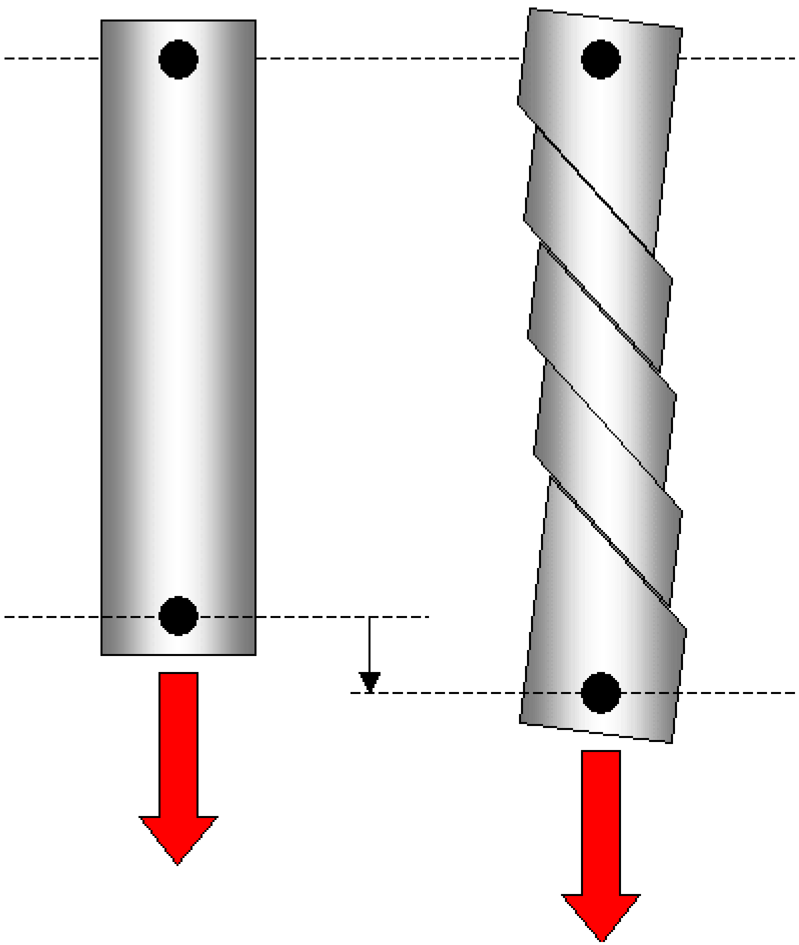
3.14 Lecture 3 Summary

21 September 2009

An Interesting Experiment

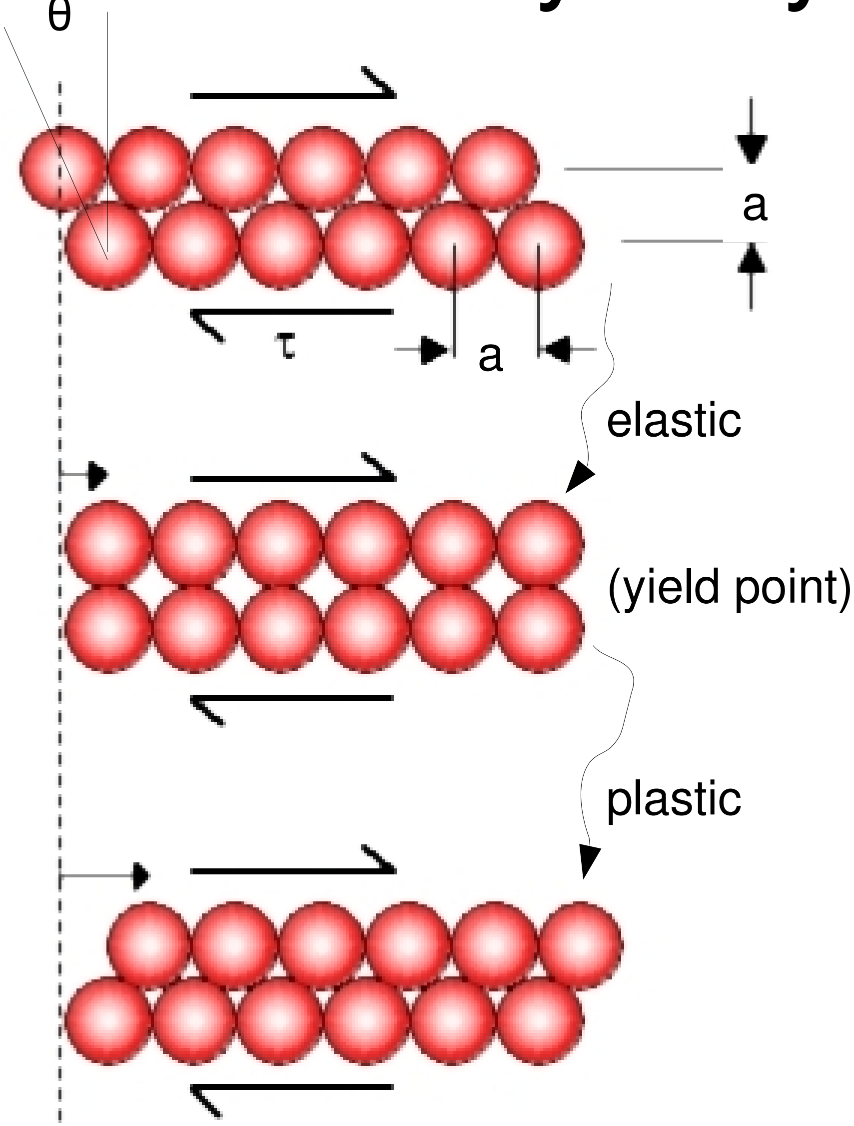


Courtesy of DoITPoMS, University of Cambridge. Used with permission.

- Take a single-crystal metal sample, and measure its stress-strain curve in tension
- Deformed sample exhibits slip steps
- The slip is always along crystallographic planes
- What is the slip mechanism?

<http://www.tf.uni-kiel.de/matwis/amat/def_en/index.html>

Initial (and incorrect) theory of crystal yield under shear



- Under shear stress, planes of atoms slide past one another, moving as a unit
- By Hooke's Law: $\tau = \mu \gamma$
- From the proposed geometry:
  $$\tau_y = \mu \gamma_y \simeq \mu \tan(\theta) = \frac{\mu}{\sqrt{3}}$$
- ~10^4 - 10^5 discrepancy between theory and experiment!
- There **must** be a lower-energy way to shear the lattice

<http://www.tf.uni-kiel.de/matwis/amat/def_en/index.html>

Crystal yield under shear (how it really happens)

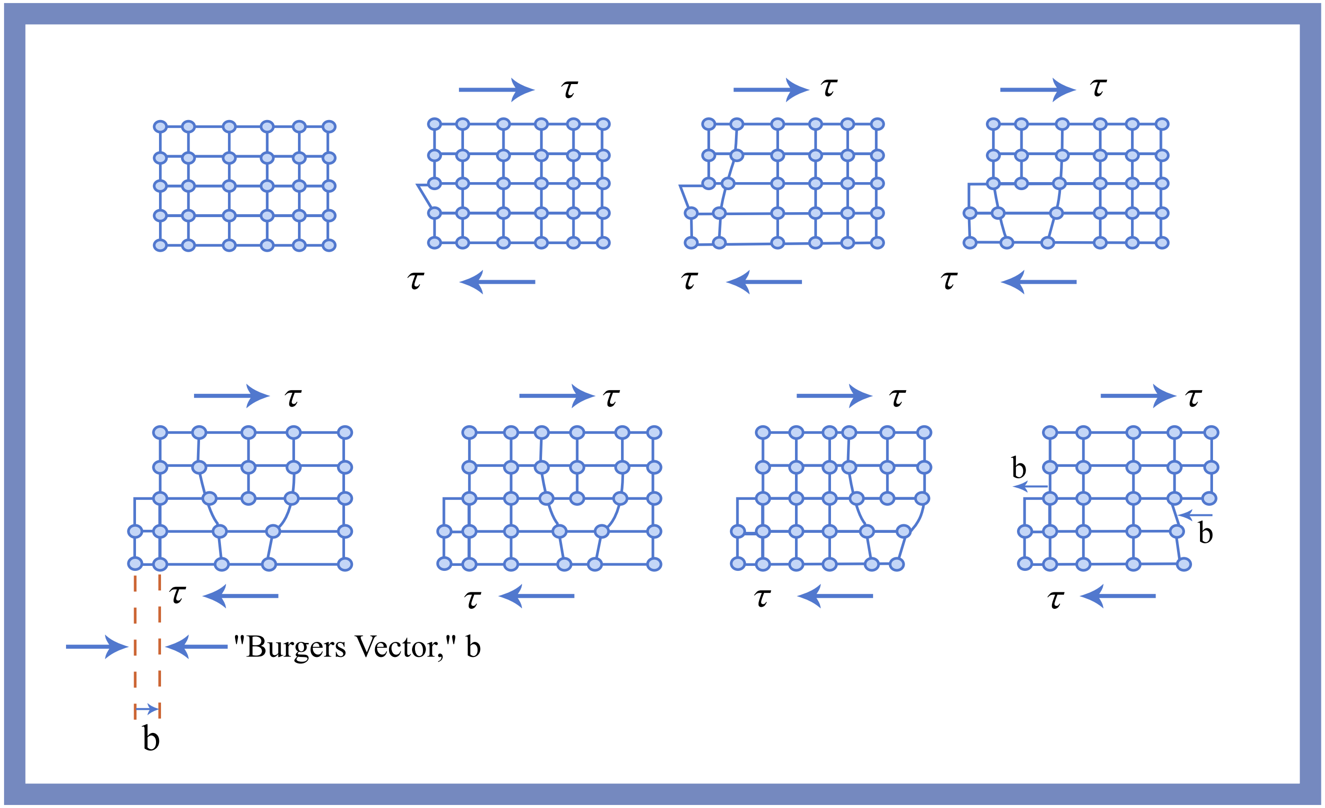
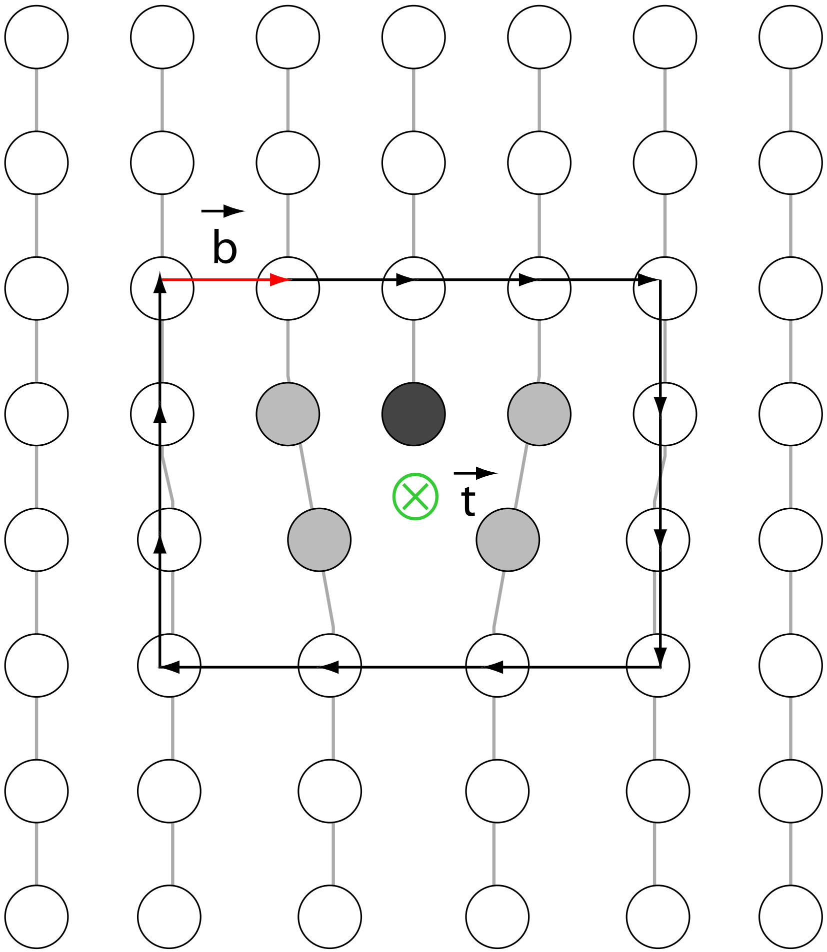


Figure by MIT OpenCourseWare. Adapted from Fig. 9.4 in Ashby, M. F., and D. R. H. Jones. *Engineering Materials 1*. Boston, MA: Elsevier Butterworth-Heinemann,2005.

- The dislocations generates a local strain field that makes it easier to shear the lattice
- Displacement ripples through the crystal, moving one column at a time

<http://courses.eas.ualberta.ca/eas421/lecturepages/microstructures.html>

The Burgers Vector (RHFS Convention)



- Define a line axis $\vec{t}$
- Construct a right-handed loop about $\vec{t}$
- $\vec{b}$ is the vector that heals the closure in the finish-to-start direction

<http://courses.eas.ualberta.ca/eas421/lecturepages/microstructures.html>

Dislocation Characteristics

- Have a single, constant $\vec{b}$ over their entire length
- Slip occurs always in the plane defined by $\vec{b}$ and $\vec{t}$
- Dislocation characterized by $\vec{b}$ and $\vec{t}$ together, not just by $\vec{b}$ alone
- Dislocations cannot terminate in a crystal

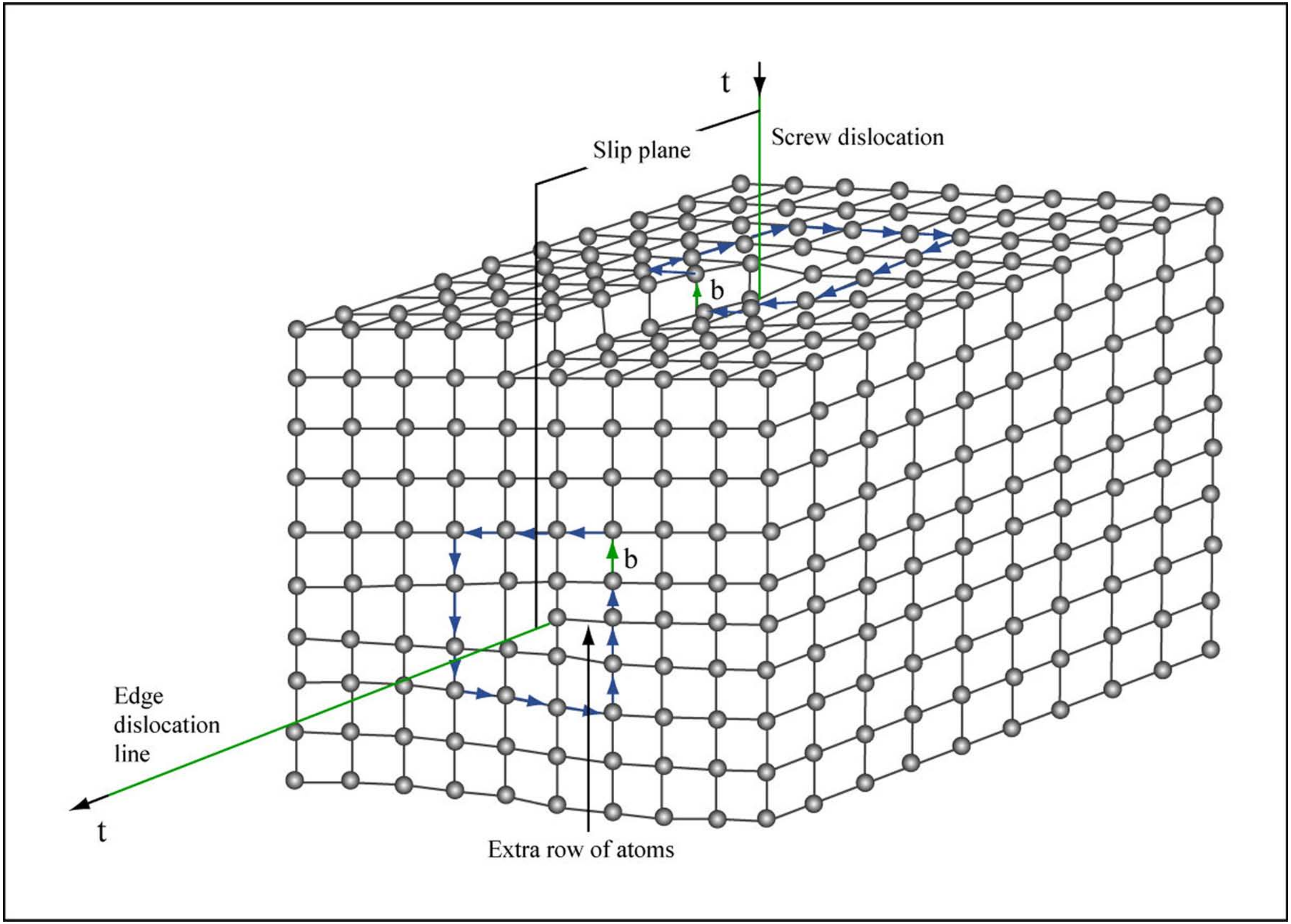
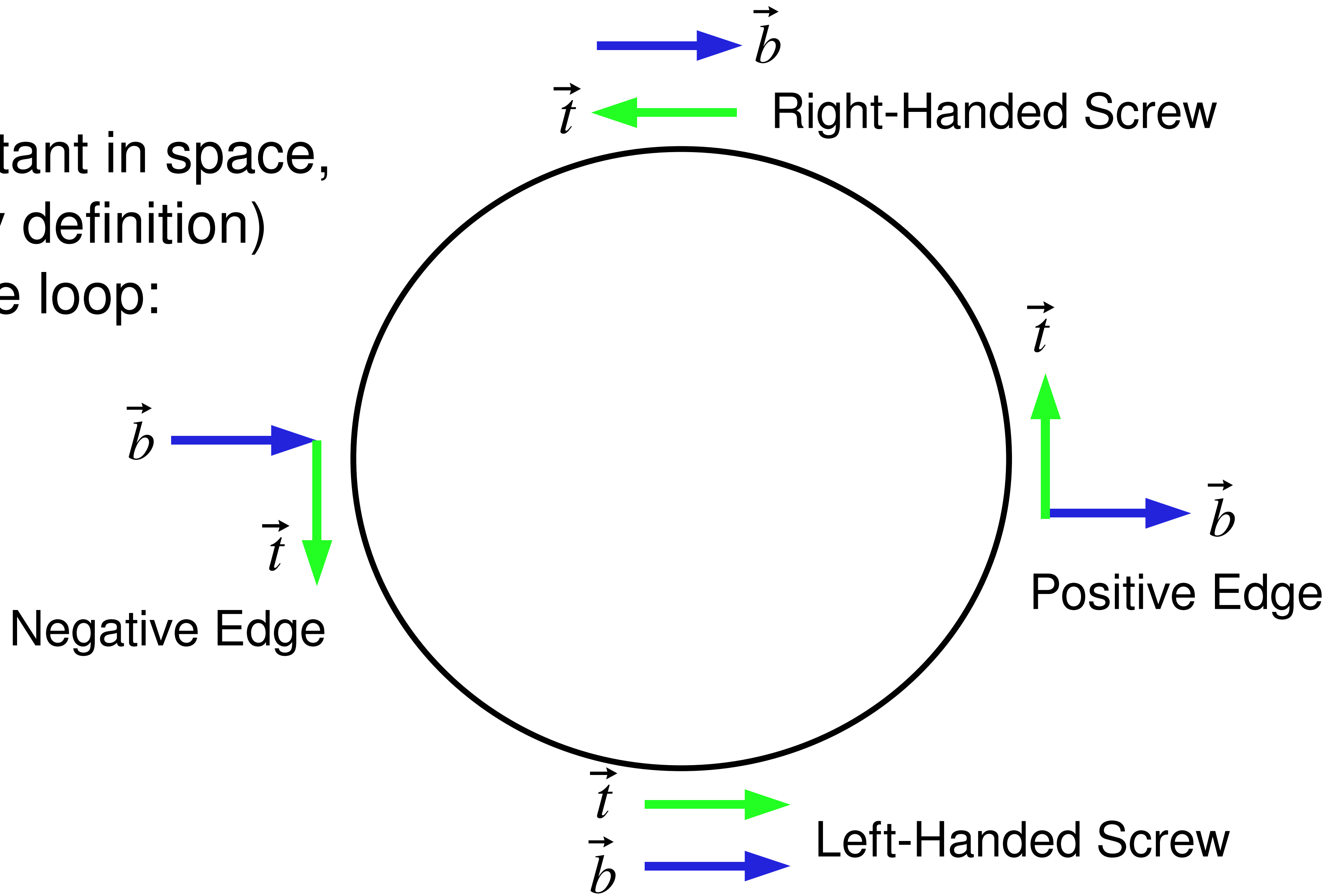


Figure by MIT OpenCourseWare.

Adapted from <http://courses.eas.ualberta.ca/eas421/lecturepages/microstructures.html>

Loop Dislocation

$\vec{b}$ is constant in space, and $\vec{t}$ (by definition) follows the loop:



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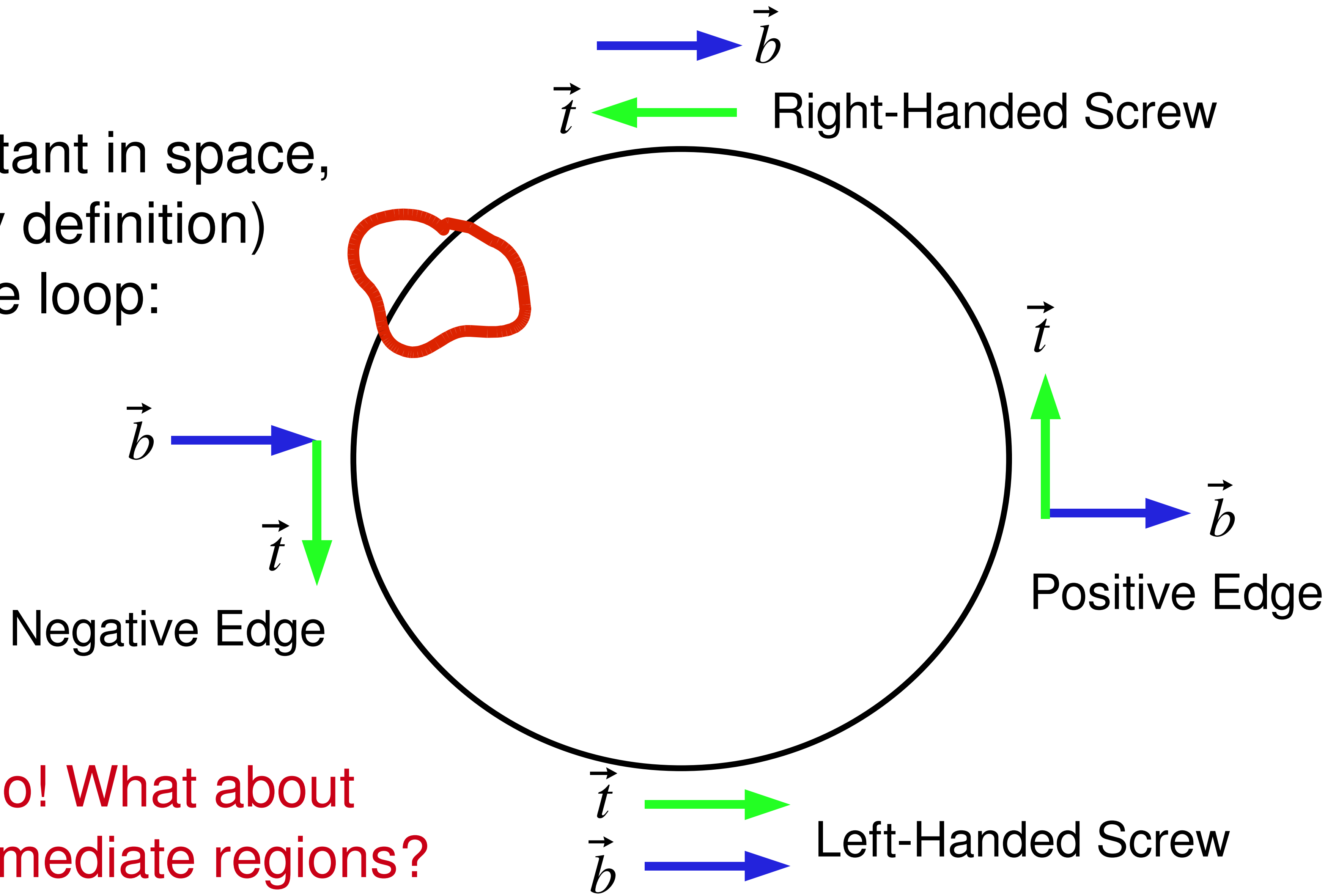
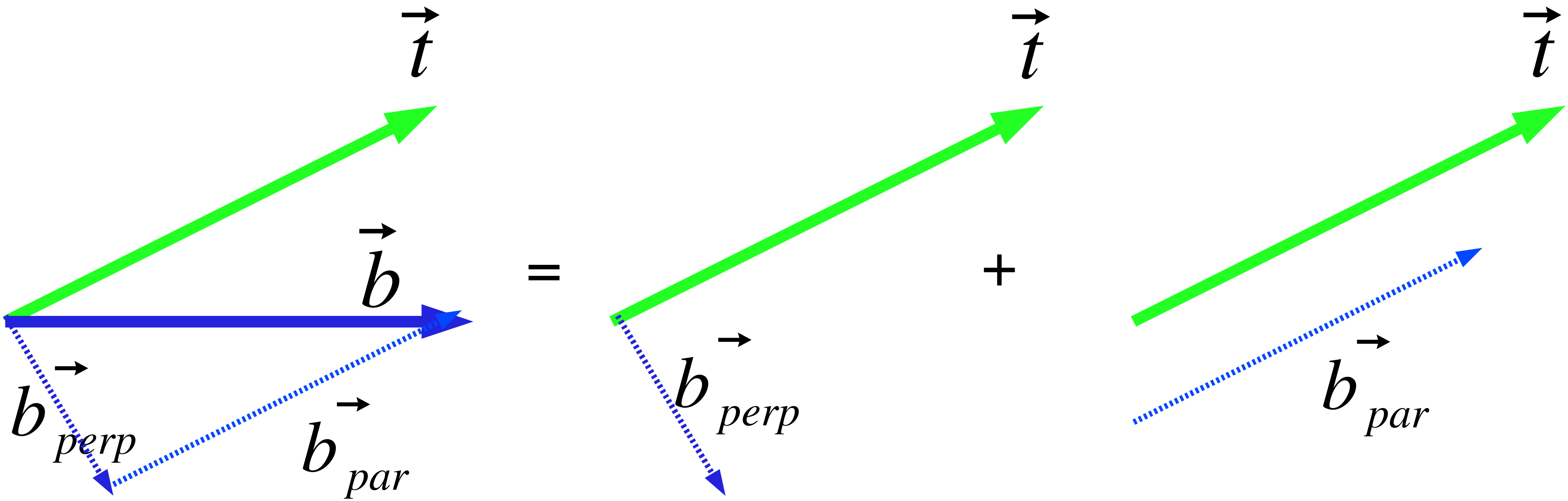
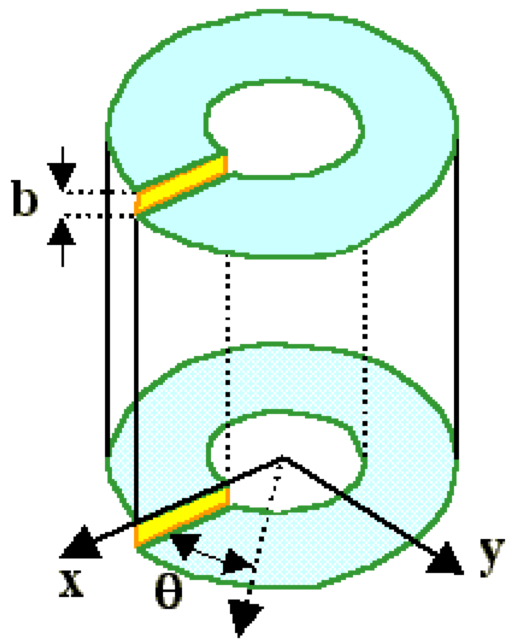


But oh no! What about the intermediate regions?

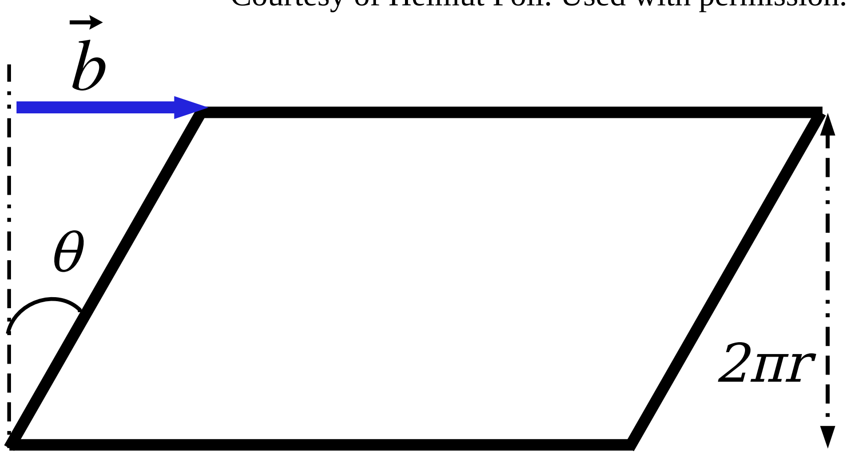
- Mixed dislocations: when $\vec{b}$ and $\vec{t}$ are neither parallel, antiparallel, or perpendicular
- Characterize them by decomposing $\vec{b}$ into parallel and perpendicular components



Stress-Strain around Dislocations



Courtesy of Helmut Föll. Used with permission.



- Displacement → strain → stress → energy
- Construct a cylinder around the dislocation axis
- Unwrapping the cylinder produces a parallelogram
- $\gamma_{rz}^{screw} = \dfrac{b}{2\pi r} = \gamma_{zr}^{screw}$

$$\underset{\sim}{\gamma} = \begin{bmatrix} \gamma_{rr} & \gamma_{zr} & \gamma_{\theta r} \\ \gamma_{rz} & \gamma_{zz} & \gamma_{\theta z} \\ \gamma_{r\theta} & \gamma_{z\theta} & \gamma_{\theta\theta} \end{bmatrix}$$

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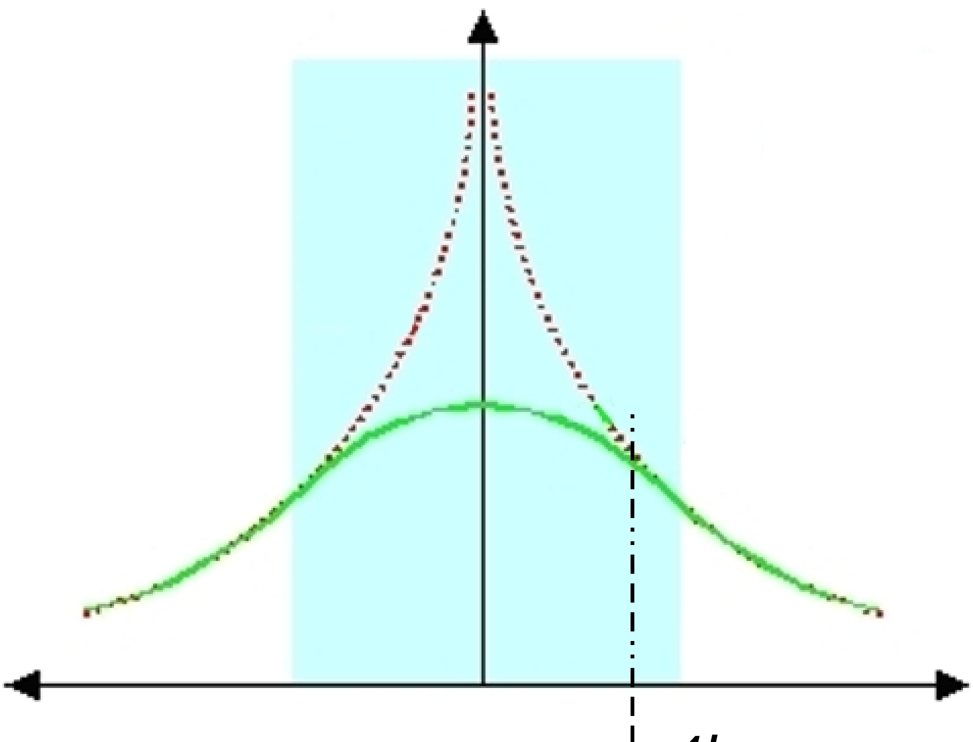

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