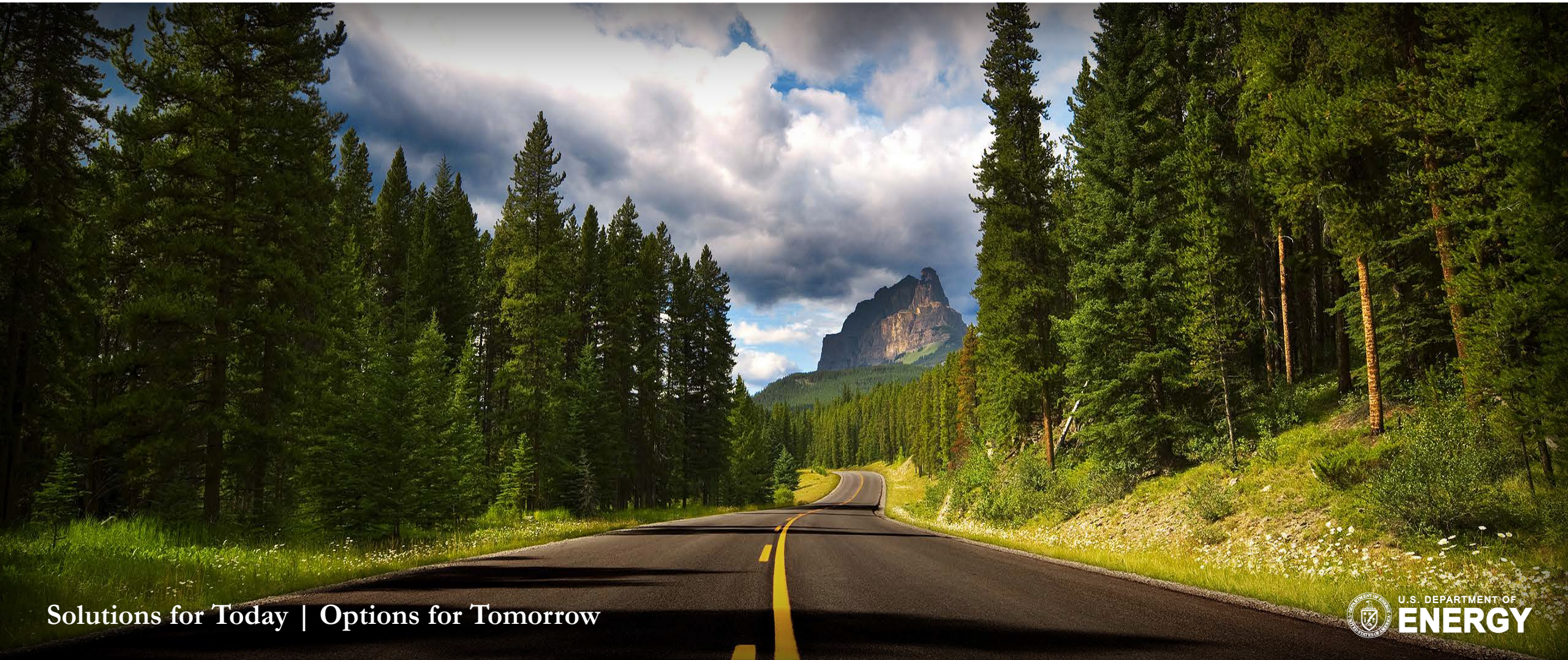
Optical Sensors for Failure Prediction



Problem/Opportunity

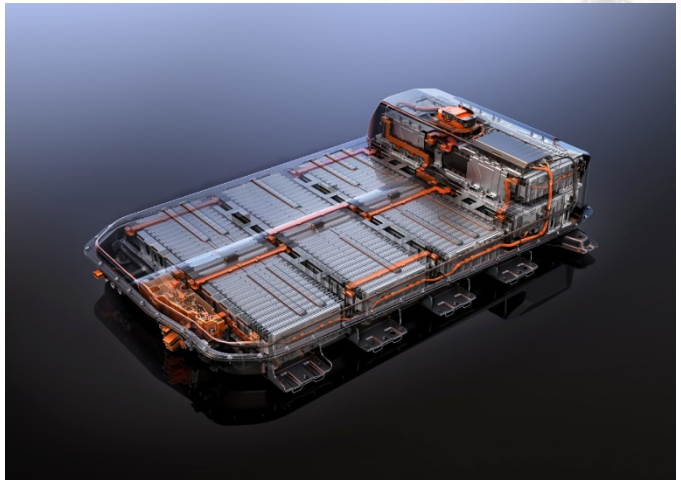
- **Power Transformers**
  - The failure of a power transformer is almost always a catastrophic event that will cause the system to fail.
  - Transformer failure happens more often than you think! 75% of power transformers in the US are more than 25 years.
  - It is important to monitor dissolved gases and temperature in order to provide long uninterrupted electrical service.
- **Li-ion Batteries and Energy Storage**
  - Fails catastrophically when a temperature rise becomes "run-away."
  - Heat generation and thermal management are crucial the safe operation of lithium-ion batteries


Metropolitan Consulting Engineering & Forensics

Current Approaches

- **Dissolved Gas Analysis in Transformer**
  - Solid state microelectronic sensors
  - Single point, electronic sensor, packaging….
  - ~ $30k-40k/installation!

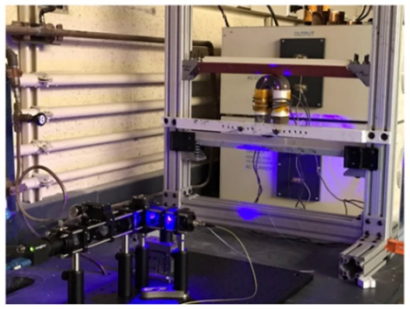
- **Thermal Management of Li-ion Batteries**
  - Single point sensor, passive analysis.
  - Multi-point temperature sensing systems exceed $20,000.

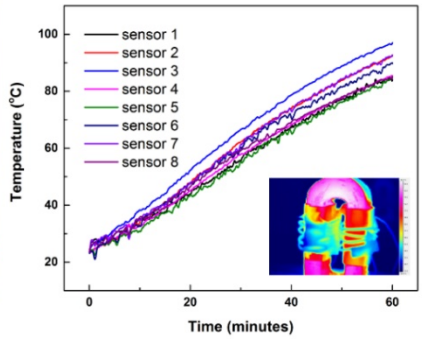


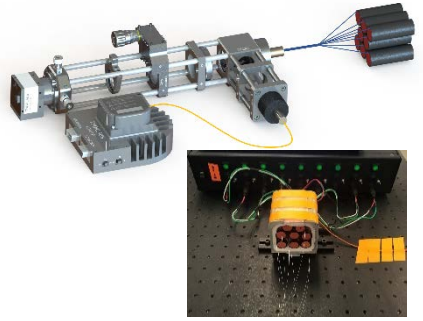
NETL Approach

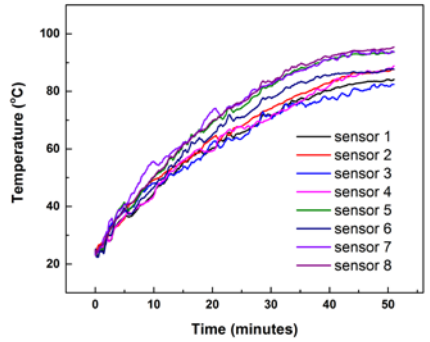
Low-Cost Multi-Point Temperature Sensor

- **Real-time monitoring of thermal dynamics of the energized compact transformer core**
  - High levels of electromagnetic interference, limited space, interactions with standard thermocouples
  - multiple sensors was installed on different locations of the core.
- **Parallel monitoring of lithium-ion battery assembly during rapid discharging process**
  - A battery pack was built using 8 Li-ion batteries (18650) with capacity of 2600mAh.
  - Sensors were embedded into the batteries.
  - Temperature rapidly increased during abnormal discharging.
- **Estimated technology cost**
  - The current technology is estimated at <$1500





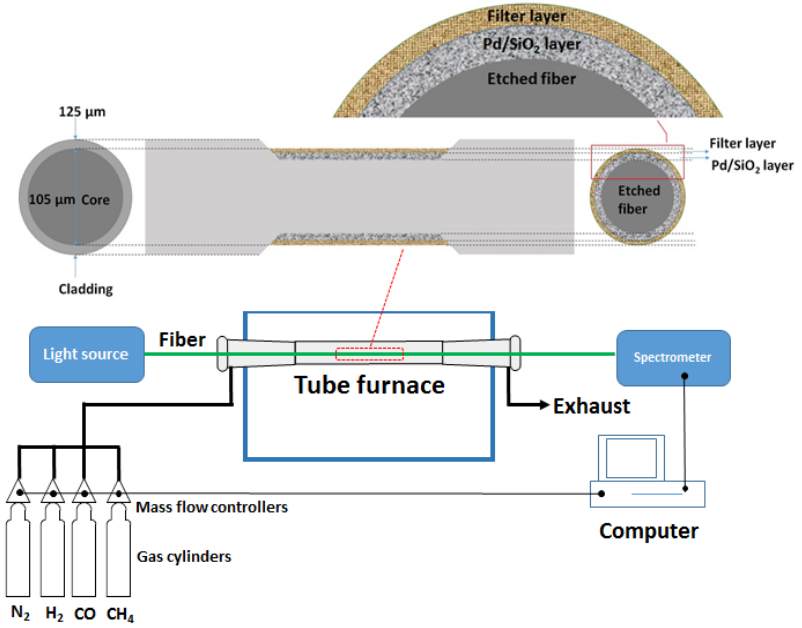


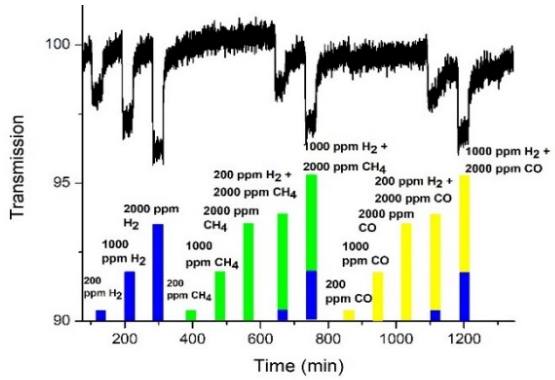


NETL Approach

Low-Cost Single Point H_2 Sensors

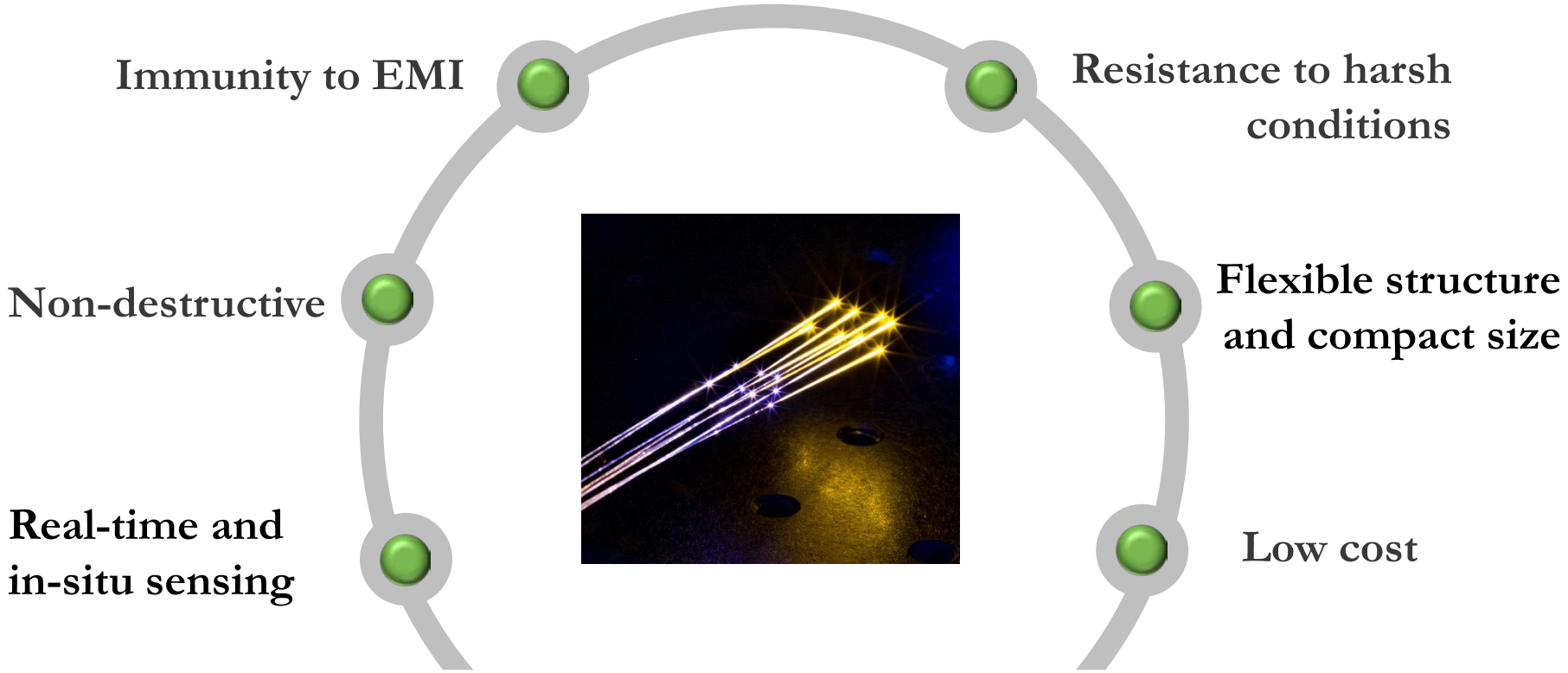
- **Real-time monitoring of H_2 concentration**
  - Filter layer based sensing probe technology to mitigate interferences
  - Low cost structure through off-the-shelf optical components and an inexpensive probe
  - Capable of detecting H_2 at levels suitable for early failure detection of power transformers based upon insulation oil degradation
- **Estimated technology cost**
  - The current technology is estimated at <$300





NETL Approach

Advantage of the Optical Sensors for Failure Prediction



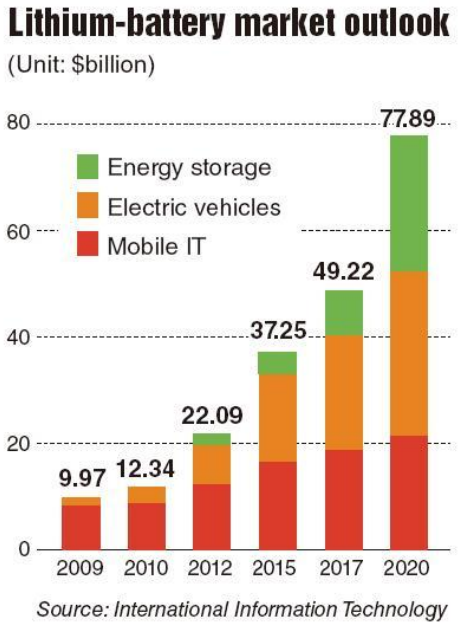
Applications

- **Low-Cost 24/7/365 Transformer Monitoring**
  - ✓ **Value:** Avoid major transformer failure and its impacts
    - 75% of power transformers in the US are more than 25 years old, and much of the electricity grid is relying on 45-year-old transformers that were designed to survive 40 years.
    - Power failure in major urban centers can cost tens of millions per hour. Fire or explosion also puts public safety and lives at risk.
    - Replacement costs for large power transformers can range from $1M to $7.5M, according to the DOE's "Large Power Transformers and the U.S. Electric Grid" .
- **Low-cost lithium battery monitoring**
  - ✓ **Value:** Avoid battery "run-away' and subsequent risks
    - Lithium battery failure, though rare, can have catastrophic effects such as in aircraft or hybrid vehicles causing loss of life.

Market Opportunity

- **Global Power Transformer** Market size is expected to reach $35.4 Billion by 2022 from $23 Billion in 2015 with a CAGR of 7.1% from 2016 to 2022.
- **The Transformer Monitoring System Market** is expected to grow from an estimated $1.47 Billion in 2016 to $2.68 Billion by 2021, registering a CAGR of 12.77% from 2016 to 2021.
- **Global lithium-ion battery market** was valued at around $31 Billion in 2016 and is expected to generate revenue of $ 68 Billion by end of 2022, growing at a CAGR of slightly above 13.70% between 2017 and 2022.
- **Electric vehicles** will be a $731 billion market in 2027 and 34% of cars on the road will be electric by 2040 – 530 million in total.

It's not just about money, it also saves lives!

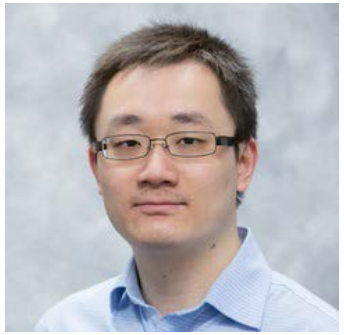


Meet Our Team

Dr. Paul R. Ohodnicki

Project lead

National Energy Technology Lab



Dr. Chenhu Sun

ORISE Postdoc Researcher

National Energy Technology Lab

Our Resource

Why are we capable of making our big idea come true?

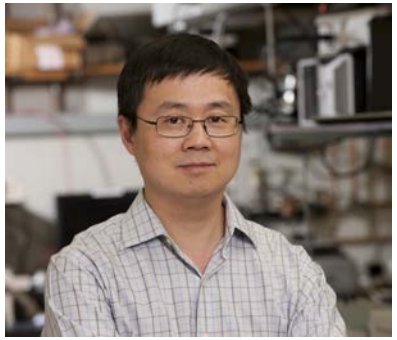
- **National energy technology laboratory**
- **Photonics labs in University of Pittsburgh**
- **Additive Manufacturing Center**
- **Research grants**

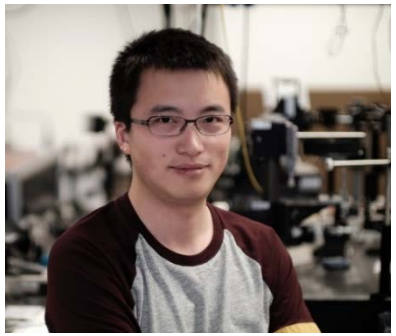
Together, we make a great team!

Dr. Kevin P. Chen

Paul E. Lego Professor in Electrical Engineering

University of Pittsburgh





Dr. Aidong Yan

PhD researcher

University of Pittsburgh

Where Are We Now?

Protect our IP

- US Patent 9,696,256: P. R. Ohodnicki, J. P. Baltrus, T. D. Brown, Palladium and platinum-based nanoparticle functional sensor layers for selective H_2 sensing, NETL Filed 10/2015.
- NETL US Patent Application Continuation: C. Sun, P. R. Ohodnicki, J. P. Baltrus, T. D. Brown, Filed 7/2017.
- Invention Disclosure: P. Chen, A. Yan, M. Buric, P. Ohodnicki et al., Low-cost Multipoint Temperature Sensors for Battery and Transformer Monitoring, Submitted 9/2017.

Successful Demonstrations

- Real-time monitoring the temperature distribution of transformer cores.
- Explore sensor integration into existing product line through an on-going project funded by the Grid Modernization Laboratory Consortium.
- Thermal dynamics monitoring of the Li-ion battery assembly under large current load.

Go-To-Market Plan

Design improvement

- Sensor integration

2017.10 - 12

Prototyping

- Packaging
- Software development

2018.1 - 2

Potential start-up opportunity

- NSF I-corps

Cooperation with main vender

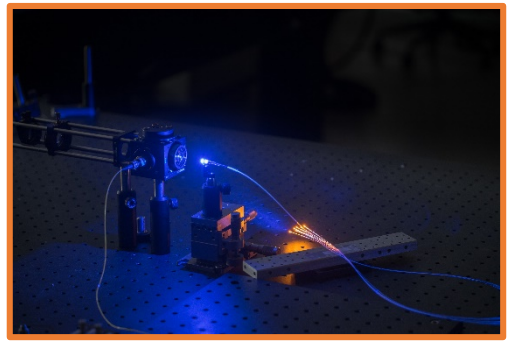
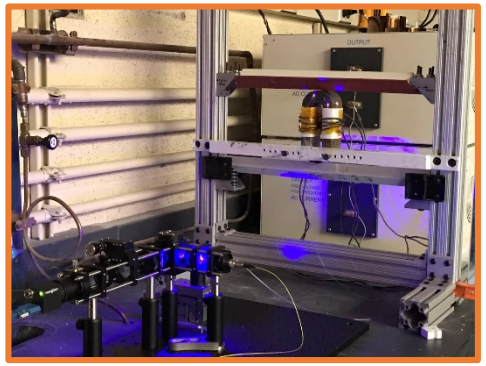
2018.1 - 6

Develop a New Product Line Around the Concept

- SBIR phase I, SBIR phase II

Summary

- **Problems** due to the lack of real-time monitoring information in energy distribution systems and **high-cost** of current approaches.
- New compact **optical sensors** has been developed for real-time temperature and chemical detection with significant **performance and cost advantages**.
- Proof of concept complete, **prototype system** design phase.
- Collaborating with transformer vendor to explore sensor integration.

Thank You!

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- Contact us with Any Further Questions