Gradient Limits - Summary of Perry Wilson, SLAC-PUB-7449

Perry Wilson present gradient limits in his paper "Scaling Linear Colliders to 5 TeV and Above"[1]. This note is a summary of the data that goes into his results. The frequency dependence of breakdown was measured by G. Loew and J. Wang.[2] The results are presented in Figure 1. The data are described by a $f^{1/2}$ dependence.

Pulse length dependence comes from A. Vlieks *et al*.[3] Perry describes these data as depending on pulse length as $T_p{}^{1/4}$. The data vs T_p are shown in figure 2 together with Perry's parametrization

$$E_b = 73.2(\mathrm{kV/cm})\left[1+\frac{11.8\mu s^{1/4}}{T_p^{1/4}}\right]$$

which seems a good description of the data. (Thanks to Perry for pointing out a mistake in the first version of this note.)

These two dependences can be combined assuming the pulse length scales as fixed fraction of the filling time which is proportional to $f^{-3/2}$. The result for the **SURFACE FIELD BREAKDOWN LIMIT** is

$$V_{surf}(\mathrm{MV/m}) = 130[f(\mathrm{GHz})]^{7/8}$$

and using a ratio of surface field to gradient of 2.3, the **GRADIENT BREAKDOWN LIMIT** is

$$G_{grad}(\mathrm{MV/m}) = 56[f(\mathrm{GHz})]^{7/8}$$

The threshold for **DARK CURRENT CAPTURE** is

$$G_{dark} = \frac{\pi mc^2}{e\lambda} = \frac{1.605\ \mathrm{MV}}{\lambda}$$

Figure 3a shows the dark current and breakdown limits.

Pulsed temperature rise is

$$\Delta T = G^2\sqrt{T_p}\,\frac{1}{Z_H^2}\,\frac{R_s}{\sqrt{\pi\rho c_\varepsilon k}}$$

Z_H is an impedance defined as

$$Z_H = \frac{G}{H_{max}}$$

where H_{max} is maximum surface magnetic field anywhere in the structure. Using $Z_H = 307\ \Omega$,

$$\Delta T(\mathrm{C}) = 424 \times G(\mathrm{GV/m})^2\sqrt{T_p(\mathrm{ns})}$$

Scaling the pulse length and surface resistance with frequency gives the gradient limit shown in Figure 3b. Note that this scaling would give a pulse length of 16 ns at 91.4 GHz, and the gradient limit would be different for different pulse lengths.

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1 Perry B. Wilson, SLAC-PUB-7449, also available as ARDB102
2 G. A. Loew and J. Wang, SLAC-PUB-4647
3 A. E. Vlieks *et al*, SLAC-PUB-4546

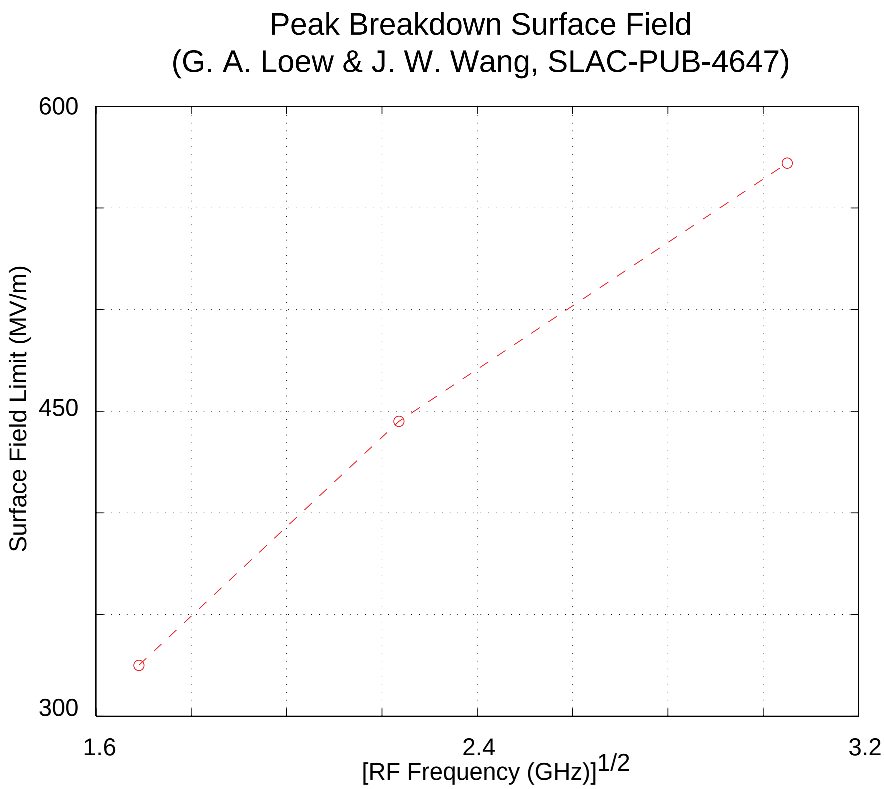

Figure 1: Peak breakdown surface field for pulses long compared to the filling time.

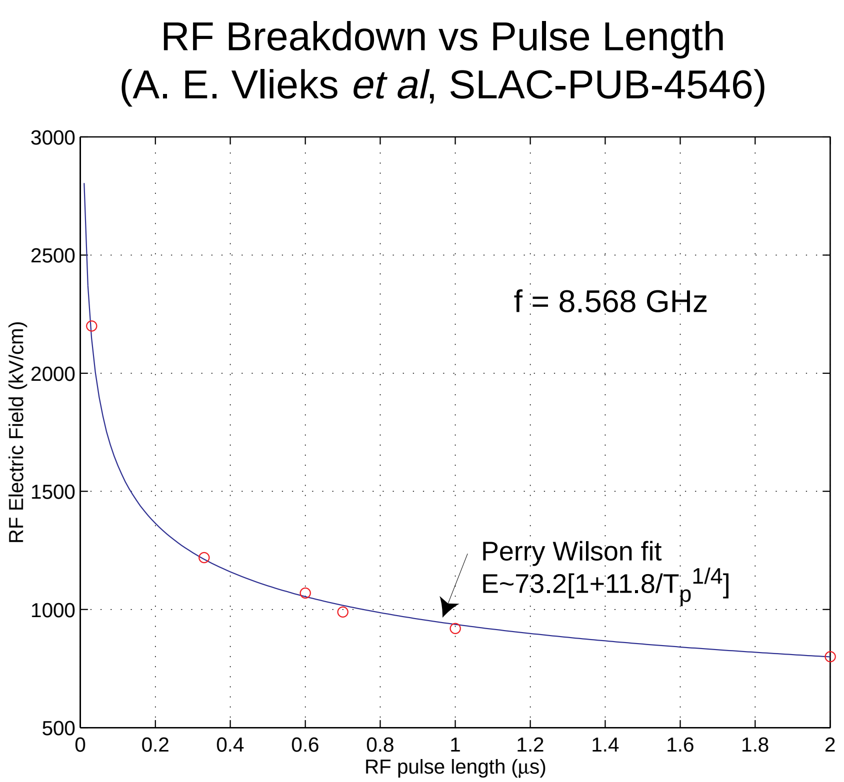

Figure 2: RF breakdown vs pulse length at 8.568 GHz..

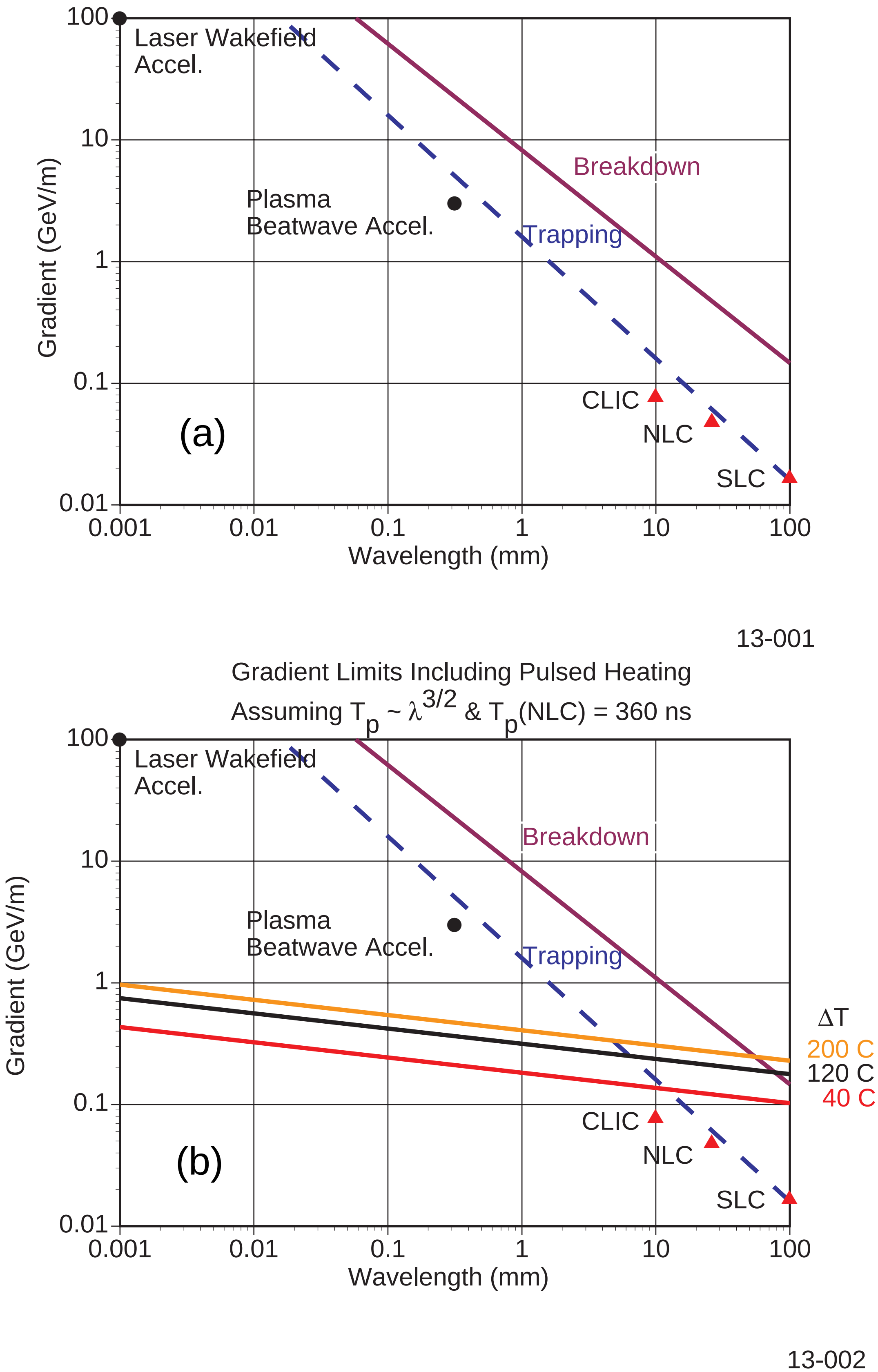

Figure 3: Gradient limits as discussed in text.