ISOLDE RILIS capabilities post-LS2

90th ISOLDE Collaboration Committee meeting

Monday 1 Feb 2021

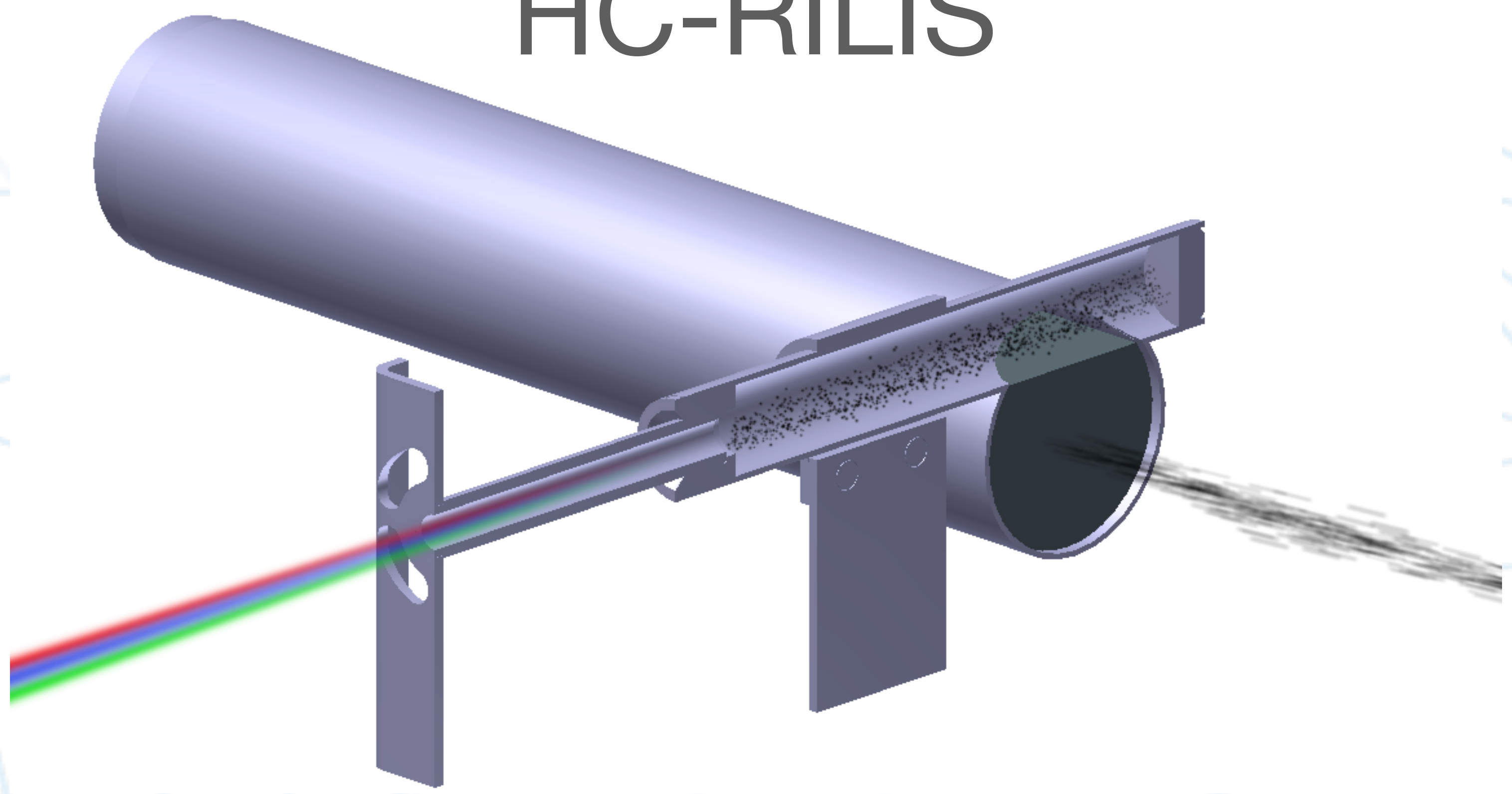
Bruce Marsh

on behalf of the SY-STI-LP RILIS team

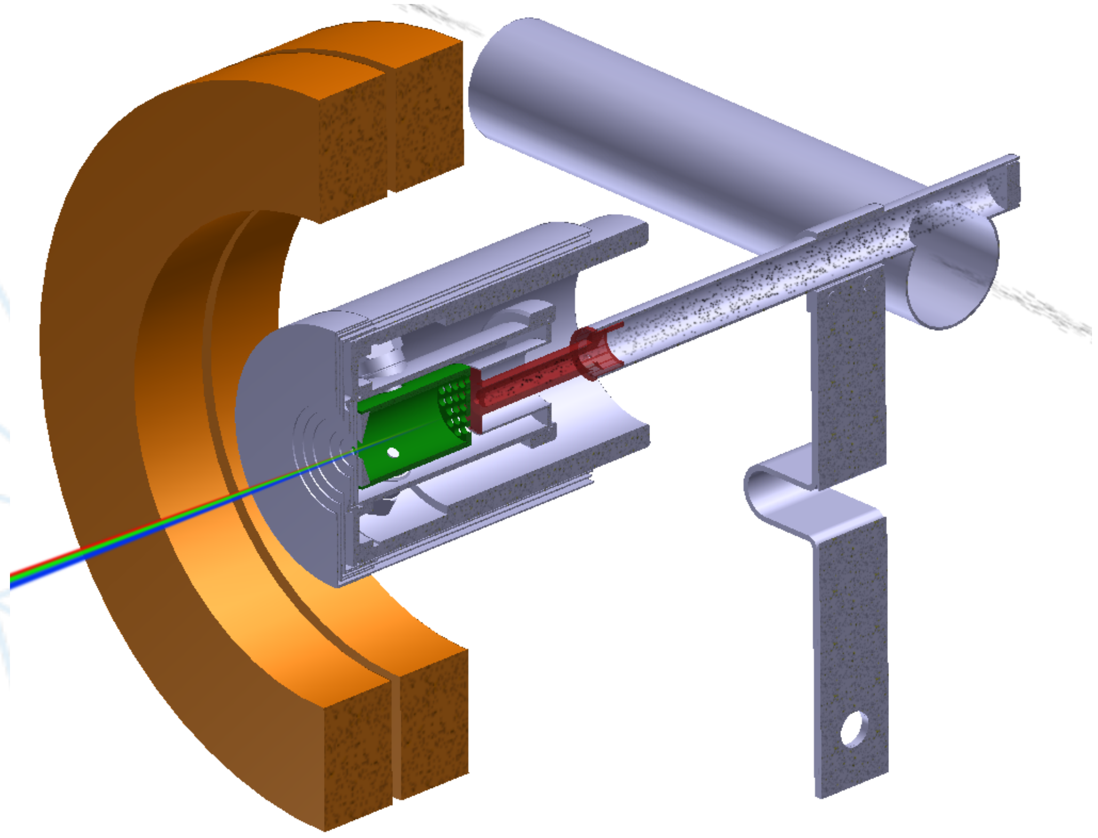
RILIS at ISOLDE

3 ion source types:

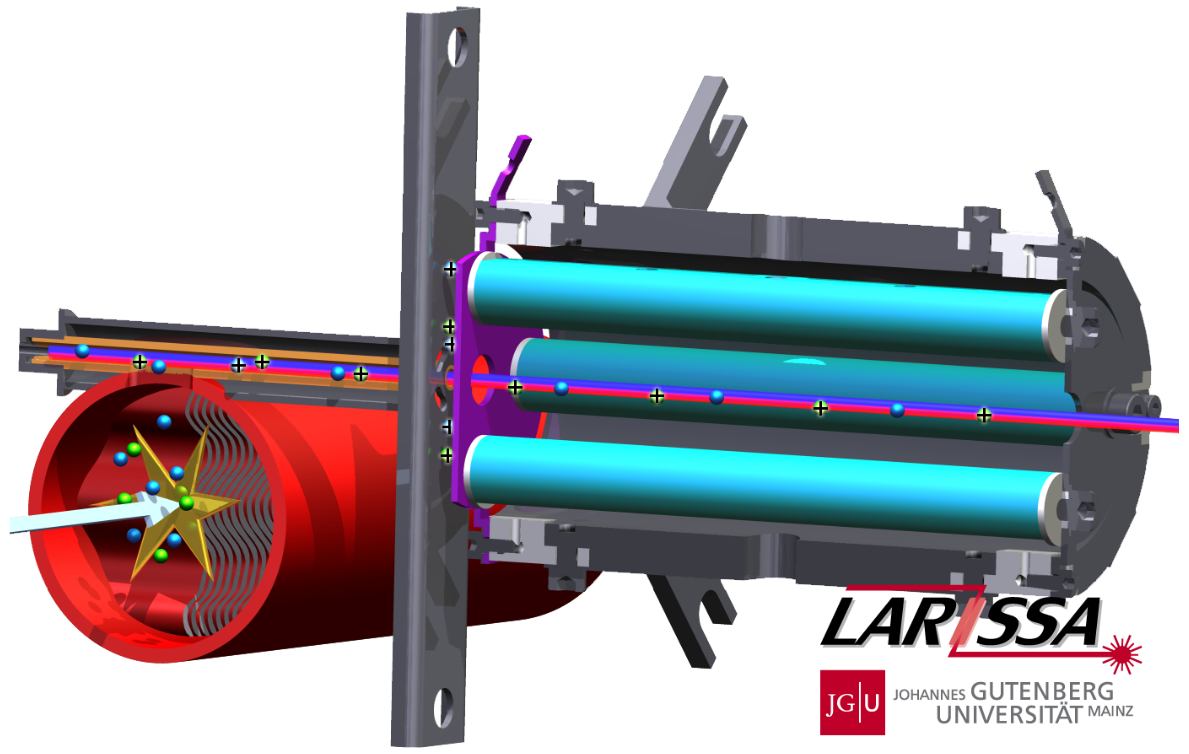
HC-RILIS

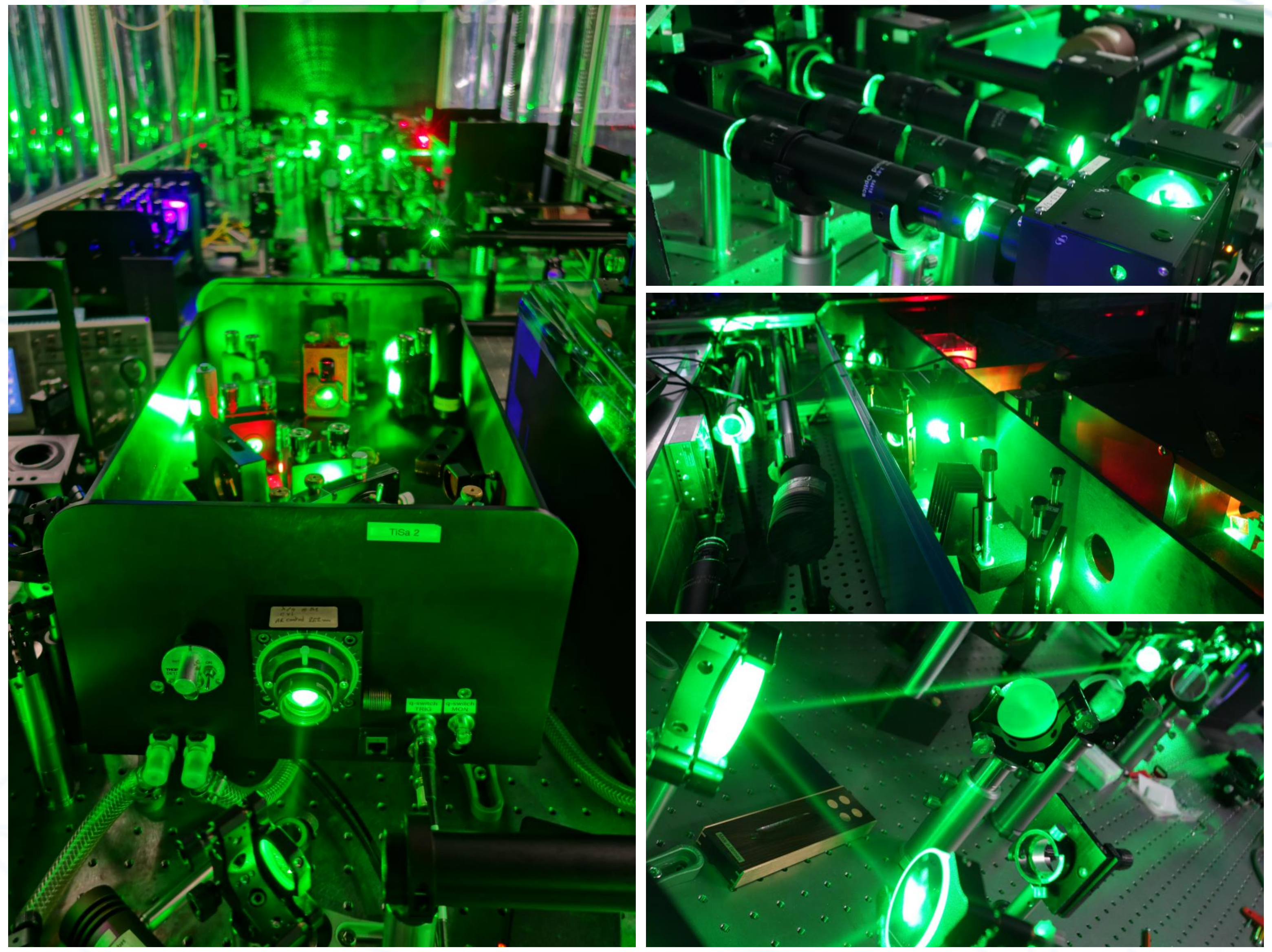


VADLIS



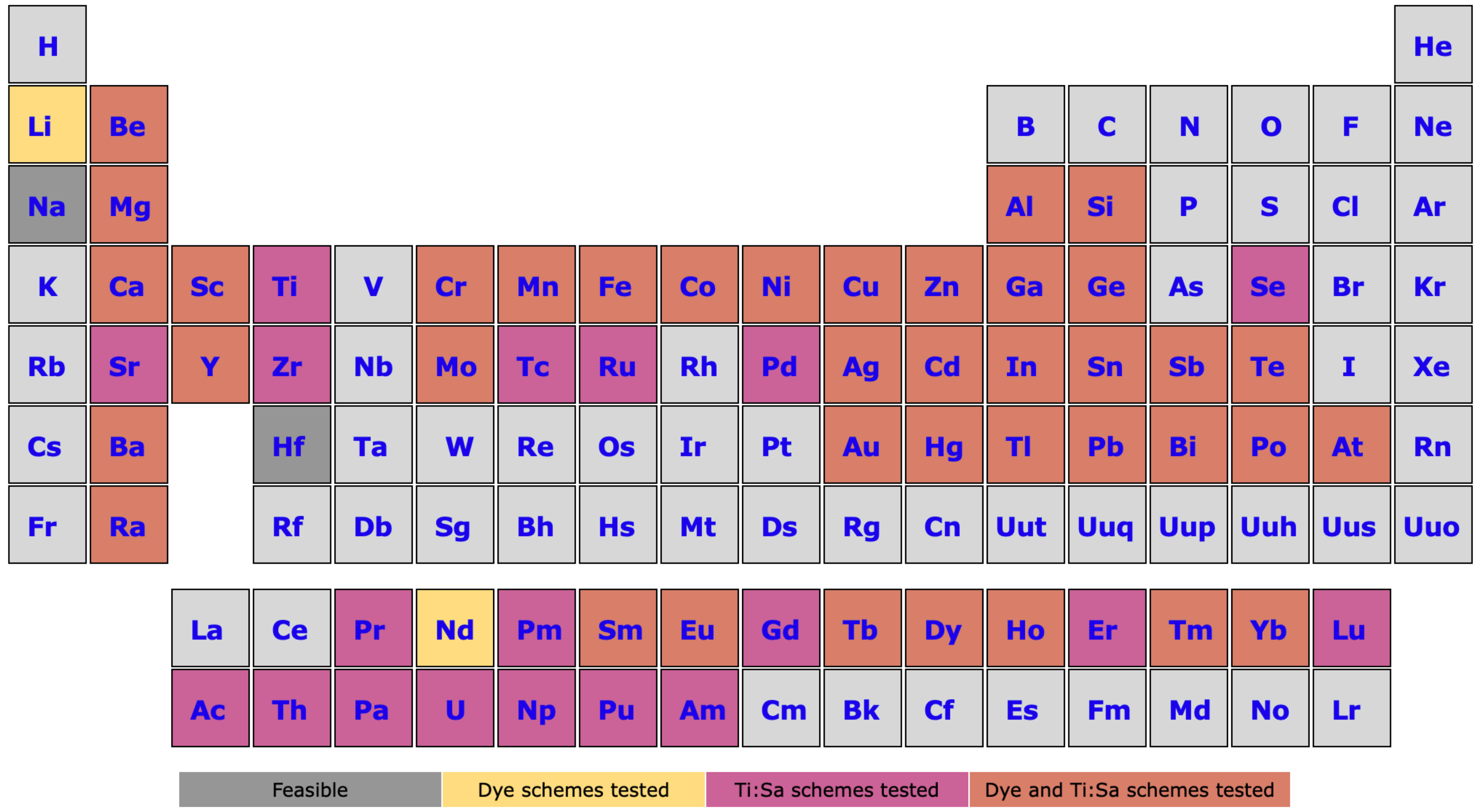
LIST



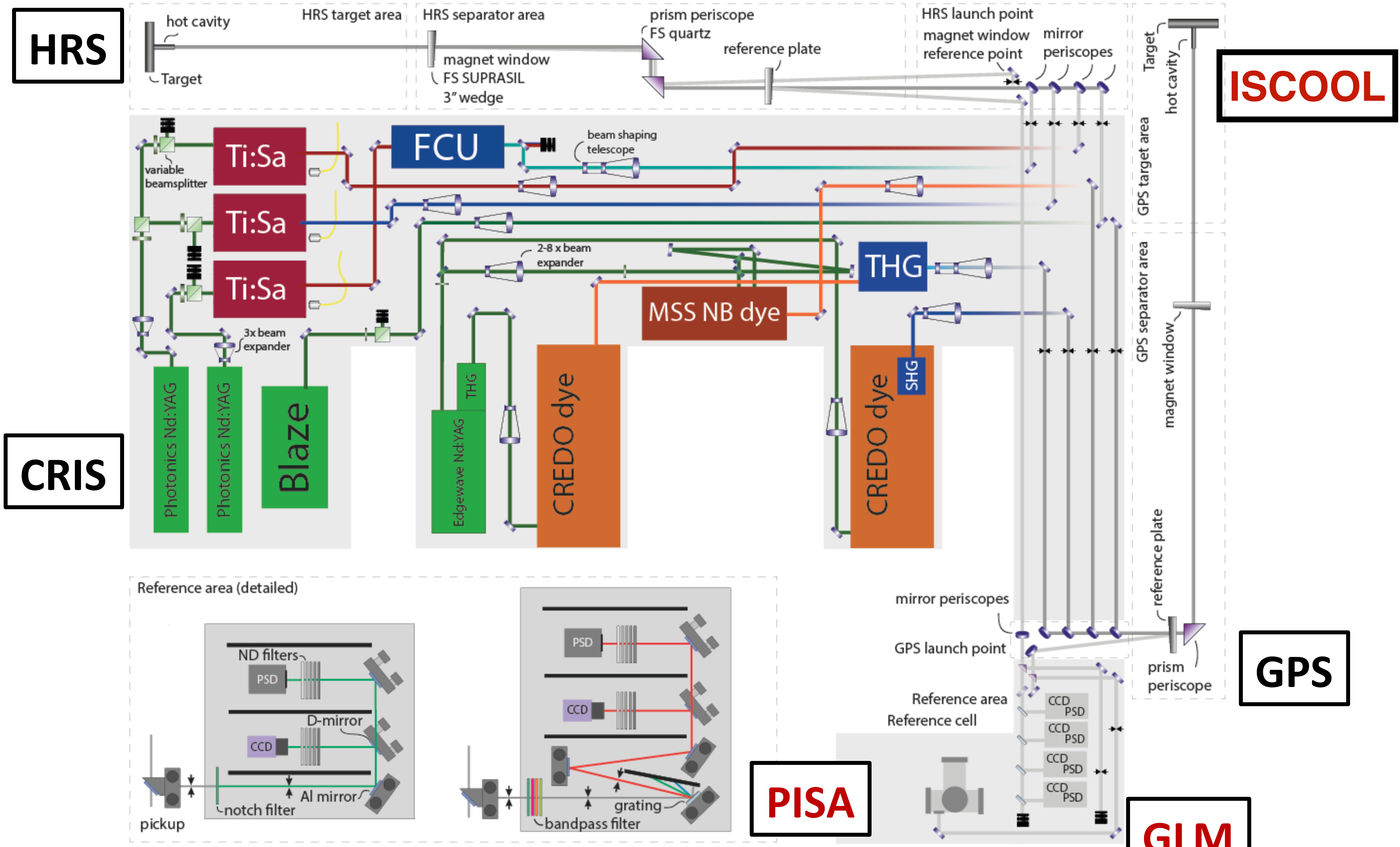


6 tuneable lasers

40 ionisation schemes



RILIS
Pre-LS2



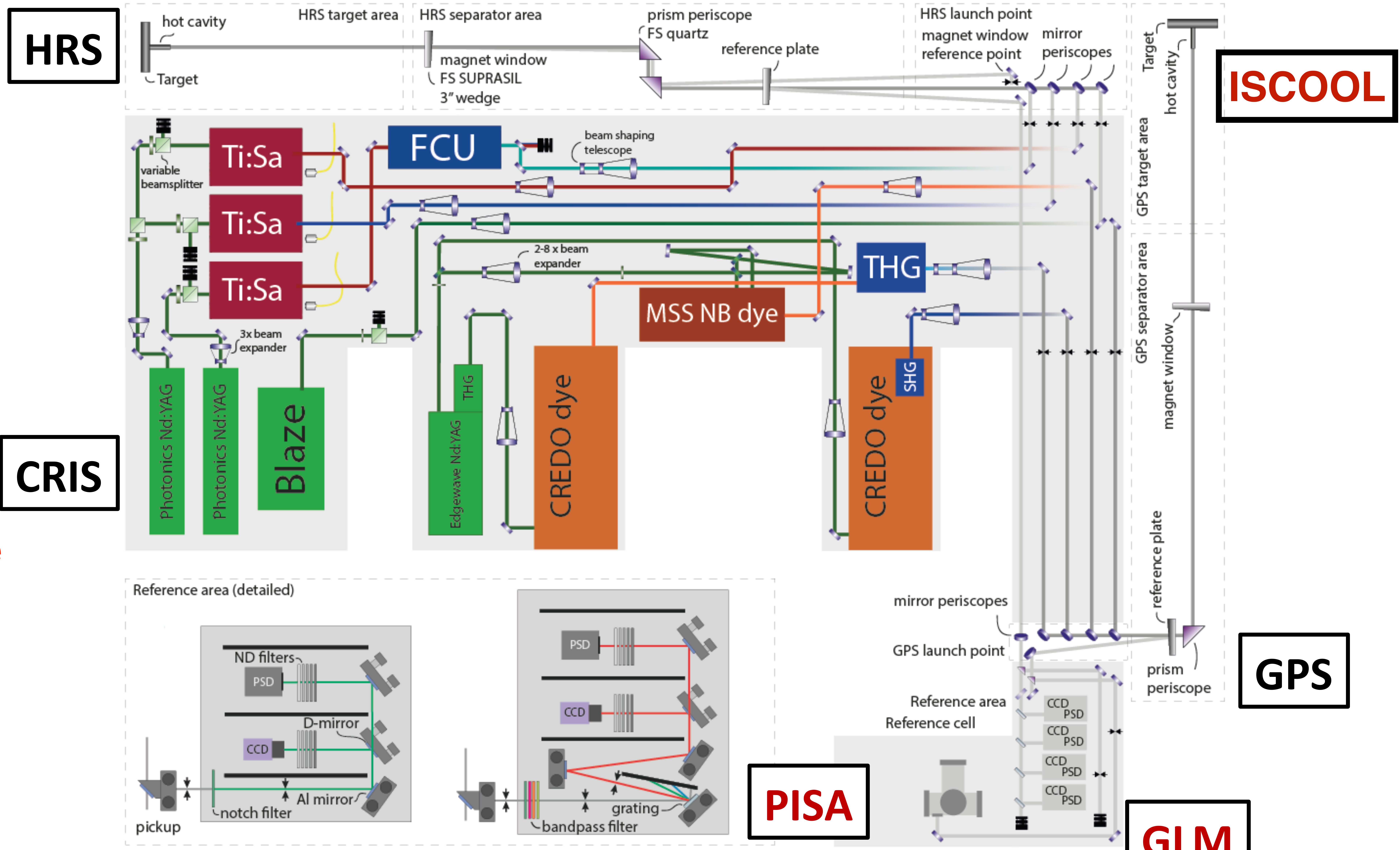
S. Rothe et al. Nuclear Instruments and Methods in Physics Research B 376 (2016) 91–96

RILIS
Pre-LS2

All pump lasers out of warranty

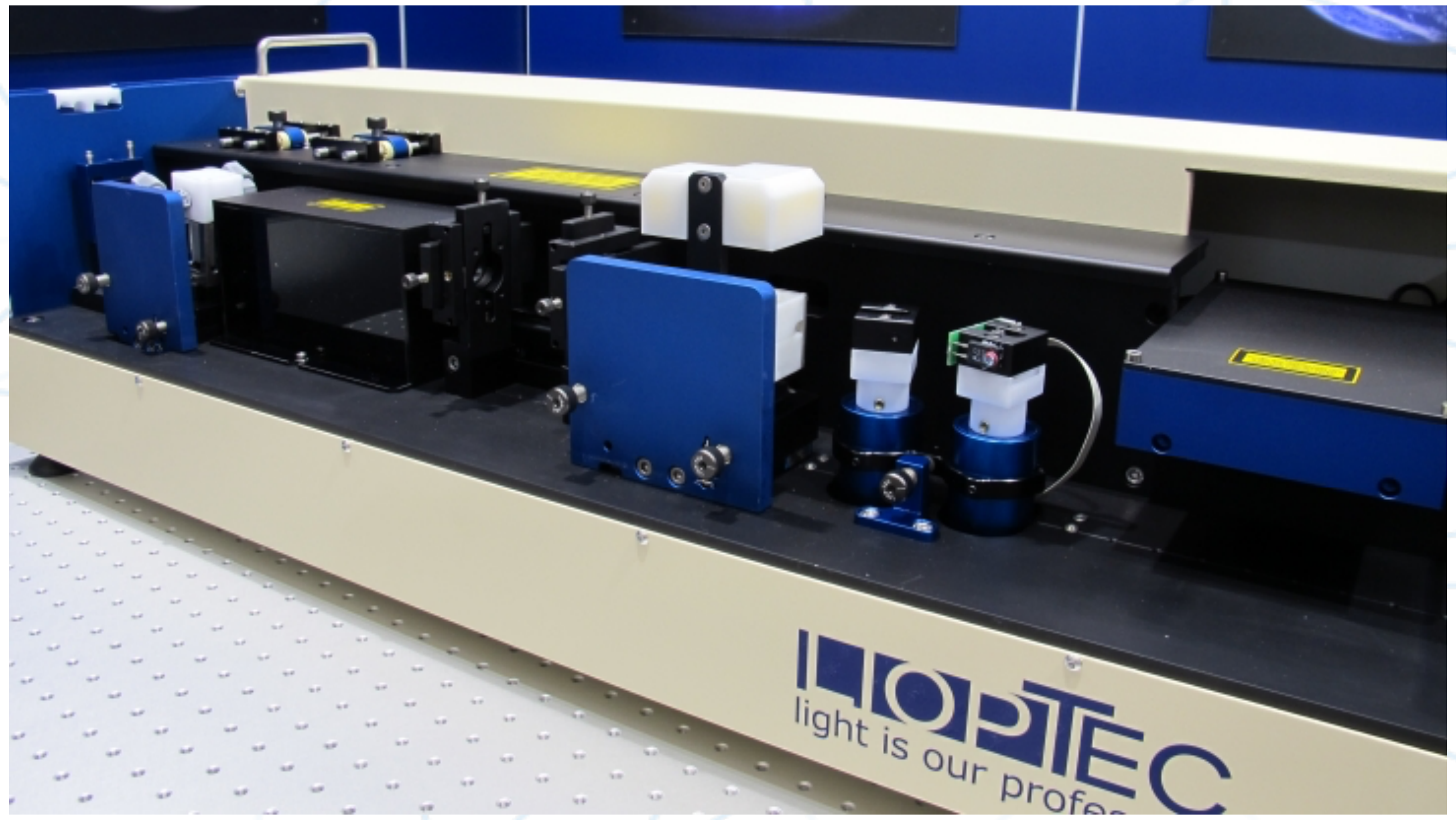
No simultaneous HRS and GPS use

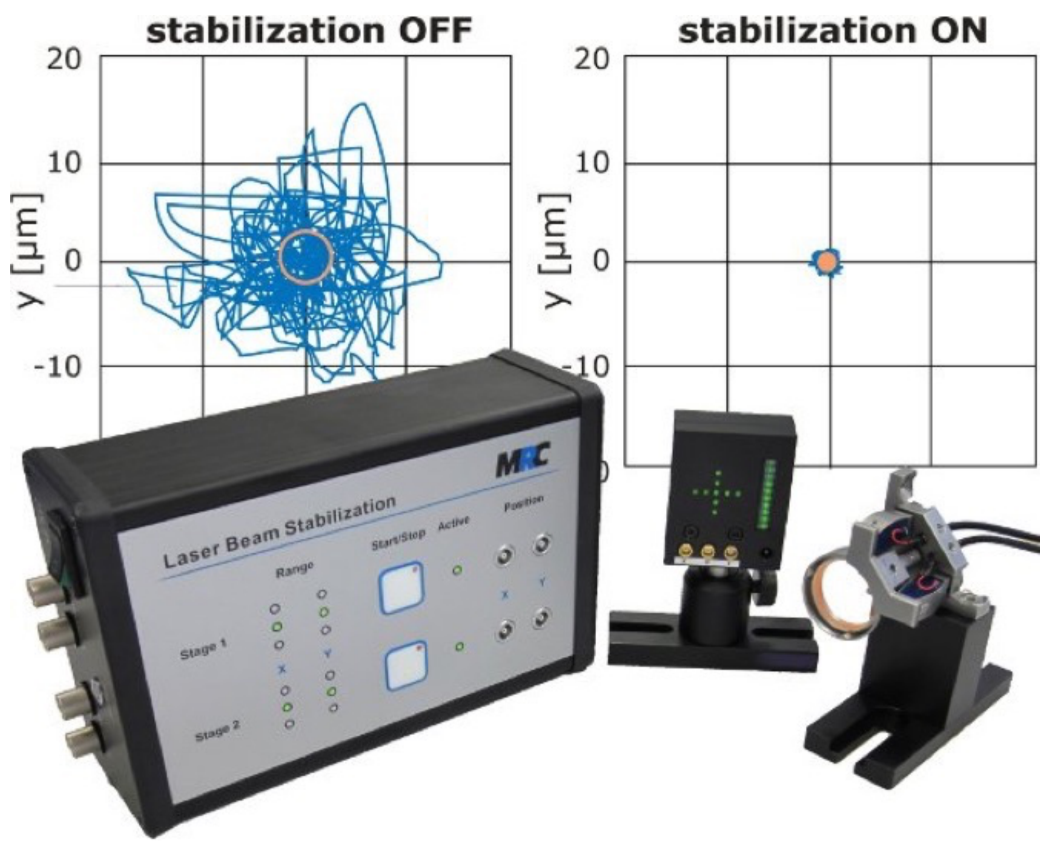
TiSa lasers are not independently triggered

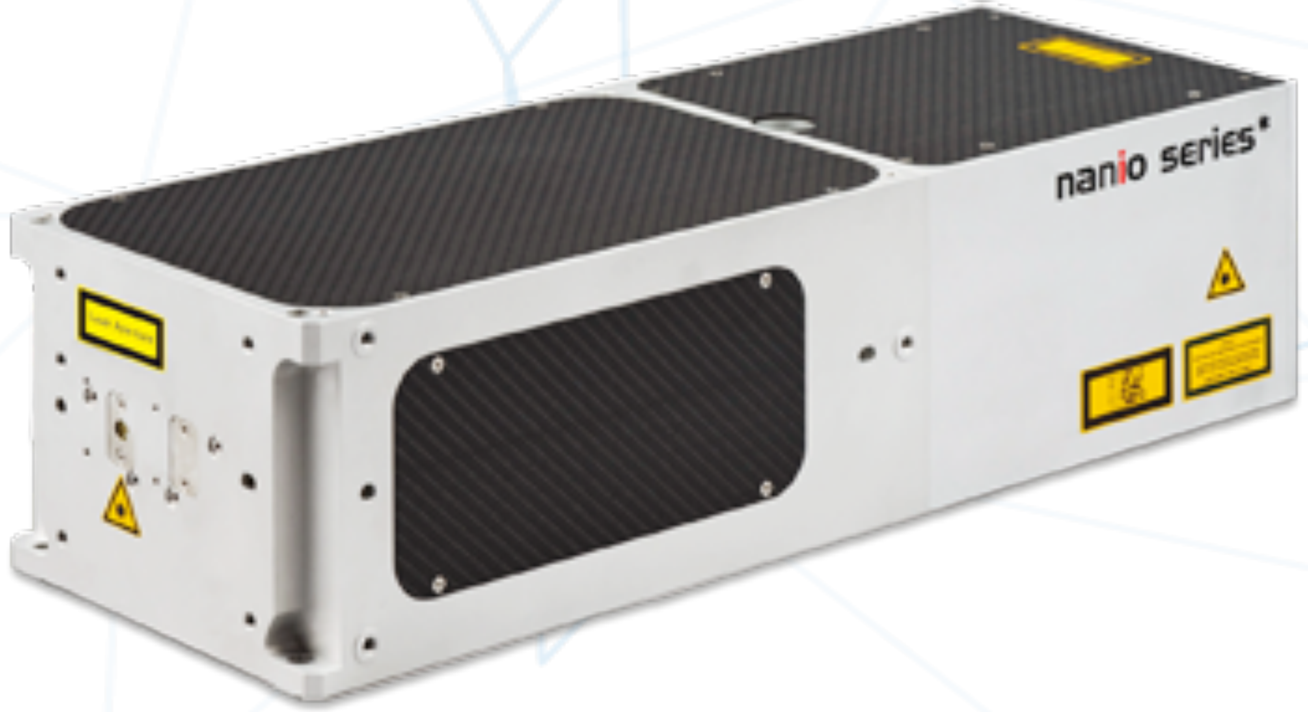


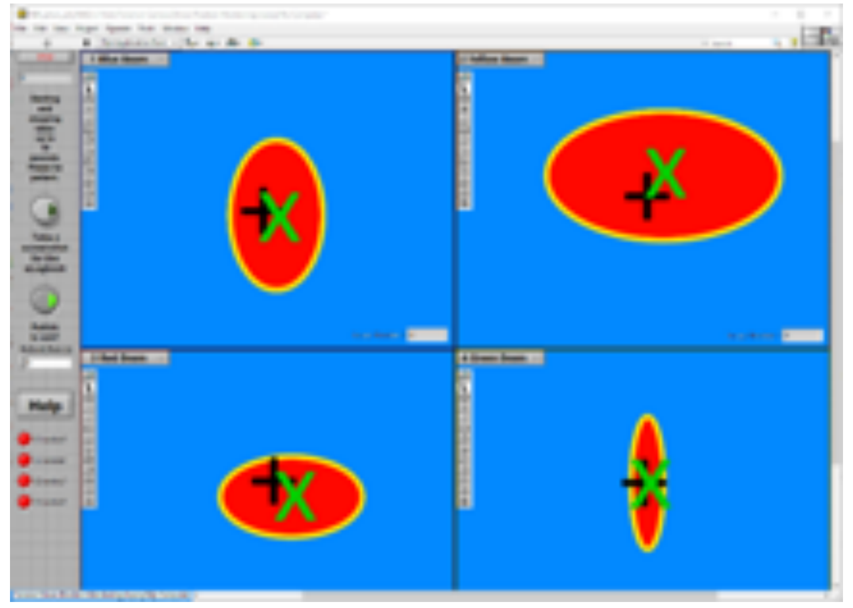
S. Rothe et al. Nuclear Instruments and Methods in Physics Research B 376 (2016) 91–96

New lasers and equipment upgrades

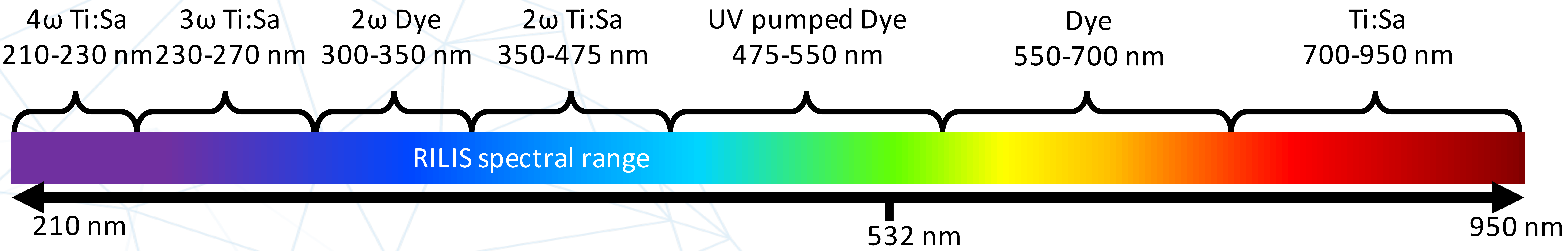






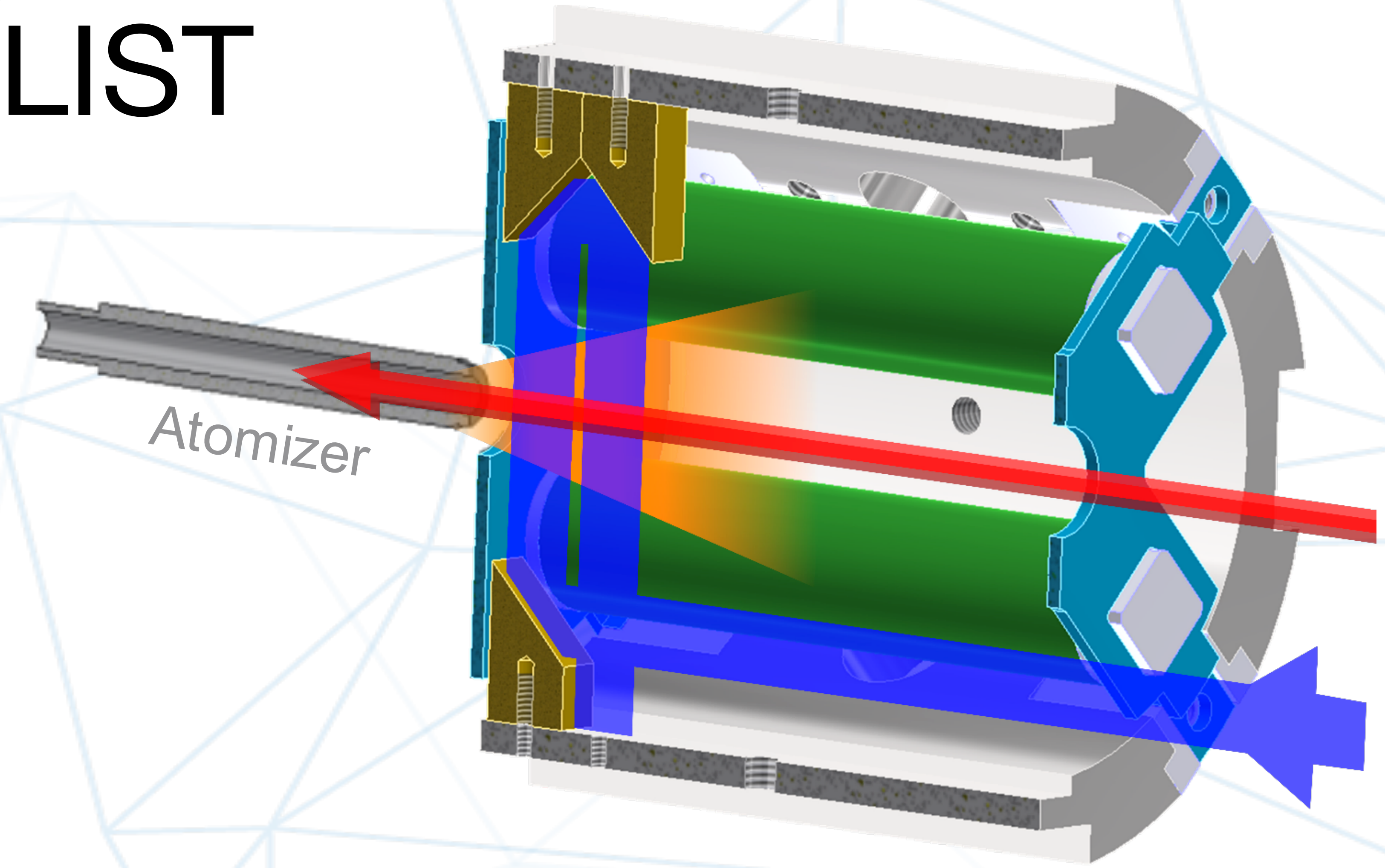


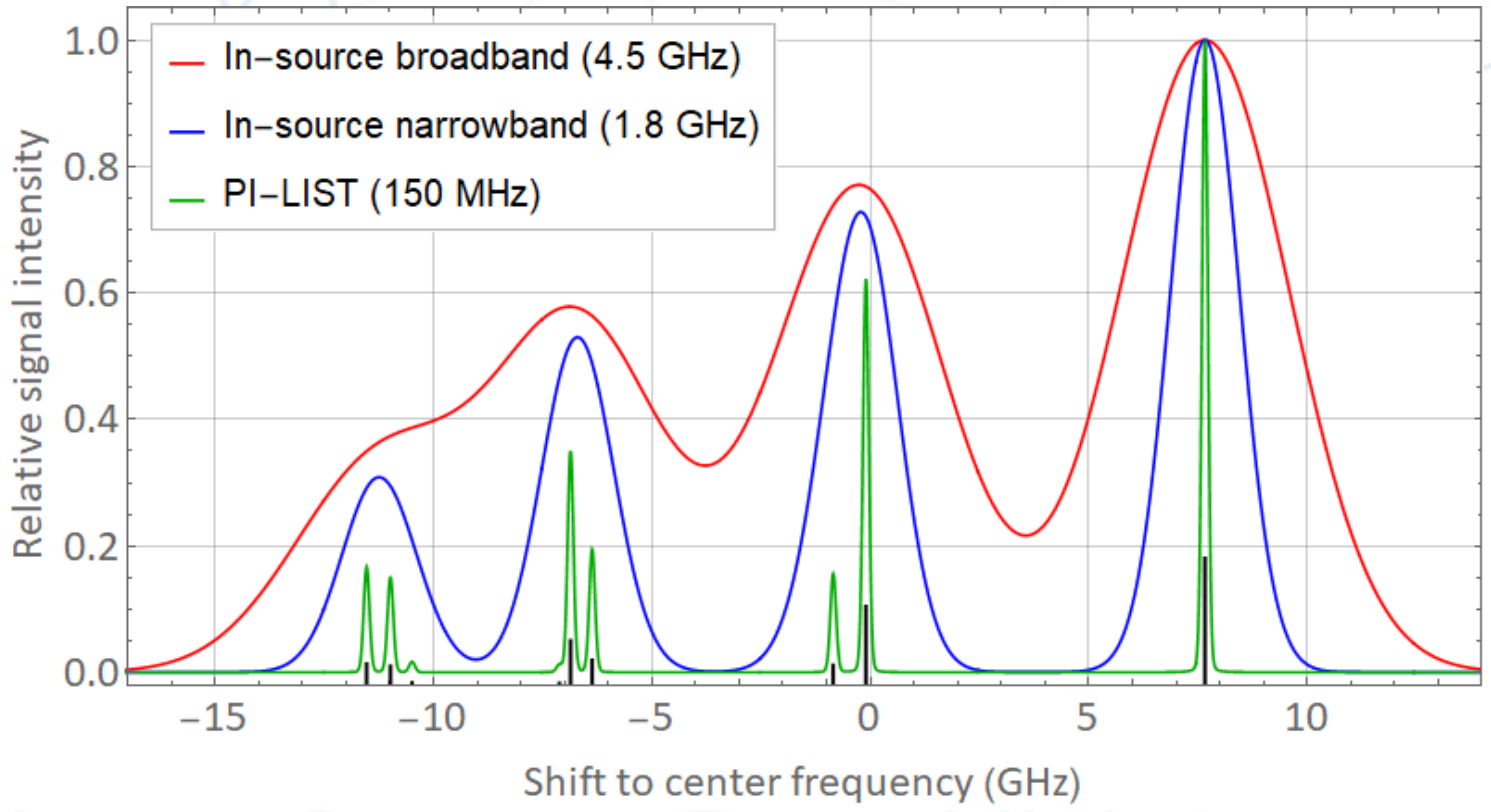
Improving access to the full spectral range



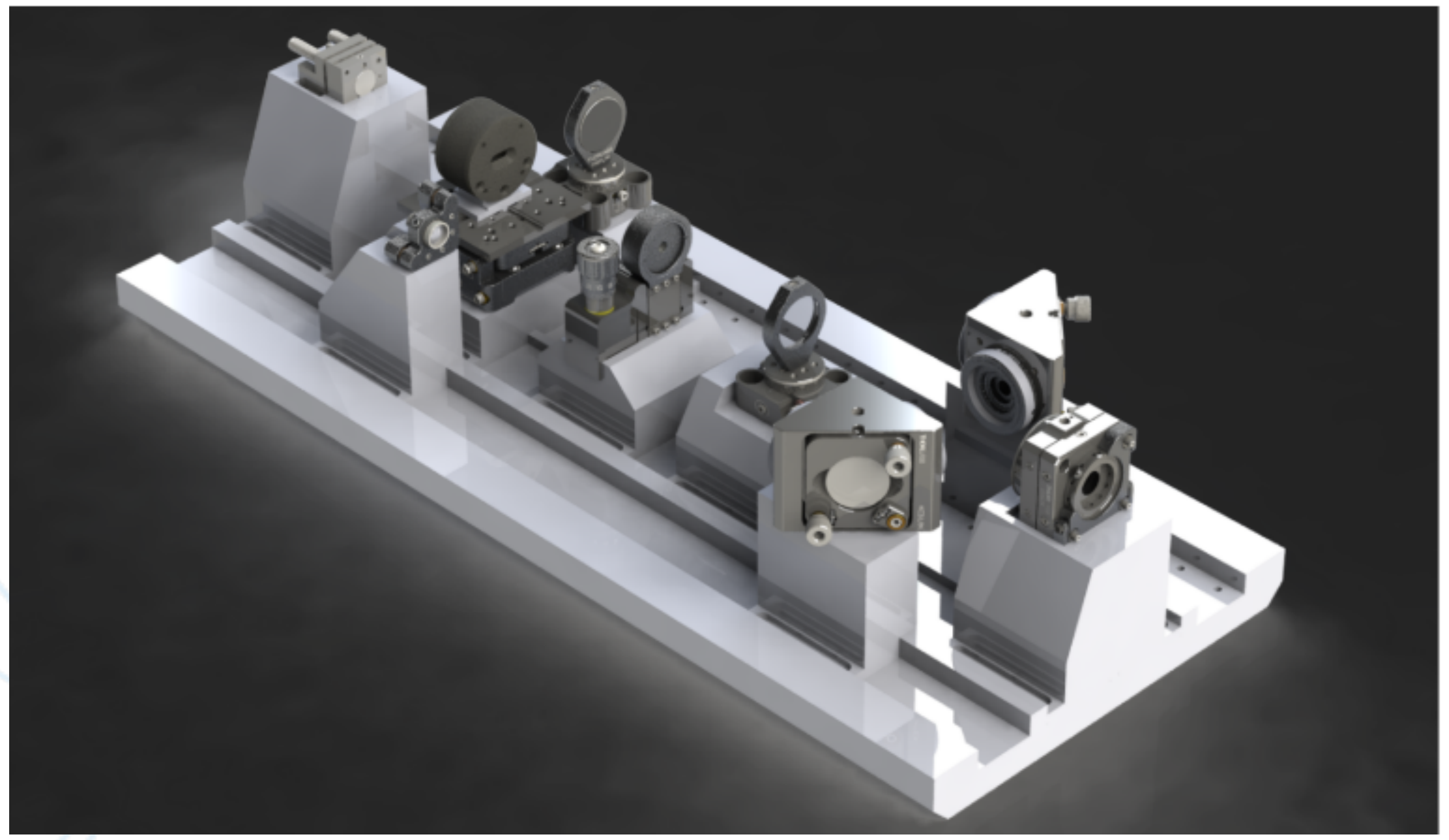
Better spectral resolution

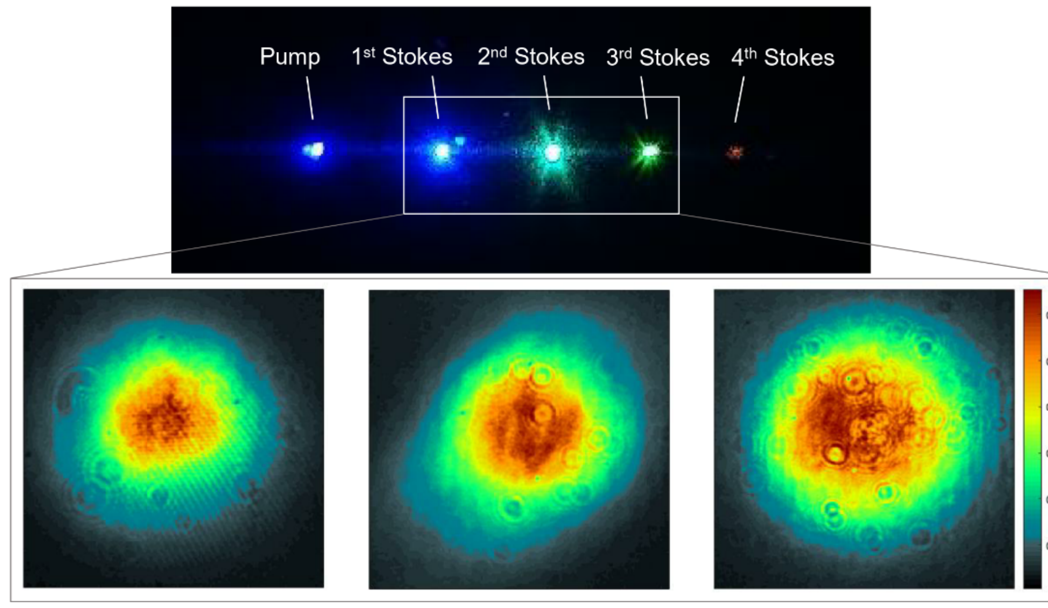
PI-LIST

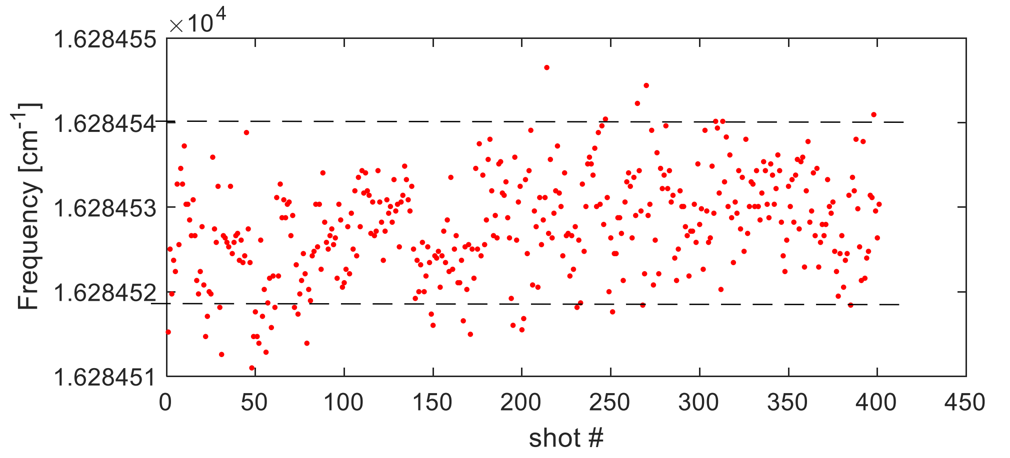




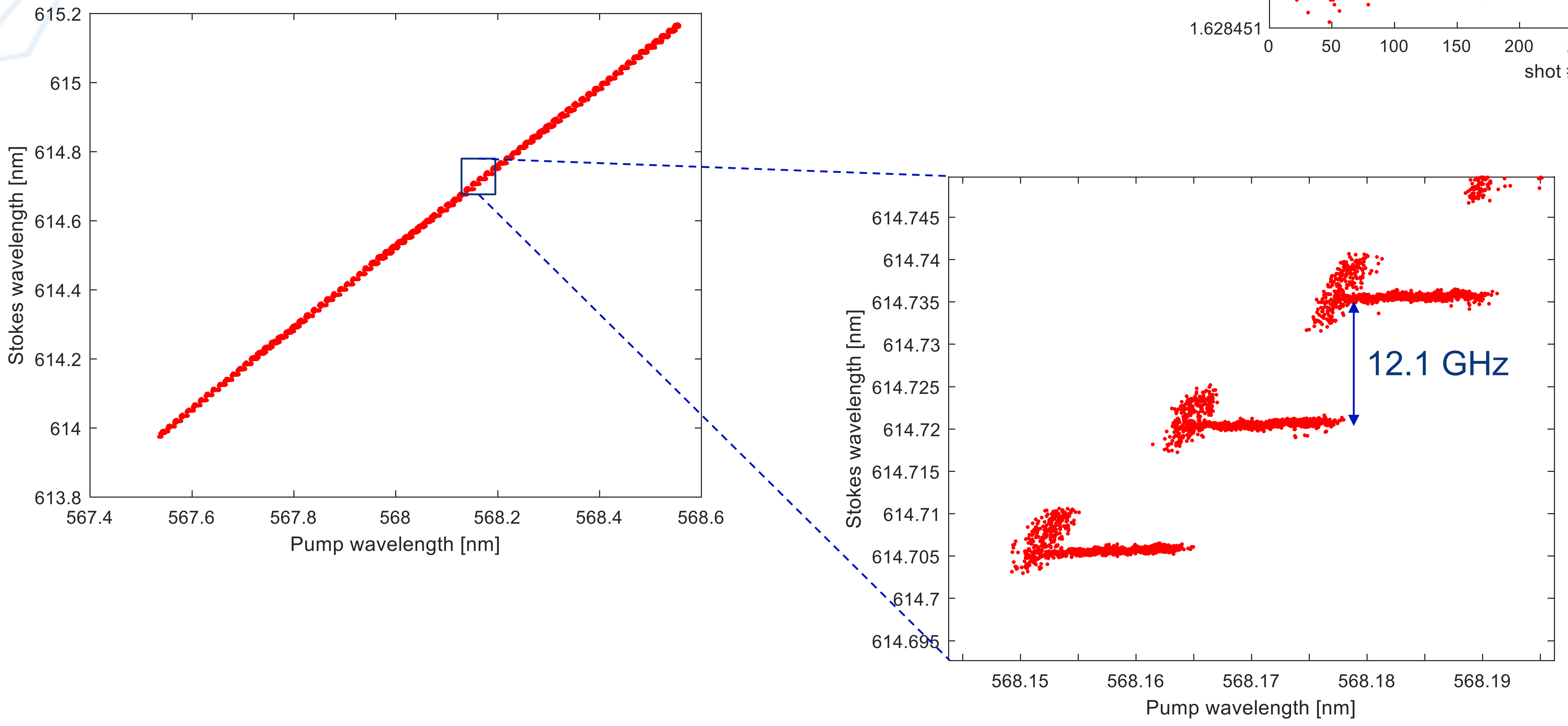
SLM Raman Laser





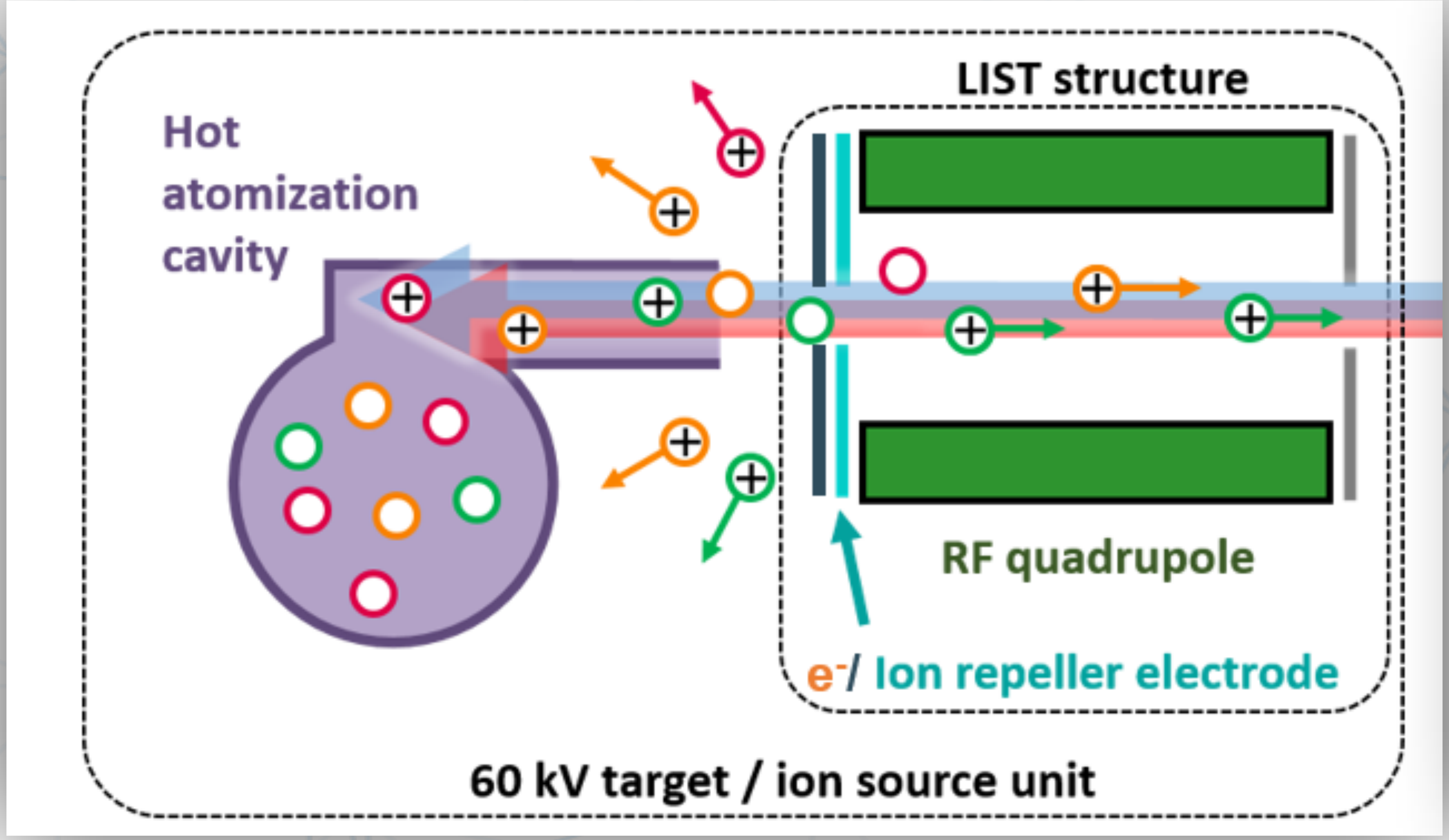


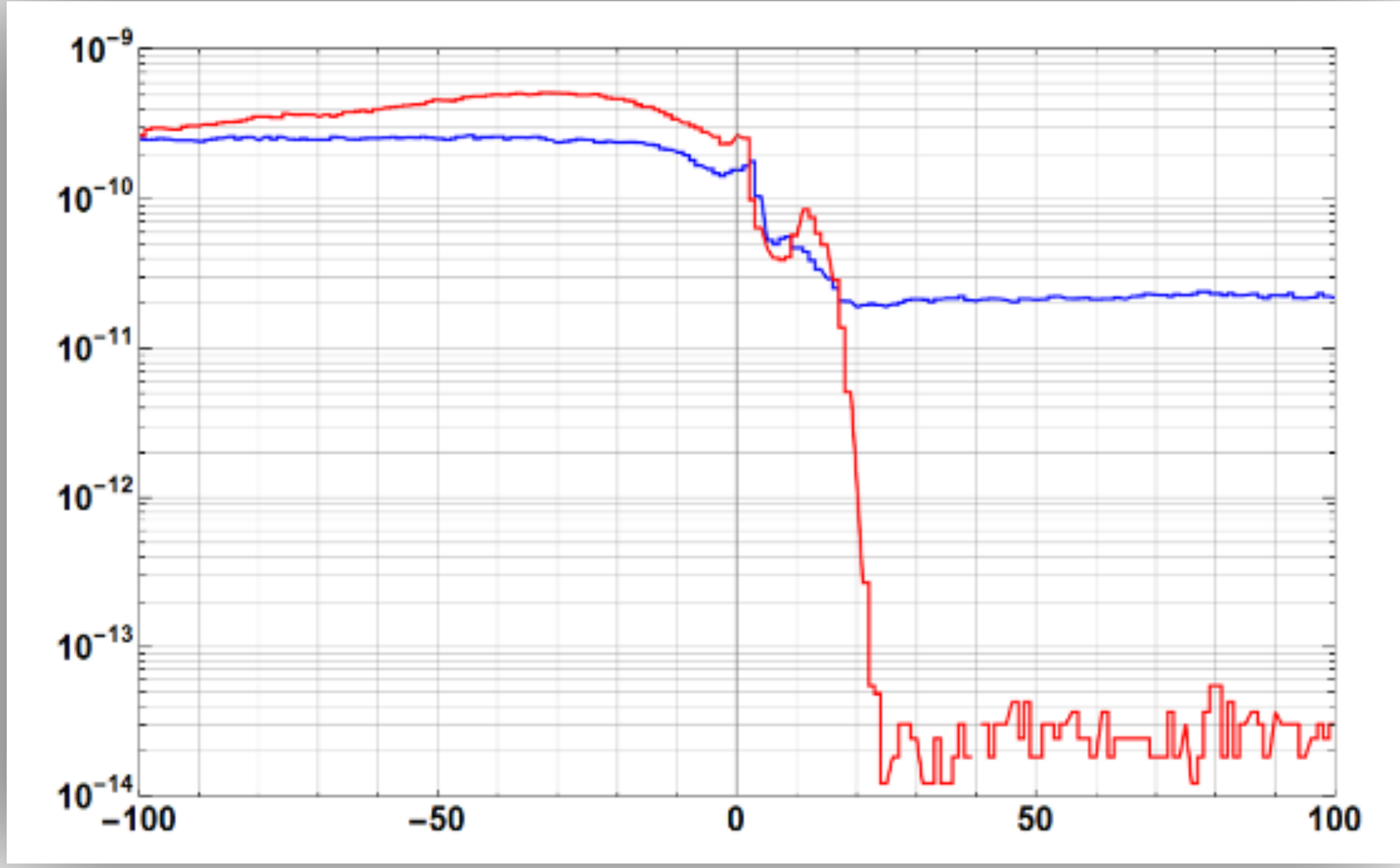
Courtesy D. Talan



Improved selectivity

Laser Ion Source and Trap (LIST) - ongoing development

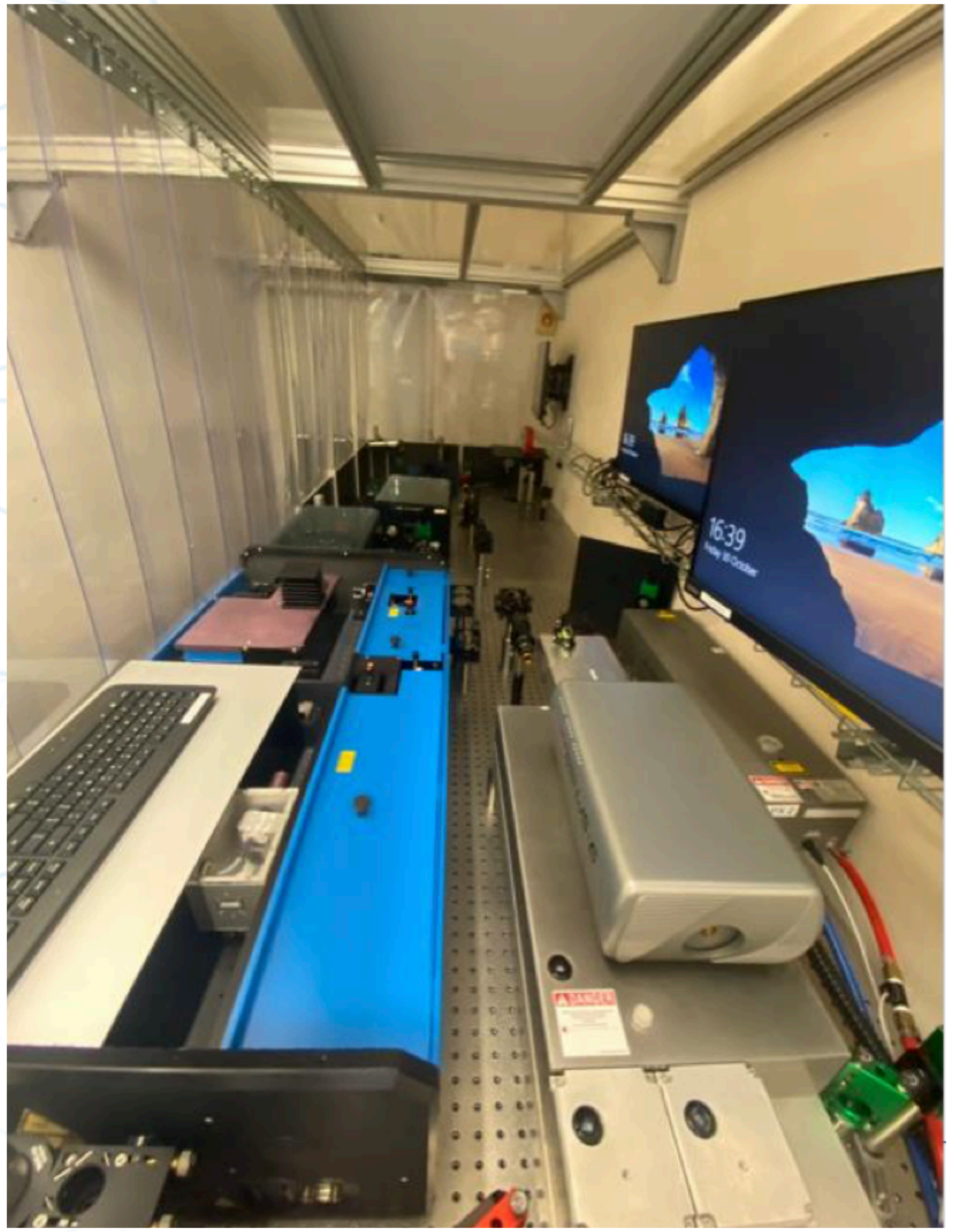




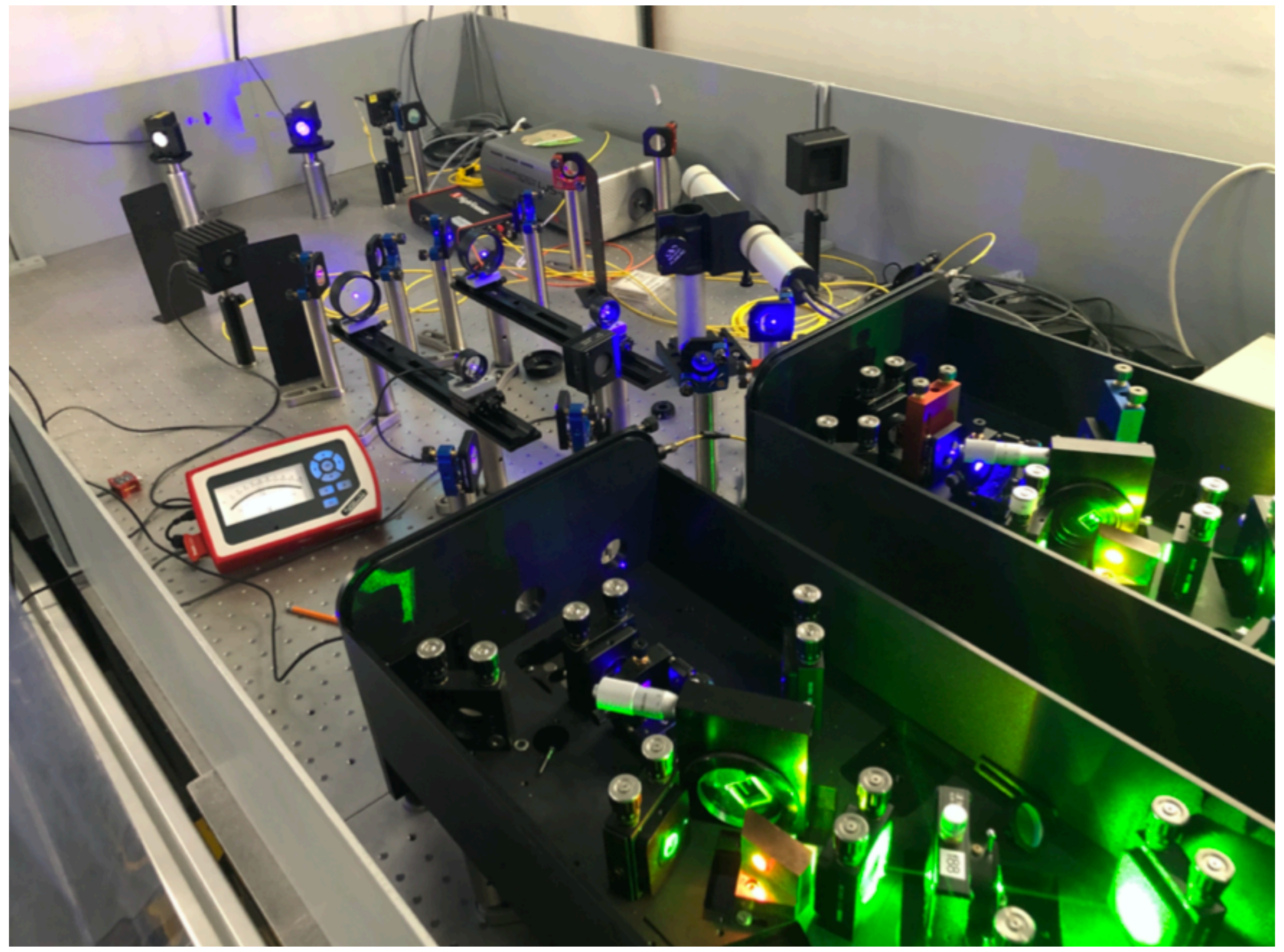
Reinhard Heinke

Ion source R&D

New Offline 2 Lab



MELISSA laser lab



New collaborations

LISA

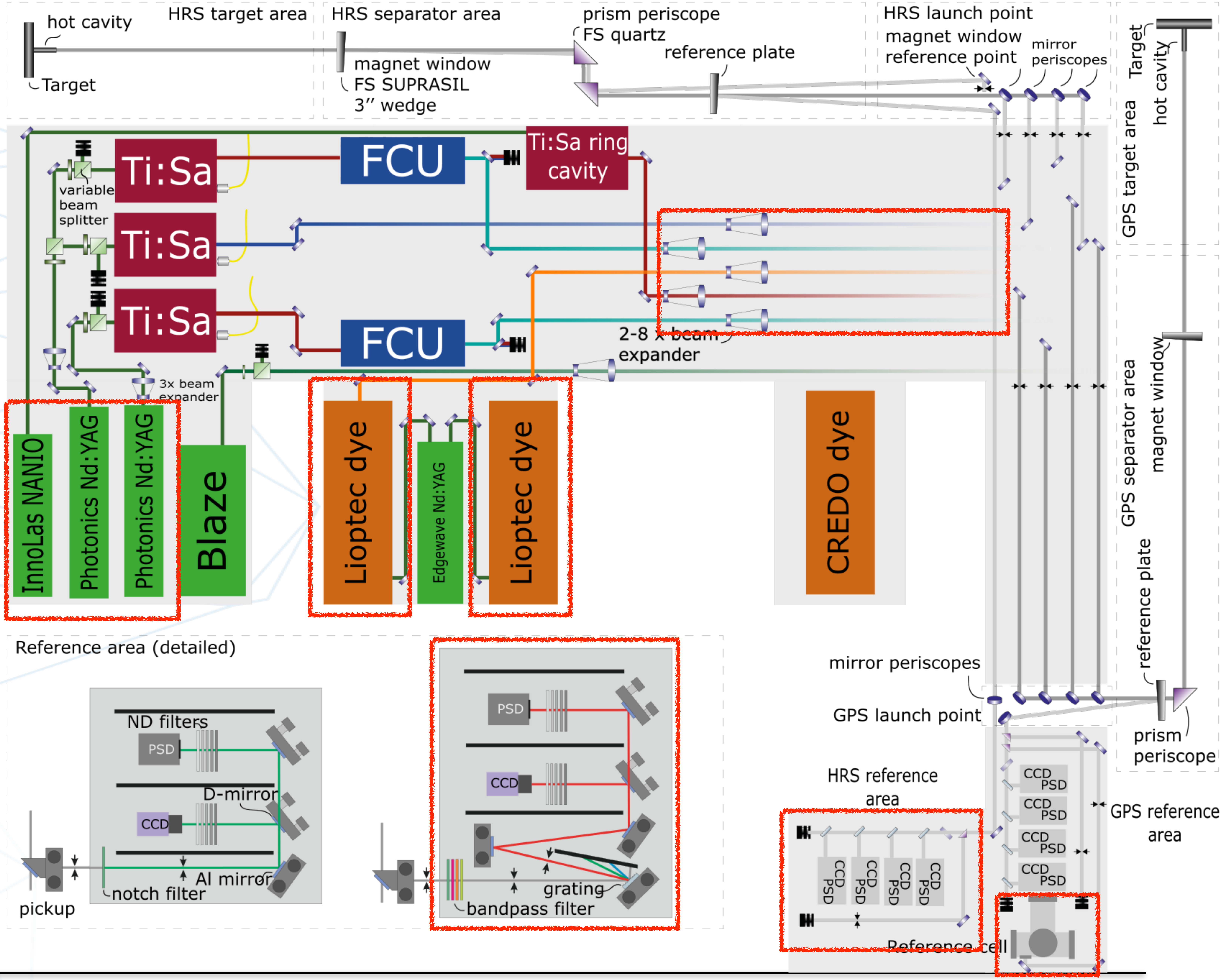
LASER IONISATION AND SPECTROSCOPY OF ACTINIDES

This Marie Sklodowska-Curie Action (MSCA) Innovative Training Networks (ITN) receives funding from the European Union's H2020 Framework Programme under grant agreement no. 861198

PRISMAS-MAP (mediso-sepa) H2020

RILIS 2021

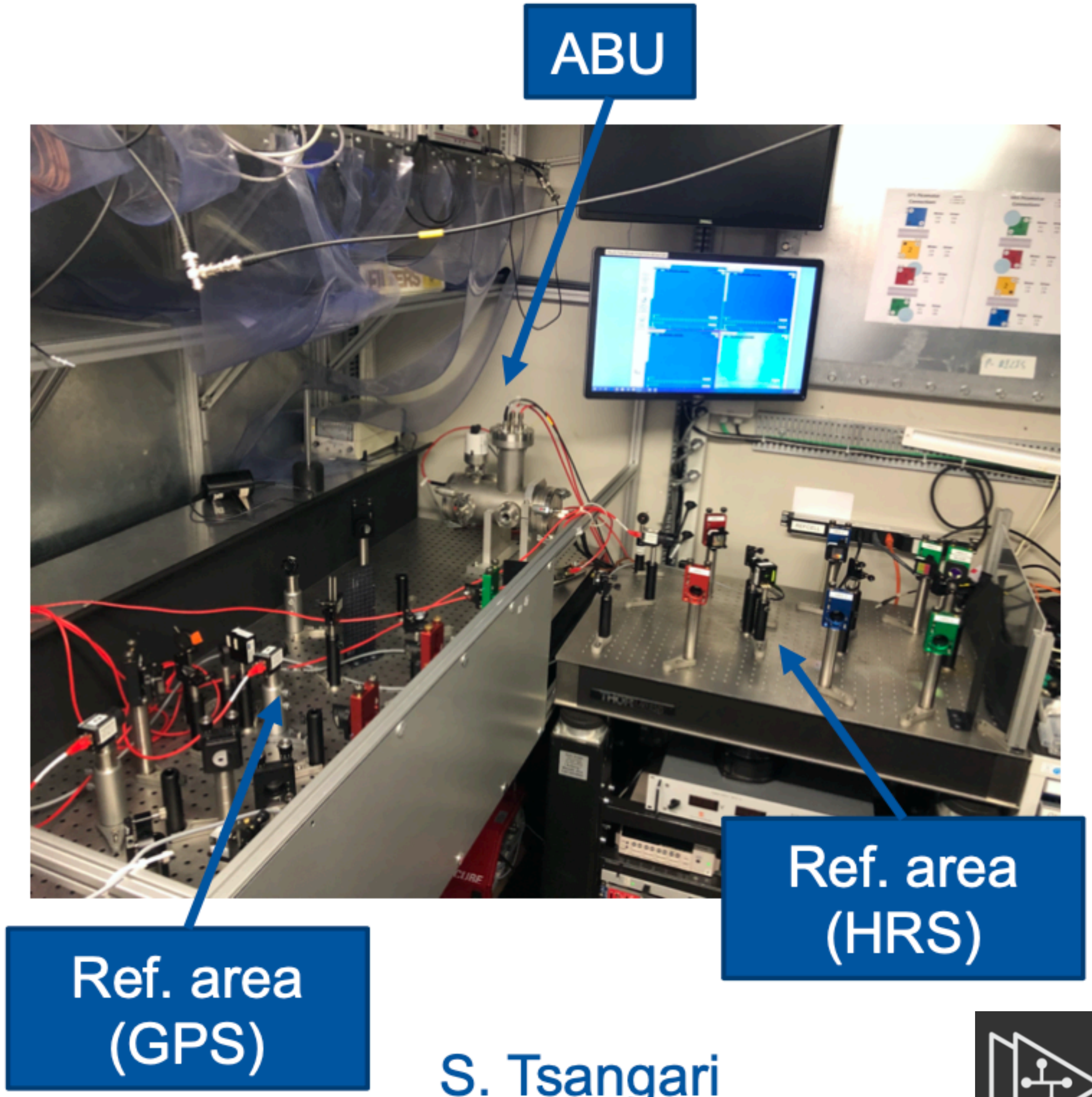
- 3 TiSa pump lasers
- 1 CREDO exchanges for 2 LIOPTEC lasers
- New reference area
- New optical layout
- Reference cell back in action
- 2nd beam stabilisation system
- 2nd set of beam imaging cameras



B.Reich (updated figure of S.Rothe)

Dual HRS and GPS operation

- Summer student project of Stavrini Tsangari for 2019.
- Reference area was redesigned.
  - Extended with **separate** GPS and HRS zones.
  - Can still use our atomic beam unit for off-line spectroscopy,
- New optics and optomechanics sourced and purchased.
  - Enables better separation and filtering of reflected reference beams.
  - More reliable imaging for challenging schemes involving UV and IR light.
- Another MRC Systems box purchased to allow **2** additional beams to be stabilized.



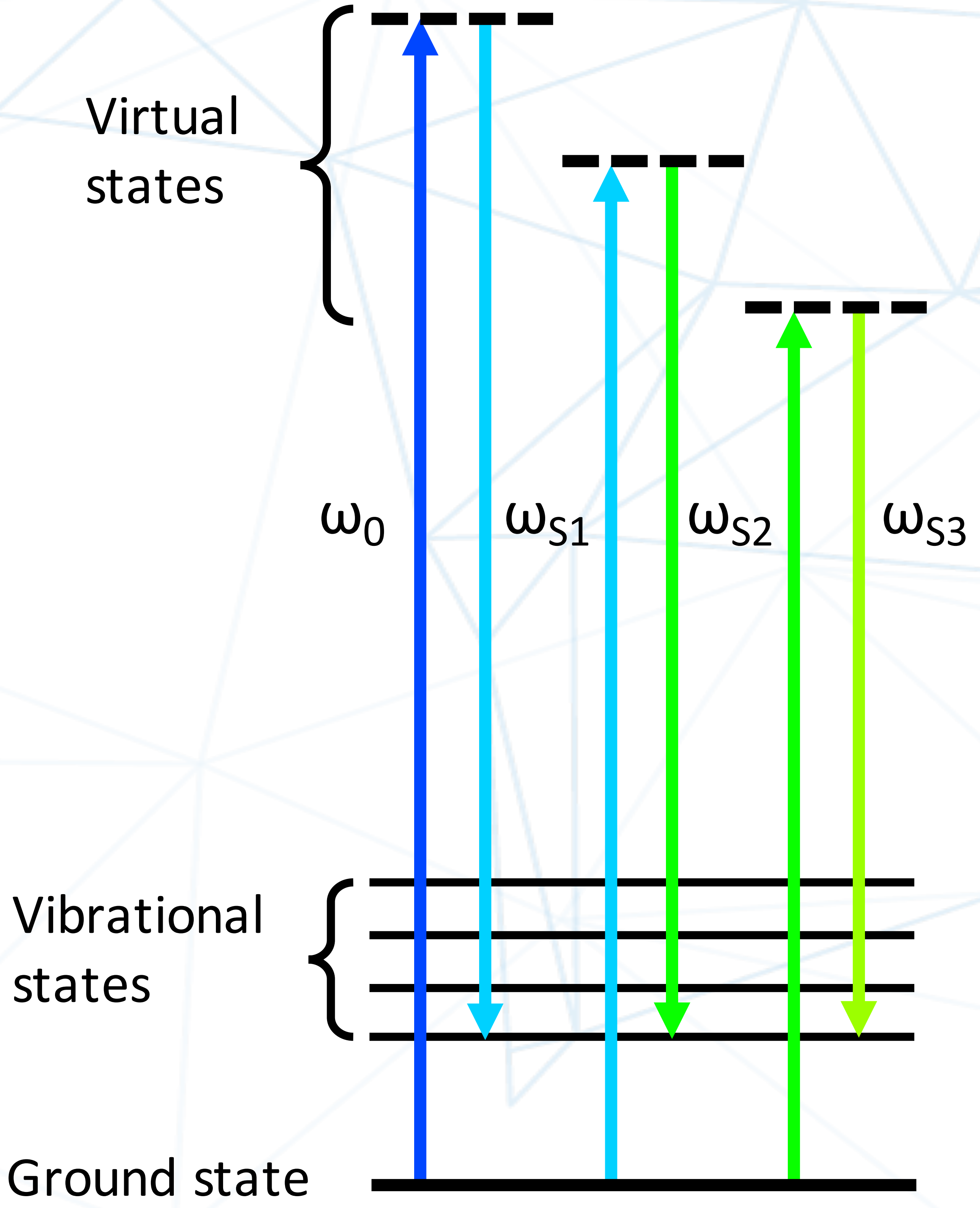
S. Tsangari

ANGARA TECHNOLOGY

S. Wilkins

Diamond Raman lasers at RILIS

Stimulated Raman scattering



Inelastic scattering of photons to achieve coherent generation of Stokes waves in the medium

Energy transferred to material is constant and independent of wavelength!!

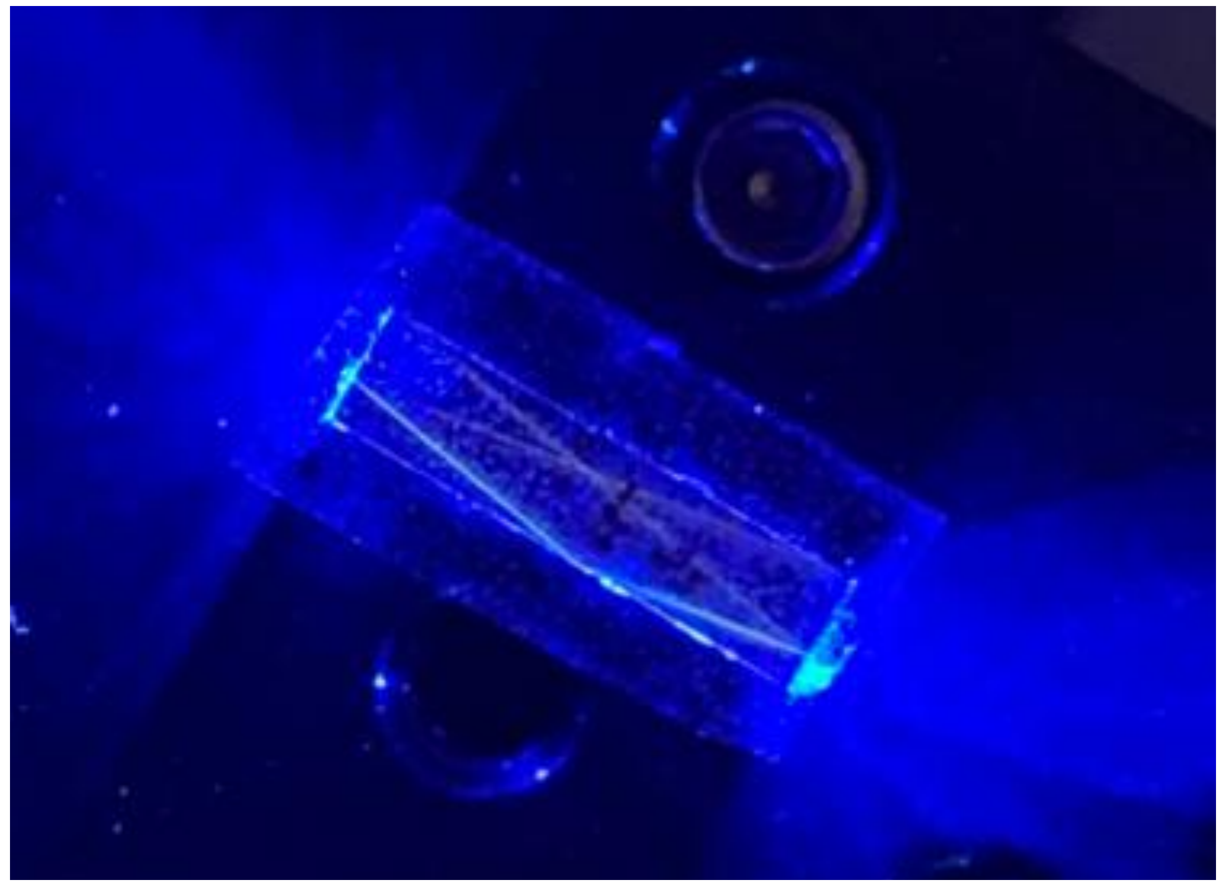
For diamond: 1332.5 cm^{-1}

High thermal conductivity

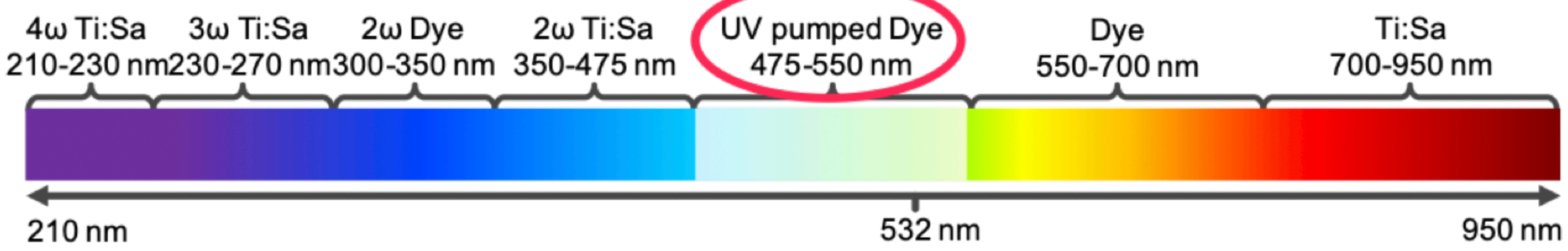
Low thermal expansion coefficient

High damage threshold

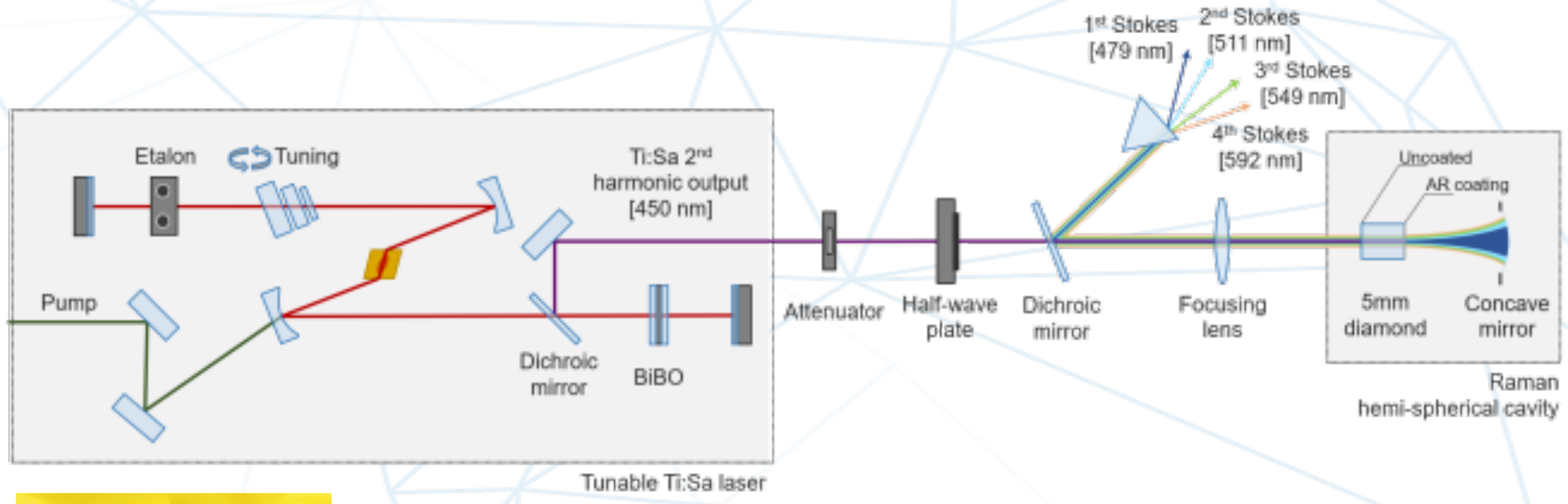
Transparency in WL range of interest

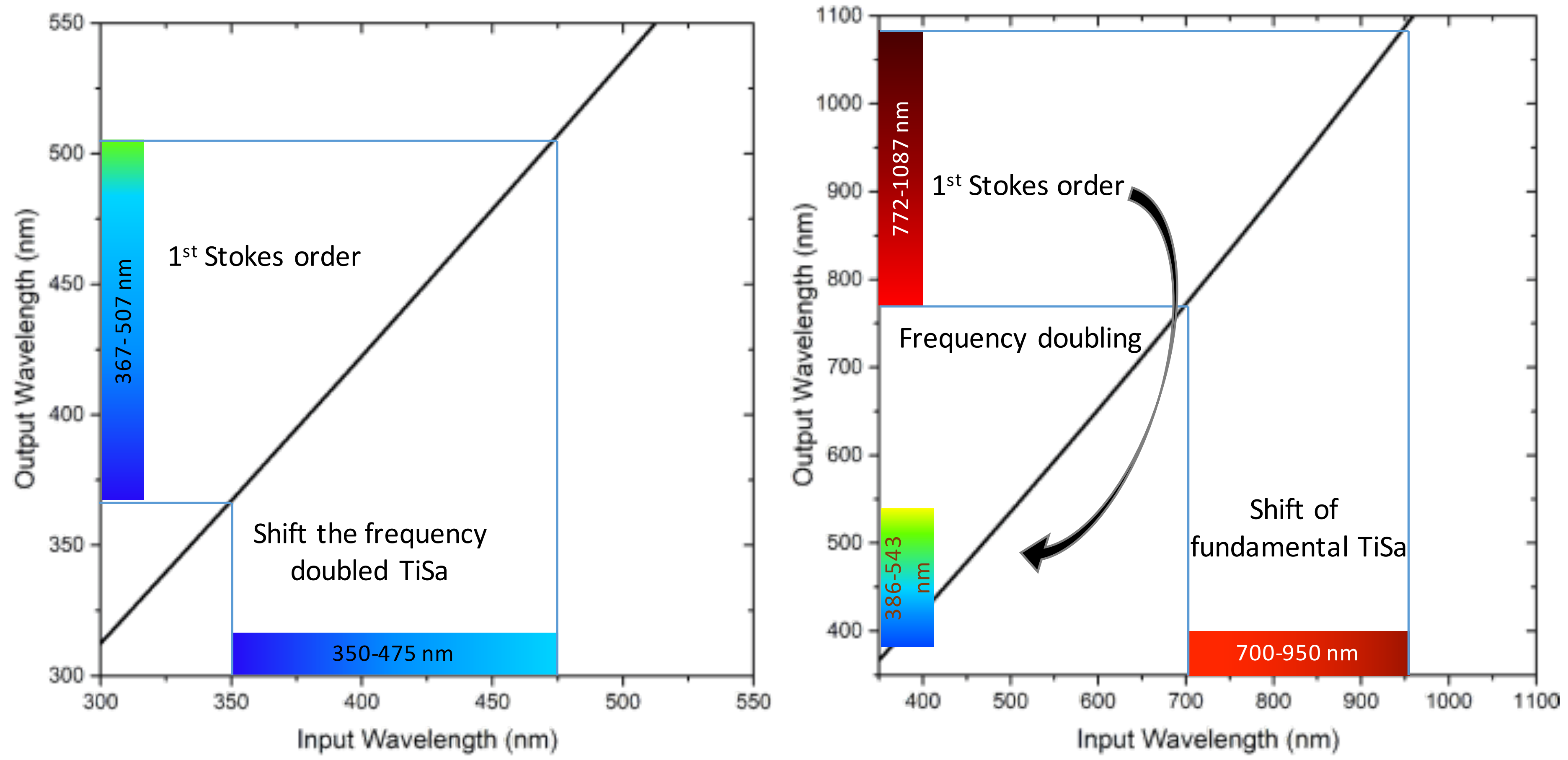


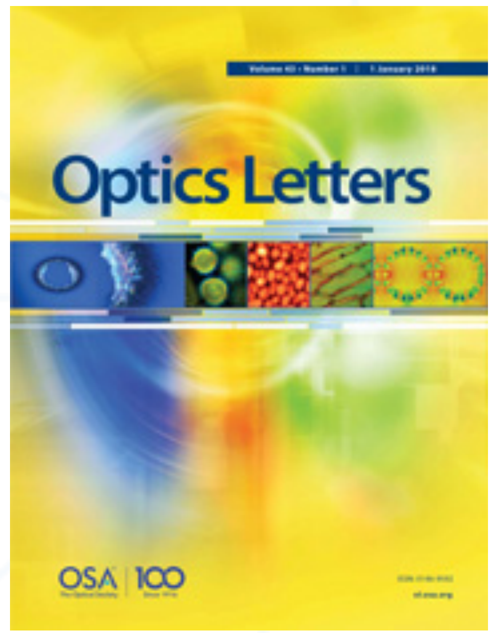
Raman lasers at RILIS



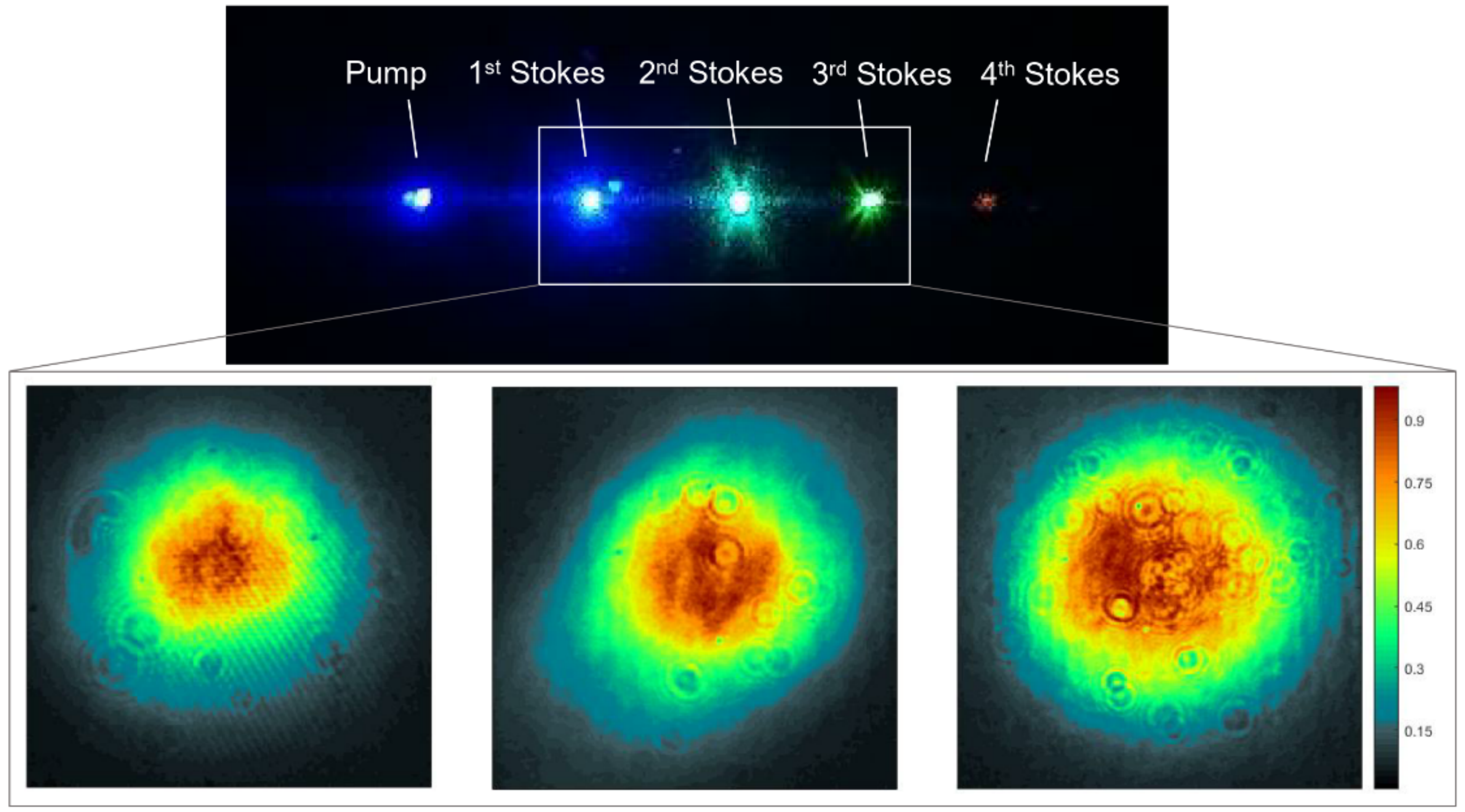
Broadband To extend the Ti:Sa tuning range towards the UV pumped dye range

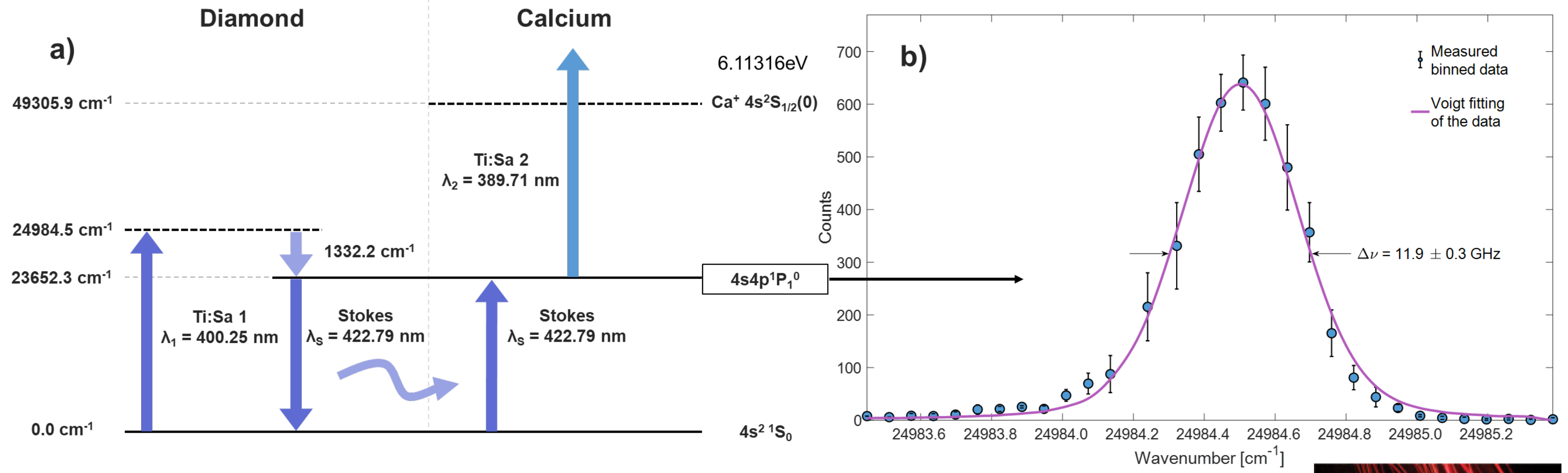




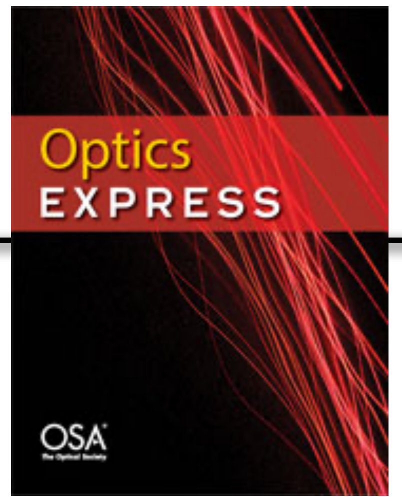


K. Chrysalidis et al



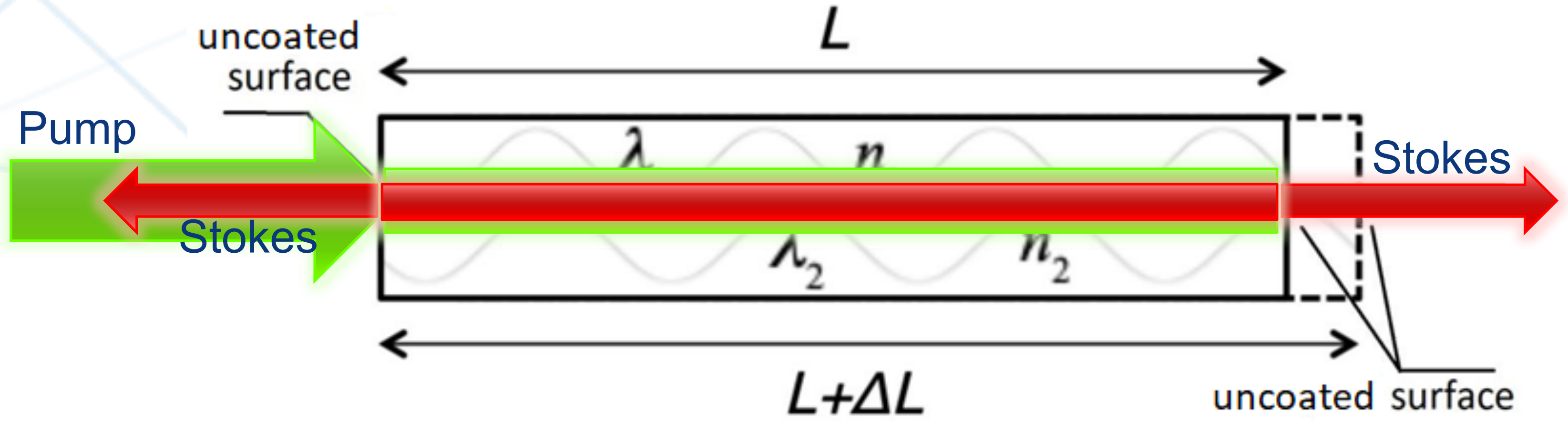


Daniel T. Echarri et al

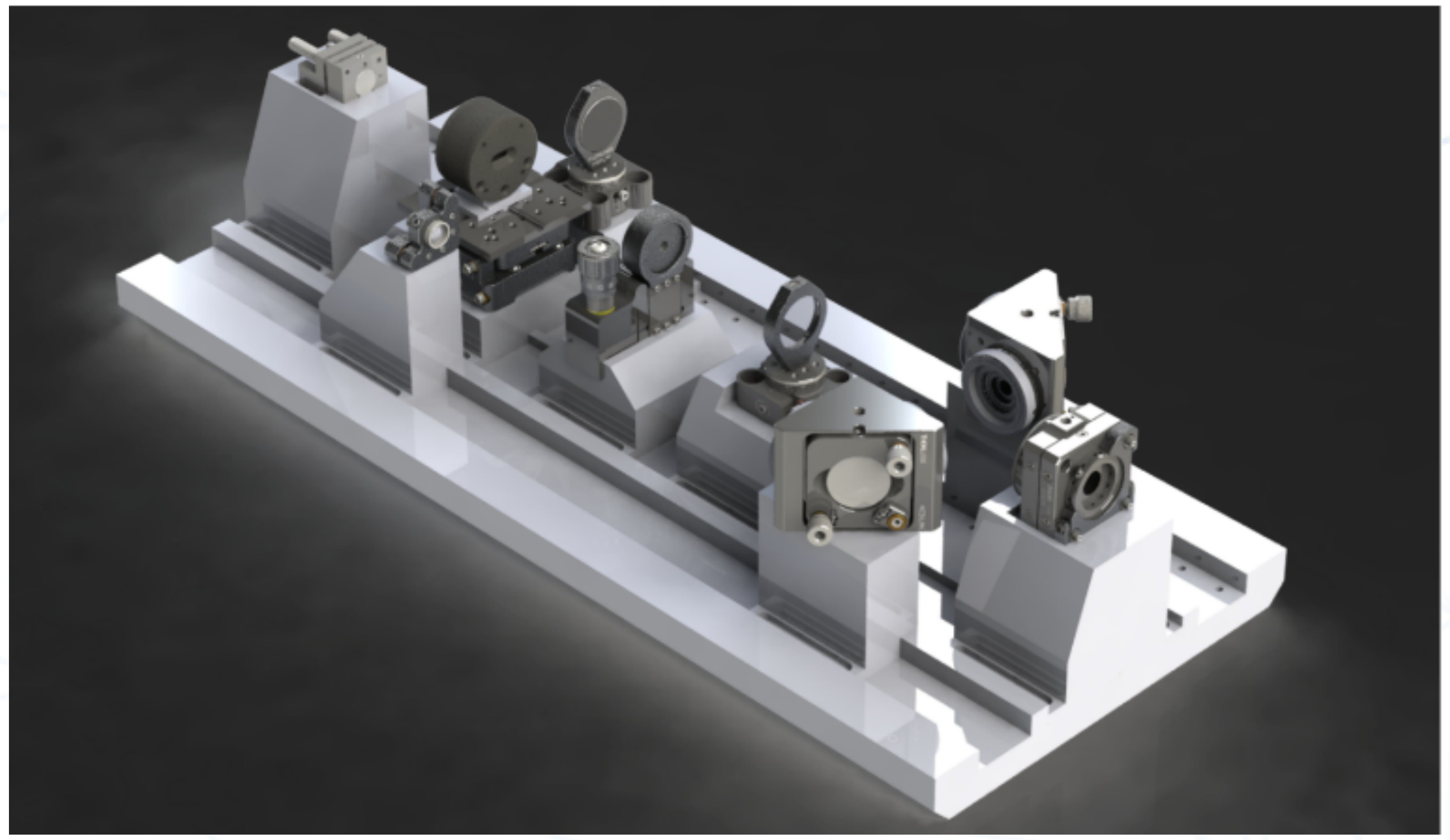


Raman lasers at RILIS

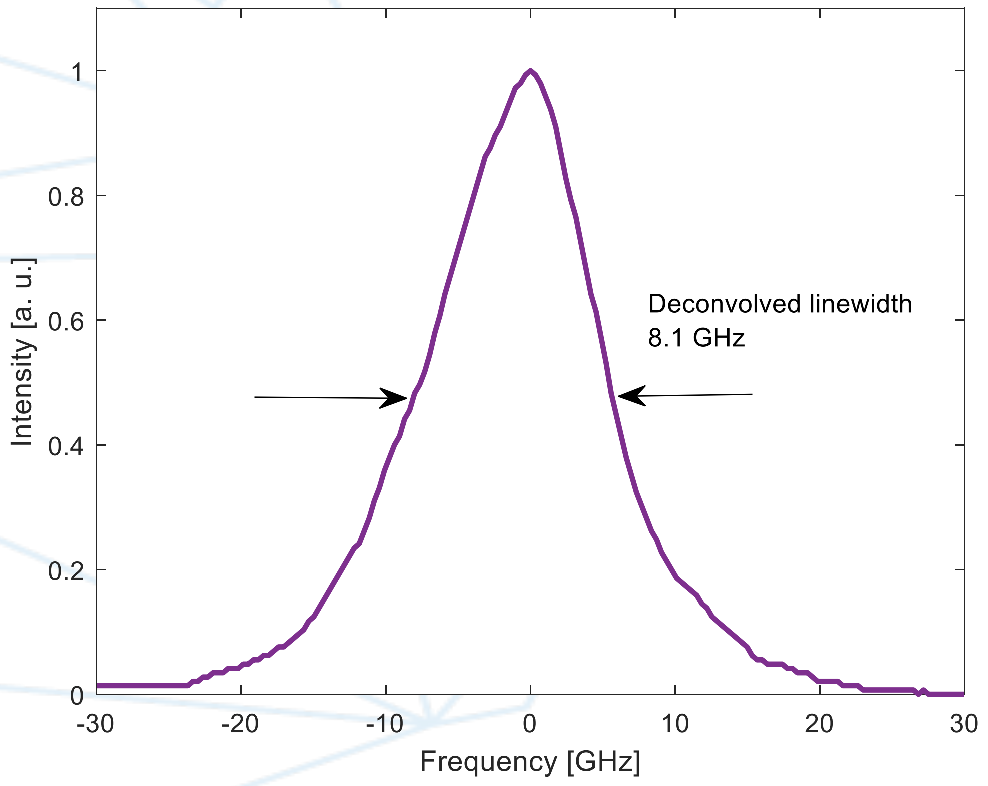
Narrowband To enable laser spectroscopy with a laser line width ~ 10x narrower than is currently possible with RILIS lasers



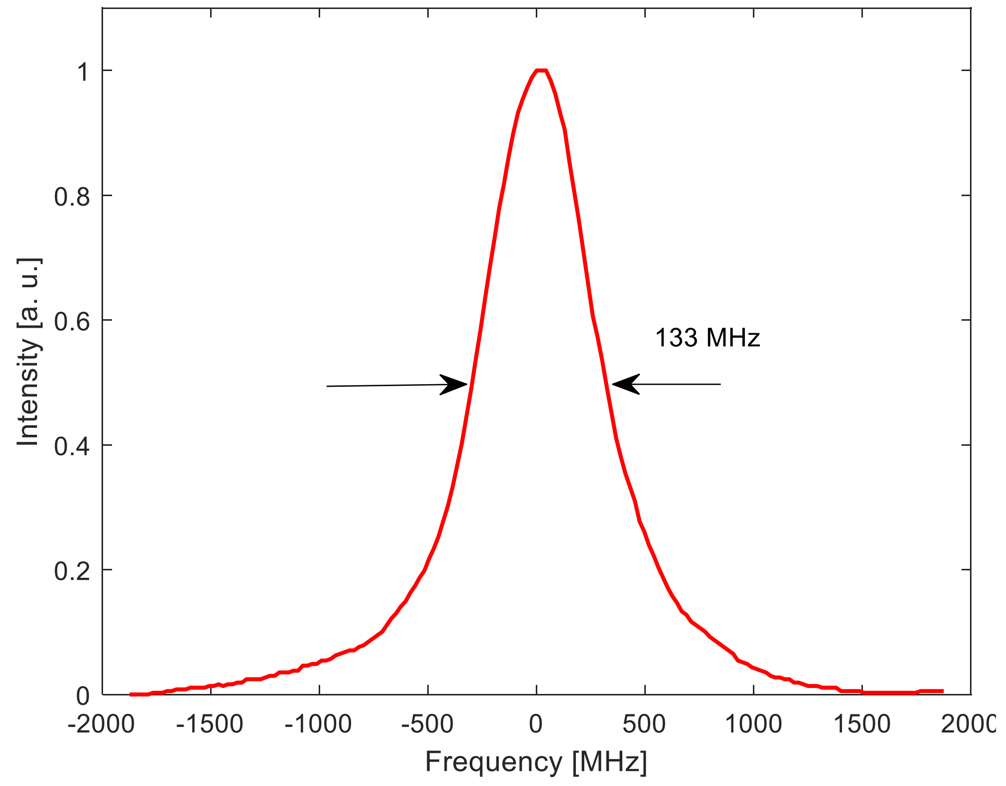
Material	Thermal expansion coefficient (μK⁻¹)
Diamond	1.1
KGW	23.0
$BaWO_4$	10.0

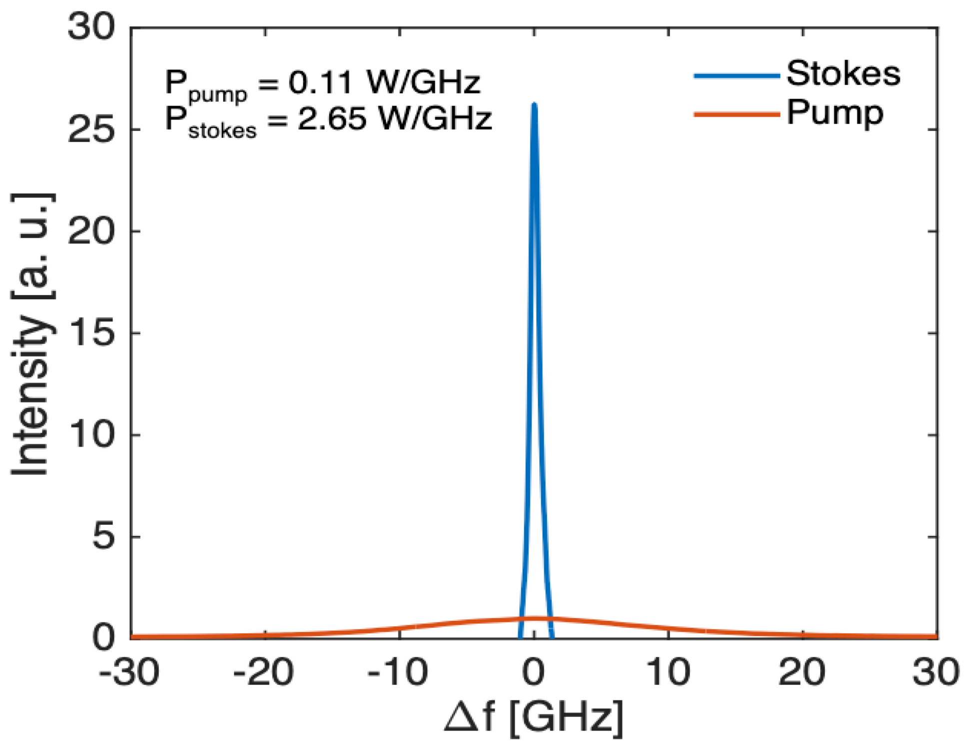


Deconvolved pump laser linewidth = 8.1 GHz



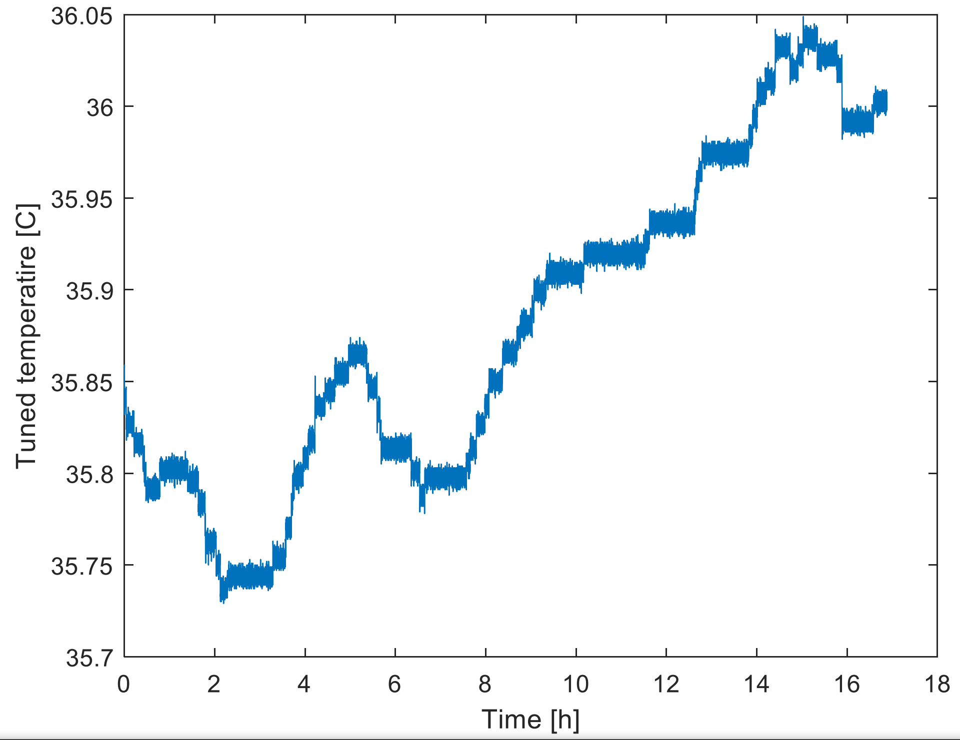
Deconvolved output Stokes linewidth = 133 MHz



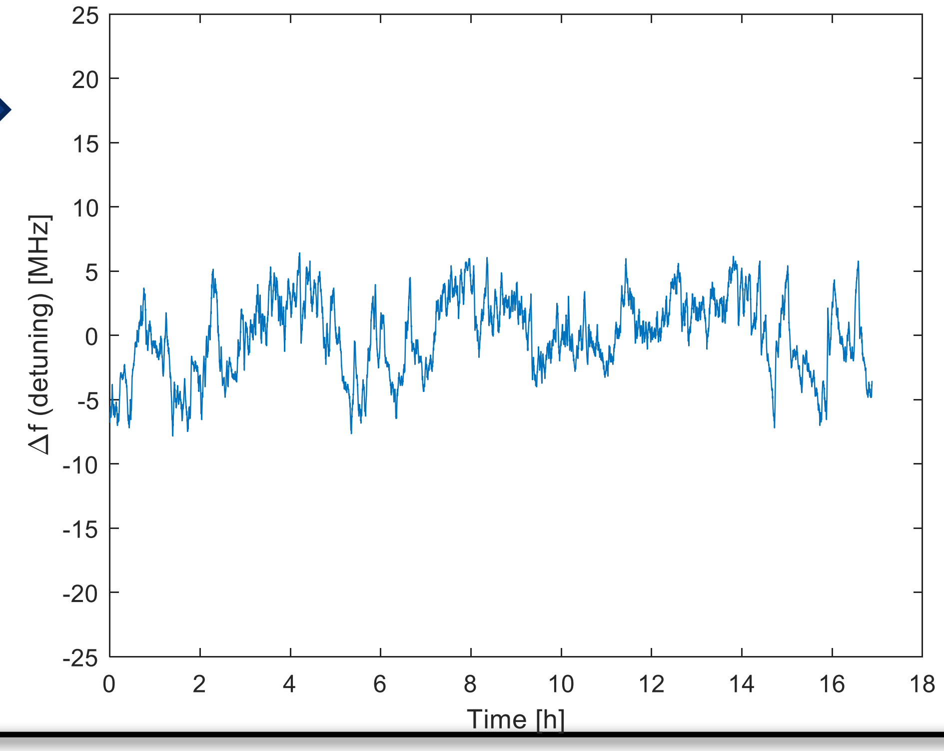


Stokes linewidth is ~60x narrower than the pump

Automatic temperature adjustment



Stokes wavelength variation*



Broadly tunable

10x linewidth reduction

Increase in spectral brightness!

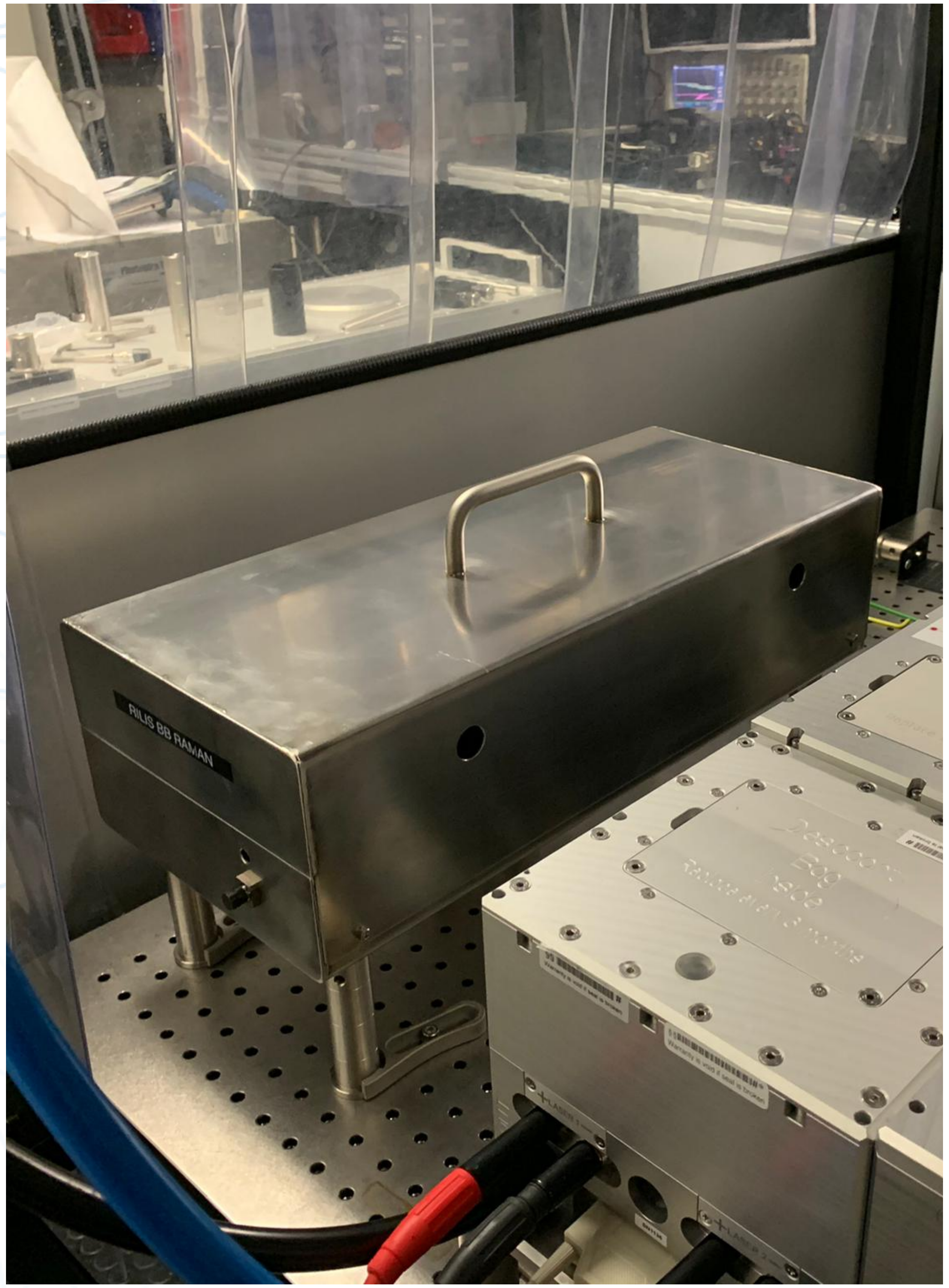
E. Granados. *Patent application submitted, CERN KT Singular light project (115 kCHF awarded)*

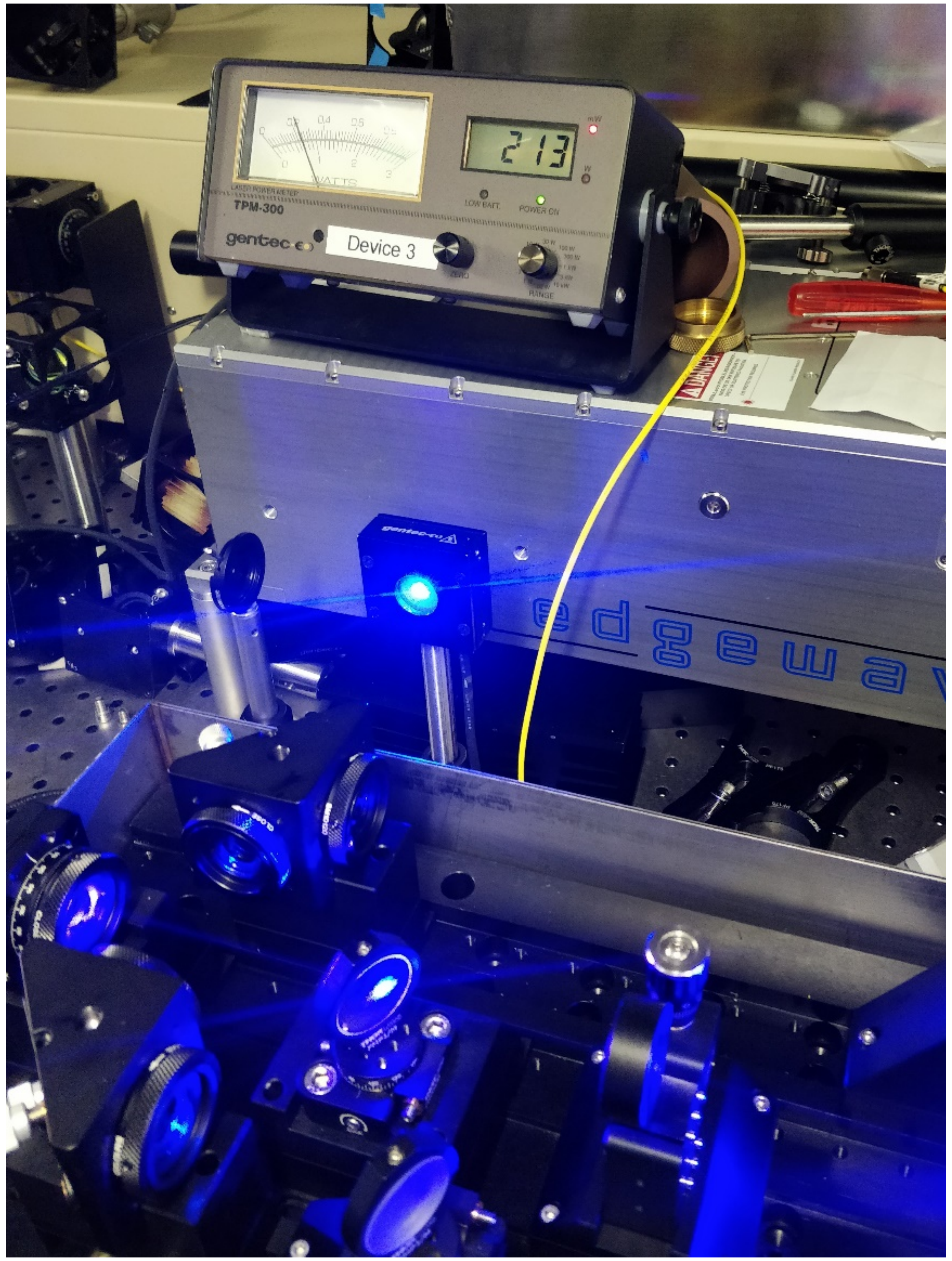
Raman status

- Two prototypes were constructed to work both as a **single mode** and as a **broadband** laser.

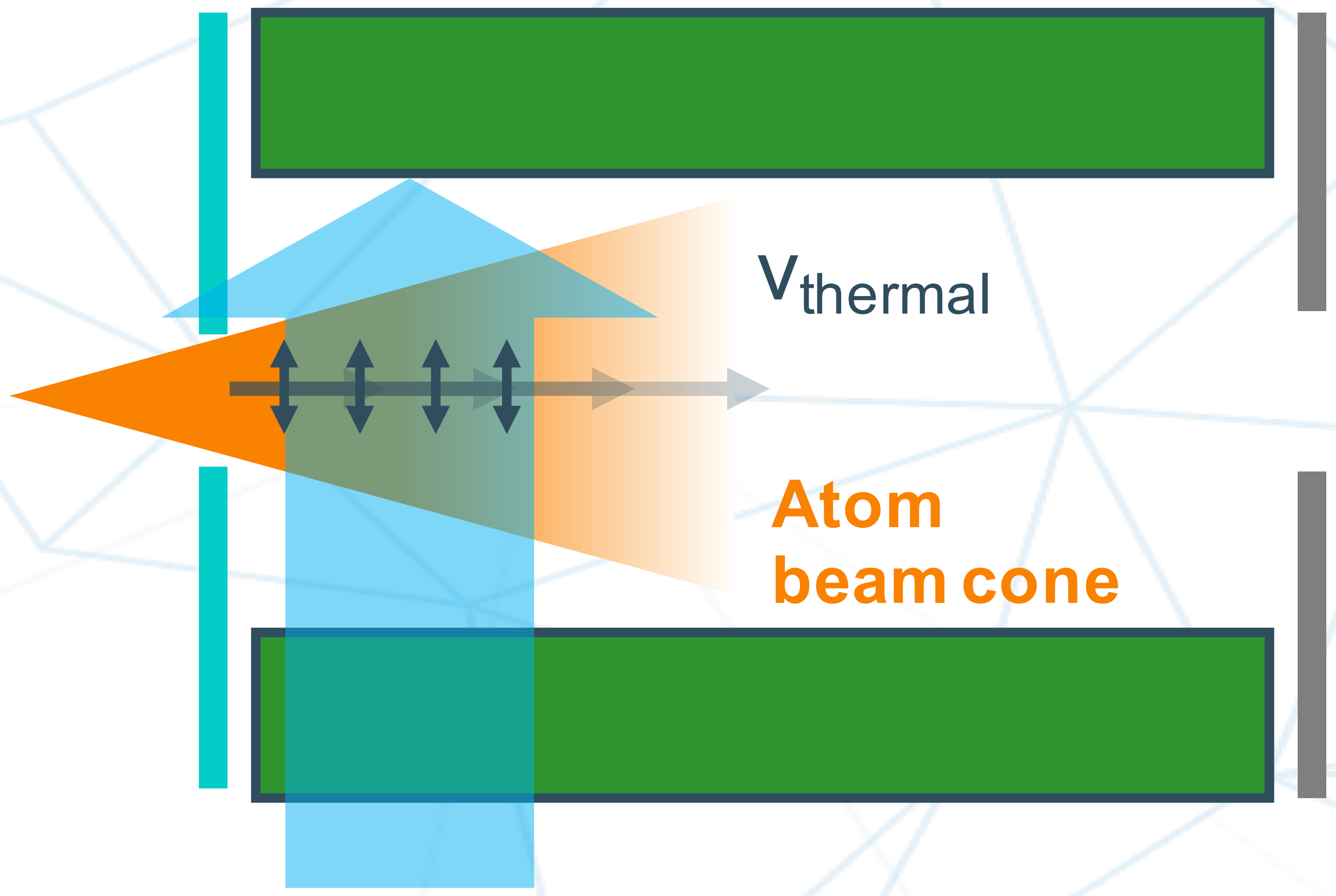
- A prototype was installed in RILIS in November 2020, lasing at a **213 mW power**.
 (With 600 mW pump power)
- Enhancements and modifications must be done for proper broadband operation.

- Single mode operation is successfully achieved by the prototype.

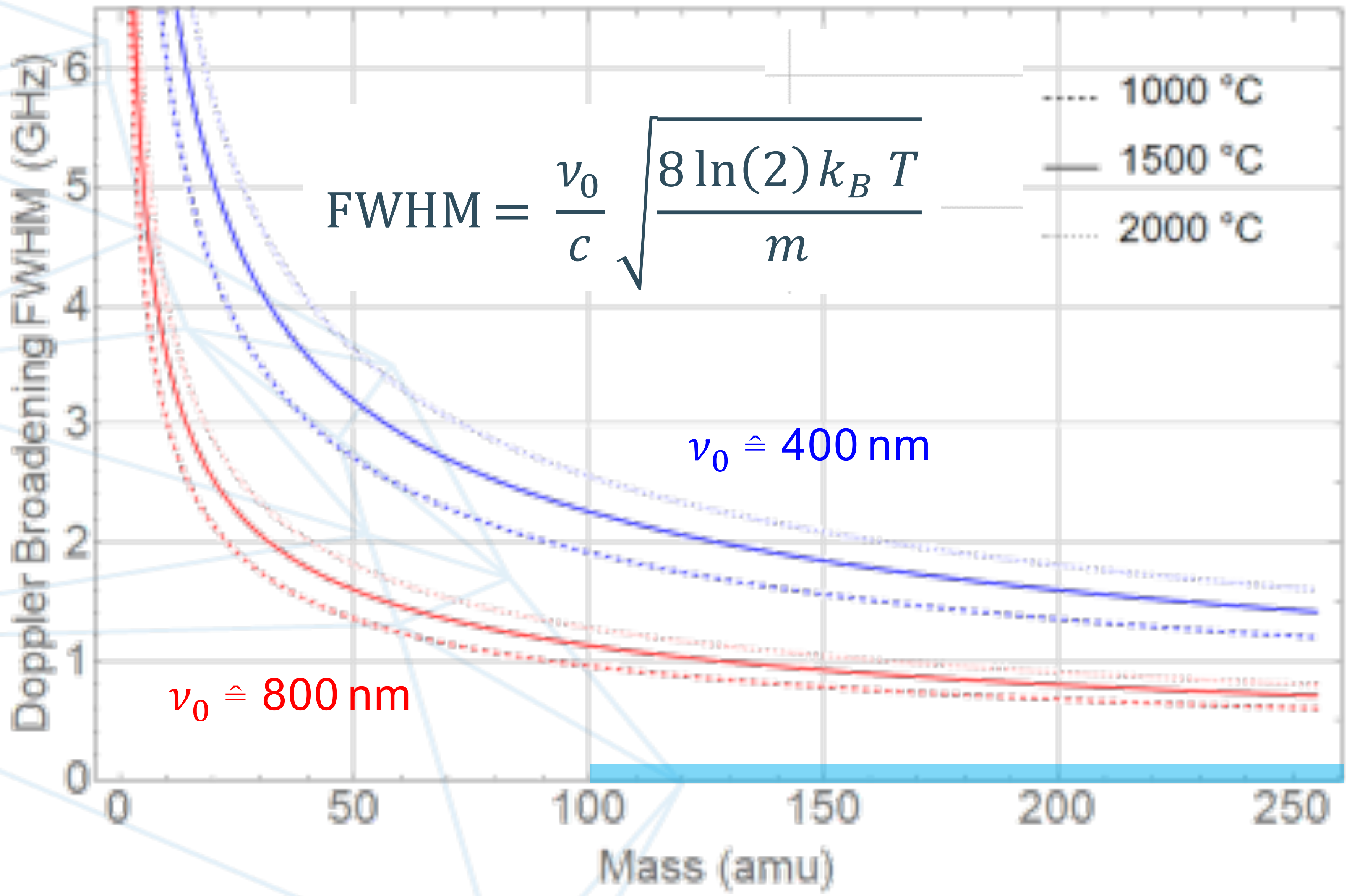




The PI LIST project

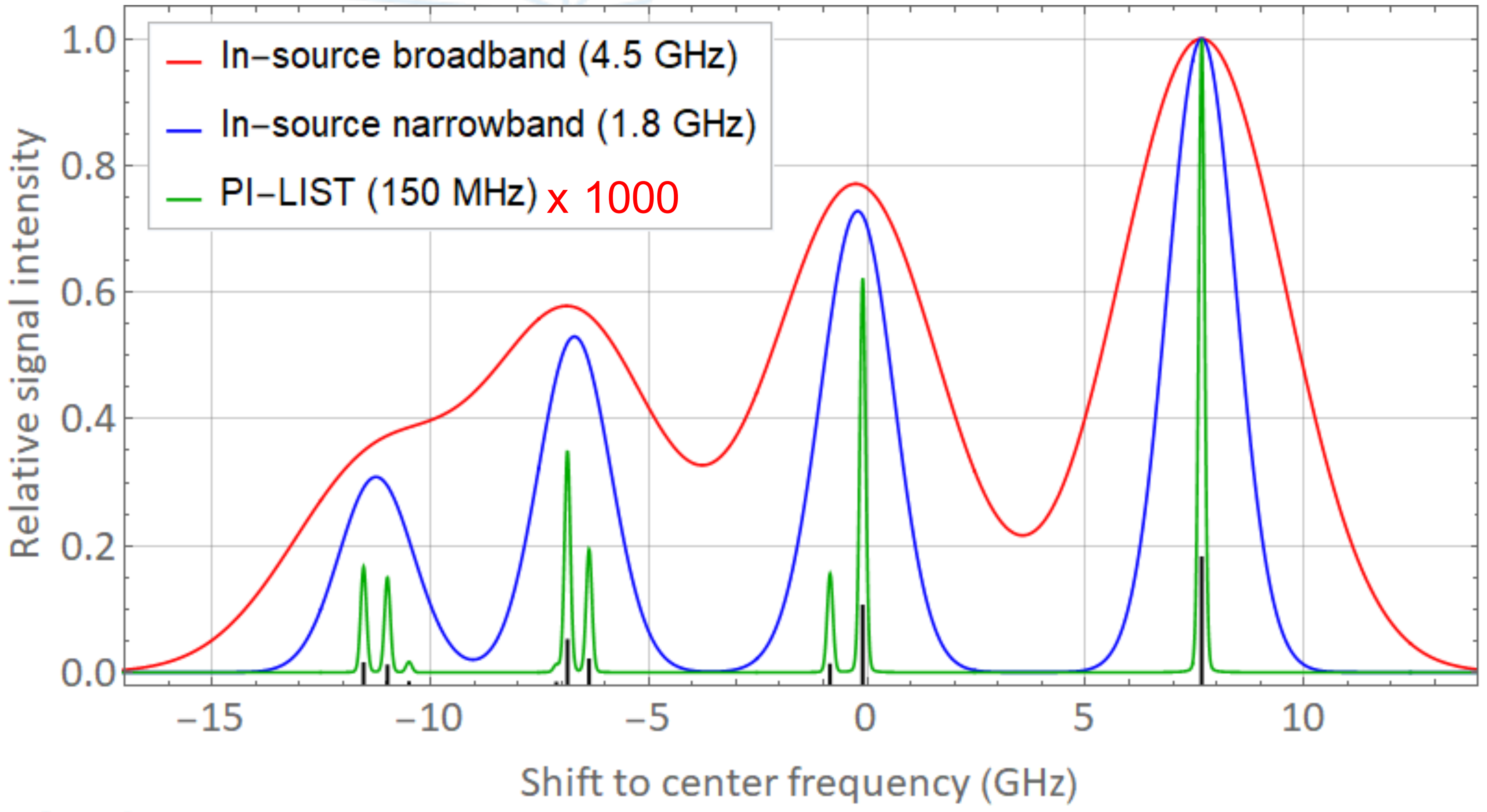


Narrow bandwidth **spectroscopy laser**



For laser spectroscopy and Isomer selective ionization

- **Doppler broadening** as limit for in-source spectroscopy
- **Reduced Doppler ensemble** in laser intersection volume
  - Resolution improvement > x10
  - At cost of efficiency 1/1000



Loss factors

RILIS → LIST ~ 30

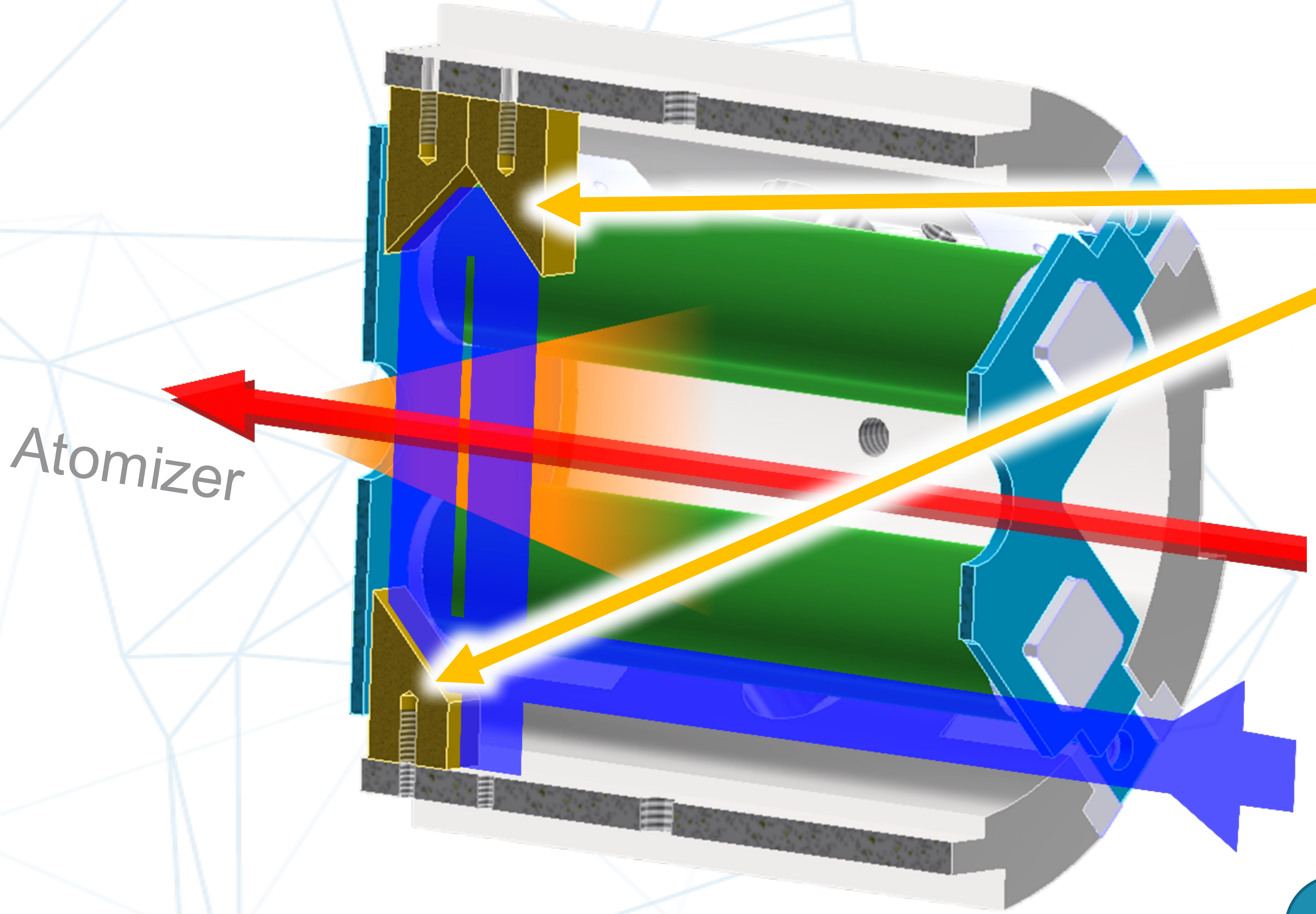
LIST → PI-LIST ~ 4

PI-LIST opt. ~ 10

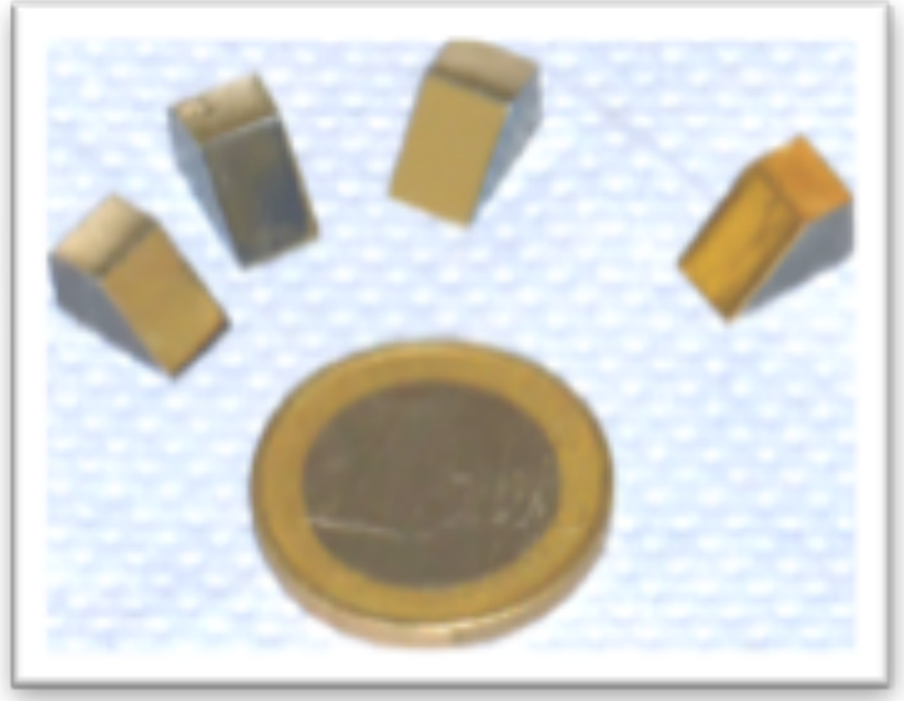
~ 1,000

R.Heinke

The PI LIST project



Robust metallic mirrors



Adapted extraction electrode

✓ Machined
Next: Extensive “real life” comparison with current version at off-line 2

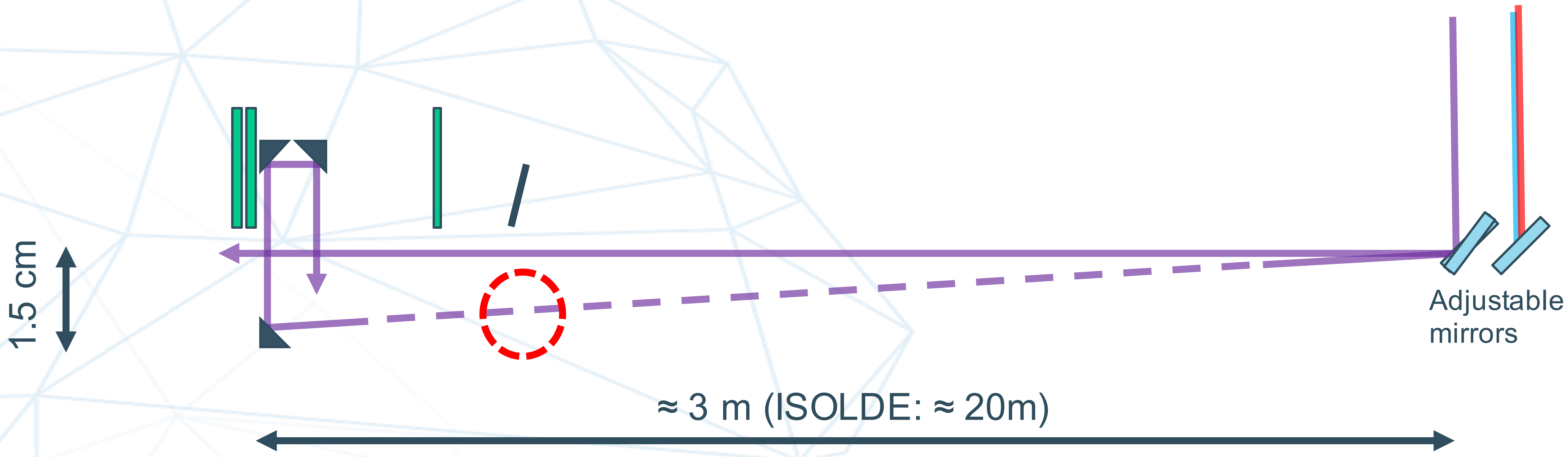
- ➢ Transversal reflection by **metallic mirror** surfaces
- ➢ **Off-axis guiding** of laser through ion beam line

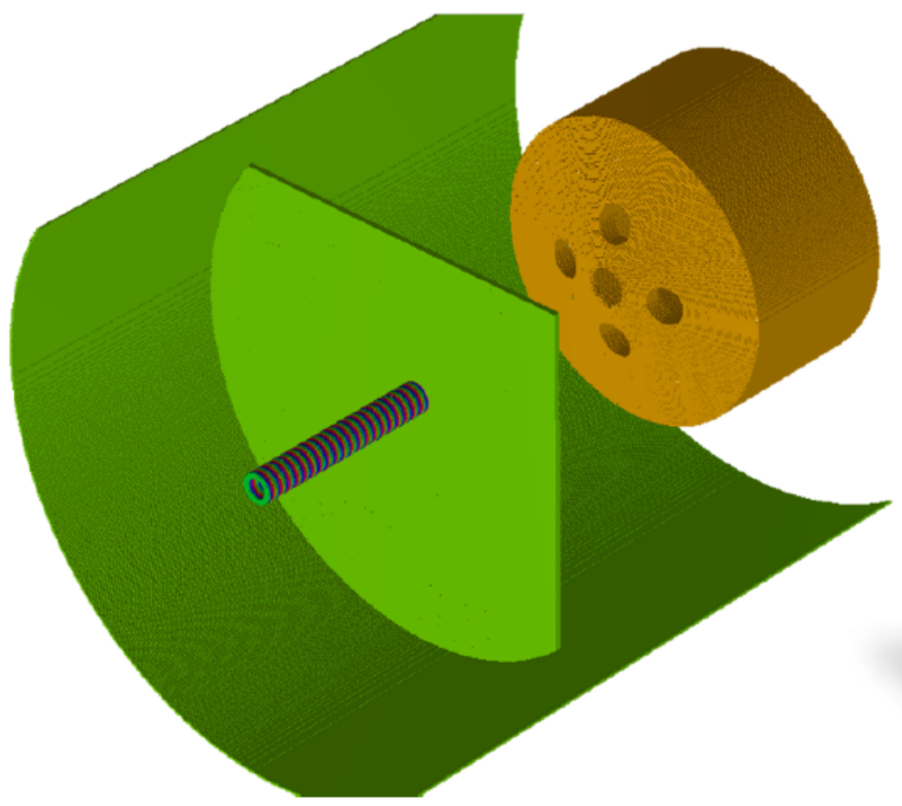
R.Heinke

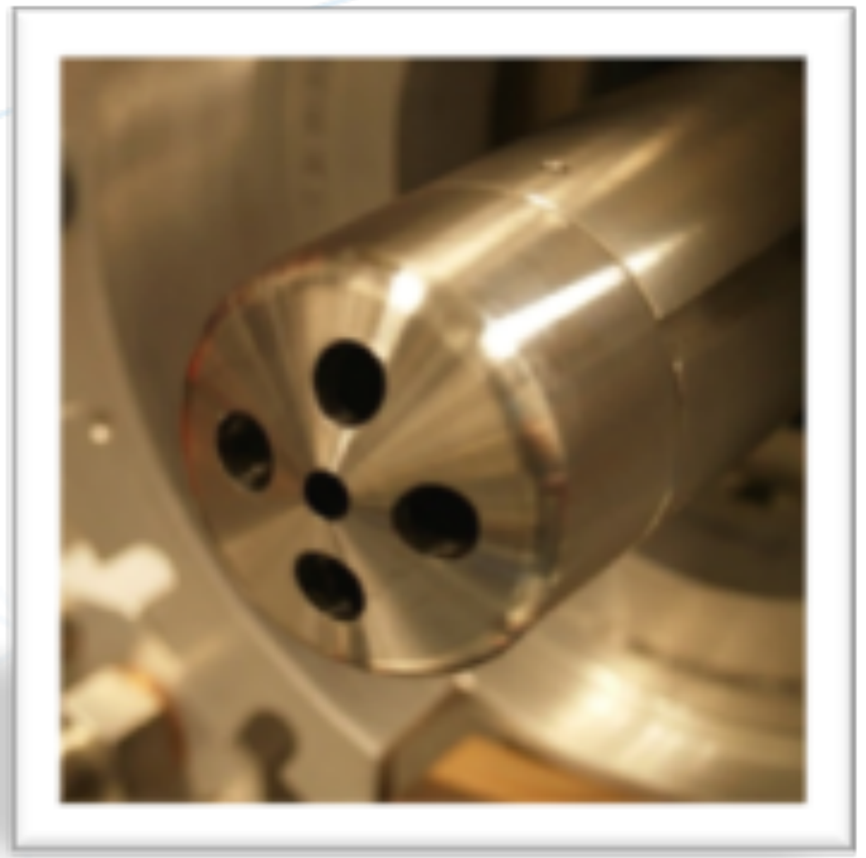
The PI LIST project

Use of existing laser infrastructure - easy mode switching by mirror adjustment

➢ Full conservation of „classical“ operation modes







Simulation and implementation successful at JGU for > 1 year

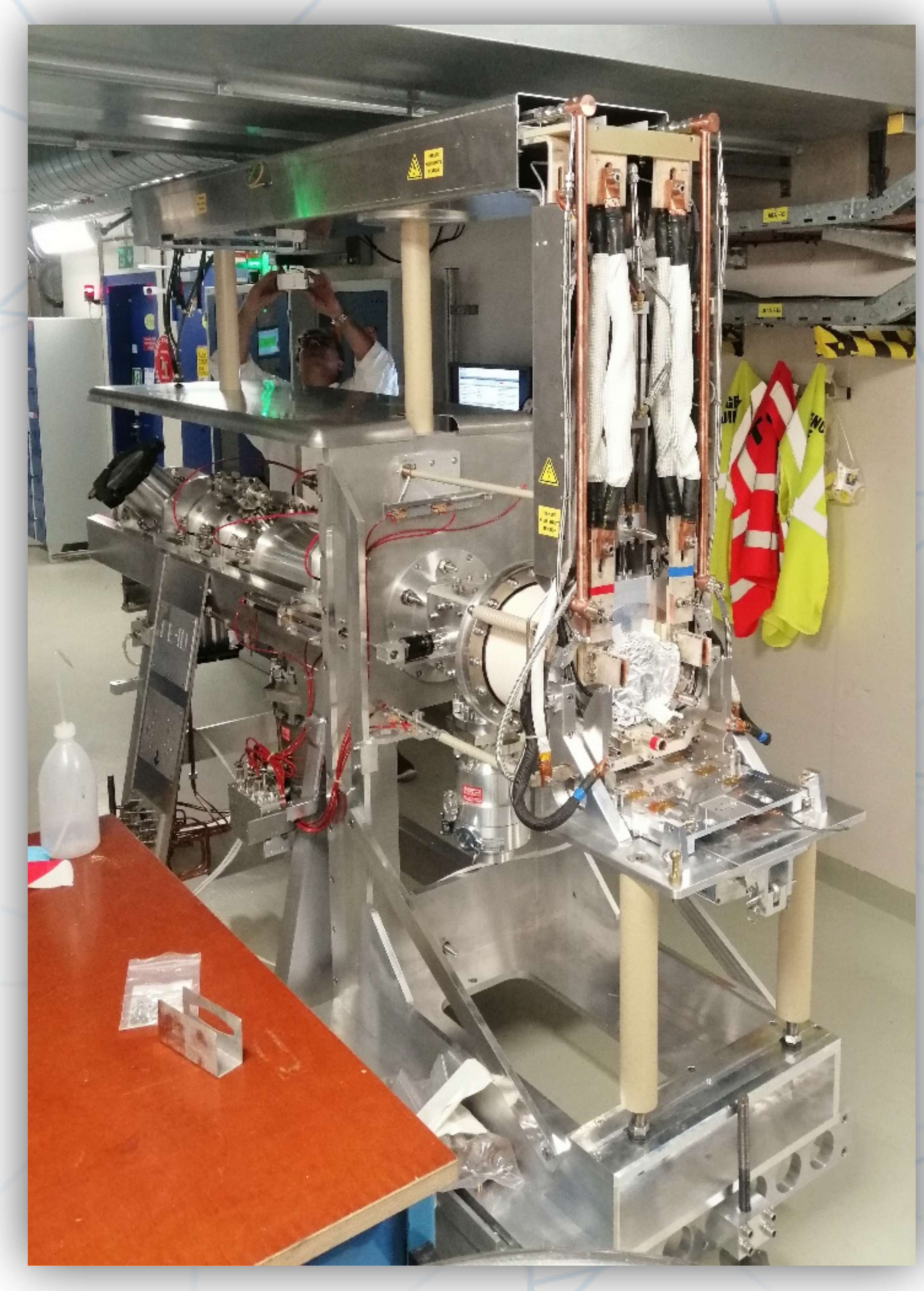
Implementation at ISOLDE:

- Simultaneous change of target and extractor?
- Design change – meshed holes?
- …

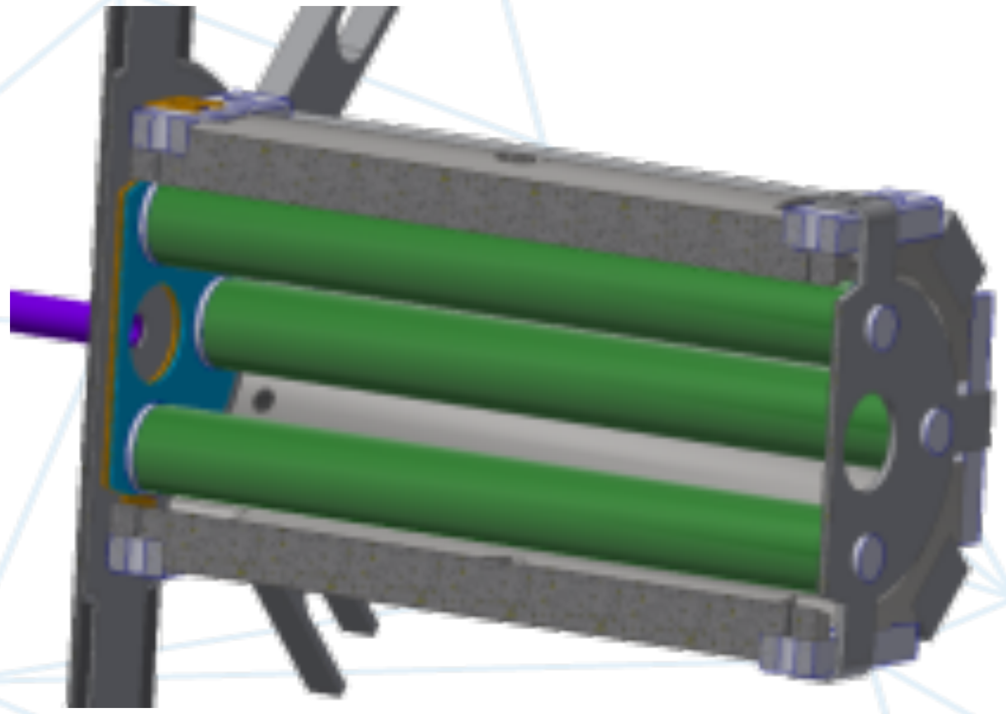
R.Heinke

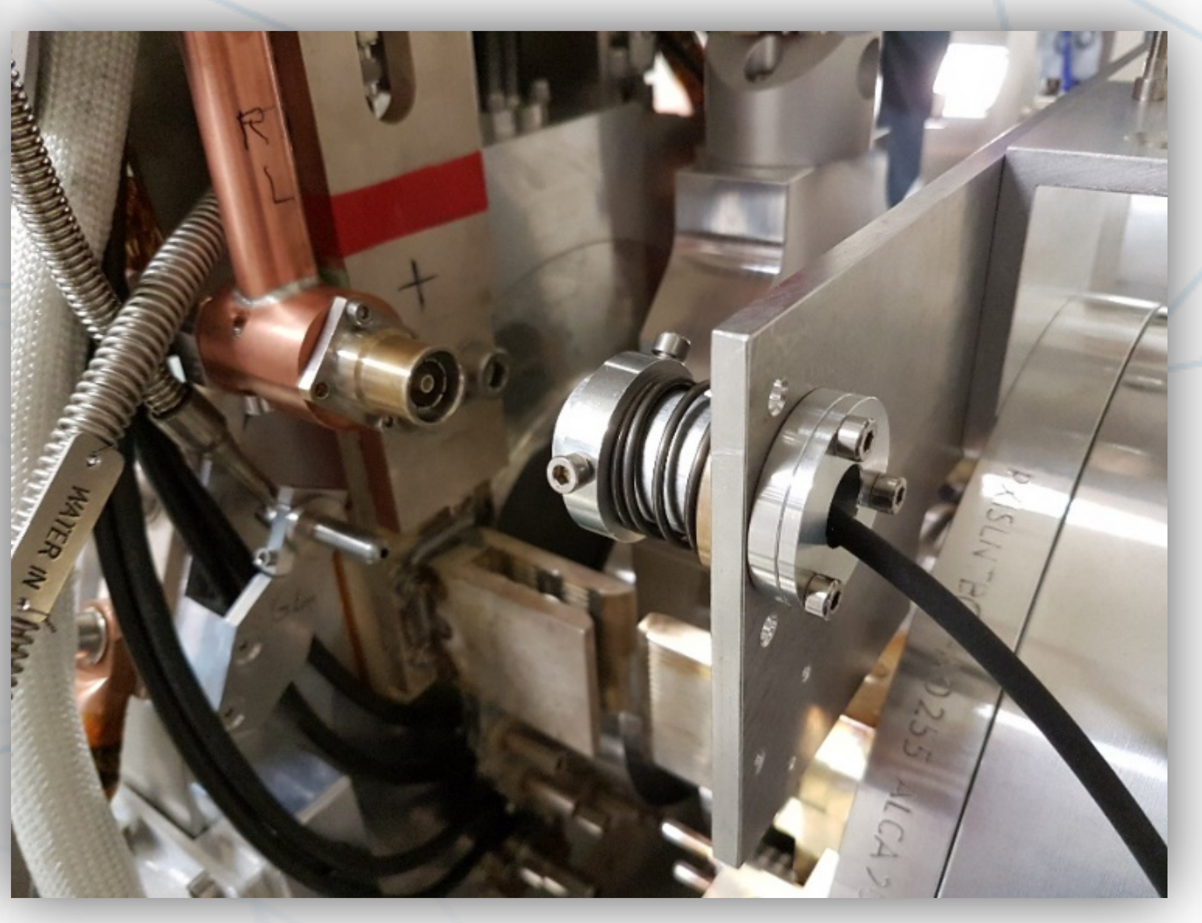
New LIST capabilities

Both GPS and HRS frontends will be compatible with LIST

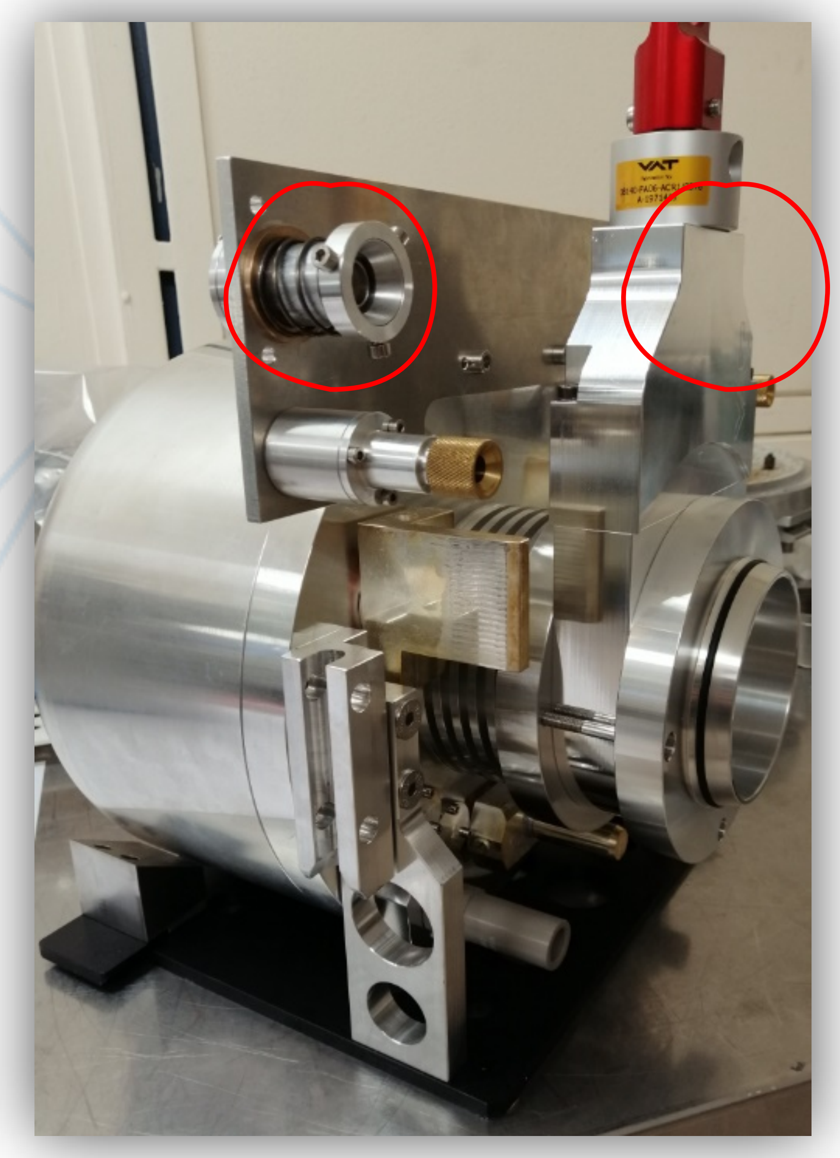


New GPS frontend





RF coupling connectors

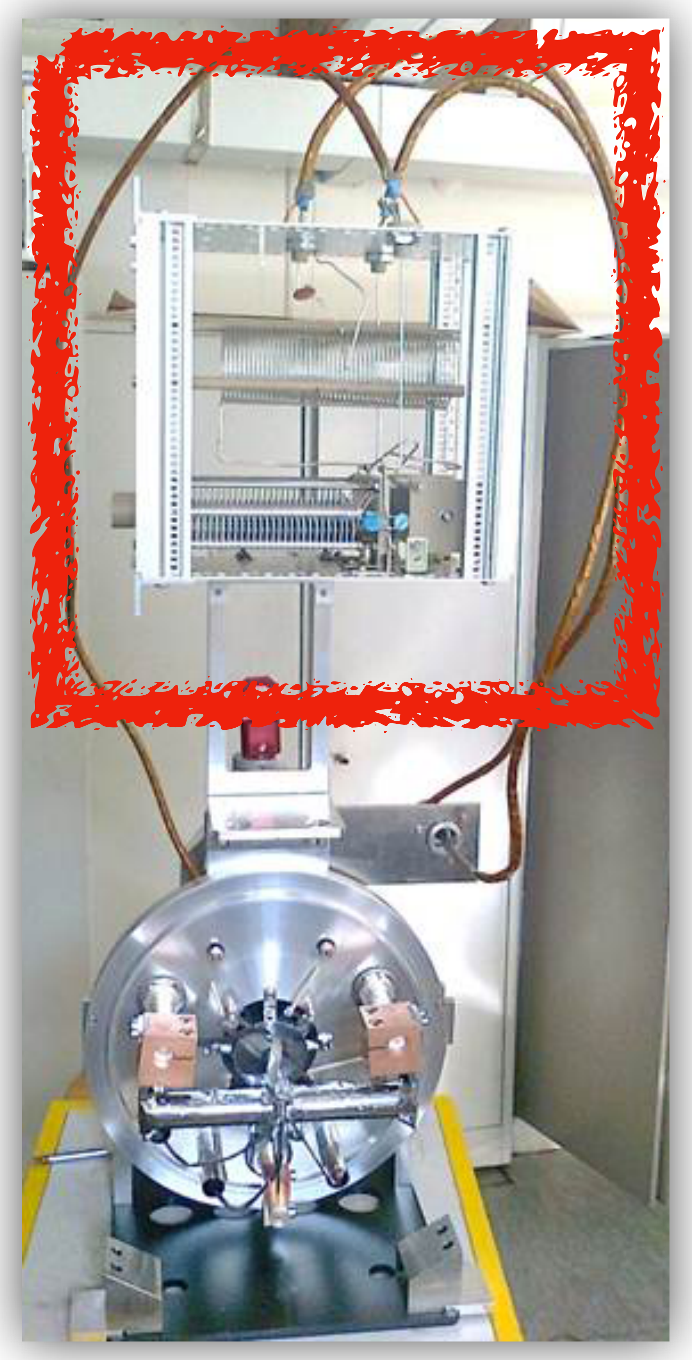


New RF and gas line connections on target side

Transformer circuit at the target unit

- Phase splitting and voltage amplification
- Radiation-hard design
- Final tuning to be done before coupling
- No direct monitoring
- Complex manufacturing for every unit
- Non-routine robot handling and storage
- Additional radioactive waste

➔ Two independent RF supply lines open up interesting alternatives!

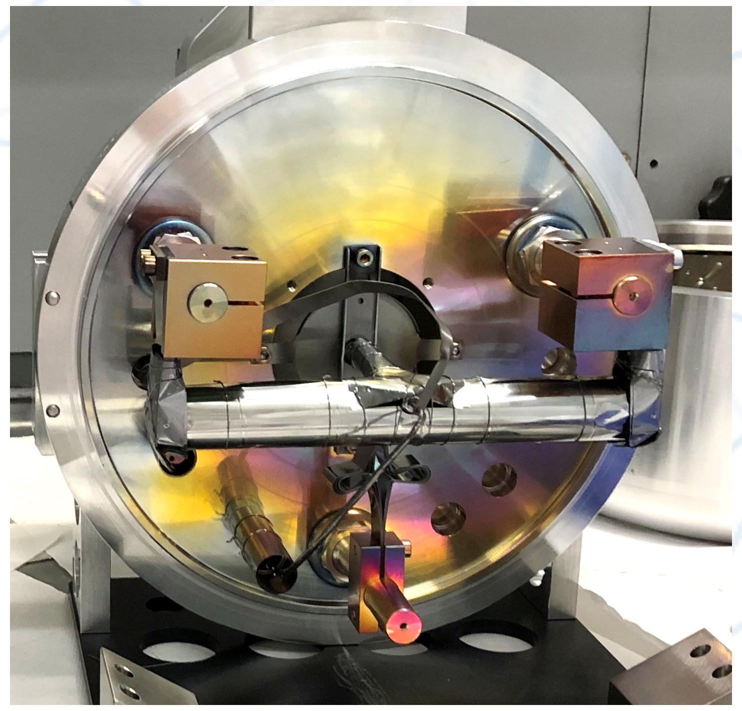


Old LIST target

R.Heinke

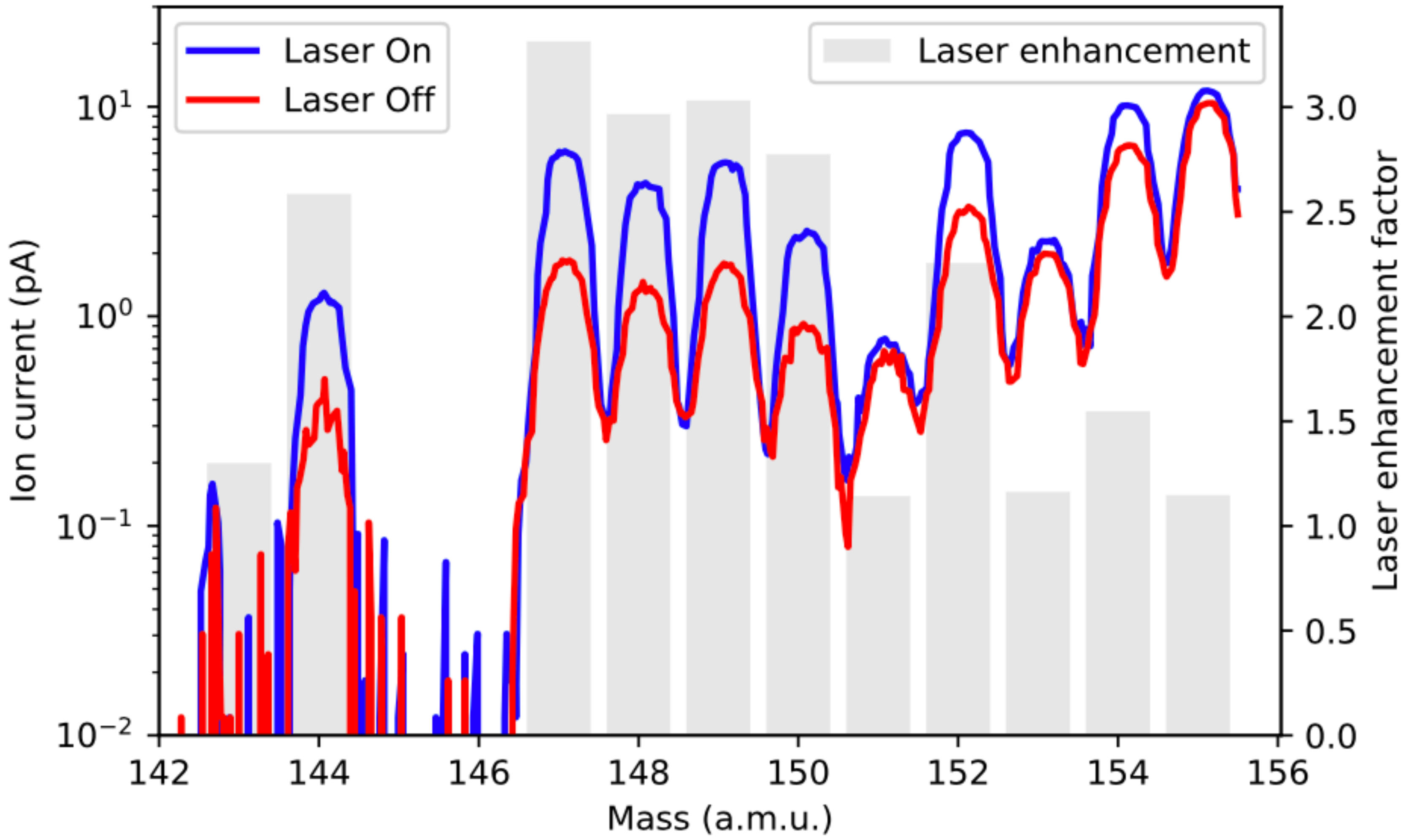
Laser Ion Source R&D

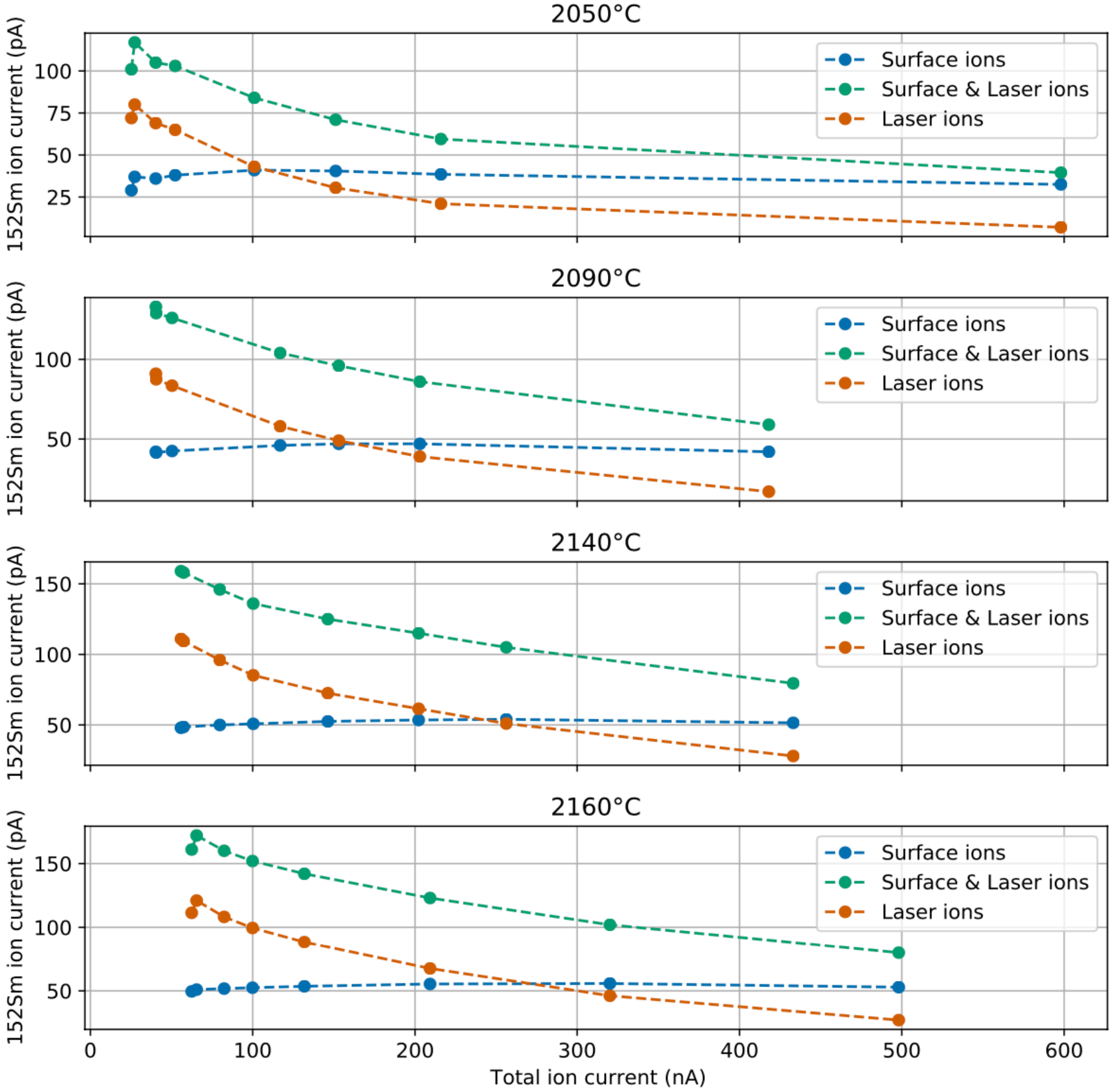
Investigating the ion throughput limit

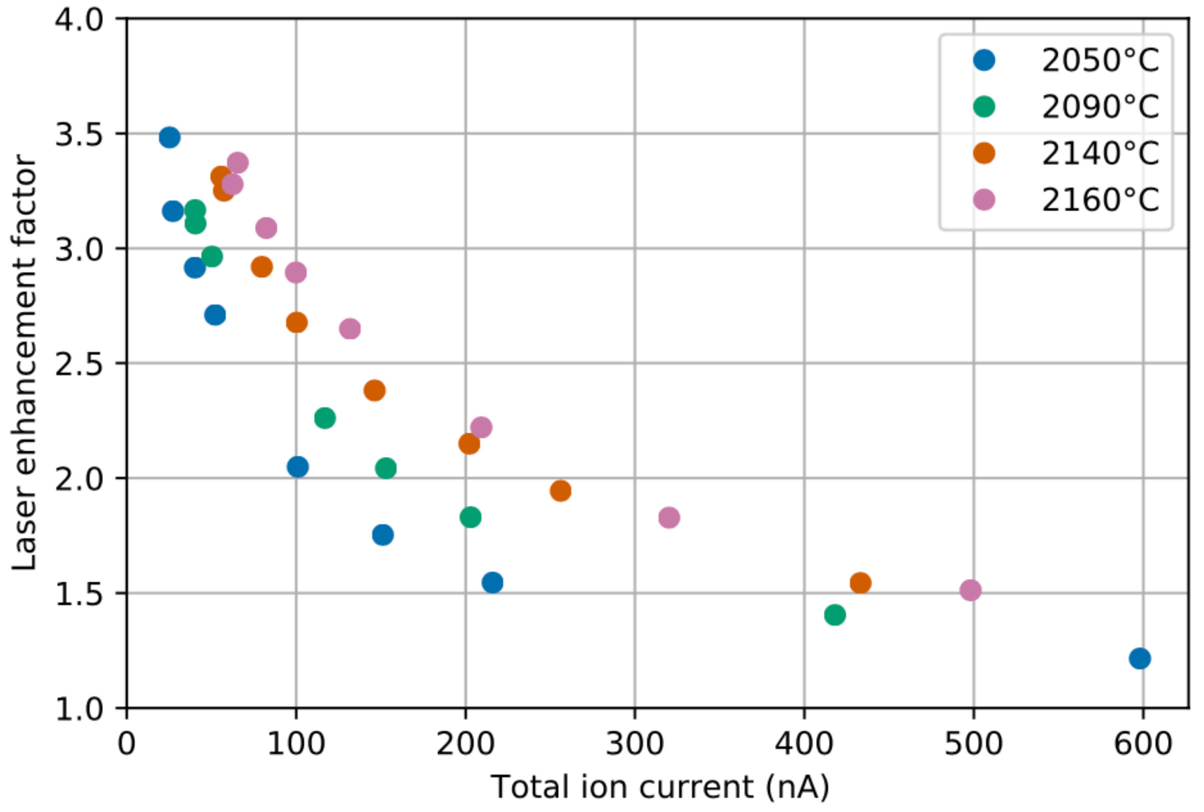


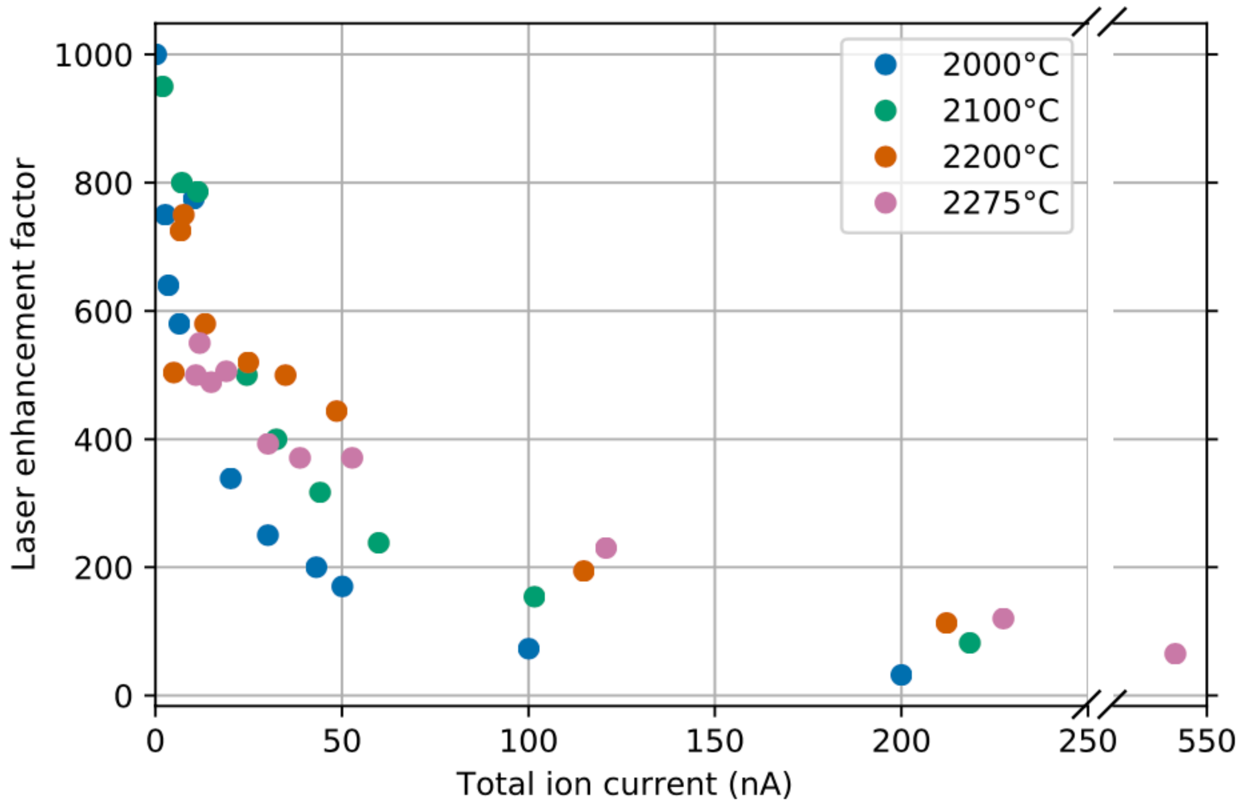
#689M (Re source)

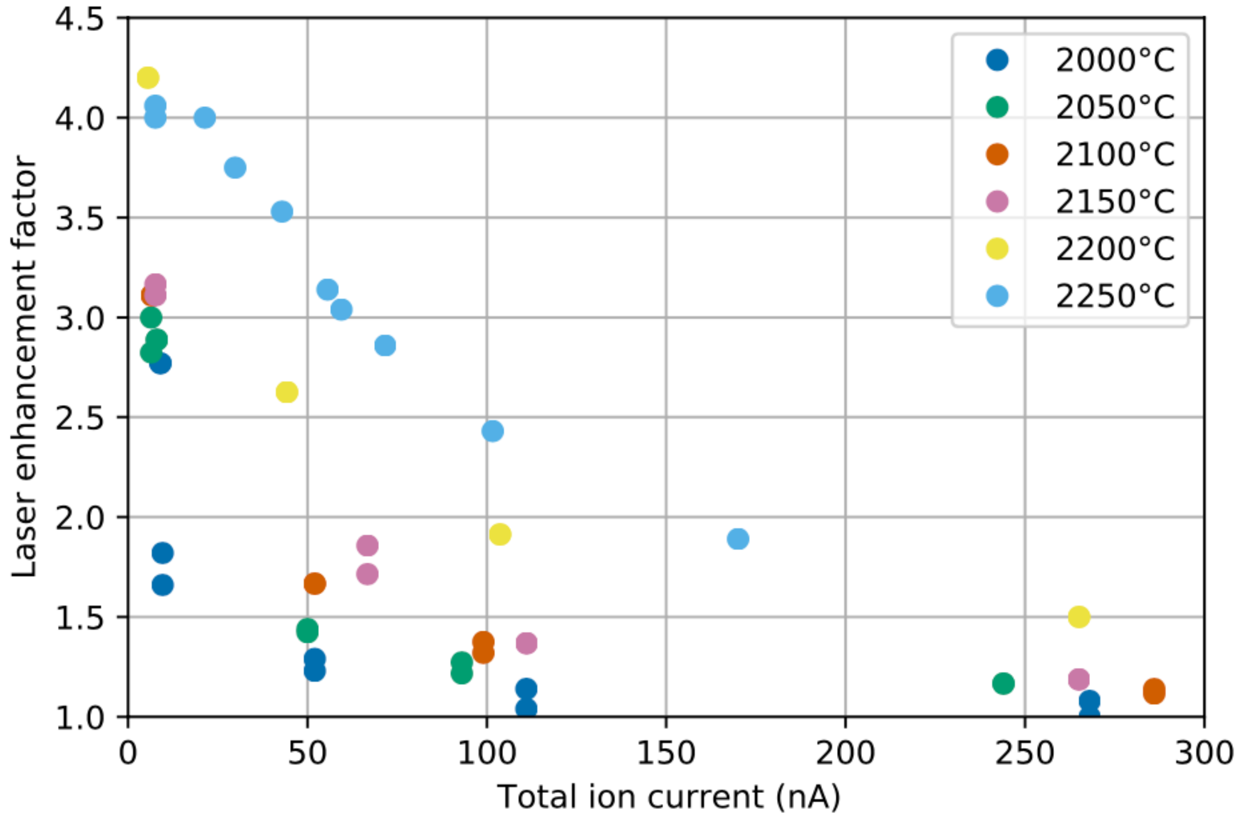
- Sm in container
- K in MM









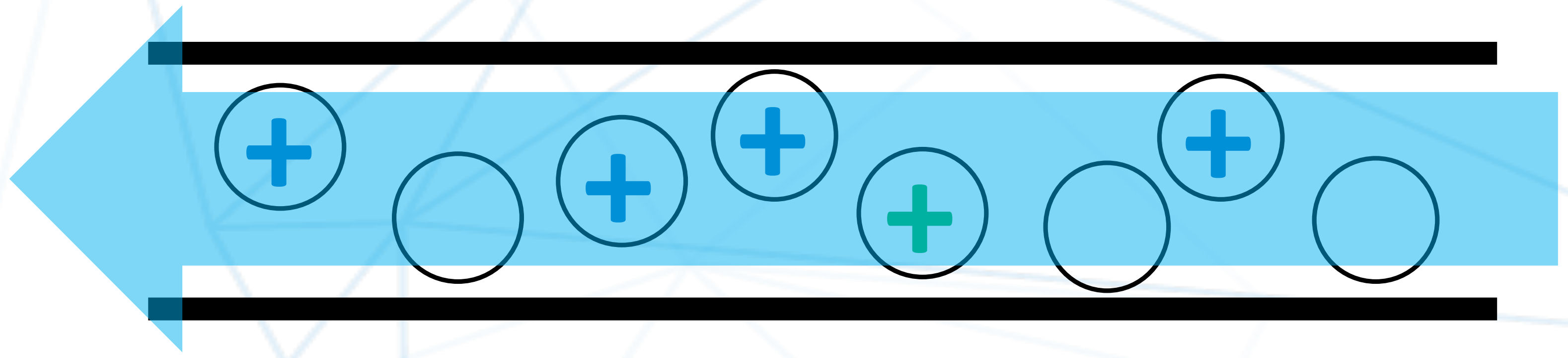


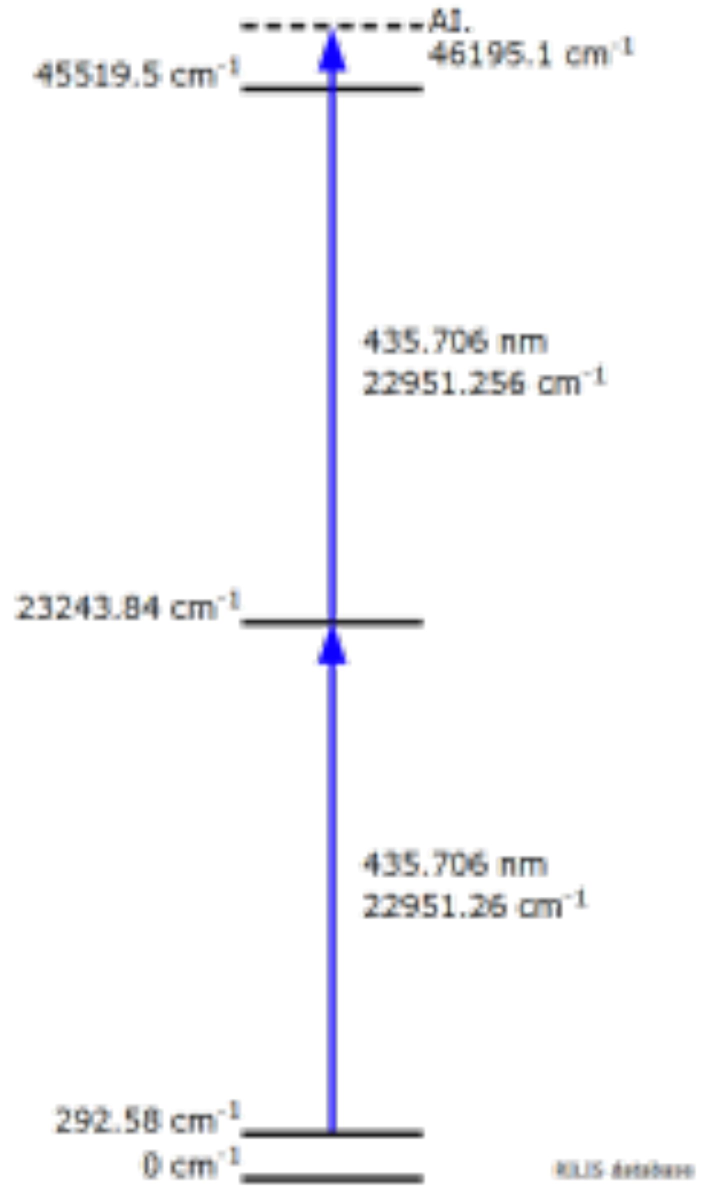
K. Chrysalidis, R. Heinke

Decoupling ‘laser ionization efficiency’ from ‘laser ion source efficiency’

“Instantaneous efficiency measurements” DOI 10.5281/zenodo.3931971

- Use two independently triggered laser systems
- Delay one system by brief time (address same atom ensemble)
- Second system will ionize only remaining atoms
- Extraction of ionization efficiencies of both systems (compare with single system ion currents)



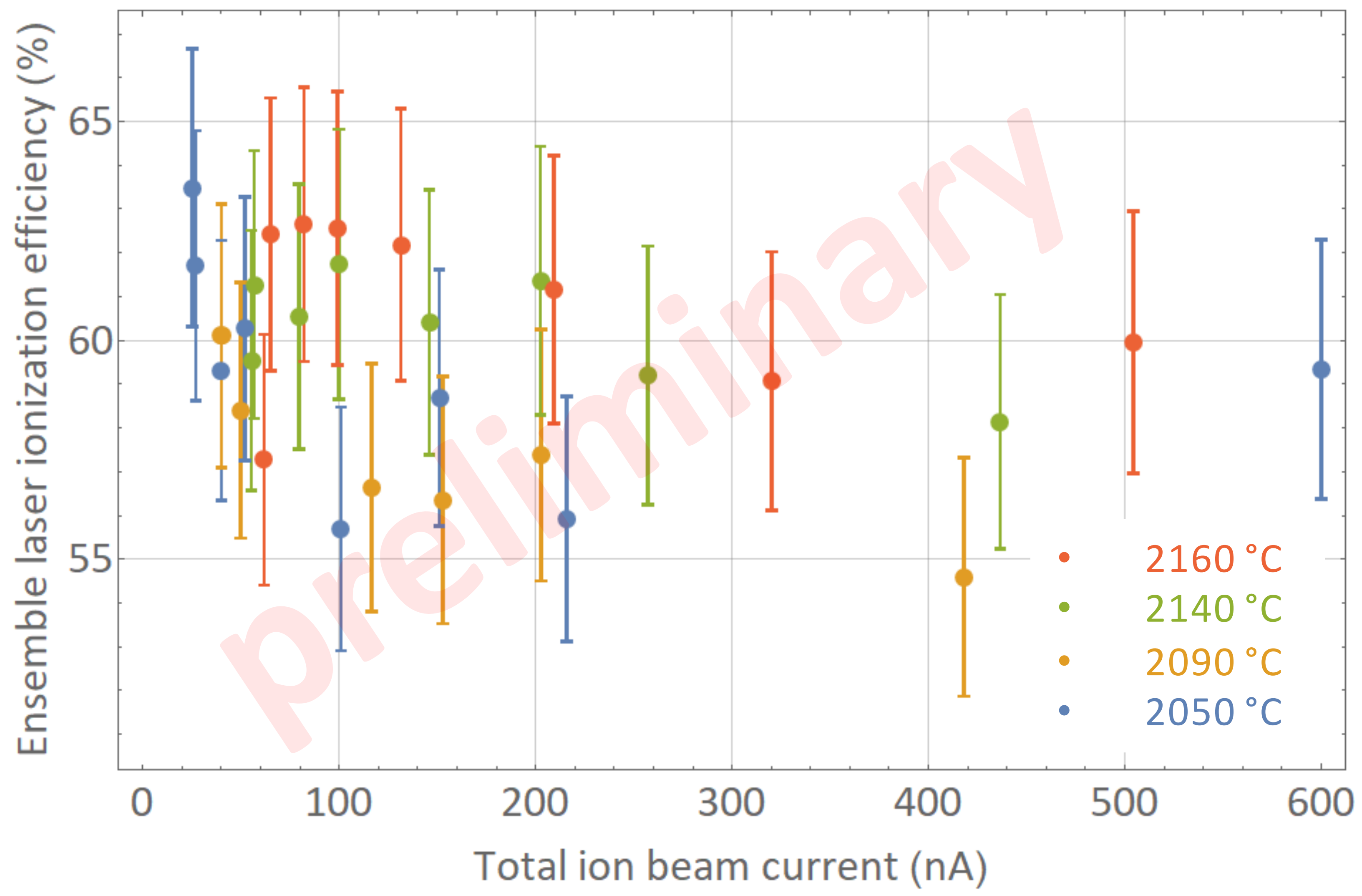


50% efficiency

25% efficiency

$$(1-E_1) * S_2 + S_1 = S_{1+2}$$

$$S_1/S_2=E_1/E_2$$



- ONLY efficiency to ionize given ensemble in right state (➔ starting point)
- NOT including evaporation, atomization, survival, extraction, transmission, …
- Sm: ≈ **60 %** of addressable atoms ionized at all checked points
- Investigate different efficiency component

K. Chrysalidis, R. Heinke

Laser Ion Source R&D

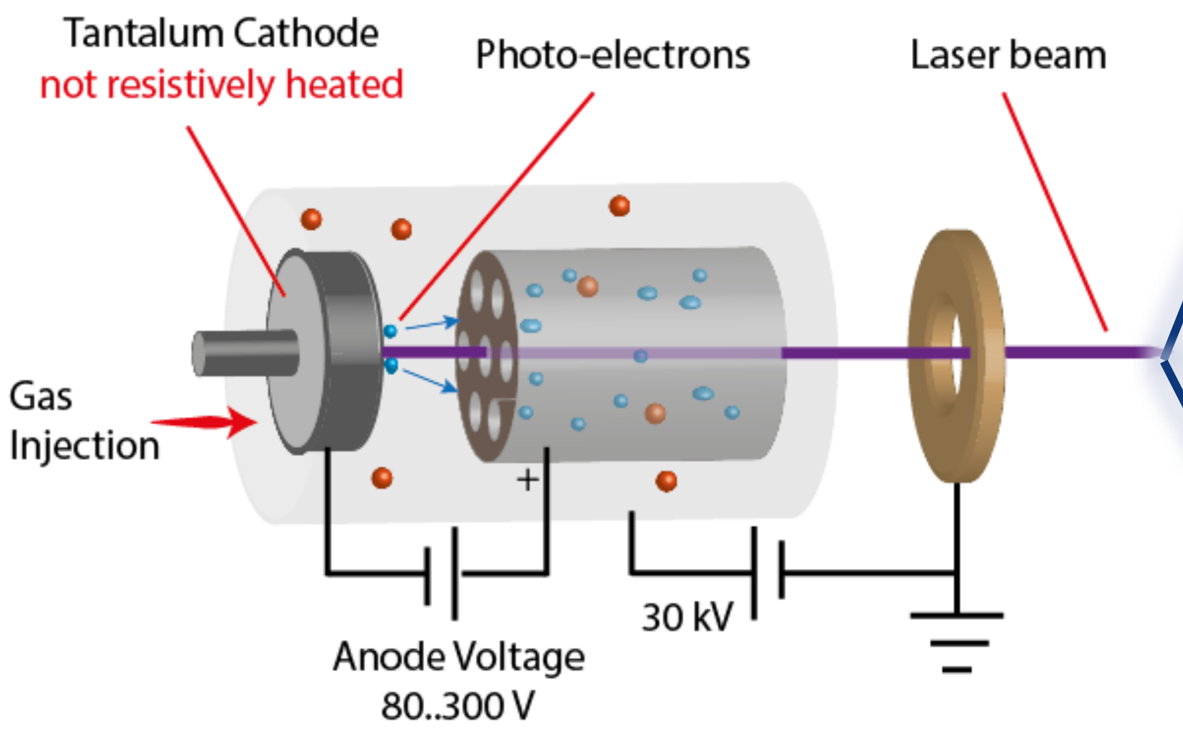
Molecular break-up and cold photo-cathode ion source investigation

Photocathode source

VADIS source at ambient temperature
Electron generation by laser, not thermal evaporation

Motivation
- Ionization of fragile molecules
- No decomposition on hot surfaces
- Diagnostic tool to measure ionization properties

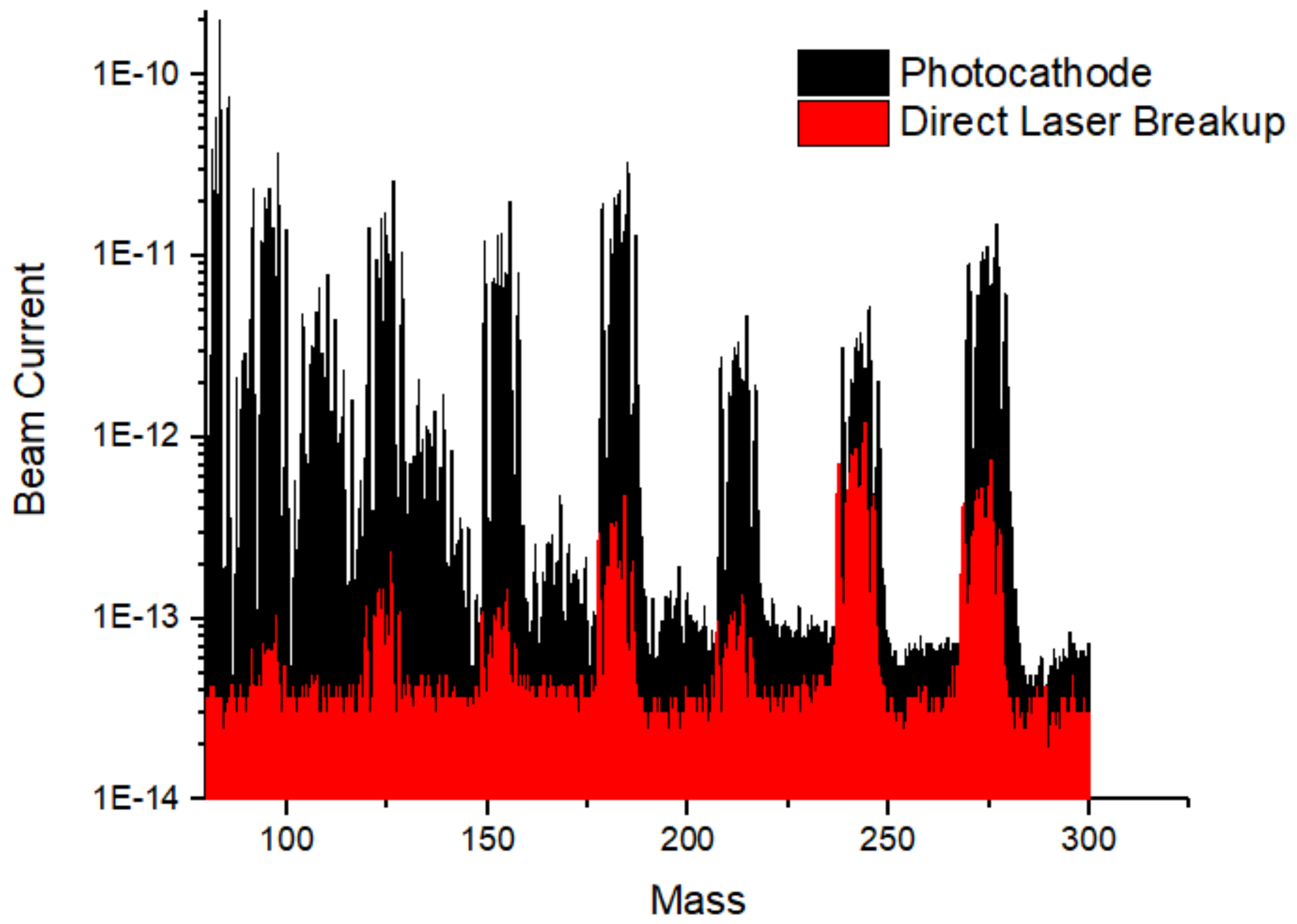
Set up



Laser properties (PHARROS)	
Pulse length	265 fs
Power	4.5 W
Wavelength	343 nm
Rep. Rate	50 kHz

J. Ballof, D. Leimbach, B.A. Marsh, A. Ringvall-Moberg, S. Rothe, S.

First Results:
Mass spectrum of $Mo(CO)_6$ + Kr



Two operation modes found

Photo cathode	Direct laser breakup
Anode biased	Anode off
Magnet 6A	Magnet off
Krypton ionized	Krypton not ionized
$Mo(CO)_3$ predominant	$Mo(CO)_5$ predominant

J. Ballof

Offline 2 RILIS lab / LISA ITN

360 kCHF for laser lab infrastructure in 2021

Laser Ion Source R&D at **ISOLDE Offline 2 separator**

- Laser Equipment is installed and initial ion source tests will begin this month.

LASER IONISATION AND SPECTROSCOPY OF ACTINIDES

- **2 LISA Fellows started at CERN**
- All **15** Fellows recruited network-wide

https://lisa-itn.web.cern.ch

[Bianca Reich](#)
ESR 02
Development of high-resolution in-source hot-cavity RILIS methods for actinides.

[Mia Au](#)
ESR 03
Target developments for extraction of actinides from thick ISOL targets followed by laser-induced molecular break-up and/or ionization.

MARIE CURIE ACTIONS

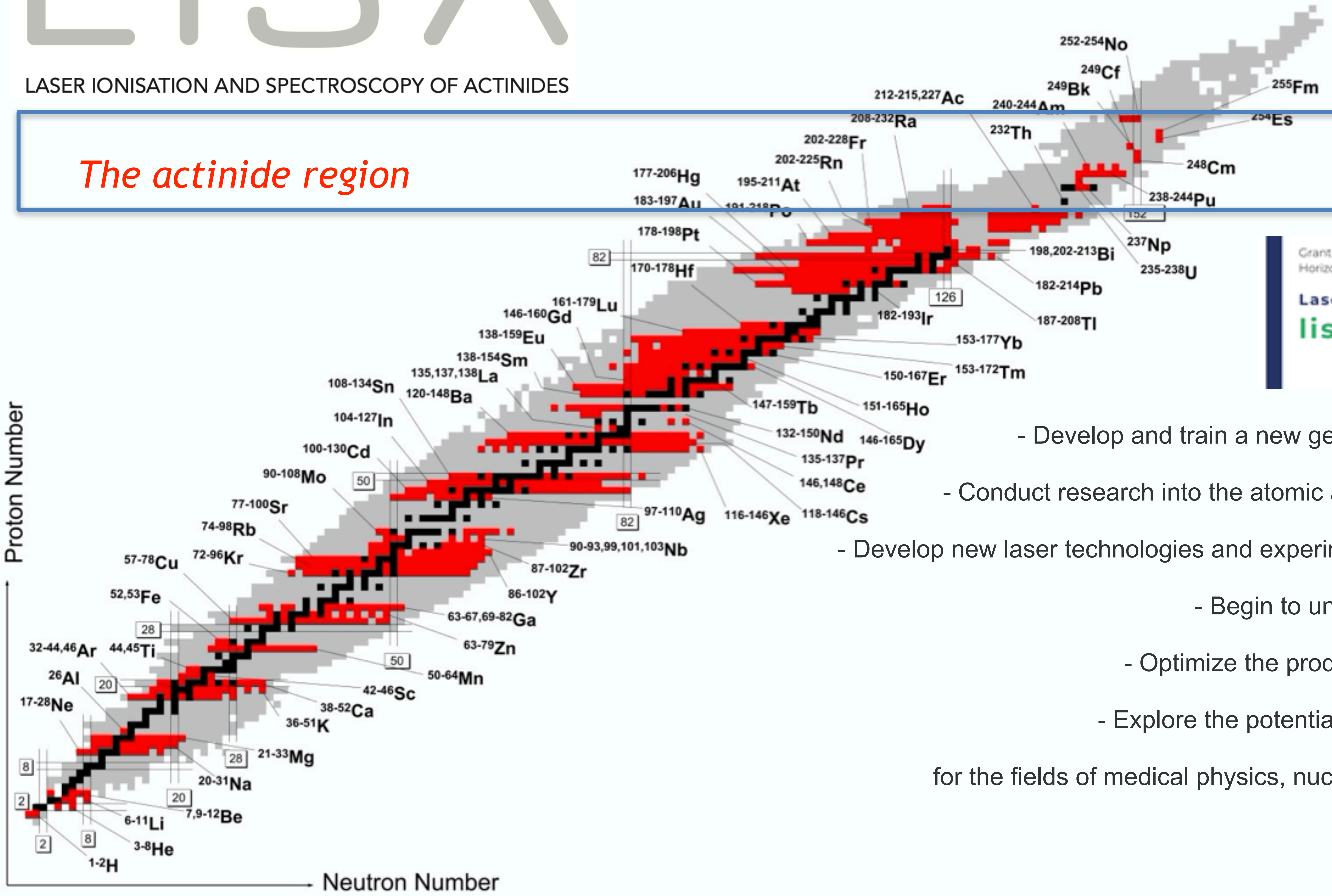
European Commission | Horizon 2020 European Union funding for Research & Innovation

LASER IONISATION AND SPECTROSCOPY OF ACTINIDES

89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
Actinium	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lawrencium
Actinide	Actinide	Actinide	Actinide	Actinide	Actinide	Actinide	Actinide	Actinide	Actinide	Actinide	Actinide	Actinide	Actinide	Actinide

The actinide region

Until very recently this has been ‘unchartered territory’



Grant Agreement No: 861198

Horizon 2020 Marie Skłodowska-Curie Action (MSCA) Innovative Training Network (ITN)

Laser Ionization and Spectroscopy of Actinides

lisa-itn.web.cern.ch

- Develop and train a new generation of atomic, nuclear and laser scientists
- Conduct research into the atomic and nuclear properties of the actinide elements
- Develop new laser technologies and experimental methods for the study of exotic isotopes
- Begin to unravel the structure of the superheavy elements
- Optimize the production, extraction and handling of the actinides
- Explore the potential practical applications of the actinide elements

for the fields of medical physics, nuclear applications and environmental monitoring

The LISA consortium

Beneficiaries + Partners

Beneficiaries

- University of Gothenburg
- University of Groningen
- ISOLDE
- GANIL / Spiral2 (laboratoire commun CEA/DRF, CNRS/IN2P3)
- GSI
- JGU
- Hübner
- Leibniz Universität Hannover
- M Squared
- Friedrich-Schiller-Universität Jena
- Jyväskylän Yliopisto / University of Jyväskylä
- KU Leuven

Partners

- Pantechnik (Boost Your Physics)
- Angara Technology
- LIOPTEC
- Lawrence Livermore National Laboratory
- Uniwersytet Jagielloński w Krakowie
- Tel Aviv University
- UNSW Australia
- Manchester 1824, The University of Manchester
- Stable Laser Systems
- IRÉPA LASER
- TRIUMF
- iER
- Nagoya University

The 15 LISA ESRs

LISA
LASER IONISATION AND SPECTROSCOPY OF ACTINIDES

UNIVERSITY OF GOTHENBURG

university of groningen

ISOLDE

GANIL spiral2
laboratoire commun CEA/DRF CNRS/IN2P3

GSI

JG|U

HÜBNER

Leibniz Universität Hannover

M SQUARED

FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

KU LEUVEN

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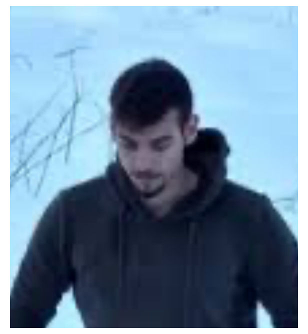
CERN Fellow
Since Jan 2020

Ralitsa Mancheva

TECH Student



Georgios Stoikos

Internship

Shane Wilkins

CERN Fellow
until end 2020

Vaila Leask

Former CERN Tech student
Now LISA ESR @ KULeuven