SINGLE PULSE DAMAGE IN COPPER

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Abstract

The Next Linear Collider (NLC)[1] electron and positron beams are capable of damaging the linac accelerating structure and beamline vacuum chambers during a single accelerator pulse. Machine protection system (MPS) considerations have an impact on the engineering and design of most machine components downstream of the damping ring injector complex. Beam tests have been done at the SLAC Final Focus Test Beam (FFTB)[2] to examine the behavior of copper at and above the damage stress threshold. In this paper we present results of damage studies in copper as the beam pulse heating is varied from below melting to near vaporization. The goal of the tests was to determine allowable limits on beam size and intensity of a benign single bunch pilot beam to be used in testing linac systems. Typical expected pilot beam parameters (compared with nominal) are: 10 times reduced intensity, 10 times increased horizontal emittance and 1000 times increased vertical emittance, resulting in a reduction in charge density of 10^5. The tests we report here used short (1 mm) beam pulses of between $I = 3 \times 10^9$ and 20×10^9 electrons with transverse sizes σ_{xy} between 45 μm^2 and 200 μm^2 .

1 INTRODUCTION

The design requirements for the NLC MPS are summarized in reference [3]. The geometry of the linear collider makes it impossible to abort an errant pulse once it has been launched into the main 10 km X-band linac. Since there is no guarantee that the first pulse will traverse the system properly, the pilot must be harmless. The purpose of the single pulse damage test was to determine the pilot pulse parameters. Energy deposition simulations indicated that the pilot pulse should have both a large emittance and a small intensity, forcing beam instrumentation to have an extended dynamic range.

It is critical to understand what constitutes damage in the X-band linac structure. It is possible that the structure performance will be degraded by impact from relatively low intensity (<0.01 of *I* nominal) pulses. In this series of tests, we hope to examine the change in the crystalline structure of the copper surrounding the impact point. Here, however, we only present images showing significant surface damage. NLC X-band structure high power tests[4] will indicate limits on structure crystalline and surface damage.

There are three thermal thresholds of interest, as illustrated in table 1. The bottom line of the table shows the temperature at which annealled copper will mechanically yield, i.e. the stresses from the beam heating exceed the tensile elastic limit. [5]

Table 1: Properties of Copper.

	E_dep (J/gm)	Temp. (°C)
Vaporization	4800	2570
Melting	400	1083
Local yielding	62	180

Downstream of the linac, damage concerns are limited to simple vacuum chambers, collimation systems and special instruments. The latter will be protected through local optics and design. The series of single pulse damage tests will allow us to determine the threshold beam parameters which generate loss of vacuum integrity.

2 DAMAGE ESTIMATES

We used a coupon 1.4 mm thick, the same thickness as the iris of the X-band disk loaded waveguide structure. The interaction between the beam and the material was modelled using the EGS code, originally developed for use with electromagnetic showers. Table 2 shows the calculated energy deposition and resultant temperature rise in the material for beam parameters used in this test and for typical NLC linac beam parameters. Copper boils at 2570 °C; it will be fully vaporized by an energy deposition of ~ 4800J/gm.

Table 2: Estimated energy deposition and temperature in the copper test coupon for test beam and typical NLC linac beam parameters.

#	$\sqrt{\sigma_x\sigma_y}$	I x10^{10}	E (J/gm)	T (°C)	
1	7	2	2425	2570	fix σ, vary *I*
2	7	1.6	1940	2570	
3	7	1.0	1210	2570	
4	7	0.7	850	2200	
5	7	0.3	360	920	
6	8	2	1615	2570	fix *I* var σ
7	10	2	1175	2570	
8	14	2	550	1430	
9	7	100	120000	-	typ NLC
10	4	100	360000	-	

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