2025 MuC School: RF Technology

Problem: Normal conducting vs. superconducting RF

When operating at high gradients, normal conducting cavities typically use very short pulses, whereas SRF cavities can operate in CW regime. Let's look at why SRF cavities are more efficient in CW mode of operation.

Assume two RF cavities, one made of Cu (KEK Photon Factory) and one of Nb (Cornell B-cell), with $R/Q = 222$ Ohm for Cu cavity and 88 Ohm for Nb cavity. The effective length for both cavities is $L_{cav} = 0.3$ m. The copper cavity has Q_0 of 4.4×10^4, while Q_0 of the Nb cavity is 2×10^{10} at 2 K. Calculate dissipation in the walls of both cavities at an accelerating gradient of 10 MV/m. (This is very moderate gradient for SRF cavities, typical for electron storage rings.)

- If the cooling water system can safely remove 100 kW of heat from the copper cavity (without it overheating), what duty factor can the copper cavity operate at?
- How many copper cavities one would need to deliver the same accelerating voltage as one Nb cavity in CW regime?

Consider the efficiency of RF systems. Assume that each RF systems is providing an accelerating voltage of 3 MV in CW regime.

- If each system transfers 300 kW to the beam, what is the ratio of power transferred to the beam to the power dissipated in the cavity walls for each system?
- For the Nb cavity, assuming the operation temperature is 2 K and $COP^{-1} = 800$ W/W, what AC wall plug power is needed for the cryogenic plant to remove the 2 K heat load from the cavity?
- Assume the RF power source has an efficiency of 50%. What AC wall plug power is needed for the high-power RF system in each case?
- Compare total AC power required by each system. Which system is more efficient to operate?