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SABINA: A RESEARCH INFRASTRUCTURE AT LNF*

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Abstract

SABINA (Source of Advanced Beam Imaging for Novel Applications) is a project aimed at the enhancement of the SPARC_LAB research facility. This enhancement is carried out through the following actions: first, the increase of the uptime through the consolidation of technological systems and the replacement of some critical equipment in order to limit the number and extent of faults; then, the improvement of the accelerator performances, by replacing some devices with updated ones. The effect will be greater reliability of the accelerator, which will allow it to be opened as a facility for external users, both industrial and scientific, with the goal of increasing the competitiveness of industries in a broad range of technological areas and enhancing collaborations with research institutions. The two user lines that will be implemented are a power laser target area and a THz radiation line, by using a dedicated undulator. The undulator and the THz line are also described in other contributions to this conference. A brief description of the project and potential exploitations are reported.

INTRODUCTION

SABINA (Source of Advanced Beam Imaging for Novel Applications) is a project co-funded with an amount of 4.5 M€ by the Regione Lazio, within POR-FESR 2014-2020 funds, for the realization – at Frascati National Laboratories – of a research facility which will be made available also to external users.

The project got first place in the rankings of the public call "PNIR Research Infrastructures development to boost the innovation rate of the regional productive sector", aimed at creating an infrastructure to increase the competitiveness of the regional research and innovation system [1].

SABINA is part of the SPARC [2] linear accelerator activities. The approved funding is envisaged as an enhancement of an infrastructure that will see its completion in EuPRAXIA@SPARC_LAB [3].

After LATINO (a Laboratory in Advanced Technologies for Innovation) [4], SABINA is the second major project for research infrastructures co-funded with regional funds won by LNF. Putting to common factor LATINO and SABINA represents the chance to set up a technological hub, within the region, that would be a reference point for both scientific and industrial community for the development of technologies related to accelerator physics.

THE PROJECT

The SABINA project aims to consolidate the research facility SPARC_LAB, which includes the photoinjector SPARC and the 200TW laser FLAME. Some key devices in the facility will be replaced to ensure the reliability and extend the accelerator up-time. Also, two user lines will be implemented: a target area for laser and a THz radiation line. Many research areas are involved, with several chances of applicative fallouts: the power laser will perform irradiation tests of samples such as vacuum optics used in aerospace; THz radiation will be used as an investigation tool in physics, chemistry, biology, cultural heritage, and material science.

It is quite an ambitious project: in order to obtain a real user facility starting from an existing accelerator used mainly for research, the machine must be made as reliable as possible, in terms of uptime and performances, such as stability and reproducibility.

SPARC_LAB Facility Upgrade

To achieve the project goals, in the preparatory phase we deeply analysed the faults and the down time of the accelerator, finding out the technological limits of the facility. Some sub-systems were found to be inadequate or obsolete for a user facility and we decided to update them.

In particular, we are replacing some parts of the facility ancillary systems. A lot of work will be carried out in the fluid distribution and cooling system: the whole compressed air plant, the main dry-cooler to allow a reliable summer run, a part of the cooling system distribution network, the water demineralizer system. Concerning the data network, we upgraded the optical fiber distribution network and all the facility switches to achieve a links up to 10 Gbit/s.

For what concerns the performances of the machine, we have identified the crucial elements that affects the parameters of the beam and we are substituting them with improved ones.

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First of all, a new S-band RF gun (together with a new focusing motorized solenoid) has been designed at LNF. Figure 1 shows the layout. It has been produced and delivered and will be installed in June 2021. This will guarantee a much better alignment system and a slightly higher accelerating gradient and will ensure better e-beam parameters. All the ancillary devices (vacuum, diagnostics) have been replaced up to the first accelerating section.

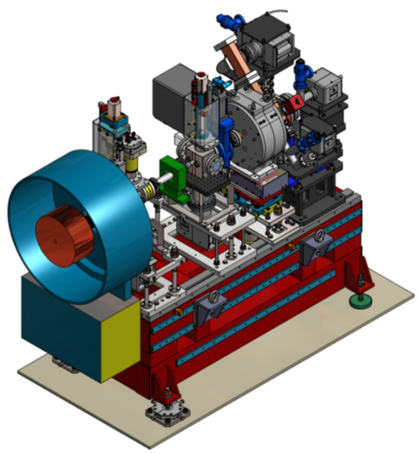

Figure 1: The new S-band RF gun schematic layout.

Also, the photo-cathode laser system will be totally replaced by a new one. The oscillator will be upgraded with a low noise model that should guarantee less than 10 fs RMS jitter respect to a reference ensuring a very stable operation, especially in a e-beam RF compression regime. The laser amplification chain will be also replaced to upgrade the uniformity of the transverse profile. A lot of new diagnostic (cameras) will be installed between amplification stages and an energy stability <1% should be achieved using a multi-pumping laser system.

The reliability and stability of the C-band RF power station will be upgraded replacing the present solid-state modulator with a new 450 kV K400 model from Scandinova (delivery foreseen by November 2021).

To have a better control and stability of the accelerating fields, we will replace all the three LLRF systems (2 in S-band and 1 in C-band). The present systems were designed and realized at LNF in early '00s when the stability requirements were less stringent. The new digital LLRF modules will be produced by Instrumentation Technology and will be delivered in fall 2021. They will guarantee an added timing jitter <10 fs RMS and amplitude jitter <0.1% and, thanks to an FPGA on-board, they are capable of fast RF pulses amplitude and phase arbitrary modulations.

To allow accelerator working point fine tuning and to ease the e-beam transport to the experimental areas, the focusing solenoids around the first two accelerating structures (3m S-band SLAC-type) will be replaced. The new solenoids will guarantee the same focusing strength and will be mechanically compatible with the present machine layout. Special attention has been put in the alignment system since it is fundamental to minimize angular kick on the beam during the focusing process.

Some new diagnostics devices have been purchased and installed: a new precise beam current monitor (turbo ICT model from Bergoz), a multi-purpose 1 GHz bandwidth signal digitizer from Tektronix and new electronics modules from Instrumentation Technologies to read the beam position monitors along the accelerator.

The expected outcome is a doubling of the present uptime. This achievement will allow us to give stable beams to users of the two facilities, one related to a THz/MIR line and the other related to the use of the FLAME high power laser.

Following paragraphs give some details of the two user lines, and their applications are also reported.

THz/MIR Line

A new THz/MIR radiation line will be implemented. The high brightness electron beams produced at SPARC photo-injector will be transported up to an APPLE-X undulator through a dogleg.

The self-amplified spontaneous emission Free Electron Laser (SASE FEL) will produce pulses covering a broad spectral region from 3 THz to 30 THz, obtained by tuning the electron beam energy between 30 and 100 MeV. The photons pulses will have length of ps and energy of tens of µJ, with linear, circular and elliptical polarization states.

A THz optics photon delivery system has been designed to transport radiation to the user experimental area, where it will be used as an investigation tool in physics, chemistry, biology, cultural heritage and material science, both for research and industrial applications. The experimental area will be equipped with a 5T magnetic cryostat and synchronized with a fs laser for THz/IR pump, VIS/UV probe experiments. Figure 2 shows a sketch of the line designed to transport the THz radiation from the SPARC bunker to the experimental area in a close building.

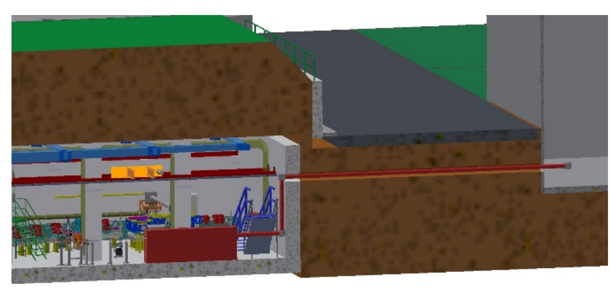

Figure 2: A sketch of the THz transport line.

The applications on samples will include spectroscopic analysis on single point or in imaging, also at cryogenic temperatures. More details on the undulator and THz applications could be found in other posters at this conference [5, 6].

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FLAME Power Laser

FLAME is a compact femtosecond laser system able to provide pulses with a maximum energy before compression of 6 J, temporally compressed down to a minimum length of 25 fs, with a peak power of 250 TW and 10 Hz repetition rate [7]. The system is a Titanium-Sapphire laser based on the so-called Chirped Pulse Amplification (CPA) scheme (the same scheme awarded by the 2018 Nobel prize). More information can be found in Ref. [8]. Figure 3 shows the layout of the system.

The laser will be used as an irradiation facility for tests on samples such as mirrors and gratings, used for example in aerospace applications. Different experimental areas will be available at varying wavelength and energies, for surface coating test, also in vacuum:

- A 532 nm, narrow bandwidth (10 J, 5 Hz) for surface coating tests on mirrors;
- An infrared beam, long (6 J, 10 Hz) for infrared coating tests;
- Vacuum tests with laser at maximum power.

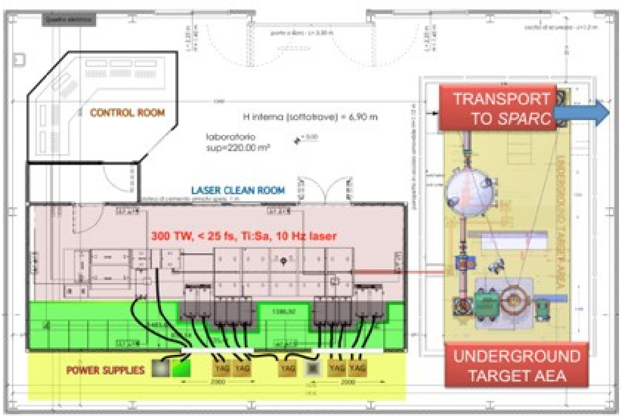

Figure 3: FLAME schematic layout.

CONCLUSION

The SABINA research infrastructure will be fully operative starting from summer 2022. A dedicated website is in preparation: www.sabina.lnf.infn.it.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Lazio Inova, Infrastrutture per la ricerca, http://www.lazioinnova.it/bandi-post/infrastrutture-la-ricerca/.

[2] M. Ferrario *et al.*, “SPARC_LAB present and future”, *Nucl. Instr. Meth. Phys. Res. B*, vol. 309, pp. 183-188, 2013. doi:10.1016/j.nimb.2013.03.049

[3] M. Ferrario *et al.*, “EuPRAXIA@SPARC_LAB Design study towards a com-pact FEL facility at LNF”, *Nucl. Instr. Meth. Phys. Res. A*, vol. 909, pp. 134-138, 2018. doi:10.1016/j.nima.2018.01.094

[4] L. Sabbatini, D. Alesini, A. Falone, A. Gallo, and V. Pettinacci, “The LATINO Project - An Italian Perspective on Connecting SMEs with Research Infrastructures”, in *Proc. 10th Int. Particle Accelerator Conf. (IPAC'19)*, Melbourne, Australia, May 2019, pp. 2277-2279. doi:10.18429/JACoW-IPAC2019-WEZPLM1

[5] F. Dipace *et al.*, “FEL Design Elements of SABINA: A Free Electron Laser for THz-MIR Polarized Radiation Emission”, presented at the 12th Int. Particle Accelerator Conf. (IPAC'21), Campinas, Brazil, May 2021, paper TUPAB100, this conference.

[6] S. Macis *et al.*, “The Sabina Terahertz/Infrared Beamline at SPARC-Lab Facility”, presented at the 12th Int. Particle Accelerator Conf. (IPAC'21), Campinas, Brazil, May 2021, paper TUPAB069, this conference.

[7] F. G. Bisesto *et al.*, “The FLAME laser at SPARC_LAB”, *Nucl. Instr. Meth. Phys. Res. A*, vol. 909, pp. 452-455, 2018. doi:10.1016/j.nima.2018.02.027

[8] SPARC_LAB, FLAME Laser, http://sparclab.lnf.infn.it/sparc_lab-home/flame-laser/.