MICRON

Report Activity 2023 at INFN-LNF

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1 Experiment overview

This research, funded by the CSN5 of INFN, is conducted in the context of the European [1] and U.S. (and international partners) Snowmass [2] Strategy for Particle Physics devoted to the "Advanced Accelerators Concepts and Technologies" for the next generation of cost effective, Dielectric (operating at optical wavelengths (1-5 μm) and Metallic (from Ka-band (36 GHz) to W-band (100-200 GHz)) High-frequency, High-gradients (>100 MV/m, beyond state of the art) Accelerating structures for research, industrial and medical applications. The MICRON experiment is a collaboration between the following participant units of the INFN: LNS, LNF, Milano, Bologna, Roma1.
For the Metallic structures, at INFN-LNF we proposed these objectives: • Design of metallic Ka-band and W-band accelerating structures at acceleration gradient >100 MV/m. "OPEN" (jointless) and "Four quadrants" RF cavity structures study. • Prototype manufacturing (R&D on material and welding techniques) • RF cold test at the RF Lab Latino [3], at INFN-LNF.

2 1st year (2022), testing of Ka-band samples

In 2022, we machined the sample copper pieces of the three-cell accelerating structure which were tested at Comeb srl for the temperature monitoring. A thermocouple was placed on the cavity RF surfaces through a hole in the cavity body. The data for the temperature plots were obtained from the video recordings. The measurements showed that the cavity body never reached the annealing temperature of copper ($\sim$ 500 °C). This was important for us to prove because it reassures that the copper is kept hard thus more resistant to RF breakdowns at high fields.

3 2nd Year (2023), Multicell Ka-band structure design and Fabrication

In 2023, we performed the RF and beam dynamics (together with the INFN-Roma1 group) of the full structure made of 10 cells. The RF power is fed through a 4-port mode launcher [4], which was also optimized at 36 GHz. In tab.1 are reported the main RF parameters of the 10-cell Ka-band accelerating structure. In fig.1, it is shown the CAD model from CST Microwave studio [5] overlapped with the electric field distribution along the axis of the structure. The input power is roughly 6 MW in order to achieve an accelerating gradient of 150 MV/m. In the figure, the color-plot E-filed distribution is also shown inside the whole structure and the mode launcher.

In fig.2, it is shown the reflection coefficient, S_{11}, at the input rectangular port of the waveguide of the mode launcher. The coupling with the operating mode is optimized to be about -27 dB.

Table 1: *Main RF parameters of the multi-ceel Ka-band accelerating structure.*

Parameter	Value
Radiofrequency, f [GHz]	35.982
Quality Factor, Q	5900
Shunt impedance, R_{sh} [MΩ/m]	130
Max Magnetic field, H_{max} [MA/m]	0.6
Max Electric field, E_{max} [MV/m]	400
Input RF power, P_{input} [MW]	6
iris aperture radius, a [mm]	2
a/λ	0.24
wall thickness, $t[mm]$	0.635
iris ellipticity	1.38
Accelerating Gradient, E_{acc} [MV/m]	150

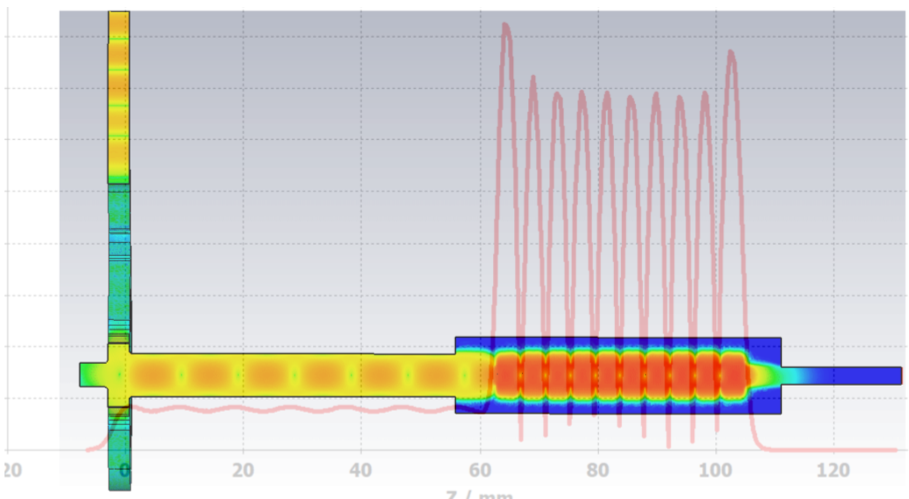

Figure 1: *CAD model from CST and electric field distribution inside the mode launcher and the RF structure.*

The multicell structure and the mode-launcher device were machined and assembled in December 2023. We are now proceeding to the procurement of all RF devices and cables needed for the RF tests with low RF power at the RF Latino Lab in Frascati. The RF characterization of the whole structure will be carried out by the end of 2024.

4 List of Conference Talks by LNF Authors in Year 2023

1. L. Faillace, F. Cardelli, M. Migliorati, V. Dolgashev and B. Spataro, The INFN MICRON project at LNF: Development of high-gradient metallic mm-wave accelerating structures, 15th Workshop on Breakdown Science and High Gradient Technology (HG2023), October 20, 2023.

2. L. Faillace, G. Torrisi, MICRON - Opportunità e Applicazioni di strutture acceleranti miniaturizzate metalliche (banda Ka) e dielettriche (ottiche) Seconda Giornata Acceleratori, INFN-

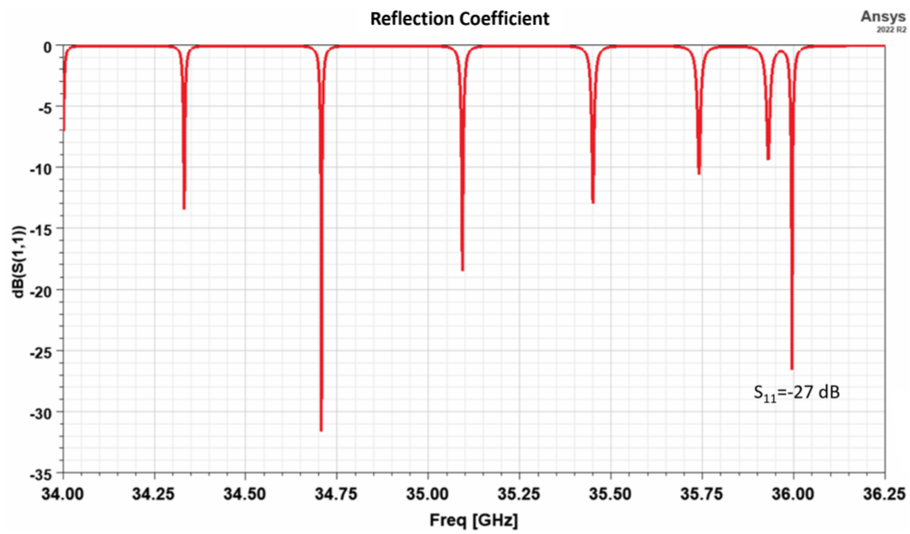

Figure 2: *Reflection coefficient, S_{11}, at the input rectangular port of the waveguide of the mode launcher.*

LNS, Catania, 02/03/2023.

5 Publications in 2023

- Faillace L., Bonifazi R., Carillo M, Dolgashev V., Giuliano L, Migliorati M, Mostacci A, Palumbo L and Spataro B., Design, Fabrication and Mechanical Tests of TIG-welded Ka-Band Accelerating Structures for Ultra-High gradient Applications, 14th International Particle Accelerator Conference,Venice, Italy, May 2023.
- Previous publications are reported in the References.

References

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2. https://snowmass21.org
3. http://latino.lnf.infn.it
4. Castorina G, Ficcadenti L, Migliorati M, Mostacci A, Palumbo L, Cardelli F, Franzini G, Marcelli A, Spataro B, Sorbello G, Celona L. A TM01 mode launcher with quadrupole field components cancellation for high brightness applications. InJournal of Physics: Conference Series 2018 Sep 1 (Vol. 1067, No. 8, p. 082025). IOP Publishing.
5. https://www.3ds.com/products/simulia/cst-studio-suite
6. V. Dolgashev, B. Spataro, L. Faillace, R. Bonifazi, Innovative compact braze-free accelerating cavity, Jinst, September 19, 2018.
7. Dolgashev VA, Faillace L, Spataro B, Tantawi S, Bonifazi R. High-gradient rf tests of welded X-band accelerating cavities. Physical Review Accelerators and Beams. 2021 Aug 10;24(8):081002.

8. Behtouei M, Faillace L, Migliorati M, Palumbo L, Spataro B. New Analytical derivation of Group Velocity in TW accelerating structures. InJournal of Physics: Conference Series 2019 Nov 1 (Vol. 1350, p. 012112). IOP Publishing.

9. Dolgashev VA, Faillace L, Higashi Y, Marcelli A, Spataro B, Bonifazi R. Materials and technological processes for High-Gradient accelerating structures: new results from mechanical tests of an innovative braze-free cavity. Journal of Instrumentation. 2020 Jan 27;15(01):P01029.

10. M. Behtouei, B. Spataro,' A SW Ka-Band linearizer structure with minimum surface electric field for the compact light XLS project', Nuclear Inst. and Methods in Physics Research, A 984 (2020) 164653

11. B. Spataro et al.,'A novel exact analytical expression for the magnetic field of a solenoid', Waves in Random Complex Media, 10 October 2020

12. Spataro B, Behtouei M, Di Paolo F, Leggieri A. A low-perveance electron gun for a high-efficiency Ka-band klystron. The European Physical Journal Plus. 2022 Jul 5;137(7):769.

13. Leggieri A, Behtouei M, Burt G, Di Paolo F, Spataro B. A novel harmonic klystron configuration for high power microwave frequency conversion. arXiv preprint arXiv:2212.12359. 2022 Dec 23.

14. B. Spataro et al.,"The Ka-band High Power Amplifier Design Program of INFN', Vacuum 191 (2021) 110377

15. B. Spataro et al.,' Ka-band Linearizer for the Ultra-Compact X-Ray Free Electron Laser at UCLA', Nuclear Inst. and Methods in Physics Research, A 1013 (2021) 165643

16. M. Behtouei, B. Spataro et al, ' Relativistic Versus Nonrelativistic approaches to a low Perveance High Quality Klystron Matched Beam for a High Efficiency Ka-band Klystron', MDPI, 10 November 2021, Instruments 2021, 5, 33

17. F. Marrese, B. Spataro et. al.,' Multiphysics Design of High-Power Microwave Vacuum Window' , Journal of Microwaves, Optoelectronics and Electromagnetic Application, Vol. 21, N. 1, March 2022.

18. Castilla A, Apsimon R, Burt G, Wu X, Latina A, Liu X, Syratchev I, Wuensch W, Spataro B, Cross AW. Ka-band linearizer structure studies for a compact light source. Physical Review Accelerators and Beams. 2022 Nov 9;25(11):112001.

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