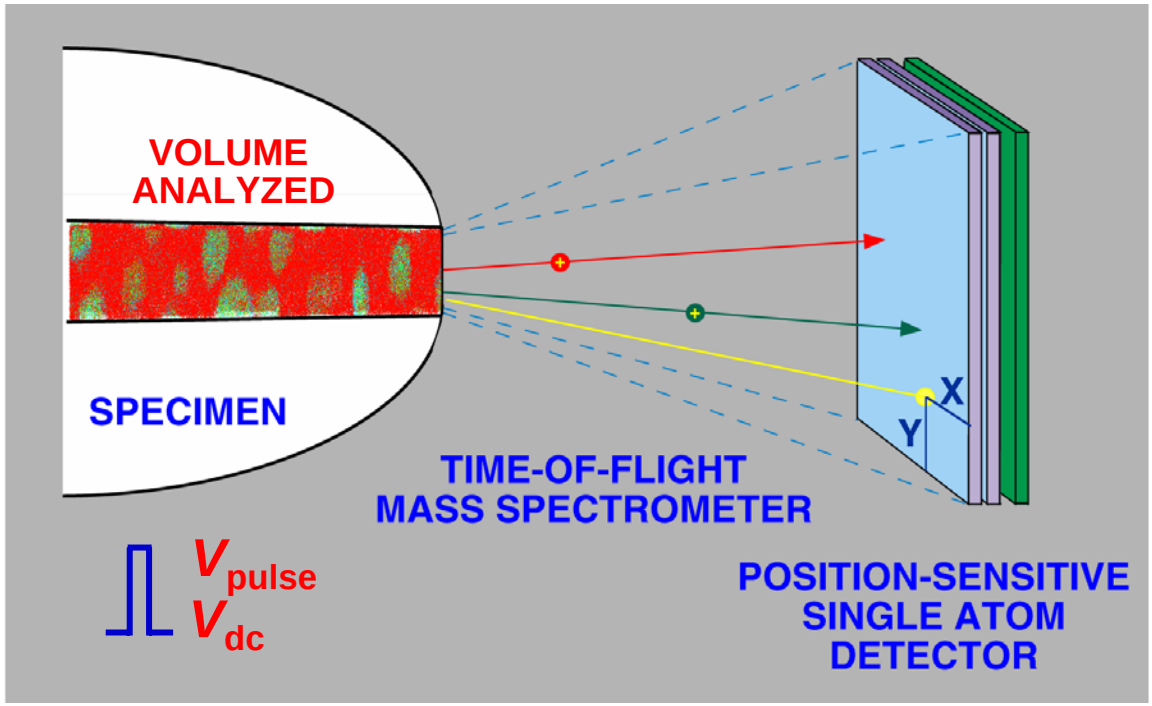
Atom Probe Tomography (APT)

- Provides a unique method for characterizing the <u>solute distribution</u> in materials from the spatial coordinates and the elemental identity of the atoms

- The <u>solute distribution</u> may be used to quantify:
  - size and composition of nanoscale precipitates
  - tendencies for clustering and chemical short range order
  - extent of solute segregation to dislocations, interfaces and boundaries

Three-Dimensional Atom Probe



The elemental identity of each atom is determined from the mass-to-charge ratio, *m*/*n*, which is estimated from the flight time, *t*, and distance, *d*, and the applied voltages, V_{dc} and V_{pulse}

$$\frac{m}{n} = c\left(V_{dc} + \alpha V_{pulse}\right)\frac{t^2}{d^2}$$

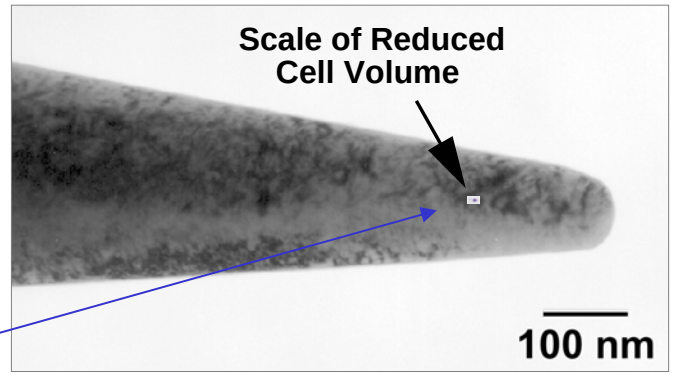
A three-dimensional atom probe (3DAP) is a time-of-flight mass spectrometer that is equipped with a position-sensitive single atom detector. Atoms are removed from the surface by pulsed field evaporation

The atom coordinates are determined from the x and y positions on the detector and the position in the evaporation sequence

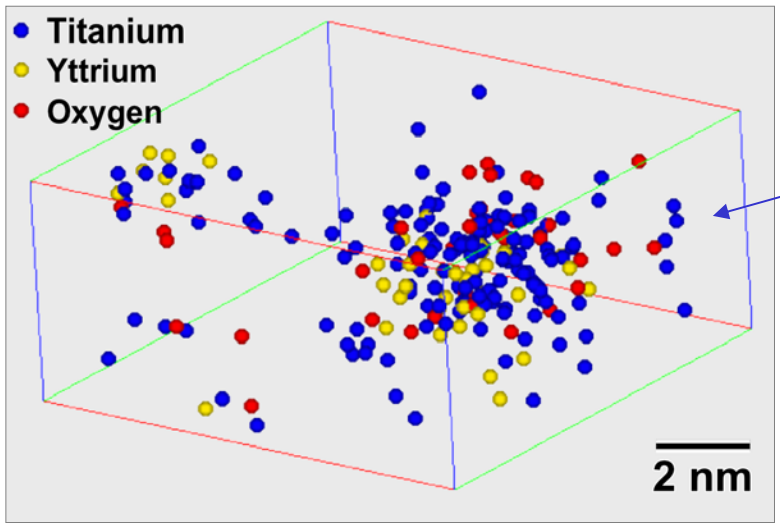
x, y, z and m/n are estimated for each atom detected

Atom Probe Scale

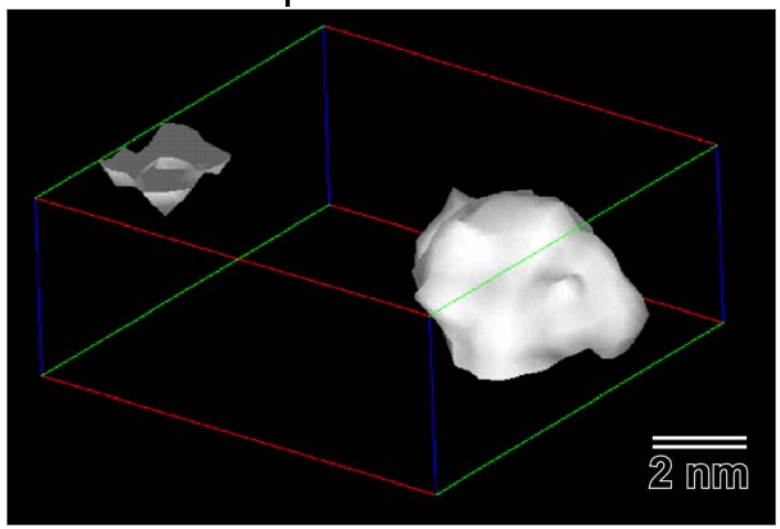
TEM BF Image



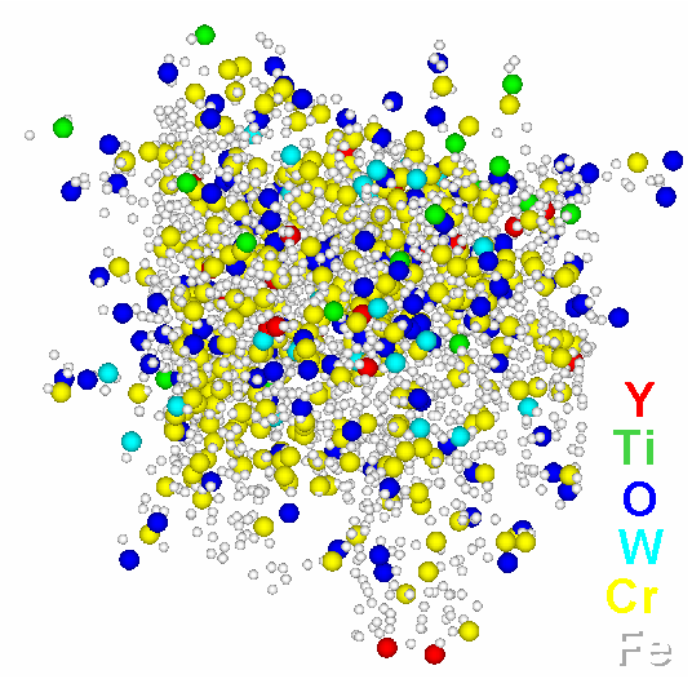
3-DAP Atomic Coordinates

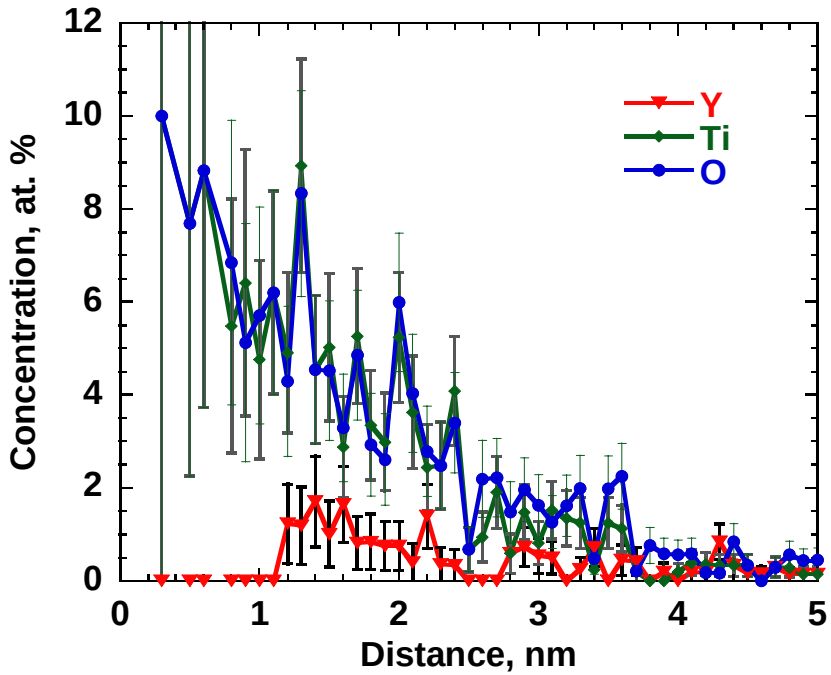


Isocompositional Surface



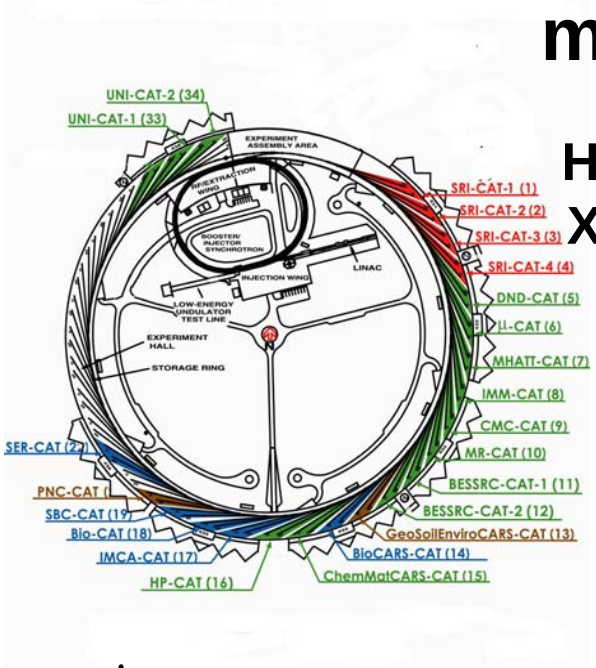
Radial Concentration Profiles



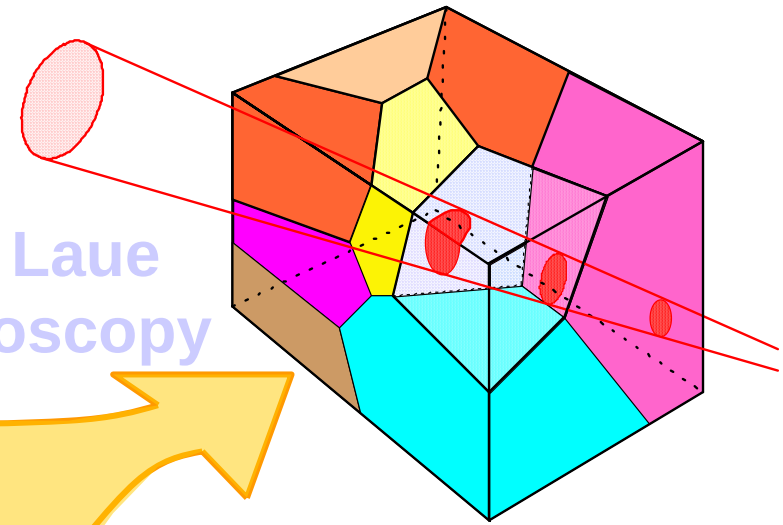


- Radial concentration profiles from the center of mass of the particle into the matrix reveal information such as solute atom partitioning and segregation of solute atoms to a particle/matrix interface
- This profile shows some evidence of a yttrium depletion at the core and an enrichment at the particle-matrix interface of a nanocluster

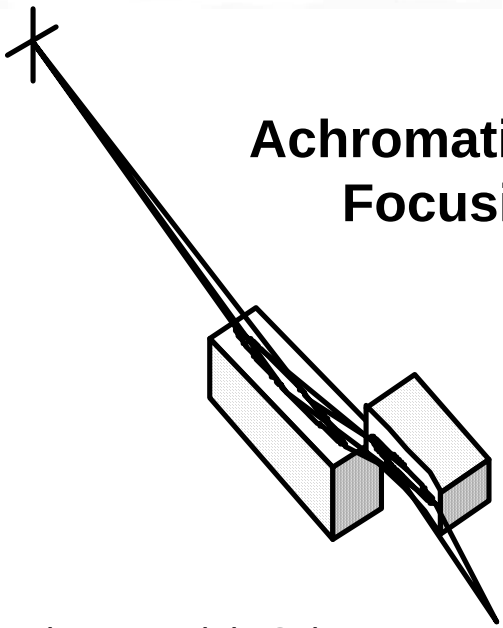
3-D X-ray Crystal Microscope Possible due to major technical advances



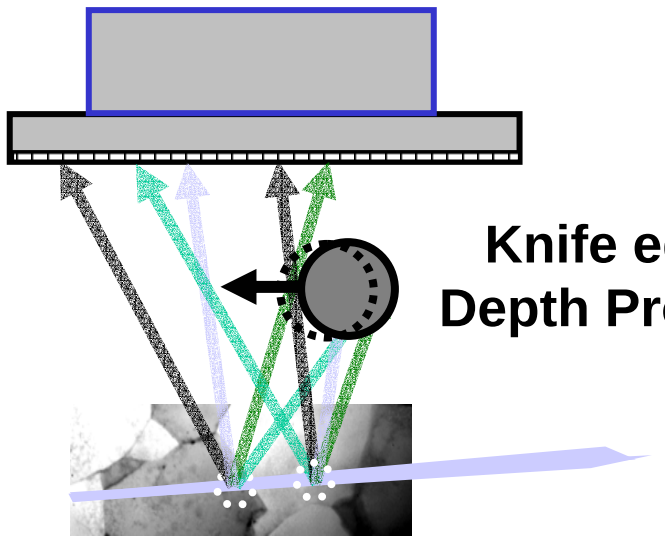
High Brilliance X-Ray Sources



3-D Laue Microscopy

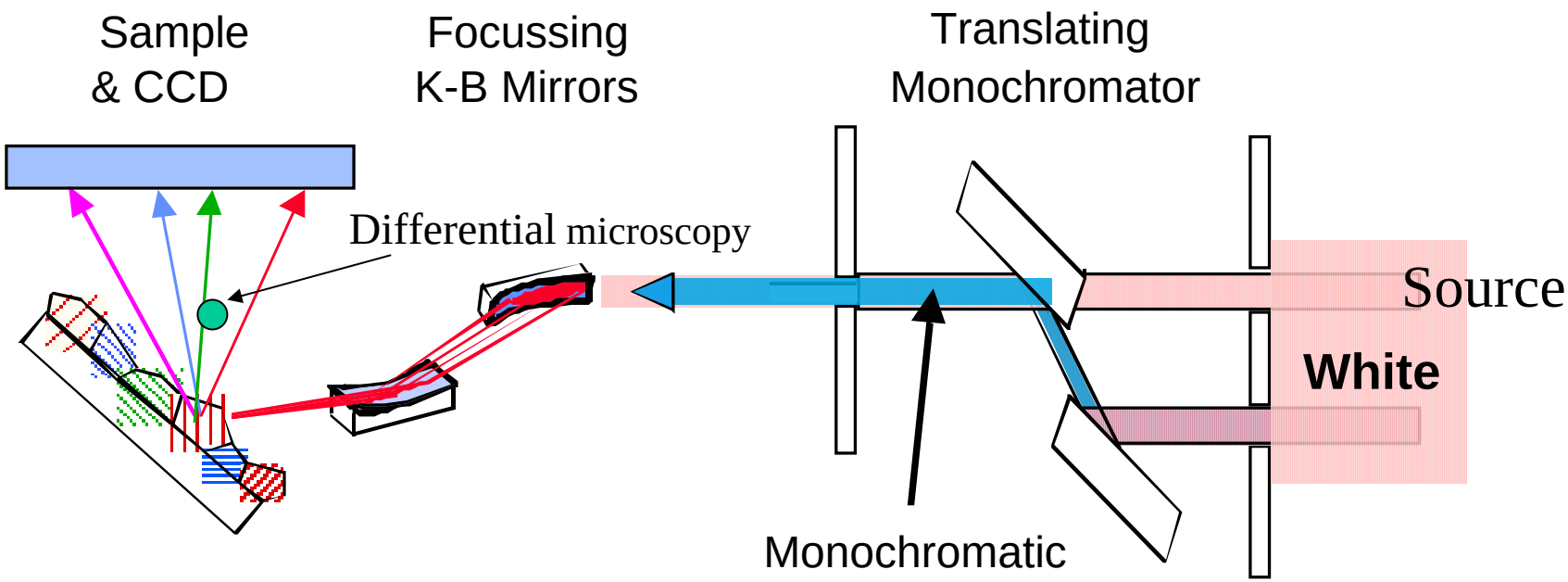


Achromatic Microbeam Focusing Optics



Knife edge-Depth Profiling

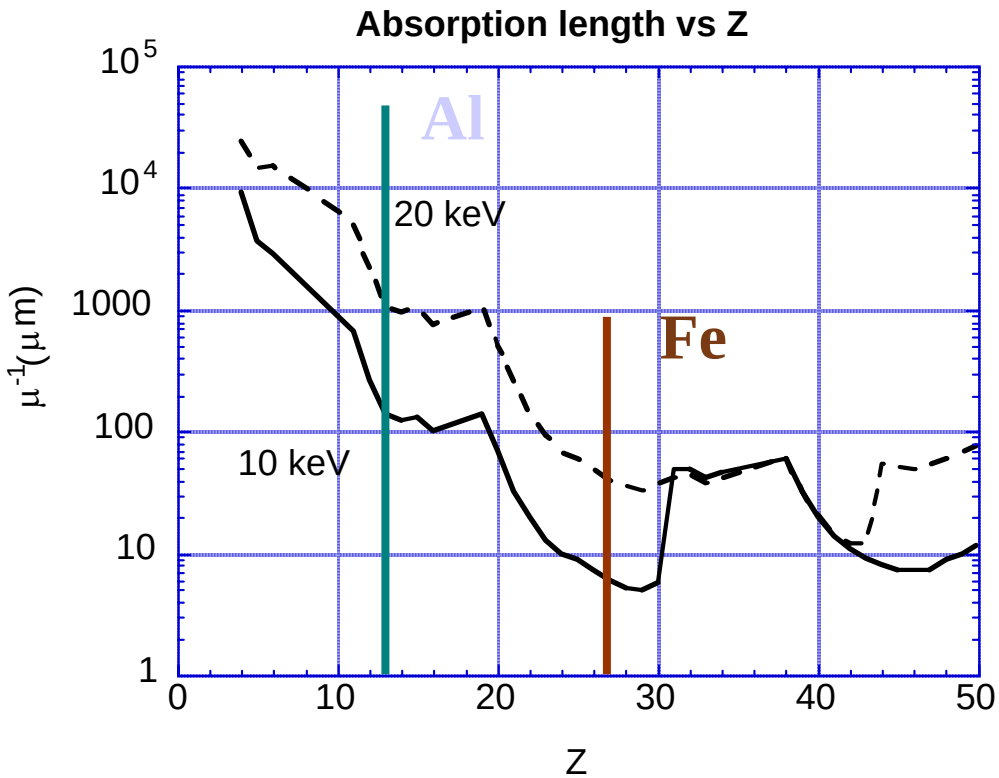
3-D X-ray Crystal Microscope has 5 key Elements



Current 3-D resolution: **<0.3 x 0.4 x 0.7 μm^3**
Current strain tensor resolution: **~10^{-4}-10^{-5}**

Ideal for Mesoscale Physics

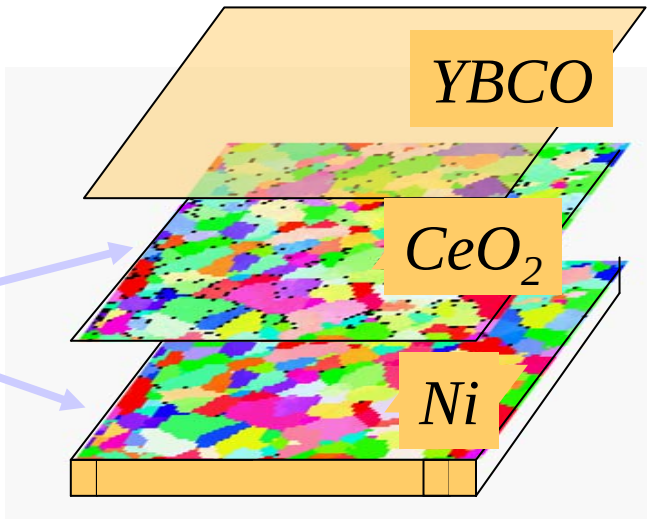
Depth probed varies strongly with Z

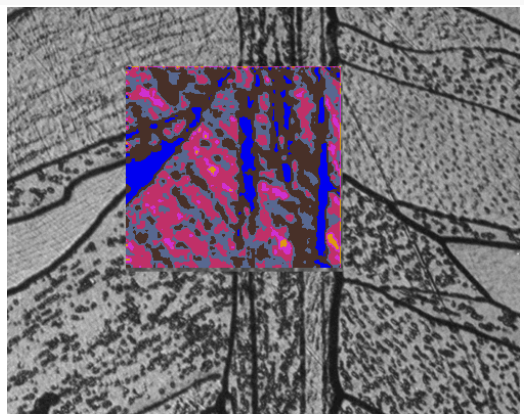


- Length scale compliments neutron residual stress (Hubbard, Payzant)

Polychromatic Microdiffraction allows Single Crystal Diffraction From Subgrains of Polycrystalline Materials

- Phase discrimination
  - spatial resolution to 0.3x0.4x0.7μm^3
- Orientation < 0.01°
  - Polycrystalline and layered structures
- Strain resolution below 10^{-4}
  - Critical driving force behind mesoscale evolution
- Deformation distribution
  - Stored energy for mesoscale dynamics

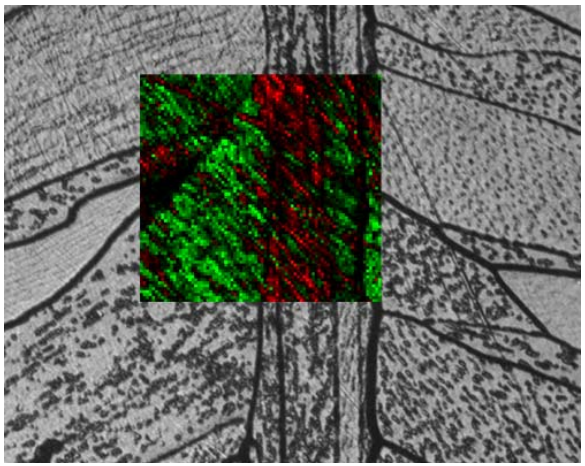




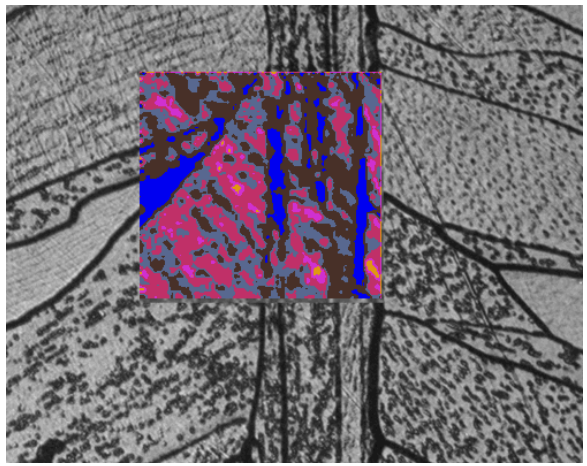
Relative Deformation in Grains at Weld

Chemistry to PPB

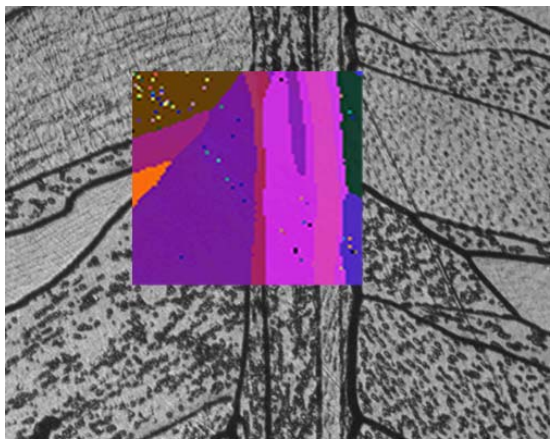
Contrast mechanisms characterize materials properties



Dislocation system

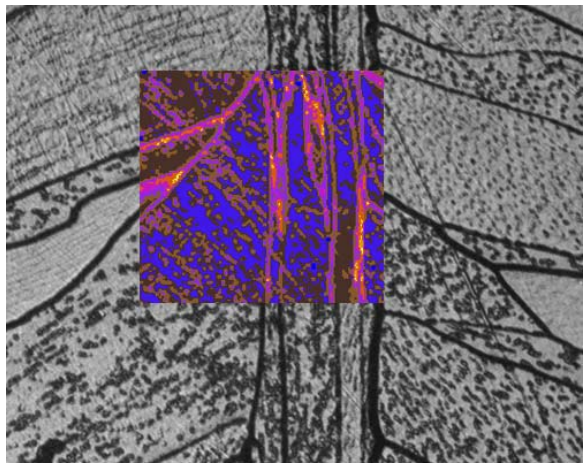


Number of unpaired dislocations



Grain orientation

240 μm



Real-time image