Spatially Distributed Temperature and Level Sensing for Advanced Reactors

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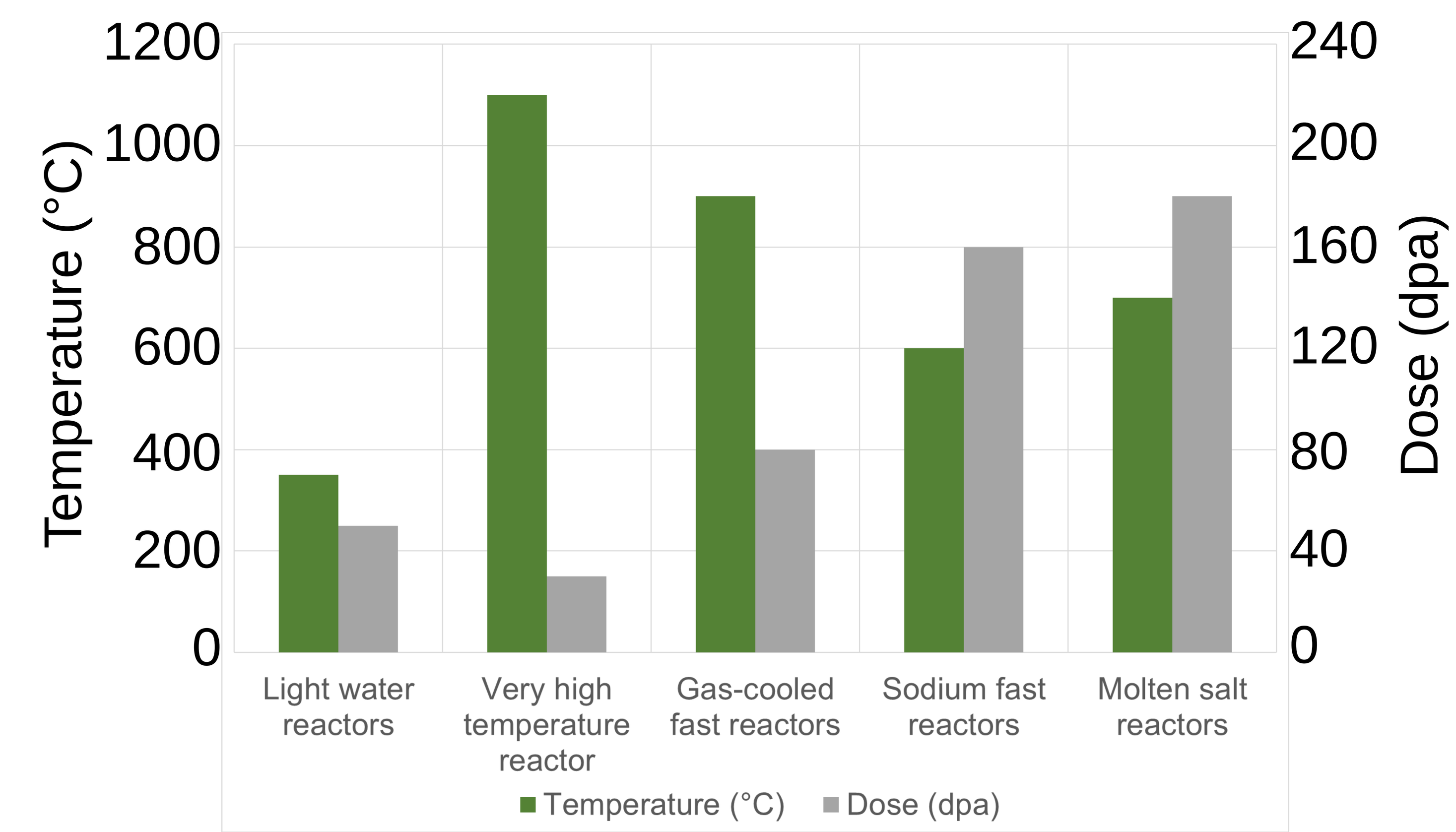
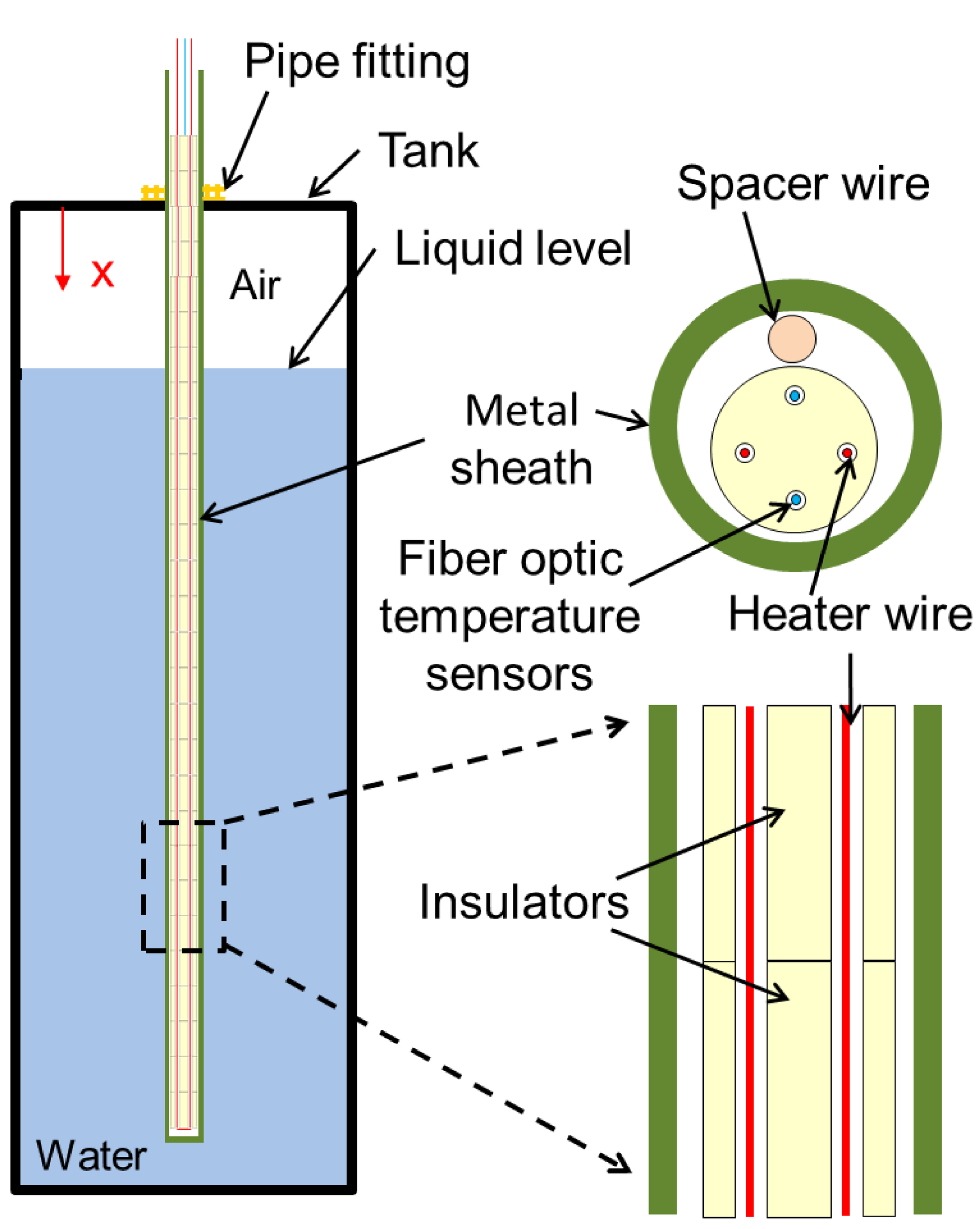
Motivation

- Instrumentation for advanced reactors must survive extreme in-core conditions and overcome operational restrictions.
  - High radiation dose
  - High temperatures
  - Electromagnetic interference
  - Chemically aggressive or opaque coolants
  - Hermetic penetrations required to pass through core pressure boundary
- Traditional sensors for temperature and liquid level have limitations.
  - Thermocouple drift due to high temperatures and transmutation
  - Thermocouples only offer single-point measurements; spatial resolution is limited by the number of vessel penetrations
  - Long-term degradation concerns for any level sensor that requires direct contact with salt or sodium
  - Bubbler-based level sensors are limited to static conditions and prevent use of purge gas for salt applications
  - Inductive and buoyancy-based level probes have poor accuracy

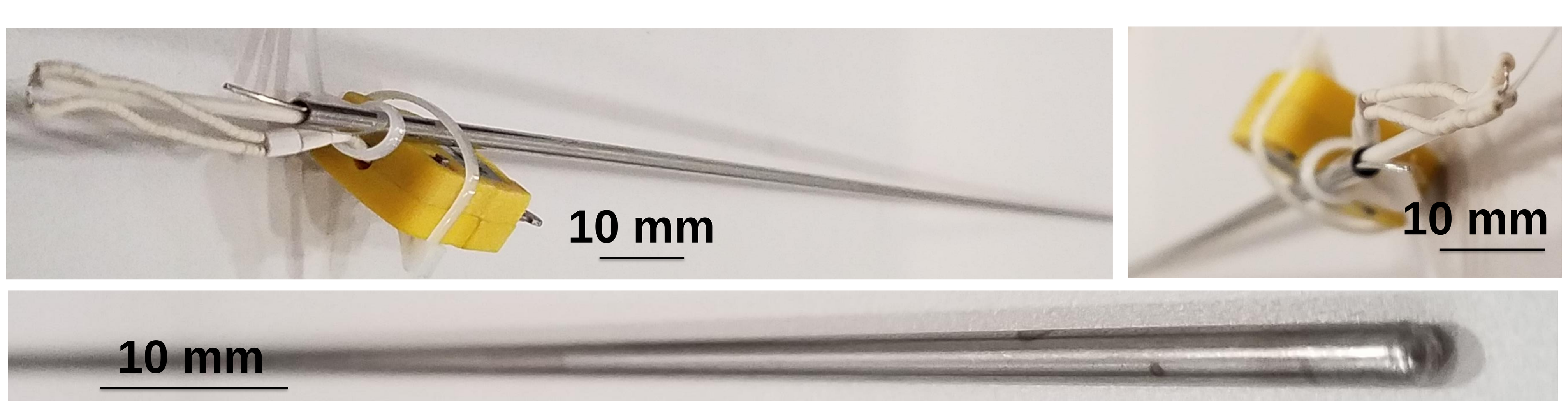


Expected peak temperatures and dose for various advanced reactor concepts.

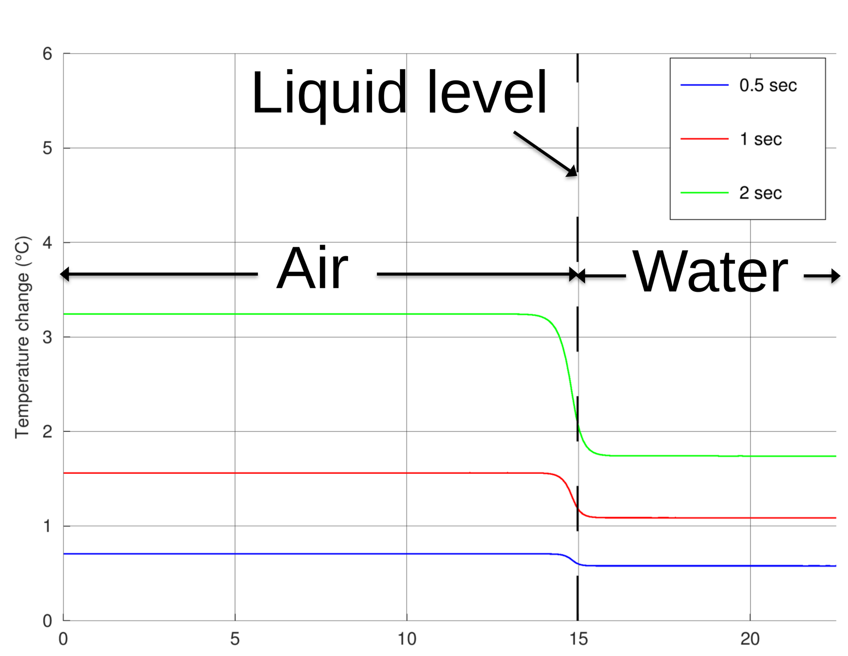
Experimental testing and analysis[1]



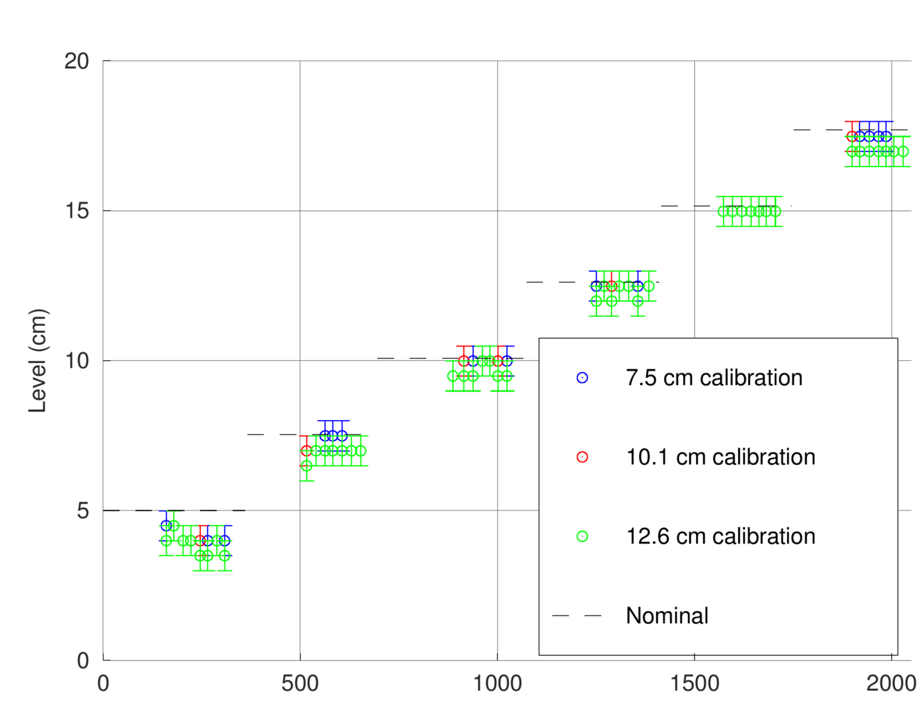
Setup for demonstration experiment in water.



Pictures of sensor prototype tested in demonstration experiment.

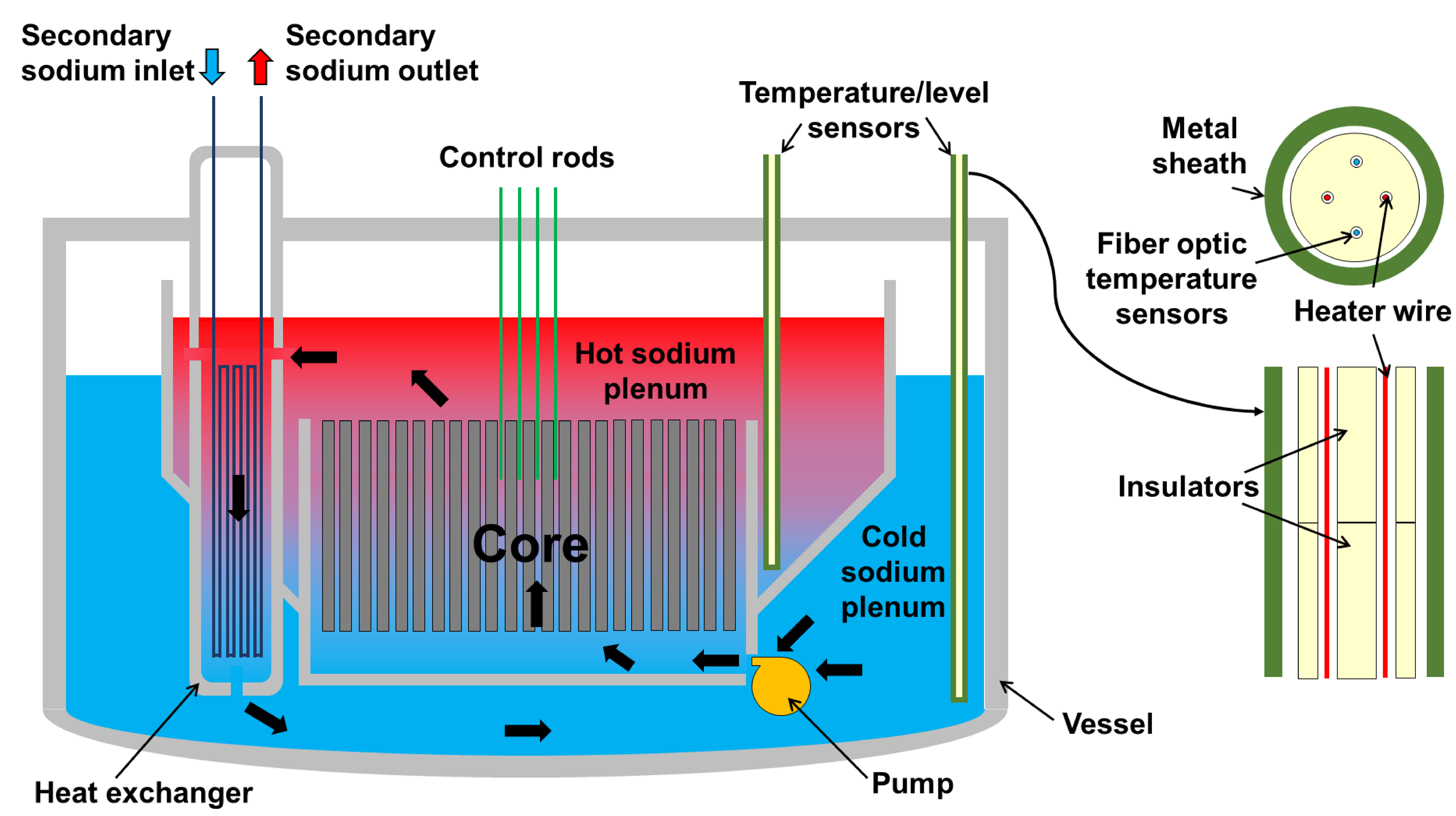


Temperature change vs. position after 0.5, 1, and 2 seconds of heating.



Measured level vs. time during demonstration experiment.

Sensor concept[2]



Combined distributed temperature/level sensor for hot and cold plenum regions of a sodium fast reactor.

Key sensor characteristics

- Combined spatially distributed temperature and liquid level sensor assembled in robust metal sheath.
  - Limits number of required vessel penetrations
  - Heater off: Spatially distributed temperature
  - Heater on: Liquid level measurement
- Level: ±0.5 cm, <2 sec response time, >5 m range.
  - Could be improved with further optimization
- Temperature: ±0.1°C, 0.2 sec response time, ±0.5 cm spatial resolution, >5 m range.
- Other work has shown successful performance of fiber optics in several harsh environments.
  - Temperature measurement up to ~1,000°C[3]
  - Successful light transmission up to >10^{21} n/cm^2 fluence[4]
  - Further testing required to evaluate signal degradation and drift at higher dose
- Future harsh environment testing planned in 2019.
  - Level sensing in liquid salt at temperatures of 600−700°C
  - Temperature sensing in high gamma field (100 Mrad/hr)

[1] C.M. Petrie and J.L. McDuffee, "Liquid level sensing for harsh environment applications using distributed fiber optic temperature measurements," Sensors and Actuators A: Physical, submitted.
[2] US Provisional patent pending: "Combined Liquid Level, Distributed Temperature Sensor, and Gamma Thermometer for In-Pile Sensing Applications," serial number 62/674,649.
[3] D. Grobnic et al., Meas. Sci. Technol. **17** (2006) 1009-1013.
[4] G. Cheymol et al., IEEE Trans. Nucl. Sci. **55** (2008) 2252-2258.