HOM COUPLER DESIGN ADJUSTEMENT FOR CW OPERATION OF THE 1.3 GHz 9-CELL TESLA TYPE SRF CAVITY

D.Kostin, J.Sekutowicz, W.-D.Moeller, DESY, Notkestrasse 85, 22603 Hamburg, Germany.

Abstract

One of the key features of a modern research facility is its versatility, ability to adjust for a multitude of the applications and user needs. A challenge for the coming European XFEL [1, 2] is to become a multipurpose laboratory with a broad applications spectrum. Primarily, the XFEL is a pulsed machine. Having the CW operation mode would be a worthy addition. CW operation of the 1.3 GHz 9-cell TESLA Type SRF Cavity was performed several times at DESY [3-6] and in the other Labs successfully [7, 8]. One of the difficulties was a heat load of the High Order Mode (HOM) couplers [9] described in [3], for example. To amend this, a HOM coupler design adjustment is proposed and simulated.

INTRODUCTION

The HOM coupler for the TESLA type cavity (fig.1) was simulated with a beam tube using the CST MWS T solver [10]. Standard (old, fig.1) and newly proposed coupler types were simulated. A particular design change is shifting the feedthrough antenna tip to the lower magnetic field region by introducing the coupling "nose" on the main HOM coupler antenna (loop). Thus, the eddy-current heating by the operating mode coupling of the antenna will be decreased. Simulation was done with monopole operating mode and monopole and dipole high-order modes, the dipole mode polarization angle was chosen to be 45 degrees, set in the cavity by the main input coupler.

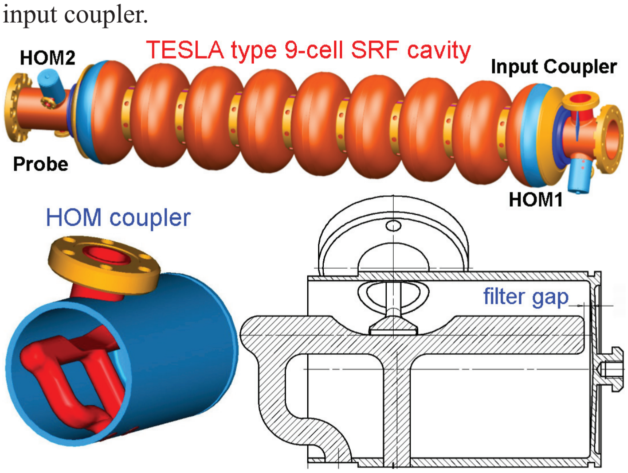

Figure 1: TESLA type SRF accelerating cavity.

HOM COUPLER MODEL

The HOM coupler model for the simulations (CST MWS) is presented in fig.2 for the old standard design and in fig.3 for the changed one. Simulated coupling "nose" length is 8.25 mm to 11.25 mm (fig.3).

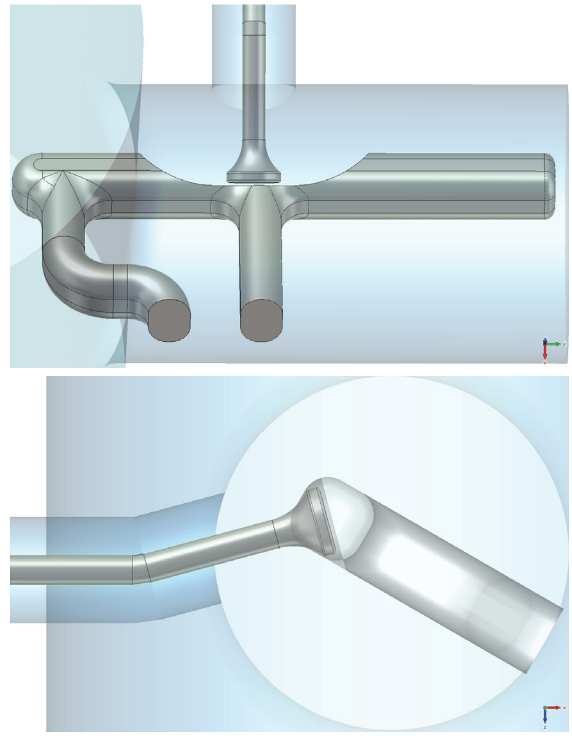

Figure 2: Standard HOM coupler model.

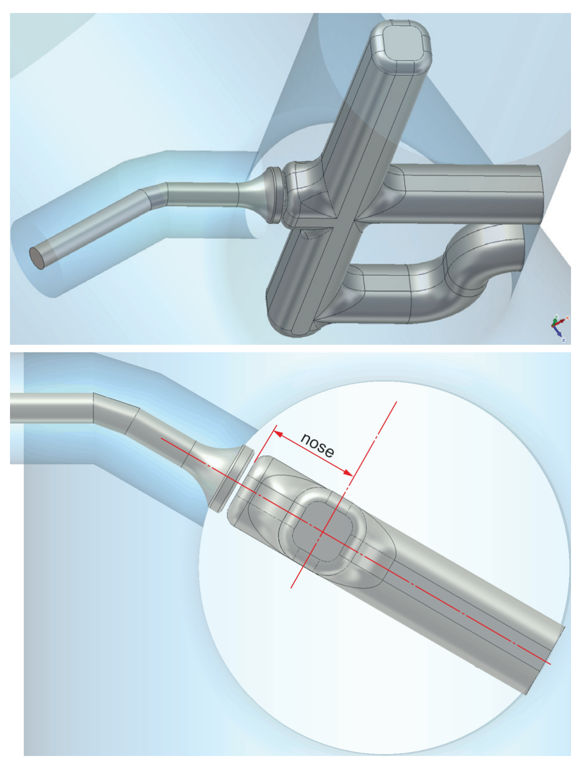

Figure 3: New HOM coupler model.

ISBN 978-3-95450-143-4

SIMULATION RESULTS

The transmission $S_{21}(f)$ is calculated in a frequency range of 1 .. 3 GHz with beam pipe set as an input port and HOM coupler feedthrough as an output port. HOM coupler electromagnetic fields are calculated for the operating (monopole) mode at a cavity operating frequency of 1.3 GHz.

Scattering Parameters ($S_{21}(f)$)

The $S_{21}(f)$ comparison in a range of 1..3 GHz shows a small difference between the transmission of the standard and new designs (fig.4, 5). The notch filter was adjusted for the new design with a new gap value of 1.27 mm with a sensitivity of 0.165 GHz/mm.

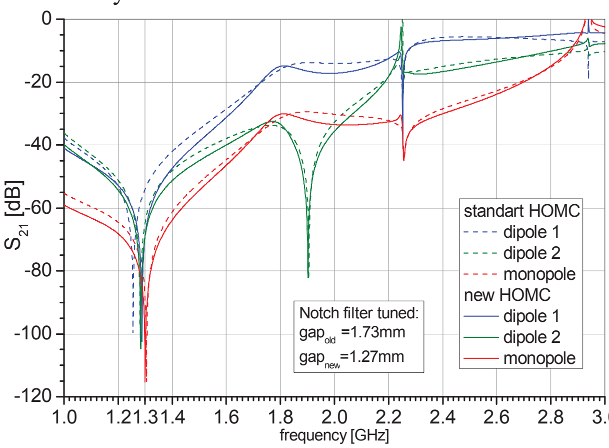

Figure 4: Transmission $S_{21}(f)$ comparison.

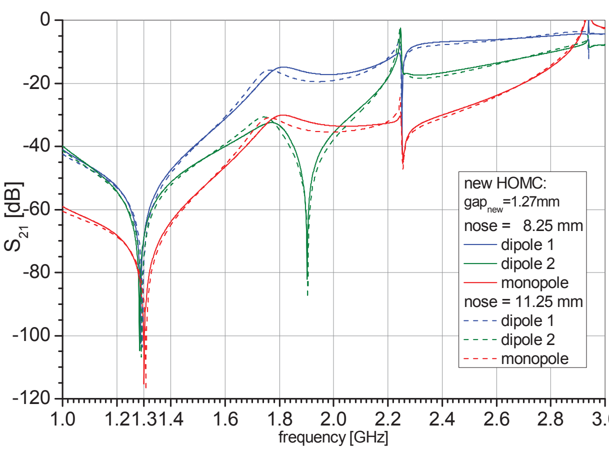

Figure 5: $S_{21}(f)$ with different "nose" lengths.

Electromagnetic Fields

Electromagnetic field distributions are shown in fig.6 - 11. Fig.8, 11 present magnetic field distributions near the main HOM coupler loop antenna for the old (fig.10) and the new (fig.11) designs scaled to feedthrough antenna tip vicinity field maximum. All fields are normalized to 1 W input port (beam pipe) RF power. The HOM coupler loop and feedthrough antenna surface magnetic (H) field amplitude distributions comparison yields the feedthrough antenna tip peak H-field ratio old/new of 0.045/0.030 = 1.5 ([A/m] with 1 W input tube power). Thus, the HOMC antenna tip was shifted to a lower H-field region (fig.10). Increasing the coupler loop protrusion (nose) length in the new design from 8.25 to 10.00 and 11.25 mm slightly changes the transmission and magnetic field distribution, so the old/new ratio is 0.045/0.026 = 1.7 for a nose length of 10 mm and 0.045/0.022 = 2.0 for 11.25 mm (but with less transmission, fig.5, 11).

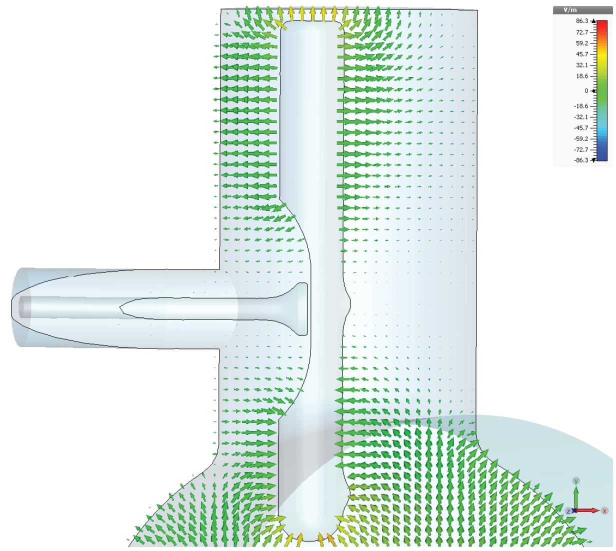

Figure 6: Electrical field at 1.3 GHz, old type.

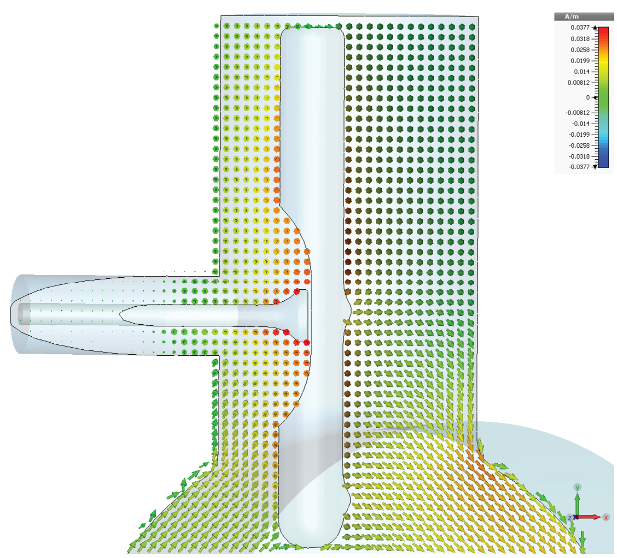

Figure 7: Magnetic field at 1.3 GHz, old type.

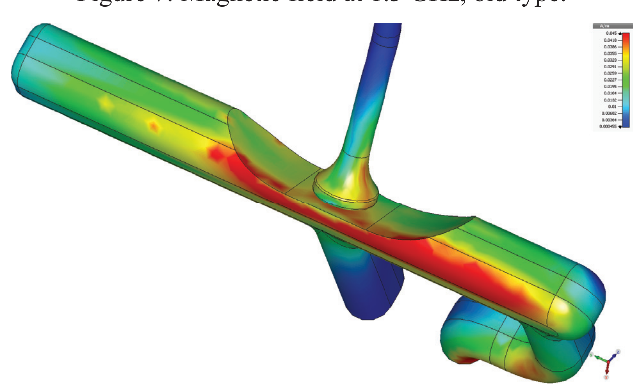

Figure 8: Magnetic field near the HOM loop, old type.

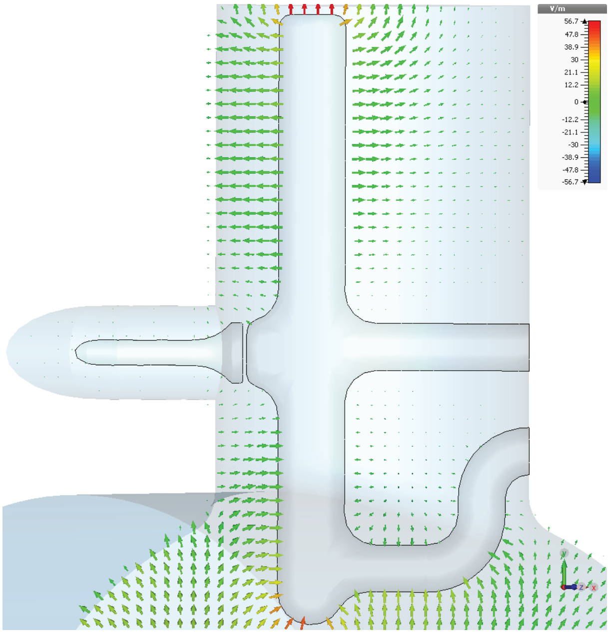

Figure 9: Electrical field at 1.3 GHz, new type.

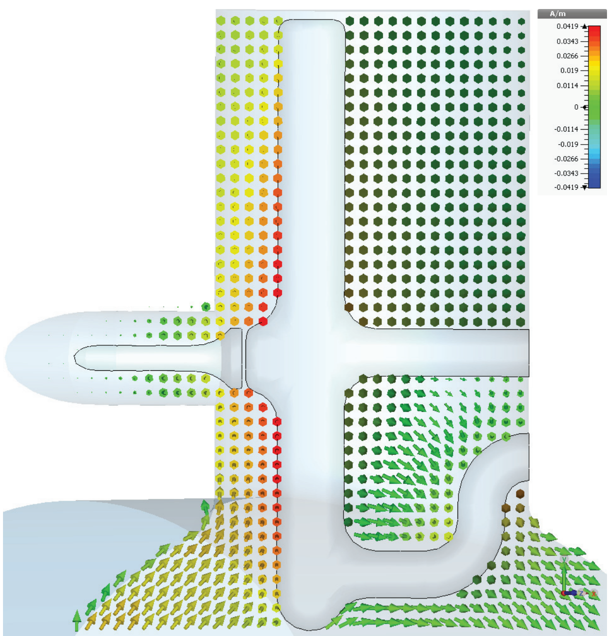

Figure 10: Magnetic field at 1.3 GHz, new type.

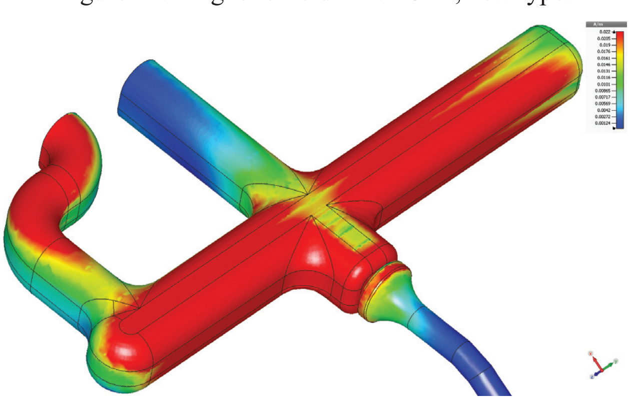

Figure 11: Magnetic field near the HOM loop, new type.

SUMMARY

- To resolve the thermal problem with HOM couplers during the cavity CW operation a HOM coupler design adjustment is proposed and simulated.
- The new HOM coupler design shifts the feedthrough antenna in the lower magnetic field region decreasing the antenna heating by eddy currents.
- Simulations show that with a minimal transmission characteristics $S_{21}(f)$ change the goal is achieved with a proposed new design adjustment. The magnetic field amplitude on the feedthrough antenna tip could be decreased 2 times compared to a standard coupler type. Thus, the operating mode power causing the feedthrough antenna heating could be 4 times less.
- Test on a cavity model is in preparation.

REFERENCES

[1] H. Weise, "The TESLA X-FEL Project", in Proceedings of EPAC 2004, Lucerne, Switzerland.

[2] http://xfel.desy.de/

[3] D. Kostin, W.-D. Möller, J. Sekutowicz, K. Twarowski, "TESLA Type 9-cell Cavities Continuous Wave Tests", The 14th International Conference on RF Superconductivity (SRF2009), September 20-25, 2009, Berlin, Germany, pp. 338-341.

[4] J. Sekutowicz, V. Ayvazyan, M. Ebert, J. Eschke, A. Gössel, D. Kostin, F. Mittag, W. Merz, R. Onken, W. Cichalewski, W. Jałmużna, K. Przygoda, K. Czuba, L. Zembala, I. Kudla, J. Szewiński, “CW and LP Operation Test of XFEL-like Cryomodule”, The International Particle Accelerator Conference, IPAC 12, New Orleans, Louisiana, USA, May 20 – 25, 2012.

[5] J. Sekutowicz, V. Ayvazyan, J. Branlard, M. Ebert, J. Eschke, A. Gössel, D. Kostin, F. Mittag, W. Merz, R. Onken, W. Cichalewski, W. Jałmużna, A. Piotrowski, K. Przygoda, K. Czuba, Ł. Zembala, I. Kudla, J. Szewiński, "Second CW and LP Operation Test of XFEL Prototype Cryomodule", The XXVI International Linear Accelerator Conference, LINAC12, Tel Aviv, Israel, September 9 – 14, 2012.

[6] J. Sekutowicz, V. Ayvazyan, J. Branlard, M. Ebert, J. Eschke, T. Feldmann, A. Gössel, D. Kostin, M. Kudla, F. Mittag, W. Merz, C. Müller, R. Onken, I. Sandvoss A. Sulimov, E. Schneidmiller, M. Yurkov, W. Cichalewski, W. Jalmuzna, D. Makowski, A. Piotrowski, K. Przygoda, K. Czuba, J. Szewinski, "Feasibility of CW and LP Operation of the XFEL Linac", The 35th International Free-Electron Laser Conference, FEL 2013, New York, NY, USA, August 25-30, 2013.

[7] P. A. McIntosh, C. D. Beard, D. M. Dykes, B. Todd, S. Belomestnykh, M. Liepe, V. Medjidzade, H. Padamsee, J. Sears, V. D. Shemelin, D. Proch, A. Buechner, P. Michel, J. Teichert, T. Kimura, T. I. Smith, J. Byrd, J. N. Corlett, D. Li, "Development of a Prototype Superconducting CW Cavity and

ISBN 978-3-95450-143-4

Cryomodule for Energy Recovery", The 10th European Particle Accelerator Conference (EPAC06), Edinburgh, UK, 26-30 June, 2006.

[8] A. Büchner, H. Büttig, M. Justus, U. Lehnert, P. Michel, C. Schneider, G. Staats, J. Teichert, "Experiences with TESLA Cavities in CW-Operation at ELBE", 41st Advanced ICFA Beam Dynamics Workshop on Energy Recovery Linacs, ERL07, May 21-25, 2007, Daresbury Laboratory, UK.

[9] J. Sekutowicz, "HOM Damping and Power Extraction from Superconducting Cavities", LINAC 2006, August 21-25, 2006, Knoxville, Tennessee USA, pp.507-510.

[10] http://www.cst.com