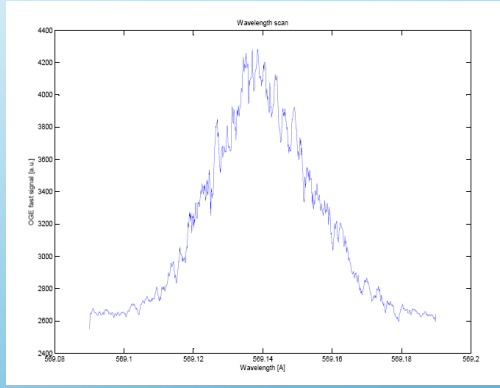
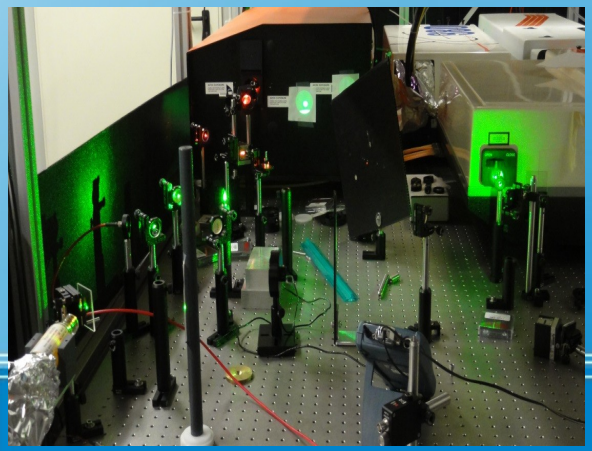
First results on Ge resonant laser photoionization in a hollow cathode lamp

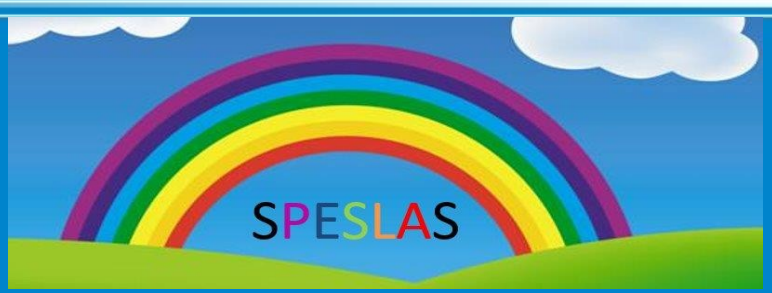


Emilio Mariotti
DSFTA – UniSiena
(on behalf of the
SPES collaboration)

SPES
Selective Production of
Exotic Species



La3Net Conference – Son Caliu, 25 March 2015



SPESLAS

Emilio Mariotti

DSFTA

Alberto Andrighetto, Daniele Scarpa

INFN Laboratori Nazionali di Legnaro

Piergiorgio Nicolosi

Università degli Studi di Padova

Alessandra Tomaselli

Università di Pavia

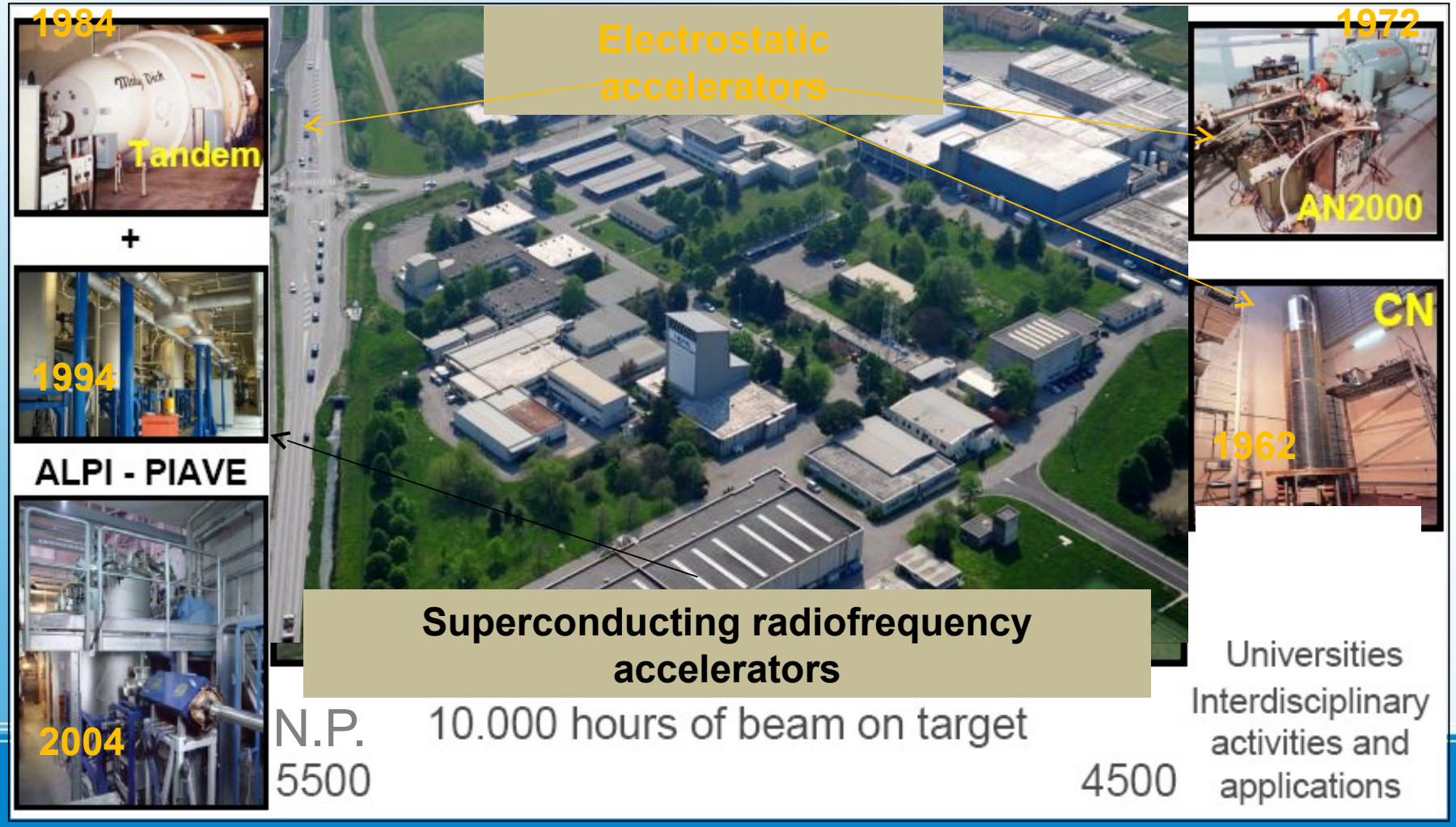
Anatoly Barzach, Dimitry Fedorov

NATIONAL RESEARCH CENTRE "KURCHATOV INSTITUTE"

The “SPES” location (?)

The “SPES” (real) location

The INFN Legnaro Laboratory



Nuclear Physics - Fundamental Interactions – Interdisciplinary Physics - Detector Techniques - Accelerator Design & Technology - Superconductivity

SPES: The “hope” of LNL

SPES is:

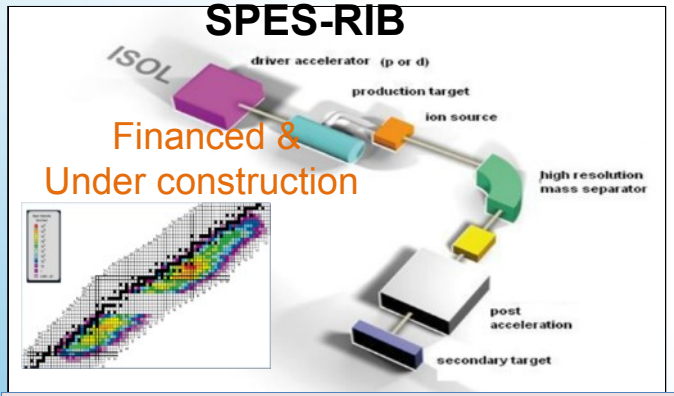
1) A second generation ISOL facility (for neutron-rich ion beams)
2) An interdisciplinary research center (for p,n applications)

SPES-DRIVER

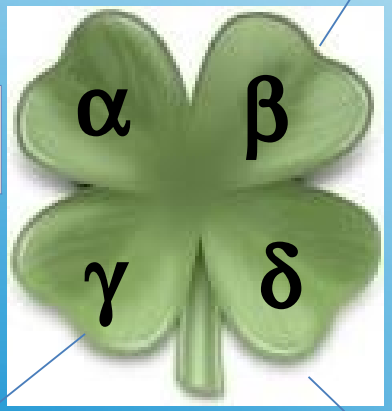
Cyclotron :

- E=70 MeV proton beam, I= 750 μA

SPES-RIB

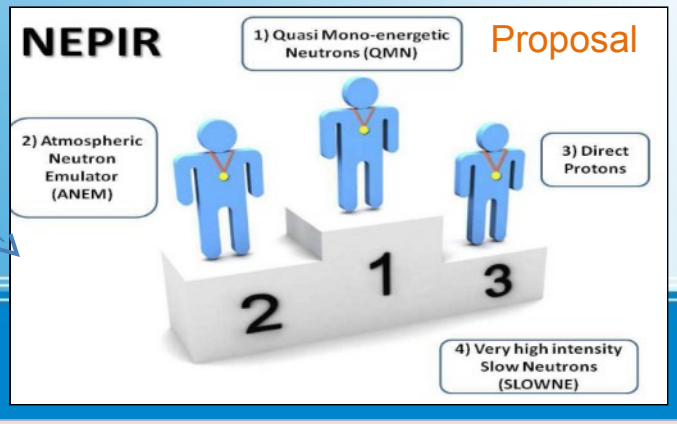


Production & re-acceleration of **exotic beams**, from **p-induced Fission** on **UCx**



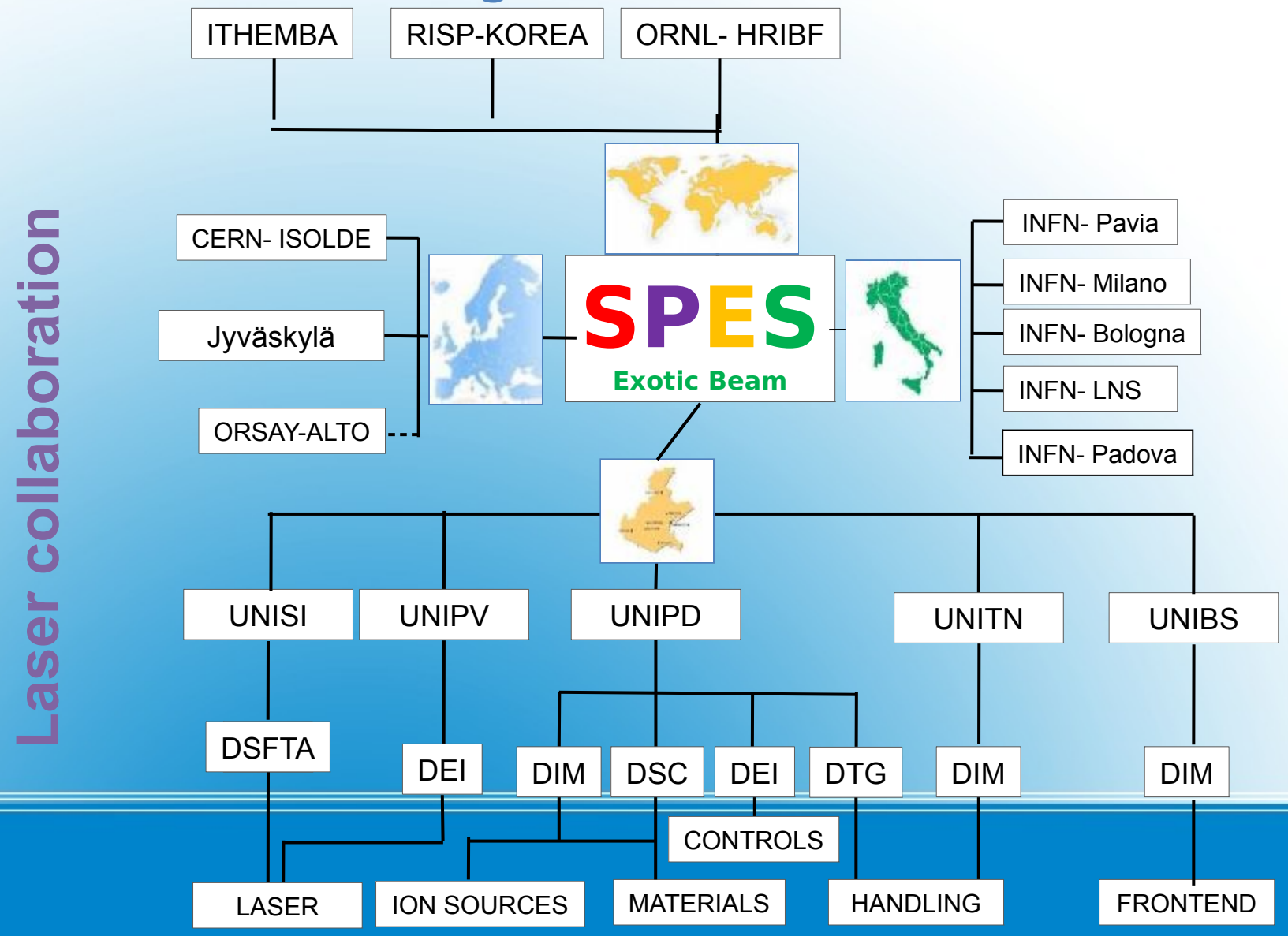
SPES-LARAMED

Research and Production of
Radio-Isotopes for Nuclear Medicine

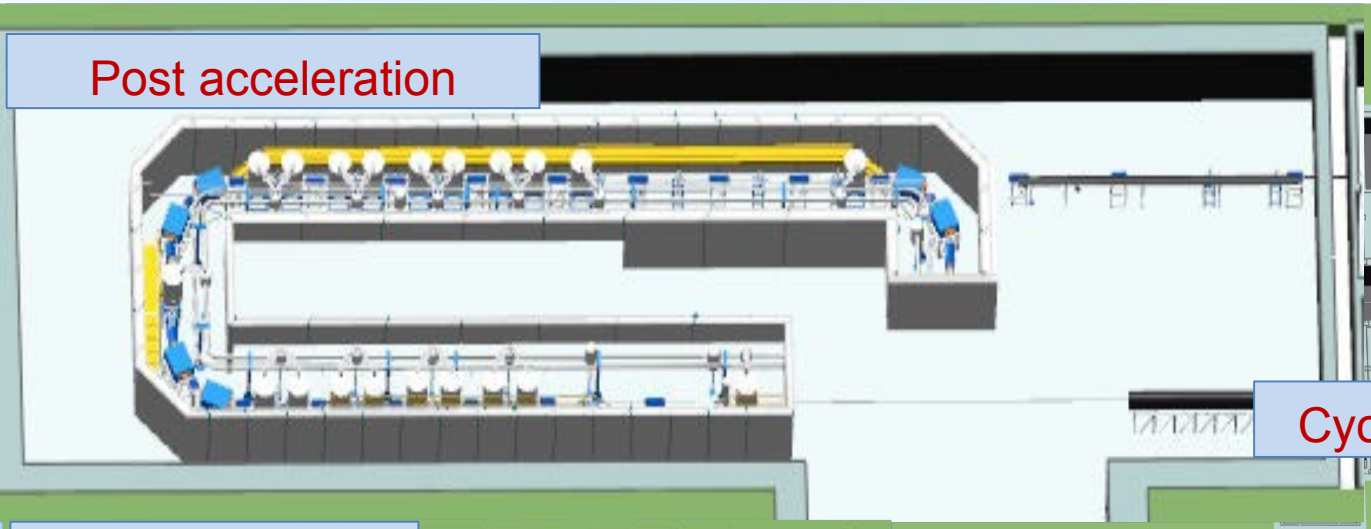


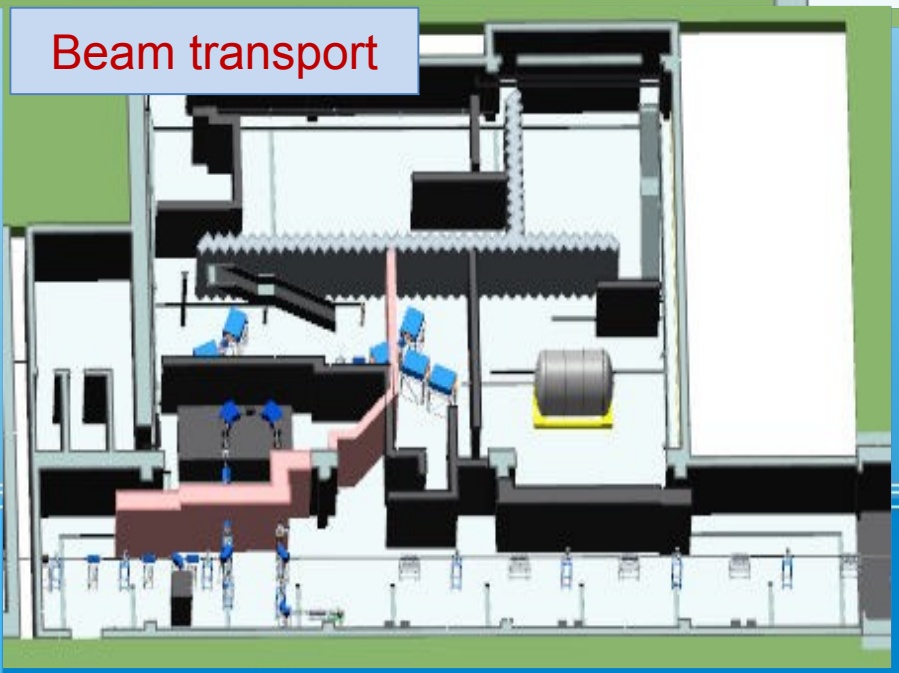
Accelerator based neutron source
(**Proton and Neutron Facility for Applied Physics**)

SPES EB : a large collaboration network...

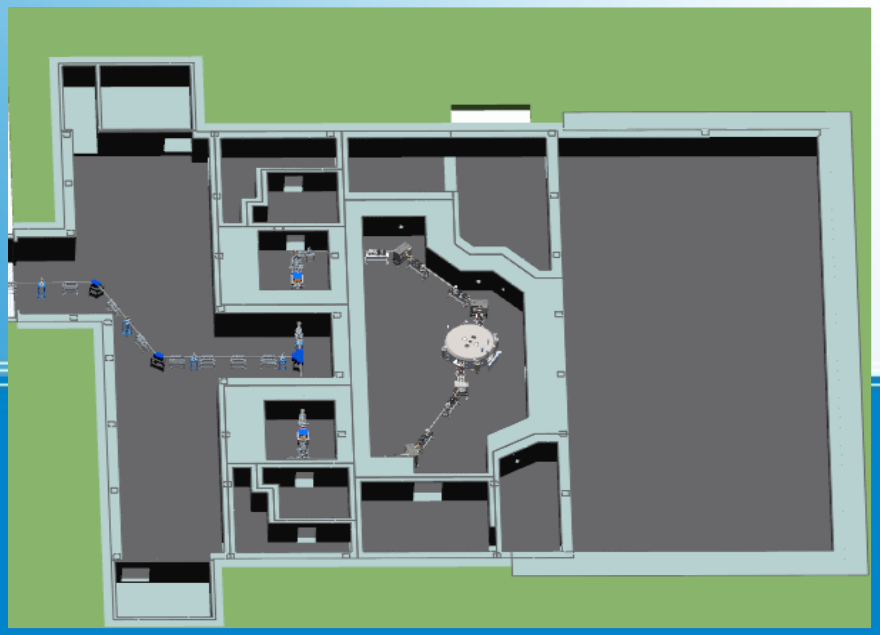


The Spes layout





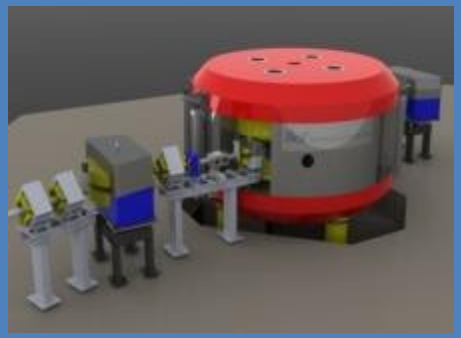
The Spes building yesterday



The SPES main apparatus

Driver:

'Commercial' cyclotron

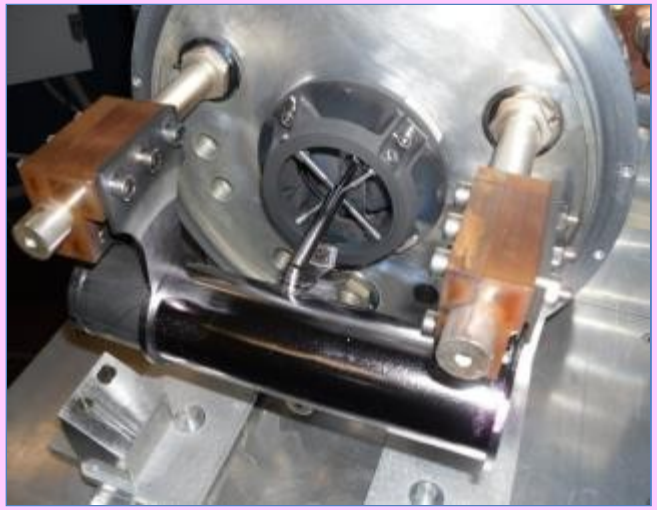


RIB manipulation stage

- Mass Separator (WF)
- Beam Couler
- HRMS
- Charge Breeder
- RFQ

Production Target:

NEW CONCEPT
(Multi-foil UCx target)



Target-Ion Source Complex:

- optimized for 8kW beam power
- Eproton = 40 MeV for RIB
- 10^13 fission/s.

Post Accelerator:

Alpi existing complex

SPES Elements production

- surface ionization mechanism
- laser ionization mechanism
- electron impact ionization mechanism
- not extracted

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
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 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une	110 Unn								

The LASER Laboratories

Offline: Spectroscopy

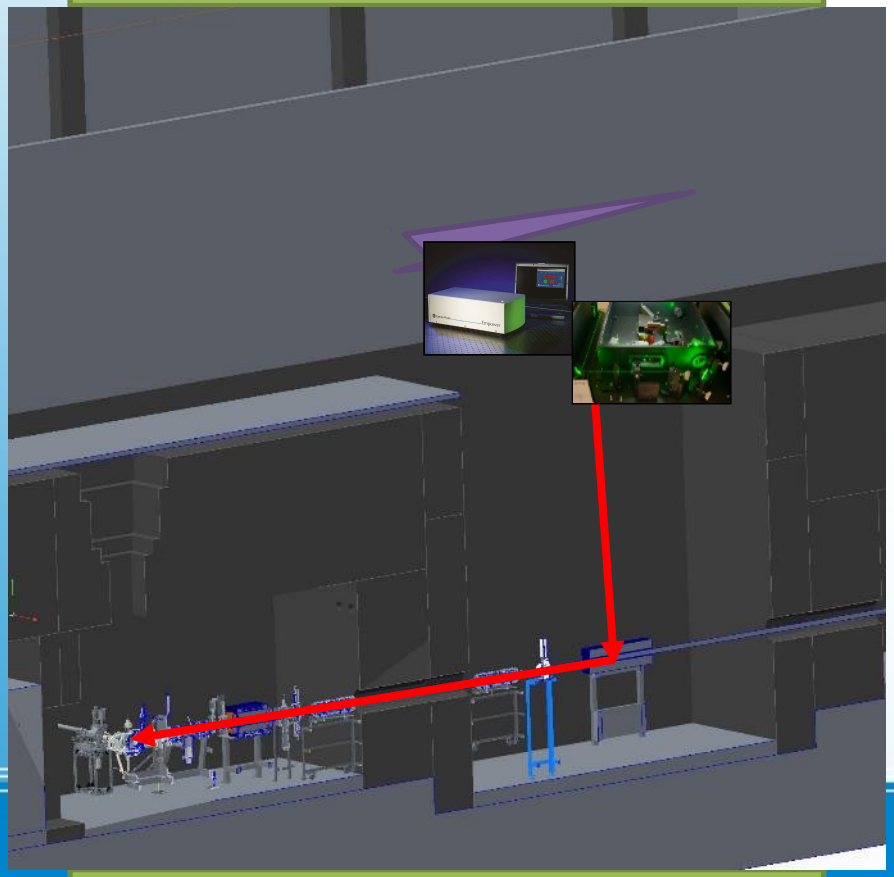
- 3 Dye Laser @ 10 Hz rep. rate

Diagnostic tools:

- Monocromator
- HCL
- ToF Mass Spectrometer

Online (SS laser): RIB prod.

- 3 TiSa Laser @ 10 kHz rep. rate



Diagnostic tools:

- Λ-meter
- Alignments System
- Ion-Beam

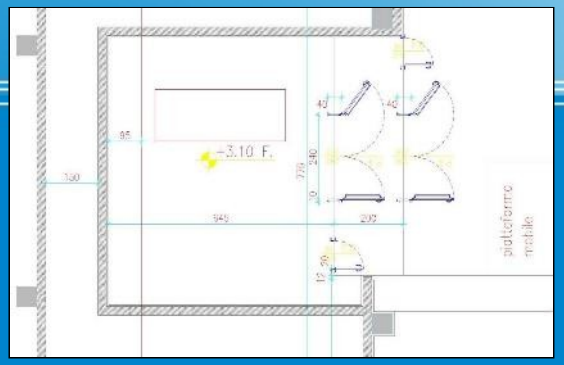
The LASER Group

Spectroscopy:

- Study of different elements of interest
- Offline-lab with 10Hz dye laser system
- HCL
- ToF-MS

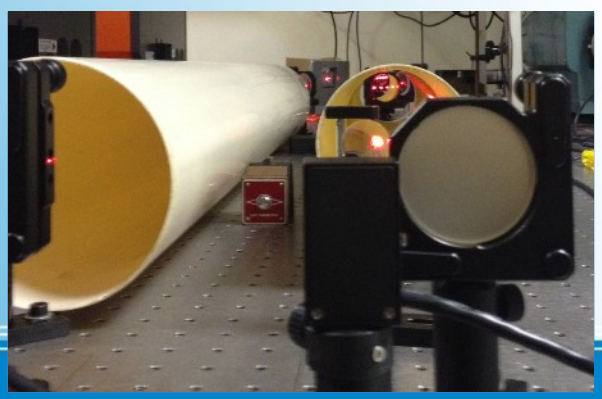
New SS laser:

- Defining RIB production laser requirements
- 10 kHz TiSa laser
- New laser lab requirements



Transport:

- Taking care of 20 m laser beam delivery
- Study of beam positioning instability compensation



Detection scheme

Hollow cathode lamp (gas discharge)
Optogalvanic spectroscopy

Designed to provide spectral emission of different elements.

- Commercial for Opto Galvanic application
- Inexpensive
- Available for almost the whole periodic table
- Electrical noise is very small, comparable with the level of shot noise
- Easy setup

$$E_i \rightarrow E_k$$

$$\Delta n_i = n_{i0} - n_{iL}$$

$$\Delta U = R\Delta I$$

$$\Delta U = R\Delta I = a[\Delta n_i IP(E_i) - \Delta n_k IP(E_k)]$$

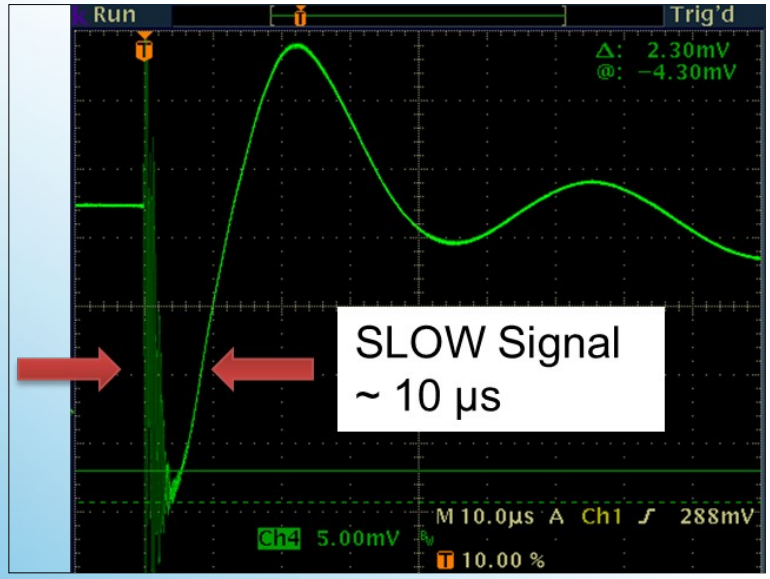
$$A(E_i) + e^- \rightarrow A^+ + 2e$$

$$A(E_i) + B^* \rightarrow A^+ + B + e^-$$

$$A(E_i) + h\nu \rightarrow A^+ + e^-$$

Opto Galvanic Signals

SLOW Opto-Galvanic Signal:
The absorption of laser radiation in the discharge results in a change in the steady-state population of bound atomic or molecular levels. Since different levels will have different ionization cross-sections or ionization probabilities, a perturbation to the steady-state situation results in a net change in the discharge current or equivalently a change in the discharge impedance. The electric signal detected is the slow signal, negative and lasting µs.

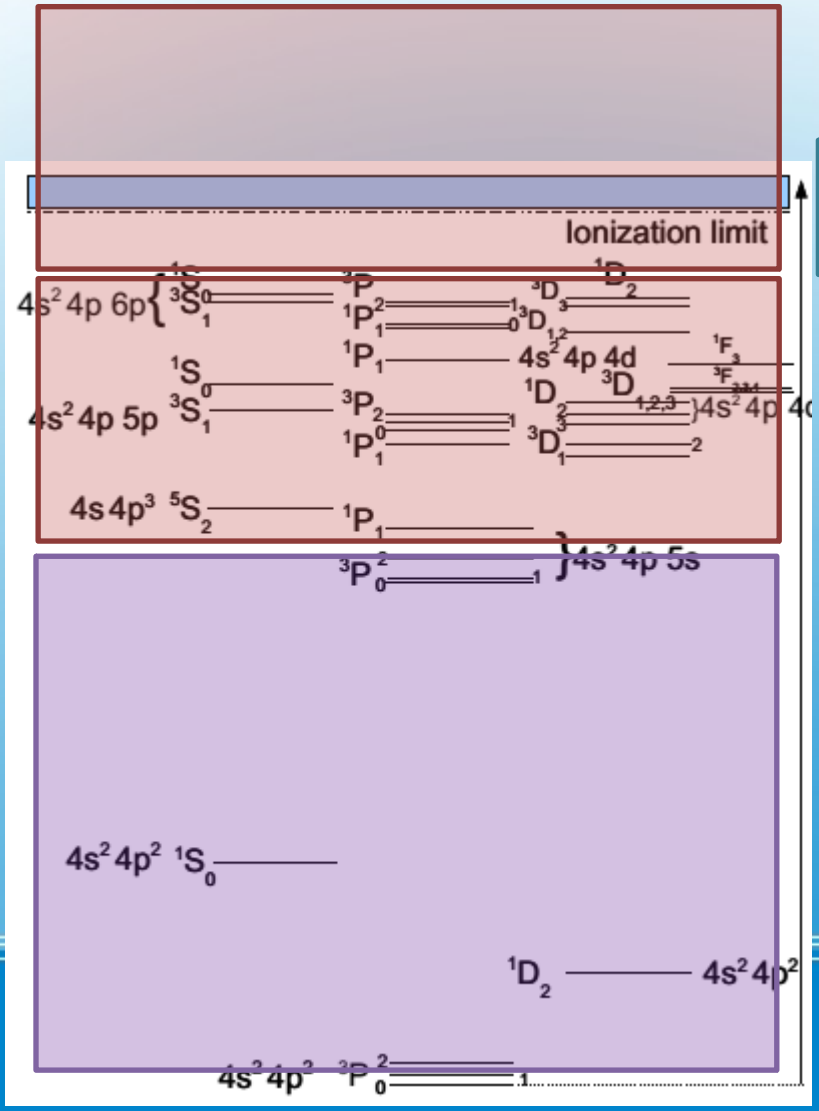


FAST Opto-Galvanic Signal:
It is a direct ionization process during laser pulse. The laser radiation brings the selectively excited atoms directly to ionization. Electrons are immediately available as carriers.
This effect produces a fast electric signal. It was found (Broglia et al 1983 [3]) that this fast signal follows the laser pulse temporal behavior (ns).

[3] M.Broglia, F.Catoni, P.Zampetti: "Temporal behaviour of the optogalvanic signal in a hollow cathode lamp", Journal de Physique, Colloque C7, supplement au n° 11, Tome 44, novembre 1983

Germanium

First element selected to perform resonant ionization:



Ionization energy => 7.900 eV, (63713.24(10) cm-1)

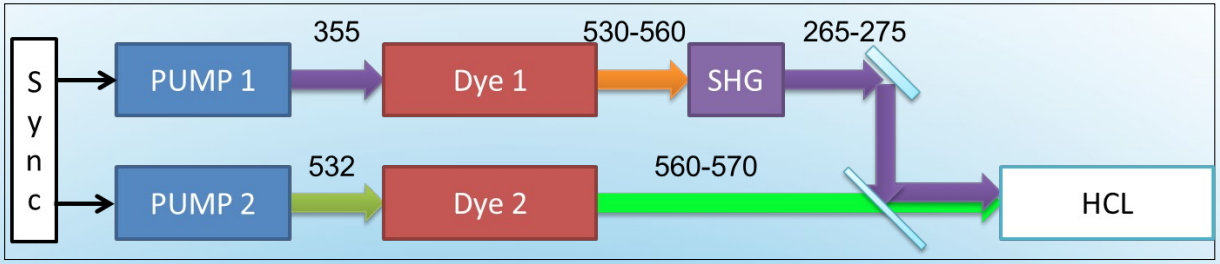
Ionization scheme:
2 color – 3 ionization step

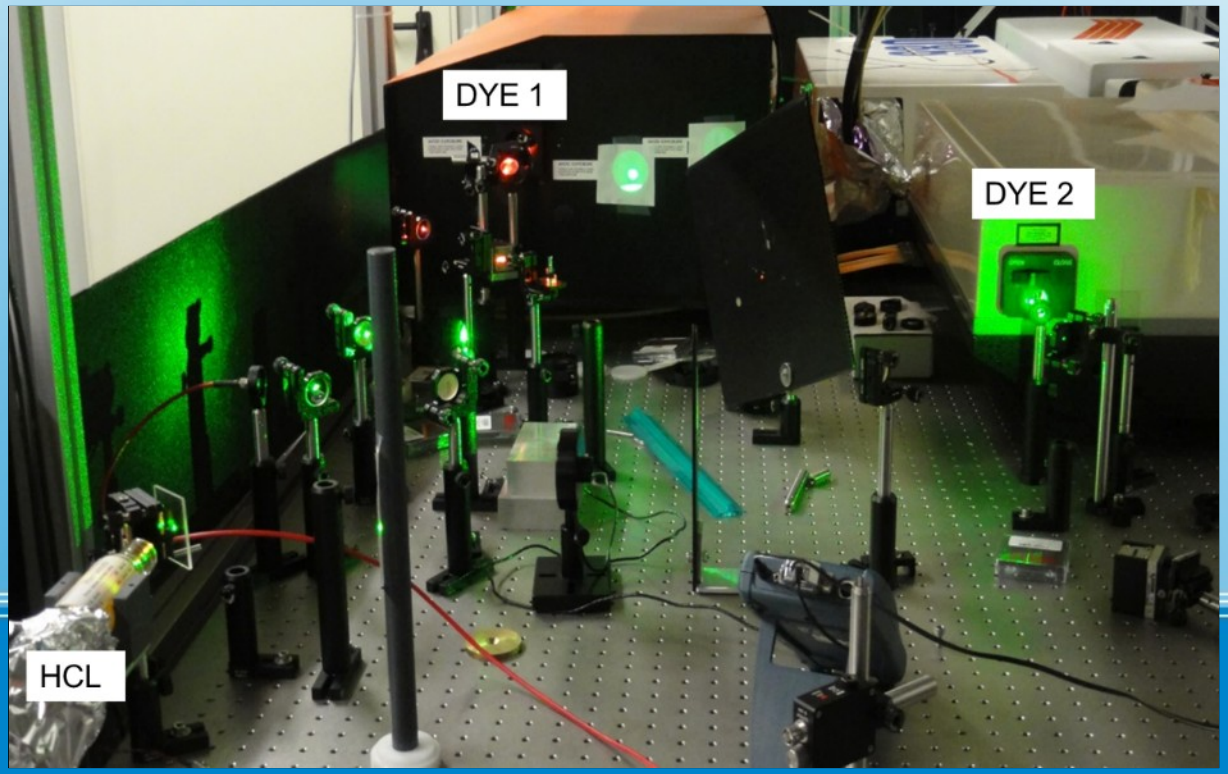
1 step in UV region

2 step in visible region

3 step recycling photons from 2 step

Experimental Setup





Pump 1:

- 355 nm pump laser
- 100 mJ - 20 nsec laser pulse
- 10 Hz rep rate

Pump 2:

- 532 nm pump laser
- 300 mJ - 20 nsec laser pulse
- 10 Hz rep rate

Dye 1:

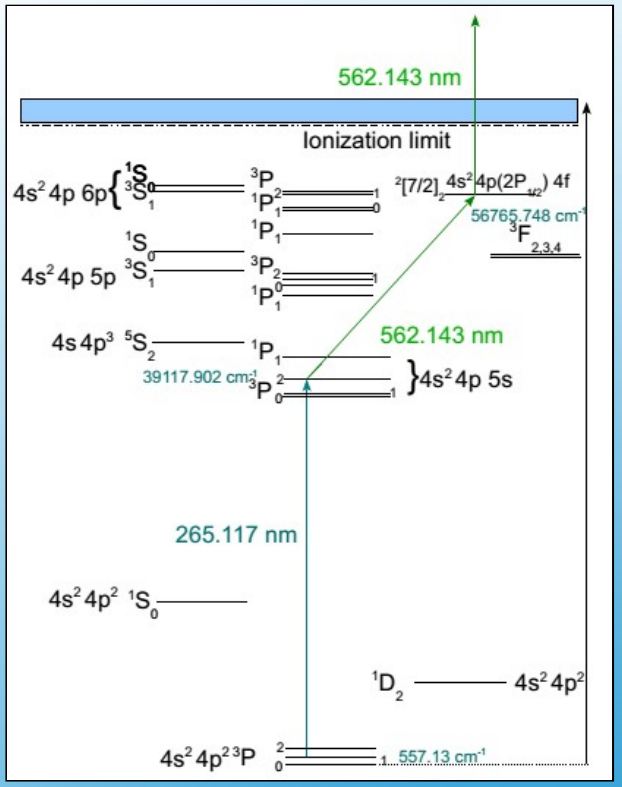
- FL2002 Lambda Physik
- Coumarin 540
- 4 to 10 µJ per pulse

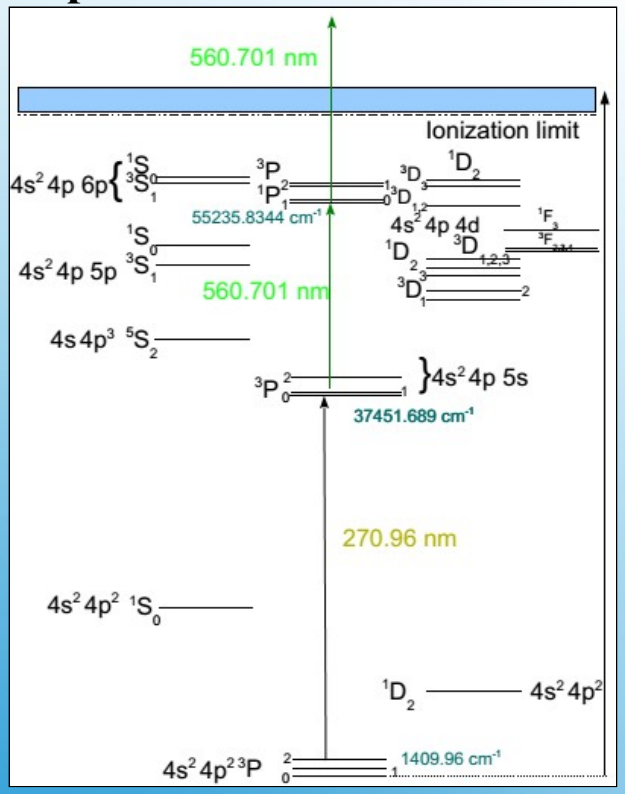
Dye 2:

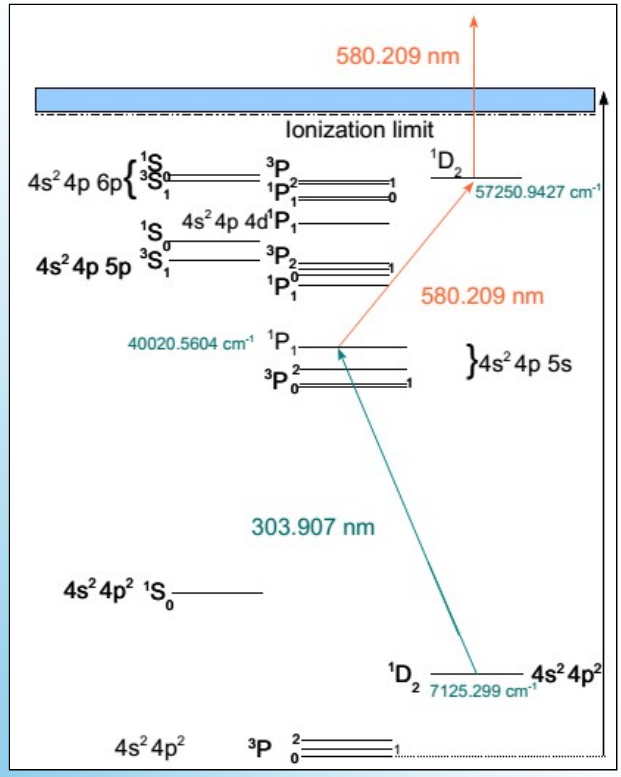
- TDL50 Quantel
- Rodhamine 6G
- 50 µJ per pulse

Results

Multiple ionization schemes tested:







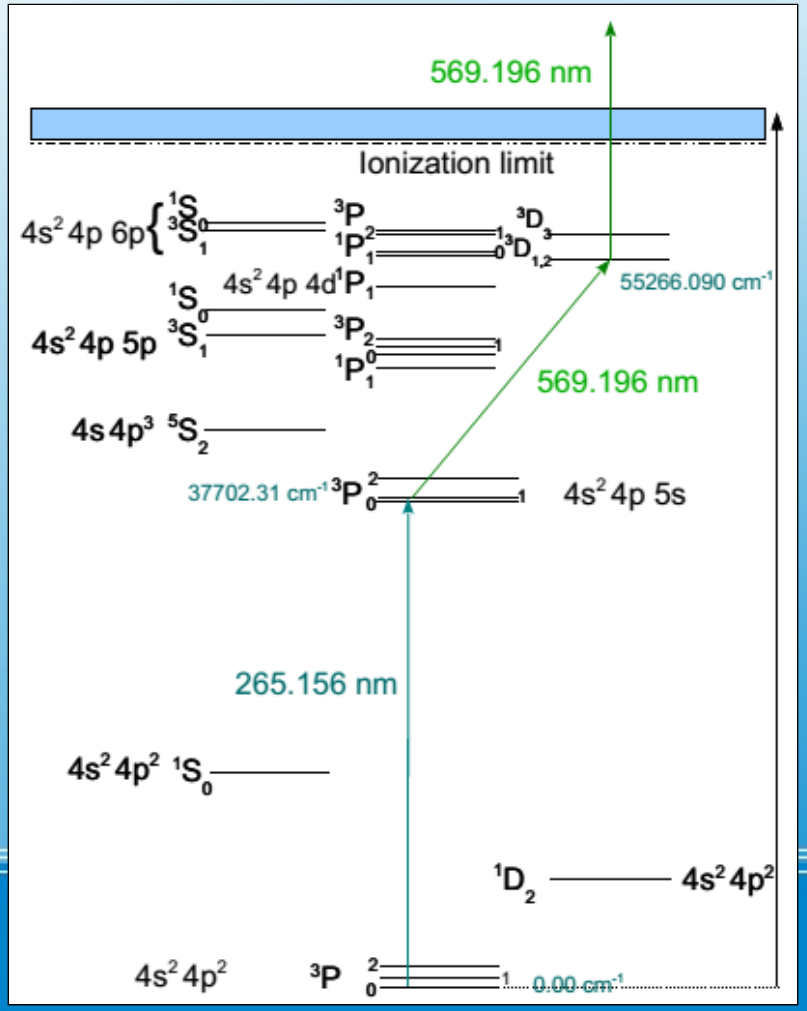
Schemes:
265,117 nm + 562,143 nm
265,117 nm + 565,596 nm
265,117 nm + 566,484 nm
265,156 nm + 561

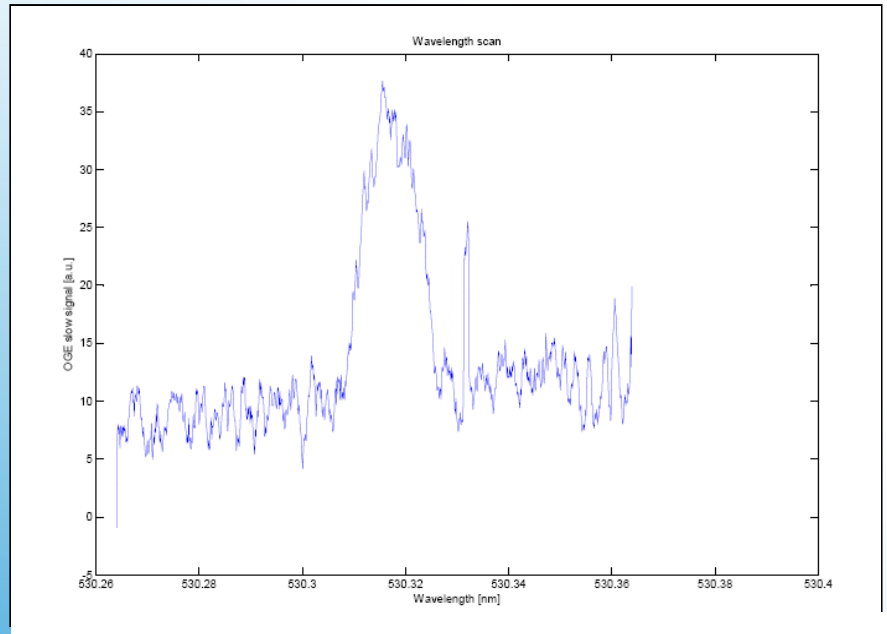
Schemes:
269,13 nm + 570,178 nm
270,96 nm + 560,701 nm
275,46 nm + 561,613 nm

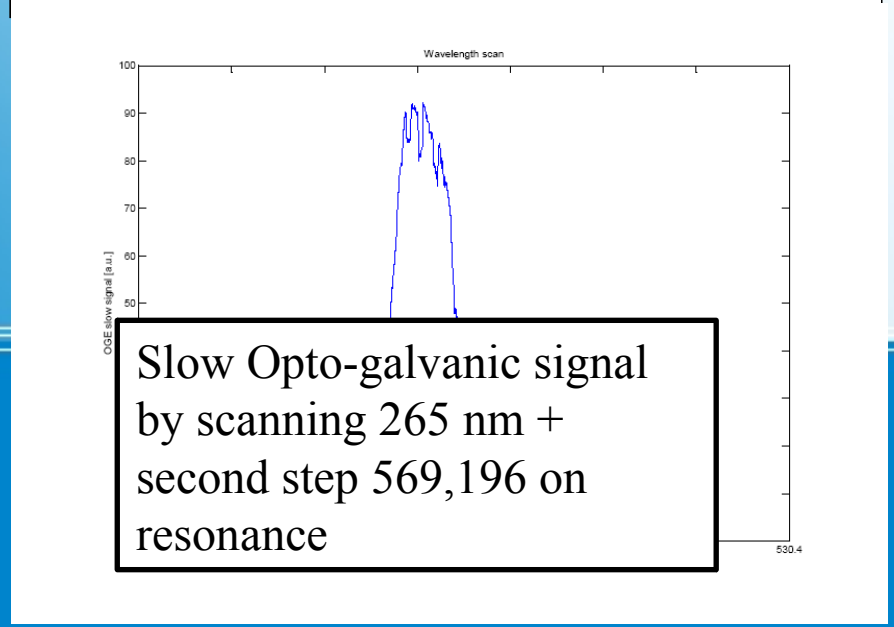
Schemes:
303,907 nm + 580,209 nm
303,907 nm + 566,423 nm

Results

Wavelength Scans along ionization paths:





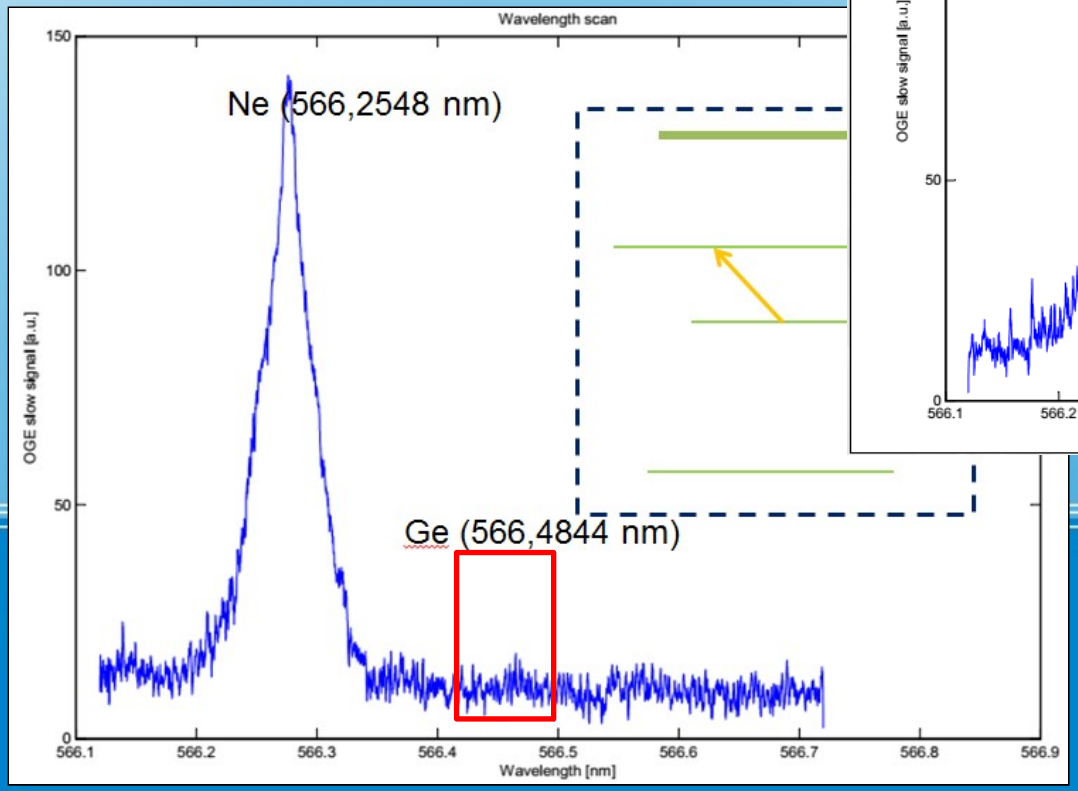


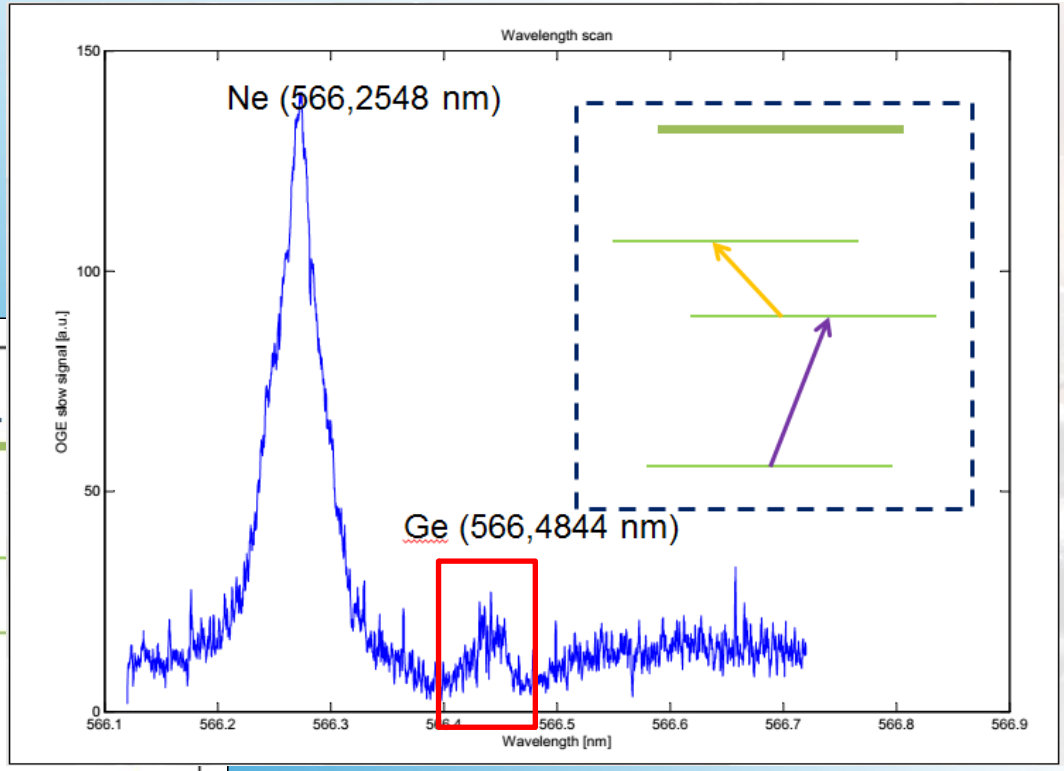
Slow Opto-galvanic signal by scanning 265 nm + second step 569,196 on resonance

“Slow signal” of ionization scan with the fixed at 303 nm first step

Scan across 566 nm resonance was performed with TDL 50

No first step; Only second step





First step + Second step

Conclusions

Since end of 2014:

- New SPES laser laboratory in LNL operational
- First results on Resonant Laser Ionization on Germanium
- Proof HCL OGE signals valid technique to perform laser spectroscopy

Development for SPES laser lab in 2015:

- Test resonant ionization with HCL for other elements (Sn; Ga; As)
- Setting up an home made ToF-MS adding MCP's
- Setting up a 'laser front end' for LIS studies for SPES project
- Purchase of new Solid State Laser System for online lab