Advanced Analytics and Highly Parallel Cold Fusion Experimentation

2014 Lattice Assisted Nuclear Reaction Colloquium at MIT
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Enhanced Web Version Slideshow

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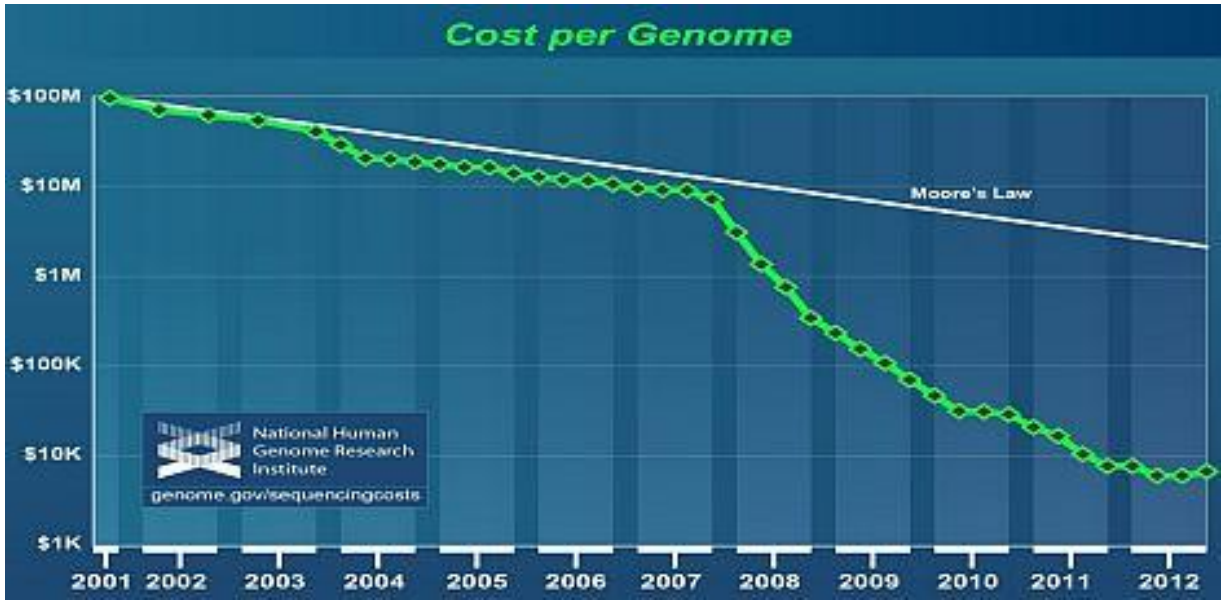
Human Genome Project Comparison

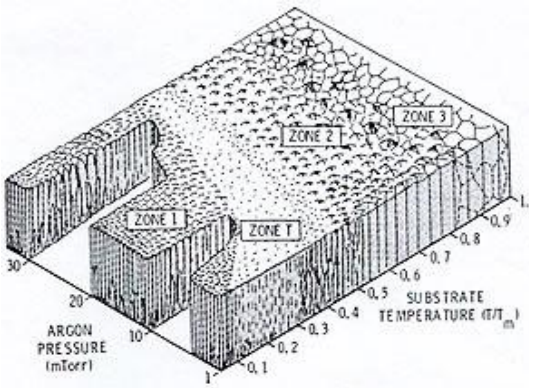


- Over $250B spent a year on alternative energy research
- When these resources become available we need to invest in lowering the cost of data
- Lower costs of materials production and tools, as well as develop new tools
- Lowering costs can help overcome barriers to entry
- Human Genome comparison: $100M for a genome dropped to 1000$ in 14 years due to highly parallel experimentation and new analytics

Sputtering CF Materials

- Sputtering can be done at low cost, excellent reproducibility, high throughput
- Focus is on sputtered thin films in gas loading experiments
- Proven itself in this field: Mitsubishi/Toyota, SKINR, etc
- Sputtering allows replication between labs and transition to industry
- Sputtered surface tends to become active (plasma discharge treatment similar morphology to sputtered surface ie Mizuno)

Structural zone model



Low cost DC sputtering system

Multi-target sputtering system

Combinatorial Material Discovery

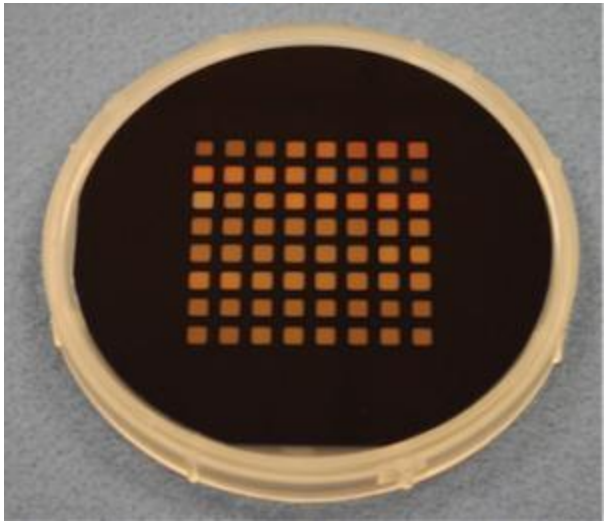
Checklist for effective CMD program:

Parameter space known? ☺

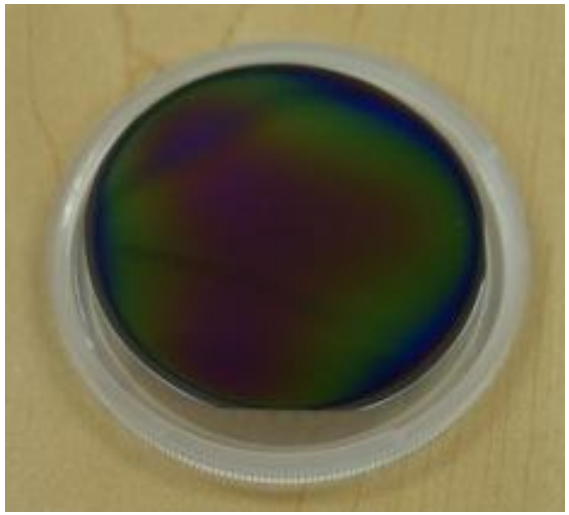
Consistent and repeatable material production? ☺

Screening indicator/Rapid analytics? ☺

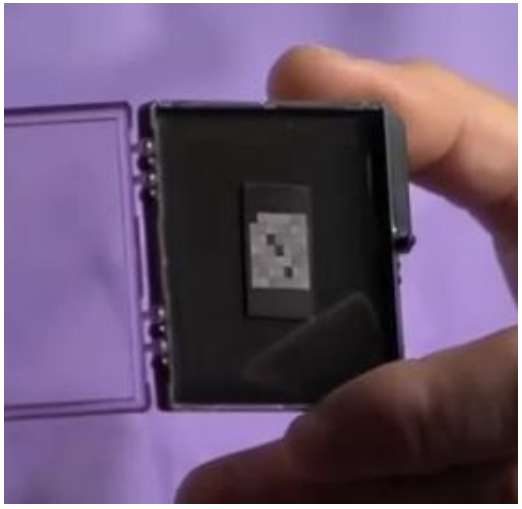
Combinatorial Matrix



Co-deposited
Composition Spread



Dr. Zawodny
NASA Langley

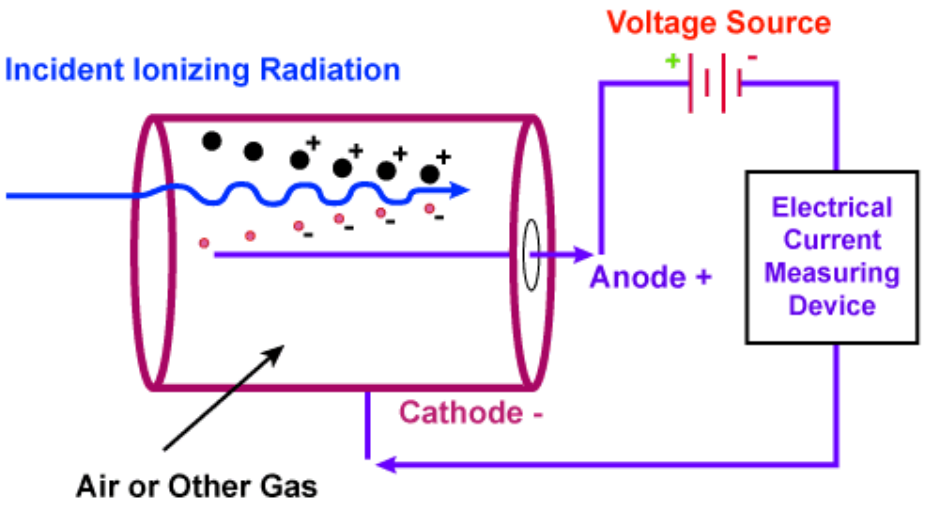


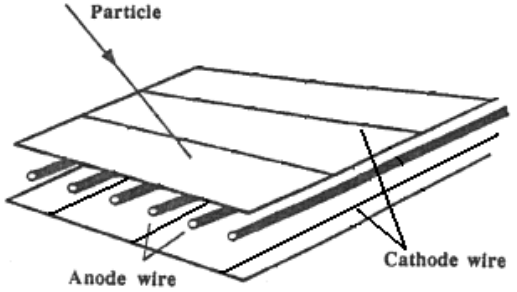
Combinatorial experimentation

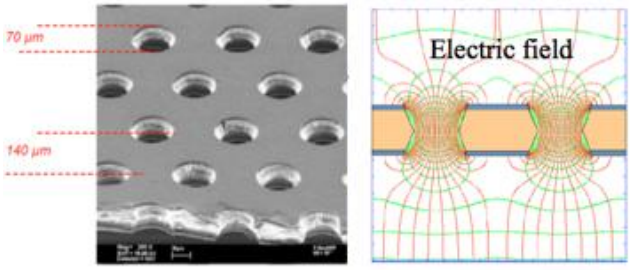
- Surface imaging and analysis before and after experiment
- Screening using real-time differential measurements
- Need real-time analytics to determine Optimal Operating Points and triggering conditions
- Experiments should be built in a modular manner for scalability
- Automation and data analysis allows for adaptive control and AI experimentation in the future

Gas ionization detectors

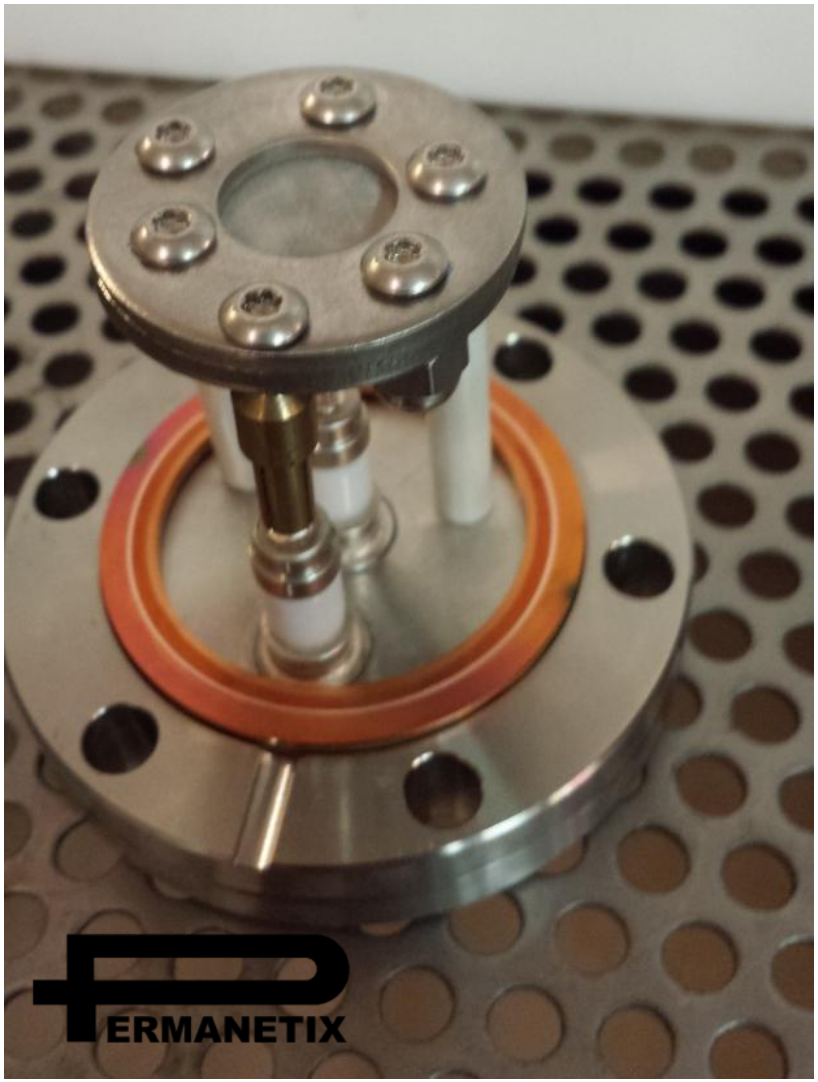
- Low cost, rugged, many configurations possible
- Spectroscopy and position resolution possible
- Highly scalable, excellent match for combinatorial materials discovery
- "Naked" detector can operate using experiment gas (D2,H2)
- Neutron detection by proton recoil







Gas Ionization Detector Prototype



Hybrid geometry, manufactured in-house
Operation up to 5kv possible with TIG welded insulated feed-throughs, isolated ground.

Can operate in high hydrogen/deuterium pressures and be placed in close proximity to substrates

Very scalable, many sensors can be placed in close contact in a single chamber

Can detect very soft radiation that would never exit experiment chamber
Ie: alphas, protons, deuterons, tritons, betas, soft neutrons/x-ray/gamma

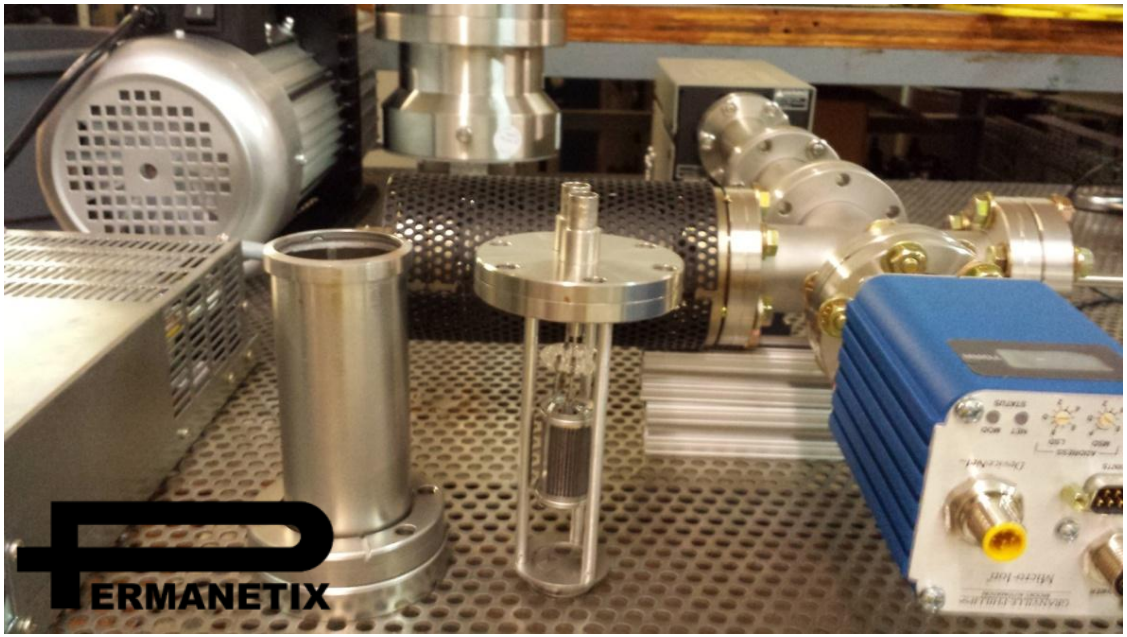
Can detect Tritium in-situ due to beta decay

Helium Isotope Analysis

- Mass Spectroscopy traditionally very expensive
- Low cost Residual Gas Analyzers coupled with custom sampling system can be used

Challenges:

1. Contamination
2. Sensitivity
3. Resolution



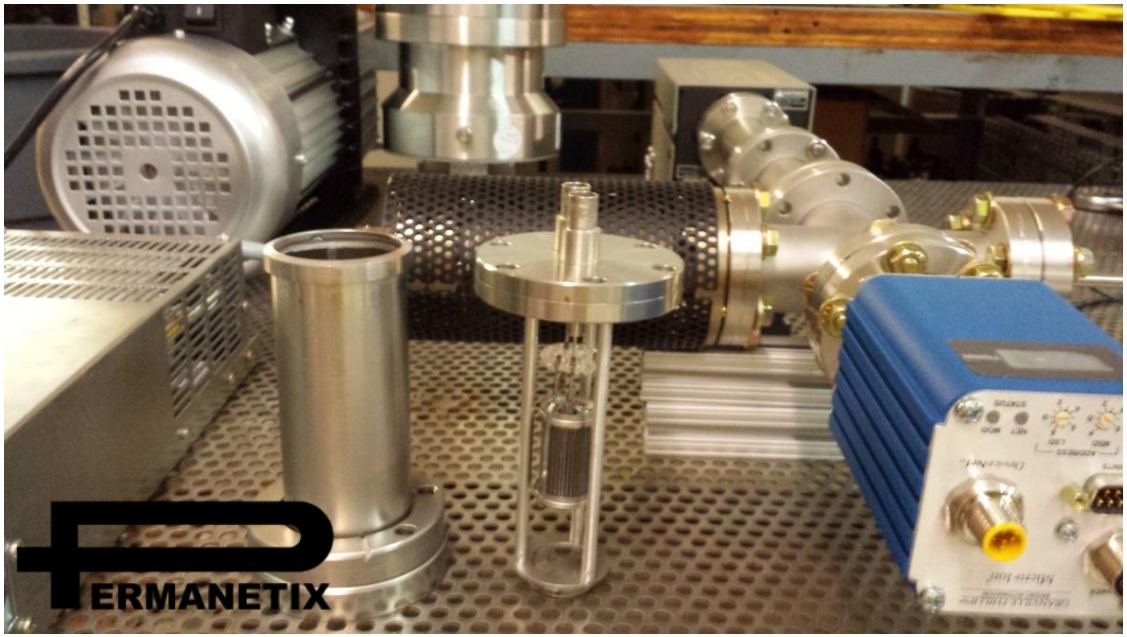
Permanetix Helium Analysis system prototype

Helium Analysis: Sensitivity/Contamination

- Air contains helium, atmospheric leaks cause false positive, not an issue using metal/metal seals and proper “bake-out” protocol.
- Levels of helium expected are simply below the threshold for modern instruments, sample must be pre-concentrated using hydrogen/deuterium removal.
- Hydrogen/Deuterium removed by a “getter” pump (below) batch-wise, until helium is above detection limits of instrument

Challenges:

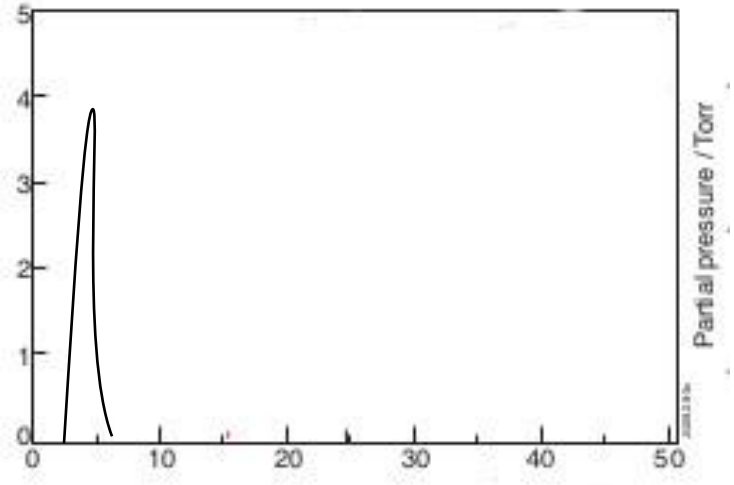
1. **Contamination**
2. **Sensitivity**
3. Resolution

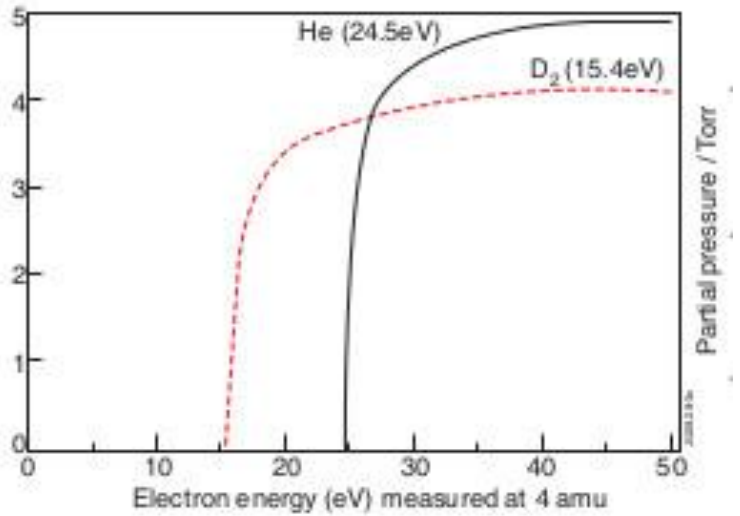


Permanetix Helium Analysis system prototype

Helium Analysis: Resolution

- He4 + DD separated by only .0256amu ☹
- He3 + DH separated by only .0054amu ☹
- Solution: Threshold Ionization Mass Spectroscopy (TIMS)
- Dynamically adjust ionization energy and graph against pressure



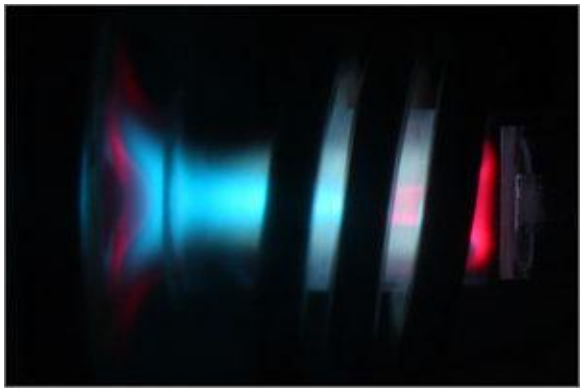


Mass Spectroscopy
D2 and He4 peaks overlap

Threshold Ionization Mass Spectroscopy
D2 and He4 peaks resolved!

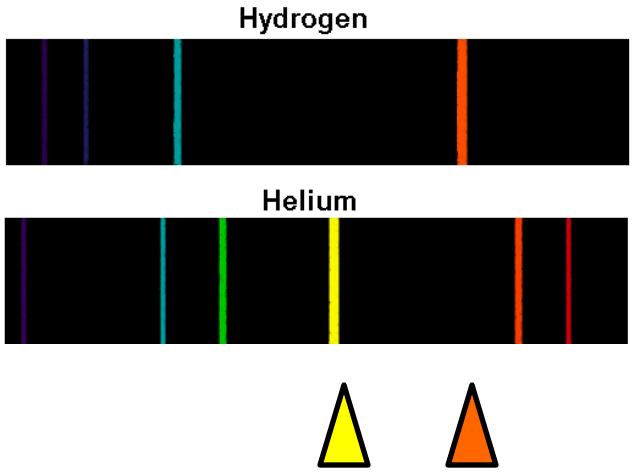
Helium Analysis: Optical Emission

- Totally different mechanism than mass spec (mass/charge vs electronic structure)
- Possibility for very low cost analytics (<10,000$)
- Resolution not an issue (below)
- Helium is concentrated and excited, optical emission spectra used to quantify



Inductively coupled plasma

Emission spectra



Conclusions

- New tools and techniques can drastically lower the cost of data
- Industry standard materials production (ie sputtering) improves repeatability and transferability
- Modular experiments required for scalability
- Material library experimental approach can contribute to scientific understanding AND retain valuable expertise
- Gas ionization soft radiation detection adds another layer of real time data, is low cost, rugged and can be used in highly parallel experimentation
- Helium analysis doesn’t have to break the bank, potential for low cost custom analytics