A Radiation Cooled Solid Tantalum Target

Paul Drumm

Rutherford Appleton Laboratory

…. history

- Looking at solid targets since NuFact'99 in Lyon
- Attractive because potential power dissipation is very large
- Experience with high power radioactive beam target (<100kW).

- Single solid bar target:
  - 20 cm long 2cm ø ≈ 125 cm^2

    $\sigma \sim 5.6696 \times 10^{-4}$ $W.cm^{-2}.K^{-4}$.

    $P = \varepsilon.\sigma.(T_r^4 - T_e^4)$

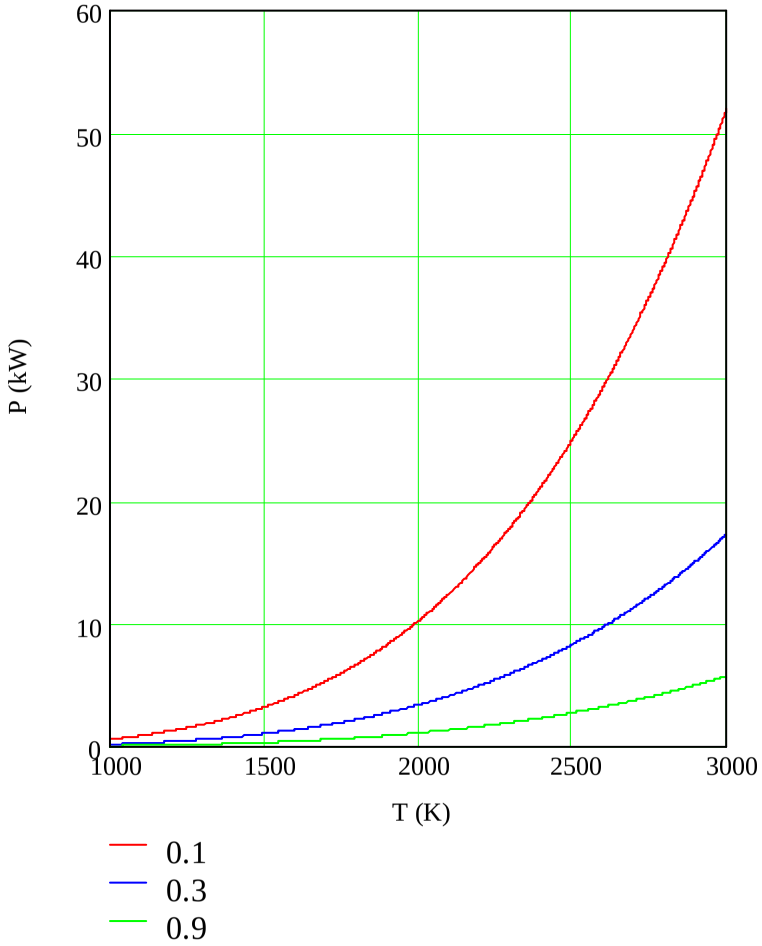
    $\varepsilon \sim 0.3$, Tr~3000K, Te~300K

    P ~17kW
- Rotating Toroid:

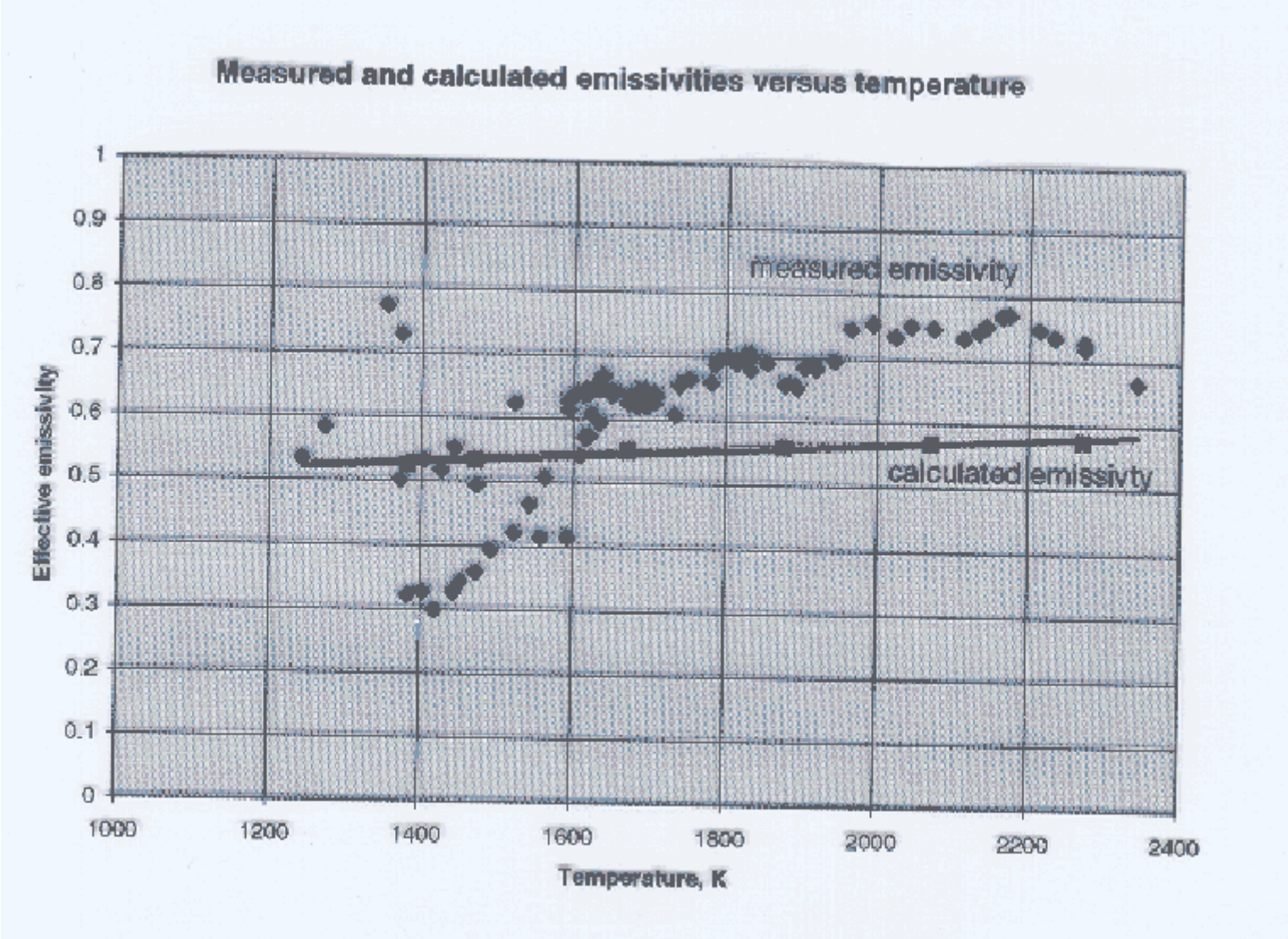
  ~20 m in circumference (R~3m)

  P ~1.7MW

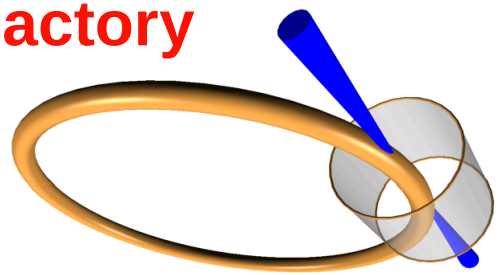
  $\varepsilon > 0.3$?




mm 10 20


Measured and calculated emissivities versus temperature
Effective emissivity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1000
1200
1400
1600
1800
2000
2200
2400
Temperature, K
measured emissivity
calculated emissivty

Target for a Neutrino Factory

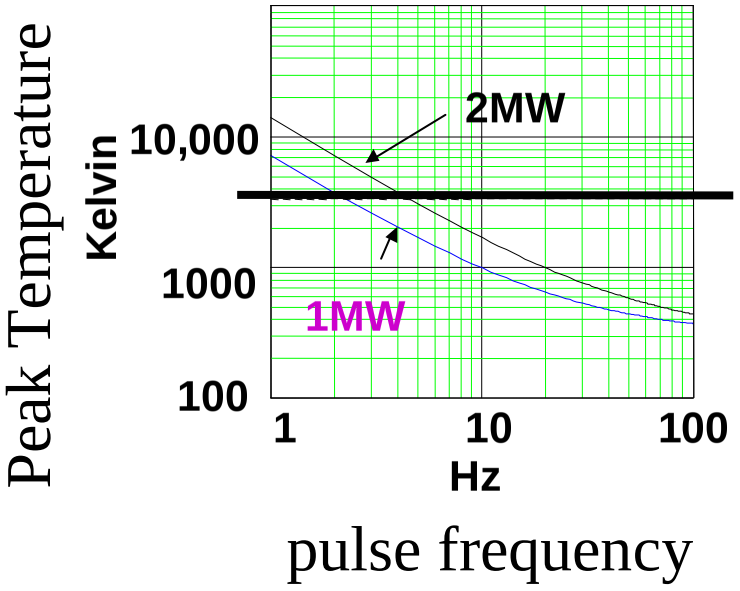


Rotating Tantalum Target Ring:

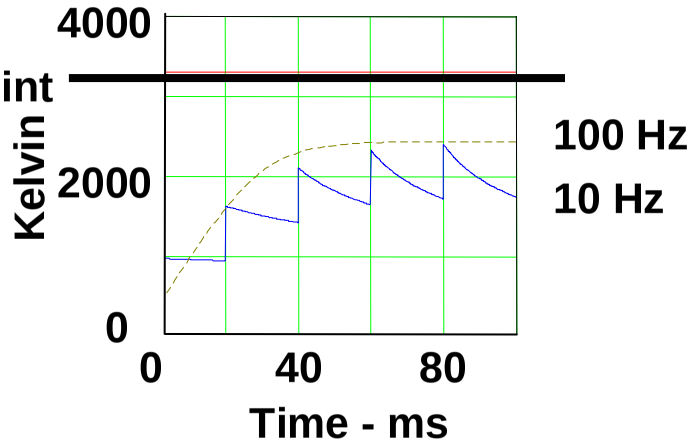
σT^4 power removal

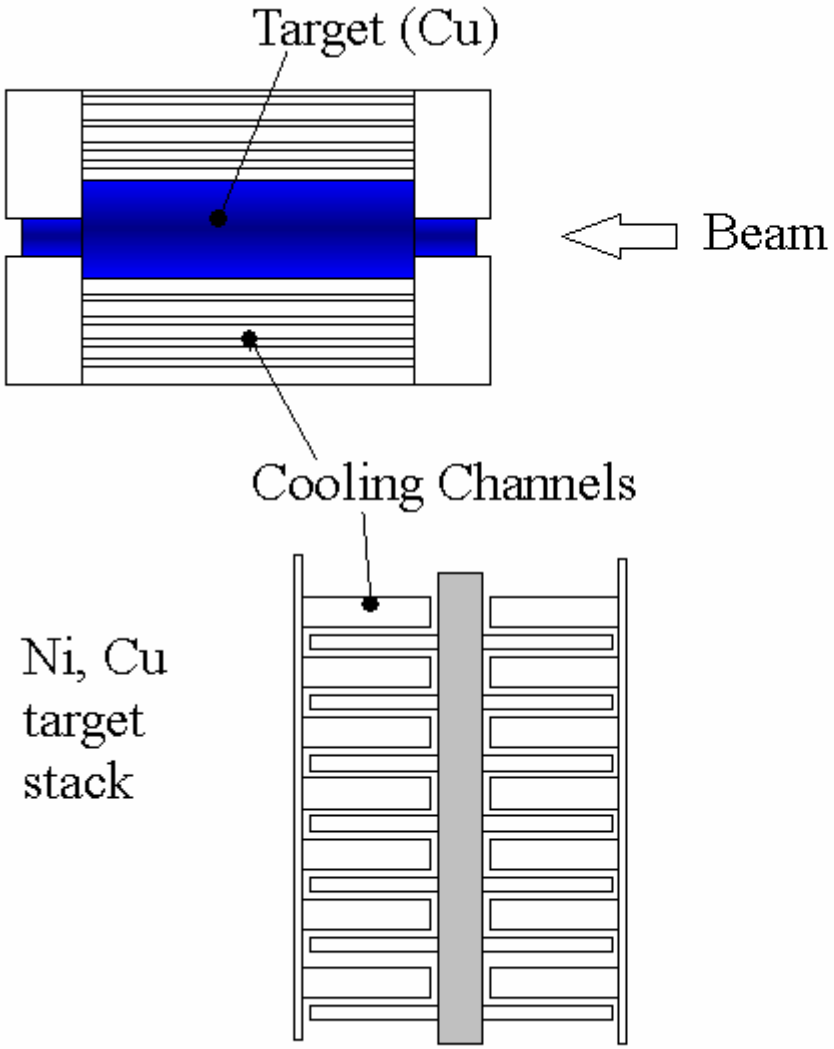
Many MW average power is no problem at high Hz

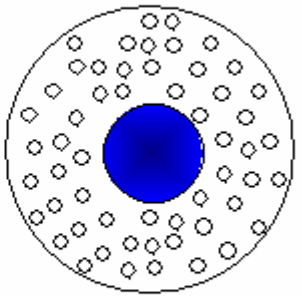
e.g. 1 MW equates to 4 MW beam power at a few GeV



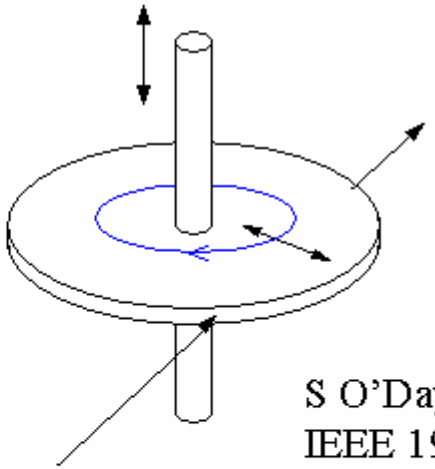
Shock induced by pulsed beam causes immense stress ($\Delta T \sim 700$ Kelvin)







K Anderson et al.,
IEEE PAC 1991,
p1946

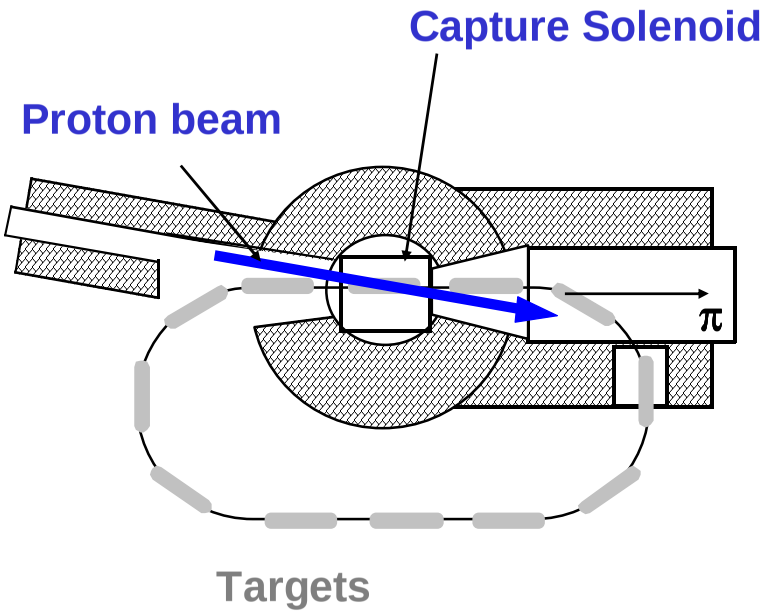


S O'Day
IEEE 1993 PAC.
p3096

FNAL 5MW/l (cf 15MW/l)
@1/4 Hz, 120GeV p

Target Lifetime

Target Station Schematic



Shock & Temperature Cycling

- reduces target lifetime

Individual Targets

- less risk of a catastrophic failure

Important to do tests

- single pulse shock limit
- cycling lifetime

Slow temperature rise ⇨ increase in volume

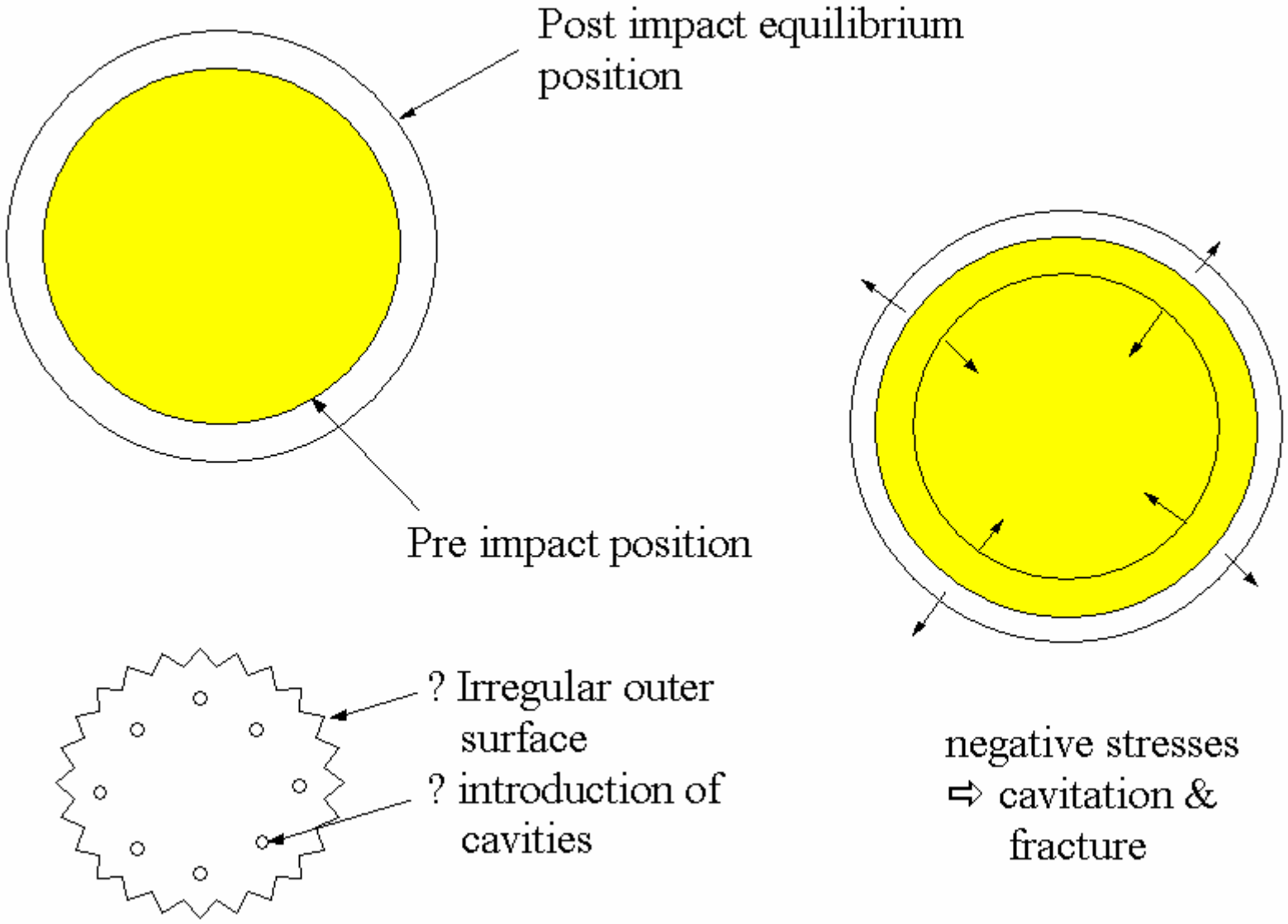
Sudden temperature rise ⇨

Pressure ⇨ atomic spacing < relaxed state

Target material responds to an impulse of pressure

Stress wave oscillates in material and can be amplified

by


Post impact equilibrium position
Pre impact position
? Irregular outer surface
? introduction of cavities
negative stresses
⇨ cavitation & fracture

Electron Beam Material Tests

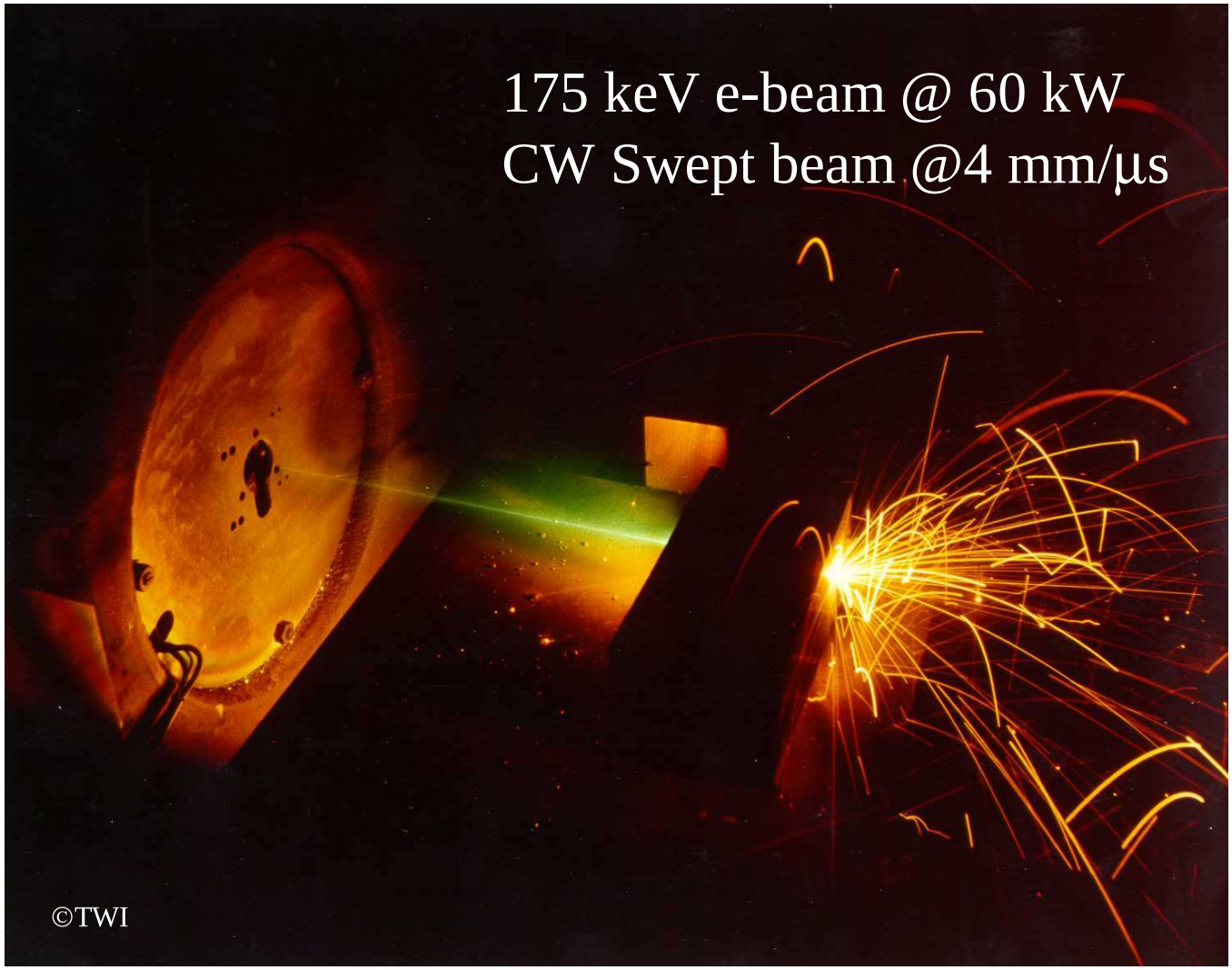
Lifetime tests of Ta foils:

: modest pulsed energy input ~ 60 mJ/pulse
: small volume ~ few mm^2 × ~10 μm deep
: v. high energy density ~ 1.5 kJ/cc ~ 90 J/gm
: repetitive ~ 100 Hz
: fast 1 μs pulse

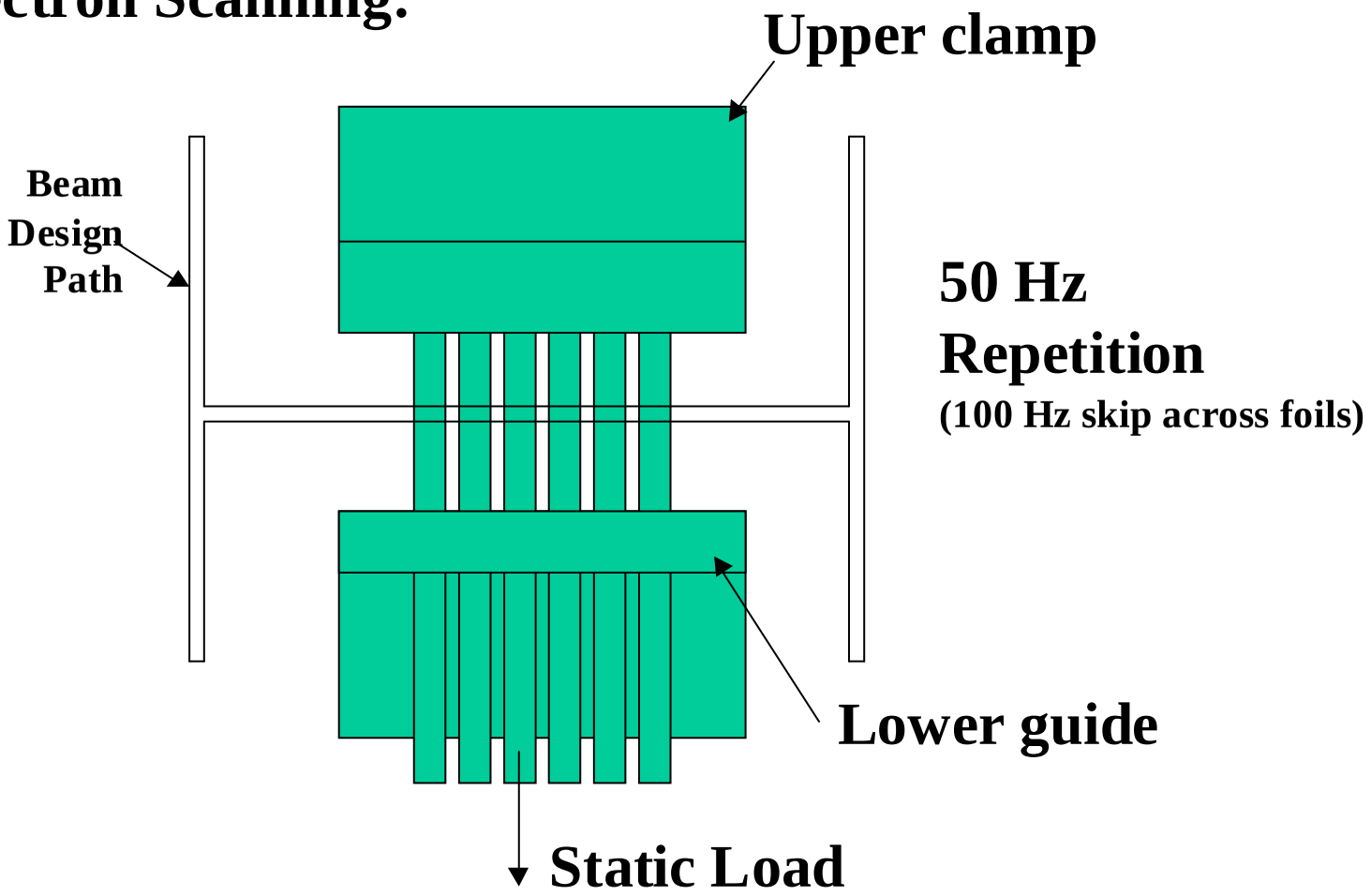
Paul Drumm & Chris Densham
CLRC Rutherford Appleton Laboratory, UK

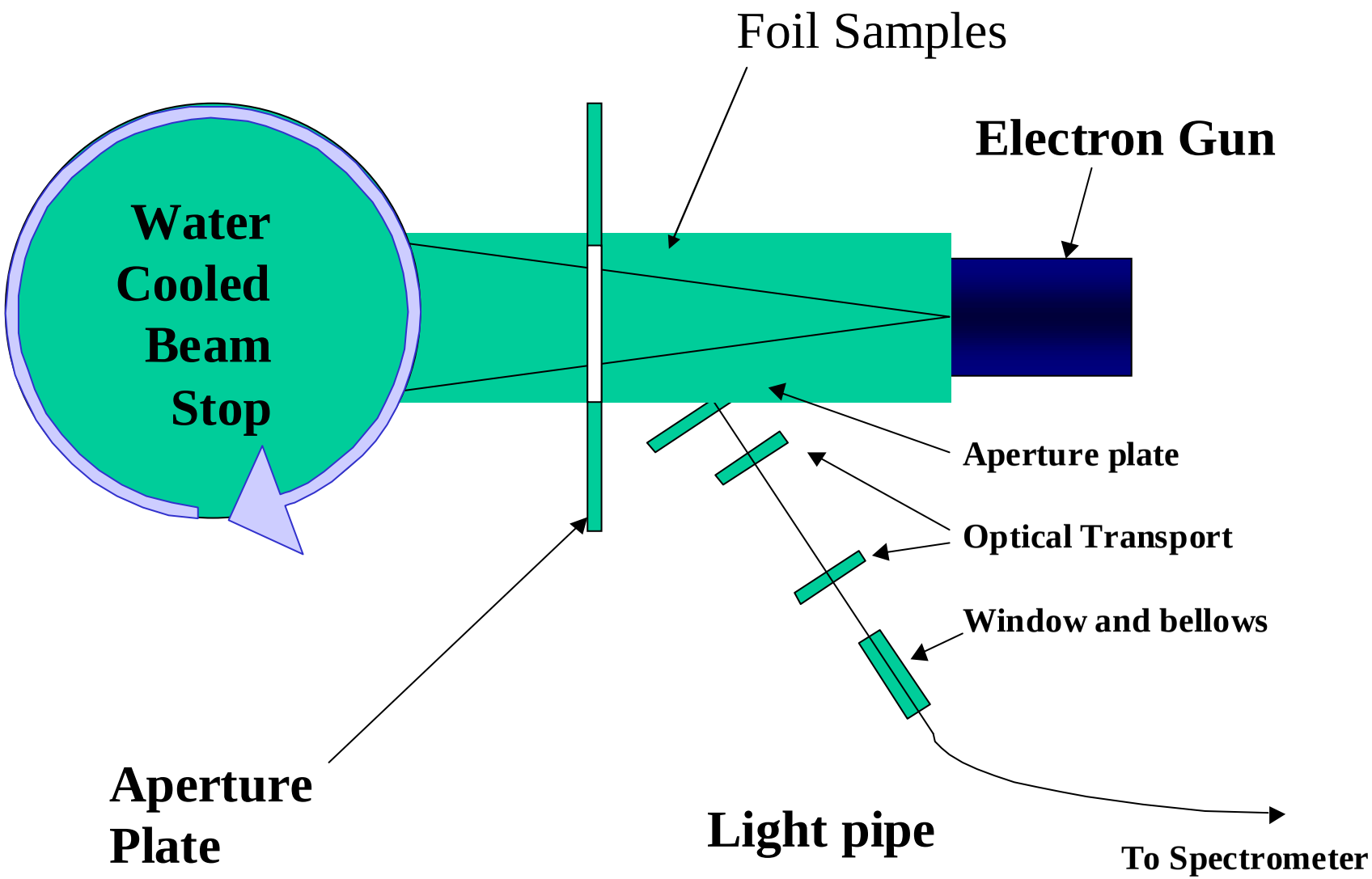
& TWI, Cambridge, UK

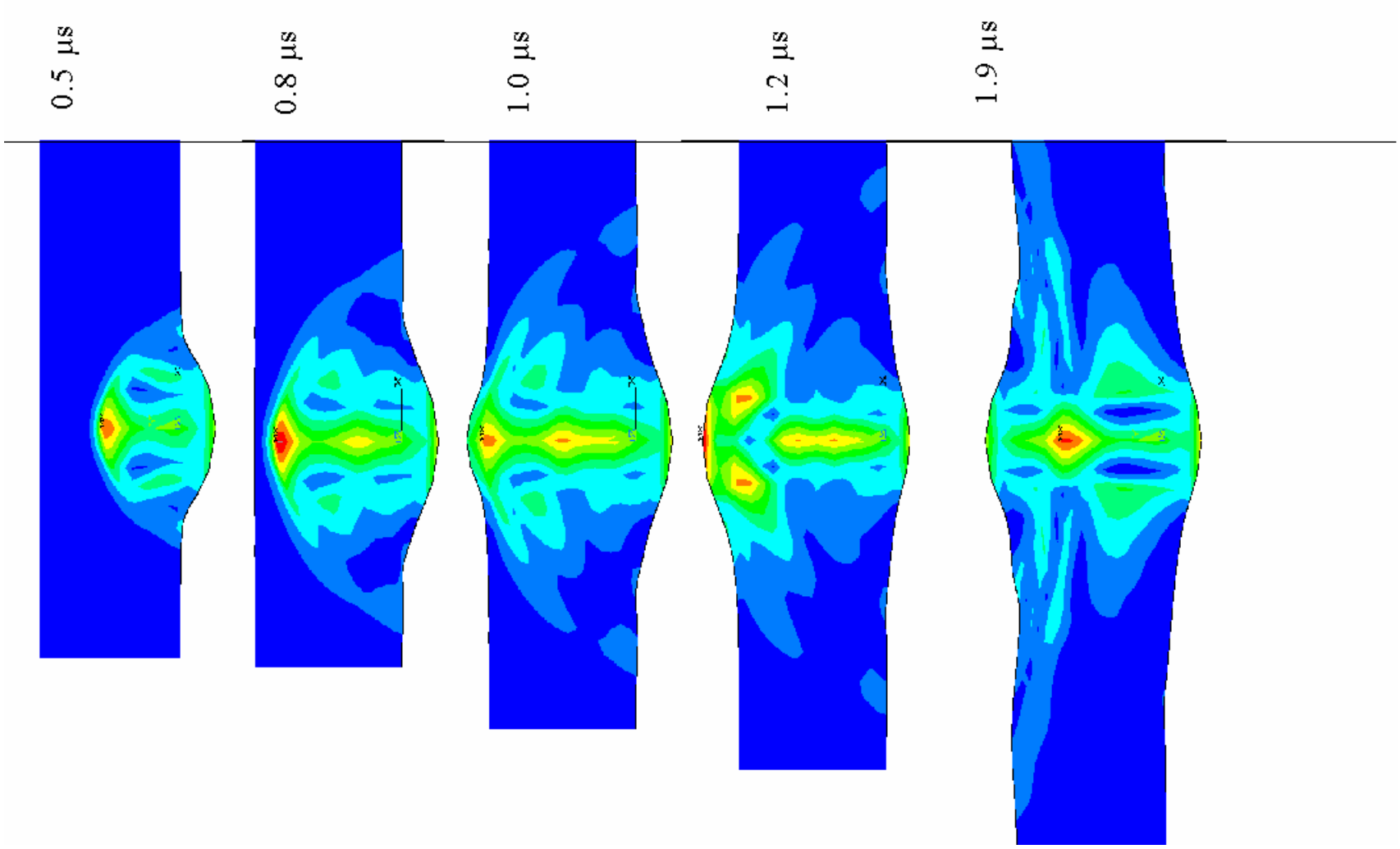
High Power Welding Machine



Electron Scanning:

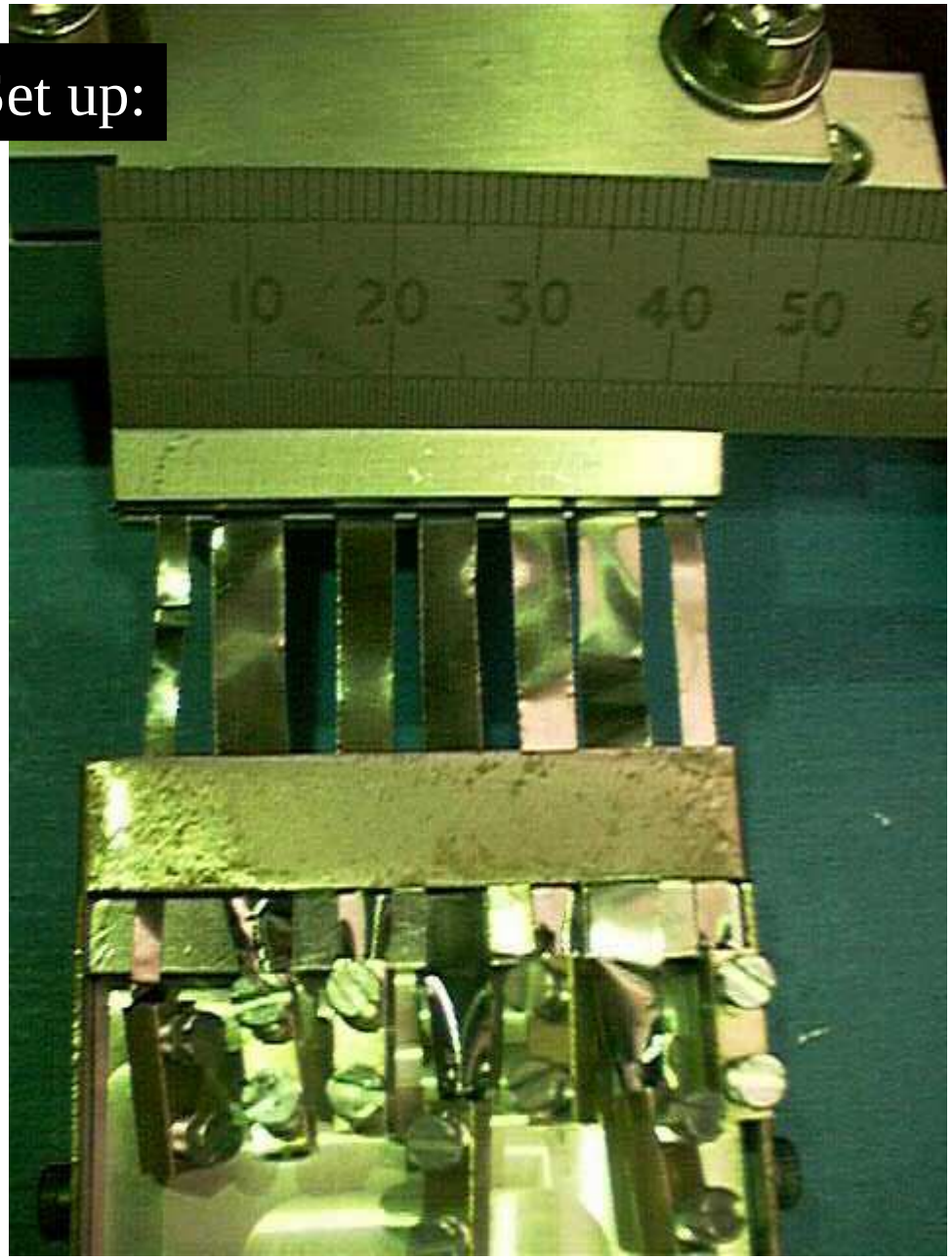


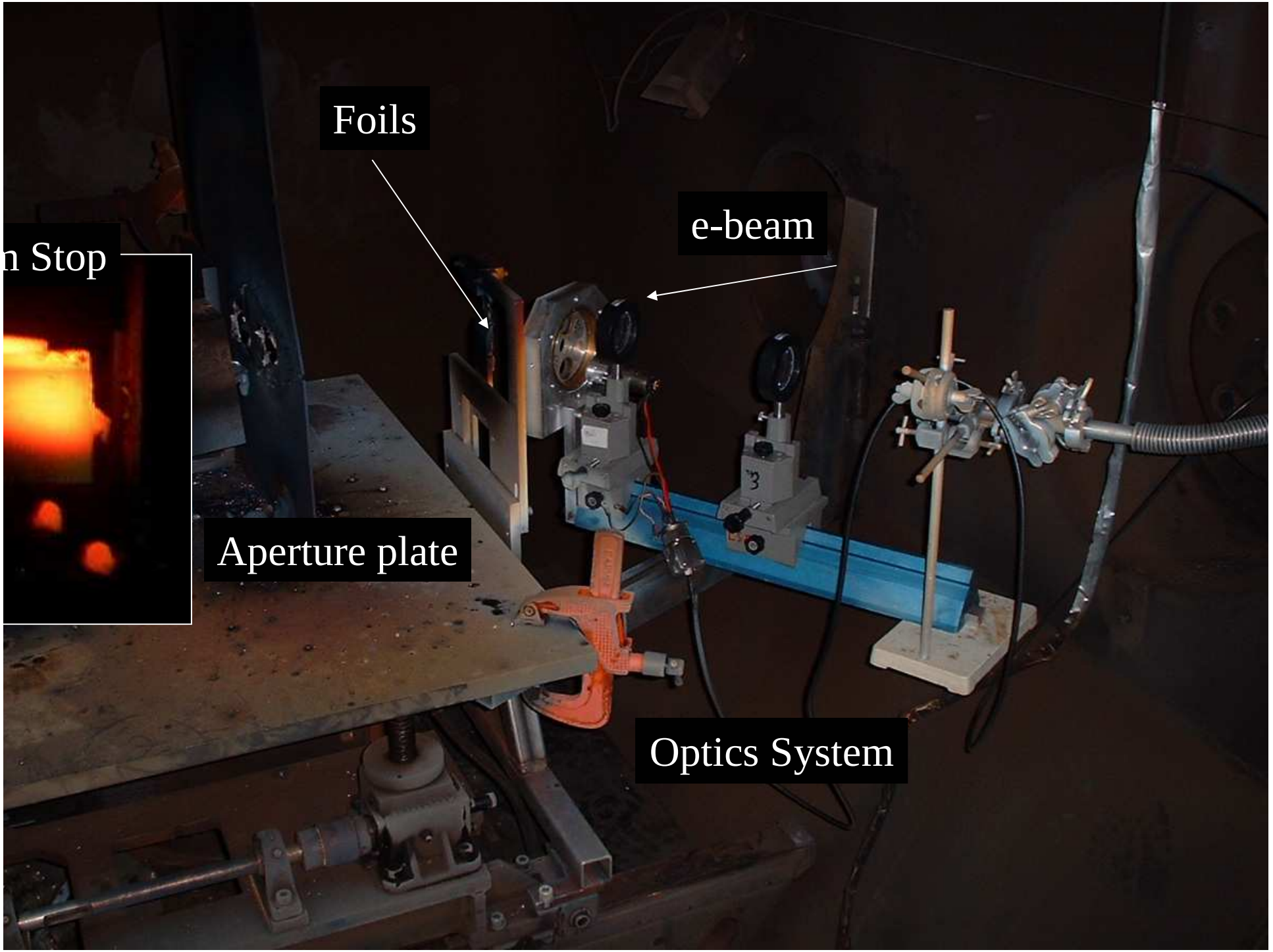

Foil Samples
Electron Gun
Water Cooled Beam Stop
Aperture plate
Optical Transport
Window and bellows
Aperture Plate
Light pipe
To Spectrometer

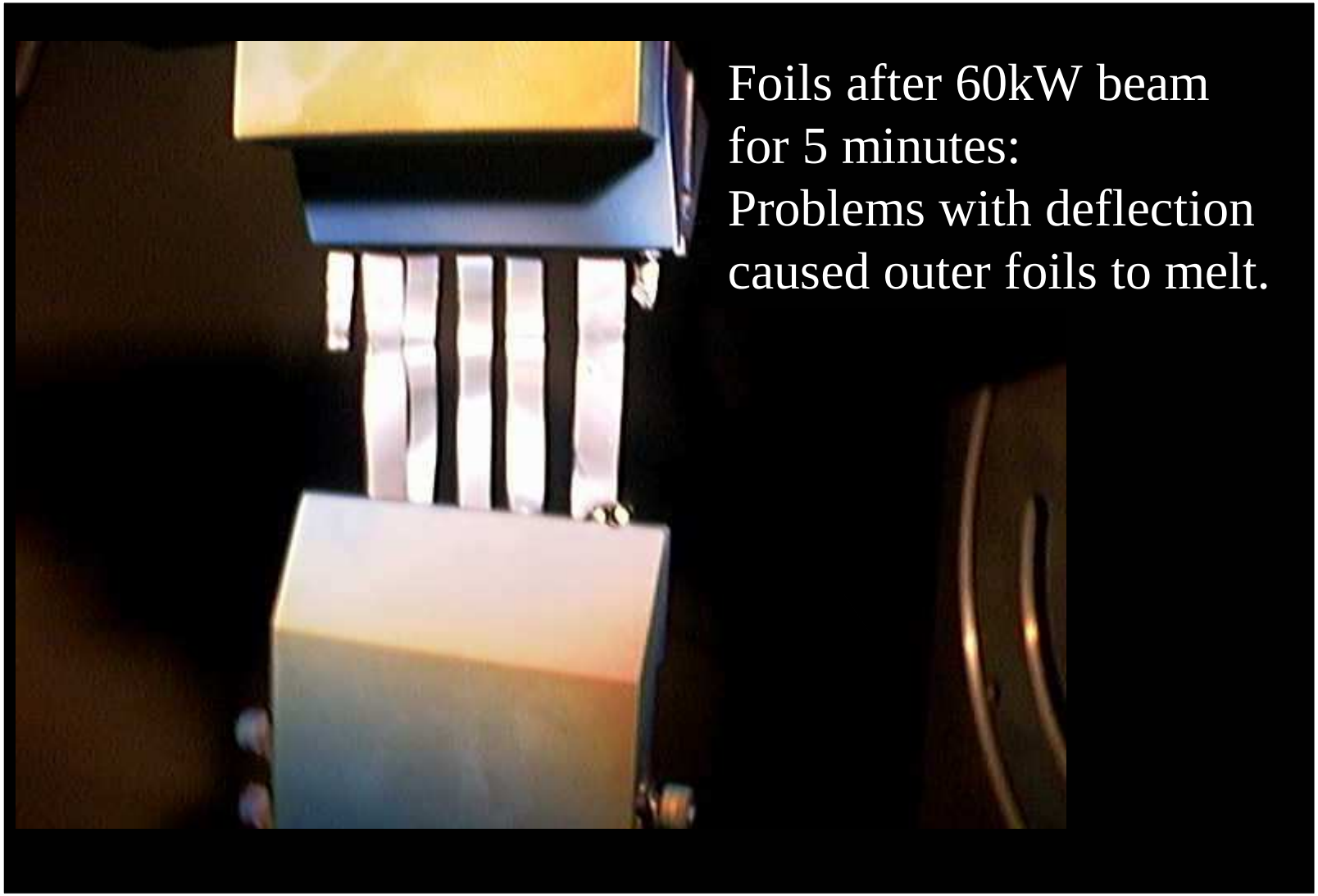


Shock Wave moving in foil

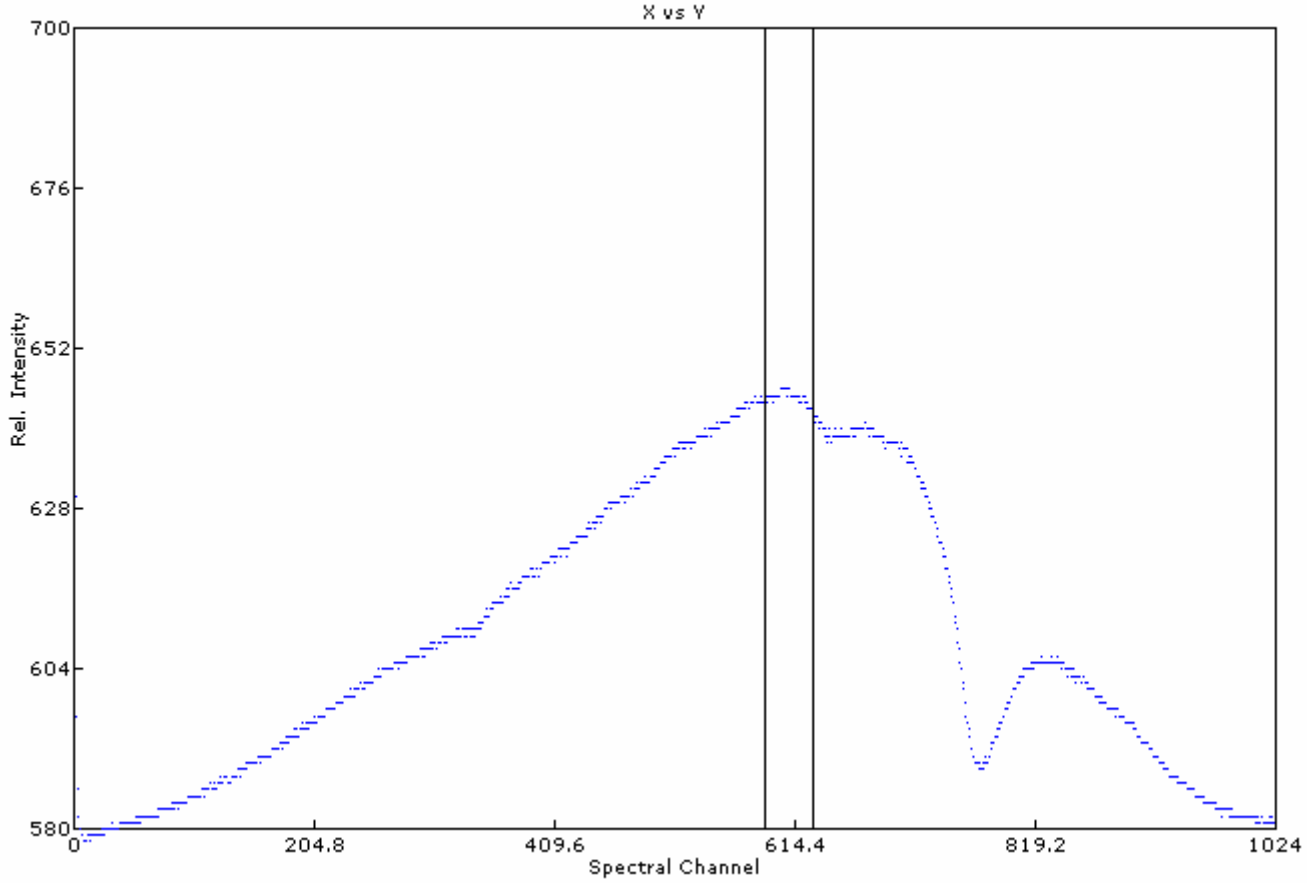
Foil Set up:




Foils
e-beam
n Stop
Aperture plate
Optics System

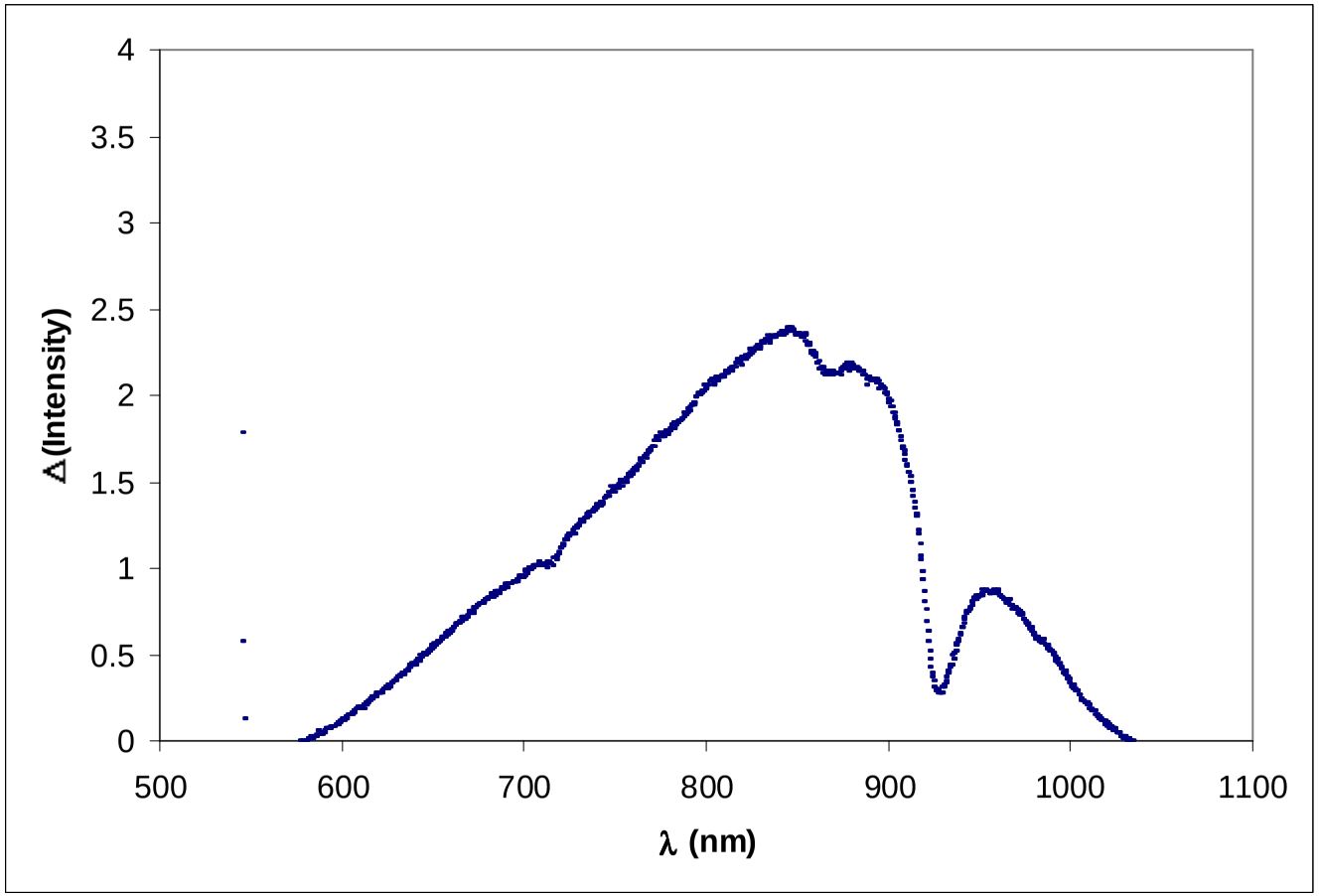

Foils after 60kW beam
for 5 minutes:
Problems with deflection
caused outer foils to melt.

Spectrometer - real time measurements - wavelength & time

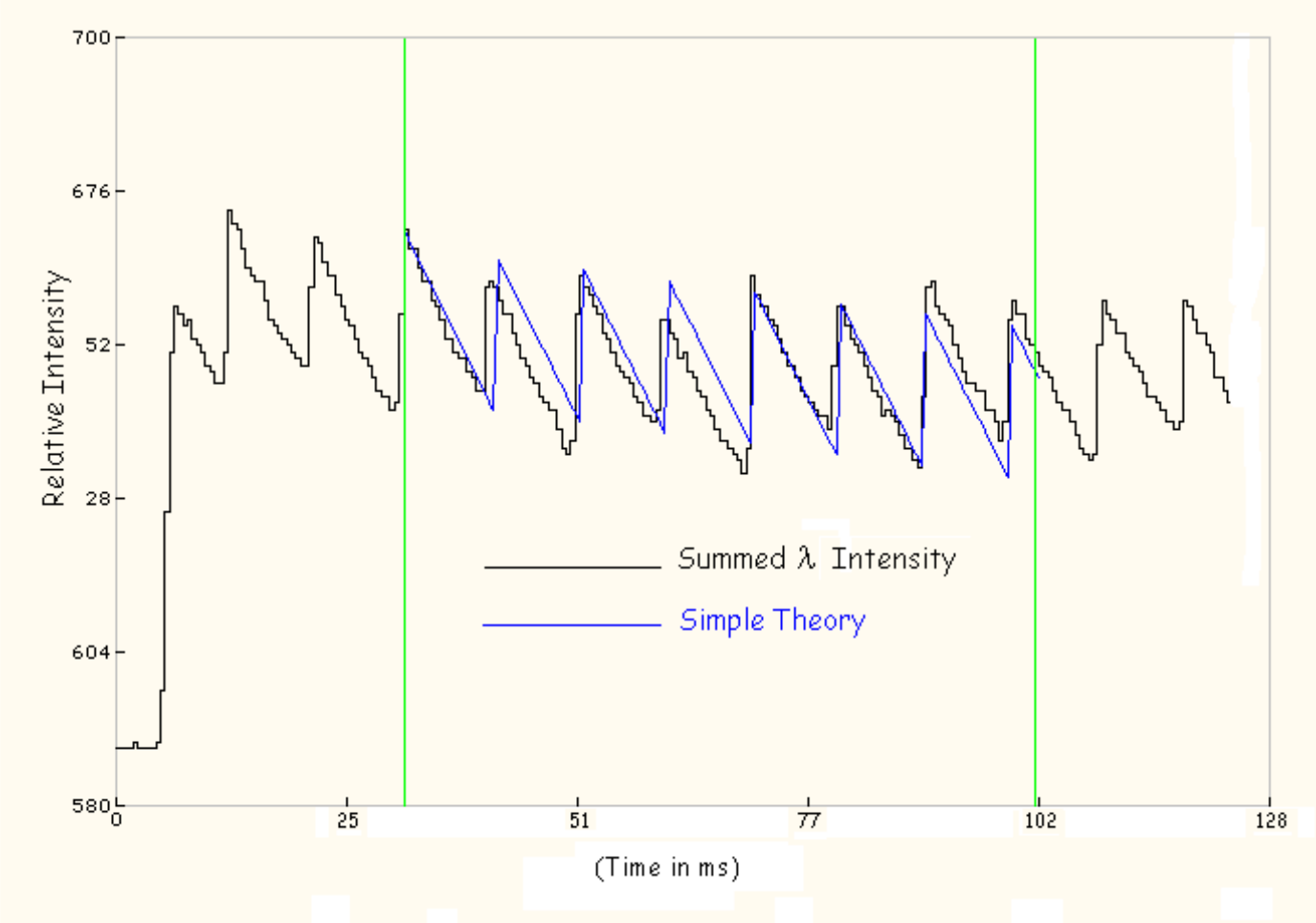


λ

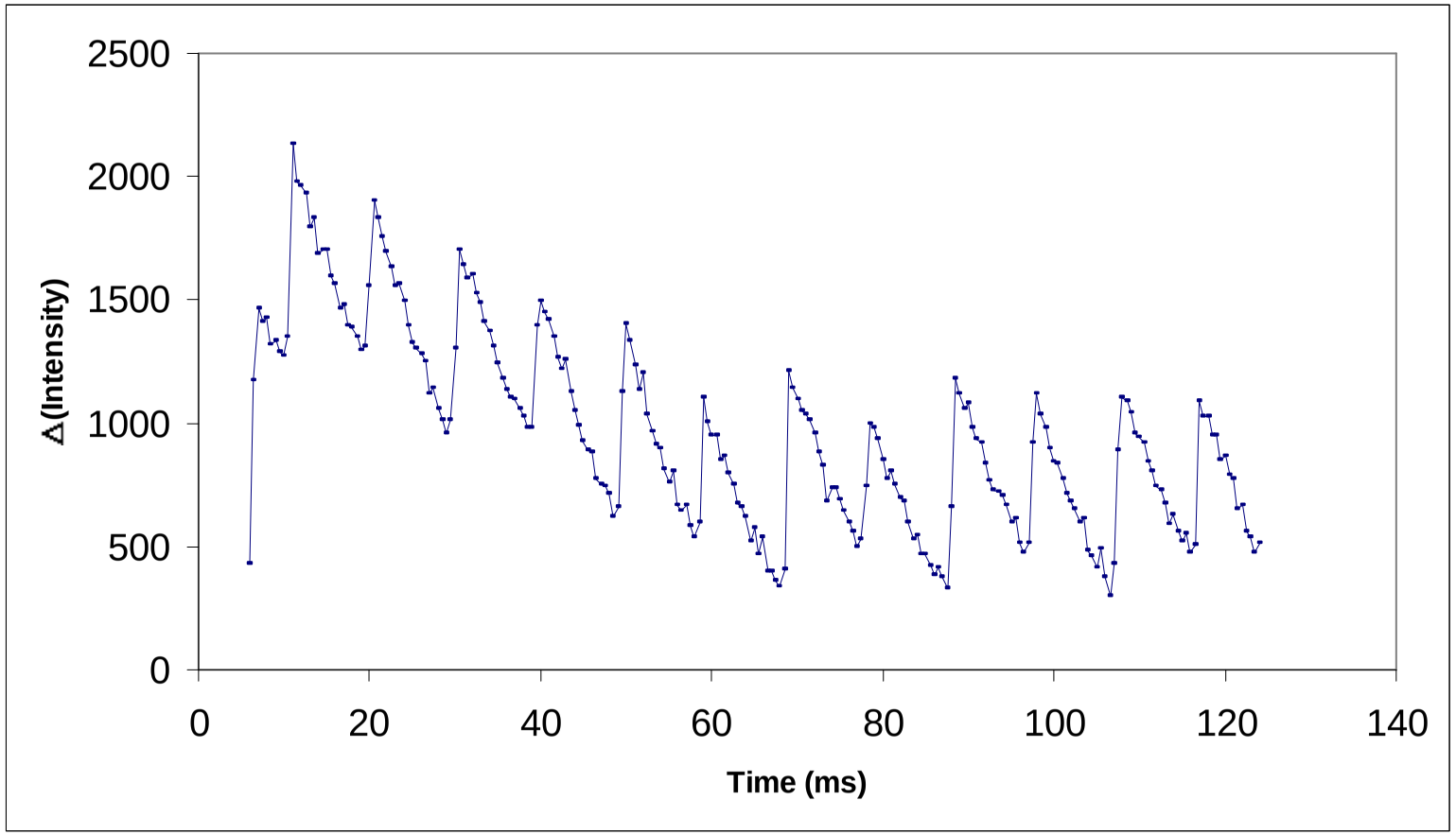
Spectrometer - real time measurements - wavelength & time



Real Time measurement of visible light from foils:



Real Time measurement of visible light from foils:

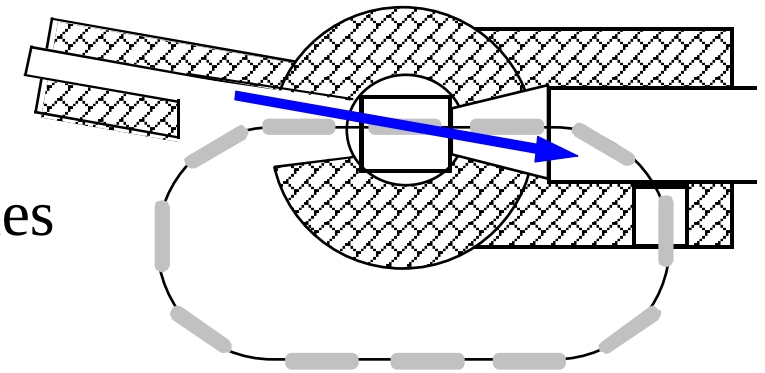


Status:

With calibration - absolute temperature measurement
Without - relative temperature jump to ~ 10 degrees

Feasibility test = 60 kW for 5 minutes = foils survived
= 30k cycles

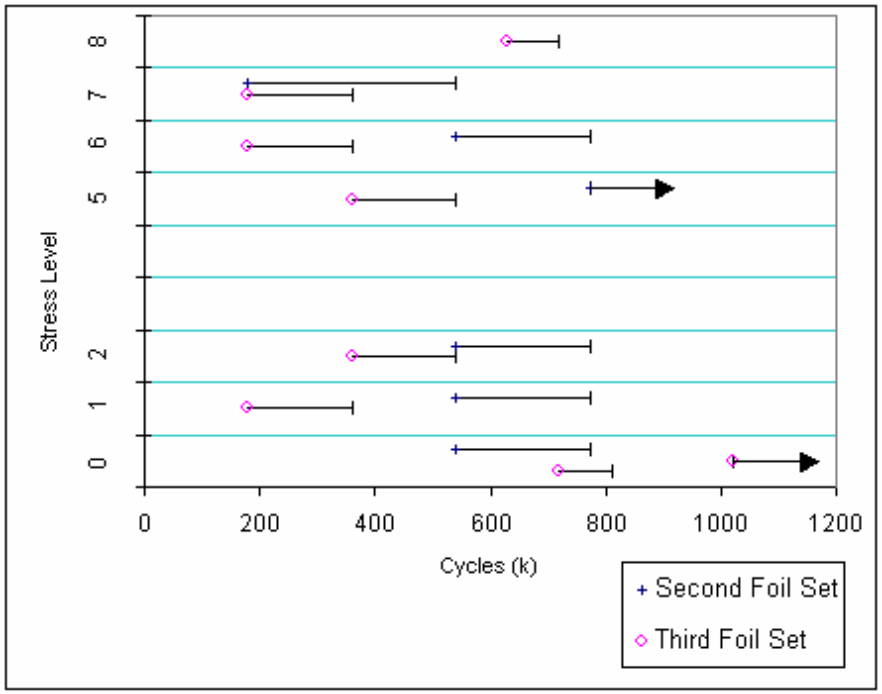
Test in progress:
Long duration run:

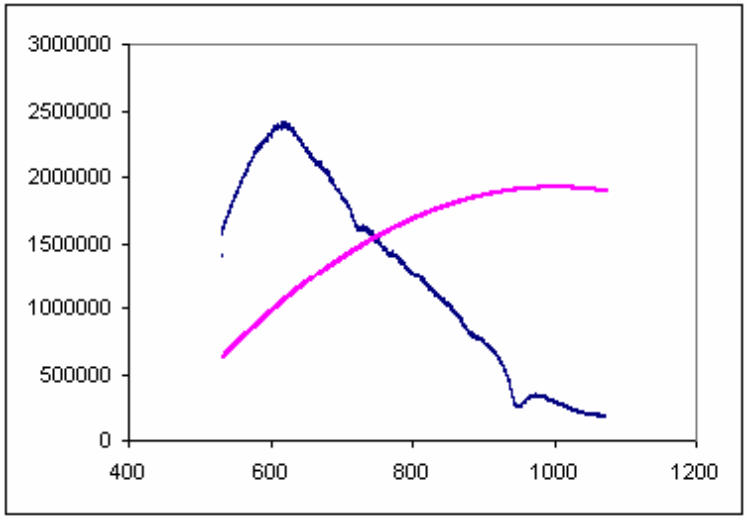


3 hr = 10^6 cycles

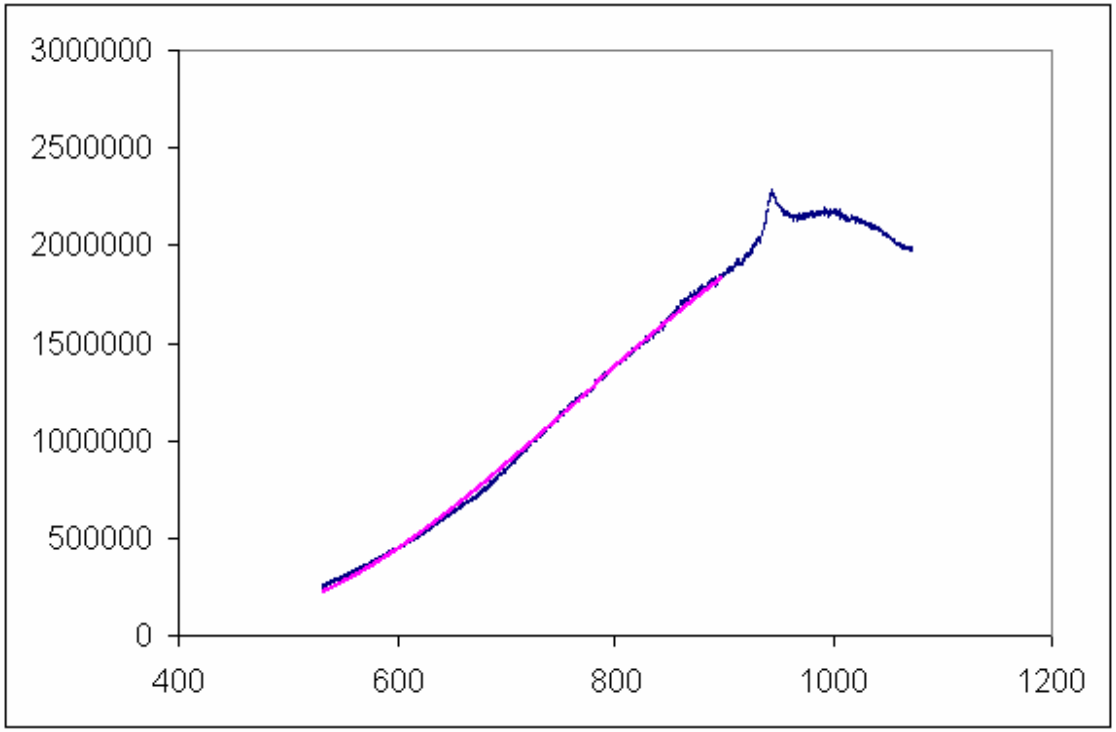
equivalent to: 115 days of νF
10Hz - 20m ring (100 x20cm targets)

Survival?


Stress Level
0
1
2
5
6
7
8
0
200
400
600
800
1000
1200
Cycles (k)
Second Foil Set
Third Foil Set

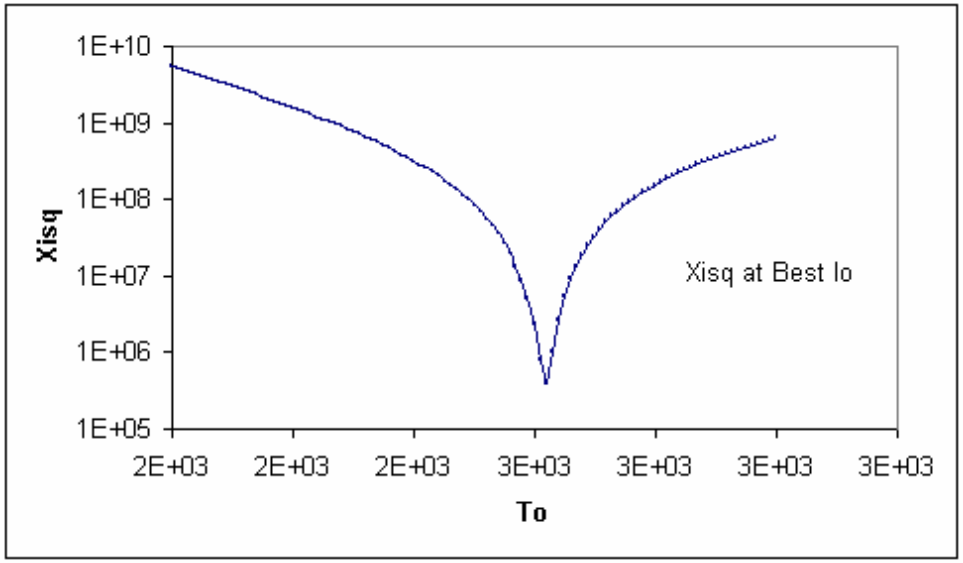


Spectrum obtained from a calibration source and the *advertised* spectrum -> *response function*



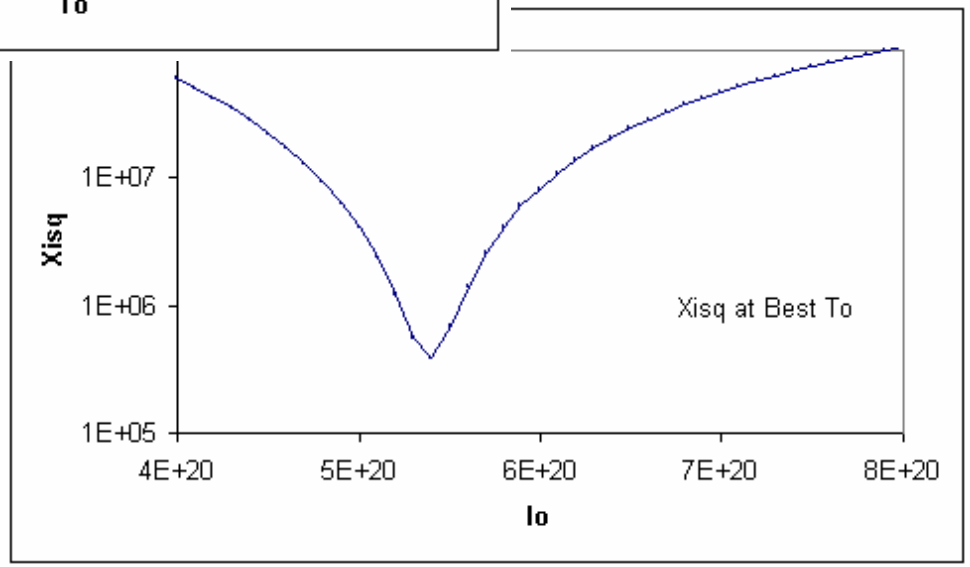
41kW Beam: after background subtraction and correction by the response function & compared to a black-body curve.

Accuracy?



Systematic errors
- tbd

±10 deg.



Next?

The exercise has been quite successful

= learning exercise = us & TWI!

= tighten up = better setup instrumentation

= better screening of foils

= other materials = zero expansion alloys

Other commitments for people and funds

Low level background activity