High Power Target R&D Simulations

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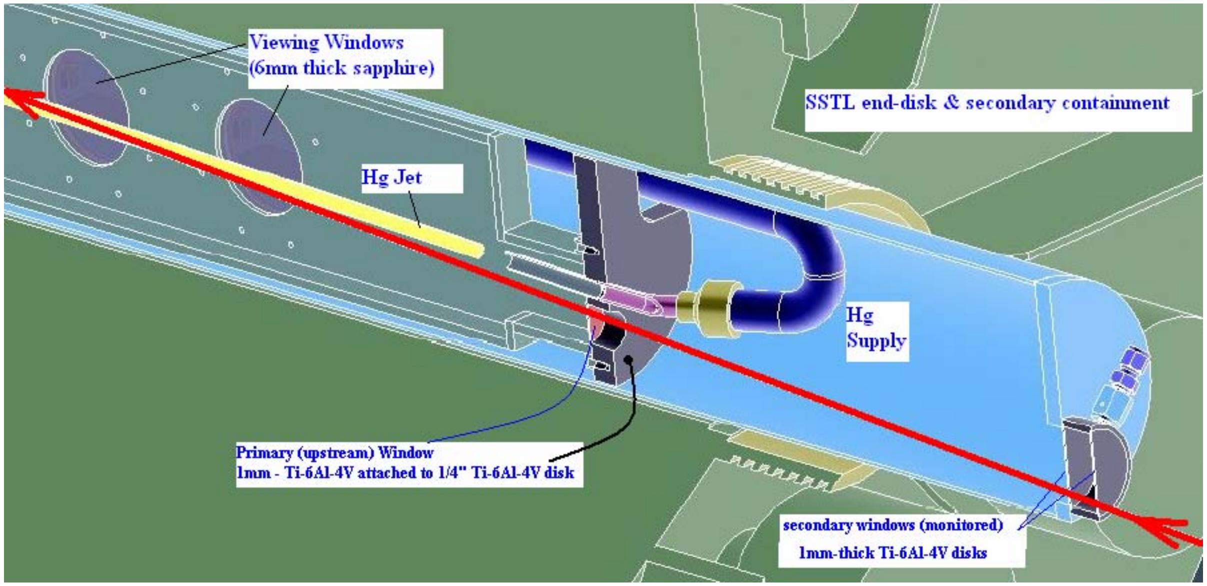
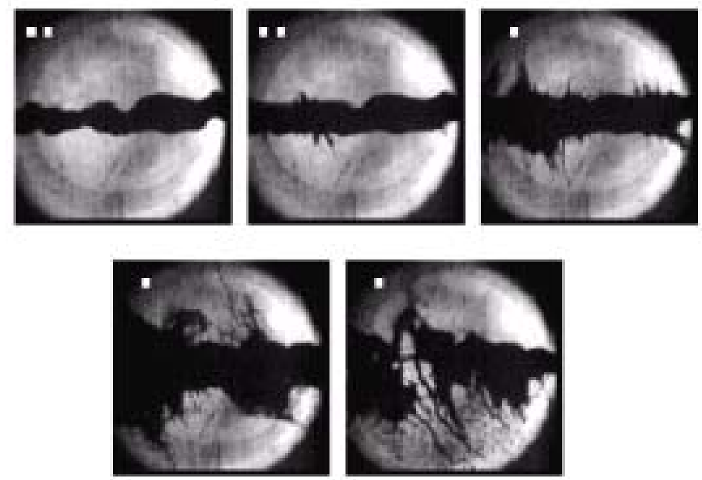
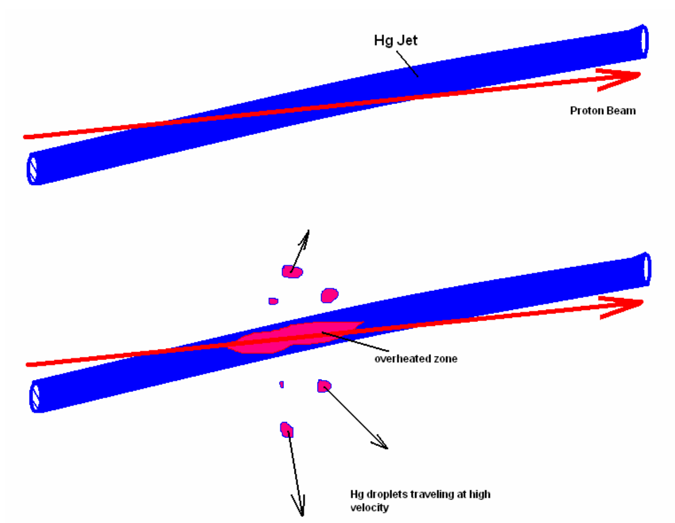
May 1-2, Oxford U., UK

Exploring Eulerian-Lagrangian Formulation Capabilities of LS-DYNA

Proton Beam - Hg Jet Interaction Experiment

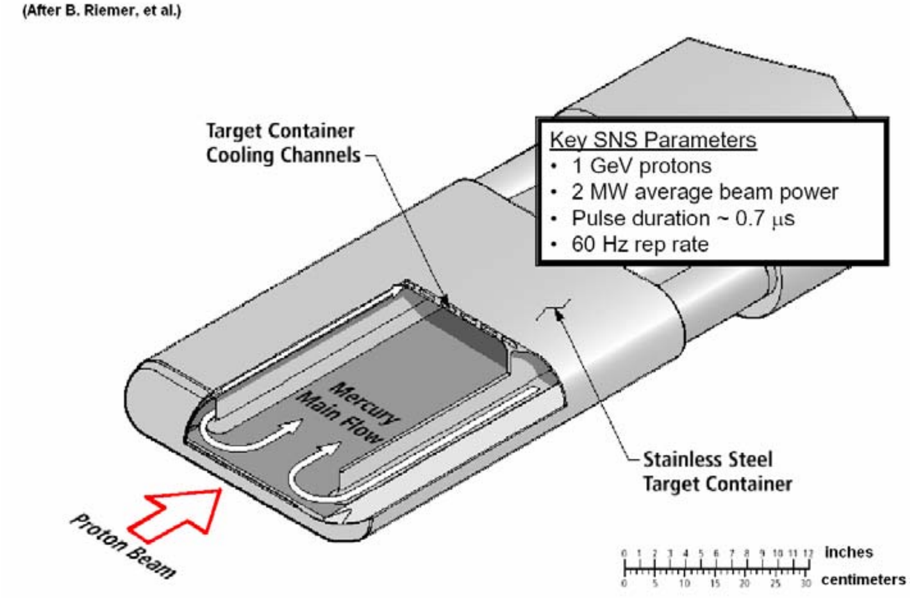


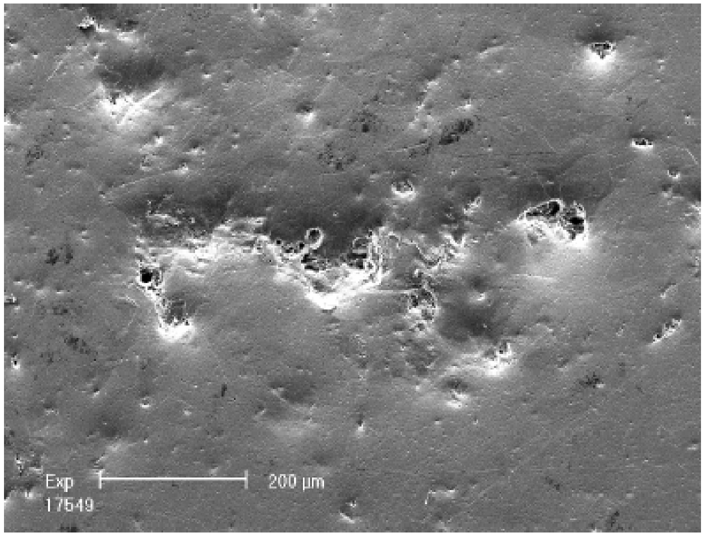




High velocity projectiles emanating from Hg target

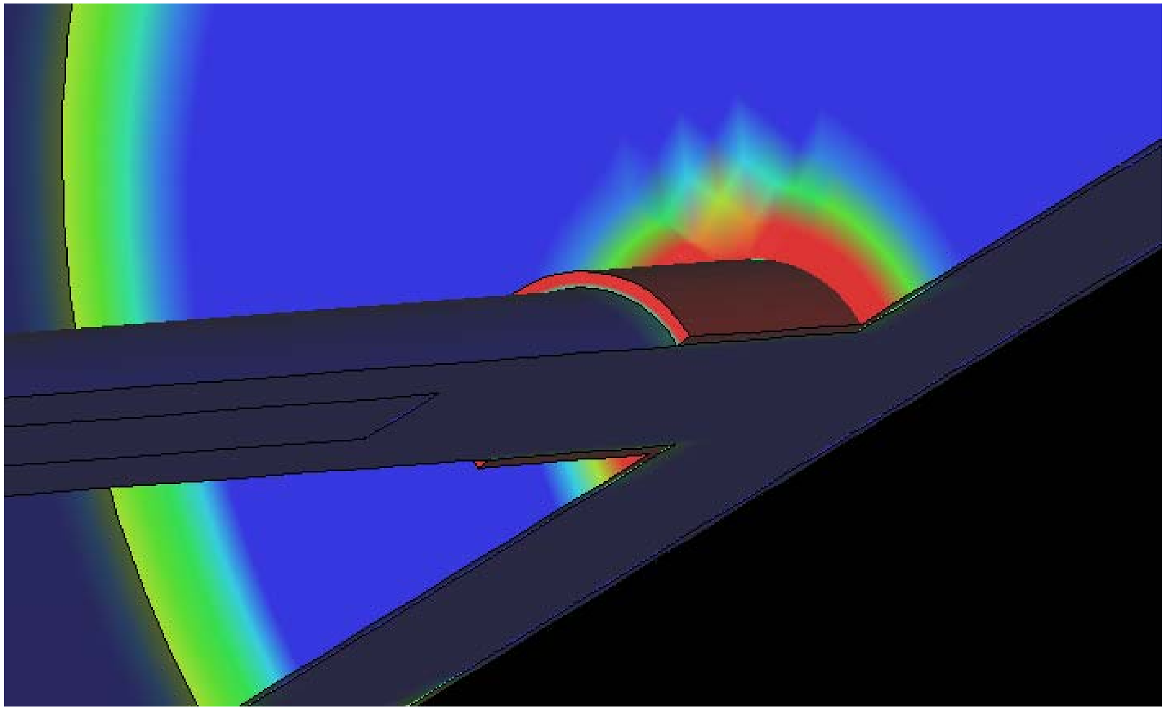
(After B. Riemer, et al.)



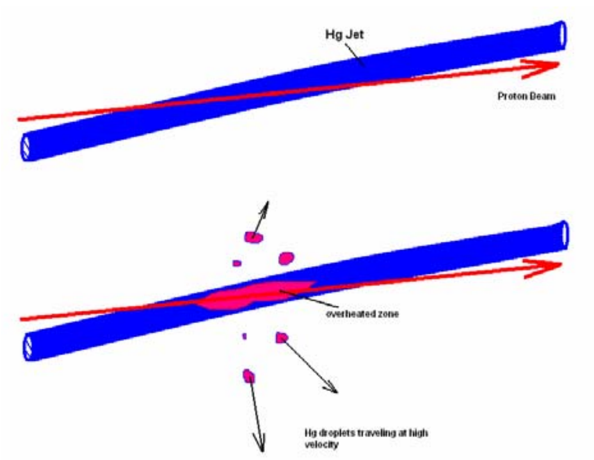


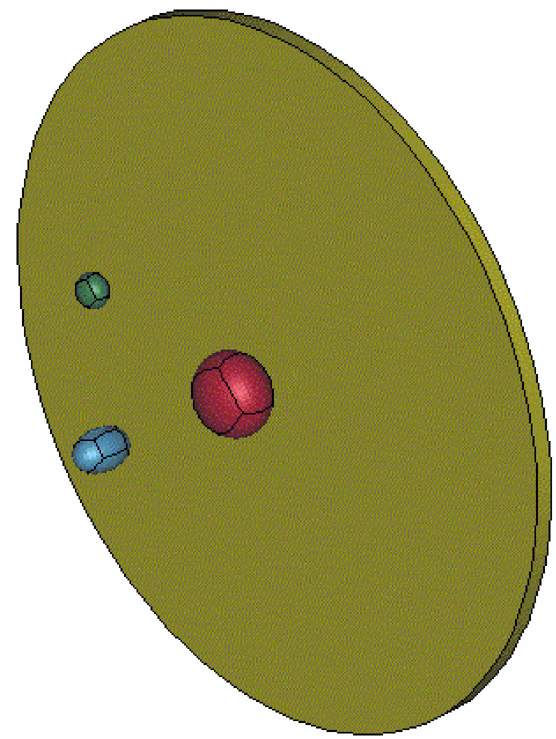
Molten Lead – Tantalum Vessel Target

Relevance to Hg Jet: Jet nozzle survivability

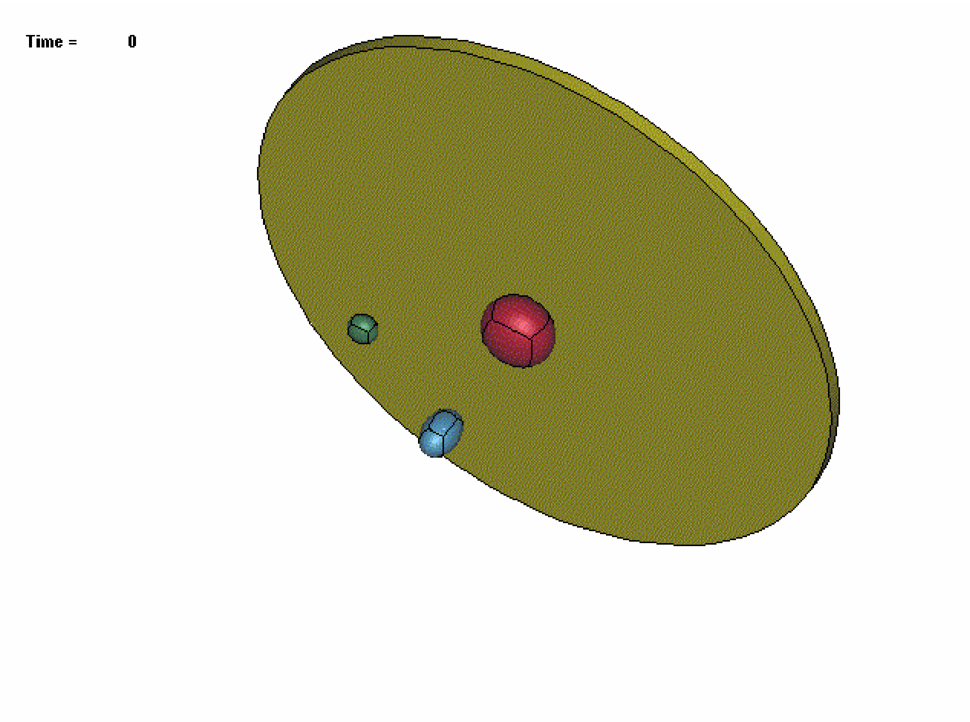


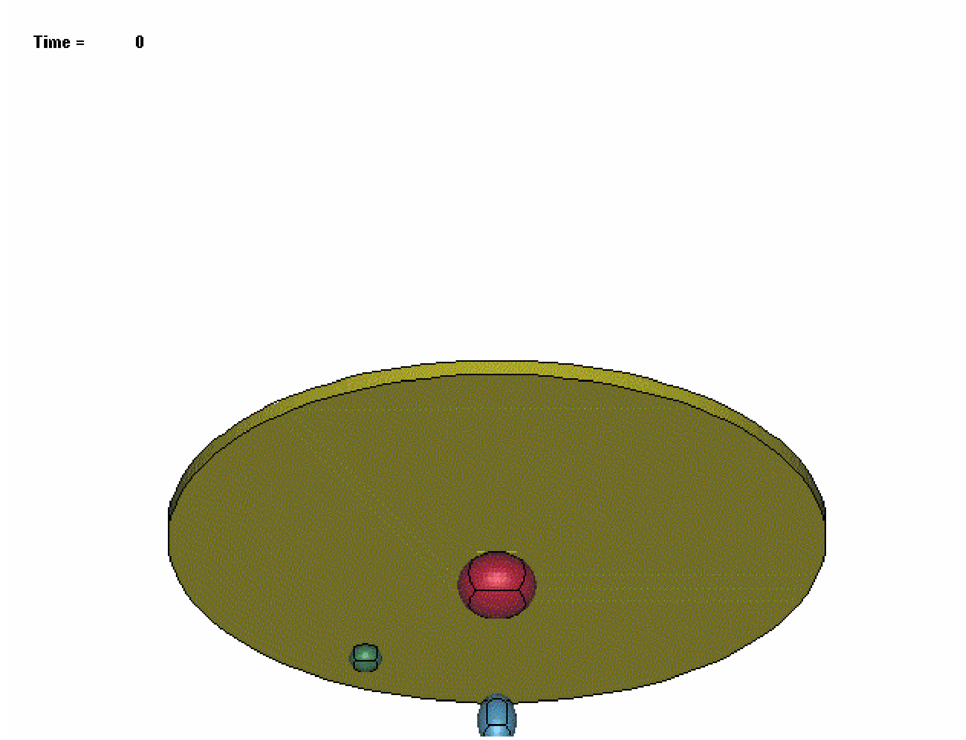
Hg Explosion Simulations

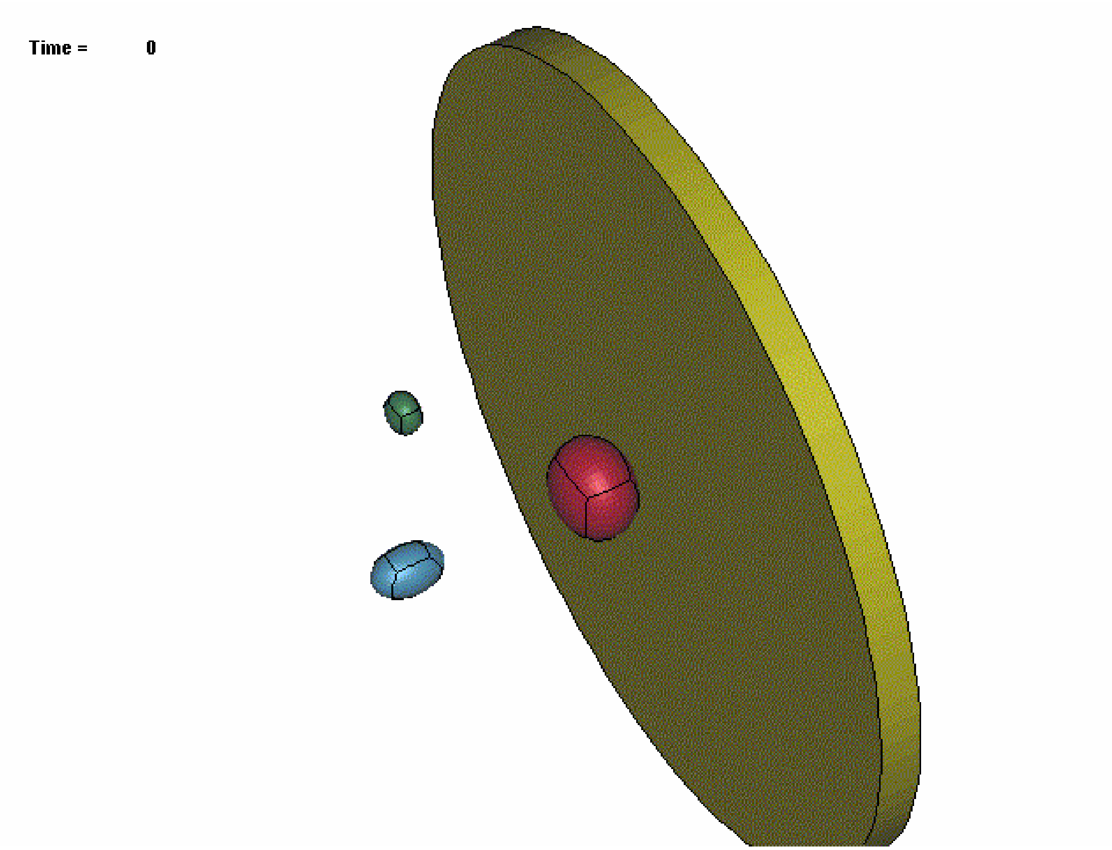




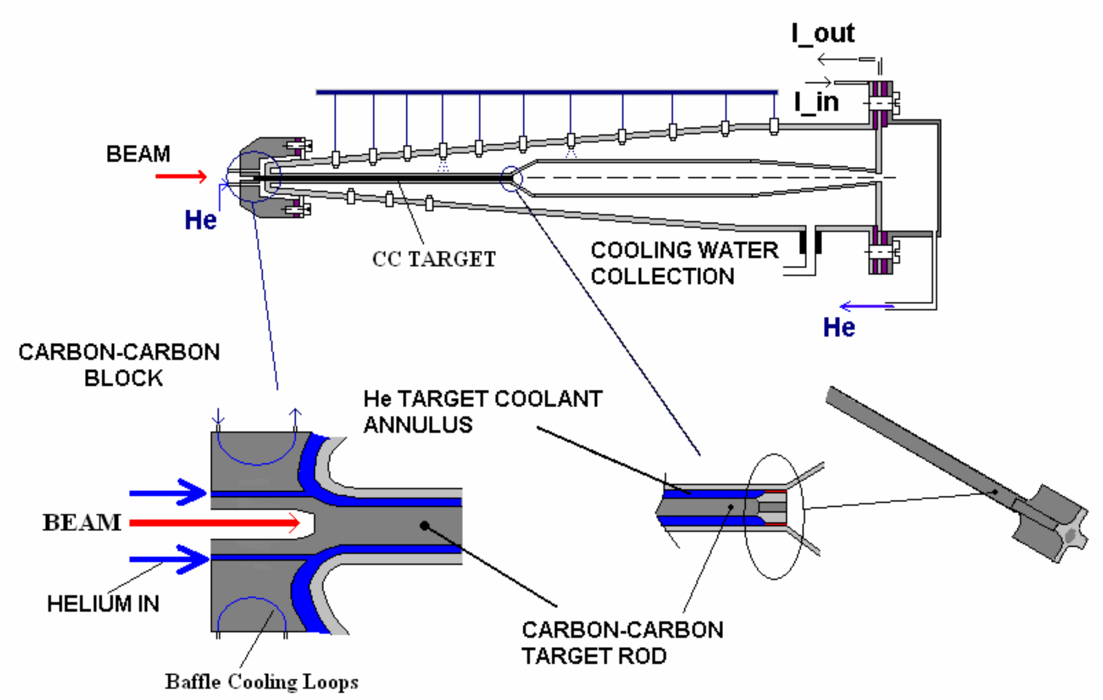
Hg explosions and Target Infrastructure

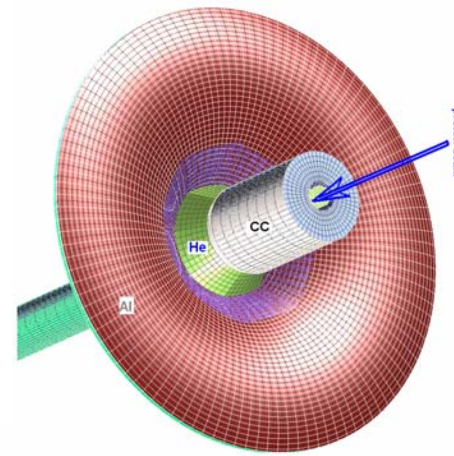


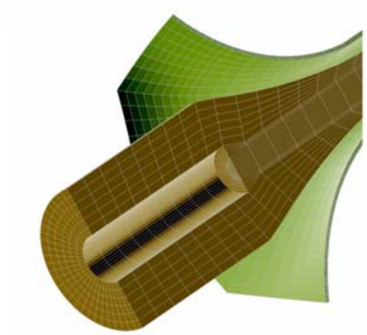


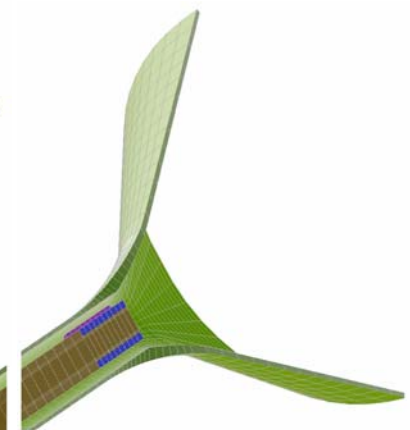

Time = 0

Superbeam Target Concept





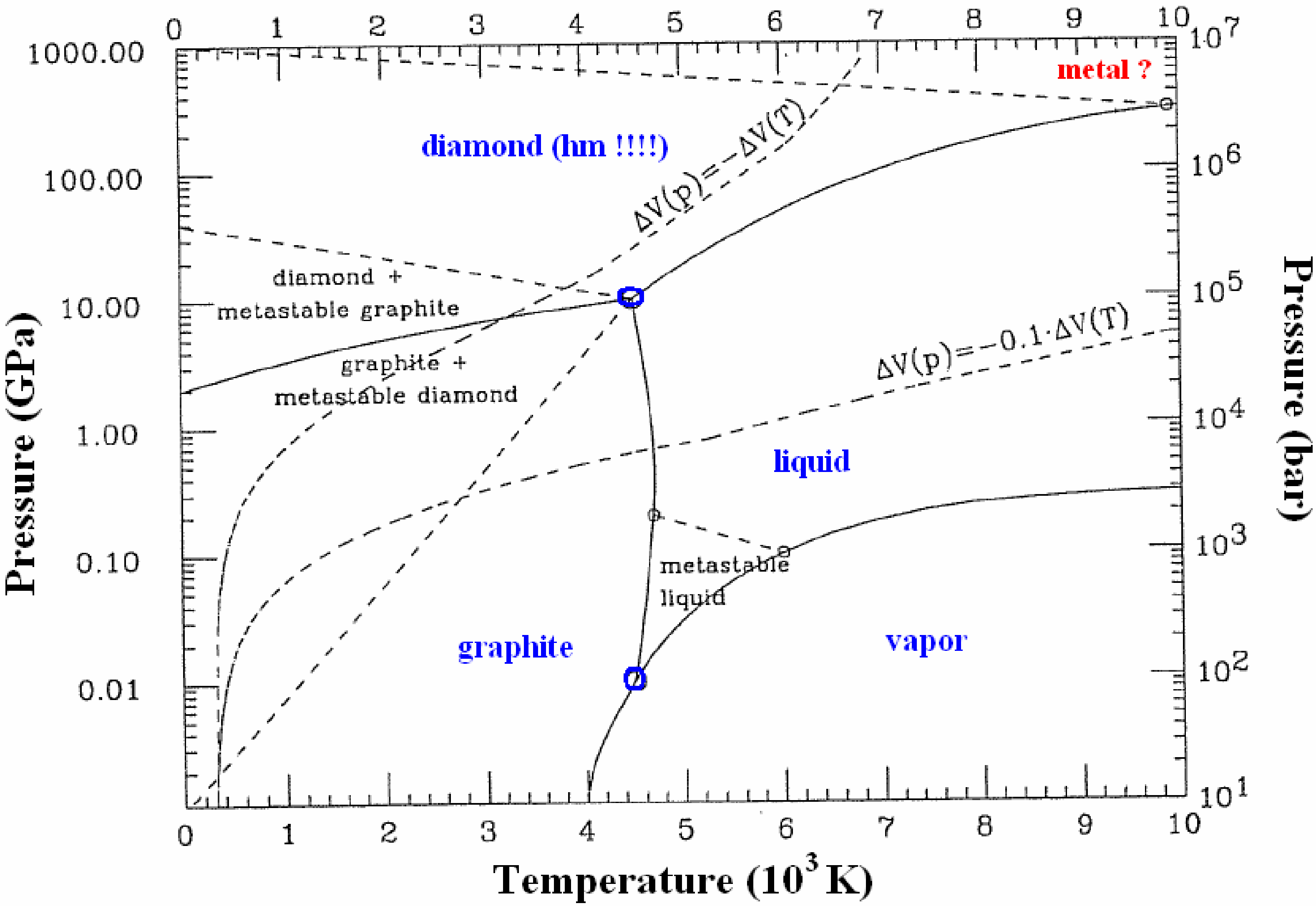




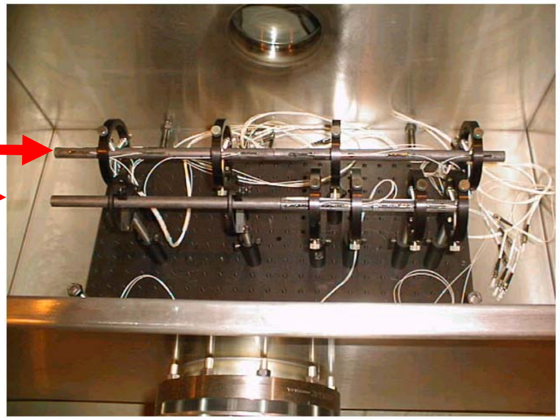
Overview of R&D Realized to-date on Solid Targets

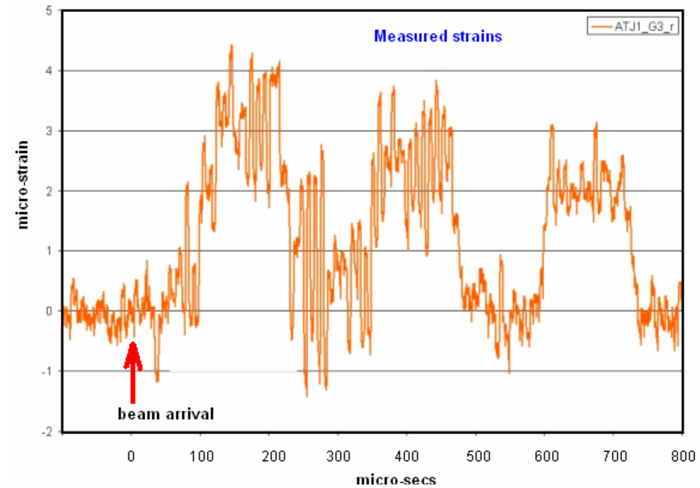
- Target Shock Studies
- Radiation damage Studies

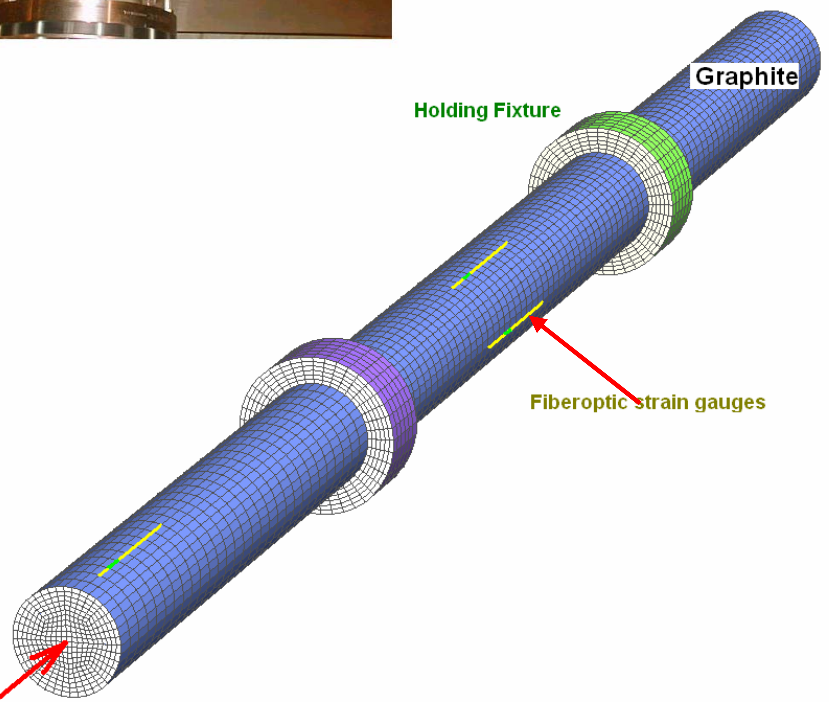
Solid Targets

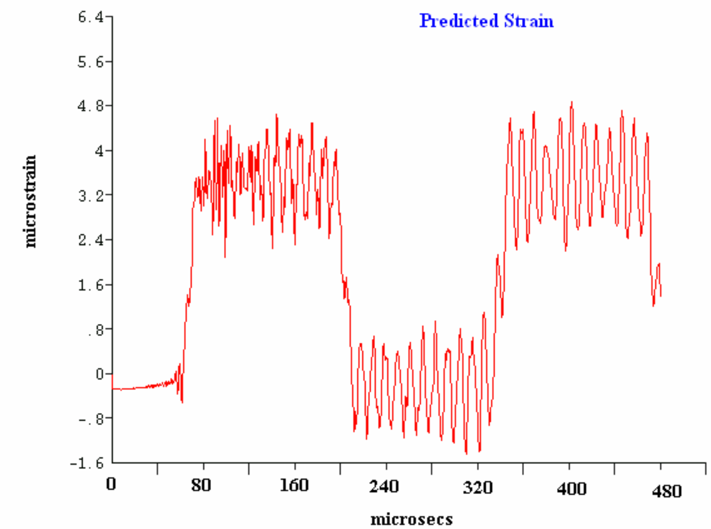


Target Shock Studies









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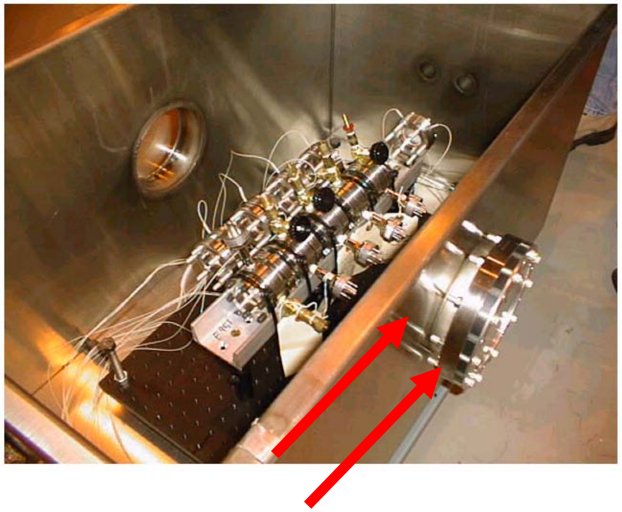
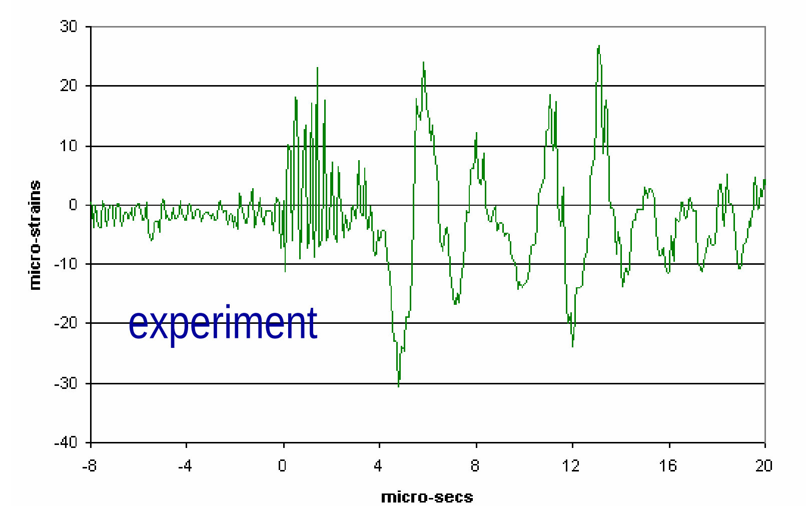
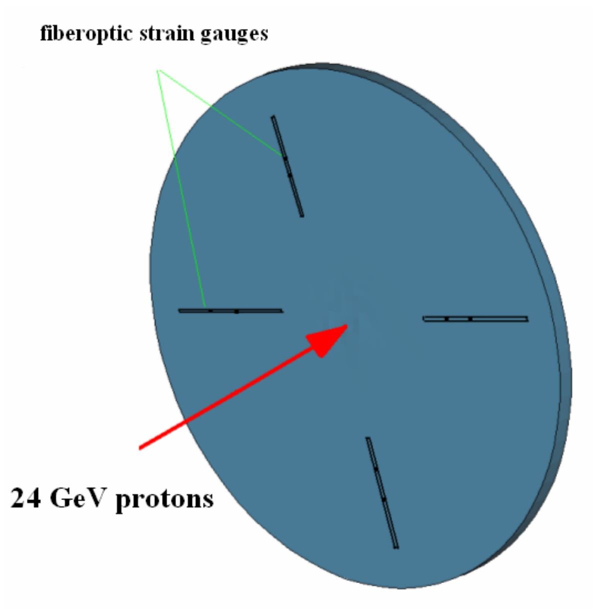
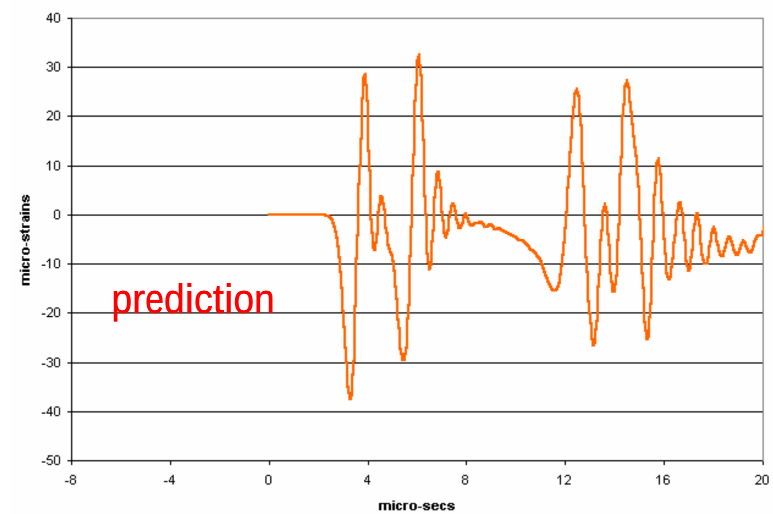
Beam-induced shock on thin targets

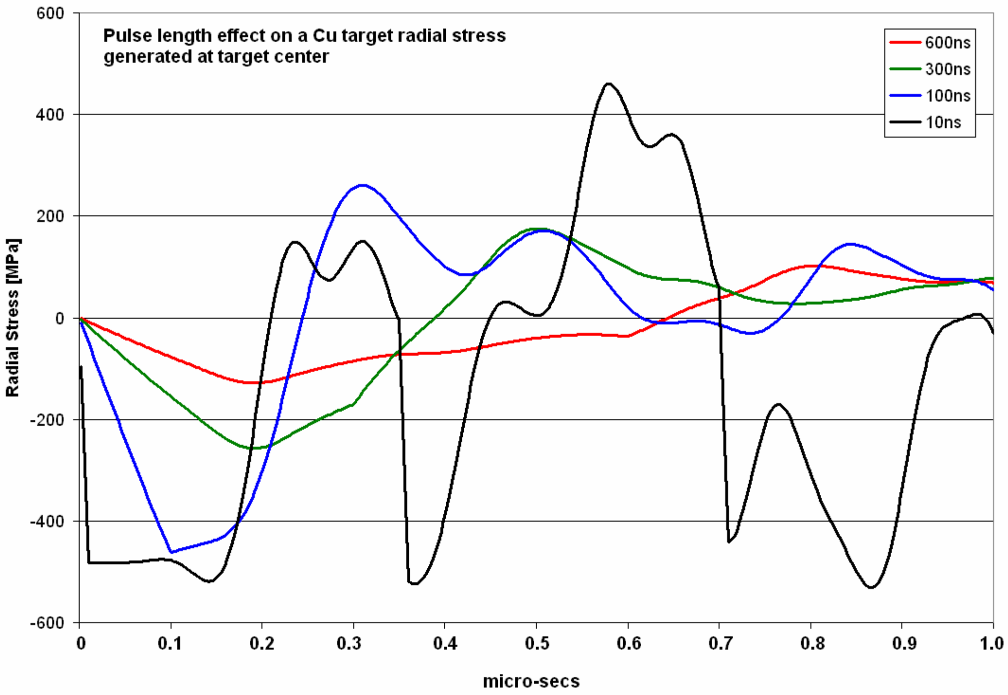


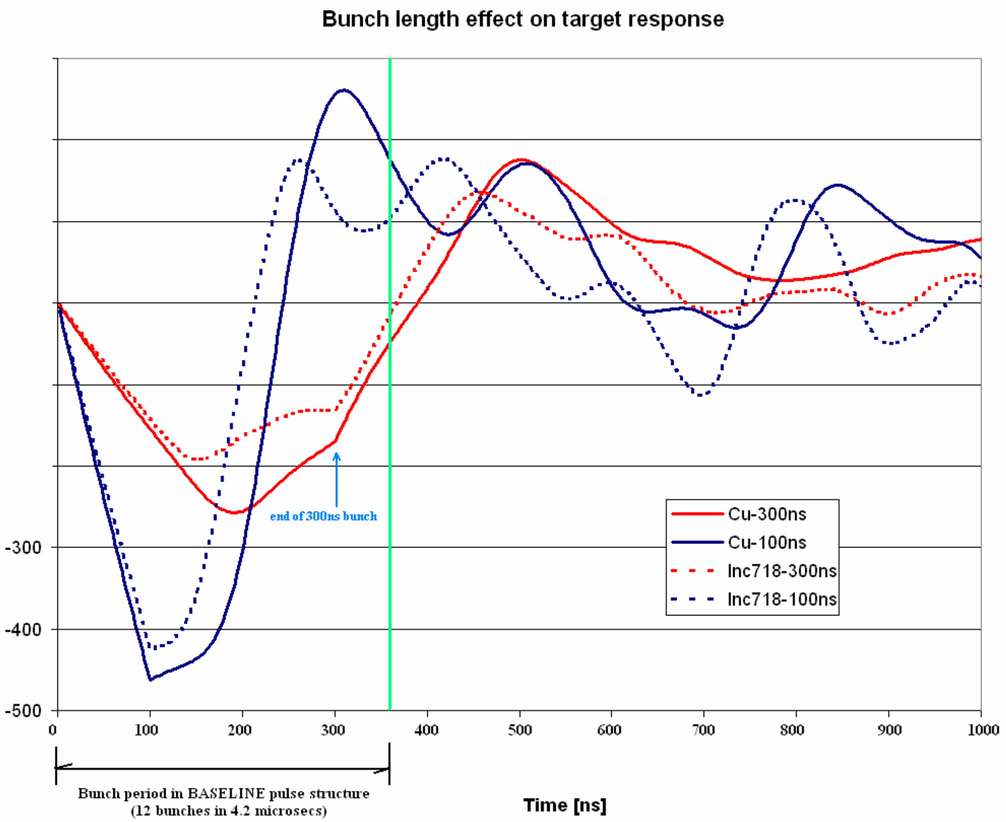






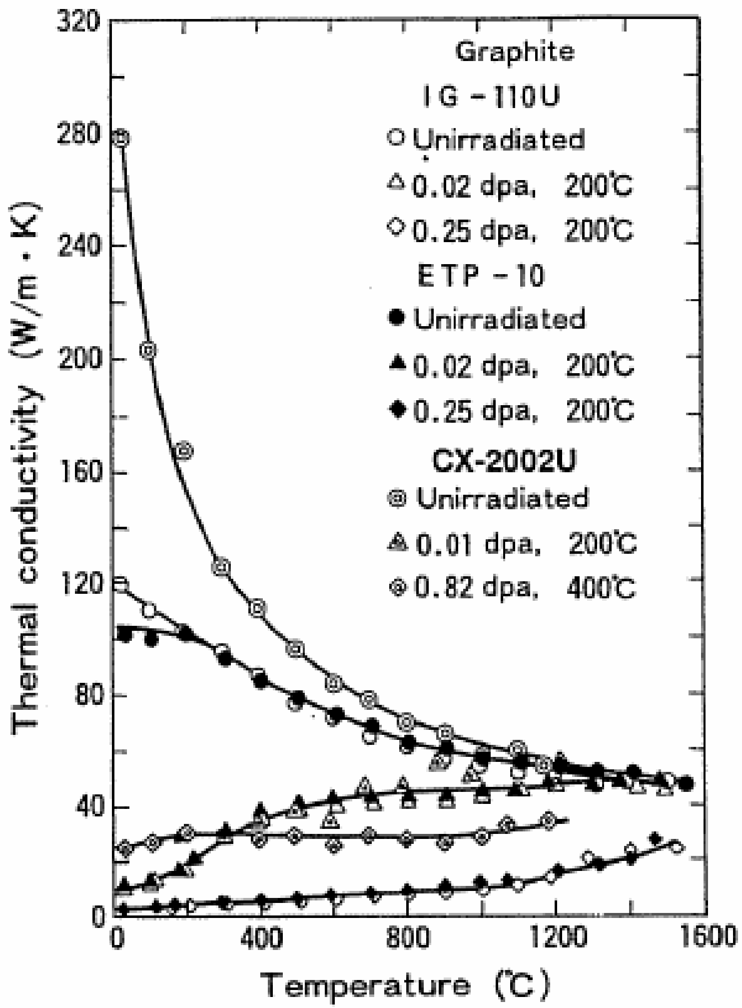
Pulse Structure





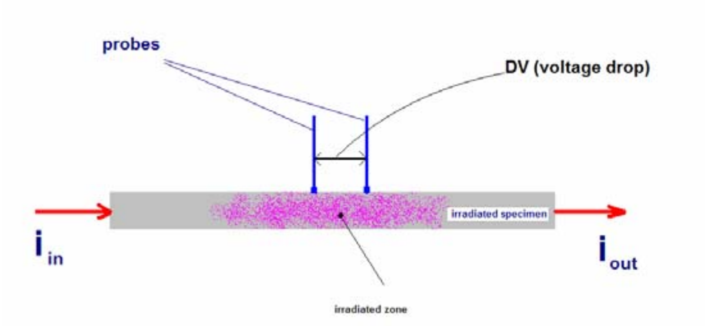
Solid Target Shock Studies

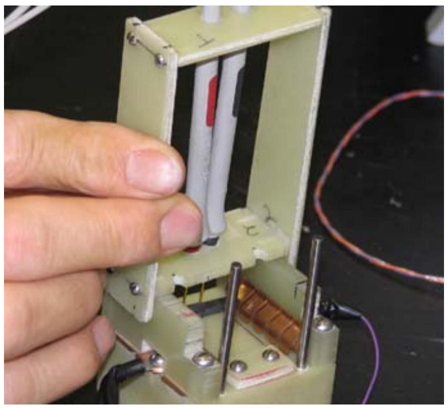
- Graphite and Carbon composites
- super-alloys
- Materials “appear” more shock resilient than conventional estimates

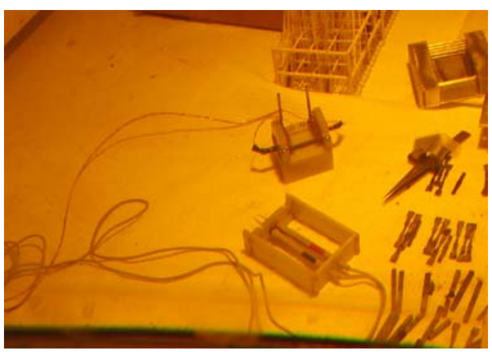


Thermal conductivity of neutron-irradiated graphites.

Thermal Conductivity







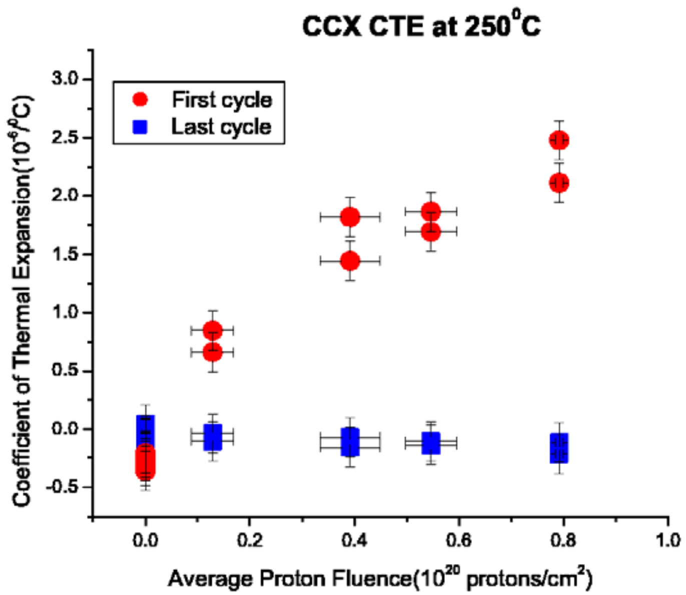
3-D CC (~ 0.2 dpa) conductivity reduces by a factor of 3.2

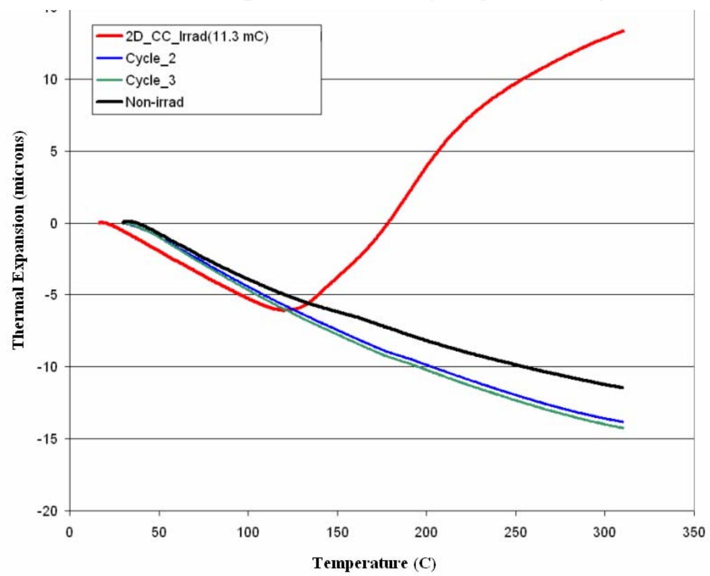
2-D CC (~0.2 dpa) measured under irradiated conditions (to be compared with company data)

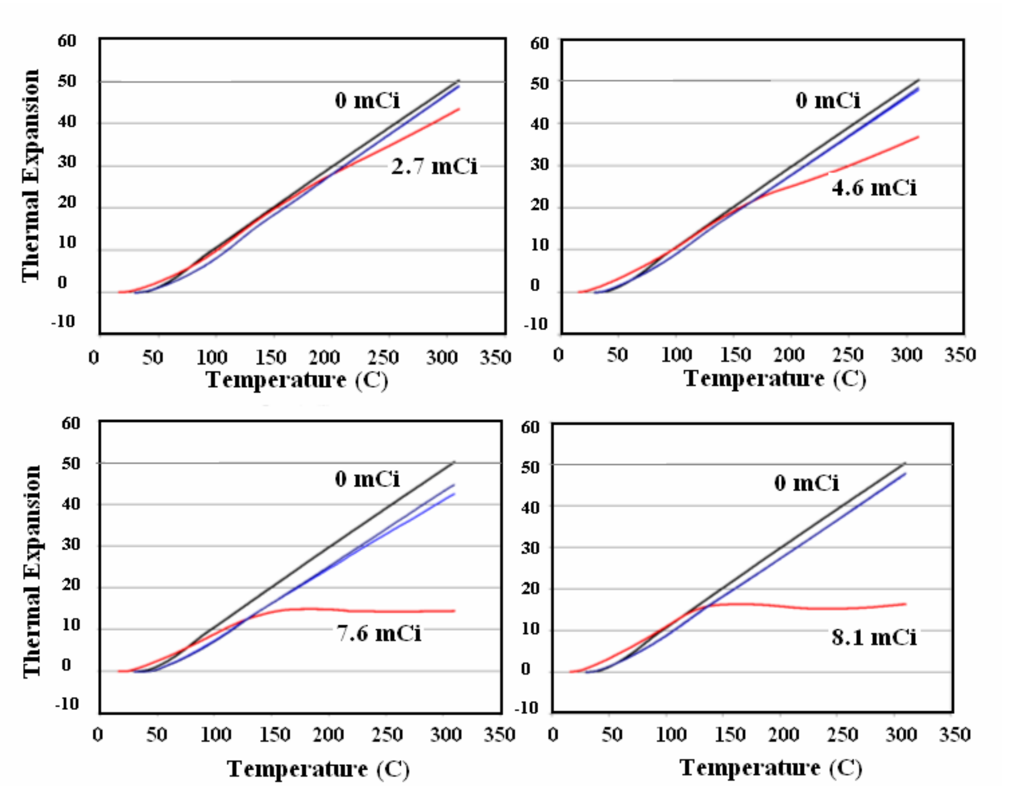
Graphite (~0.2 dpa) conductivity reduces by a factor of 6

W (1+ dpa)	➔	reduced by factor of ~4
Ta (1+ dpa)	➔	~ 40% reduction
Ti-6Al-4V (~ 1dpa)	➔	~ 10% reduction

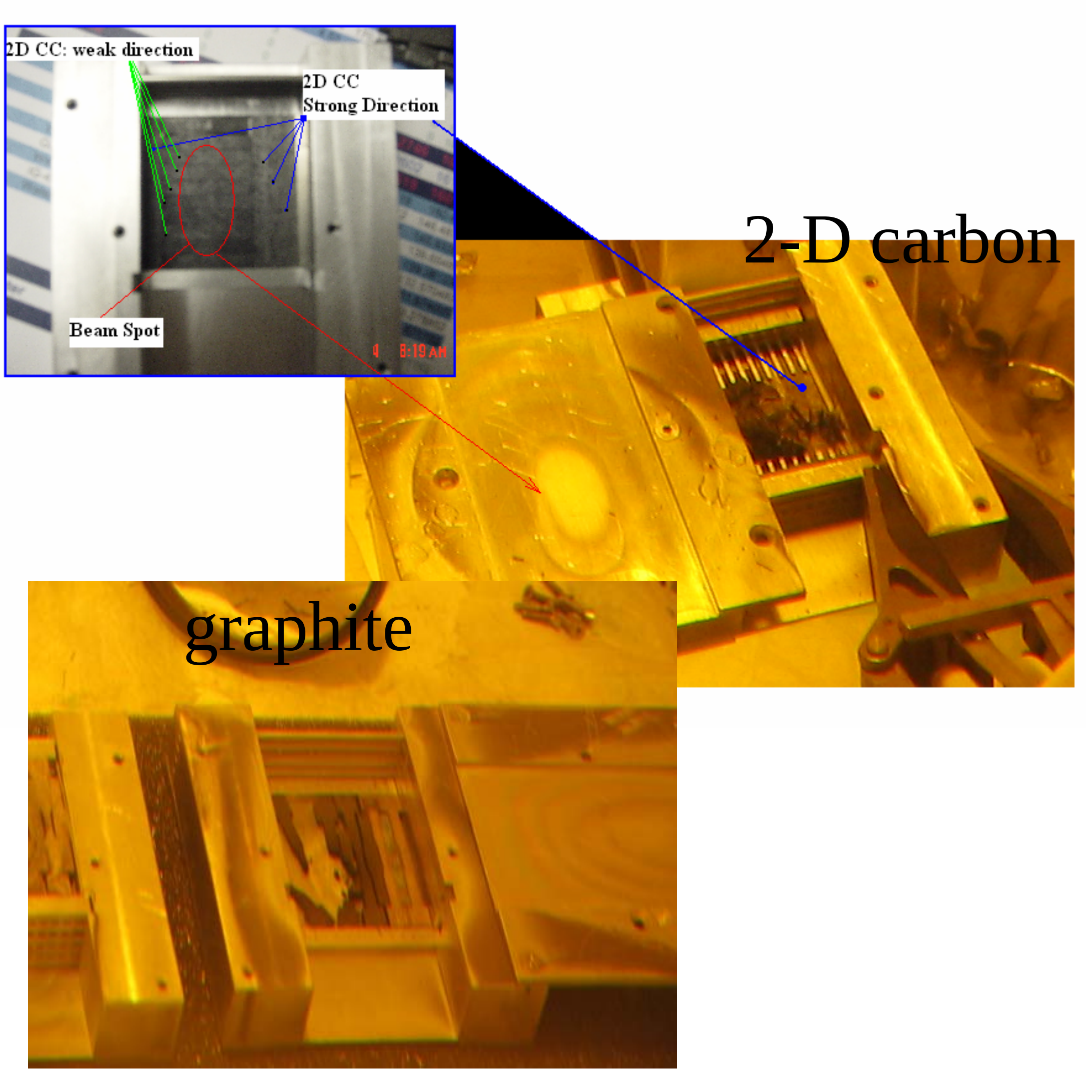
Radiation Damage in Carbon-Carbon Composites

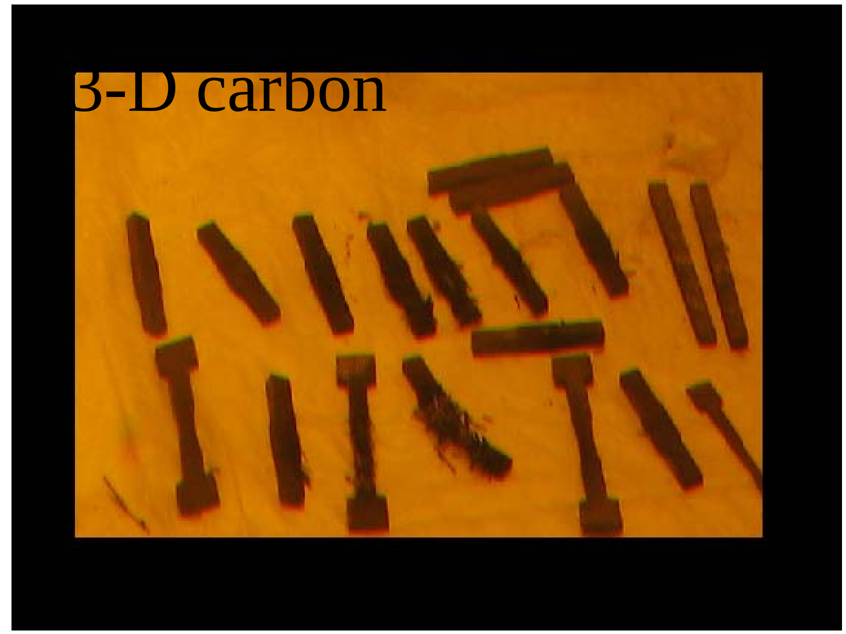






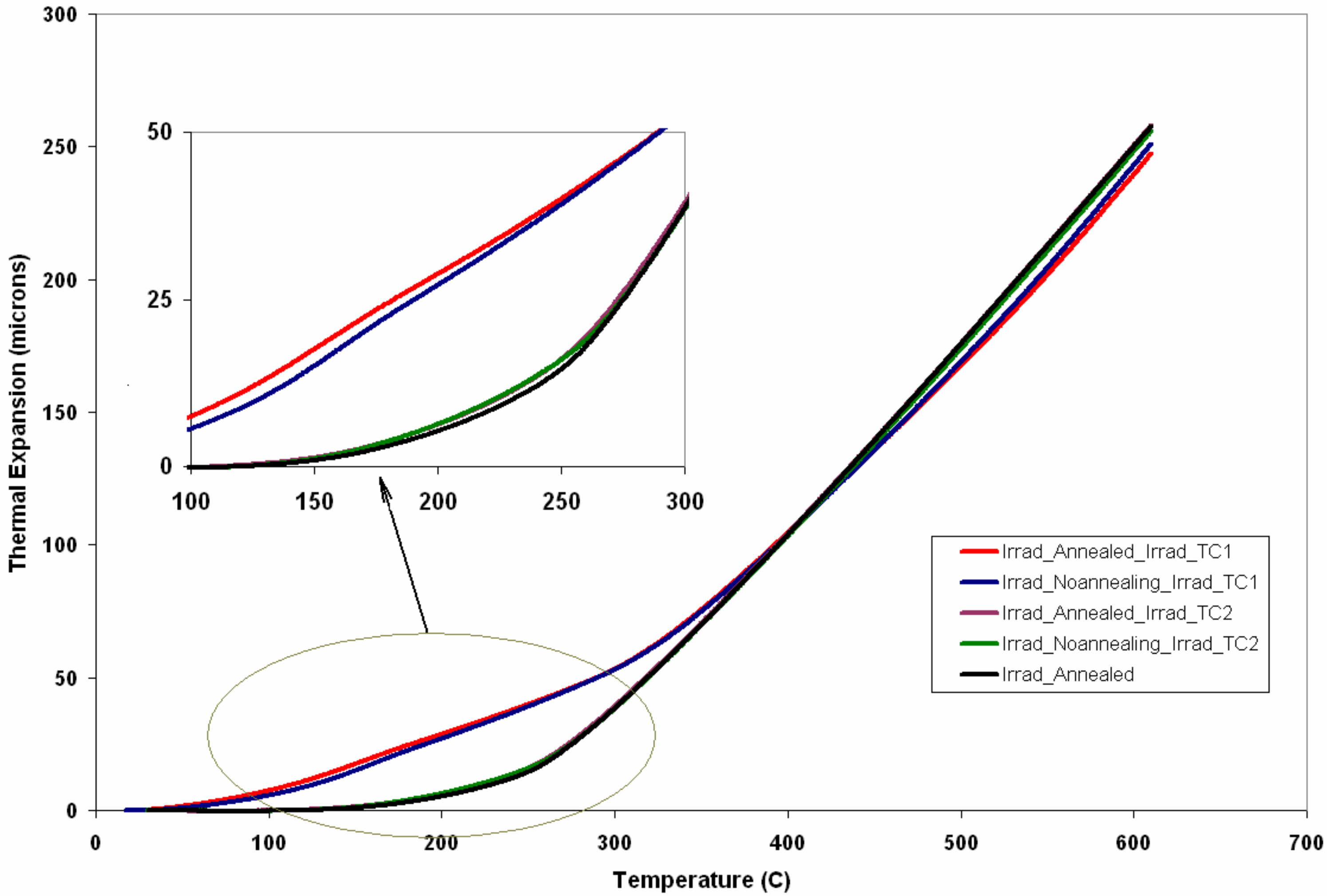
Radiation Damage in Carbon-Carbon Composites and Graphite





[fluence ~10^21 p/cm2]

“annealing” of super-Invar



ONGOING 3rd irradiation phase: neutron exposure

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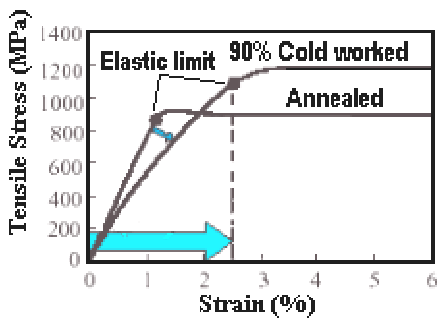
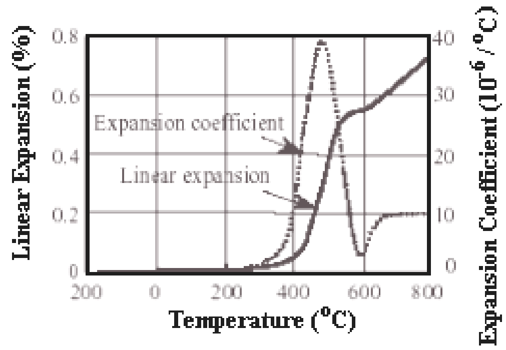
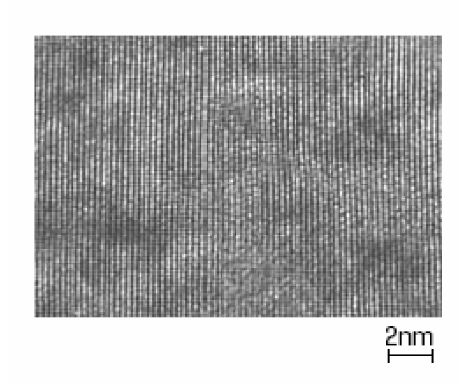
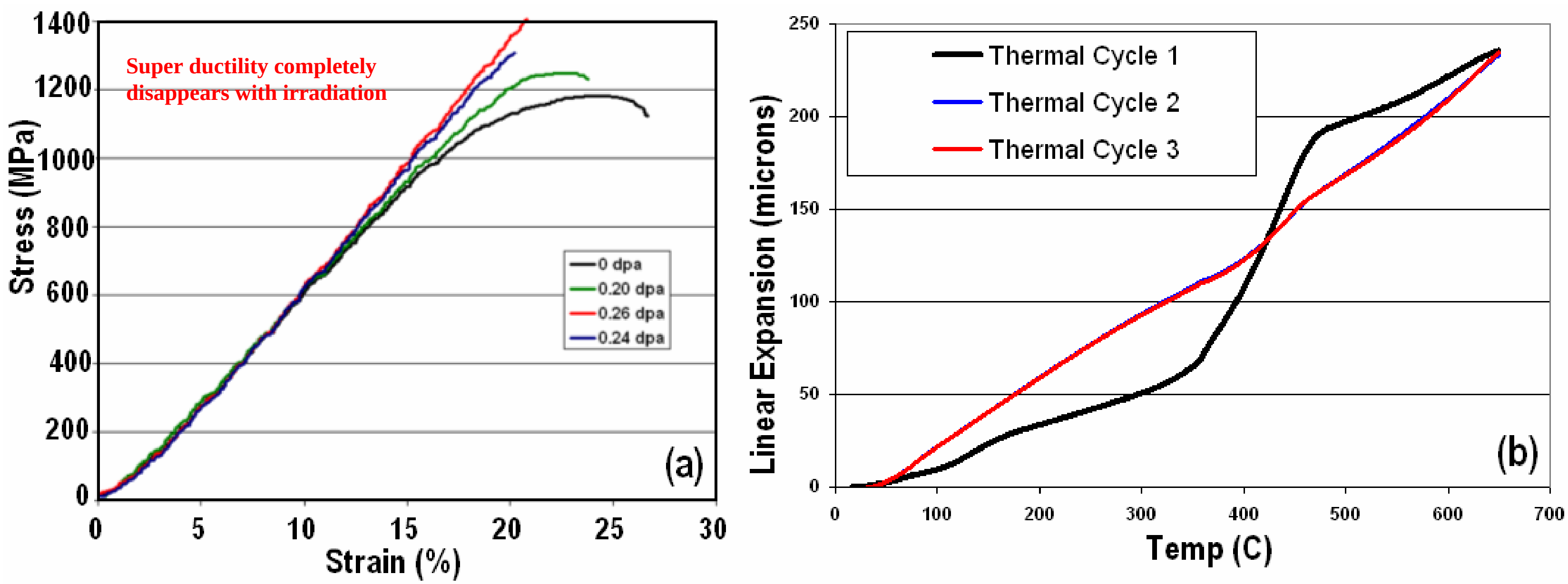
Radiation Damage of Super Alloy "Gum" metal

Enhancement of properties are attributed to the "dislocation-free" plastic deformation mechanism







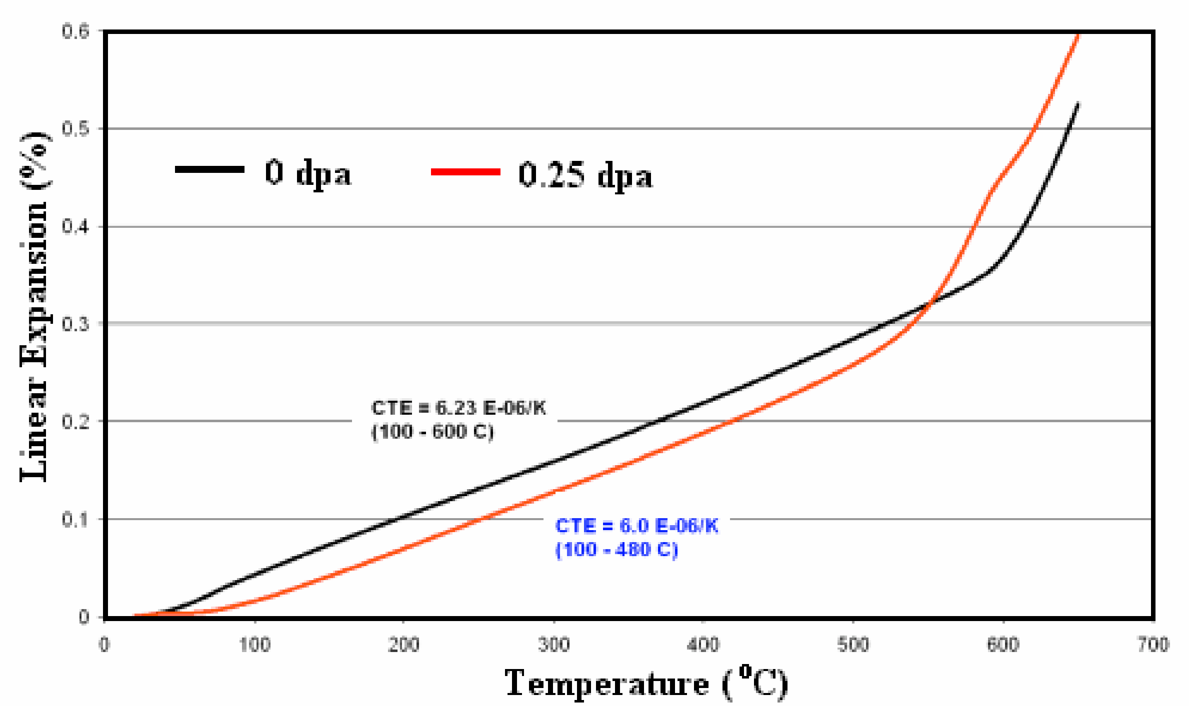


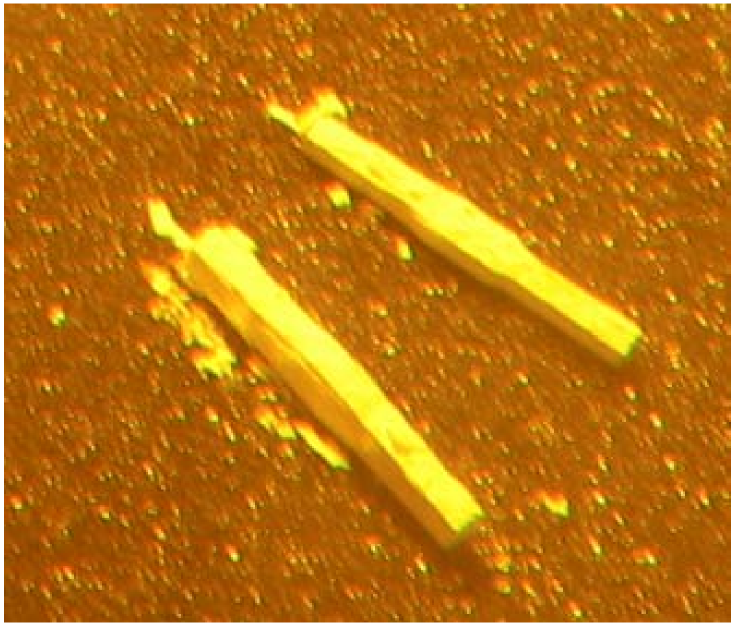
As observed in other studies (AlMg-alloy)

0.2 dpa was enough to remove cold-work microstructure

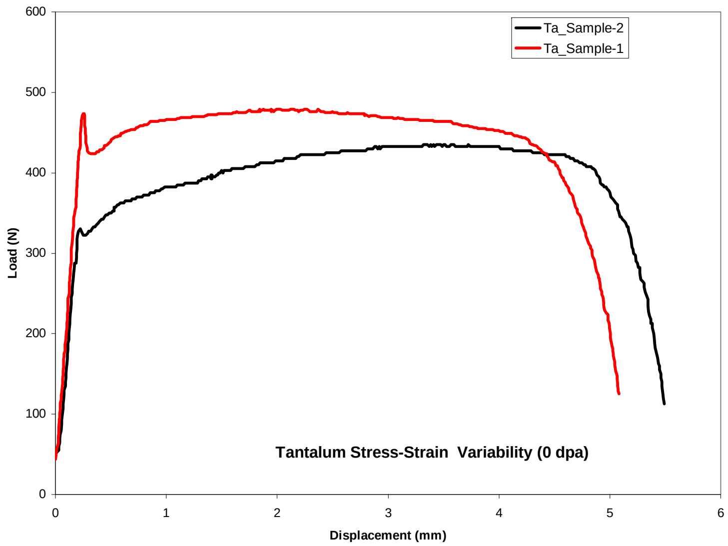
Radiation Damage Studies – High-Z Materials

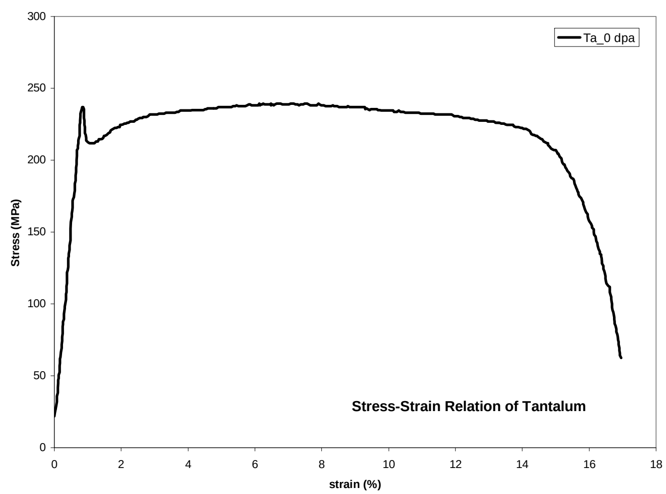
Tantalum





Tantalum





Radiation damage problems in high power spallation neutron sources

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Institut für Festkörperforschung und ESS-Projekt des Forschungszentrums Jülich, D-52425 Jülich, Germany

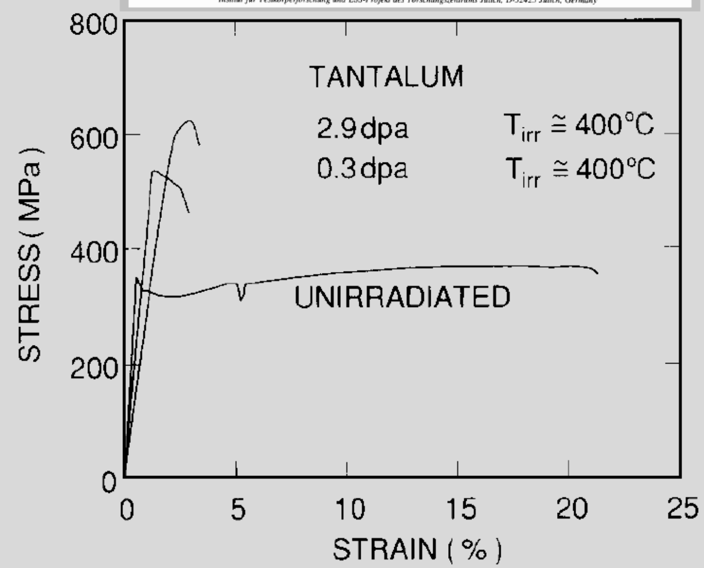
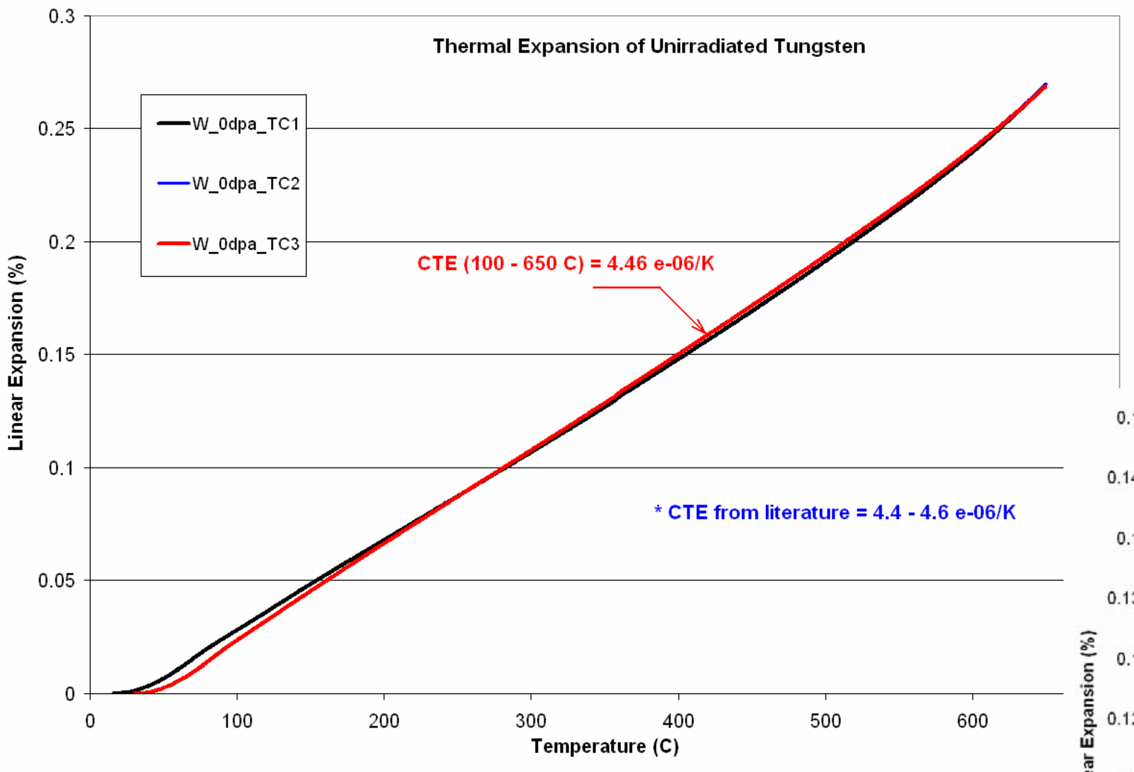
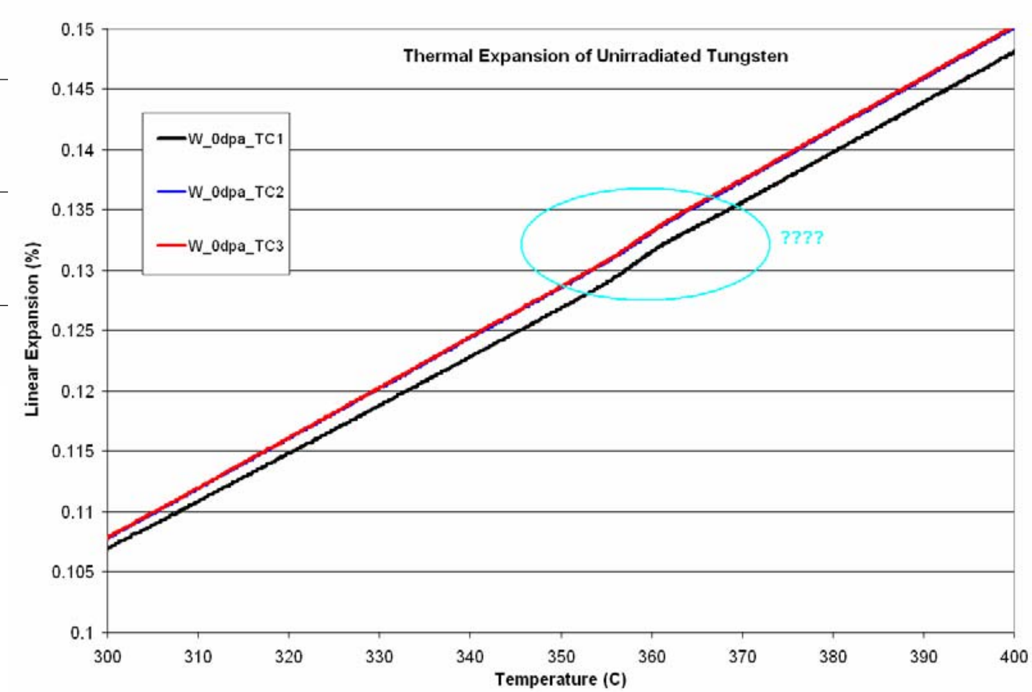


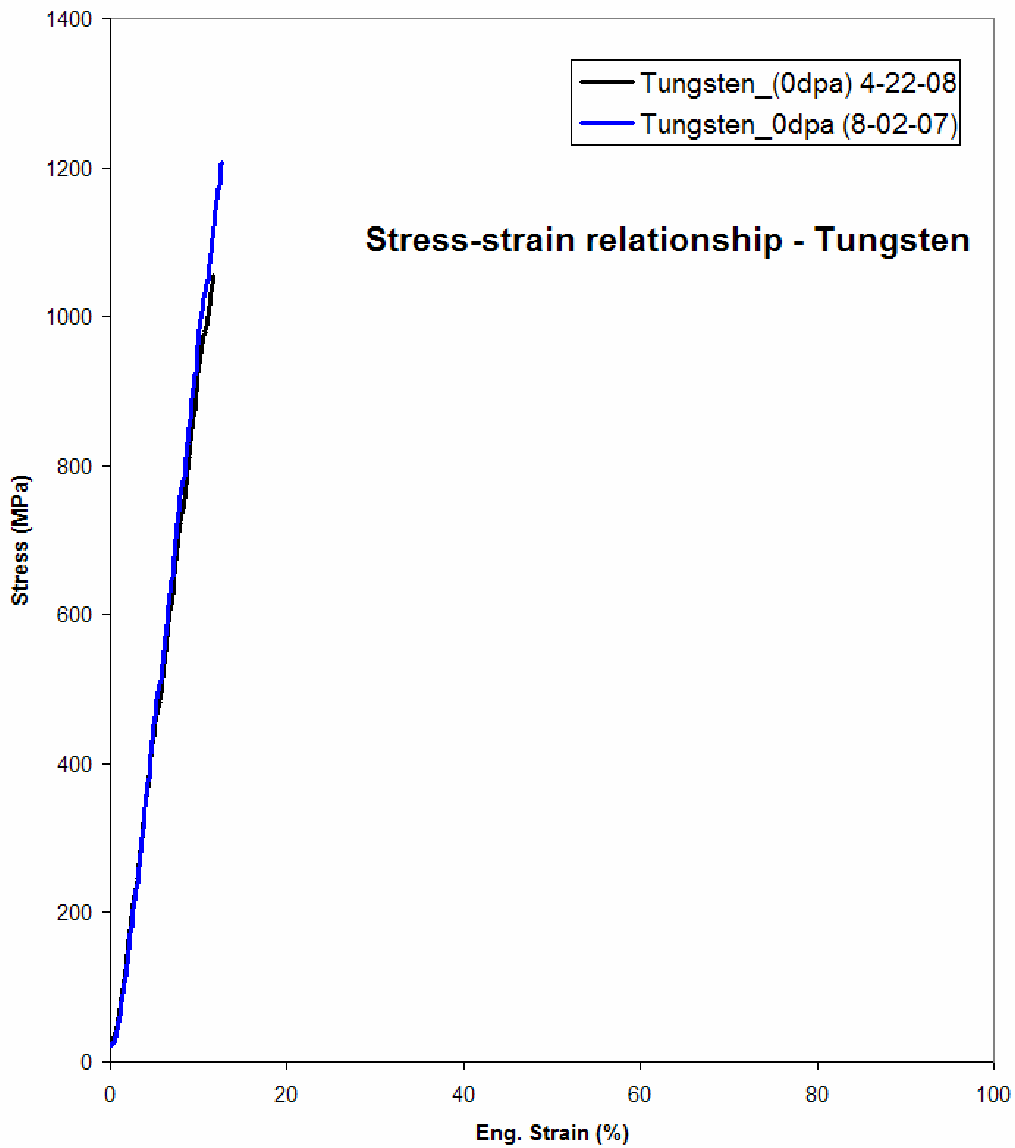
Fig. 8. Stress-strain curves at room temperature for proton-irradiated and unirradiated Ta R.D. Brown, M.S. Wechsler and C. Tschalär, in: Effects of Radiation on Materials Properties, 13th Int. Symp. ASTM STP 956, eds. F.A. Garner, C.H. Henager and N. Igata (ASTM, Philadelphia, 1987) p. 131.

Tungsten


Thermal Expansion of Unirradiated Tungsten
W_0dpa_TC1
W_0dpa_TC2
W_0dpa_TC3
CTE (100 - 650 C) = 4.46 e-06/K
* CTE from literature = 4.4 - 4.6 e-06/K
Linear Expansion (%)
Temperature (C)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
100
200
300
400
500
600


Thermal Expansion of Unirradiated Tungsten
W_0dpa_TC1
W_0dpa_TC2
W_0dpa_TC3
????
Linear Expansion (%)
Temperature (C)
0.15
0.145
0.14
0.135
0.13
0.125
0.12
0.115
0.11
0.105
0.1
300
310
320
330
340
350
360
370
380
390
400

Tungsten



Stress-strain relationship - Tungsten
Tungsten_(0dpa) 4-22-08
Tungsten_0dpa (8-02-07)
Stress (MPa)
0
200
400
600
800
1000
1200
1400
Eng. Strain (%)
0
20
40
60
80
100

NEXT STEP ?

- Focus on irradiation damage and thermal shock/fatigue of key components that could be the limiting factors in the lifetime of the overall experiments

- Appreciate the value of multi-physics based simulations for the engineering side of things (where actual limitations lie) and use them to push the envelope