Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 77 (2015) 15 – 20

Physics Procedia

International Conference on Laser Applications at Accelerators, LA3NET 2015

Developing Ti: Sa laser systems for REGLIS^3

L.Hijazi[a,*], N. Lecesne[a], J.L. Henares[a], R. Leroy[a]

[a]GANIL, BP 55027, 14076 Caen Cedex 5, France

Abstract

SPIRAL2 (Système de Production d'Ions Radioactifs Accélérés en Ligne) is a research facility under construction at GANIL (Grand Accélérateur National d'Ions Lourds) for the production of radioactive ion beams by isotope separation on-line methods and low-energy in-flight techniques. REGLIS^3 (Rare Element in Gas Laser Ion source and Spectroscopy) at S^3 will be the new device which is also under construction at GANIL for producing RIBs (Radioactive Ion Beams) and for studying the ground state properties of the nuclei at low energy beam. The Ti: Sa laser cavities existing now at the GISELE (GANIL Ion Source using Electron Laser Excitation) setup are going to be developed in order to adapt them for the requirements of REGLIS^3. A full description of REGLIS^3 is presented, RILIS technique which was developed at the last century is also discussed, developing the Ti: Sa laser cavities is presented also that is essential for the usage of automatic scan of wavelength instead of the manual one.

Peer-review under responsibility of the University of Liverpool

Keywords: Ti: Sa Lasers; REGLIS; Motorization; RILIS; Gas Cell; Programming; Lab-view

1. Introduction

GANIL (Grand Accélérateur National d'Ions Lourds) will host in the near future the new SPIRAL2 (Système de Production d'Ions Radioactifs Accélérés en Ligne) facility for the production of intense stable heavy ion beams.

SPIRAL2 is based on the superconducting LINear Accelerator LINAG. A full description of SPIRAL 2 is given by Bertrand [1] and Ferdinand [2]. SPIRAL2 will provide protons, deuterons and stable heavy-ion beams ranging from Helium to Uranium. The beam energies for heavy ions will be up to 14.5MeV/u with intensities up to 10^{14} ions per second.

S^3 is the new super separator spectrometer being constructed at SPIRAL2 which was explained by Drouard [3] and Dechery [4]. S^3 is designed to combine high acceptance, high degree of primary beam rejection, and high mass

* Corresponding author. Tel.:+337 53 58 6 526 .
E-mail address: hijazi@ganil.fr

1875-3892
Peer-review under responsibility of the University of Liverpool
doi:10.1016/j.phpro.2015.11.004

resolving power to study many physics domains as for example super-heavy and very-heavy nuclei, spectroscopy at and beyond the neutron drip line, ground state properties and deep inelastic reactions. The primary ion beams can be from Helium to Uranium. The energy needed ranges from 2A MeV to 14.5A MeV. The primary beam delivered by LINAG collides with a thin rotating production target and radioactive nuclei are produced by fusion evaporation.
The REGLIS (Rare Elements in-Gas Laser Ion Source and Spectroscopy) device will be installed at S^3. REGLIS as described by Ferrer [5] will be a source for the production of new and pure radioactive ion beams at low energy as well as a spectroscopic tool to measure nuclear hyperfine interactions. It consists of a gas cell (see Figure 1) in which the heavy ion beam coming from the S^3 spectrometer will be stopped and neutralized, coupled to a laser system that assures a selective re-ionization of the atoms of interest. Owing to the unique combination of such device with radioactive heavy ion beams from S^3, a new area of unknown isotopes at unusual isospin will become accessible. The buffer gas that is found inside the gas cell of $REGLIS^3$ can be Argon or Helium. It can have a pressure ranging from 200 to 500 mbar, depending on the energy of the incoming ion beam. The laser beams can be sent either in the gas cell or in the gas jets streaming out of the cell that assures a selective re-ionization of the atoms of interest where the ionization process is based on RILIS that will be explained later. A series of RadioFrequency Quadrupoles is added to capture the photo-ions and to guide them to the low-pressure zone thereby achieving good emittance of the produced low-energy beam. Then they will be sent to a MR-TOF-MS (Multi Reflection Time Of Flight Mass spectrometer) which is an ion trap of 2.4m length. It consists of a coaxial arrangement of two electrostatic ion mirrors between which the charged particles are reflected thousand times back and forth. The electric fields inside it are optimized such that ions with the same mass have exactly the same revolution period. Thus, a high mass-resolving power up to 10^5 is achieved and the ions of interest can be selecting among other contamination ions.

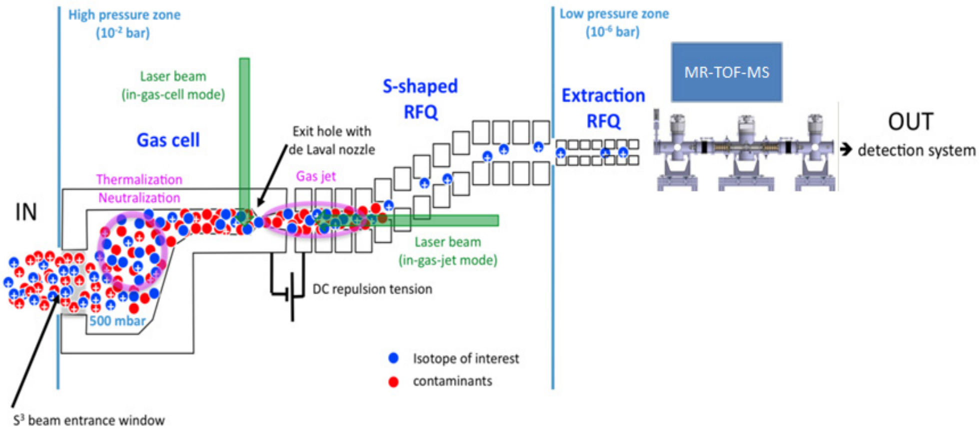

Fig. 1. Schematic figure of REGLIS3.

2. RILIS

RILIS technique is the Resonant Ionization Laser Ion Source used in many Laboratories around the world. It has emerged as an important technique in many facilities to selectively generate Radioactive Ion Beams (RIBs). It combines Z-selectivity with an efficient ionization process. It is based on step-wise resonant photo-ionization of the elements of interest. RILIS was introduced the first time by Ambartzumian and Letokhov [6] and it is used for the production of isobaric-pure Radioactive Ion Beams (RIBs). RILIS is used either in a hot cavity tube as described by Mishin [7] or in a gas cell as described by Kudryavtsev [8] which means the ionization process can take place in one of these two. The spectrum of the atoms in hot cavity tube inherits a Doppler broadening because of the high temperature that can reach up to 2000K. In gas cell, the spectrum of the atoms inherits a pressure broadening because of the increase of pressure. There are different parameters in order to compare between RILIS in gas cell, gas jets or hot cavity tube. The time of the residence of atom inside the hot cavity and the gas jets is 10 µs while in the gas cell it is much higher, about 100 ms. So, in order that the all the atoms interact with lasers at least one time, the laser's repetition rate used in the hot cavity and in the gas jets is 10KHz while in the gas cell it is only 200Hz as described by Lecesne [9].

3. Laser system at GANIL

TiSa laser system has proved its suitability for producing radioactive ion beams in hot cavities at ISAC (TRIUMF, Canada), ISOLDE (CERN), Jyväskylä University (Finland) and Mainz University (Germany) among others. At GANIL, the GISELE TiSa laser system as mentioned by Lecesne [10] has been built, installed and commissioned in strong collaboration with the LARISSA group from Mainz University and the TRILIS group from TRIUMF. A 10 kHz, 75 W, q-switched, frequency doubled pump laser, supplied by Photonics Industry, pumps 3 TiSa cavities developed by the TRILIS group. The obtained infrared laser beams, ranging around 690 to 1000 nm, can be frequency doubled, tripled, and quadrupled in frequency converting cavities developed by the LARISSA group, in order to extend the range to 200–480 nm. Typical output powers of the Ti:Sa are up to 5 W in the fundamental, up to 1 W for the second harmonic generation, and up to 200 mW for the third harmonic generation. These laser beam powers allow saturating the optical transitions most of the time. By properly investigating and selecting ionization schemes, the Ti:Sa system allows the resonant ionization of at least 80% of the elements in the periodic table. One extra Ti: Sa cavity is equipped with a motorized grating for continuous wavelength range tunability which is useful for ionisation scheme search.

Each cavity as described in Figure 2 contains an output coupler mirror, etalon, Birefringent Filter (BRF), High Reflection end mirror and pockels cell. Each cavity can have the same energy equal to the transition level's energy in the ionization scheme of the atom of interest.

Laser beams are produced inside the laser cavities and are transported to the experimental setup of REGLIS3 device situated 20 m away.

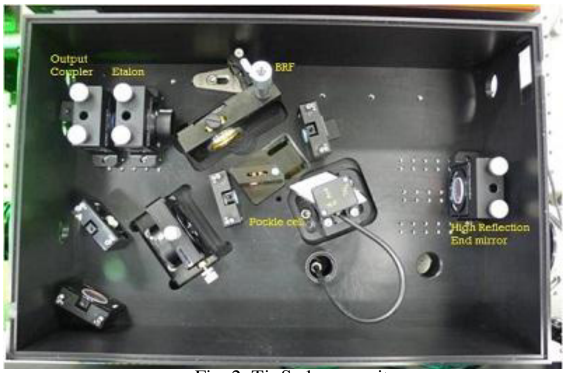

Fig. 2. Ti :Sa laser cavity.

4. Laser Spectroscopy with REGLIS3

The resonant ionization of atoms will be performed by two or three steps ionization schemes. Laser spectroscopy will be performed by scanning the laser frequency of one atomic transition while detecting the number of photo-ions or the corresponding emitted radiation. The ground state properties of many elements will be studied by the help of REGLIS^3 as tin (Sn), Actinium (Ac), Silver (Ag), Zirconium (Zr) and Nobelium (No) atoms as planned for the day-one experiments at S^3.

For some atoms, the two steps ionization schemes are not already known and as mentioned by Raeder [11] scanning in the blue region by the lasers is necessary to find useful transitions.

Scanning of wavelength with lasers is also an efficient tool to resolve the spectrum of hyperfine structure of the transition. The later is important in identifying the nuclear properties as the isotope shift that gives direct information on the nucleus size, isomer shift that gives information on the ground state and the isomeric state. Moreover, hyperfine splitting gives information on quadrupole moments, spins and magnetic moments of the nuclei.

5. Development of the Ti: Sa laser cavities

The development of the Ti: Sa cavities for online use at REGLIS[3] represents a building block of the RILIS monitoring and control project and is outlined in the following sections by recognizing the requirements, identifying the tasks to be fulfilled and finally describing the project design and implementation plan.

The stabilization system has to provide the ability to perform a uniform and constant wavelength scan to verify the resonance wavelength, as well as to quickly switch between different isotopes within a certain range. Where possible, the system relevant parameters will be monitored and controlled using network attached RS-232 acquisition devices enabling the integration of additional sensors into the system.

5.1 Software Setup

The software development platform Laboratory Virtual Instrumentation Engineering Work-bench (Lab-VIEW) by National Instruments Corporation (NI) is already used in many of the control and monitoring applications at different laboratories around the world. Therefore, its use in the project was necessary to meet the requirement of easy maintainability and integration into the existing system structure. Additionally, Lab-VIEW provides an intuitive graphical programming interface which facilitates the modification or extension of Lab-VIEW programs by users who lack a thorough training in programming. Lab-VIEW follows a data flow oriented design and development paradigm and is programmed in the graphical, general purpose programming language G.

By using a Lab-VIEW controlled stepper driver, the system meets the requirements of modular design, interchangeable standard components and easy to maintenance of a computerized actuator. Also this system allows for quick changes and manual intervention on several levels: manual adjustment of the thumbscrew, the changing of positions manually, and manual control in the control loop software. The concept of modularity is furthermore found in software by defining shared variable interfaces for each module to allow for easy change of individual components. The Lab-VIEW Program implements a closed control loop, in which the measured wave number is compared to the set point wave number. The program then applies the necessary corrections by controlling the driver.

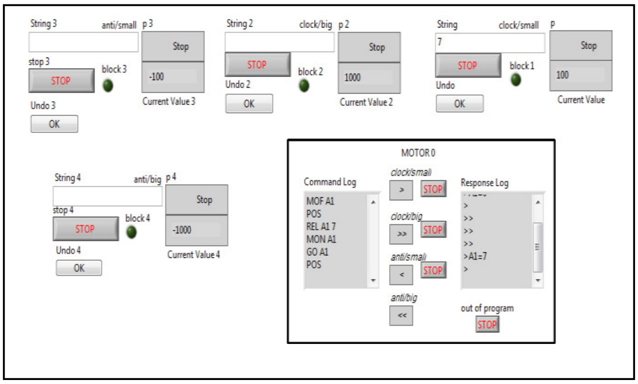

Fig. 3.Example of Lab-VIEW program.

5.2 Hardware Setup

5.2.1Motorization of transport mirror

As already mentioned, the laser beams will be transported through 20m. For the moment, the transport mirrors are monitored using joystick as they are disposed in a 2m high platform and therefore not easily accessible. They will be developed in order to monitor them automatically by computer for more accuracy and easier recording of the different transport configuration tunings.

The LAB-view program will contain many buttons for fast or slow range of movement as in Figure 3, for remembering and saving the useful information that the one needs.

5.2.2 Motorization of Etalon

To change the wavelength, the element determining the smallest mode bandwith of the Ti: Sa laser have to be manipulated. The main elements used to filter the wavelengths are a mirror set coated to reflect a wide range, a bifringent-filter and an etalon. Motorization of the Etalon, i.e. motorized change of the angle of the etalon, will be useful for automatic scan of the wavelength on a small range. It is also useful for checking that the lasers are very well tuned with the specific transition, because with on-line experiments it is mandatory to find the correct position of the transition of radioactive beams.

Motorization of the etalon will also make possible the development of wavelength stabilization system which can be designed to correct laser wavelength drifts due to gradual temperature changes. Short term fluctuations caused by changing air flow or vibrations create possible instabilities in laser beam pointing. The speed and sensitivity of the stepper motor being used in many laboratories is not suitable for the required position stabilization. In this case, an upgrade of the mirror mount with Piezo actuators can be considered. Such actuators would be able to quickly react to minute position changes and would supplement the spatial component to the spectral stabilization.

5.2.3 Motorization of BBO crystal

For laser spectroscopy purpose, it has been mentioned previously that the blue region of wavelength has to be scanned, over a wide range if the transition are not known. Therefore, we will use the already existing motorized Ti:Sa cavity equipped with a grating to produce the Infra Red (IR) beam which will be send to a motorized rotating BBO (beta-Barium Borate) crystal for frequency doubling. For each IR wavelength, the angle of the BBO crystal has to be slightly changed in order to optimize the converted blue beam intensity. Then, by continuously monitoring the exit intensity with a power-meter, the rotation of the BBO crystal can be remotely and automatically controlled during a scan.

The 8410-NewFocus Closed-Loop Picomotor Rotary Stage includes an encoder for superior position feedback for rotational accuracy. The Latter will be used instead of a mount for tracking and it provides micro-radian precision and continuous 360° rotation. Each stage comes complete with an adapter for mounting components with a 1 inch diameter.

All the presented optical mounts will be placed and the new lab-view program will be tested in the next few months.

6. Conclusion

The REGLIS^3 setup as well as the GANIL TiSa laser system GISELE were explained, and will compose the new device for the production of RIBs at low energy at GANIL/SPIRAL2. The existing laser system GISELE is manually operated and has to be adapted for on-line use at S^3. Therefore, it has been explained how the main laser beam components will be motorized, and in particular the optical mounts, to be adapted to the requirements of REGLIS^3.

Acknowledgements

The author would like to thank the REGLIS[3] collaboration. This work is part of the LA3NET and has received funding from the European Union's Seventh Framework Program for research, technological development and demonstration under grant agreement no 289191.

References

[1] Bertrand P, R Ferdinand; SPIRAL2 accelerator construction progress; *XXVI Linear Accelerator Conference LINAC12; Joint Accelerator Conferences Website*; 2013, P.773-776.

[2] Ferdinand R; P. Bertrand, X. Hulin, M. Jacquemet, E. Petit; Progress of Construction and Installation of the SPIRAL2 Accelerator; *IPAC 13 - The 4th International Particle Accelerator Conference*; 2013, P. 2-3.

[3] Drouart A; AM Amthorb, D Boutin, O Delferriere, M Duvalb, S Manikonda, JA Nolen, J Payet, H Savajols, M- H Stodel, D Uriot; The Super Separator Spectrometer (S3) for SPIRAL2 stable beams; *Nuclear Physics Volume 834, Issues 1–4, 1 March 2010, Pages 747c–750c*, the 10th International Conference on Nucleus-Nucleus Collisions; 2009, P.2-3.

[4] Dechery F; A Drouart, H Savajols, J Nolen, M Authier, AM Amthor, D Boutin; Toward the drip lines and the superheavy island of stability with the Super Separator Spectrometer S3; *Eur. Phys. J. A (2015) 51: 66, DOI 10.1140/epja/i2015-15066-3*; 2015, P. 2-15.

[5]Ferrer R; B Bastin, D Boilley, P Creemers, P Delahaye, E Lienard, X Flechard et al.; In gas laser ionization and spectroscopy experiments at the Superconducting Separator Spectrometer (S3): Conceptual studies and preliminary design; *Nuclear Instruments and Methods in Physics Research B 317 (2013) 570–581*; 2013, P. 577-580.

[6]Ambartzumian RV, Letokhov VS; selective two step (STS) photoionization of atoms and photodissociation of molecules by Laser Radiation; *Appl. Opt. 11,354*; 1972, P. 354-358.

[7]Mishin VI; VN Fedoseyev, H-J Kluge, VS Letokhov, HL Ravn, F Scheerer, Y Shirakabe, S Sundell, O Tengblad; Chemically selective laser ion source for the CERN ISOLDE online mass separator facility; *Nucl. Instr. and Meth B 73 (1993) 550*; 1993, P. 550–560.

[8]Kudryavtsev Y; R Ferrer, M Huyse, P Van den Bergh, P Van Duppen, L Vermeeren; Two-step laser ionization schemes for in-gas laser ionization and spectroscopy of radioactive isotopesa; *Review of Scientific Instruments 85(2), 02B915. DOI 10.1063/1.4850695.* ; 2013, P.1-2.

[9]Lecesne N; Laser ion sources for radioactive ion beams; *Rev. Sci. Instrum. 83, 02A916 (2012); doi :10.1063/1.3681148 ;* 2012, P. 1-2.

[10]Lecesne N; R Alvès-Condé, E Coterreau, F De Oliveira, M Dubois ; GISELE: A resonant ionization laser ion source for the production of radioactive ions at GANIL; *Review of Scientific Instruments,81,02A910* ; 2010, P.2-6.

[11]Raeder S; Comparison between dye and TiSa laser systems regarding the laser spectroscopy experiments at S3.*Report IKS, KU Leuven, Celestijnenlaan 200d, 3001 Heverlee*; 2014, P. 11-15.