



Development of a Laser Ultrasonics-based Approach for Rapid Screening of High Entropy Alloys

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Changing the World's Energy Future

Amey Rajendra Khanolkar, Subhashish Meher, Austin C Matthews, Dennis Stephen Tucker, Wesley Jones, David H Hurley



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**Idaho National Laboratory
Idaho Falls, Idaho 83415**

<http://www.inl.gov>

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A laser ultrasonics-based approach for rapid screening of high entropy alloys

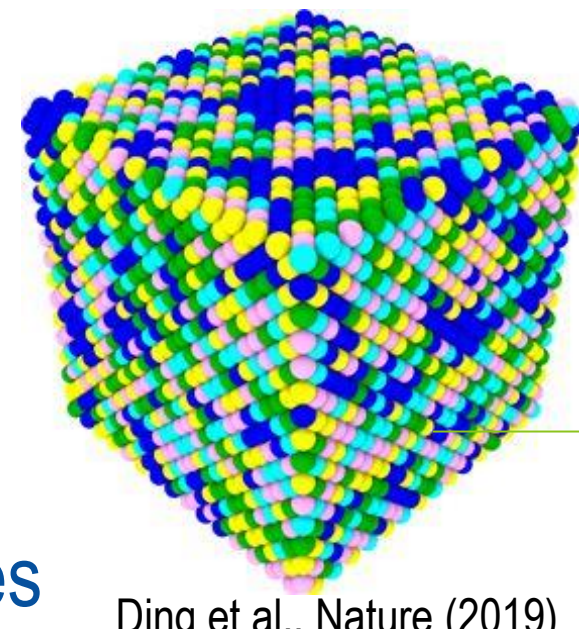
Initiative: Advanced Materials & Manufacturing for Extreme Environments

Amey Khanolkar¹§, Subhashish Meher², Dennis S. Tucker¹, Austin C. Matthews¹, J. Wesley Jones¹, David H. Hurley¹

¹Energy & Environment Science and Technology Directorate, ²Nuclear Science and Technology Directorate

High Entropy Alloys (HEAs)

- Composed of nearly equal parts of several primary base metals
- Unconventional compositions and chemical structures hold promise for achieving unprecedented combinations of mechanical properties

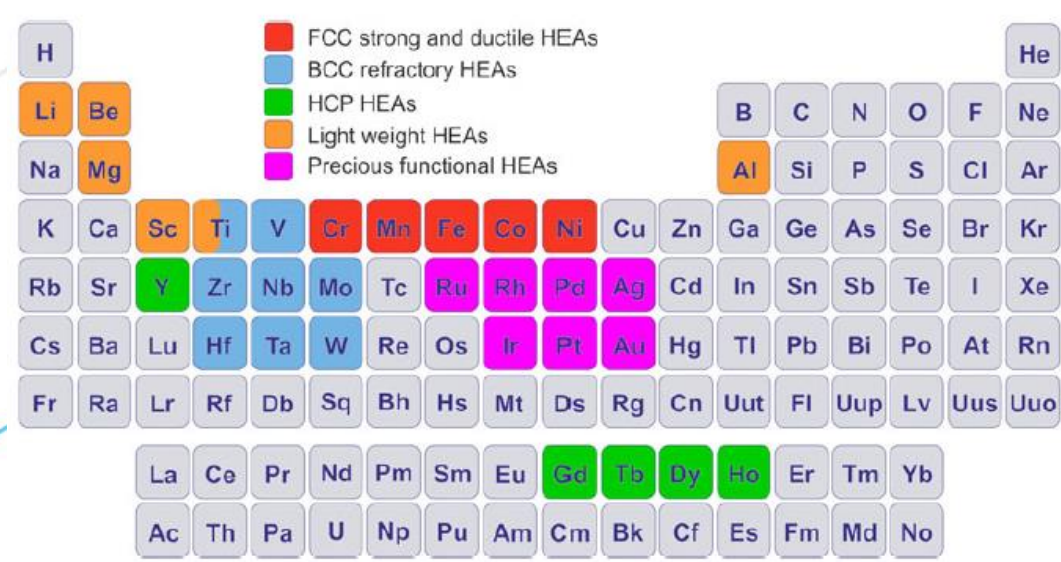


Ding et al., Nature (2019)

HEAs: Structural Materials for Extreme Environments

- High mechanical strength at elevated temperature
- Corrosion resistance
- Radiation resistance
- Fossil energy
- Nuclear energy (advanced fission & fusion reactors)
- Concentrated solar power plants

The challenge with HEAs: Vast compositional space for exploration

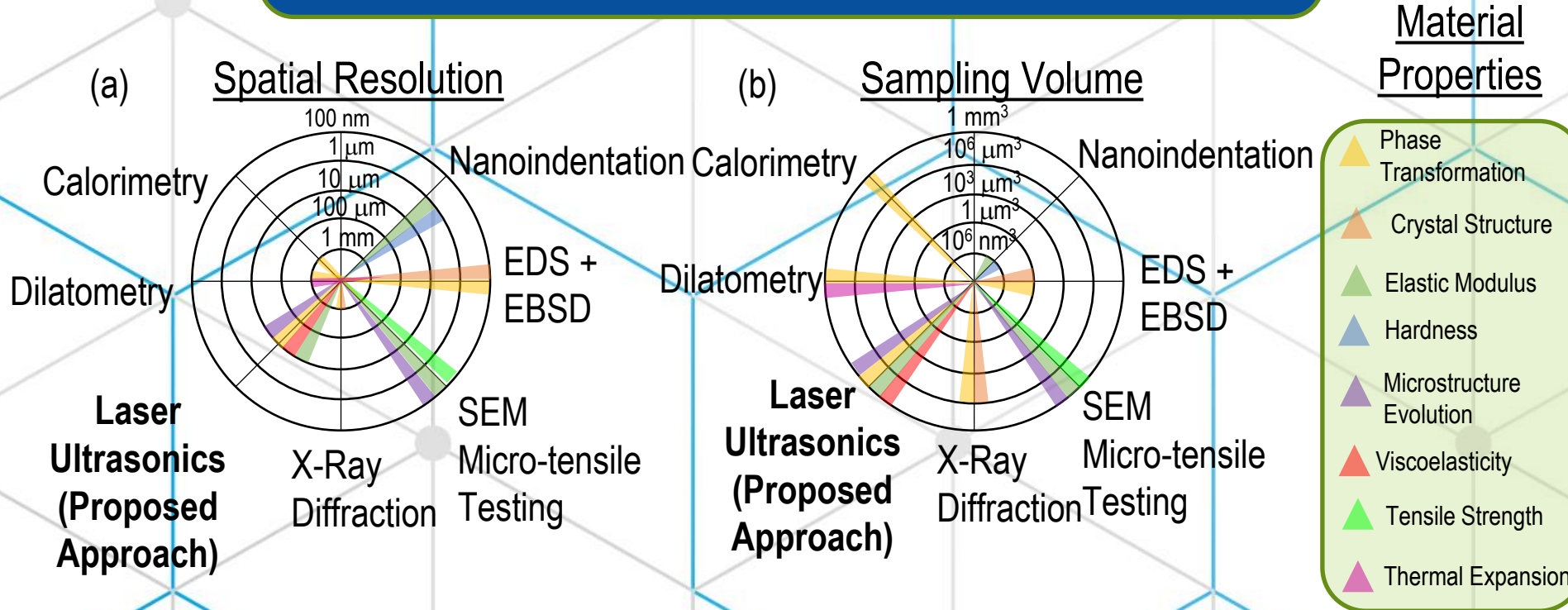


Z. Li, ..., D. Raabe, J. Mat. Res., 33(19), 3156-3169 (2018).

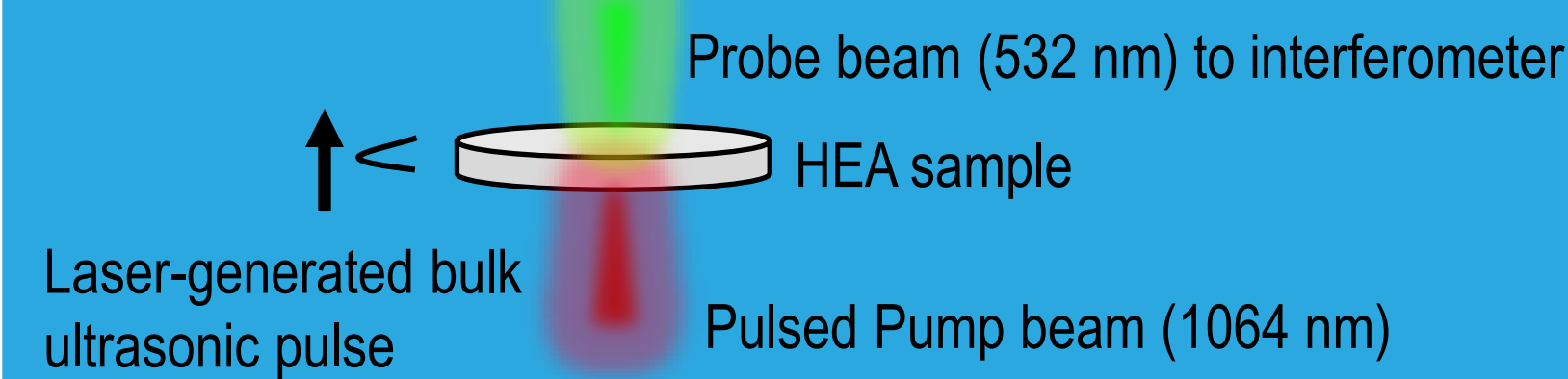
- ~592 billion new HEA bases with 3-6 principal elements
- Prohibitively expensive & impractical to study using conventional methods

D. Miracle, Nat. Comm., 10: 1805 (2019)

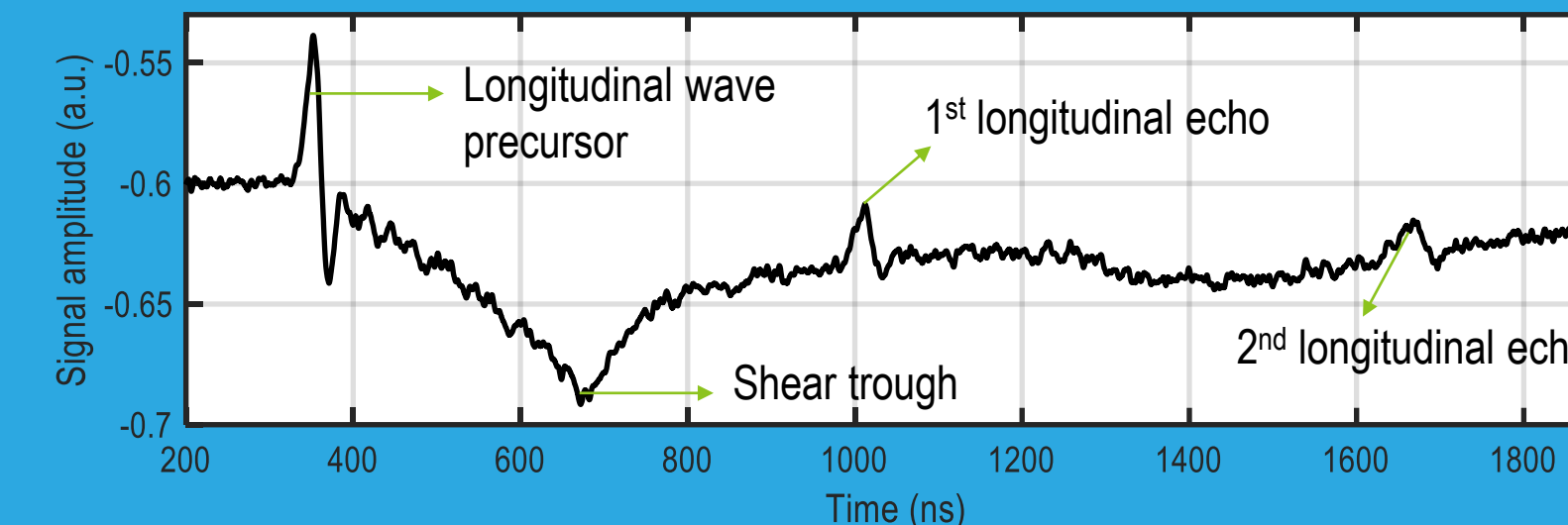
High throughput characterization tools needed



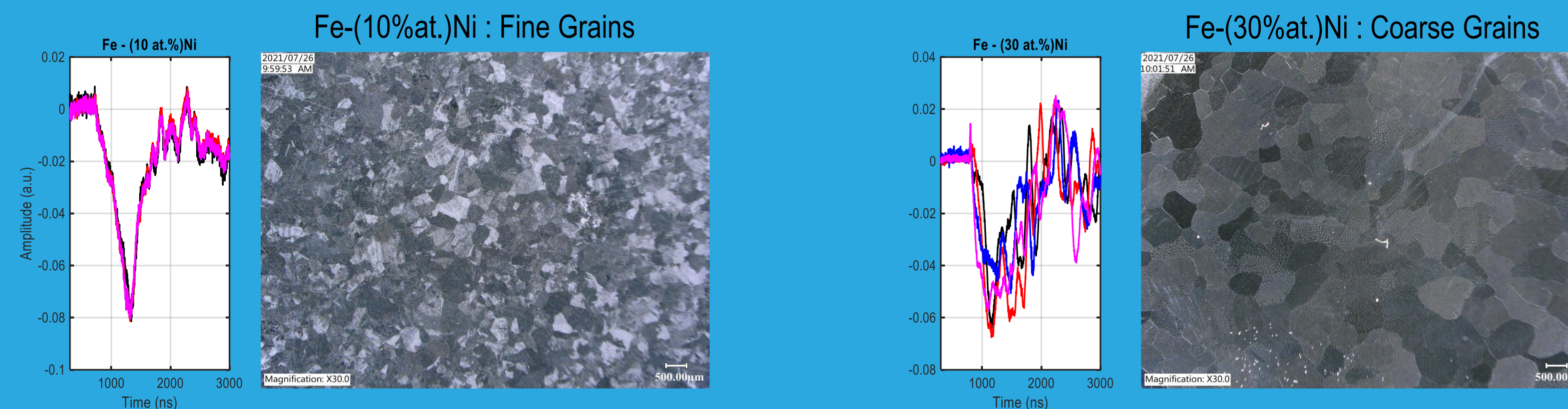
The laser ultrasonics technique monitors microstructure changes and aids in rapidly screening the vast composition space of High Entropy Alloys



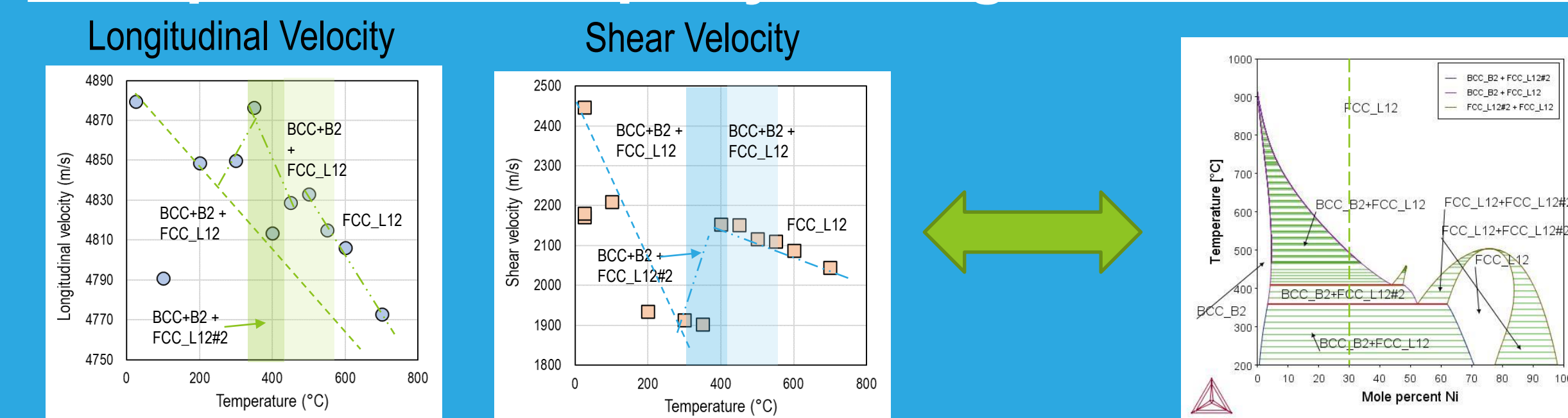
Ultrasonic strain wave generated via thermoelastic expansion



Ultrasonic Scattering → Grain Growth



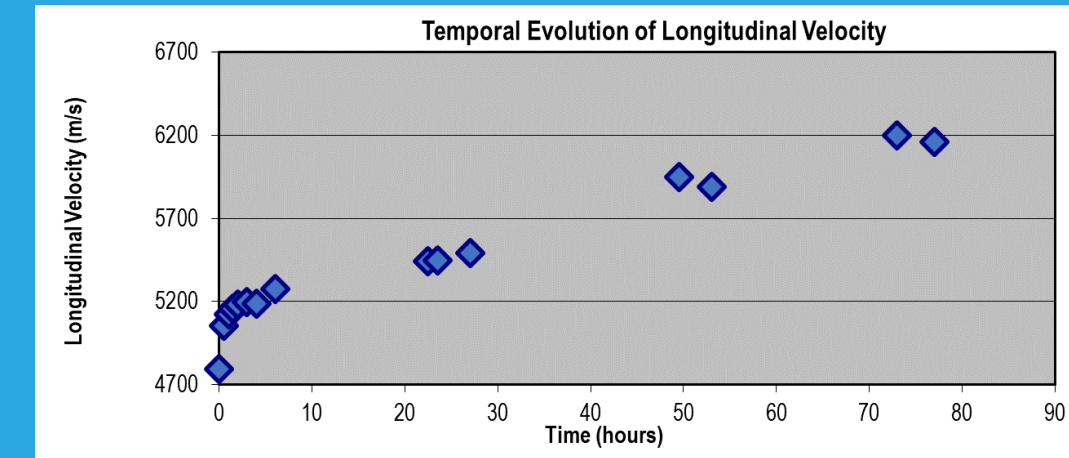
Abrupt Elastic Property Changes → Phase Transformations



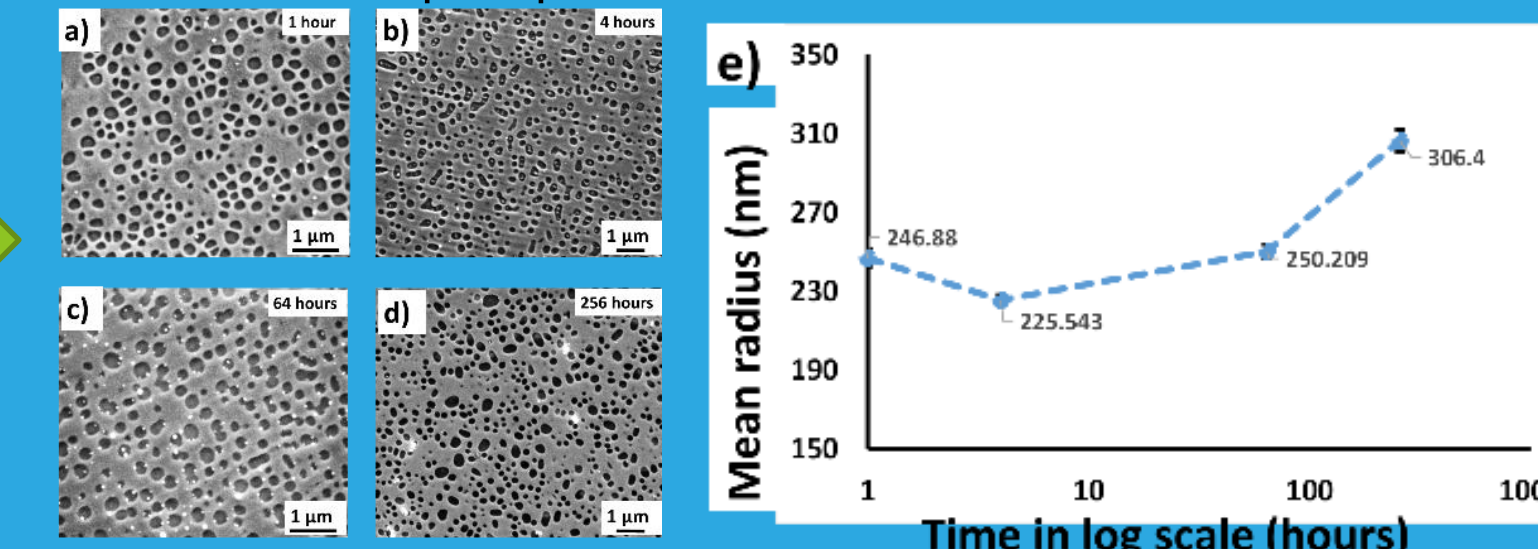
Validation of Calculated Equilibrium Phase Diagrams (CALPHAD)

Temporal Evolution of Elastic Properties → Coarsening Kinetics

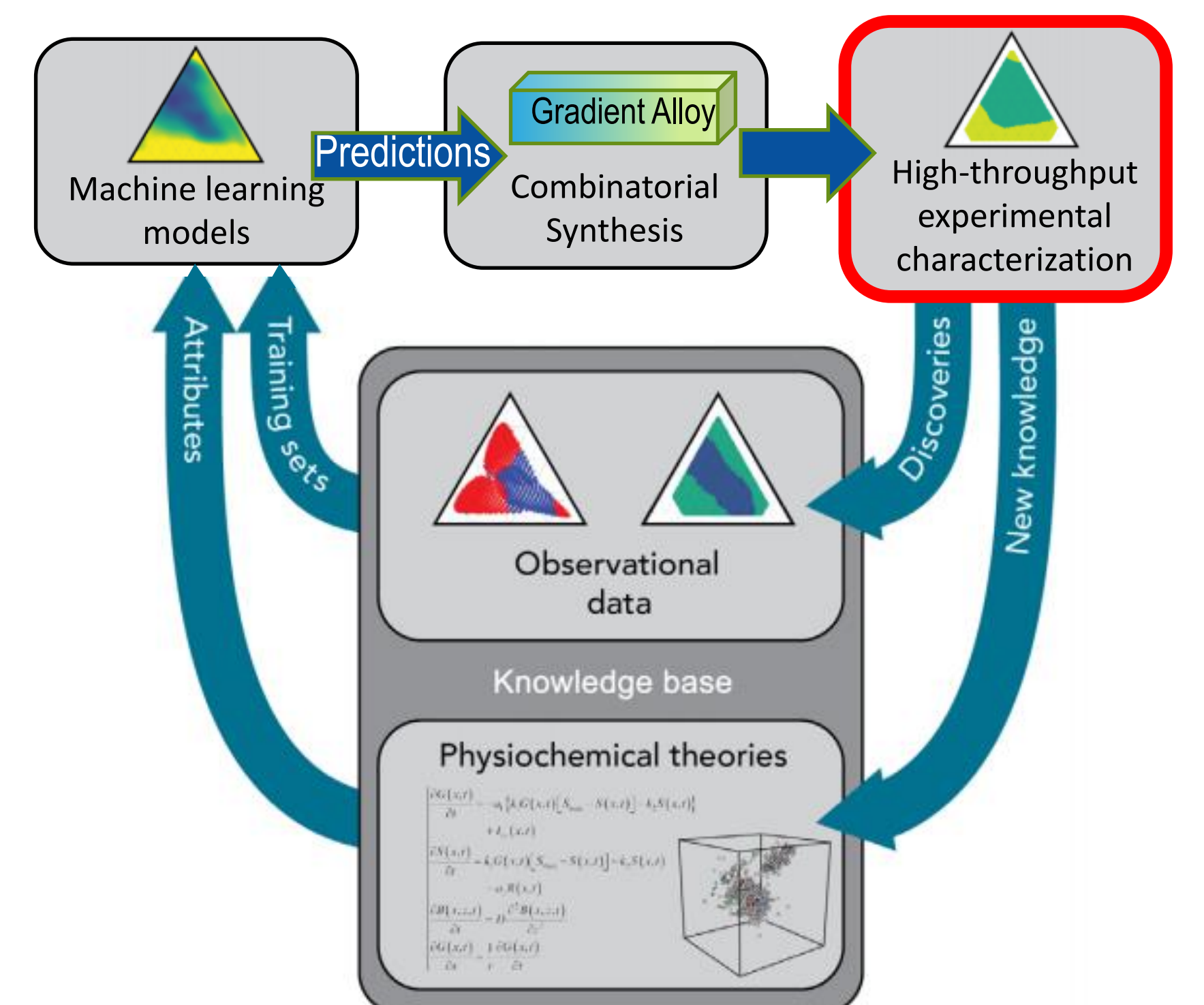
In-situ monitoring of longitudinal velocity in Al-Ni-Cr-Co-Fe HEA while holding at 950°C



Evolution of B2 precipitate size in Al-Ni-Cr-Co-Fe HEA

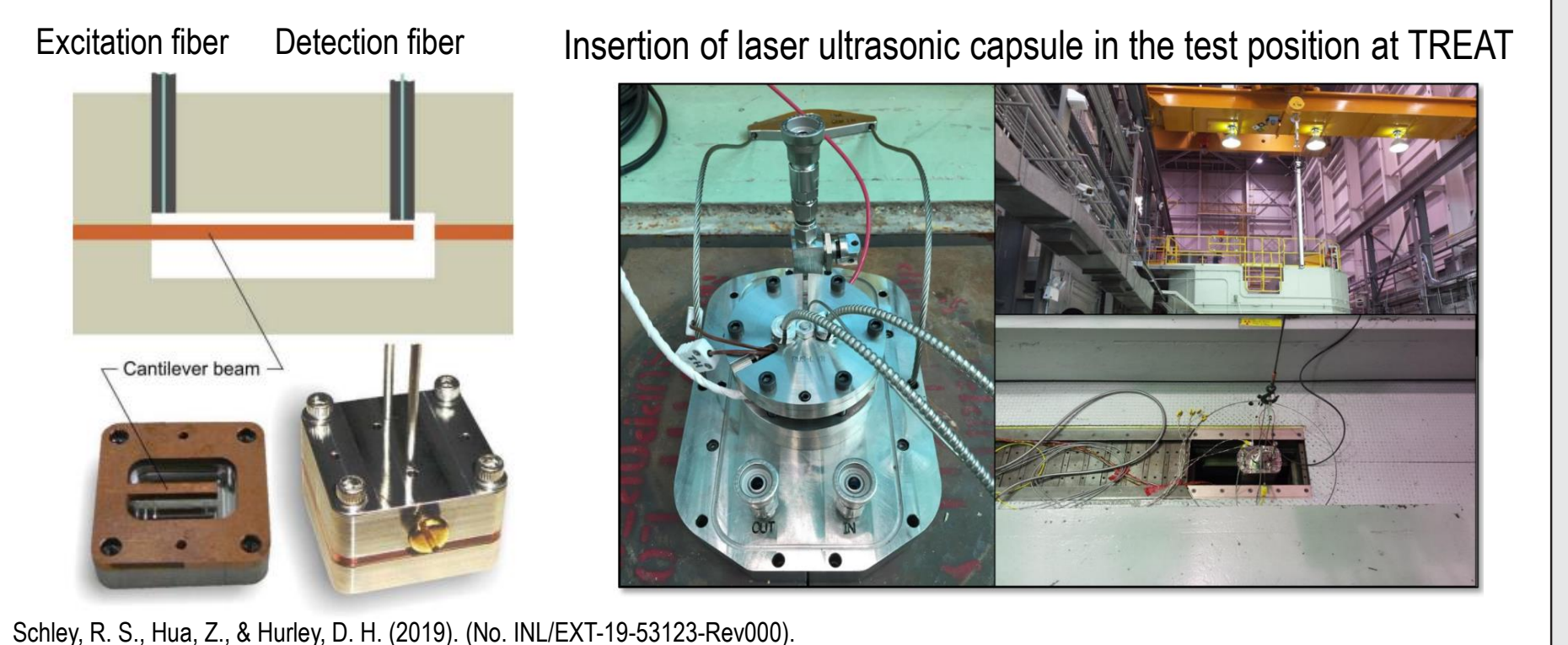


Integrated Machine Learning + High Throughput Combinatorial Approach for Accelerated Alloy Development



F. Ren, ..., A. Mehta, Science advances, 4(4), 1566 (2018).

In-pile Laser Ultrasonic Measurements in Radiation Environments



Schley, R. S., Hua, Z., & Hurley, D. H. (2019). (No. INL/EXT-19-53123-Rev000).

Research Output: Conference Presentation

A. Khanolkar, S. Meher and D.H. Hurley, *Rapid Screening of High Entropy Alloys using Laser Ultrasonics*, presented at the **Sixth International Workshop on Structural Materials for Innovative Nuclear Systems (SMINS-6)**, 12-15 September 2022, Idaho Falls, ID.

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