Multiphysics Analysis of Normal Conducting RF Cavities for High Intensity Proton Accelerators

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Abstract

Normal conducting cavities are typically used in the front end of proton accelerators to get the beam accelerated to velocities approximately a few tenths of the speed of light, where superconducting cavities could then be used to accelerate the beam to the speed of light. The warm part of a typical proton accelerator would contain a radio frequency quadrupole (RFQ) and several buncher cavities.

For instance, Figure 1 shows the layout of Project X; a planned high intensity proton particle accelerator of Fermilab. The warm part of Project X contains the ion source, RFQ and MEBT (medium energy beam transfer section). Figure 2 shows the results of the RF heating analysis carried out for the RFQ both in 2D and 3D using COMSOL Multiphysics®. It is imperative for a proper operation of the RFQ to estimate the frequency shift due to the deformations caused by thermal stresses.

On the other hand, ferrite-tuned copper booster cavities are also needed in synchrotron accelerators, where the beam is boosted from several hundreds of MeV to several GeV. Fermilab booster is one of those synchrotron accelerators that used ferrite-tuned cavities. The booster ring has 19 ferrite-tuned cavities. Each RF cavity is a half-wave resonator loaded with three coaxial ferrite tuners separated by a 90° rotation angle and the cavity is fed by a tetrode power amplifier located at the fourth 90° angle.

Thermal analysis was carried out to the booster cavity model using COMSOL Multiphysics considering the Ohmic (resistive), electric and magnetic losses as sources of heating. Figure 3 shows the thermal profile of the Fermilab booster cavity under current 7 Hz repetition rate and future required 15 Hz one, projecting the additional heating risks.

In this paper, a COMSOL based multiphysics analysis investigating the RF, thermal, and mechanical properties of several normal conducting cavities are presented.

Conclusion: The RF heating in normal conducting cavities has been successfully modeled using COMSOL Multiphysics for several resonant structures including the RFQ, rebuncher cavity of Project X, and the Fermilab booster cavity. For the RFQ results demonstrated, the projected frequency shift that could happen due to thermal stresses--which is a vital factor for proper operation as the whole RFQ structure--is basically fine-tuned through water temperature. On the

other hand, for the Fermilab booster cavity, simulations have shown the thermal profile of the cavity after changing the repetition rate from currently 7 Hz to 15 Hz, which is a vital part for the success of the future proton improvement plan of Fermilab.

Reference

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Figures used in the abstract

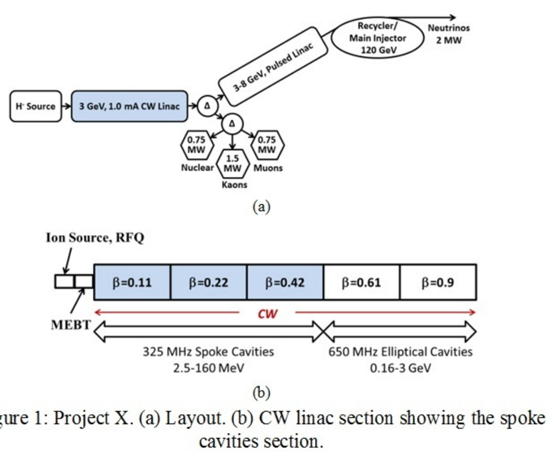

Figure 1: Project X. (a) Layout. (b) CW linac section showing the spoke cavities section.

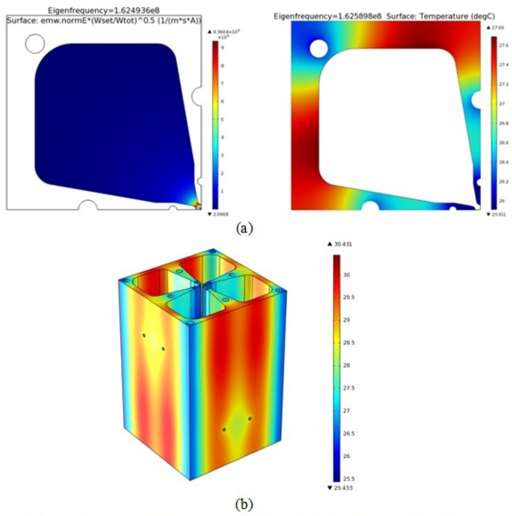

Figure 2: Thermal Analysis of the RFQ. (a) 2-D. (b) 3-D

Figure 2: Figure 2: Thermal analysis of the RFQ. (a) 2D. (b) 3D

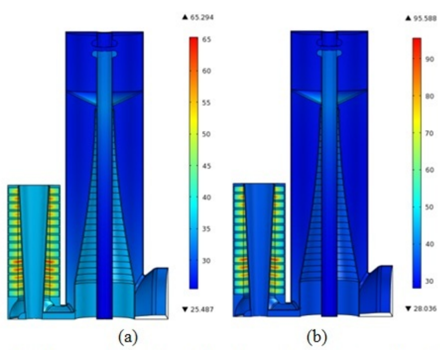

Figure 3: Thermal profile of the Booster cavity under (a) 7 Hz operation. (b) 15 Hz operation.

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