



Acoustic Phonons in Pulsed Very High Gradient Cavities to Lower Peak Surface Heating?

- ◆ In recent tests surface field strength exceeding 750MV/m have been obtained in a single cell 30 GHz cavity for pulse lengths (exponential decay) of 25 ns. The cavity with a loaded Q of 3800 was excited by a 4 ns long bunch train with 3 GHz spacing.[1] These 750 MV/m surface field are linked to an accelerating gradient of 480MV/m
- ◆ For such high gradients we get current densities of about $3 \cdot 10^8$ Ampere/cm². Earlier calculations [2] have shown that approaching 1 GV/m, surface heating close to the melting point (pulse length>50 ns) has to be considered. This is due to the extremely high current densities in a thin (0.35 micron) skin depth layer (30 GHz).



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- ◆ The electron mobility in copper amounts to $43 \text{ cm}^2/\text{Vs}$. Normally the current related velocity of these conduction electrons is well below 1 mm/s and thus much smaller than the thermal velocity at room temperature.
- ◆ But for a current density of $3 \cdot 10^8 \text{ A/cm}^2$ [=1 MAmp/m] we obtain a current related electron velocity of about 130 m/s . This value is one and a half orders of magnitude off the velocity of sound in copper (3900 m/s).
- ◆ The surface temperature increase up to values approaching the melting point was calculated assuming normal heat diffusion, but including the temperature dependent heat conductivity [2].



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- ◆ One important difference between acoustic waves and heat waves is the coherence. Heat can be understood as incoherent (un-correlated movement) of electrons and ions, where ultrasound is a coherent movement.
- ◆ In the thin skin depth layer of 0.35 micron the electrons are moving coherently with 30 GHz and due to this coherent movement there may be a certain probability to excite also a coherent movement of the copper ions in this thin layer.
- ◆ In that case there may be part of the “heat” converted into ultrasound (or hypersound above 1 GHz).
- ◆ This hypersound would propagate (tangentially to the surface) much faster than normal heat diffusion



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- ◆ At 30 GHz we can expect strong scattering of acoustic waves (acoustic phonons) at grain boundaries as well as high attenuation. Thus a considerable part of the tangentially propagating waves may be scattered and deflected into the bulk of the material where they would be absorbed (converted into thermal phonons) within a few 10 micron due to the high attenuation
- ◆ But such an effect (10 micron=2.5 ns) may help to lower the peak surface temperature by a certain amount for the operating conditions mentioned in the beginning.
- ◆ Independently of such a hypersound phenomenon which may be very difficult to measure directly, we should see normal thermo-acoustic excitation of the cavity in the region of a few MHz and below (ringing bell).



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- ◆ Is there any quantitative theory available for the concept described above? Maybe one can find estimates which tell us, that such an effect is, for the parameters given, in the order of permille...percent...10 percent...50 percent?
- ◆ Acknowledgements: Thanks for helpful discussion on the subject with E.Jensen, I.Syratchev, L.Thorndahl, I.Wilson and W.Wuensch
- ◆ References:
[1] H.Braun et al "A Very High Gradient Test of a 30 GHz Single-Cell Cavity", 7. EPAC, Vienna 2000 or CERN/PS2000-045(RF) or CLIC 444
[2] I.Wilson "Surface heating of the CLIC Main LINAC Structure", CLIC Note 52 (15.10.87)