Beam Pulse Structure and Targets

Roger Bennett

Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, UK

roger.bennett@rl.ac.uk

Targets

1. Solid

   Suffer from thermal stress

1. Free liquid jets

   Thermal shock is not a problem - **provided the pulse is short enough**.

Shock, Pulse Length and Target Size

When a solid experiences a temperature rise the material expands. Because of mass inertia there will always be a slight lag in the expansion. This causes pressure waves to ripple through the material. When the temperature rise is relatively large and fast, the material can become so highly stressed that there is permanent distortion or failure - shock.

Short high intensity beam pulses will give rise to shock in a target.

The shock wave travels through matter at the speed of sound,

$$s = \sqrt{\frac{E}{\rho}}$$

where E is Young's modulus of elasticity and ρ is the density.

The time taken for the wave to travel from the outer surface to the centre is given by

$$\tau_s = \frac{d}{s}$$

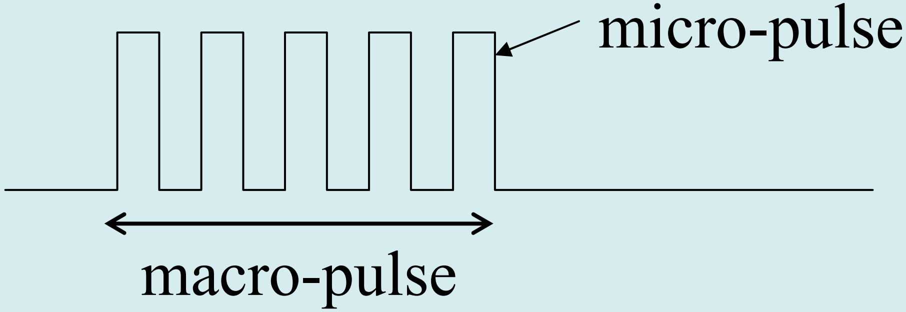
If the beam pulse (τ_p) is long compared to the characteristic time τ_s, then little energy goes into the target in this time and the shock wave in the target is reduced.

If the target is *small* compared to the beam pulse length the shock is reduced.

If $$\tau_s = \frac{d}{v} < \tau_p$$ No problem!

Must have sufficient pulsed energy input!

The Proton Pulse



Proton beam "macro-pulses" and "micro-pulses".

Traditionally we have considered the micro-pulses as ~1 ns wide and **the macro-pulses as ~1 μs wide**. The temperature rise per macro-pulse is $\Delta T \sim 100$ K at 50 Hz.

For the tantalum bar target, radius 1 cm and length 20 cm, then:

- The time for the shock wave to travel a radius is 3 μs
- The time for the shock wave to travel half the length is 30 μs

However, in the RAL proton driver scheme with ~5 micro-pulses, it is likely that they could be spaced apart by **~60 μs**, thus reducing the effective thermal shock to only $\boldsymbol{\Delta T \sim 20}$ **K**.

NF Target:

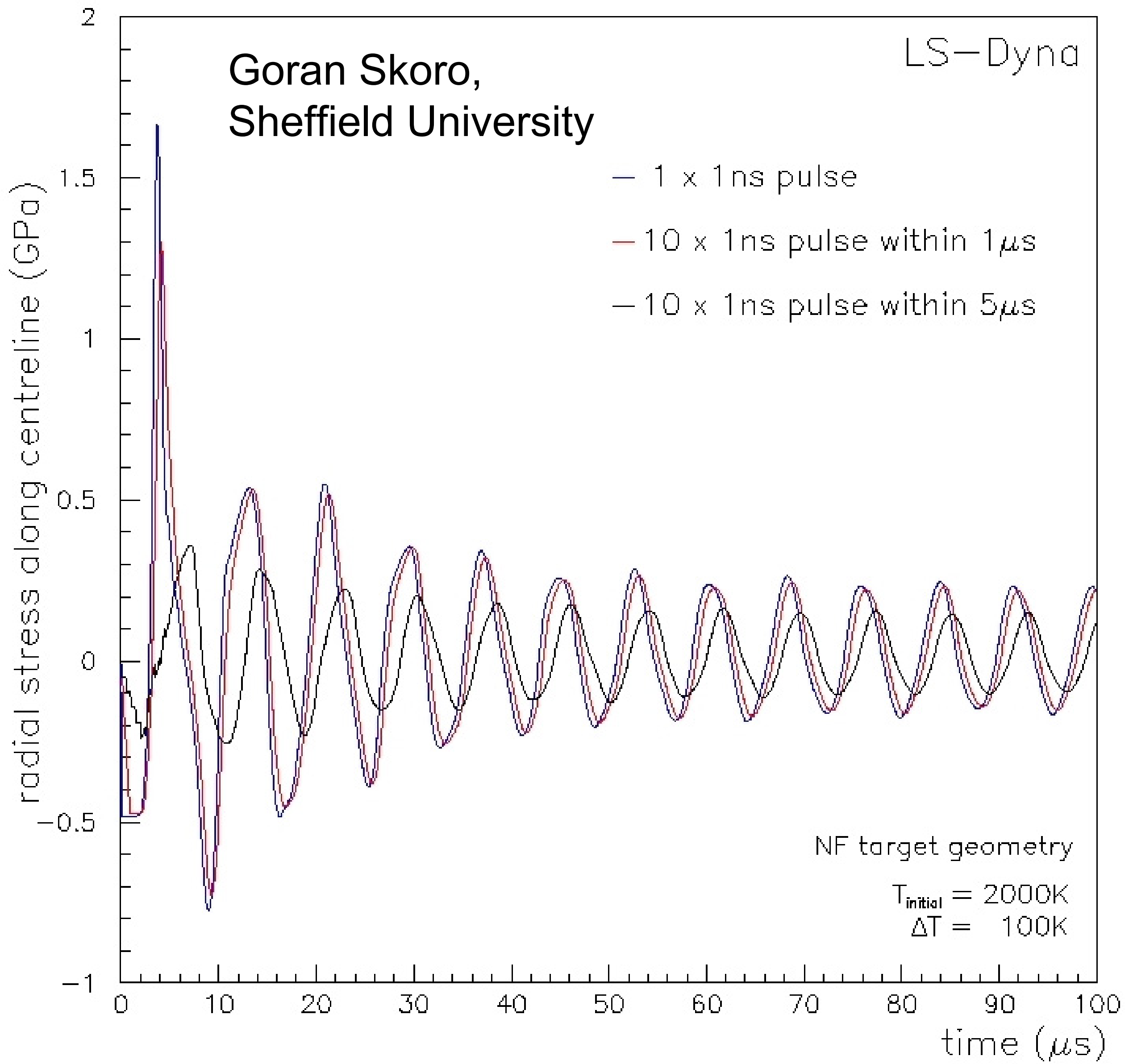
1 cm radius

20 cm long

$\tau = 3\ \mu s$

Total temperature rise:

$\Delta T = 100$ K



Effect of 10 micro-pulses in 1 and 5 μs long macro-pulses.

Summary

To reduce adverse thermal shock effects on the targets the beam pulse structure should preferably be:

Target	Repetition Rate	Micro-pulse
Solid Target	As high as possible	As many as possible, Spaced apart by ≥30 μs
Free Mercury Jet Target	≤ 50 Hz	Any number within ~50-100 μs