U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE

SETO CSP Program Summit 2019

Raman Spectroscopy-Based Molten Salt Composition Monitoring System

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

Principal Investigator: Kevin Harsh (harshk@sporian.com)

Presenter: Jon Lubbers (jlubbers@sporian.com)

Sporian Microsystems, Inc.

energy.gov/solar-office

Outline

- Motivation
- Technical Approach and Background
- Envisioned Final Product
- Project Status and Timeline

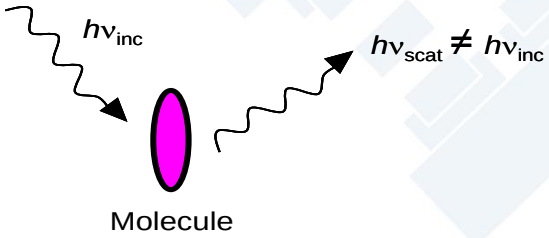
DOE Phase II Project Motivation

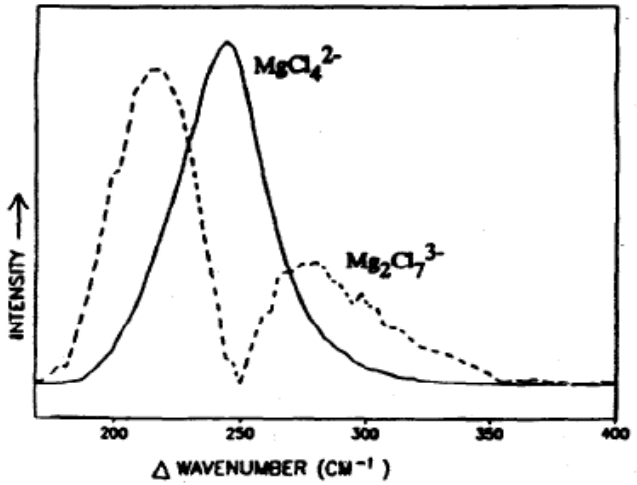
- **Motivation:** The DOE/CSP industry developed roadmap identifying technology gaps and pathways for next gen CSP plants (CSP Gen3)
  - Recommended research activity: **in-situ, real time, online monitoring** for molten salt composition/chemistry
  - Identify changes in the melt that may lead to severe 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

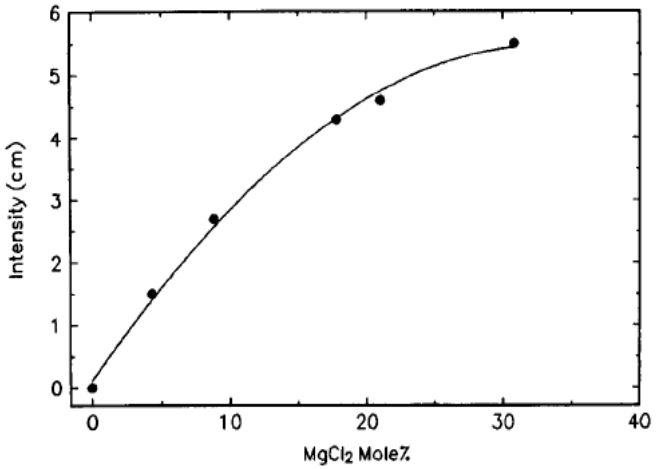
Technical Approach: Raman Spectroscopy with Molten Salts

- **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





Example Raman peaks for $MgCl_4^{2-}$ and $Mg_2Cl_7^{3-}$ in a molten NaCl-KCl-$CaCl_2$-$MgCl_2$ at 720°C [1]



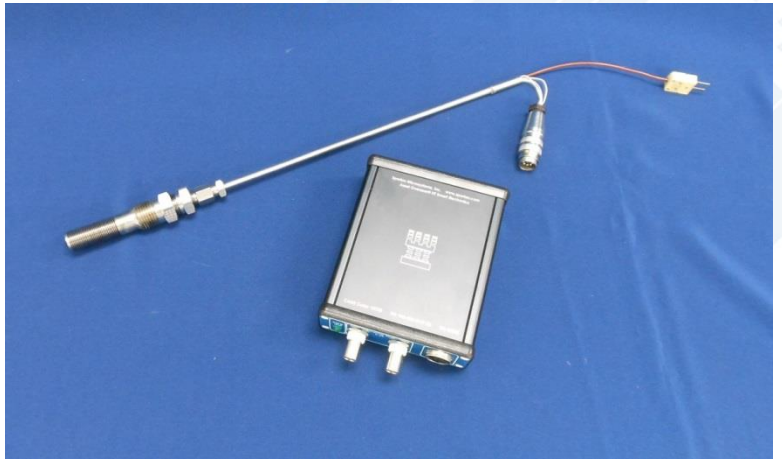
Example $MgCl_2$ Raman peak intensity versus concentration at 720°C [2]

[1] Young, J. P., et al. “Application of Raman spectroscopy to high-temperature analytical measurements”. No. CONF-970201--3. Oak Ridge National Lab., TN (United States), 1997.
[2] Dai, S., et al. Development of Raman spectroscopic sensors for magnesium in a molten salt system. No. CONF-920514--1-Extd. Oak Ridge National Lab., TN (United States), 1991.py." Applied spectroscopy 47.8 (1993): 1286-1288.

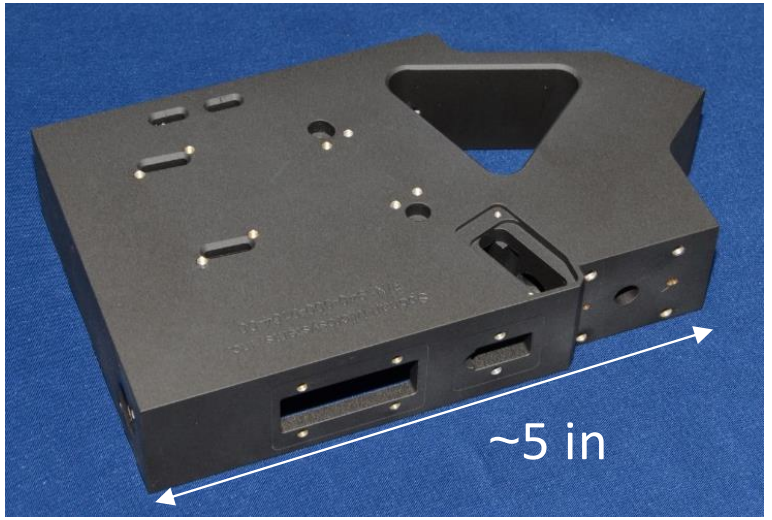
Relevant Prior Development at Sporian

- **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



Molten Nitrate Salt Pressure Sensor

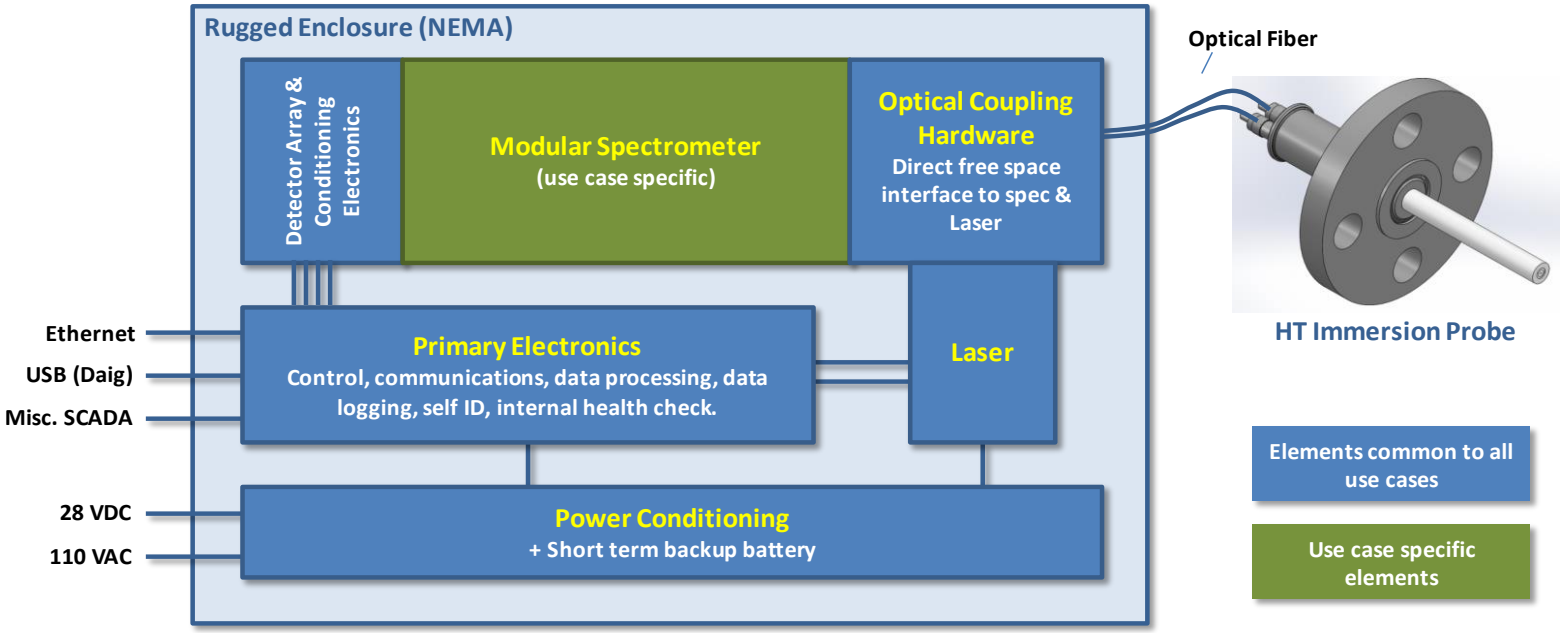


Pilot Breathing Air Monitoring System

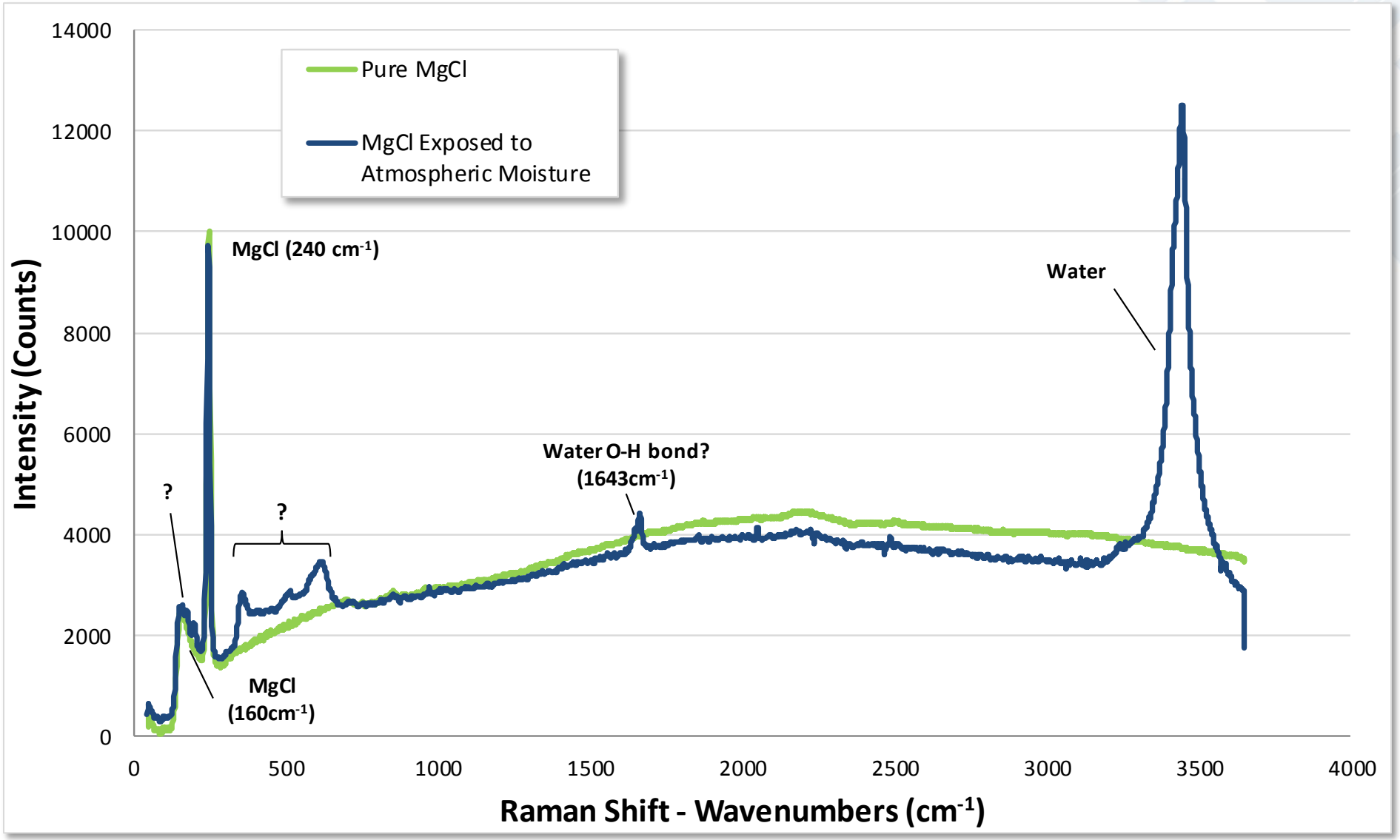
Molten Nitrate Salt Flow Sensor

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



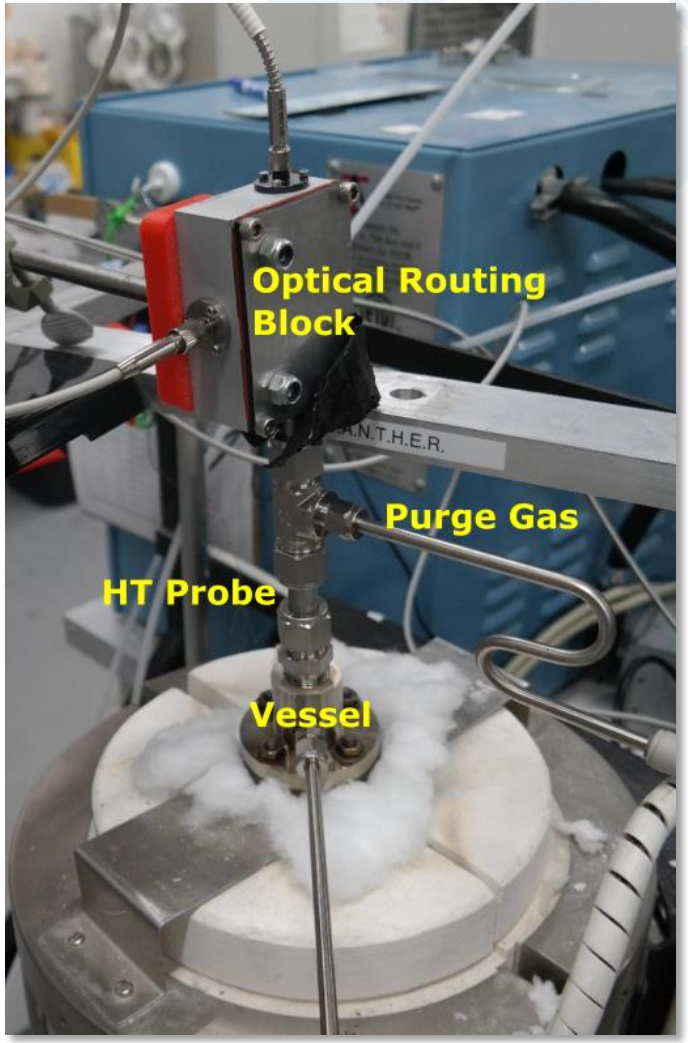
Current State of Development

- 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



Example 1000°C test system