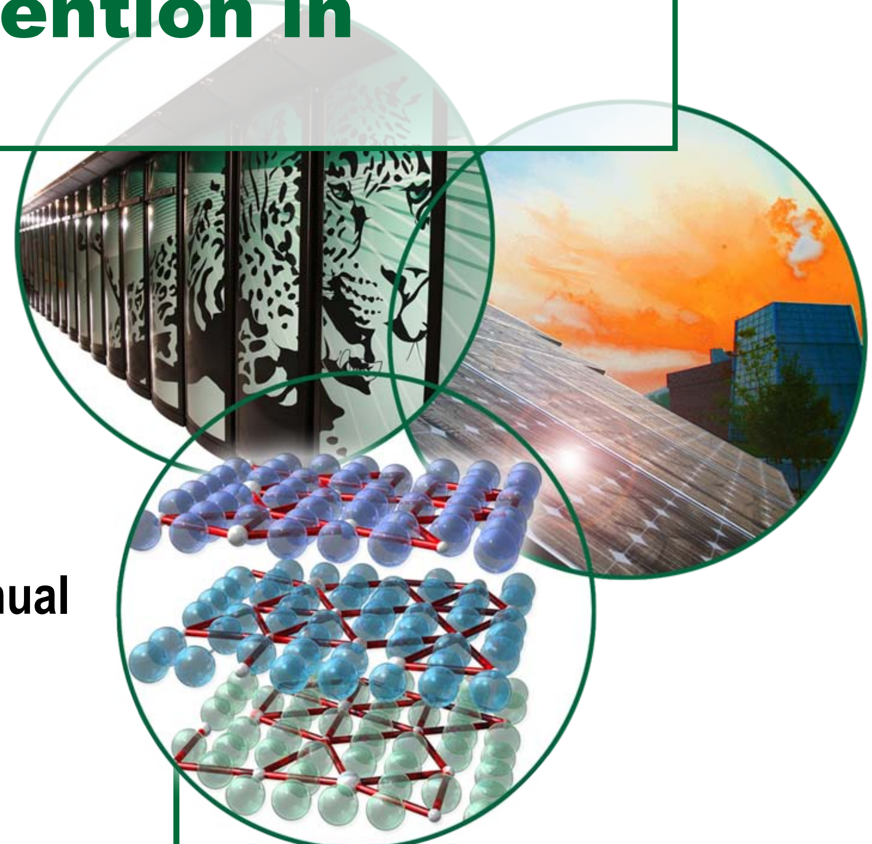
LM017240: Fundamental study of the relationship of austenite-ferrite transformation details to austenite retention in carbon steels



PI: Mike Santella and Eliot Specht

Presenter: Zhili Feng

2010 DOE Vehicle Technologies Program Annual Merit Review and Peer Evaluation Meeting

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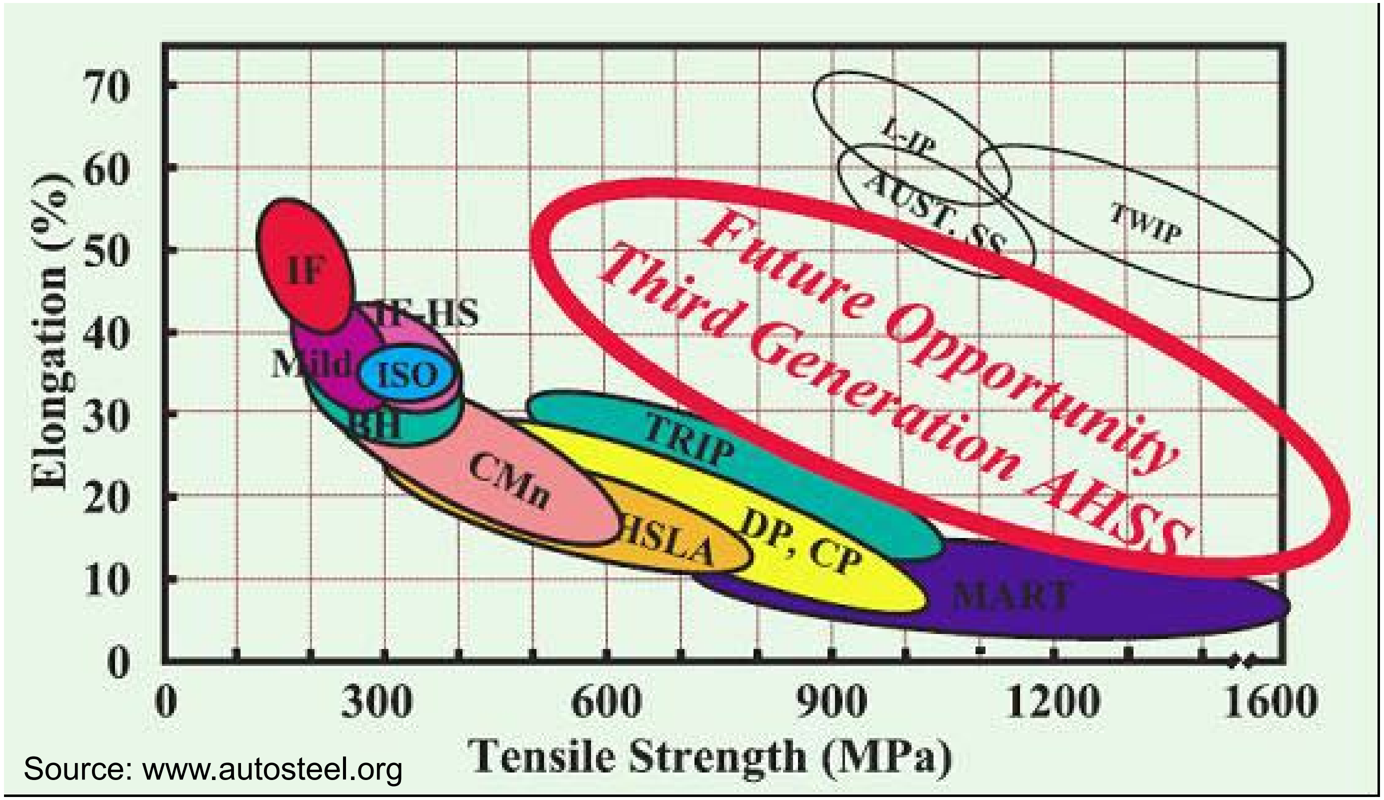
Washington, D.C.

Project ID: LM017

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Technology Gap: Develop high strength-high ductility steel at current pricing



Controlling costs will require:

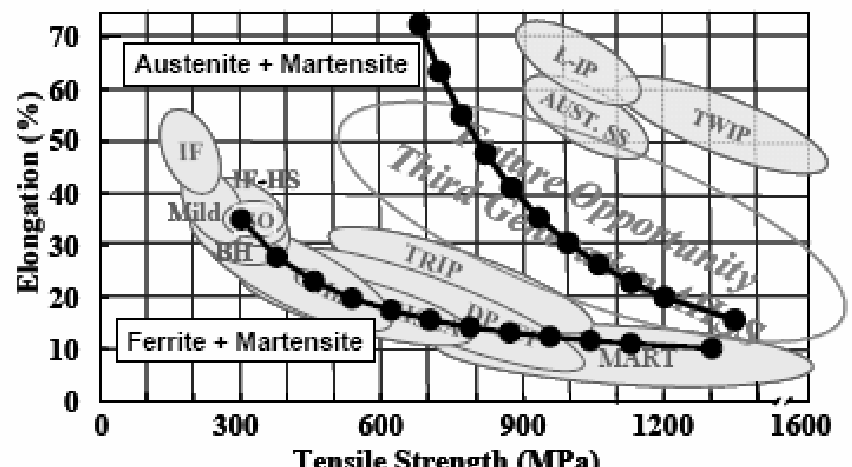
- Gen III AHSS be no more than modestly alloyed compared to Gen I steels
- Capability of being produced within existing steel-mill infrastructures
- Forming and welding characteristics consistent with existing steels

Possible path to Gen III includes:

1. Alloying, but with content near those of Gen I steels
   – Only modest additional alloying tolerated
2. Modified/novel processing & heat treatments
   – Must produce desired bcc + fcc microstructures

Predictions based on mechanical behavior suggest high strength + high ductility may be possible with microstructures of:

– Austenite + martensite, bainite, ferrite
– Ferrite + larger amounts of metastable austenite
  • Larger TRIP effect

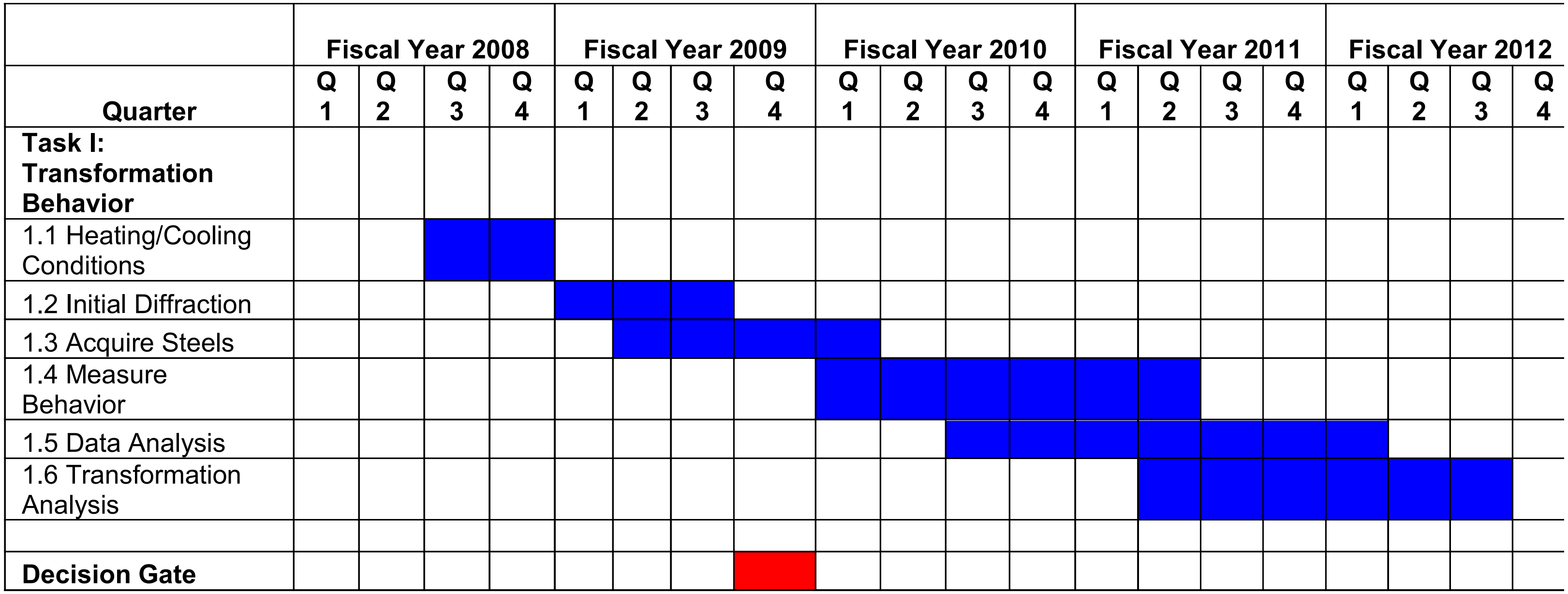


David K. Matlock and John G. Speer, "Design Considerations for the Next Generation of Advanced High Strength Sheet Steels," The 3rd International Conference on Advanced Structural Steels Gyeongju, Korea, 2006

Project Goal/Deliverables:

- The objective is real-time characterization of austenite-ferrite transformation behavior
  - During T/t conditions representative of processing AHSS
  - Determine conditions that promote retained austenite
    - This will contribute to building the scientific foundation needed for development of Gen III AHSS
- Deliverables:
  - Quantitative description of austenite-ferrite transformation behavior during simulated finishing operations
    - including the effects of carbon, manganese, and silicon
  - Quantitative description of alloying element partitioning between austenite and ferrite
  - Assessment of how retained austenite can be maximized within constraints of normal sheet processing infrastructure

Project plan/history:



- **Funding history:**

FY	Budget, k$	Carry over, k$
2008	75	67
2009	230	87
2010	200	

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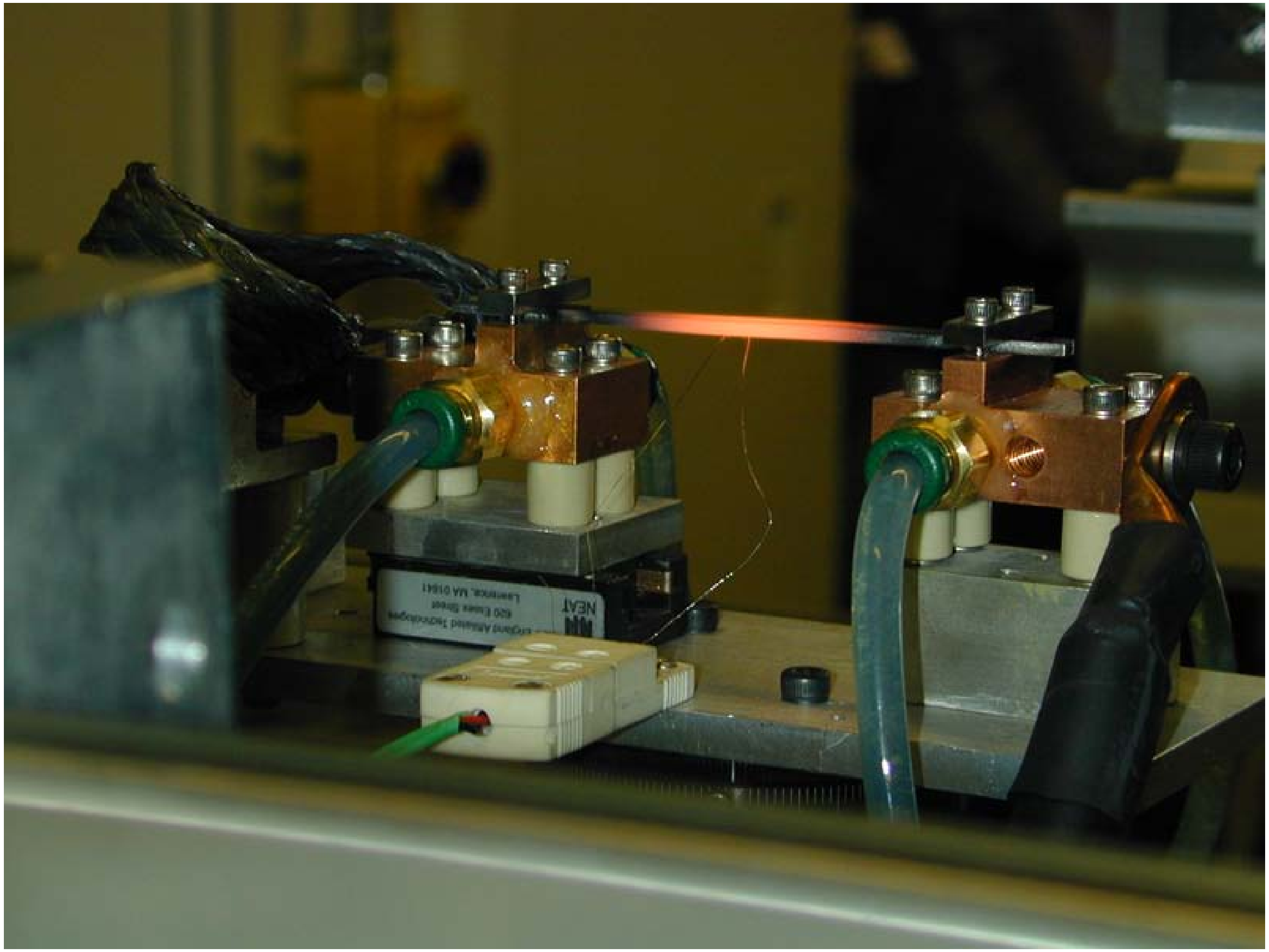
Milestones and Deliverables:

- Experimental determination of transformation behavior of the alloys of interest will be done. October 2009
  - Demonstrated basic feasibility of the approach
- Experimental and data analysis procedures will be reexamined to determine possible sources of errors, and an approach for minimizing the effects of surface reactions will be established. October 2010
  - A proposal for additional beam time at APS was approved (12/22/2009)
  - Synchrotron beam time was allocated for 03/20-23/2010
- Experimental alloys will be formulated and analyzed for the possibility of increasing retained austenite over commercial steel grades. October 2011

Approach:

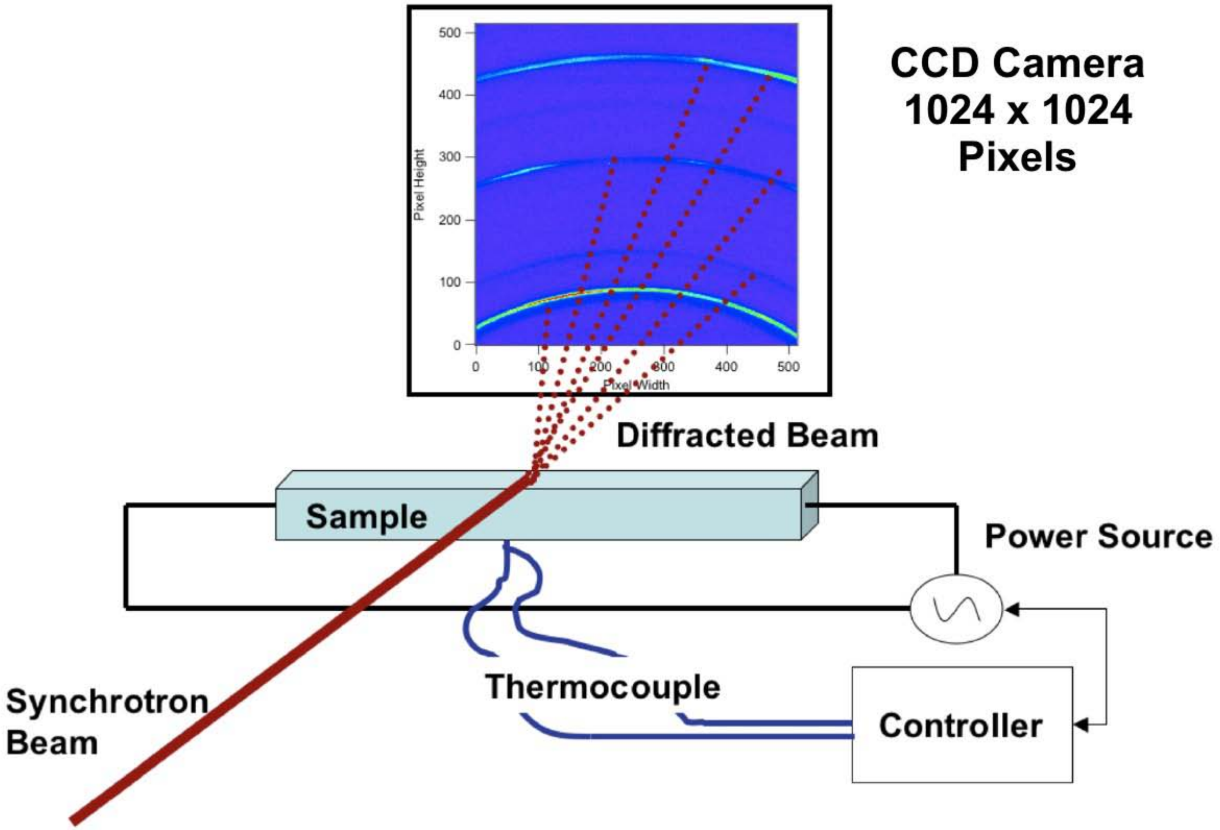
- High-speed diffraction experiments are being conducted at the Advanced Photon Source
  - The austenite-ferrite phase transformation behavior is being characterized *in-situ* under the rapid heating/cooling conditions

Specimens are heated by resistance in vacuum



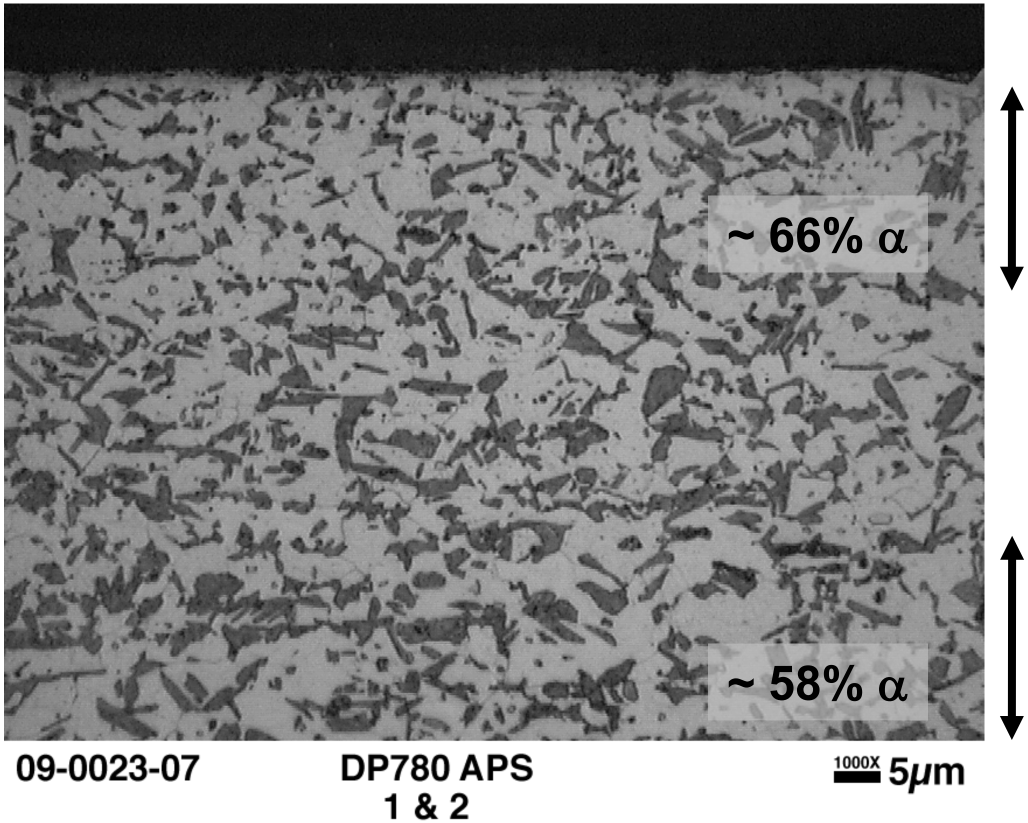
- **Thermocouple feedback is used for temperature control**
- **Specimen grip is spring-loaded to maintain positioning**

APS synchrotron flux + brilliance permits diffraction patterns at ~ 1/s



- Calibrated Debye arcs are converted into plots of Intensity-vs-(d-spacing)

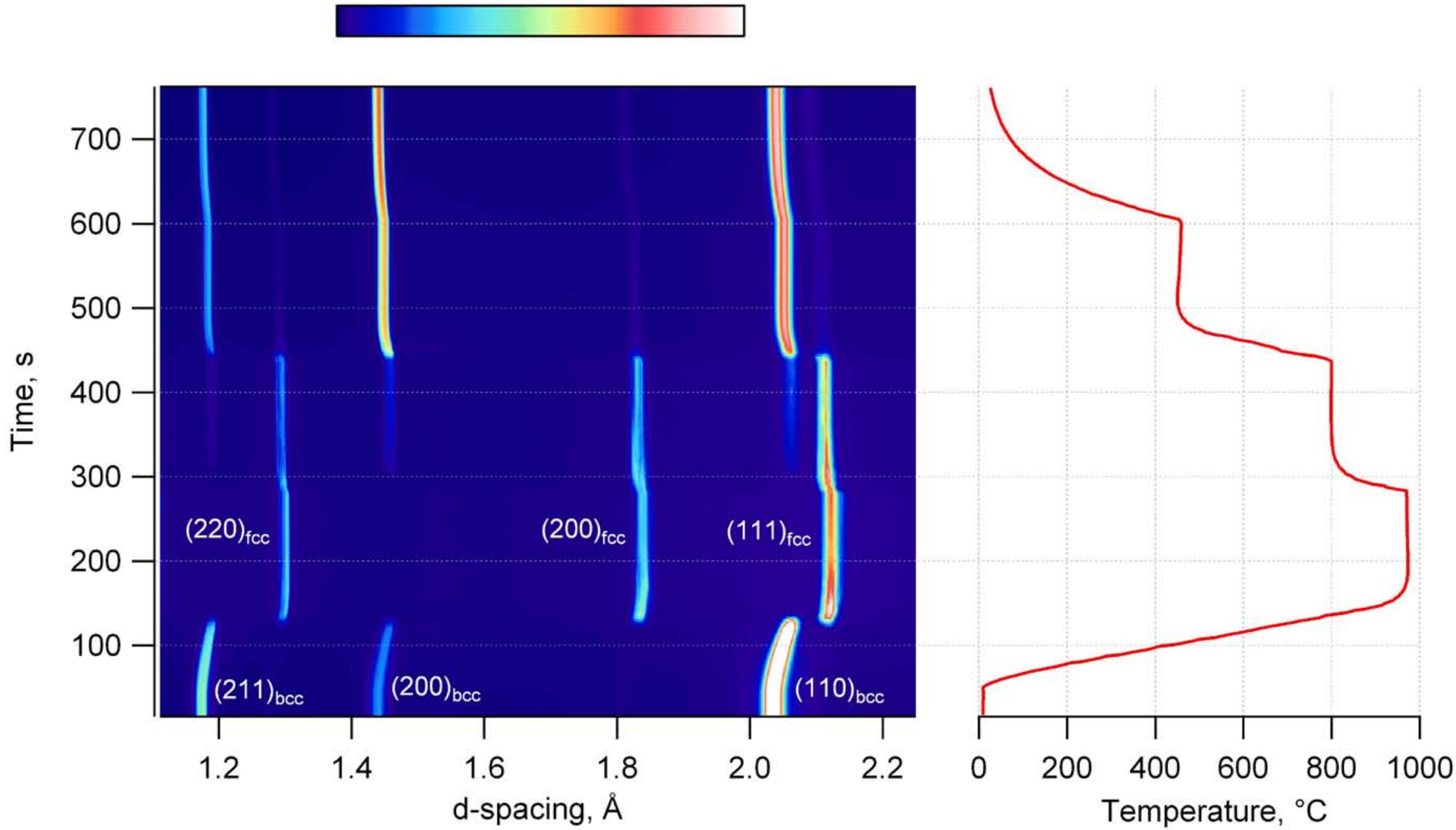
DP780 is being used as a reference AHSS



Element	Analyzed wt%
Carbon	0.11
Manganese	1.93
Phosphorus	0.015
Silicon	0.24
Chromium	0.03
Aluminum	0.045
Nitrogen	0.008

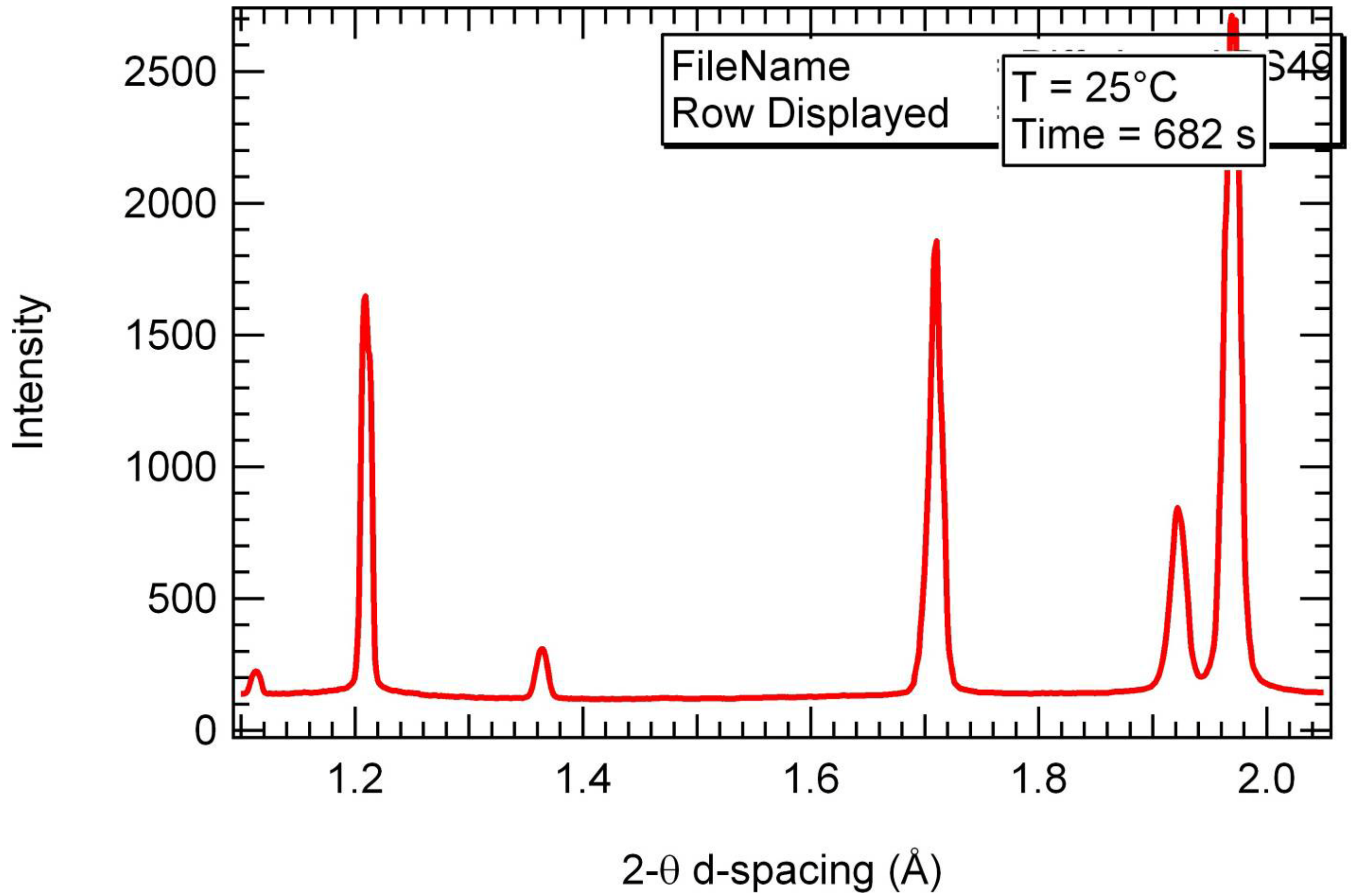
- Microstructure is ferrite + martensite
- Slightly higher ferrite amount near surface indicates slight decarburization

DP780-APS103 overall ferrite-austenite transformation behavior



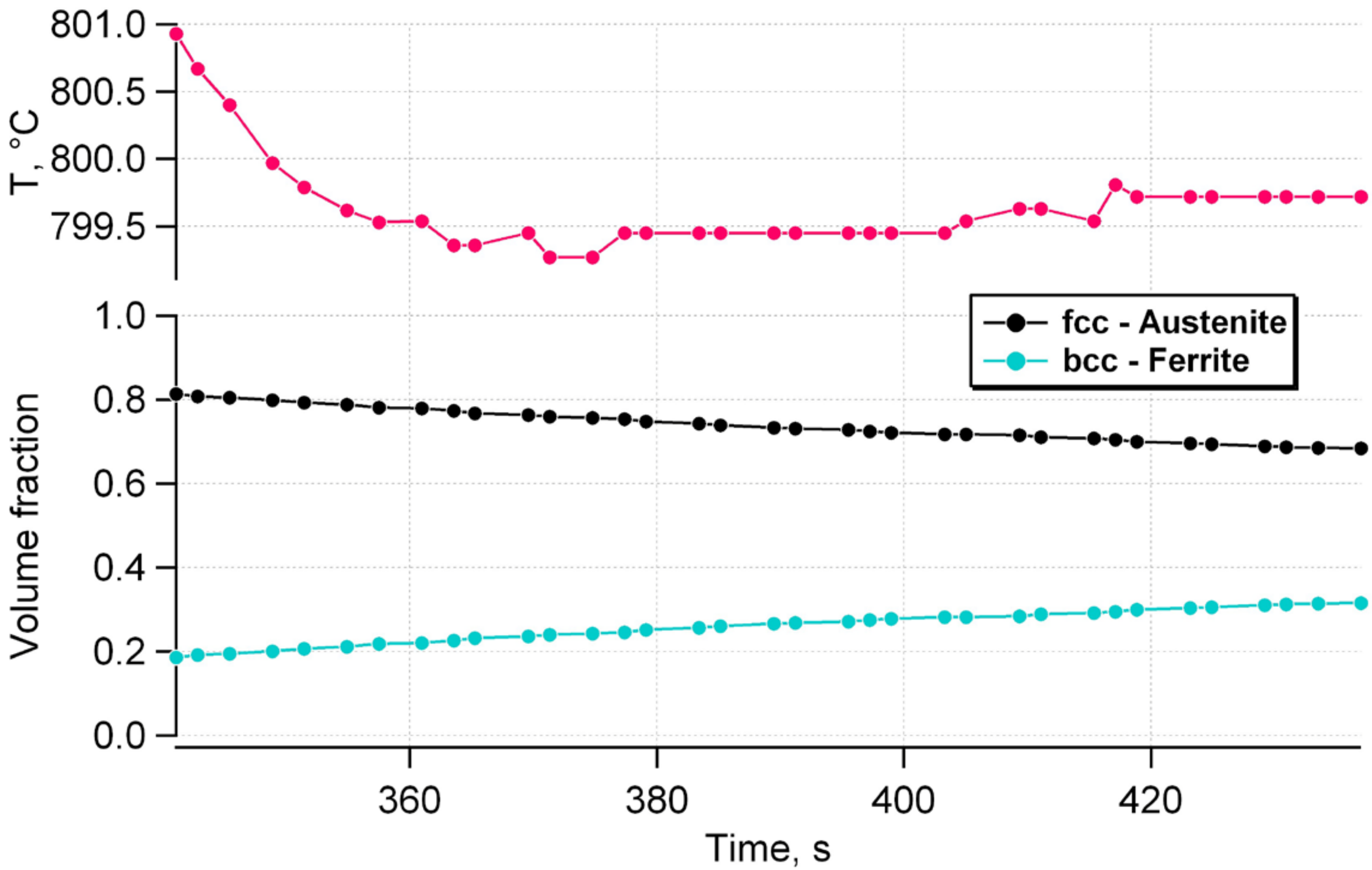
- **Austenite is retained with the selected cooling conditions**

Direct comparison method is used to determine phase fractions



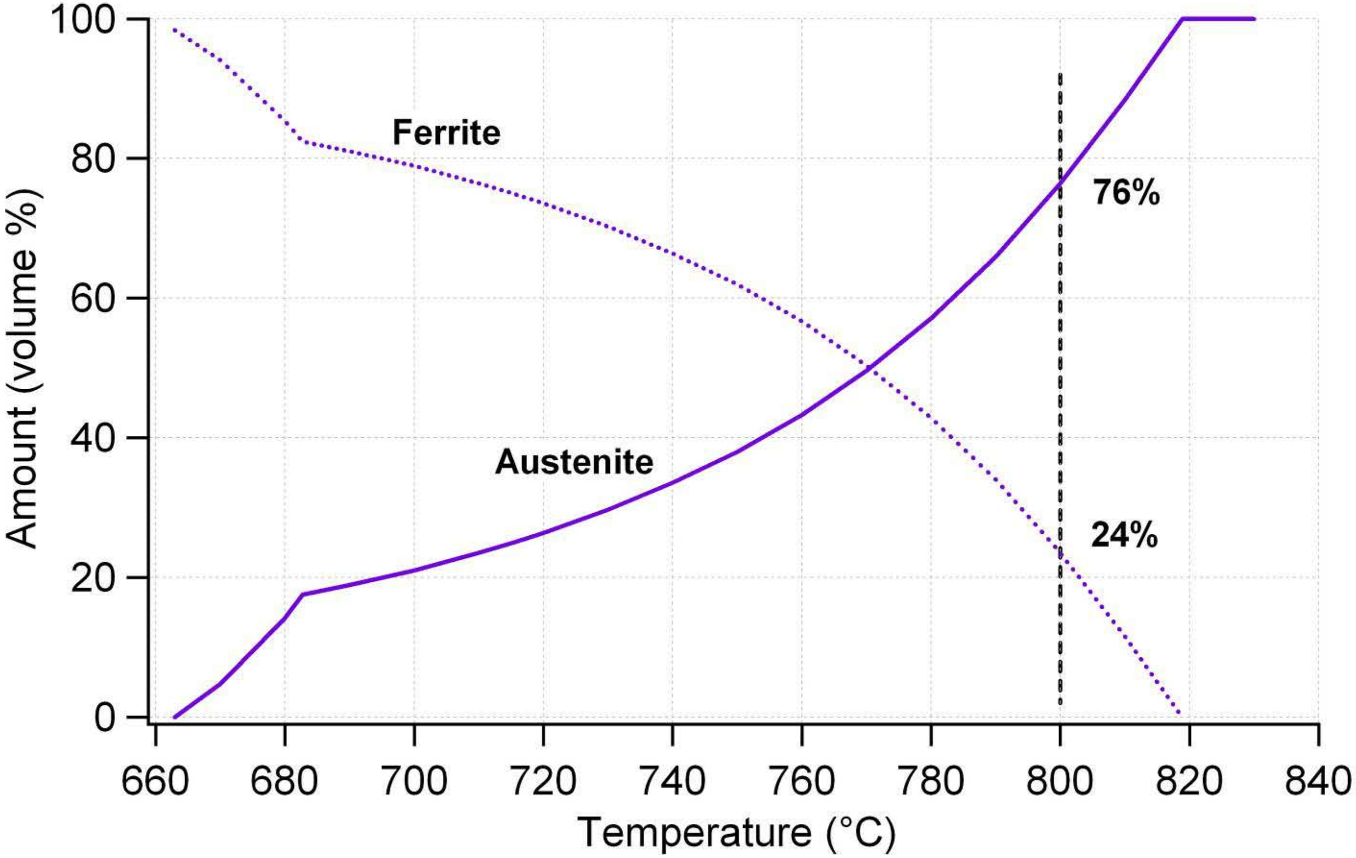
- Peak areas are corrected for polarization, temperature
- Integrated intensities are corrected for texture

DP780-APS103 intercritical transformation behavior details



- **Cooled to 800°C from 970°C followed by 120 s hold at 800°C**

Equilibrium prediction results based on bulk composition of DP780



- **Results are fairly consistent with diffraction fcc = 70-80%**
- **Roughly consistent with independently done heat treatment at 800°C**

Gleeble simulations at 800°C show α/γ is in range of 20/80

- $\Delta T/\Delta t$ = 10°C/s to 970°C, hold for 120 s
- $\Delta T/\Delta t$ = 16°C/s to 800°C, hold for 10 s
- Gas quench

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Agreement of diffraction with thermodynamic predictions and Gleeble heat treatments is good

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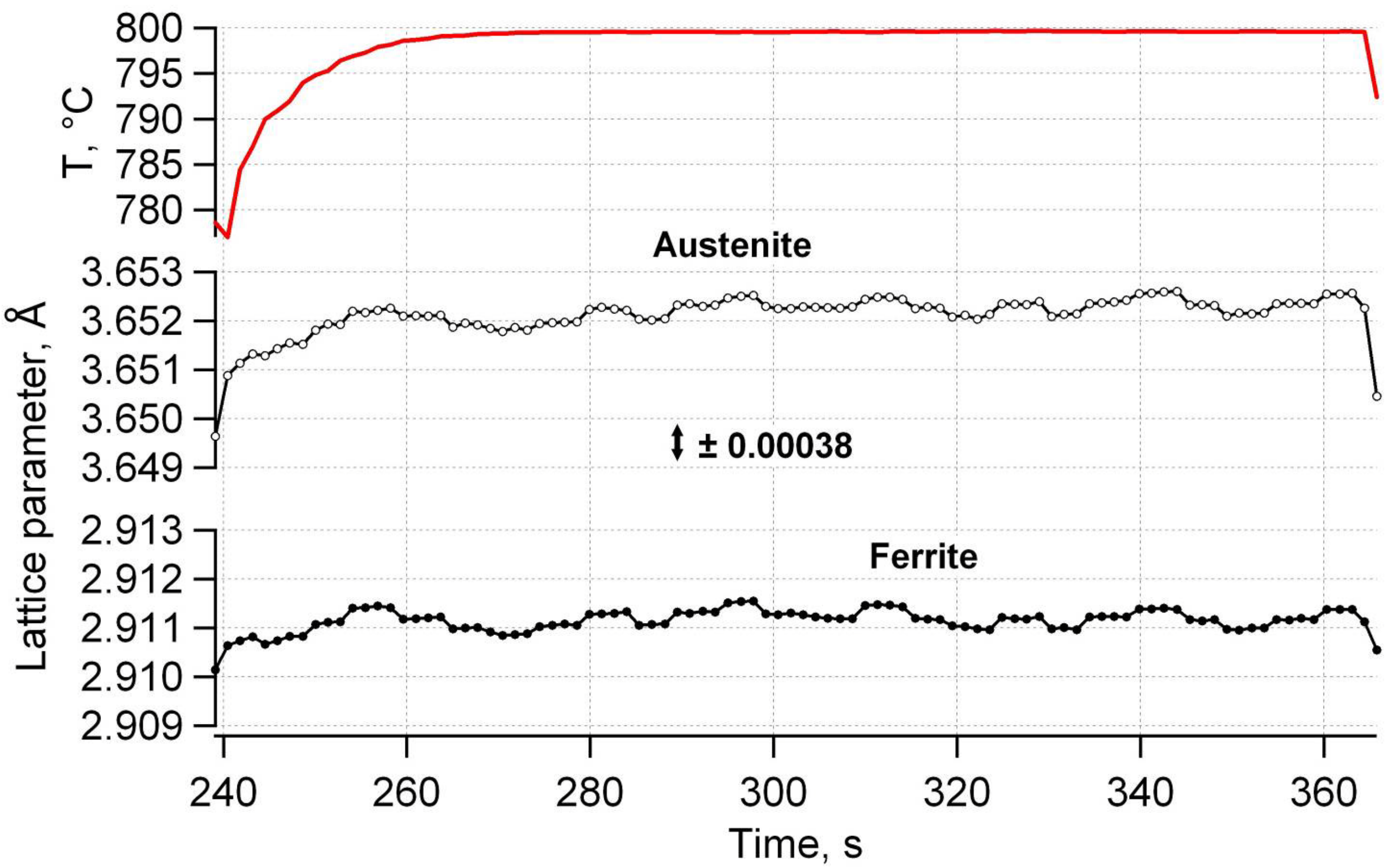
DP780-APS49: Lattice parameter during 800°C hold



- **Further analysis will yield information about alloy element partitioning between bcc/fcc**

Summary:

Status:

- Demonstration was successful for tracking α-γ transformations during rapid heating/cooling
- Measurements of lattice parameters are possible

Challenges/Risks:

- Continuous proposal writing for APS beam time
- Experimentation & data analysis not "canned"
  - Being perfected in parallel with experiments

Future work (beginning late FY2010):

- Experimental alloys are being defined to promote austenite through alloying
- Novel processing scheme to produce ferrite + austenite is under consideration

Industry/university collaborations are being sought