

Topic Area 2B: Gen3 Research & Analysis

# Thermophysical Property Measurements of Heat Transfer Media and Containment Materials

(Gen3 CSP Kick-Off, June 25<sup>th</sup> 2018)

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Research Engineer II

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Ph.D. Candidate

# Thermophysical Property Measurements of

**H**eat **T**ransfer **M**edia  
(e.g., Molten Salts)

&

**C**ontainment **M**aterials  
(e.g., high temperature alloys)

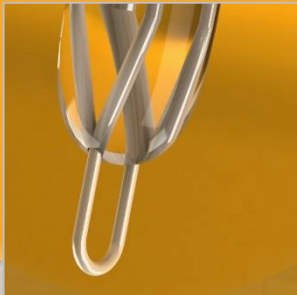
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Thermophysical  
Property Database



**HL**  
HEAT LAB

Immersion  
Electrothermal Probe



**HL**  
HEAT LAB

Advanced Photo-  
thermal Technique



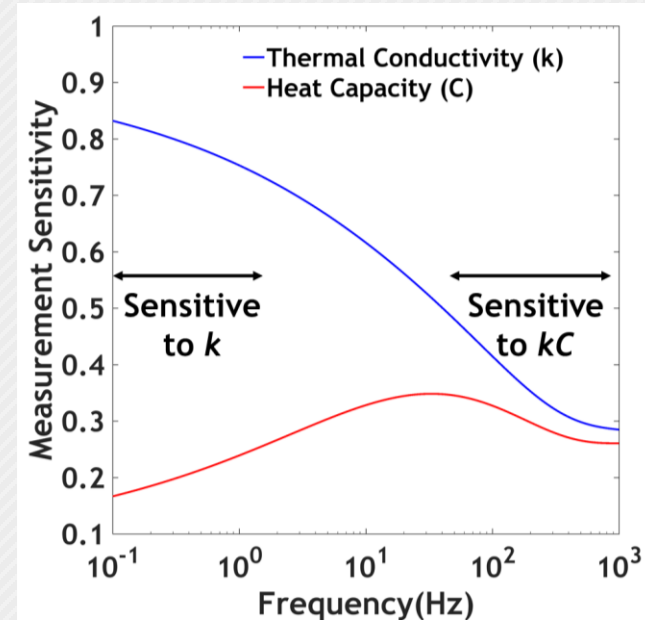
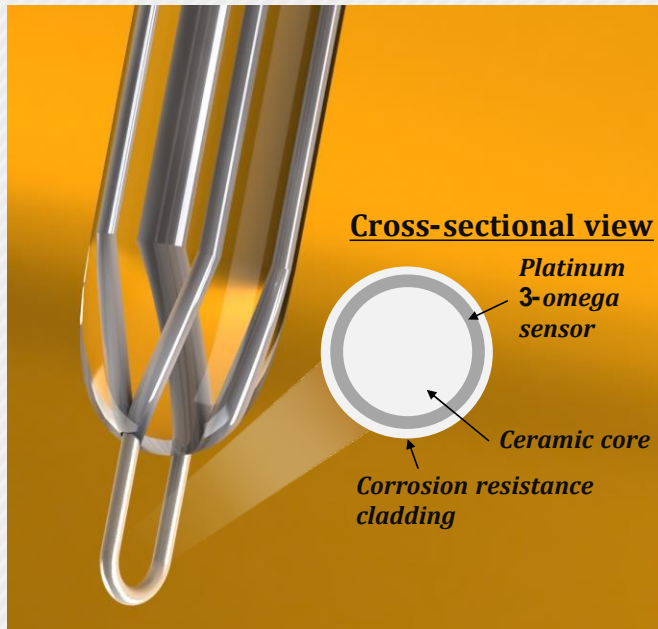
Measurement Accuracy at  
High Temperatures in Corrosive Environments

# Project Goals

## Provide research and support analysis (Topic 2B) supporting Gen3 integrated thermal system:

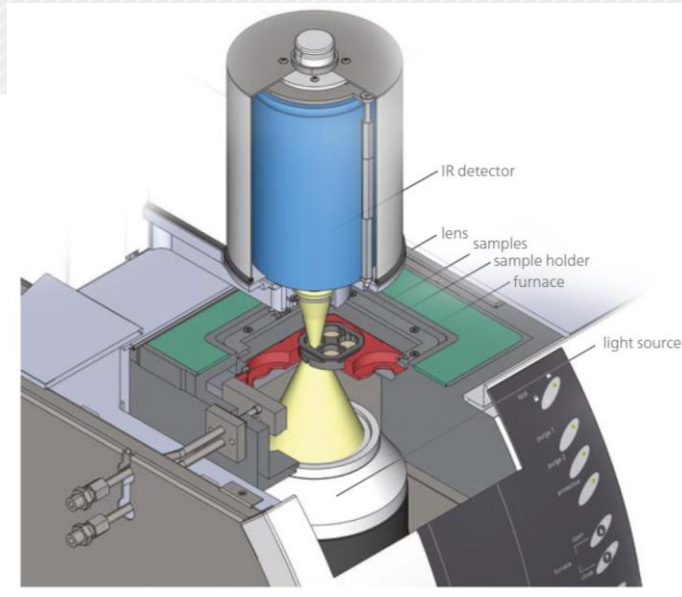
- Perform thermophysical properties measurements using advanced immersion electrothermal and photothermal techniques on:
  - HTMs (i.e. molten salts chemistries proposed by Topic 1 awardees)
  - CMs (i.e. alloys, ceramics, cermets proposed by Topic 1 and 2A awardees)
- Develop engineering model describing the effects of composition, contamination, corrosion, *etc.* on thermal conductivity and diffusivity of HTMs and CMs
- Curate the datasets openly, publicly, and digitally through our university library

# Immersion Electrothermal Probe (for HTMs)



- Ability to determine  $k$  and  $C$  simultaneously by measuring over wide frequency ranges
- Measurement insensitive to properties of the cladding material

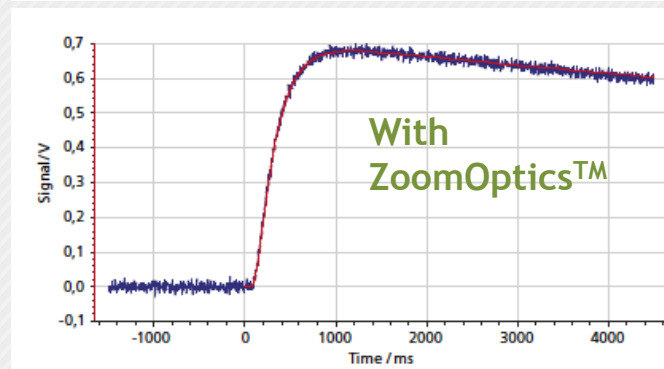
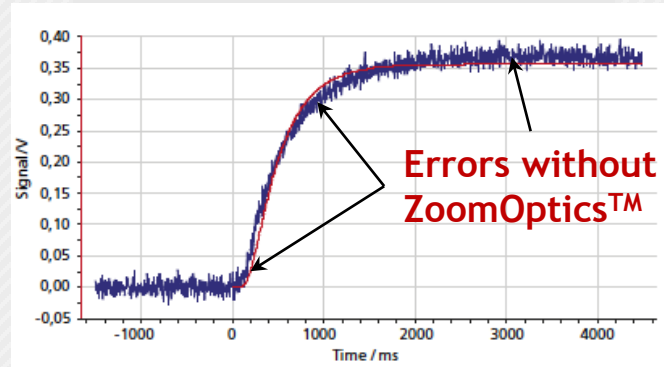
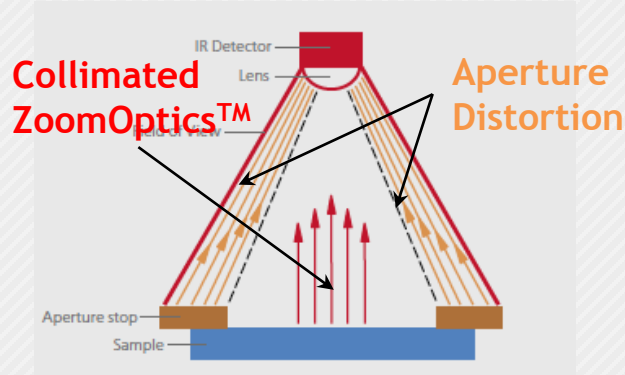
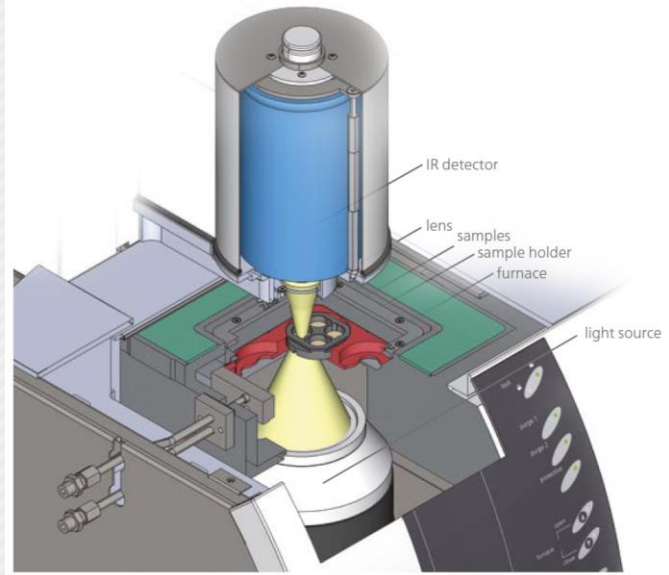
# Photothermal Technique (for CMs)



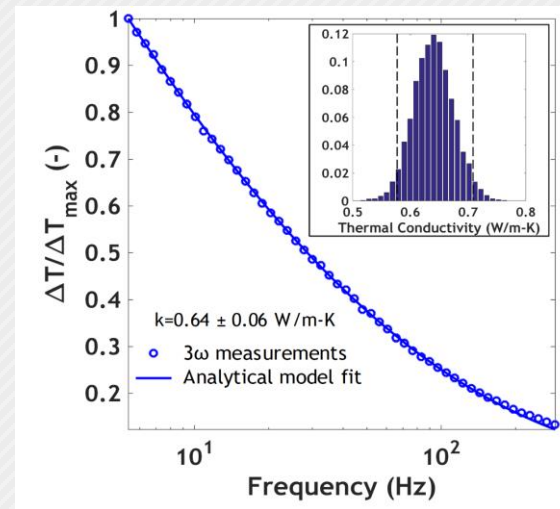
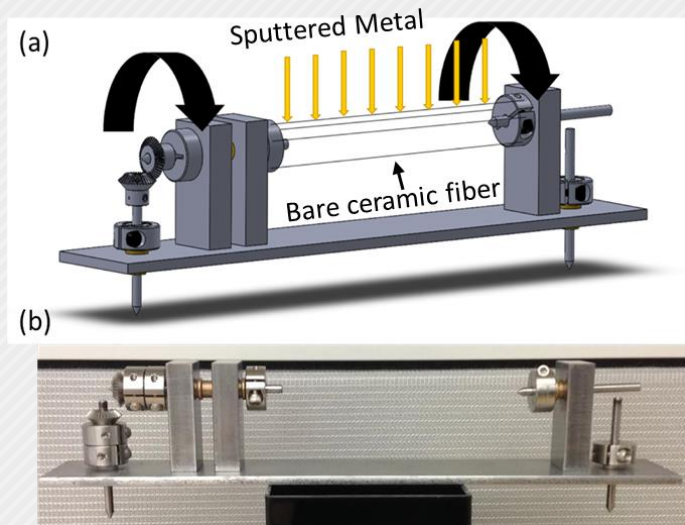
- Modified Xenon flash technique to measure thermophysical properties up to 1250 °C.
- Data analysis software can account for sample porosity, roughness, and transparency.

# New Equipment

to support Gen3 CSP Thermophysical Property Measurements

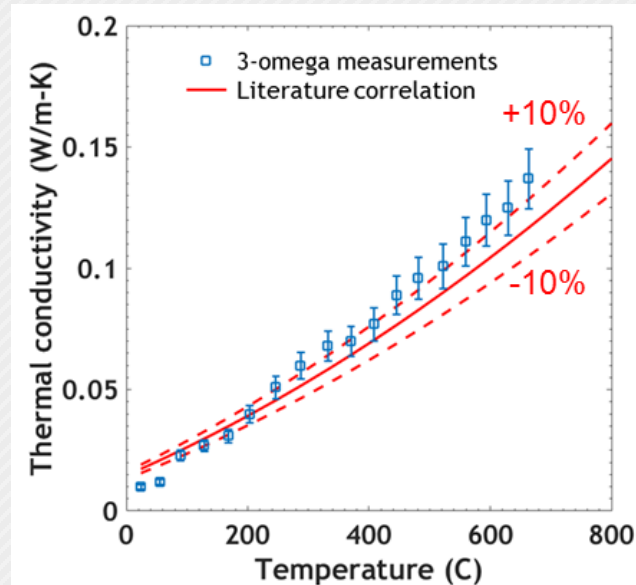
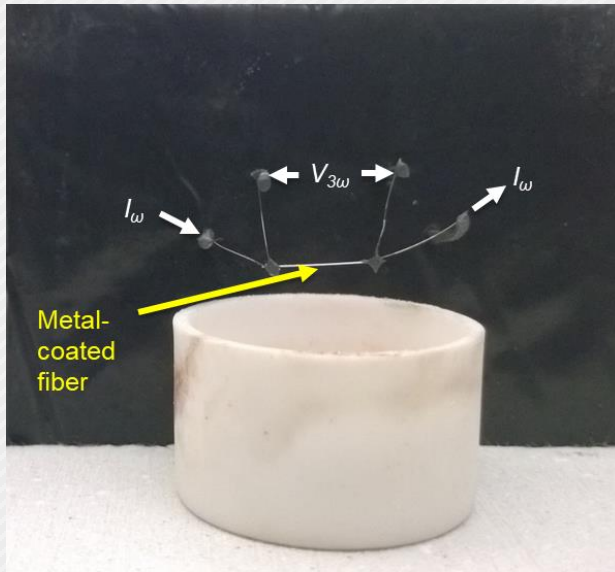


# Feasibility and Preliminary Data



- Custom rotary deposition lathe to achieve uniform circumferential coating (thickness variation <10%)
- Data analysis performed using a multilayered radial heat transfer model with robust Monte-Carlo analysis

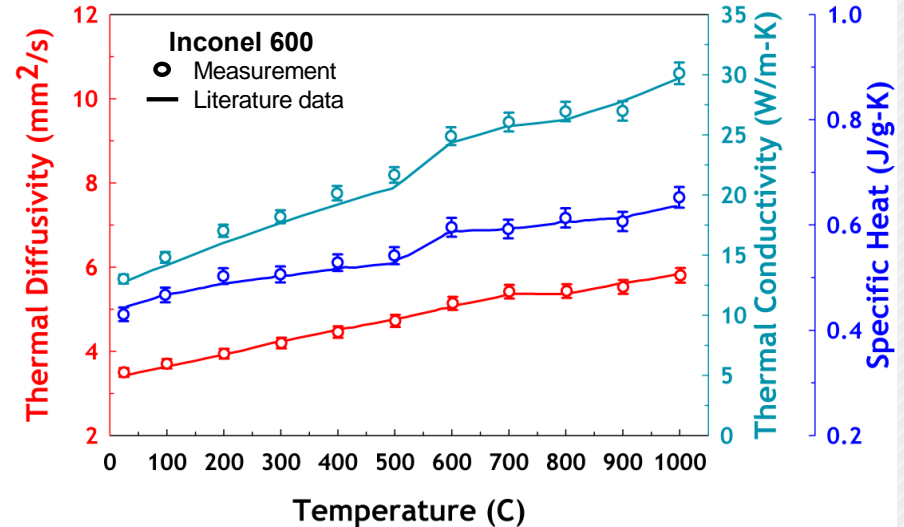
# Feasibility and Preliminary Data (contd.)



- Preliminary measurements on Alumina powder between 25 °C and 700 °C, using a platinum-coated silica fiber
- Measured thermal conductivity in good agreement (within 10%) with empirical correlation developed in literature



# Feasibility and Preliminary Data (contd.)



- Preliminary measurements on Inconel 600 between 25 °C and 1000 °C, using the modified Xenon flash technique
- Measured thermophysical properties in good agreement (within 5%) with values reported in literature

# Innovation and Impact

Steady-state techniques	Transient techniques (time domain)	Transient techniques (frequency domain)
1D reference bar (ASTM D5470) <sup>11</sup>	Transient hot-wire (THW) <sup>15</sup>	3-omega <sup>4</sup>
Radial heat flow method <sup>9,12</sup>	Time-domain thermoreflectance <sup>16</sup>	Frequency-domain thermoreflectance <sup>19</sup>
Guarded hotplate (ASTM D1518) <sup>13</sup>	Laser flash method <sup>17</sup>	Pulsed power technique <sup>20</sup>
DC thermal bridge method <sup>14</sup>	Transient plane source <sup>18</sup>	

- Proposed electrothermal immersion probe sensor can become the standard characterization technique at temperatures  $>700$  °C
  - *Addresses key challenges present in current state-of-the-art techniques*
- The modified Xenon flash technique could serve to benchmark high temperature characterization of solids
  - *Versatility - its can be useful for other high temperature applications*

# Key Milestones & Deliverables

## Budget Period 1

## Budget Period 2

## Budget Period 3

Photothermal  
Technique  
Qualification  
(M2.1)

Thermophysical  
Property Database  
Launching  
(M5.3 / GNG2)

Engineering Model Development  
(describing thermophysical properties)  
(M5.4, 5.7 & 6.3)

Immersion  
Electrothermal  
Technique  
Qualification  
(M3.2 / GNG1)

Robust thermophysical property  
measurements of the most promising  
HTMs and CMs, supporting Topic Area  
1 and 2B awardees  
(M5.7 / GNG3)

Detailed studies of  
Contamination,  
Corrosion, and  
Composition of  
thermophysical  
properties  
(M6.1-6.2 & M7.1-7.2)

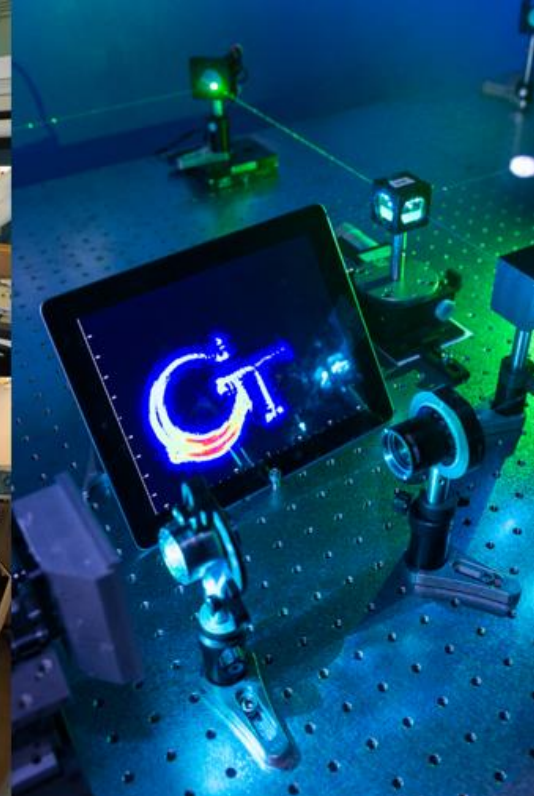
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# Project Team & Facilities

- Prof. Shannon Yee (PI)
- Dr. Andrey Gunawan  
(Senior Personnel)
- Scalable Thermal Energy  
Engineering Laboratory



# Thermophysical Property Measurements of

**H**eat **T**ransfer **M**edia  
(e.g., Molten Salts)

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**C**ontainment **M**aterials  
(e.g., high temperature alloys)

**Thank you!**

**Questions?**

**LIBRARY NEXT**

*Thermophysical  
Property Database*



**HL**  
HEAT LAB

*Immersion  
Electrothermal Probe*



**HL**  
HEAT LAB

*Advanced Photo-  
thermal Technique*



*Measurement Accuracy @  
High Temperatures in Corrosive Environments*



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# Thermophysical Property Measurements of Heat Transfer Media and Containment Materials

PI: Prof. Shannon Yee, / Georgia Institute of Technology

## Technology Summary

Topic Area 2B: Thermophysical property measurements of **heat transfer media (HTM)** and **containment materials (CM)** using advanced immersion electrothermal and photothermal techniques, curating the data openly and publicly through a public university library.

## Technology Impacts

### Immersion Electrothermal Probe for HTM:

Thermal conductivity & diffusivity of molten salts

**Operating temperatures** (700 – 1200 °C)

**Stable in multi-corrosive environment** (e.g, KCl, etc.)

**Study composition & contamination** (e.g, H<sub>2</sub>O, O<sub>2</sub>, etc.)

### High Temperature Photothermal Measurements of CM:

Thermal conductivity & diffusivity of alloys & ceramics

**Modified flash diffusivity**

**Study composition, contamination, & corrosion effects**

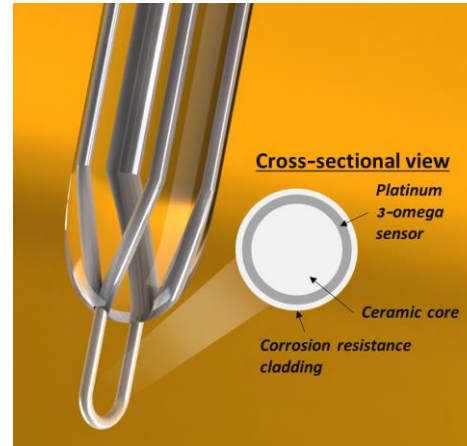
### Curating & Disseminating Thermophysical Data:

Freely, openly, and publicly through a university library.

**Online repository and database for Gen3 CSP properties**

## Project Goals

- **Qualify an inline immersion probe** to measure and monitor thermal properties of molten salts
- **Develop engineering models** describing the effects of composition, contamination, & corrosion on thermal conductivity and diffusivity of HTMs and CMs.
- **Develop a freely accessible & open database** of thermophysical properties of HTMs and CMs.



## Key Milestones & Deliverables

Budget Period 1 (15 mo.)	<ul style="list-style-type: none"> <li>• Qualify immersion electrothermal probe</li> <li>• Qualify photothermal technique</li> </ul>
Budget Period 2 (15 mo.)	<ul style="list-style-type: none"> <li>• Release thermophysical property database</li> <li>• Perform robust thermophysical property measurements of the most promising HTMs and CMs, supporting Topic Area 1 and 2A awardees.</li> </ul>
Budget Period 3 (30 mo.)	<ul style="list-style-type: none"> <li>• Perform detailed studies of contamination, corrosion, and composition of thermophysical properties</li> <li>• Develop engineering models describing thermophysical properties</li> </ul>

## Resources (\$)

Total Project (5 yr.)	DOE Funds	Cost Share
\$2,184,935	\$1,966,441	\$218,493