SAND2016-7460PE

Sandia and the Dynamic Compression Sector (DCS)

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Campaign 2 POC for SNL

SWG for DCS meeting

May 12, 2016

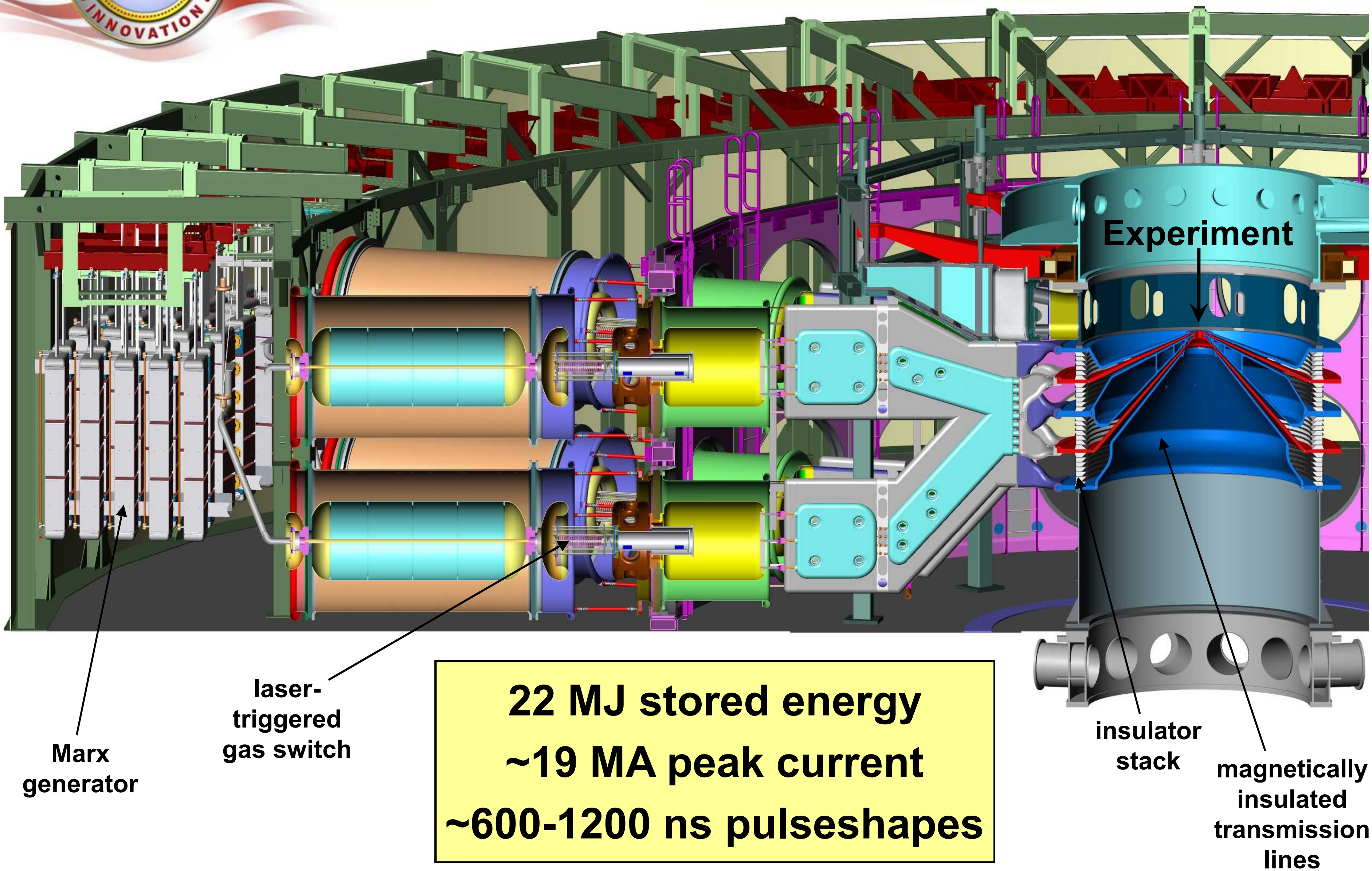
Sandia dynamic materials work is focused on local facilities

- Our flagship facility is the Sandia Z machine
  - This machine has the capability of producing very high velocity flyers for shock experiments
  - We can also use the magnetic force as a pressure source to isentropically compress materials
  - Or, combine these two techniques to reach states between these two paths

- We also rely on several local gas guns:
  - We have access to gas guns covering a range of velocities at our STAR and DICE facilities
  - These are used to study materials at lower pressure ranges
  - They are also utilized to help us develop new diagnostic capabilities that we would eventually use on Z

Powder gun at STAR

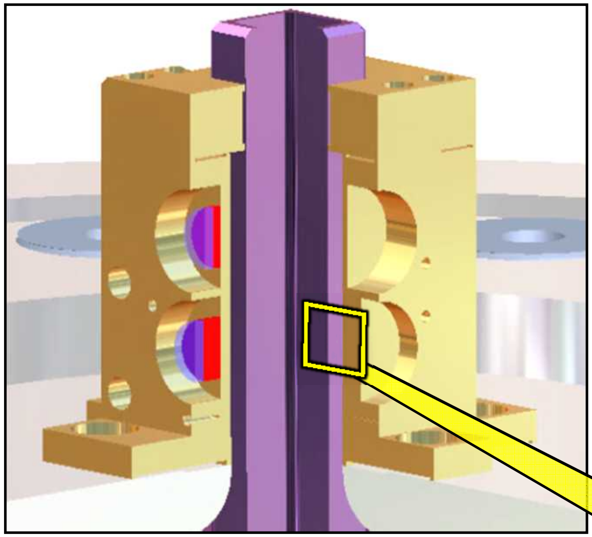
The Sandia Z Machine



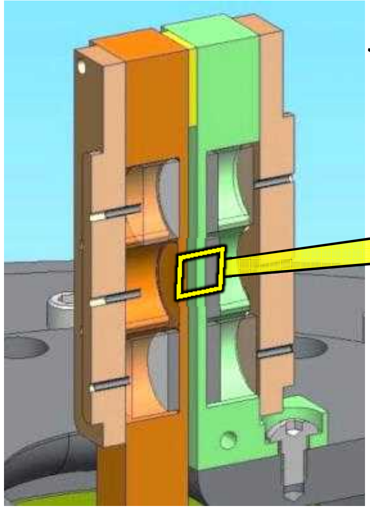
22 MJ stored energy
~19 MA peak current
~600-1200 ns pulseshapes

DMP experiments use Z as a pulsed magnetic pressure driver (peak B-field = 100-1200 Tesla)

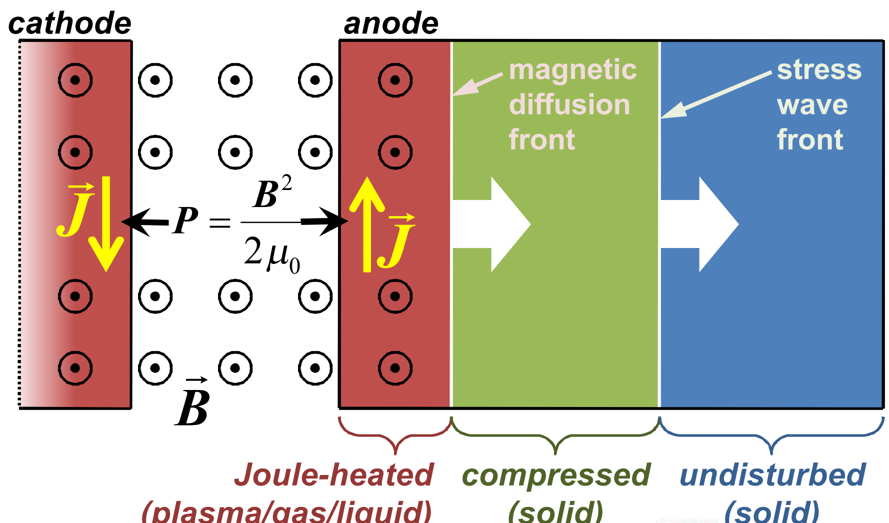
4-sided co-axial



stripline



- current pulse of 7-26 MA delivered to load
- controllable pulse shape, rise time 100-1200 ns
- magnetic ($J \times B$) force induces ramped stress wave in electrode material
- stress wave propagates into ambient material, de-coupled from magnetic diffusion front



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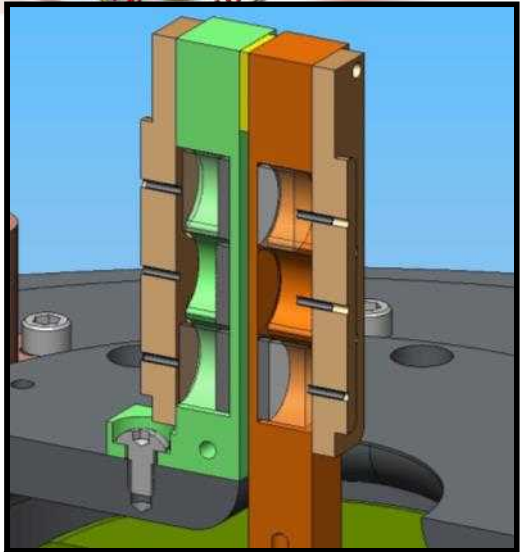
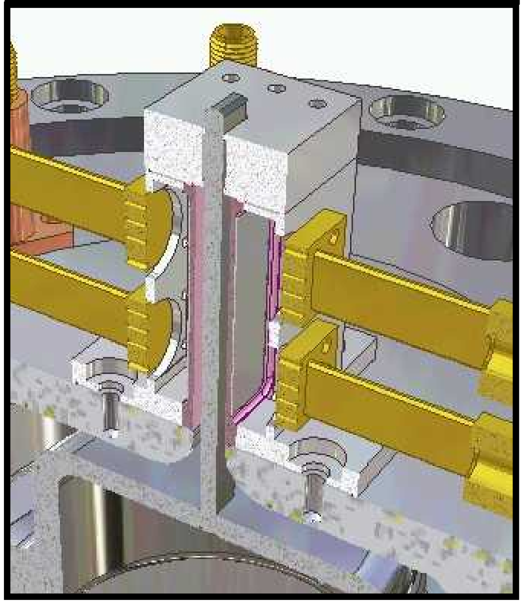
DMP experiments on Z generally fall into one of two categories: shockless compression & flyers





Shockless Compression (previously called "ICE")

- Pulse rise times > 400 ns (demonstrated to 1200 ns)
- Shock formation limits maximum sample thickness
- Reverberation limits minimum sample thickness
- Demonstrated quasi-isentrope measurement > 4 Mbar
- Direct analysis techniques require simple-wave isentropic-flow assumptions
- Samples generally 0.5-1.5 mm thick

Magnetically-Launched Flyer Plates

- Pulse rise times < 400 ns
- High velocity from reverberation in thin electrode plate
- Peak acceleration > 10^{10} g's, peak P = 6 Mbar
- Hugoniot experiments at velocities to > 40 km/s
  - exceeds gas gun velocities by > 5X and pressures by > 10X with comparable accuracy
- 50-250 µm of flyer front solid density at time of impact

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Sandia is also developing a new pulsed power driver focused entirely on dynamic materials experiments

Thor is a modular pulsed power system that can finely control the electrical pulse shape and therefore the loading of the material

- The first generation facility contains 8 modular bricks and is undergoing testing
- Eventually, we hope to have a 144 brick capability able to reach pressures of 100 Gpa with a ramp pulse

Dynamic Materials Priorities at Sandia

- Strategic priorities for the DMP program are:
  - Map out material phase diagrams
  - Measure temperature and characterize structure & phase in shock & ramp experiments
  - Measure and analyze strength along complex loading paths
  - Understand the role of kinetics and microstructure
- Tactical priorities are:
  - Shock-ramp and/or high pressure ramp experiments (cylinder or asymmetric ramp)
  - Platform &diagnostic development to address strategic objectives or improve quality of data
  - Further develop analysis techniques to take advantage of complicated loading paths

Sandia Priorities for utilizing DCS focus on the unique capabilities that exist there

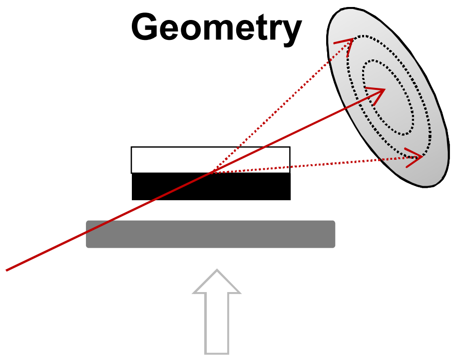
- Diffraction:
  - The measurement of phase boundaries and characterization of mixed phase regions is a high priority
  - We believe experiments at DCS utilizing diffraction will help us develop expertise and optimize our approach for experiments on Z
  - The time-dependent sensitivities of these phases and their boundaries to various material properties is also an area of emphasis (kinetics)
- Phase contrast imaging
  - Investigation of heterogeneous materials and meso-scale properties on dynamic properties is an important aspect of our work for the future
  - Imaging of shocks and other dynamic effects is where DCS can play a unique role

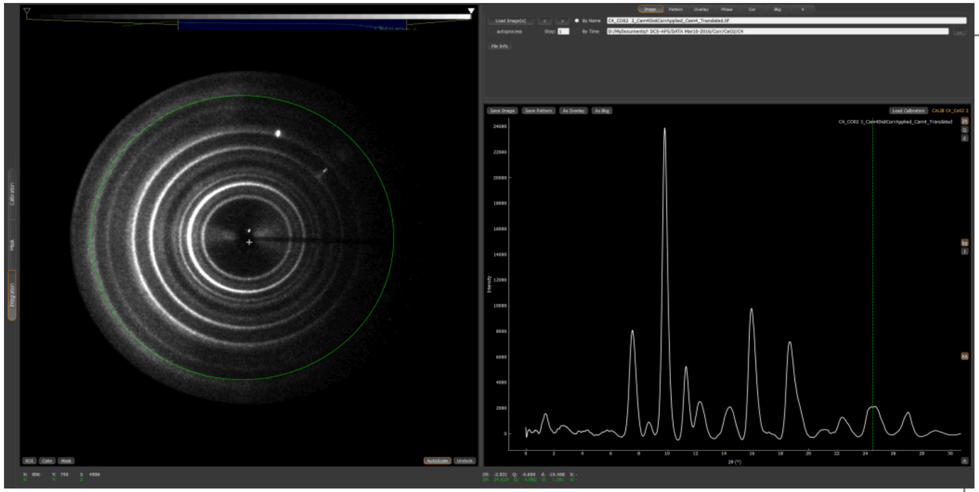
Specific issues of interest for DCS experiments

- Investigation of solid-solid phase transformation mechanisms and kinetics
- Understanding the role of inelastic deformation on phase transformation mechanisms and kinetics
- Understanding material strength after a phase transformation (both solid-solid and liquid-solid)
- Understanding mechanisms responsible for temporary loss and recovery of strength observed in brittle ceramics
- Understanding how deformation processes change in the transition from ramp compression to steady shock
- Phase contrast imaging of mesoscale behavior (shock fronts, grain interactions, etc)

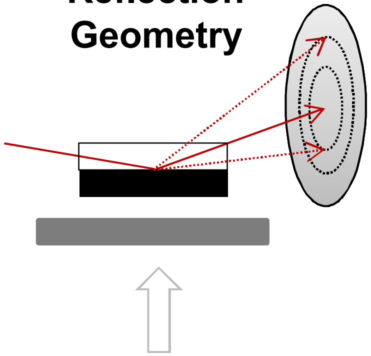
DCS-APS-ANL: First SNL Experiments

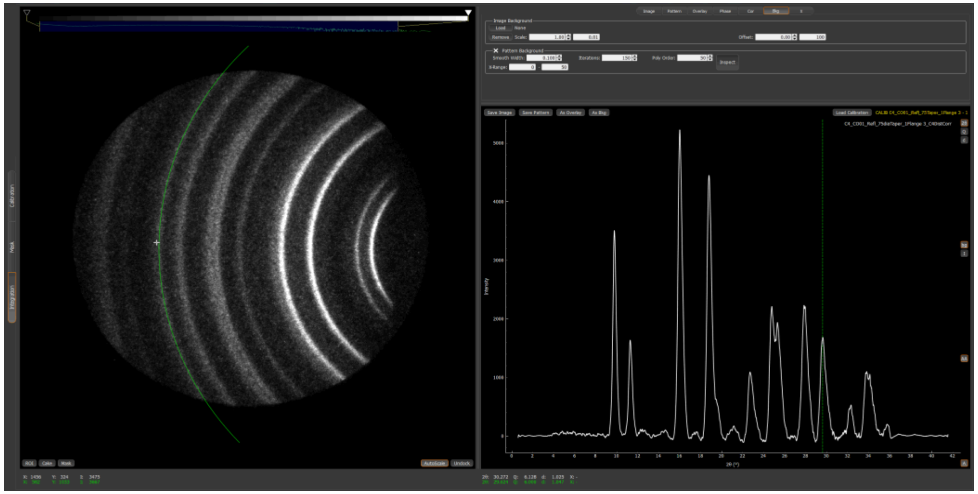
XRD in Transmission Geometry





XRD in Reflection Geometry





First SNL team visit

- Jan. 19-21, 2016
- Team: Patricia Kalita, Seth Root, Tracy Vogler
- Purpose: learning about DCS setups, guns, x-ray delivery, detectors

First SNL team XRD test

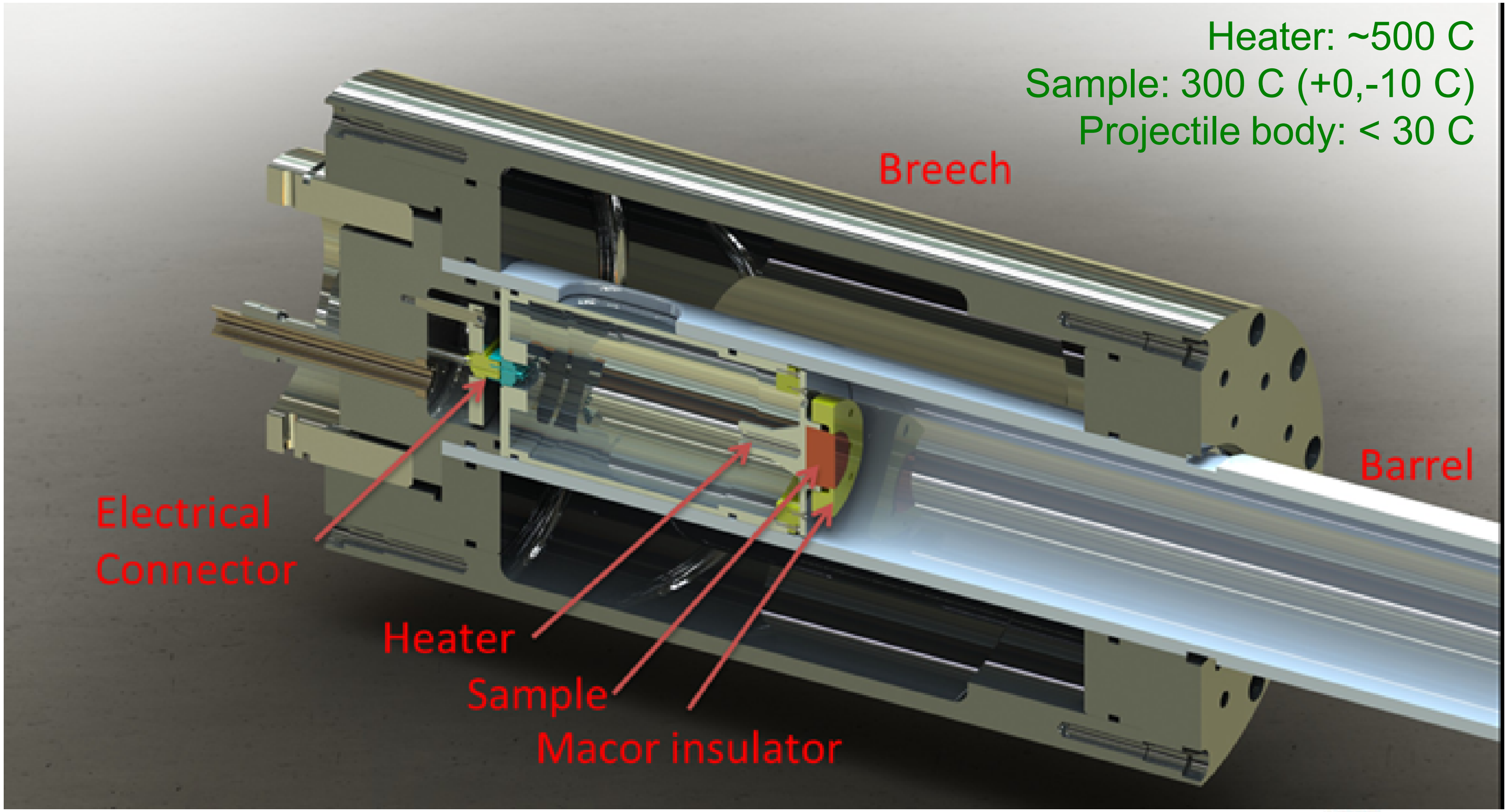
- Mar. 9-11, 2016
- Team: Patricia Kalita, Seth Root, Tom Ao
- Purpose: testing of XRD on various samples, at ambient conditions, in transmission and reflection geometries

Suggestions for Effective use of DCS

- Providing important information to PI's
  - For Diffraction, need a spectrum for every shot, or at least data that supports that information
  - For shock physics, should include flyer velocities, break-out times, etc.
- Also need to provide clear information on capabilities
  - Spatial resolution for phase contrast imaging
  - Reliable information for experimental planning
    - » Physical dimensions and layouts
    - » Expected shot rates and turn-around times
    - » Available wavelength options and intensities
    - » Beam divergences and possible focusing ability

A heated impact system similar to what is used at DICE could enhance the capabilities at DCS

- **Resistive heater installed inside projectile (wrap-around breech)**
  - **Slow heating after vacuum achieved, stabilized for an hour**
  - **Electrical connector automatically releases at launch**



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Governance issues- Allocation of time

- Sandia would support a roughly equal distribution of shots at DCS among the NNSA labs
  - Of course, each Lab may not actually be able to use their full allocation, which could then be utilized by others
  - For example, Sandia would probably seek to have from 3-5 experimental runs next year and it would be difficult for us to immediately utilize significantly more time
  - We would expect that effort to grow in the coming years

Governance issues- Proposal selection

- For selection of proposed experiments, we could support a couple of options
  - First and foremost, we understand and expect that the DCS staff would need to weigh in on the feasibility of any given experimental plan
  - Our preferred method is to go through an internal evaluation of our proposed work and select our highest priorities as authorized experiments
  - We could also support a board (similar to the HED board) made up of knowledgeable people in the NNSA programs to that would rate proposed experiments
- For outside users, the formation of a users group with a oversight committee or board would be appropriate
  - The size and composition of this board would depend on how much time would be given to outside groups
  - Should be focused on basic science for dynamic materials