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SUPERCONDUCTING RF MODULES OF TARLA*

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Abstract

The Turkish Accelerator and Radiation Laboratory (TARLA) is proposed as an accelerator based radiation source facility to provide a research instrument for researchers from both Turkey and region. The facility is located at the Ankara University Institute of Accelerator Technologies and proposed as the first accelerator based research infrastructure in Turkey. The superconducting accelerator of TARLA is currently under commissioning and will drive two Free Electron Laser (FEL) lines in the mid- and far-infrared ranges and a high flux Bremsstrahlung radiation to 40 MeV electron beam in Continuous Wave (CW) mode. The SRF cryomodules have been delivered by industry in 2017. In this paper, we present the achieved vertical test results of the SRF cavities, the results of the high power RF test of the fundamental power couplers and the first test results of the integrated piezo tuner. After successful commissioning of the cryogenic plant operating at 1.8 K with ±0.2 mbar pressure stability, the commissioning of the SRF cryomodules is now ongoing and the current status and results achieved so far are explained.

INTRODUCTION

TARLA will provide free electron laser (FEL) between 5-350 μm in medium and far infrared regions and a Bremsstrahlung radiation in 5-30 MeV [1,2]. Thermionic triode electron gun will deliver 250 keV beam to the superconducting accelerator modules in continuous wave (CW) mode. Two cryomodules originated by ELBE facility [3] will accelerate the electron beam to 40 MeV. The electron beam will be transmitted to two independent undulator magnets inside the optical cavities. A Bremsstrahlung line is planned to perform astro-physics and nuclear experiments between 5-30 MeV using the electron beam. Additionally, we plan to conduct fixed target experiments by electron beam directly. The overview of the TARLA facility is shown in Fig. 1. The main electron beam parameters are listed in Table 1.

Table 1: Main Electron Beam Parameters of TARLA

Parameter	Unit	Value
Beam energy	MeV	15-40
Max. average beam current	mA	1.5
Max. bunch charge	pC	120
Horizontal emittance	mm.mrad	<15
Vertical emittance	mm.mrad	<12
Longitudinal emittance	keV.ps	<85
Bunch length	ps	0.4-6
Bunch repetition rate	MHz	0.001-104
Macro pulse duration	μs	50-CW
Macro pulse repetition rate	Hz	1-CW

TARLA CRYOMODULES

Electron bunches delivered by thermionic triode gun with ~500 ps will be compressed by buncher cavities, i.e. namely subharmonic and fundamental bunchers, to 10 ps [4]. Buncher cavities are the normal conducting accelerators operating by velocity modulation to compress the electron bunch [5]. Electron beam will be able to accelerate to 40 MeV using two superconducting cryomodules. A cryomodule is a structure that contains two TESLA cavities [6], whose achievable accelerating gradient of 10 MeV/m at CW mode. The accelerating structure of TARLA comprises of an injector part with low energy, two superconducting cryomodules and a bunc compressor between cryomodules (Fig. 1). Bunch compressor is a structure, rotating the beam at longitudinal phase space, preserving the longitudinal emittance, but reducing the bunch length at the expense of the energy spread. By this way, TARLA bunch compressor will allow to optimize the micropulse duration and energy spread of the beam by phasing the cavities. The electron beam will be delivered either to Bremsstrahlung or one of two FEL beamlines. The parameters of cryomodules are given in Table 2.

Table 2: Cryomodule Parameters of TARLA

Parameter	Unit	Value
Frequency @1.8 K	MHz	(1300±5)
Tuning range	kHz	120
Ext. Q of input couplers	–	$(1.2\pm0.2)\times10^7$
Ext. Q of HOM couplers	–	$>5\times10^{11}$
Accelerating Voltage/CM	MV	>20
Cryogenic losses at max grad.	W	<75
Coupler power@CW	kW	≥15
Tunning Resolution	Hz	1
Tunning speed	kHz	1

Since TARLA cryomodules have been planning to operate in pulsed mode operations besides CW mode, the tuning system of the cryomodules has been modified by adding piezo stack on the lever arms of the mechanical tunning system. The aim of this modification is to have better RF performance especially for pulsed mode operations. Fig. 2 depicts the modification of TARLA tuning mechanism. The

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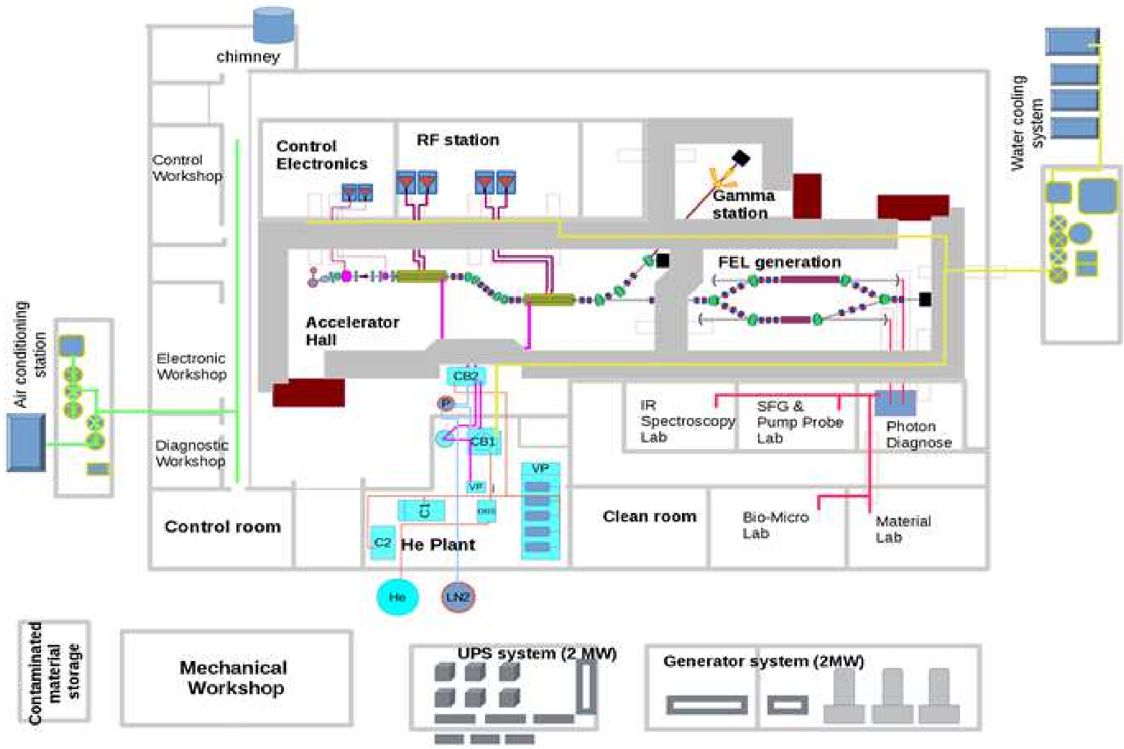

Figure 1: Layout of TARLA facility.

simulation and bench-top tests in room temperature were verified between each other. The resolution and the speed of tuning has been improved as 10 Hz-5 Hz/ms to 1 Hz - 1 kHz (Fig. 3). The cavities were produced in accordance with XFEL manufacturing procedure and assembled into helium vessel then vertically tested at DESY in 2016. Fig. 4 illustrates the vertical test results of TARLA. After testing of all cryomodule components such as cavity vertical tests, piezo tuning tesst, coupler tests, leak test etc., the cryomodules were delivered to TARLA by Research Instruments GmbH [7] at the end of 2017 and ready for assembly to the helium plant. Fig. 5 depicts the actual location, where the first cryomodule will be positioned on the beam-line in accelerator hall.

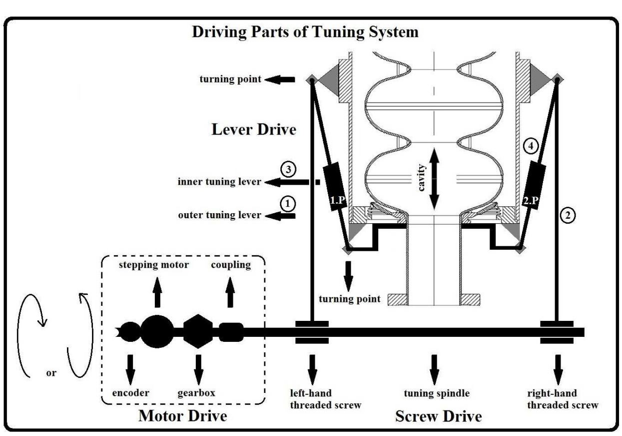

Figure 2: Modified tuner mechanism of TARLA.

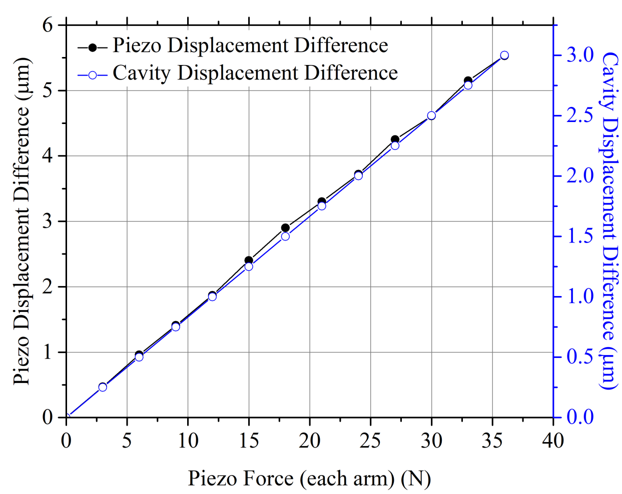

Figure 3: Simulation results of TARLA piezoelectric tuner mechanism.

HELIUM PLANT

TARLA cryogenic system provides super fluid helium at 1.8 K with ±0.2 mbar @ 210 W. The distribution system transmits the super fluid helium through the lines from cryoplant to cryomodules. The system consists of a He gas storage tank, a compressor station, an oil remover, a He refrigerator and a dewar with transfer lines. A cold compressor, cooling by a warm vacuum pumps and a heat exchanger performs 1.8 K He flow at 16 mbar±0.2 mbar. Fig. 6 illustrates the TARLA He plant diagram. The plant is manufactured by

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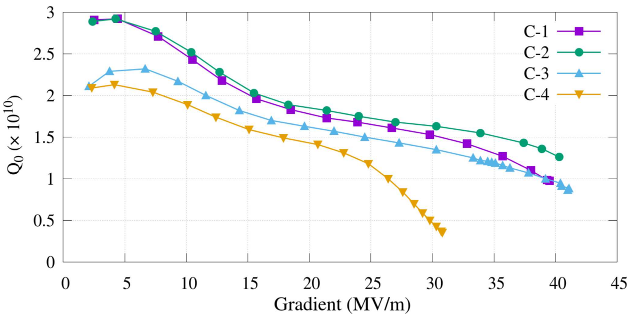

Figure 4: Vertical tests of TARLA cryomodules.

Figure 5: Photo of the location, where the TARLA cryomodule will be positioned on the beam-line in accelerator hall.

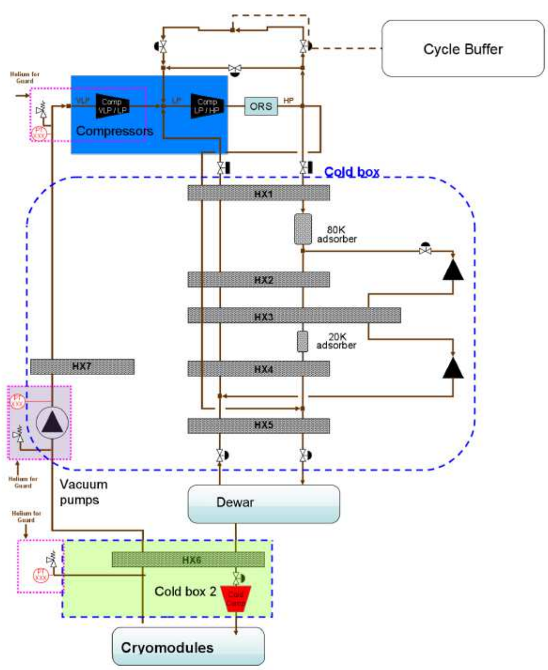

Figure 6: Schematic view of TARLA cryoplant.

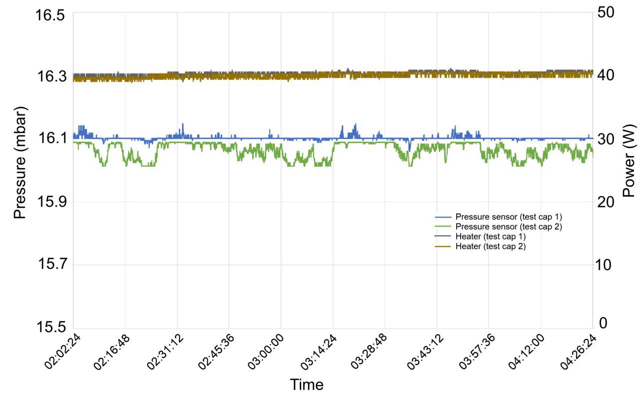

Figure 7: Pressure stability of liquid helium in test caps.

Air Liquide Advanced Technologies [8] and completed most of the site tests. Nowadays, the commissioning works are ongoing together with the cryomodules site tests. The long term operation tests are performed by using test cups instead of cryomodules, as a simulator. The main responsibility of the plant is keep the pressure stability 16 mbar. Fig. 7 illustrates the measurement results of the plant using by test caps which are equipped with heater equal to the full heat loss of the modules.

RF AMPLIFIERS

TARLA high power RF (HPRF) system comprises of four 18 kW RF power amplifiers and RF network of wave-guides [9]. RF waves are produced by power amplifiers and transmitted to the accelerator modules by a distribution sys-tem. Fig. 8 depicts the photo of a 18 kW RF amplifier with the test setup. 18 kW RF amplifiers are manufactured by SigmaPhi [10] and delivered in 2019. The main parameters of RF amplifiers are listed in Table 3. The factory accep-tance and TARLA site tests are in line with the expected parameters in Table 3 [11, 12]. Fig. 9 illustrates the graph of CW output power of a 18 kW TARLA RF amplifier. As it is seen on the graph, the nominal power is ~ 16 kW, which equals to 72 dB.

Table 3: 1.3 GHz RF Amplifier Parameters of TARLA [11]

Parameter	RF Amplifier	Unit
Frequency range	1300 ± 5	MHz
Output power (CW & Pulsed)	16.4@ 1 dB	kW
Linear gain	≥72	dB
Output Harmonics (2^{nd} & 3^{rd})	<-45	dBc
Phase drift coefficient typical	0.35	deg/K
Gain drift coefficient typical	0.4	%/K
Efficiency typical @ 18 kW	> 42	%

CONCLUSION

Nowadays, thermionic triode electron gun and injector operating and commissioning works are in progress [13]. Helium cryoplant commissioning are successfully completed. The superconducting cryomodules delivered at the end of

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Figure 8: Photo of TARLA 1.3 GHz RF amplifiers with test setup.

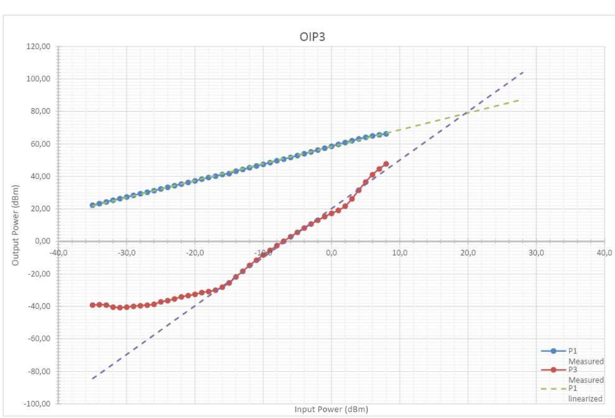

Figure 9: CW output power test results of TARLA high power RF amplifiers.

2017 and site tests are about to be completed. The planned schedule is that the first cryomodule will be in operation, about the beginning of 2020 and the second one is at the end. We are expecting to have the first lasing, in 2022 and to provide the users in the same year.

The first experimental station consisting of a conventional laser source has already in operation, since 2018. TARLA is the only accelerator based user laboratory providing oppor-tunities to the researchers who need high power FEL in mid and far infrared region. Pump-probe, IR spectroscopy and the laser diagnostic experiment halls have been equipped at the same time with commissioning works of accelerator part.

ACKNOWLEDGMENTS

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REFERENCES

[1] A. Aksoy, Ö. Karslı, and Ö. Yavaş, "The turkish accelerator complex ir fel project," *Infrared Physics & Technology*, vol. 51, no. 5, pp. 378 – 381, 2008, 4th International Workshop on Infrared Microscopy and Spectroscopy with Accelerator-Based Sources. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1350449507001065

[2] A.Aksoy and O. Karsli, "The technical design report of turkish accelerator and radiation laboratory in ankara," Ankara University, Tech. Rep., 2015.

[3] J. Teichert, A. Büchner, H. Büttig, F. Gabriel, P. Michel, K. Möller, U. Lehnert, C. Schneider, J. Stephan, and A. Winter, "Rf status of superconducting module development suitable for cw operation: Elbe cryostats," *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, vol. 557, no. 1, pp. 239 – 242, 2006, energy Recovering Linacs 2005. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0168900205020000

[4] A. Aksoy, O. Karsli, A. Aydin, C. Kaya, B. Ketenoglu, D. Ketenoglu, and O. Yavas, "Current status of turkish accelerator and radiation laboratory in ankara: the tarla facility," *Canadian Journal of Physics*, vol. 96, no. 7, pp. 837–842, 2018. [Online]. Available: https://doi.org/10.1139/cjp-2017-0750

[5] T. Wangler, *RF Linear Accelerators*, ser. Physics textbook. Wiley, 2008. [Online]. Available: https://books.google.com. tr/books?id=OJdgVI-UrikC

[6] B. Aune *et al.*, "Superconducting tesla cavities," Phys. Rev. ST Accel. Beams, vol. 3, p. 092001, Sep 2000. doi: 10.1103/PhysRevSTAB.3.092001

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-THP028

[7] "RI Research Instruments, Research Instruments website," https://research-instruments.de/, [Accessed: 08-December-2018].

[8] "A.L.A.T. Air Liquide Advanced Tehnologies, Air Liquide Advanced Tehnologies website," https://advancedtech.airliquide.com//.

[9] O. Karsli and O. Yavas, "A design study on high power rf system for the tarla facility of tac," *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, vol. 693, pp. 215 – 219, 2012. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S016890021200784X

[10] "SigmaPhi Accelerator Technologies, SigmaPhi website," https://www.sigmaphi.fr/, [Accessed: 07-December-2018].

[11] O. Karsli, M. Dogan, F. Ahiska, and O. Orkun Surel, "Implementation of high power microwave pulse compressor," IEEE Transactions on Plasma Science, vol. 47, no. 6, pp. 2823–2831, June 2019.

[12] C. Kaya, E. Kazancı, V. Karakilic, M. Yildiz, B. Koc, S. Özkorucuklu, E. Polat, Ö. Karslı, S. Kuday, A. Aksoy et al., "Beam diagnostics e-gun test stand at tarla," 2014.