ACTIVITY REPORT OF THE TEX FACILITY

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on behalf of the TEX technical team.

1 Introduction

TEX ("TEst stand for X-band") is a dedicated facility at INFN-LNF, specifically designed for testing X-band (11.994 GHz) radiofrequency technology used in linear accelerators [1, 2, 3, 4, 5]. Since its commissioning, the facility has significantly consolidated its key role in the Frascati laboratories, enhancing operations and technical activities. TEX serves as a critical infrastructure for testing advanced X-band accelerating structures, RF components, vacuum and control systems essential to the design of the EuPRAXIA@SPARC_LAB project [6, 7]. Additionally, the facility actively fosters in the last year robust collaborations with both national and international research institutions, as well as industrial partners. Recently, thanks to the PNRR project Rome Technopole [8], TEX underwent a substantial upgrade aimed at significantly expanding its testing capabilities, positioning the facility to effectively support cutting-edge research and future technological advancements.

2 Upgrade of the TEX Facility

During the past year and a half, a major upgrade program of the TEX facility has been carried out to expand its testing capabilities [9, 10]. The upgrade was implemented and funded within Spoke 5 of the PNRR Rome Technopole project and included the following main activities:

- Installation of a BOC (Barrel Open Cavity) [11], RF pulse compressor developed at PSI on the first X-band RF line connected to the 50 MW source commissioned in 2022. This system enables temporal compression of the RF pulse, increasing the available peak power beyond 50 MW for testing of X band structures and RF components.
- Integration into the facility of an X band, 11.994 GHz, RF source based on the Canon E37119 klystron and solid state modulator, capable of operating at repetition rates up to 400 Hz and delivering peak power levels of 25 MW.
- Integration into the facility of a C band, 5.712 GHz, RF source based on the Canon E37217 klystron and solid state modulator, capable of operating at repetition rates up to 400 Hz with peak power up to 20 MW.
- Implementation of two new waveguide lines, one in C-band and one in X-band, both including BOC type pulse compressors, to transport the RF power generated by the new sources into the bunker and to feed devices and accelerating sections under test.

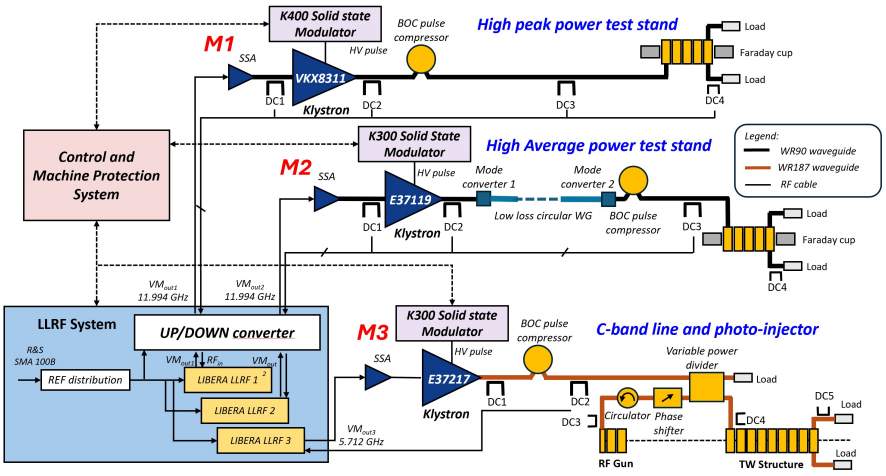

Figure 1: *Schematic layout of the TEX facility with the three RF sources after the upgrade.*

- Upgrade of the Libera Low Level RF (LLRF) System for the generation and monitoring of all the RF signals with a new system working in C-band [12] and a Machine Protection System (MPS) designed to handle the higher duty cycles [13, 14].
- Installation of a new dry cooler in the TEX technical area to provide adequate cooling for the newly installed high power RF sources.
- Installation in the bunker of a photocathode laser system based on a Titanium Sapphire laser.

After successful factory testing, the sources were shipped and installed in their final position at the TEX facility in Frascati. Table 1 provides a summary of the RF sources that will be available at the TEX facility after the upgrade, including their key specifications and in Fig. **??**

Table 1: Overview of the RF sources available at the TEX facility.

Source Number		**1**	**2**	**3**
Klystron		CPI VKX8311A	Canon E37119	Canon E37217
Modulator		Scandinova k400	Scandinova k300	Scandinova k300
RF Frequency	GHz	11.994	11.994	5.712
Cathode peak voltage	kV	420	312	254
Beam Current	A	320	199	196
Max RF Peak Power	MW	50	25	21
Max RF Pulse Length	μs	1.5	1.5	2.5
Max Rep. Rate	Hz	50	400	400
Gain	dB	48	47	50
Pulse Flatness	%	$\leq \pm 1$	$\leq \pm 1.6$	$\leq \pm 1$
Pulse to pulse stability	ppm	16	13	14

They will be the first sources of their kind to demonstrate reliable operation at such high repetition rates. Together with the sources, all the other systems have been successfully procured

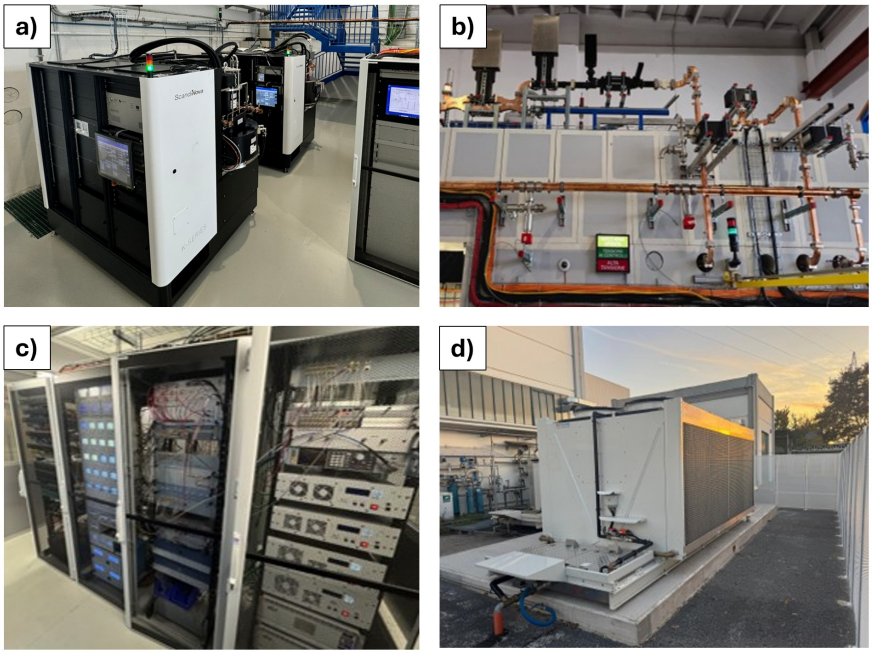

Figure 2: *a) X-band and C-band high repetition rate RF sources installed at the TEX facility, b) X-band and C-band waveguide system installed c) new LLRF, control system and vacuum systems in the rack room and d) new dry cooler in the TEX technical area.*

and installed in the facility, as shown in the figures 2.

The upgraded configuration substantially improves the operational flexibility and overall performance of the facility. The additional X-band station effectively doubles the conditioning and validation capacity for EuPRAXIA@SPARC_LAB RF components, adding a test bench for high average power testing. Moreover, the RF source based on the Canon E37119 klystron is of strategic importance, as it is currently being considered as the baseline high power RF source for the EuPRAXIA X-band linac. Meanwhile, the C-band source will be used for component and structure testing, but also to implement a high repetition rate C-band photo-injector prototype.

3 High repetition rate C-band photo-injector

As part of the R&D program on advanced photo-injectors for the EuPRAXIA linac [17], and exploiting the recently installed C band RF source at TEX, the facility is being upgraded to host a high brightness injector prototype. In its final configuration, the system will comprise a brazing free C band RF gun operating at 5.712 GHz, a matching solenoid, a 0.5 m traveling wave accelerating structure, a diagnostics section including beam diagnostic chambers and a quadrupole triplet, and a dipole magnet for beam dumping.

The C-band RF gun has been specifically designed to sustain cathode peak surface electric fields in excess of 160 MV/m [15, 16]. The prototype has already been manufactured and successfully high power tested at PSI within the framework of the European I.FAST project and the INFN Commission V TUAREG initiative. All components, with the exception of the traveling wave accelerating structure, have been procured during the past year and will be installed in the

bunker in the upcoming commissioning phase.

Preliminary beam dynamics simulations indicate that the injector will be capable of delivering bunch charges in the range 30 pC to 75 pC, with rms normalized emittances of approximately 0.4 mm mrad at 30 pC and about 4 mm mrad at 75 pC. The system is designed to operate at repetition rates up to 400 Hz, fulfilling the requirements in terms of average current and beam brightness for next generation FELs and plasma based acceleration schemes. The injector will therefore act as a demonstrator of a high efficiency, high repetition rate RF C-band photo-injector fully compatible with the EuPRAXIA accelerator architecture.

4 List of Conference Talks and Posters by LNF Authors in Year 2024-2025

Include a list of conference talks by LNF authors.

1. F. Cardelli, TEX Facility, 1st workshop on Fundamental research and applications with the EuPRAXIA facility at LNF, Frascati, Italy, 4-6 Dec 2024
2. G. Latini, Machine protection system for TEX facility, IPAC'24 - 15th International Particle Accelerator Conference, Nashville, USA, 2024
3. G. Latini, Machine learning algorithms using PCA and autoencoder based on data preprocessing techniques aim to predict electron beam spot size and to perform emittance and energy virtualized measurements, 110° Congresso Nazionale SIF, Bologna, Italy, 9-13 September 2024
4. L. Piersanti, RF power station stabilization techniques and measurements at LNF-INFN, IPAC'24 - 15th International Particle Accelerator Conference, Nashville, USA, 2024
5. F. Cardelli, Towards 400Hz RF system for EuPRAXIA@SPARC_LAB, EuPRAXIA_PP Annual Meeting, Isola d'Elba Italy, 22-28 September 2024
6. F. Cardelli, TEX Facility, 1st workshop on Fundamental research and applications with the EuPRAXIA facility at LNF, INFN-LNF, Frascati, 4-6 December 2024
7. F. Cardelli, Applications of C and X band extremely high gradient RF structures at LNF, INFN Convegno Nazionale: Quarta Giornata Acceleratori, INFN-LNL, Legnaro, 3-4 April 2025
8. F. Cardelli, TEX Facility at LNF: Upgrade and X-band Developments, HG-2025 16th International Workshop on Breackdown Science and High Gradient Technology, Merida, Mexico, 24-28 March 2025
9. F. Cardelli, High gradient X-band linac as a driver for PWFA user facility, 7thEuropean Advanced Accelerator Conference EAAC2025, Isola d'Elba, 21-27 September 2025
10. F. Cardelli and C. Di Giulio, Frascati Linac last experience with klystrons and modulators, 4th Pulsed High Power RF Workshop, Elettra, Trieste, Italy, 11-13 November 2025

References

1. S. Pioli et al., *"TEX - an X-Band Test Facility at INFN-LNF"* in Proc. 12th Int. Particle Accelerator Conf. IPAC'21, Campinas, Brazil, (2021).
2. F. Cardelli et al., *"Status and commissioning of the first X-band RF source of the Tex Facility"* in Proc. 13th Int. Particle Accelerator Conf. IPAC'22, Bangkok, Thailand, (2022).

3. C. Di Giulio, et al., *"TEX (TEst stand for X-band) at LNF."* arXiv preprint arXiv:2308.03053 (2023). Proceeding of International Workshop on Future Linear Colliders (LCWS 2023), 15-19 May 2023. DOI: https://doi.org/10.48550/arXiv.2308.03053

4. F. Cardelli, et al., *"X-band activities at INFN-LNF."* in Proc. 14th Int. Particle Accelerator Conf. IPAC'23, Venice, Italy, (2023).

5. S. Pioli, et al., *"Control and Functional Safety Systems Design for Real-Time Conditioning of RF Structures at TEX."* in Proc. 13th Int. Particle Accelerator Conf. IPAC'22, Bangkok, Thailand, (2022).

6. D. Alesini et al., *"EuPRAXIA@SPARC_LAB Conceptual Design Report"*, INFN-18-03/LNF, (2018).

7. F. Villa et al., *"EuPRAXIA@SPARC_LAB Status Update"*, Proceedings of SPIE Conference Volume 12581, X-Ray Free-Electron Lasers: Advances in Source Development and Instrumentation VI; 125810H (2023). https://doi.org/10.1117/12.2668643

8. PNRR Rome Technopole project, https://www.rometechnopole.it

9. F. Cardelli, et al., *"Advancements in X-band technology at the TEX facility at INFN-LNF"* in Proc. 4th Int. Particle Accelerator Conf. IPAC'13, Shanghai, China, (2013).

10. F. Cardelli, et al., *"Preliminary R&D on X-band components for the X-band based user facility EuPRAXIA@SPARC_LAB"* Eur. Phys. J. Spec. Top, (2025).

11. R. Zennaro, et al., *"C-band RF pulse compressor for SWISS-FEL."* in Proc. 4th Int. Particle Accelerator Conf. IPAC'13, Shanghai, China, (2013).

12. L. Piersanti, *"RF power station stabilization techniques and measurements at LNF-INFN"*, in Proc. 15th Int. Particle Accelerator Conf. IPAC'24, Nashville, TN, (2024).

13. G. Latini, et al., *"Machine protection system for TEX facility."*, in Proc. 15th Int. Particle Accelerator Conf. IPAC'24, Nashville, TN, (2024).

14. G. Latini, et al., *"MPS design for TEX Facility"*, Nota interna LNF INFN-25-07-LNF, ID:5997 (2025).

15. F. Cardelli, *"Design and realization of high-gradient C-band standing wave RF gun"*, il Nuovo Cimento C, issue 5, (2024). DOI: 10.1393/ncc/i2024-24272-y

16. D. Alesini, et al., *"Design, realization and high power RF test of the new brazed free C band Photo-Gun."* in Proc. 15th Int. Particle Accelerator Conf. IPAC'24, Nashville, TN, (2024).

17. A. Giribono, et al., *"Dynamics studies of high brightness electron beams in a normal conducting, high repetition rate C-band injector."*, Phys. Rev. Accel. Beams 26, 083402, (2023).