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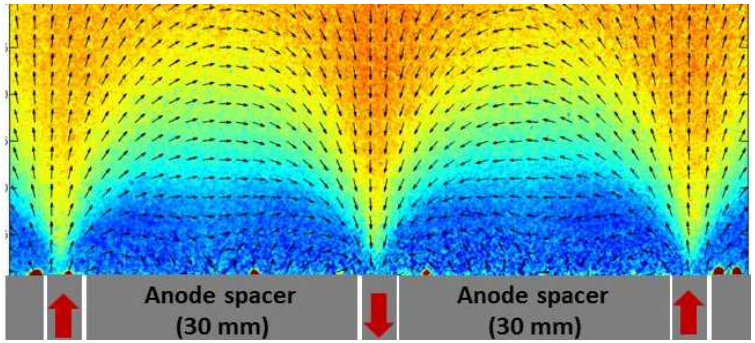

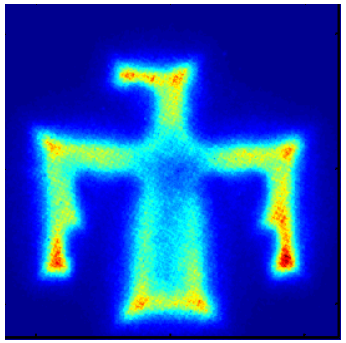

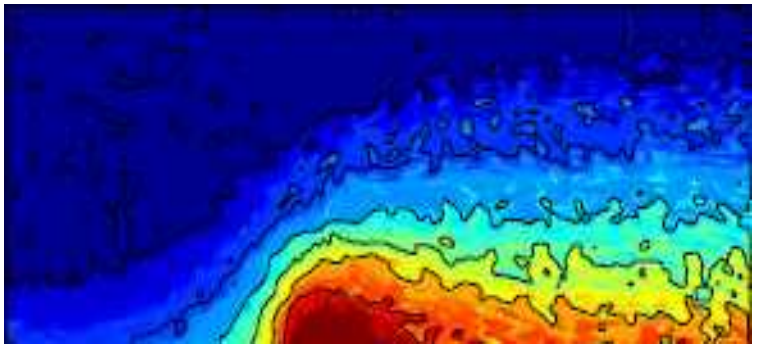

Diagnostics to Facilitate Research and Enable Discovery in Low-Temperature Plasma Science

Ed Barnat

Science Challenges in Low Temperature Plasma Science and Engineering

August 22-23, 2016

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Diagnostics Are Ubiquitous in Low Temperature Plasma Science

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- Diagnostics will enable advancements in the focus areas discussed at this Workshop.
  - Cross-cutting nature of diagnostics supports a broad “mission space”.
  - Provide insight into when, where, and how energy is deposited.
- “Means to an end”…
  - Close “knowledge gaps” associated with plasma physics (rates, lifetimes).
  - Used to validate model predictions: Target key quantities of interest (QOI).
- “End unto themselves”…
  - What are the emerging challenges that need to be answered?
  - Are new enabling technologies available that open up new opportunities?

Diagnostics play key roles in assessing our understanding of processes that occur in low temperature plasmas as well as through discovering otherwise unexpected behaviors

SNL Missions Rely on Predictive Simulations

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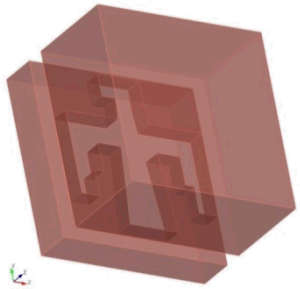
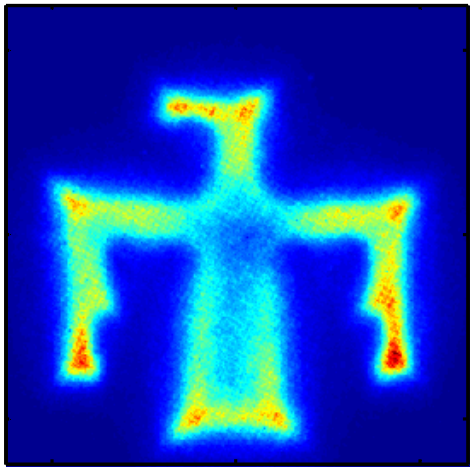
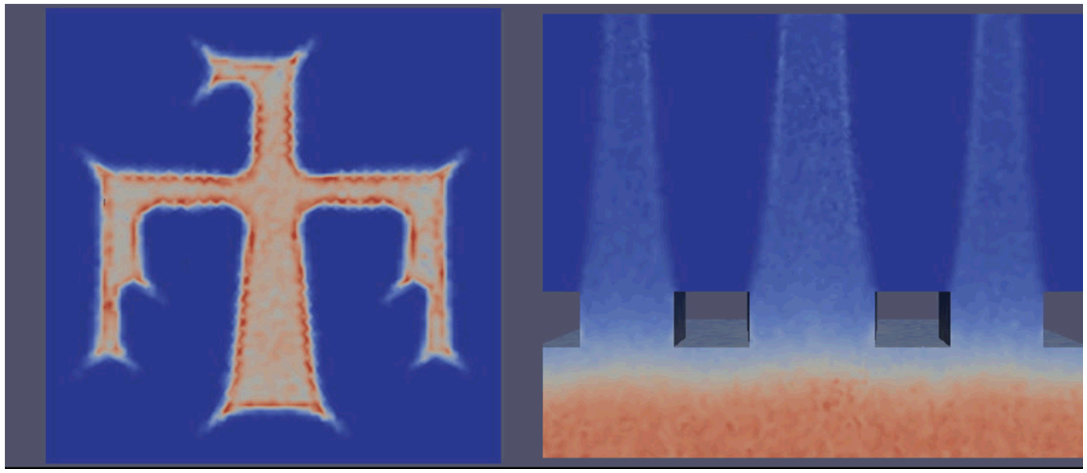
- Verification and validation (V&V) is the metric for code acceptance.
  - Verification – Solving equations correctly.
  - Validation – Solving the right equations.
- Measurements are needed to validate codes.
  - Reduce complex problem into simple pieces – build up.
  - Implement appropriate diagnostics to extract quantities of interest (QOI).



Validation of ion extraction from a dynamic plasma



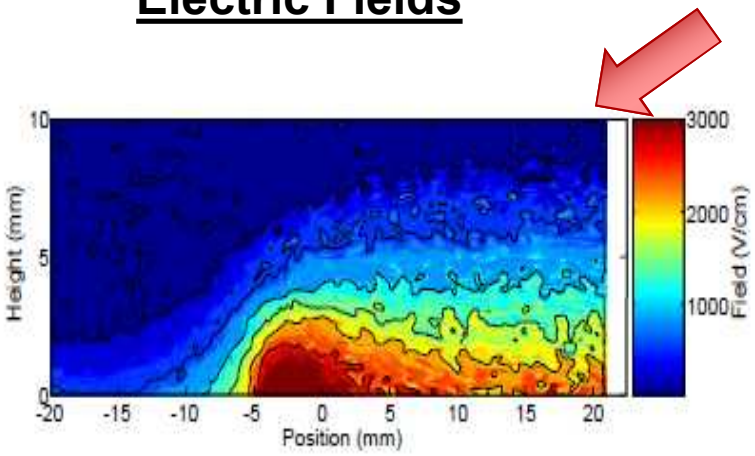


Did we do a good job validating the predictive capabilities???

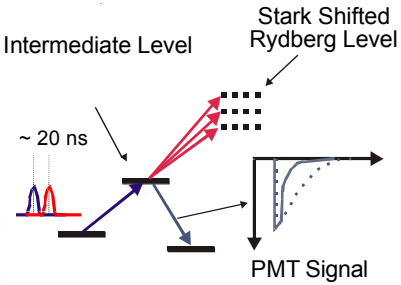
Multiple Methods to Needed to Reduce Uncertainty

- Identify, modify and implement methods needed to assess QOI.
  - "Find the right tool for the job".

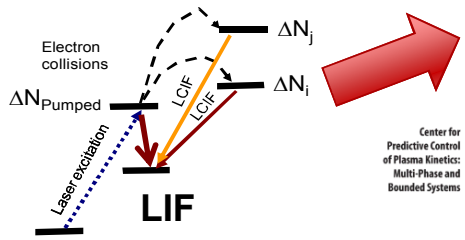
Electric Fields



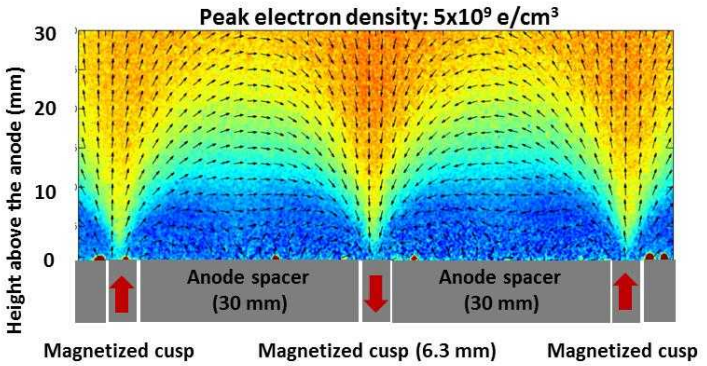
LIF-Dip concept



LCIF concept



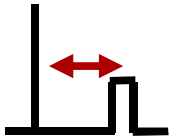
Electron Densities



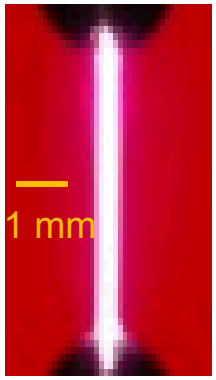
Many developed from earlier research LTP efforts….
Subsequently leveraged to support other LTP efforts!

Future Challenges Facing LTP

- This was the “easy” stuff!
  - “Large” dimensions (1mm), “Long” lifetimes (10’s ns), “Simple” chemistries.
- Emerging trends in plasma science “raise the bar”…
  - Smaller dimensions (<< mm), sorter lifetimes (10’s ps), multi-phase systems.



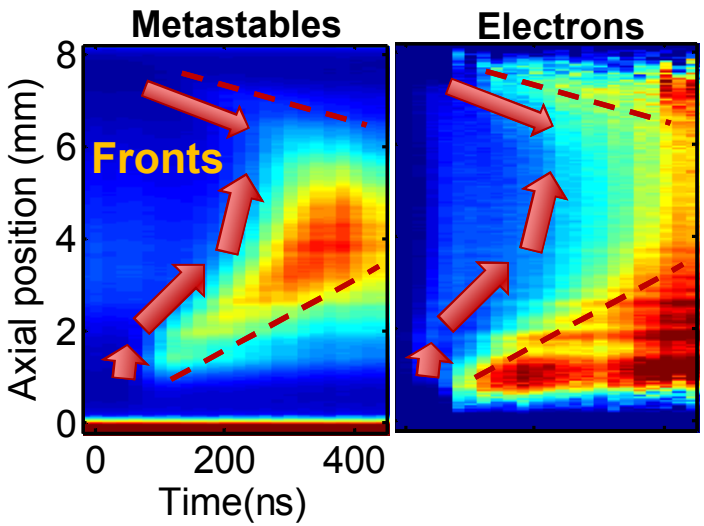
Powered anode



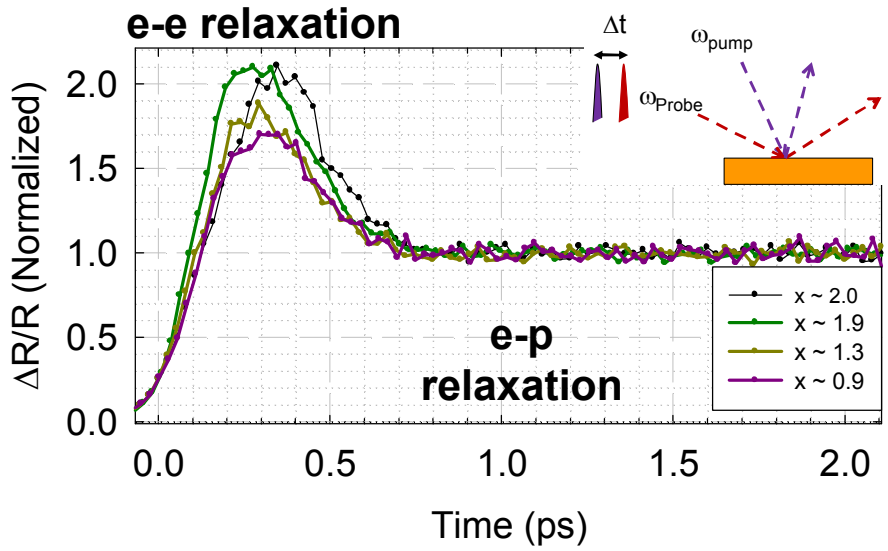
Grounded cathode

Potential diagnostics to address emerging challenges

High-pressure LCIF



Ultrafast thermoreflectance



New sets of eyes are needed to address these challenges…
When methods do not exist they need to be developed!

Considerable Risk in Developing and Implementing Diagnostics

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- "Unknown unknowns" make investment in new capabilities risky.
  - Rabbit holes of competing interactions, false signals, plateaus and cliffs!
- Need for multiple sets of eyes makes implementation expensive.
  - Devil in the details – one size will not fit all.
- Thoughts on mitigating risks….
  - Built in tolerance to risk … calls specifically seeking diagnostics development.
  - Mechanisms that enable and provide access.

Novel diagnostics are continuously being developed based on clever combination of exploitation of traditional techniques or invention of complete new diagnostics being compatible with the plasma environment

…

but appropriate support and encouragement is needed to facilitate this development and ensure access

Thank you!

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