DSG NPS Collaborators’ Meeting Update

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Materials Used in Simulation

• PbWO₄ crystals
  – Thermal conductivity (orthotropic): 2.4 W/m·K (x and y directions), 2.0 W/m·K (z)
  – Source: Journal of Chemical & Engineering Data

• Carbon fiber dividers
  – Thermal conductivity (isotropic): 0.5523 W/m·°C
  – Source: Granta Design Typical Materials (Ansys)

• Mu metal dividers
  – Thermal conductivity (isotropic): 19 W/m·K
  – Source: https://mumetal.co.uk/?p=101

• Copper shell
  – Thermal conductivity (isotropic): 396.7 W/m·°C
  – Source: Granta Design Typical Materials (Ansys)
Baseline Simulations – 0 W and 3.5 W

- \( Q = 0 \) W (left) and \( Q = 3.5 \) W (right)
- Ambient temp. = 22°C
- Film Coefficient (convection) = 5 W/m² · °C for all bodies
- No Cu shell
- No carbon fiber dividers
- No mu metal dividers
• $z = 20 \text{ cm}$

• $Q = 0$
• Ambient temp. = 22°C
• Film coefficient (convection) = 5 W/m$^2 \cdot ^\circ$C
• Cu shell temp. = 10°C
• Max. temp. = 12.252°C
• Start of carbon fiber cladding (2 cm)
- z = 18 cm
- End of carbon fiber cladding (2 cm)
Full-length Crystal Simulation (0 W)

- $z = 2 \text{ cm}$
- Start of mu metal cladding (2 cm)
- $z = 0.1 \text{ cm}$
- End of mu metal cladding
Full-length Crystal Simulation (3.5 W)

- $z = 20 \text{ cm}$
- $Q = 3.5 \text{ W}$
- Ambient temp. = 22°C
- Film coefficient (convection) = 5 W/m$^2$·°C
- Cu shell temp. = 10°C
- Max. temp. = 17.801°C
- Start of carbon fiber cladding (2 cm)
Full-length Crystal Simulation (3.5 W)

- $z = 18$ cm
- End of carbon fiber cladding (2 cm)
Full-length Crystal Simulation (3.5 W)

- $z = 2$ cm
- Start of mu metal cladding (2 cm)
Full-length Crystal Simulation (3.5 W)

- $z = 0.1$ cm
- At 3.5 W central crystal is $\sim 18^\circ$C
- End of mu metal cladding
Total Heat Flux (3.5 W)

- Heat load = 3.5 W
- Majority of heat is dissipated within the first 2 cm
Plot of $T_{\text{max}}$ vs. $Q$

- For all values of $Q$:
  - Cu shell temperature fixed at 10°C
  - Model included carbon fiber and mu metal dividers
  - Heat applied directly to the rear face of each crystal

$y = 1.775x + 11.589$

$R^2 = 1$
Conclusion

• Conducting thermal analysis of a 3x3 PbWO$_4$ crystal array to determine temperature profile
  – 3.5-W heat load leads to a maximum temperature of $\sim$18°C for the central crystal

• Heat conduction to the Cu shell is more at the mu metal end due to better conductivity of mu metal compared to carbon fiber

• Need to know thermal properties for carbon fiber

• Plan to scale up to full 36x30 model
Thank You!