Electron beam damage effects simulations for LLNL

The NLC beam density after the damping rings has sufficient current density to damage accelerator components. We wish to understand the limitations on beam density to avoid damage, and the type of damage that would result from exceeding these densities.

The following parameters represent the full range of interest in electron beam parameters.

<table>
<thead>
<tr>
<th>Electron beam parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine cycle rate (macropulse)</td>
<td>120Hz (probably not significant)</td>
</tr>
<tr>
<td>Machine bunch rate (micropulse)</td>
<td>357MHz</td>
</tr>
<tr>
<td>Number of microbunches</td>
<td>1 to 100</td>
</tr>
<tr>
<td>Microbunch length (lab frame)</td>
<td>3x10^{-13} second to 8x10^{-13} second (sigma)*</td>
</tr>
<tr>
<td>Microbunch charge</td>
<td>1x10^8 to 1.2x10^{10} e^-</td>
</tr>
<tr>
<td>Beam size (elliptical)</td>
<td>1 - 500 micron sigma (50-200 micron is the region of greatest interest)</td>
</tr>
<tr>
<td>Beam energy</td>
<td>10 - 500 GeV</td>
</tr>
</tbody>
</table>

*Simulation should be able to handle different time structures to a resolution of 10^{-13}s.

**Target parameters:** The target is assumed to be composed of metals. The materials of particular interest are: Copper, Titanium, Tungsten, Beryllium, Indium, Tin, Lead. The target is composed of simple geometric shapes of these materials, with length scales larger than 10 microns.

**Simulation issues:** This is a combined mechanical and electrodynamic problem. We believe that the following simplifying assumptions can be made:

- The frequencies involved are lower than the plasma frequency in the target.
- The back reaction on the electron beam from the electrical fields can be ignored.
- Multiple train effects are not expected to be important. (however multiple bunch effects are important).

Unfortunately the following effects need to be considered:

- Thermal conductivity during the pulse train.
- Acoustic / shock wave propagation.
- Target state change: melting / boiling.
Skin depth effects and electromagnetic field propagation into the target.

The non-equilibrium effects from the very rapid heating of the target during a micro bunch are not known and may be significant.

**Damage is believed to be due to the following mechanisms:**

**Direct beam absorption:** The distribution of energy deposited in the target from the particle shower can be provided by SLAC using EGGS simulations (or similar tools).

**Direct electric field ionization:** The charge density of the electron beam can produce electrical fields sufficient to directly ionize the target.

**Electromagnetic pressure:** The electromagnetic pressure on the sample from the electron beam can be significant. (We believe that this is a small effect)

**Induced current heating:** Heating of the target due to image currents is significant. This mechanism can cause damage even when there is no direct beam interception.

**Effects of interest**

Condition of the target after damage: Is the damage restricted to a local area, or are there fractures extending over an extended region? If the target melted, and then rapidly resolidified, has its surface or crystal structure changed significantly? Has material been spalled or evaporated from the target?

**The following specific simulations are of particular interest:**

1. Single electron bunch, Q=1x10^9 e^−, 400 femtosecond sigma, 40 micron round spot sigma, 250GeV. Target is copper, 3mm thick, normal incidence. This simulates potential damage from the pilot bunch to the accelerator structures