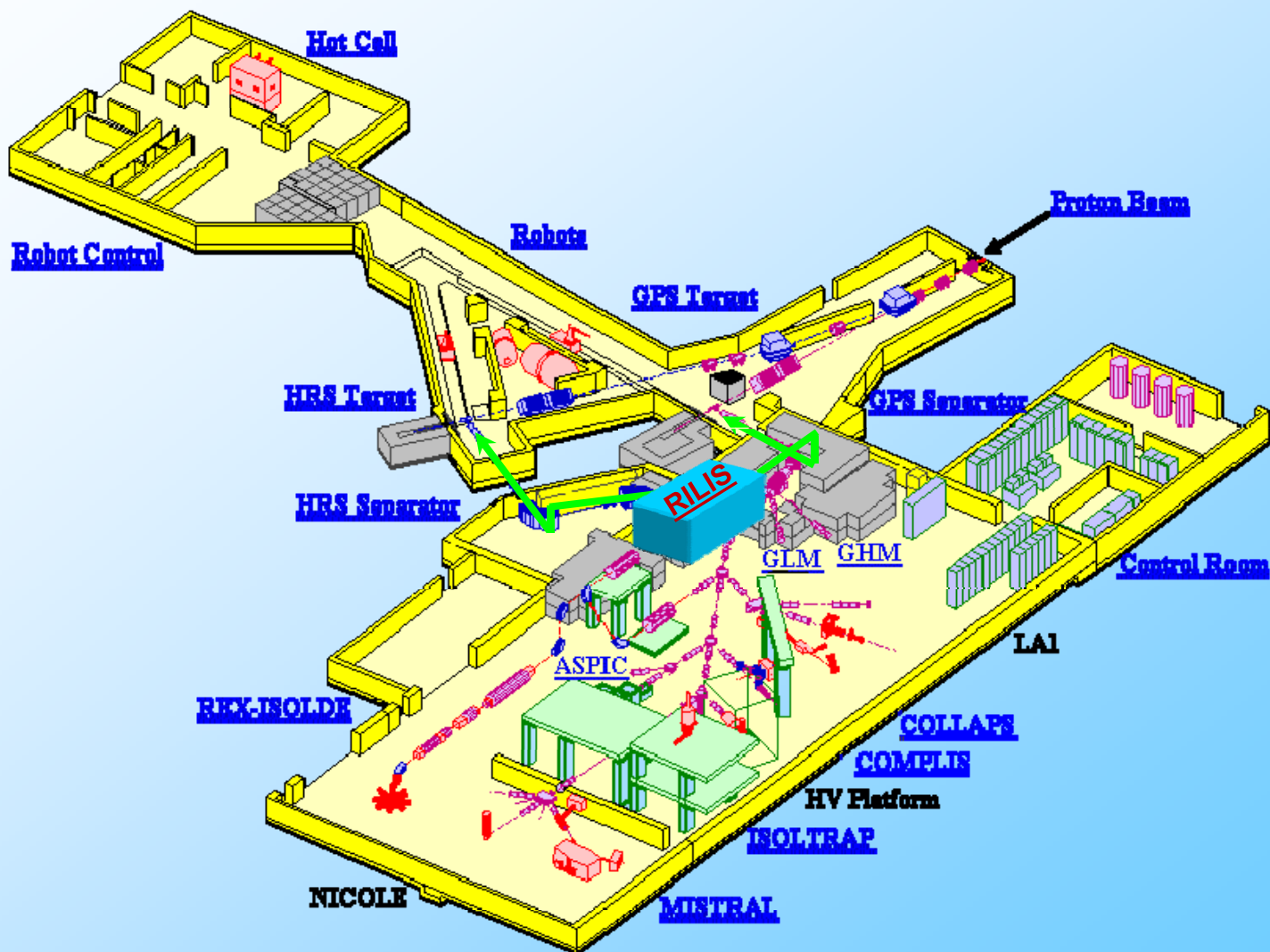
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# RILIS at ISOLDE Facility





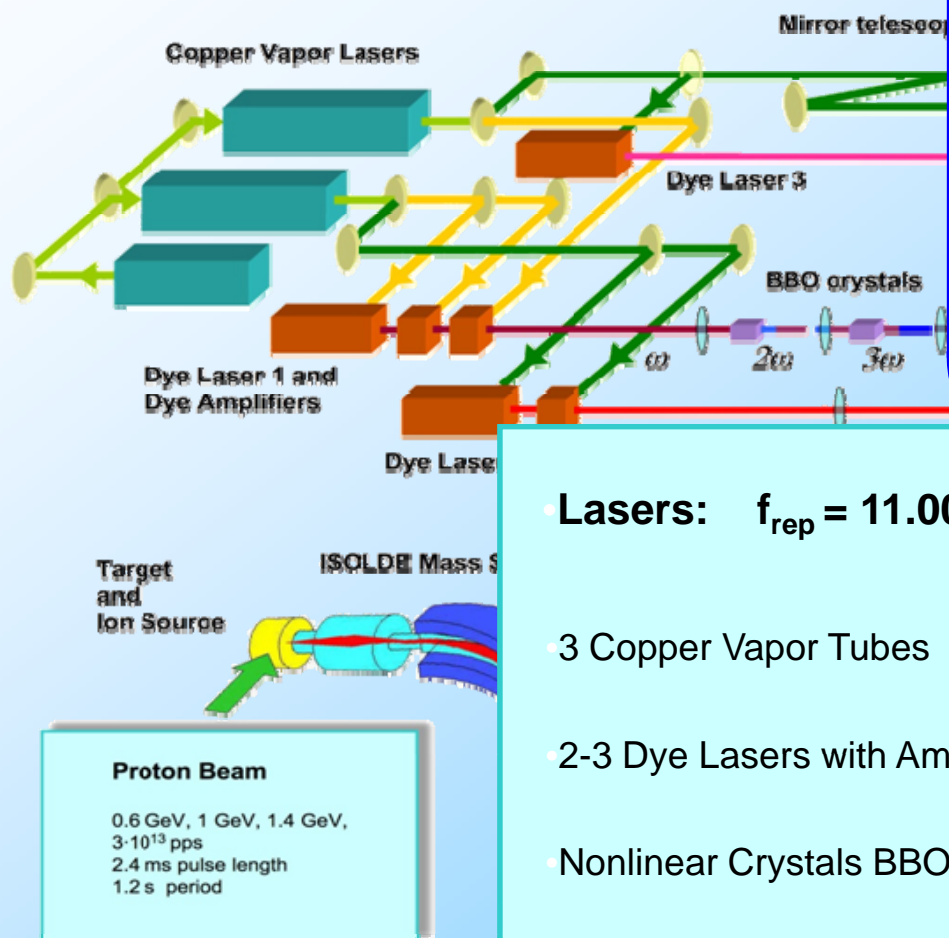
# RILIS ion beams

Ion beams of 29 elements are produced at RILIS

elements available at ISOLDE LIS																		
1 H	ionization scheme tested																He	
3 Li	4 Be	ionization scheme untested																
11 Na	12 Mg																	
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn	
87 Fr	88 Ra	89 Ac	104 Rf	105 Ha	106 Sg	107 Ns	108 Hs	109 Mt	110	111	112							



# RILIS lasers



• Wavelength tuning range:

- Fundamental ( $\omega$ )
- 530 - 850 nm
- 2nd harmonic ( $2\omega$ )
- 265 - 425 nm
- 3rd harmonic ( $3\omega$ )
- 213 - 265 nm

• Lasers:  $f_{\text{rep}} = 11.000 \text{ Hz}$ ,  $t_{\text{pulse}} = 15 \text{ ns}$

• 3 Copper Vapor Tubes -

$$P_{\text{Cu}}^{\text{total}} \leq 80 \text{ W}$$

• 2-3 Dye Lasers with Amplifiers -

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

• Nonlinear Crystals BBO -

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

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



# Copper vapor lasers



Green Beams  
45 W @ 511 nm

Yellow Beams  
35 W @ 578 nm



- 2 hr start time
- Pulse-to-pulse instability (jitter)
- Aging equipment
- Procurement of consumables is difficult
- Risky combination:
  - High tension ~ 16 kV
  - High temperature ~ 1500 C
  - Cooling water



**Upgrade is needed !**

# Upgrade of RILIS laser system

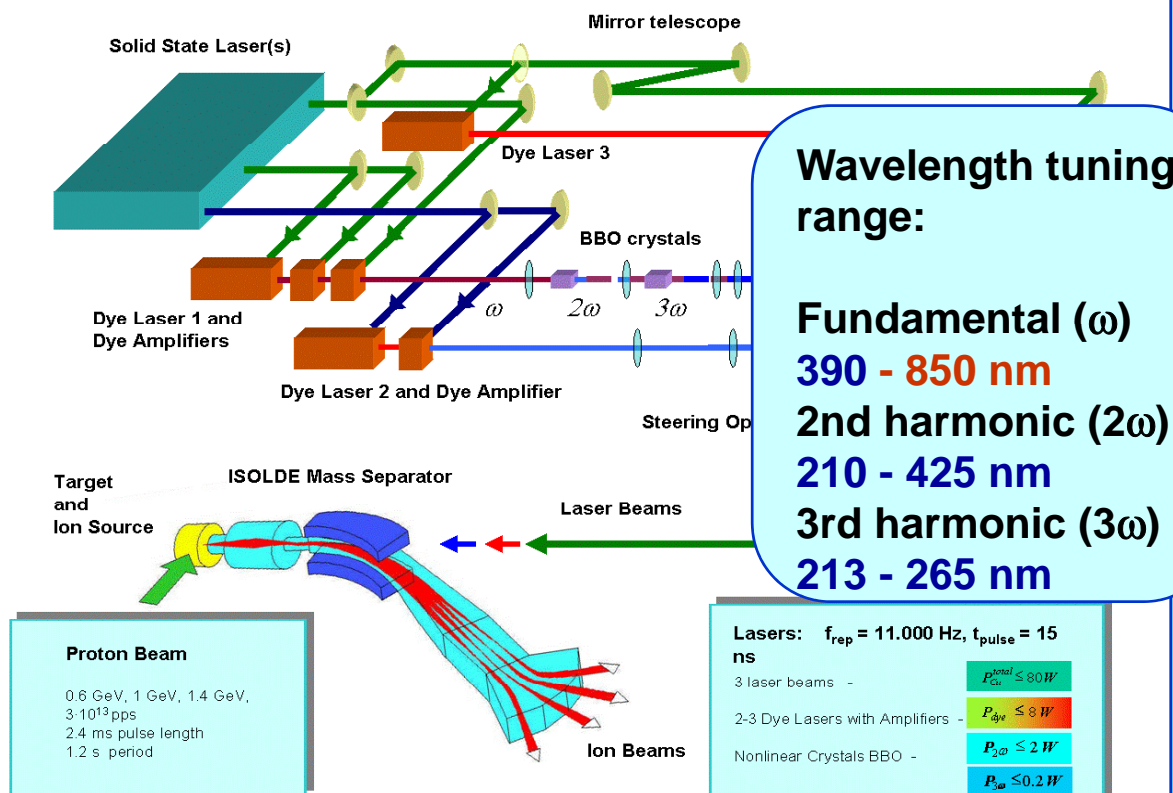
Replacement of CVL by SSL

## Advantages:

- Better beam quality
- Stability of operation
- Spectral coverage UV-NIR without gaps

## Questions:

- New ionization schemes
- Reliability
- Service



## Requirements to RILIS Solid State Lasers

	<b>Beam A - 532 nm</b> High quality beam for ionization	<b>Beam B – 532 nm</b> Medium quality beam for dye laser pumping	<b>Beam C – 355 nm</b> Medium quality beam for dye laser pumping
Pulse repetition rate	8-15 kHz	8-15 kHz	8-15 kHz
Pulse duration	10-30 ns	10-20 ns	10-20 ns
Output pulse timing jitter	< 3 ns	< 3 ns	< 3 ns
Average power	40 W	30-40 W	15-20 W
Power stability	+/- 5% over 24 hours	+/- 5% over 24 hours	+/- 5% over 24 hours
Beam divergence or $M^2$	< 0.1 mrad after expanding to 20 mm diameter	$M^2 = 5-20$	$M^2 = 15-20$
Beam pointing stability	< 0.02 mrad after expanding to 20 mm diameter		

- Replacement of CVL system

## Enquiries and contacts in 2003 – 2006:

- |   |  |
|---|--|
| <b>1. Coherent Inc.</b><br>USA                | <b>8. Groupe QUANTEL</b><br>France                   |
| <b>2. Lambda Physik AG</b><br>Germany         | <b>9. LEE LASER, Inc</b><br>USA                      |
| <b>3. Spectra-Physics LAS GmbH</b><br>Germany | <b>10. THALES LASER S.A.</b><br>France               |
| <b>4. Lightwave Electronics</b><br>USA        | <b>11. Photonics Industries International</b><br>USA |
| <b>5. Quantronix Corporation</b><br>USA       | <b>12. Powerlase Limited</b><br>UK                   |
| <b>6. Positive Light, Inc</b><br>USA          | <b>13. EdgeWave GmbH</b><br>Germany                  |
| <b>7. Spectron Laser GmbH</b><br>Germany      | <b>14. General Atomics Photonics</b><br>USA          |

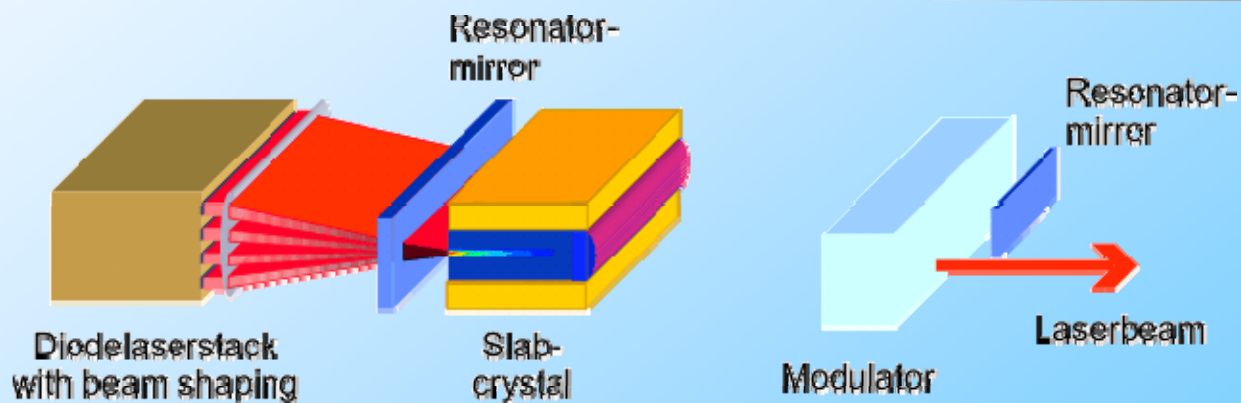
+ Contacts with other companies at Laser exhibitions at Munich (2003, 2005) and CLEO Conference



DIODE Pumped Nd:YAG, Nd:YLF  
and Nd:YVO<sub>4</sub> lasers

3 lasers:  
2 x Green + 1 x UV

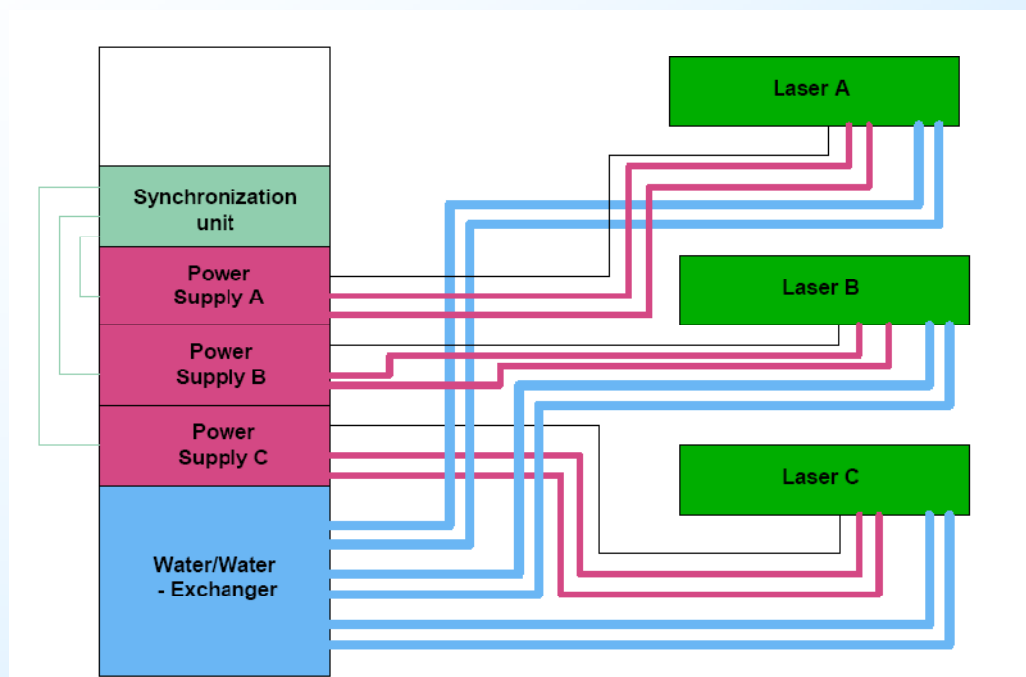
- Short cavity : naturally shorter pulses
- Specifications more or less satisfied in previously supplied lasers
- Separate laser system
- Small, relatively new company
- Long term availability of parts/service?



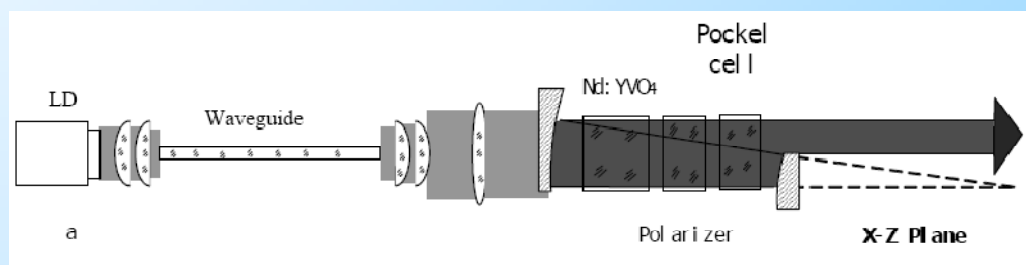
Nd:YLF, pulse length 10 ns at  
10kHz, output average power  
40W,  $M^2 = 1,7$

Nd:YLF, pulse length 12 ns at  
10kHz, output average power  
20W,  $M^2 = 4,$

# SSL design proposal 1



	Beam A 532 nm	Beam B 532 nm	Beam C 355 nm
Pulse duration	9 ns	9 ns	10 ns
Jitter	< 3 ns	< 3 ns	< 3 ns
Average power	40 W at 10 kHz	40 W at 10 kHz	20 W at 10 kHz
Beam diameter	10 mm	10 mm	5 mm
Beam divergence	<0.2 mrad	0.2 mrad	0.3 mrad
Beam pointing stability	<0.04 mrad	<0.04 mrad	<0.06 mrad



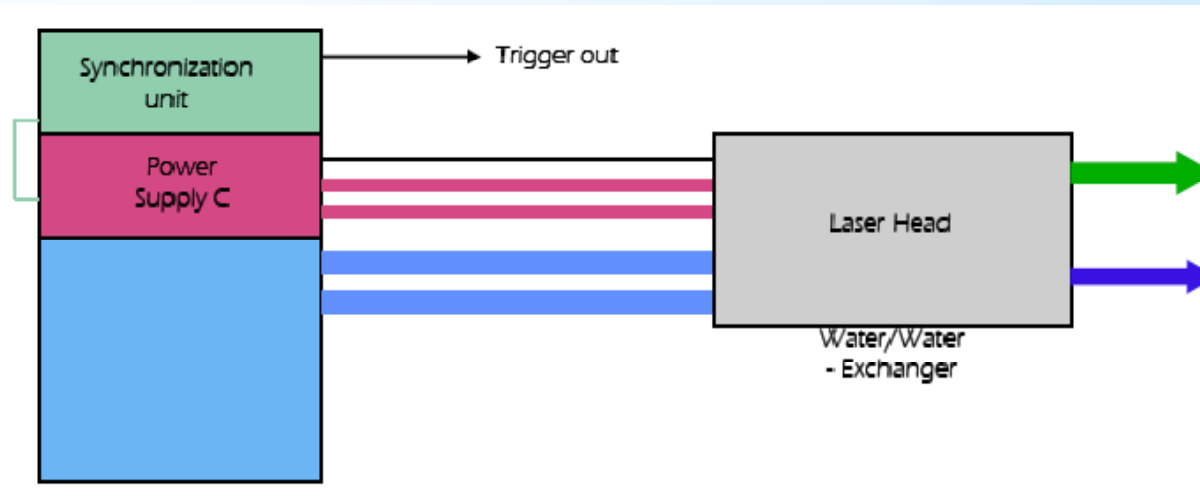
Scheme of the oscillators

- EdgeWave will build up a spare laser, incl. one laser head, one power supply and the software.
- If failure happens, EdgeWave will send the spare laser immediately to CERN.



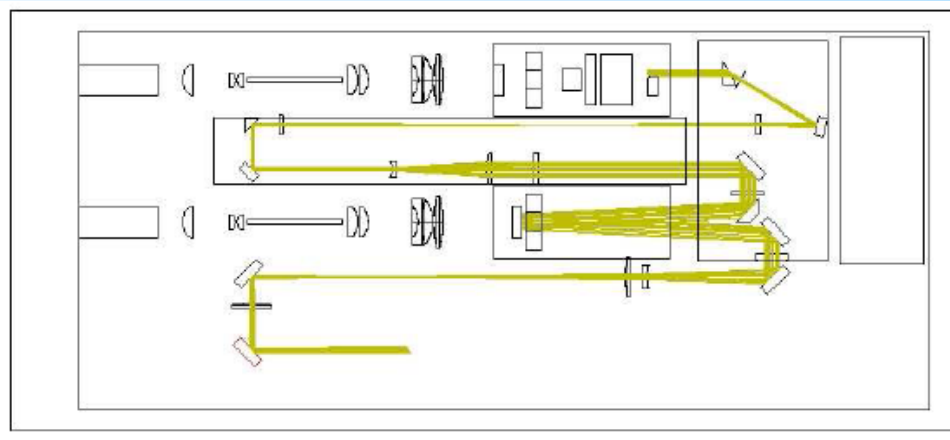
## SSL design proposal 2

Suggested on 31.10.2007 following difficulty to fulfill the requirement of jitter < 3 ns



Beam A+B  
**80W @ 532nm**

Beam C  
20W @ 355nm



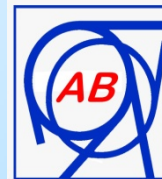
Scheme of the Nd:YAG oscillator - amplifier

- EdgeWave will build up two laser heads and power supplies.
- Both laser systems will be shipped to CERN.

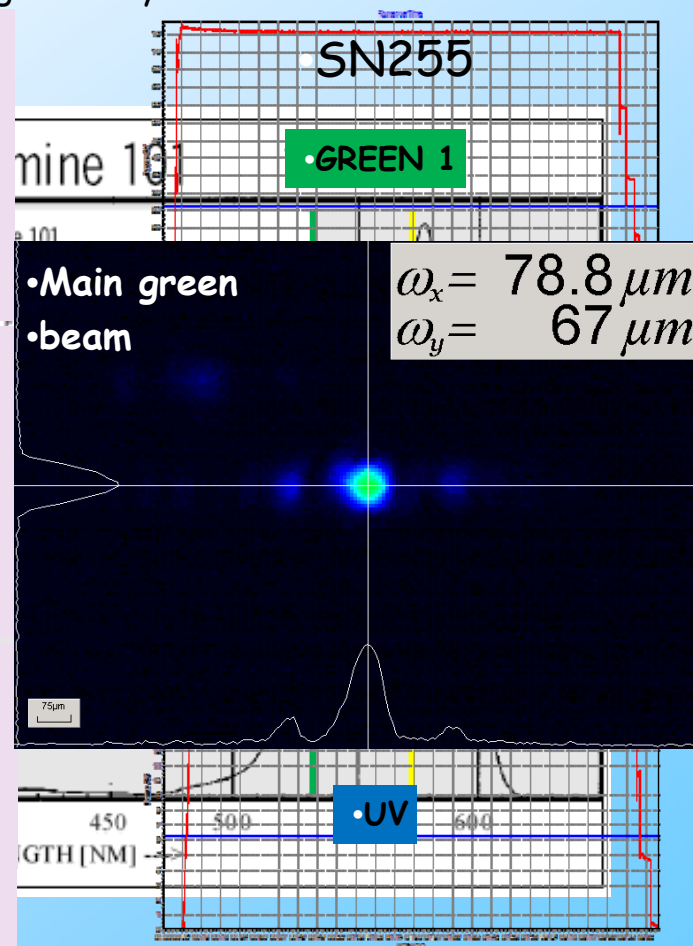
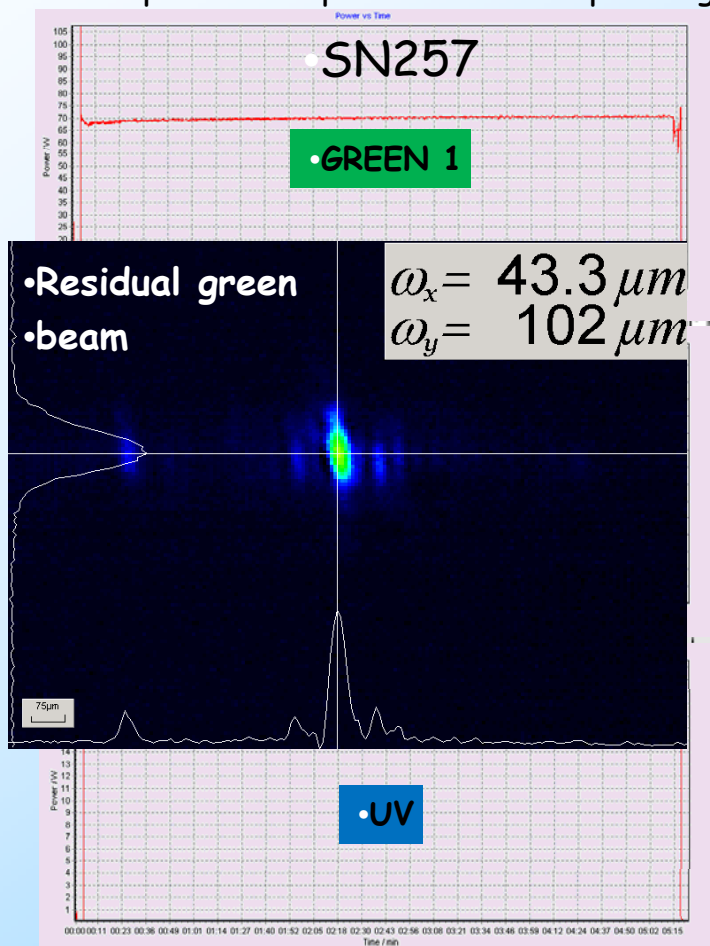
Warranty period = 2 years  
+ 2 years of warranty extension included



# Main considerations and concerns



- 1) Green beam quality for efficient focusing into the 3mm hot cavity ion source, > 20m away
- 2) Dye laser efficiency with shorter pulse length pumping and different pump wavelengths
- 3) Long term and reproducible power and beam pointing stability





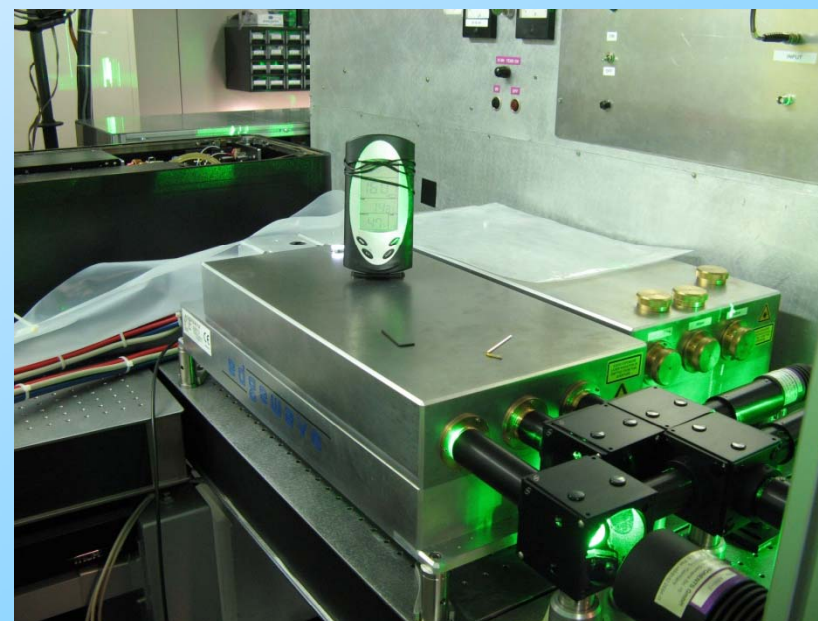
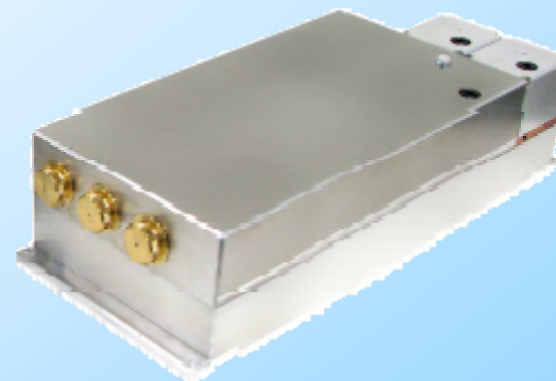
# Actual laser purchase details

- A single DIODE Pumped Nd:YAG laser
- Oscillator/Amplifier configuration
- + Spare DIODE Pumped Nd:YAG lasers
- Double Nd:YAG crystal Oscillator configuration

Frequency doubling and tripling (GREEN and UV)

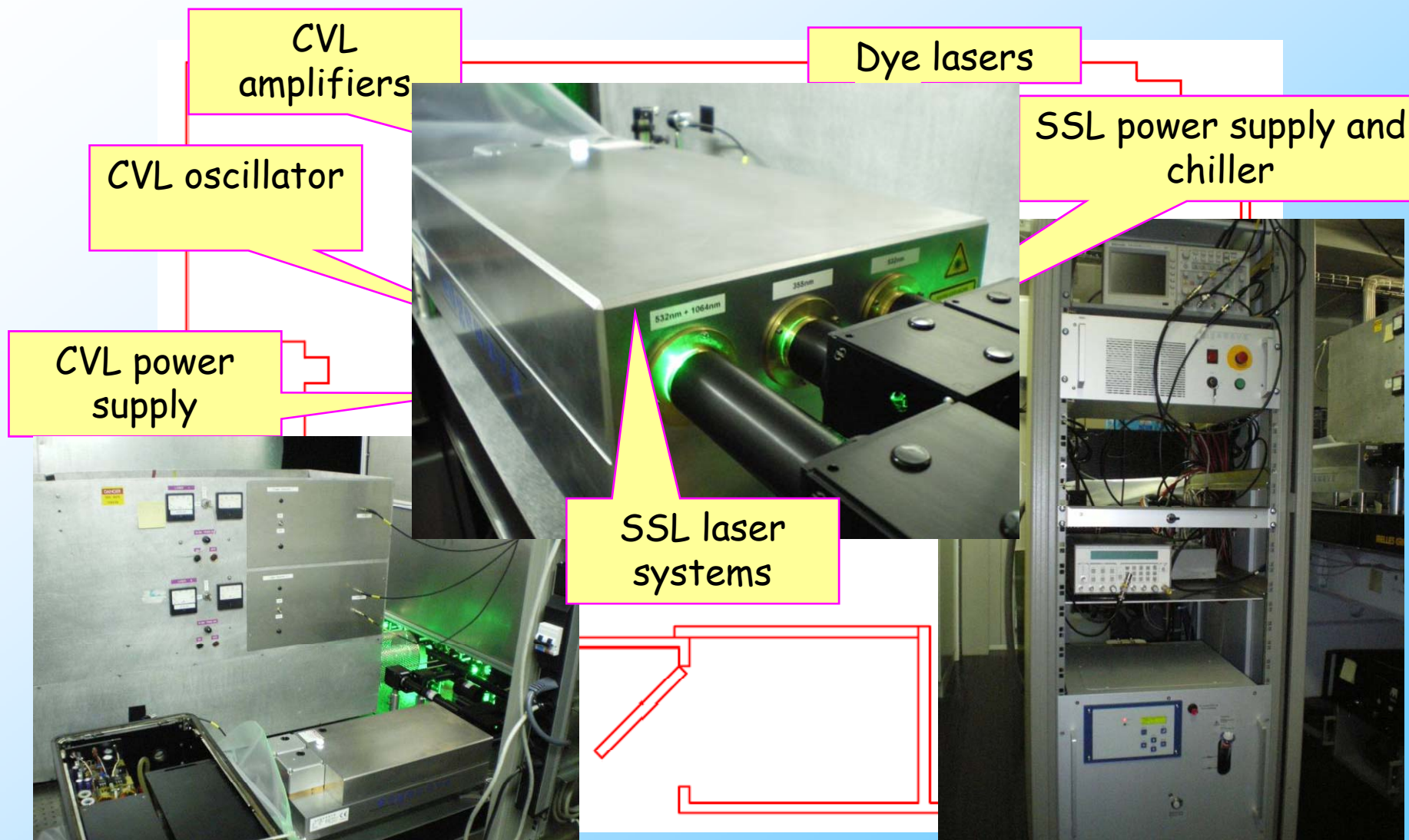
3 Outputs:

- Principal green beam: 76 W
- UV beam: 20 W (can be disabled)
- Residual IR + Green beam: (16-27 W of green light)
- 10 kHz, ~ 10ns pulse length.
- Delivery of first laser (Osc/Amp model) in March 08
- and 2nd laser (Osc only model) in May.





# SSL implementation in RILIS room



# Nd:YAG lasers in operation

Diode Pumped Solid State Nd:YAG Lasers as replacement of Copper Vapor Lasers:

**CVL**

15 ns @ 11 kHz

Green Beams  
45 W @ 511 nm

Yellow Beams  
35 W @ 578 nm



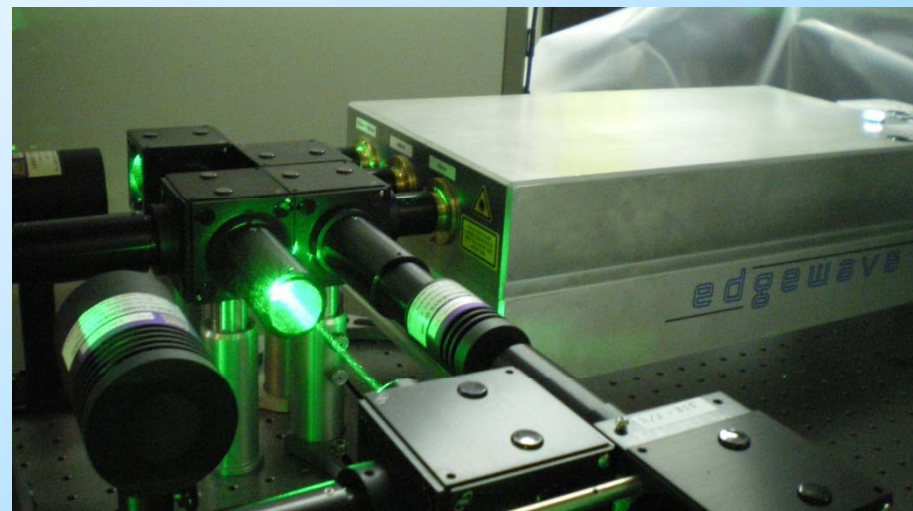
**SSL**

8 ns @ 10 kHz

Green Beams  
90 - 100 W @  
532 nm

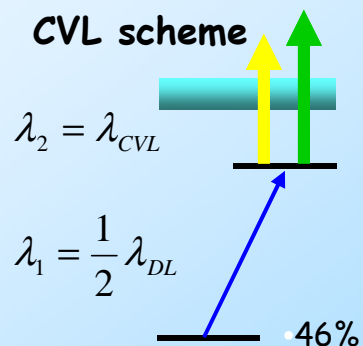
UV Beam  
18 W @ 355 nm

IR Beam  
35 W @ 1064 nm

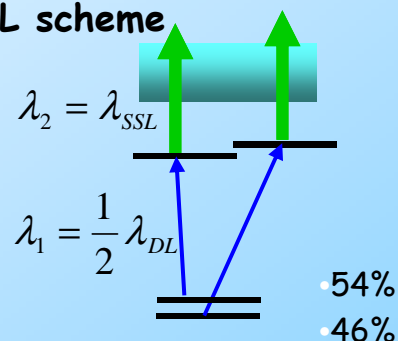


Improvement of Ga ionization efficiency by SSL :

**CVL scheme**



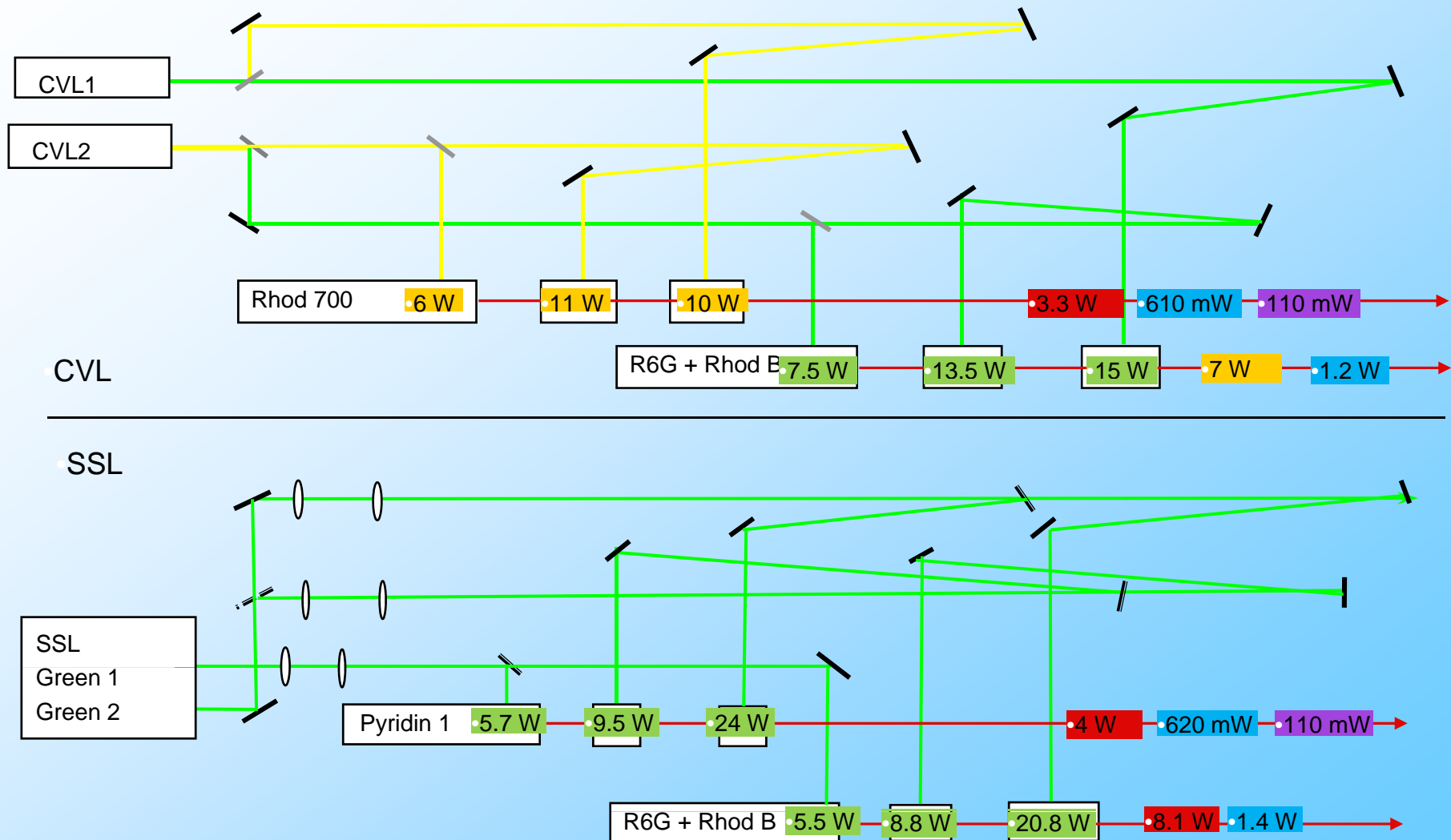
**SSL scheme**



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



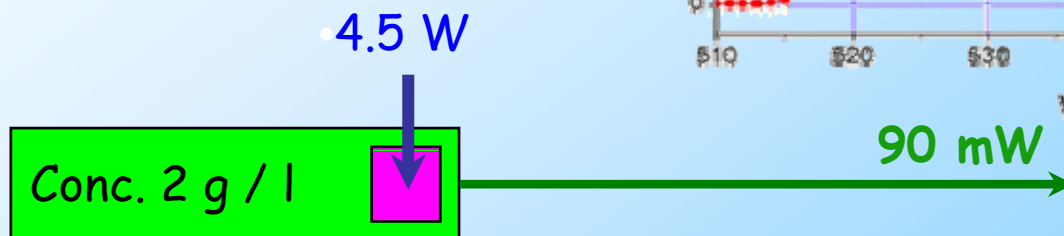
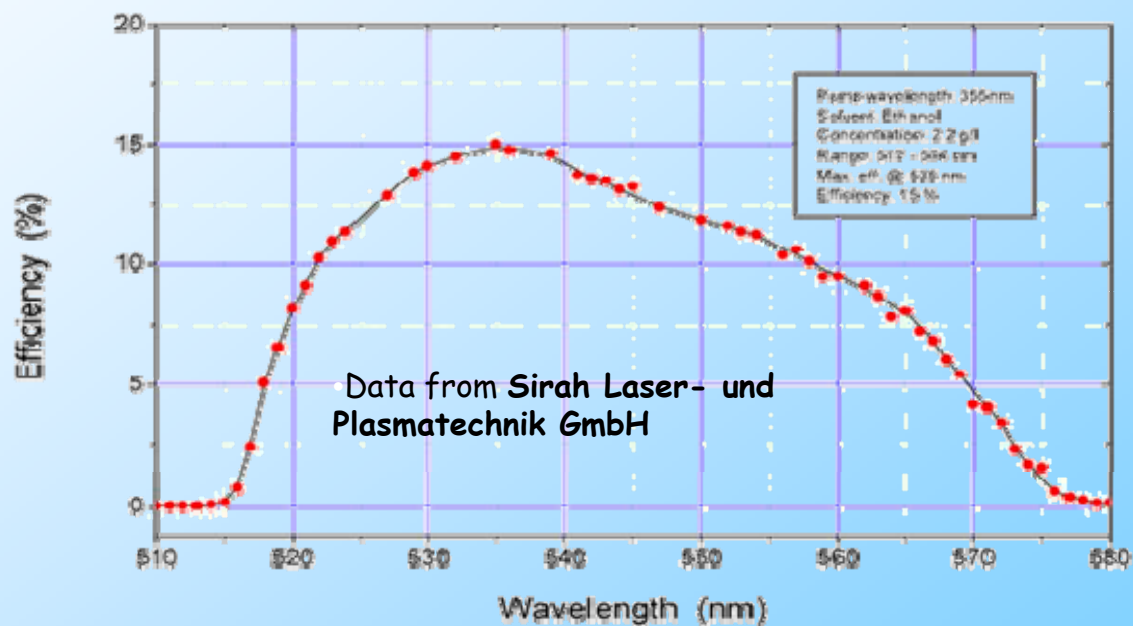
# New beam set-up for Be ionization





# UV pumped dye laser test

Generation of 535 nm  
laser beam using  
Coumarin 540A Dye



- Test confirms that the pump beam input optics work for UV
- For blue output the dye laser beam expander would need to be changed
- Safety: The use of the UV pump beam will require better containment of scattered light

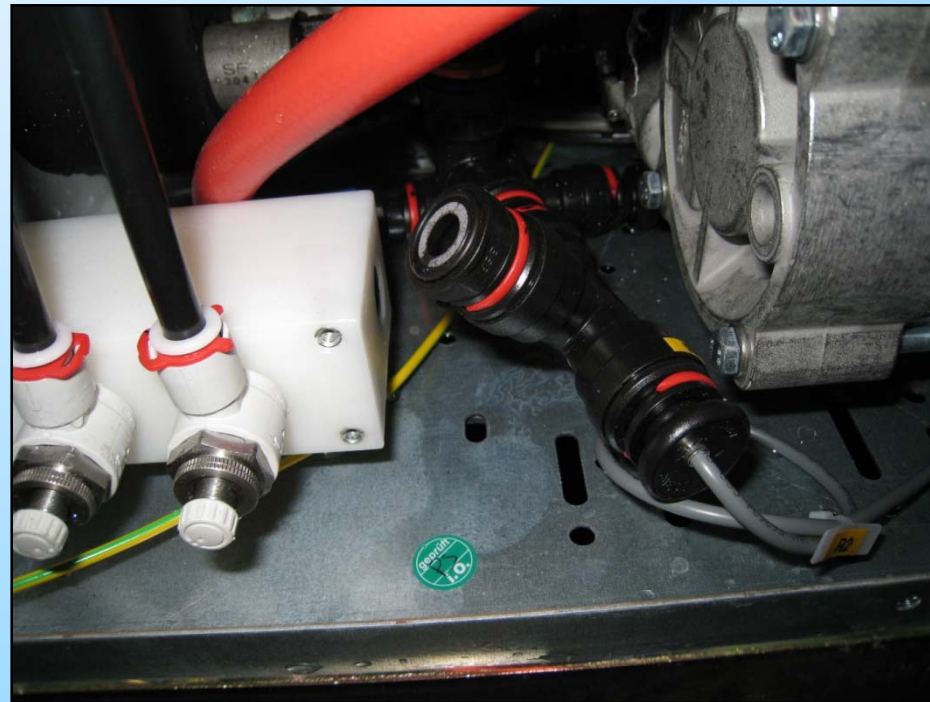
## Troubles of first months

- July 2008: Power of UV beam degraded from 21W to 13W
  - Laser sent to EdgeWave for inspection and repair

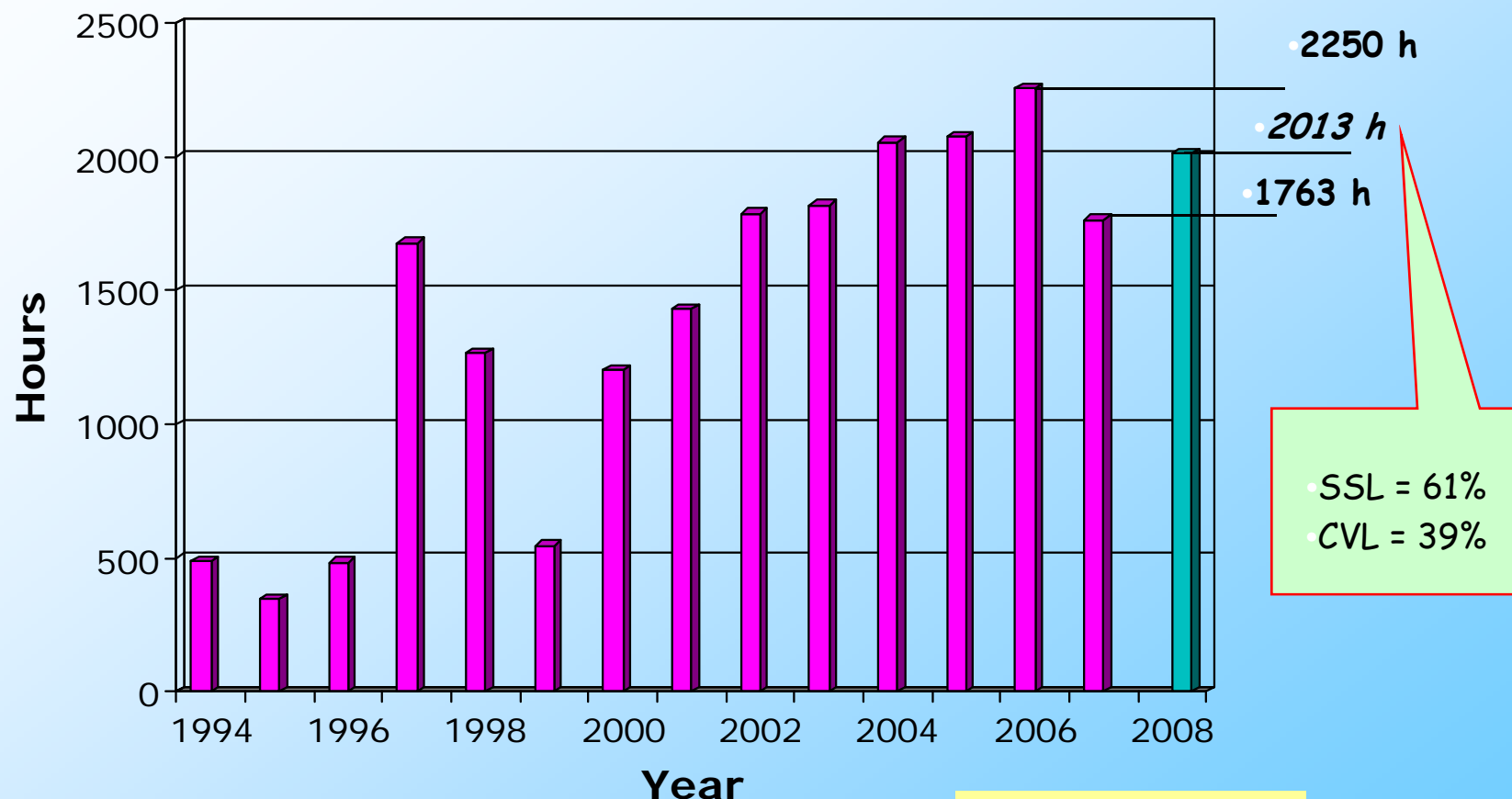
- The UV-power degradation results from degradation of coating of LBO and optic components.

- September 2008:  
Water leak in laser  
chiller

- Replacement details sent to CERN, chiller repaired at the place
- Spare chiller is purchased



# RILIS operation 1994 - 2008



Ion beam produced with the CVL in 2008:

Be, Cd, Mn, Au

Ion beam produced with the SSL in 2008:

Ga, Tl, Be, Nd, Cu, Mg, Pb



## Lessons learned

- More laser power
- Short-time stability of SSL power is much higher
- SSL requires much less supervision
- Time from cold start of SSL to nominal operation ~ 30 min.
- No electromagnetic noise to experimental hall from RILIS
  - SSL alignment and repair is possible only at EdgeWave
  - SSL beam focusing in a far-field is not so efficient as expected
  - Use of UV beam should be minimized to avoid crystal damage
  - Efficiency of dye lasers is reduced due to shorter pump pulse
- More time is required between runs for RILIS setup optimization
- New ionization scheme is needed for Mn
- CVL is to be kept as a backup during at least 2009
- Operation of dye lasers and harmonics generators still requires continuous supervision by laser specialists



# RILIS hardware



- CVL lasers
  - Built >15 years ago, to be replaced by Nd:YAG lasers
  - In operation during 2008-2009
- Nd:YAG lasers
  - New, installed in 2008
  - In operation since 2008
- Dye lasers and dye amplifiers
  - Built >15 years ago
  - Upgrade planned for 2009
- Non-linear optics elements
  - Consumable crystals
  - Could be included in new dye lasers (2009)
- Laser beam transport optics
  - Quartz prisms - losses > 40%
  - Minor improvements are possible
- Control tools
  - Currently only local control for most of parameters
  - Remote control is under development



# Road map of RILIS upgrade (wish list)



2008

- ↖ Installation of solid state lasers for dye laser pumping. Keeping CVL lasers at RILIS as backup until reliable SSL performance is reached.

2009

- ↖ Market survey for high pulse rate dye lasers. Purchasing of new dye lasers.

2010

- ↖ Providing conditions for remote control of key RILIS parameters

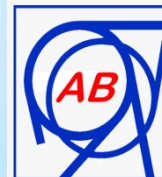
- ↖ Including RILIS operation in the ISOLDE separator courses

- ↖ Switching RILIS running from “shift” to “on-call” operation mode

2011

- ↖ Installation of Ti:Sapphire lasers in addition to dye lasers

- ↖ Possibility of quick switch of RILIS from one element to another



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