Raman Spectroscopy-Based Molten Salt Composition Monitoring System

DOE-Funded Phase II SBIR effort (August 2018 - August 2020)
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Outline

• Motivation
• Technical Approach and Background
• Envisioned Final Product
• Project Status and Timeline
DOE Phase II Project Motivation

**Motivation:** The DOE/CSP industry developed roadmap identifying technology gaps and pathways for next gen CSP plants (CSP Gen3)

- Recommended research activity: in-situ, real time, online monitoring for molten salt composition/chemistry
- Identify changes in the melt that may lead to severe material (salt and containment) degradation

**Need:** The development of a “smart” in-situ, real time molten salt composition monitoring system

- Measure range of molten salt compositions, contaminants, and byproducts
- CSP Gen3 operational temperatures (up to 800°C) - rugged for industrial applications
- “Smart” features - compliance with industry integrated data systems
  - On-board signal processing self-calibration, built in test, and support digital/data bus communications
Technical Approach: Raman Spectroscopy with Molten Salts

- **Raman Spectroscopy Technique:**
  - Optically excited molecules emit according to vibrational modes
  - Species exhibit distinct spectral “fingerprints”
  - Established method of chemical/molecular analysis
  - Used in complex media
  - Prior work with molten salts

[Image of Raman scattering diagram]

**Example Raman peaks for $\text{MgCl}_4^{2-}$ and $\text{Mg}_2\text{Cl}_7^{3-}$ in a molten NaCl-KCl-CaCl$_2$-MgCl$_2$ at 720°C [1]**

[Graph of Raman peak intensity versus concentration at 720°C]

Relevant Prior Development at Sporian

- Range of high-temp (1000-1800°C) sensor technologies
  - CSP TES/HTF pressure & flow sensors (>800°C)

- Compact spectroscopic monitoring systems - Raman
  - Water monitoring (commercial)
  - Aircraft for gas/atmospheric composition monitoring
Envisioned System Hardware Architecture

- **Commercial vs research type systems**: Conflict of requirements
  - Dynamic range vs resolution (vs cost)
- **End Product**: Flexible architecture for diverse applications
  - Largely automated operation
  - Cost and ruggedness
  - Target-dependent subsystems
Example System Data

Graph showing Raman shift vs. intensity (counts) for various samples:
- Pure MgCl
- MgCl exposed to atmospheric moisture

Key features:
- MgCl at 240 cm\(^{-1}\)
- Water O-H bond at 1643 cm\(^{-1}\)
- MgCl at 160 cm\(^{-1}\)

Questions:
- Water O-H bond? (1643 cm\(^{-1}\))
Current State of Development

• Internal performance testing & characterization ongoing...
  • High-temperature immersion probe (800°C)
    ➢ Evaluating window and windowless designs
• Compact optics module
• Standalone light source and spectrometer

• Fully integrated system in development...
Evaluation, Validation, and Expected Availability

• **Next-gen system design:** Prototypes ready spring 2019

• **3rd Party testing:** Evaluate performance and utility, and support ongoing Gen3 research
  – NREL (Golden, CO)
  – University of Arizona
  – Through late 2019 / early 2020

• **Analytical modeling:** Confirm and interpret test results
  – NREL (Boulder, CO)
  – Through mid/late 2019

• **Target completion date for performance testing:**
  August 2020