# **Modeling of HAPL FW Tests**

**Jake Blanchard** 

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# Outline

- Fracture Modeling for Surface Tests (short pulse XAPPER, RHEPP, Z, Dragonfire
- Flat Specimens in IR facility
- Cooled Specimens in IR facility

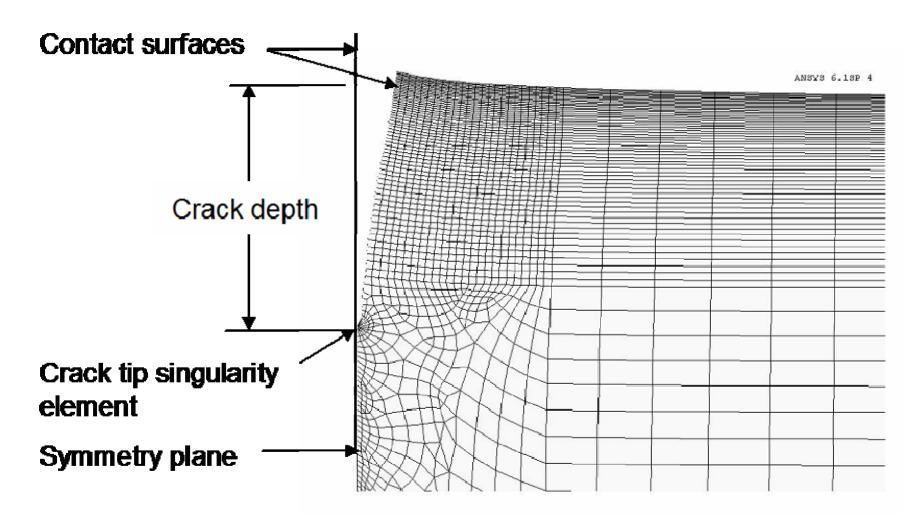


# Purpose of Modeling

- Goal: Ensure wall survival
- Tests will help us determine design limits of tungstencoated steel walls
- Modeling is required to help us understand failure mechanisms
- Hypothesis is that damage is thermomechanical
- Combination of tests and modeling will help with design
- Previous analyses predicted cracking at tungsten surface



# Fracture Model



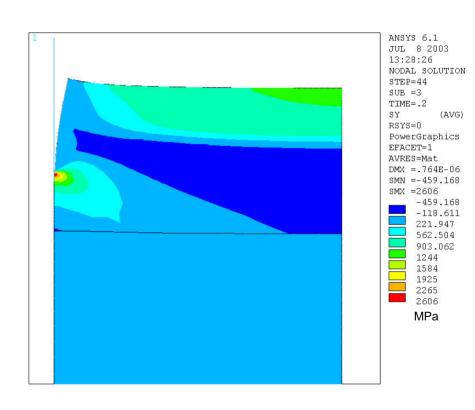


## **Typical Behavior in HAPL Chamber**

### **Stresses at Maximum Temperature**

### ANSYS 6.1 JUL 8 2003 13:32:23 NODAL SOLUTION STEP=38 SUB =3 TIME=.310E-05 (AVG) RSYS=0 PowerGraphics EFACET=1 AVRES=Mat DMX = .392E - 06SMN = -695.884SMX = 6.156-695.884 -617.88 -539.875 -461.871 -383.866 -305.862 -227.857 -149.853 -71.848 6.156 MPa

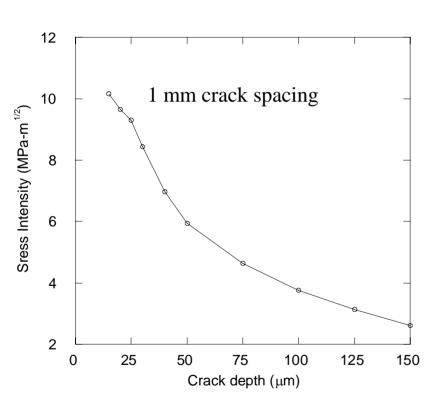
### **Stresses After Cool Down**

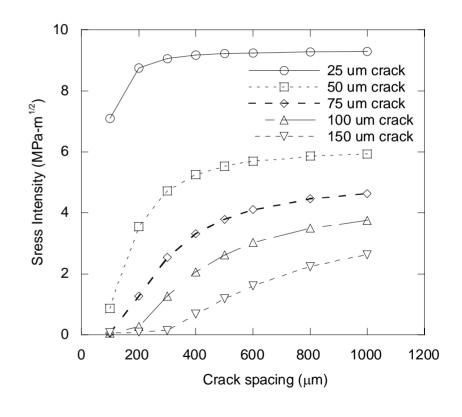




# **Fracture Mechanics Analysis Results**

250 microns W7 m Chamber150 MJ Target







# Validation Tests

- To validate modeling, several tests are under way
  - Ions at SNLA
  - X-Rays at LLNL (XAPPER) and SNLA (Z-Machine)
  - Lasers at UCSD
  - Infrared at ORNL
- First three tests are shorter pulse times and higher intensity
- Infrared is longer pulse (excellent model for interface stresses)

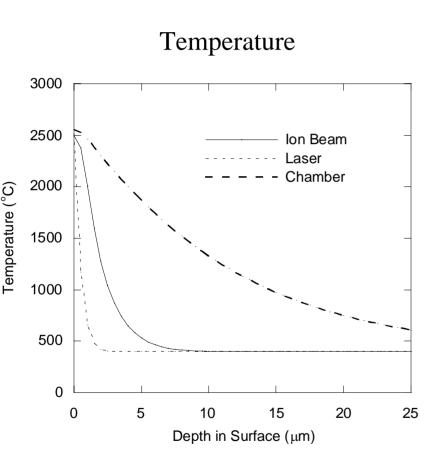


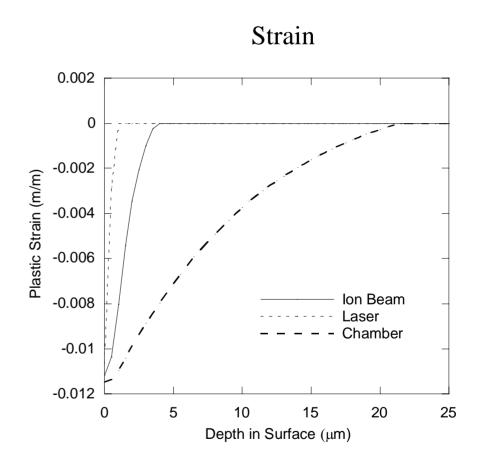
# **Test Parameters**

Type	Energy (keV)	Maximum Fluence per Pulse (J/cm²)	Depth of Energy Deposition (microns)	Flat Top Pulse Width (ns)
RHEPP	750	7	1-10	100
XAPPER	0.8-1.2	3000	1-2	6
Z	0.1-0.4	7	1-2	30-50 (FWHM)
Laser		0.7	0	8



# Representative Temperature and Strain Comparisons

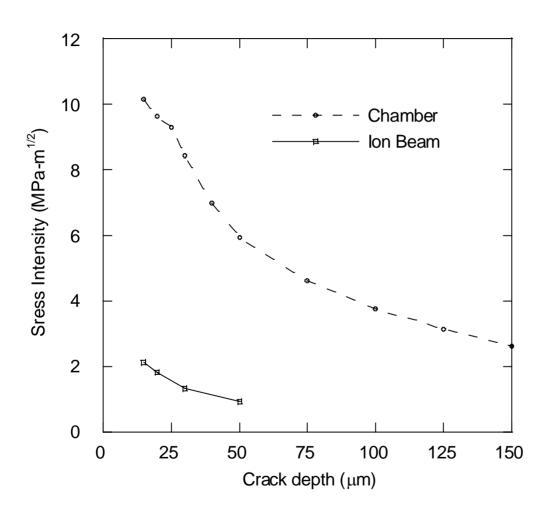




End of Pulse



# Fracture



- •Tests are not conservative from fracture point of view
- •Cracks will stop at a more shallow position
- •Simulations should allow us to correlate growth rates and make conclusions relevant to chamber



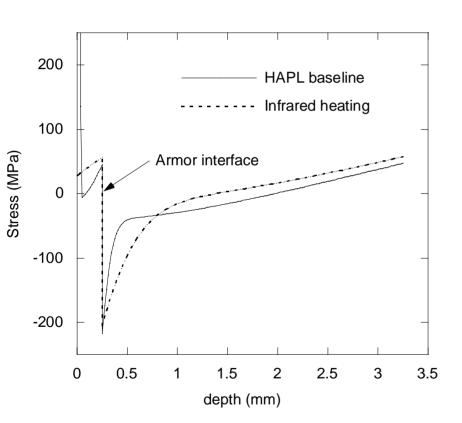
# IR Tests

- The IR tests are longer pulses (~20 ms, moving towards 1 ms or less), but have high average power
- Matching time-averaged power provides good simulation of interface behavior
- Hence, IR complements the other tests

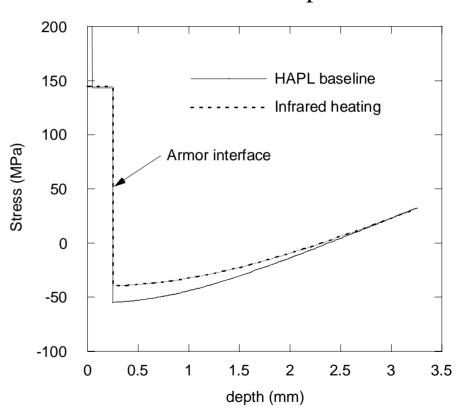


# **Infrared Testing**





### Prior to next pulse



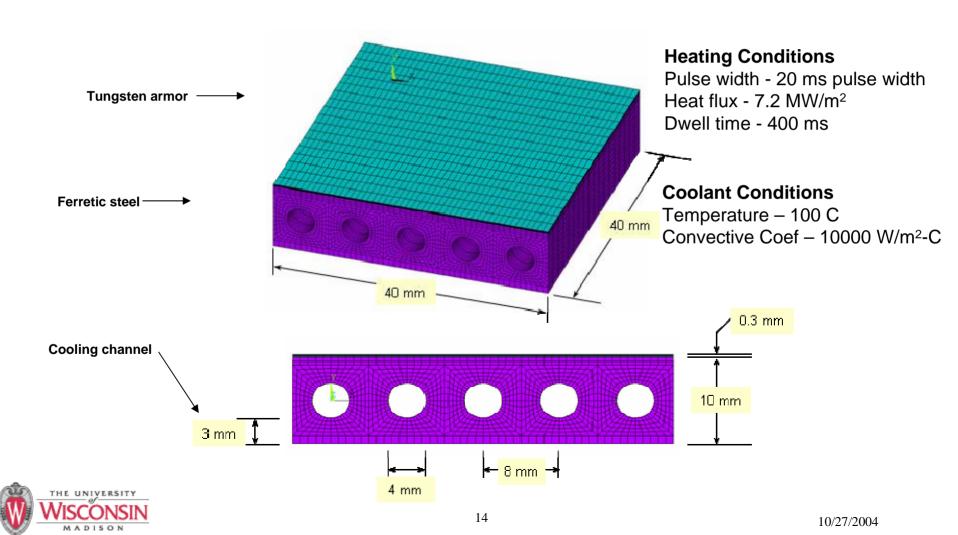


# **Next Phase**

- To demonstrate next level of operation, we need to demonstrate interface survival in a more realistic component
- Approach is to design cooled sample with sufficient surface area to avoid edge effects



# Infrared Heating Test Specimen with Internal Cooling Channels



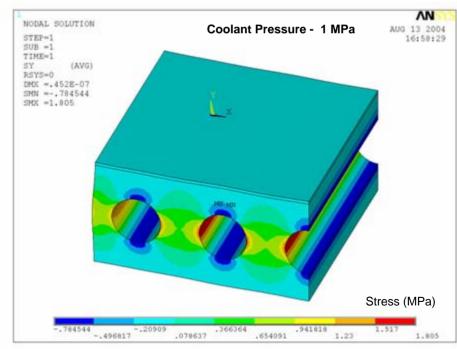
### **Stresses Produced by Pressure in Coolant Channels**

- Additional stresses will be produced by the coolant pressure which has yet to be determined
- Maximum stress for 1 MPa pressure is 1.8 MPa and less than 1 MPa at the tungsten to steel interface

### **Stress in Horizontal Direction**

# NODAL SOLUTION STEP=1 SUB =1 TIME=1 SX (AVG) RSYS=0 DMX =-452E-07 SNN =-.769727 SNX =1.507 Stress (MPa) Stress (MPa)

### **Stress in Vertical Direction**





### **Infrared Test Specimen Transient Thermal Response**

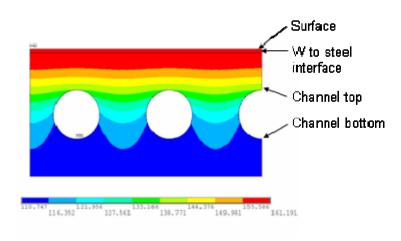
- At interface temperature changes nearly 60 C during cycle
- An equilibrium condition is reached after 25 cycles

# Transient Temperatures (50 Pulses)

### 

Temperature

### **Temperature Before 51st Pulse**



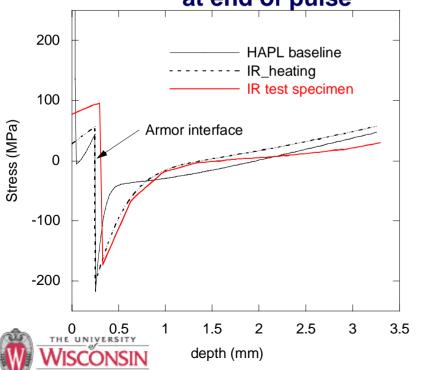
# Comparison of Specimen Stresses with HAPL wall design with baseline and IR Heating

- Stresses through the thickness compared at center of specimen
- HAPL and IR cases are for 250  $\mu\text{m}$  armor on 3 mm thick steel with direct backside cooling

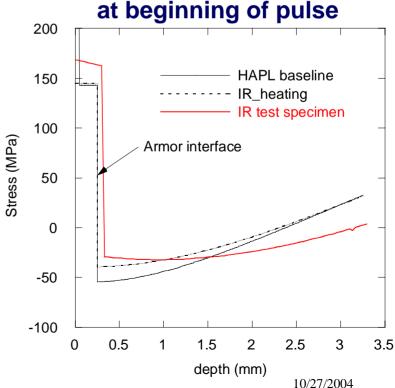
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 Specimen stresses are slightly higher due to slightly higher temperature rise compared to coolant (reference) temperature

Stress variation thru thickness at end of pulse



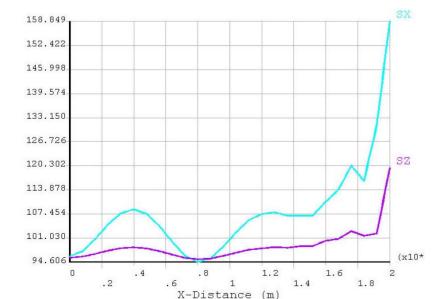
Stress variation thru thickness at beginning of pulse



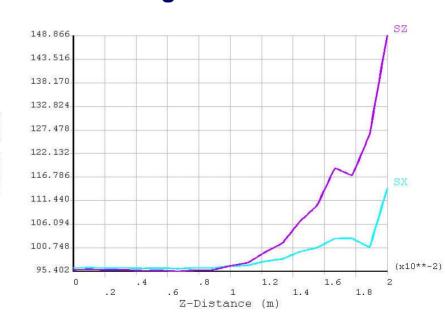
# Tungsten Interface Stress Variations along Length and With of Specimen

- Large area of uniform stress exists at center of specimen
- Stresses increase by 50% near edges of specimen
- A 15% stress increase is observed over cooling channel

# Stress variations normal to cooling channels



# Stress variations parallel to cooling channels





(MPa)

# **Conclusions**

- Tungsten walls will crack, but cracks are expected to arrest for sufficiently deep tungsten layers
- Surface experiments will underestimate depth of arrest
- IR tests are excellent models for interface stresses

