Diffraction contrast imaging

Lecture 12 Part 1

Review: Planar faults

Strain fields - generally

Dislocations

Coherent precipitates

Strain fields

As with planar faults, strain fields also introduce changes in the location of atoms within the crystal

In other words, any strain field introduces an $\vec{R}(\vec{r}_n{}')$, where:

Location of defective unit cell

$$\vec{r}_n{}' = \vec{r}_n + \vec{R}_n$$

Regular lattice positions

Displacement function

With planar faults, the shift between one lattice and the next is single valued

What happens if the strain field is continuous?

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Dislocations

A dislocation is a line defect which bounds one region of a crystal that has slipped with respect to another

Is thus the crystal defect that mediates plastic (irreversible) flow in a crystal

The slip that occurs is a discrete increment of lattice translation

- This slip increment has both a magnitude & a direction
- It can be described by a vector (called it's Burgers vector)
- It can be either a full or partial lattice vector

Dislocations

Parameters of interest:

- Burgers vector: want to characterize both magnitude & direction
- Line direction: what crystallographic direction does the dislocation line lie along
- Slip (or glide) plane: what plane does the dislocation move along when a stress is applied

Additionally:

- How does it interact with other dislocations & defects?
- Is the dislocation straight, jogged or kinked?

Why do we care?

- These parameters can (with other insights) be used to understand the characteristics of plastic deformation in a material

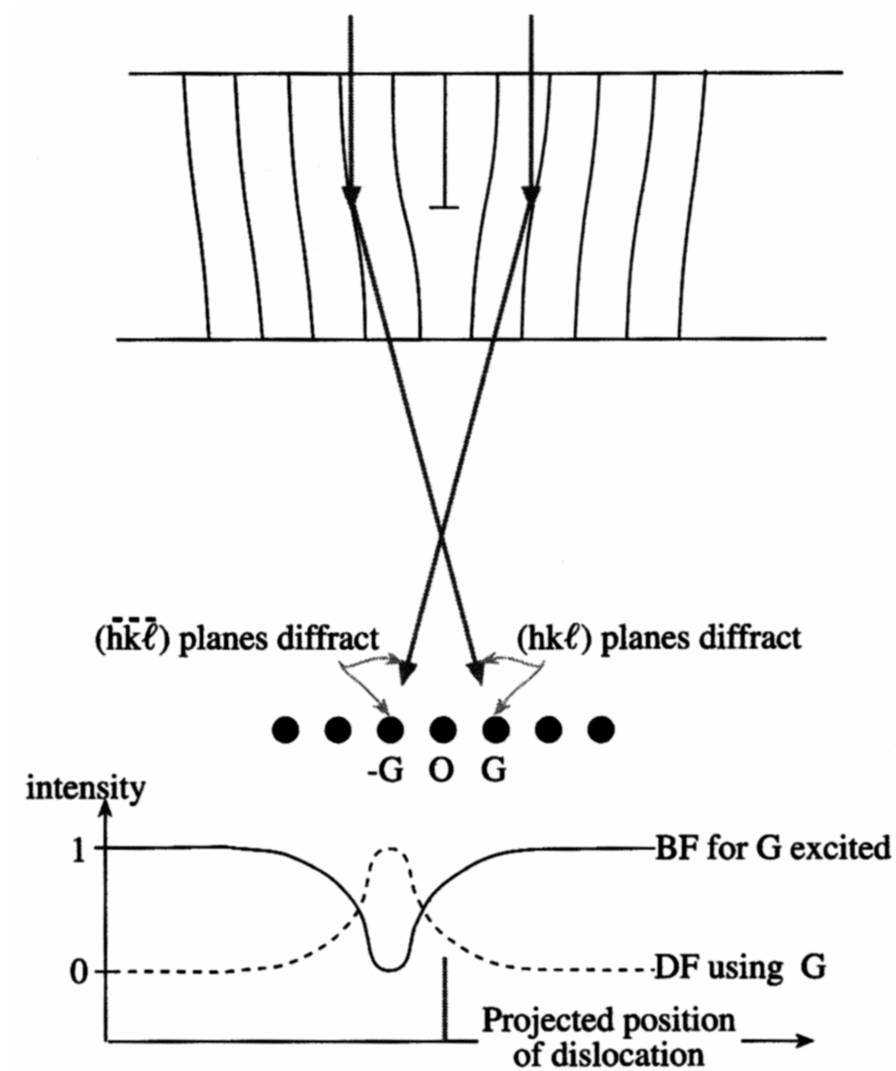
Dislocations

Edge dislocations

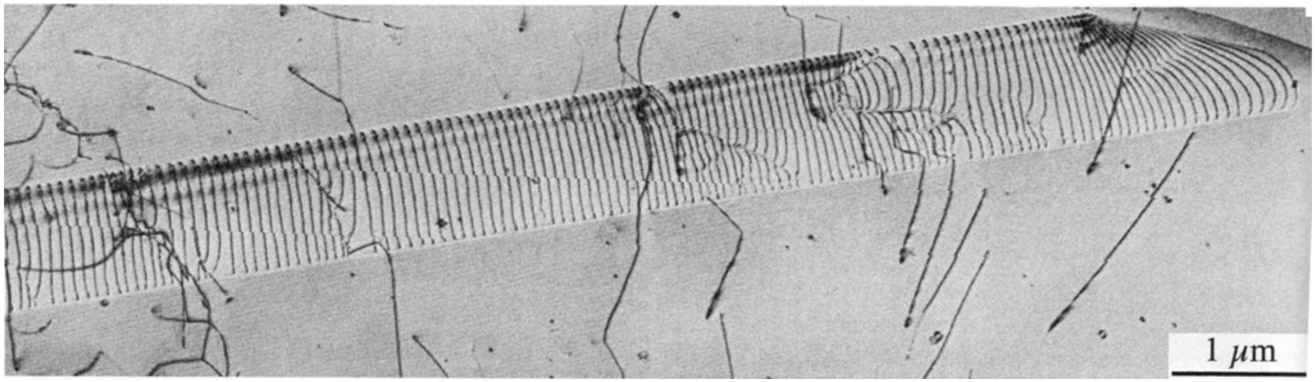
- Extra 'half plane' present in the sample
- $\vec{b} \perp \vec{u}$
- Slip confined to a plane that contains both $\vec{b}$ & $\vec{u}$

Any dislocation introduces distortion (strain!) in the lattice

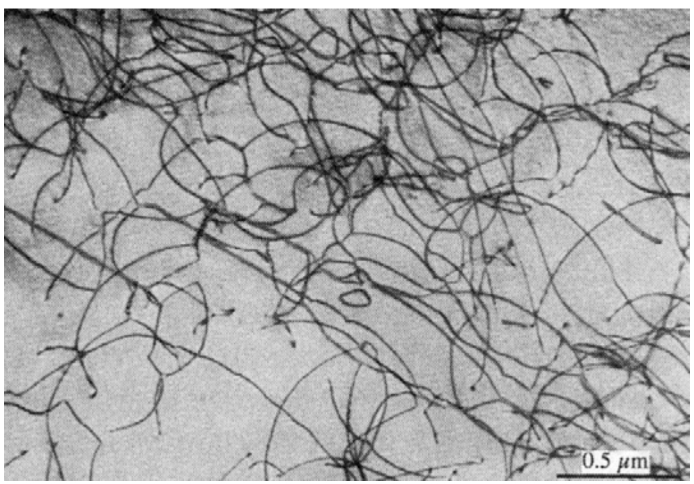
It is this distortion & the local changes in diffraction condition that we image



Dislocations interactions & tangles

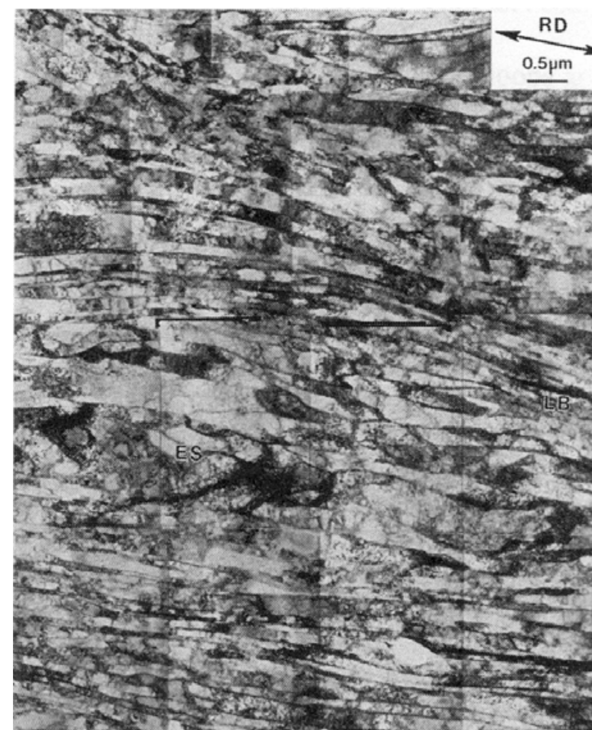


HVEM Image of slip along an inclined plane

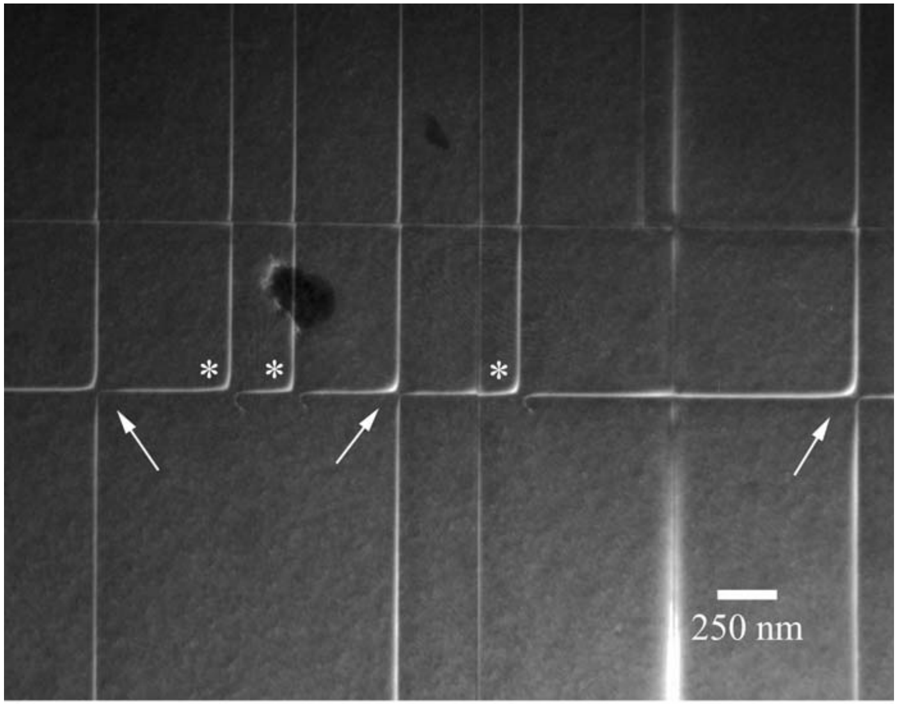


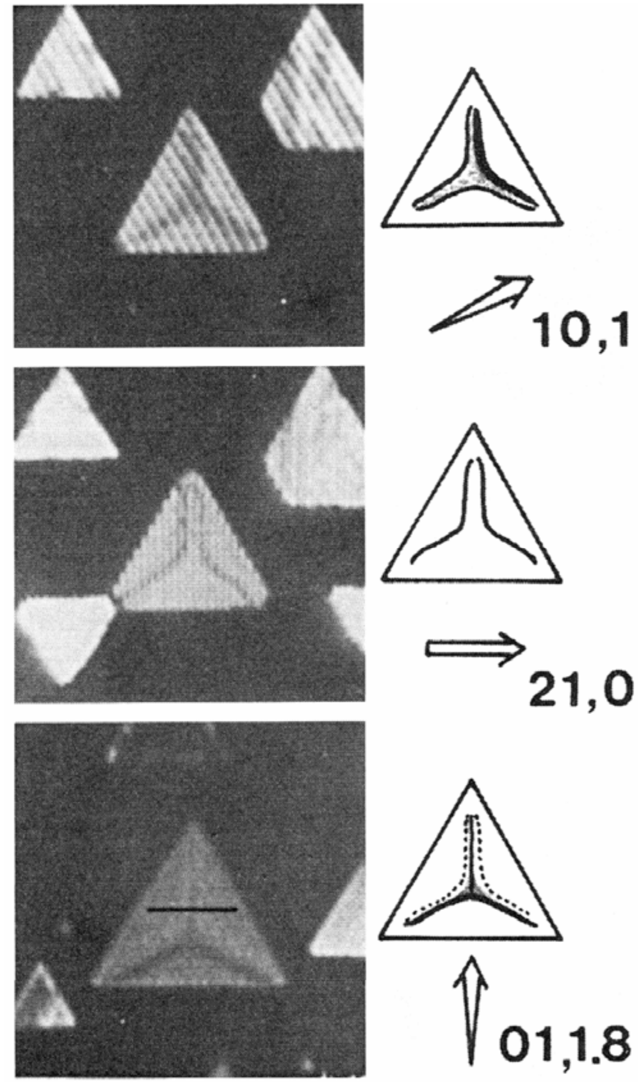
A complex dislocation tangle

Cold rolled alloy



Surface effects & interfaces





Interface misfit dislocations are a common class of defects to image

Be aware of surface relaxation effects (i.e $\vec{g}\cdot\vec{b}\times\vec{u}\neq 0$)

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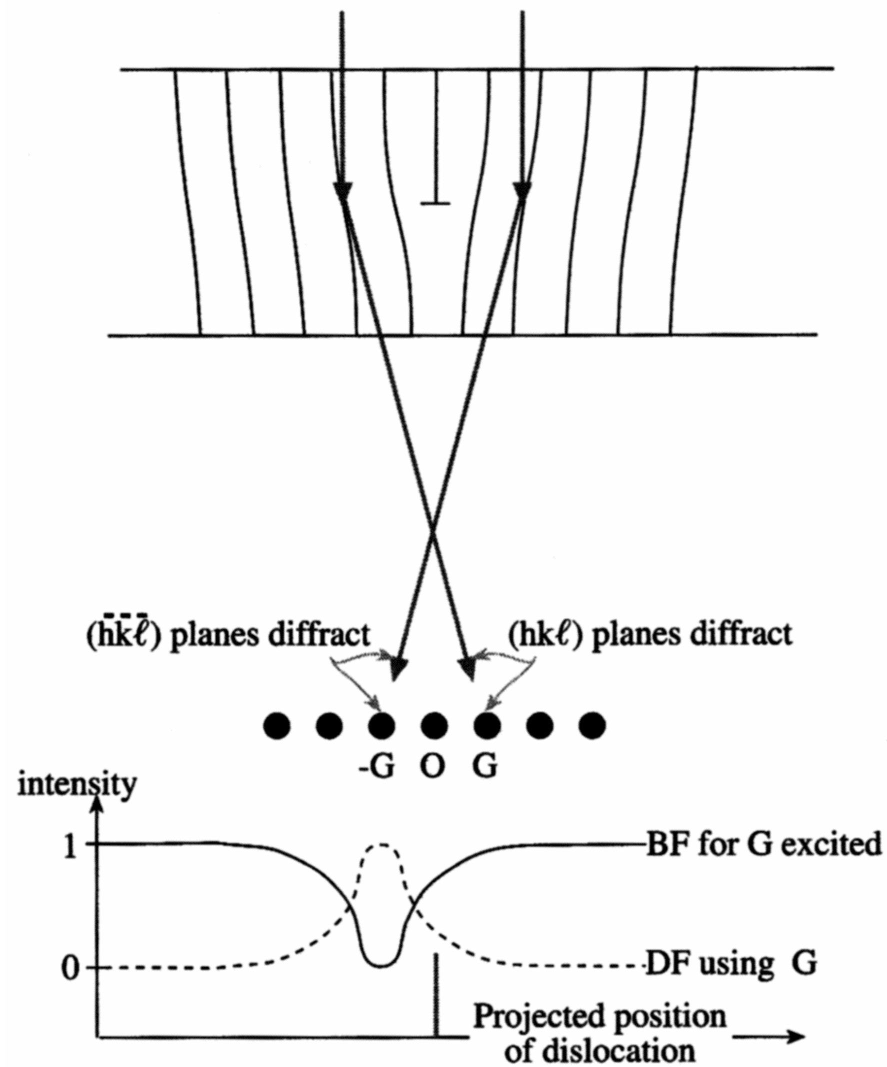

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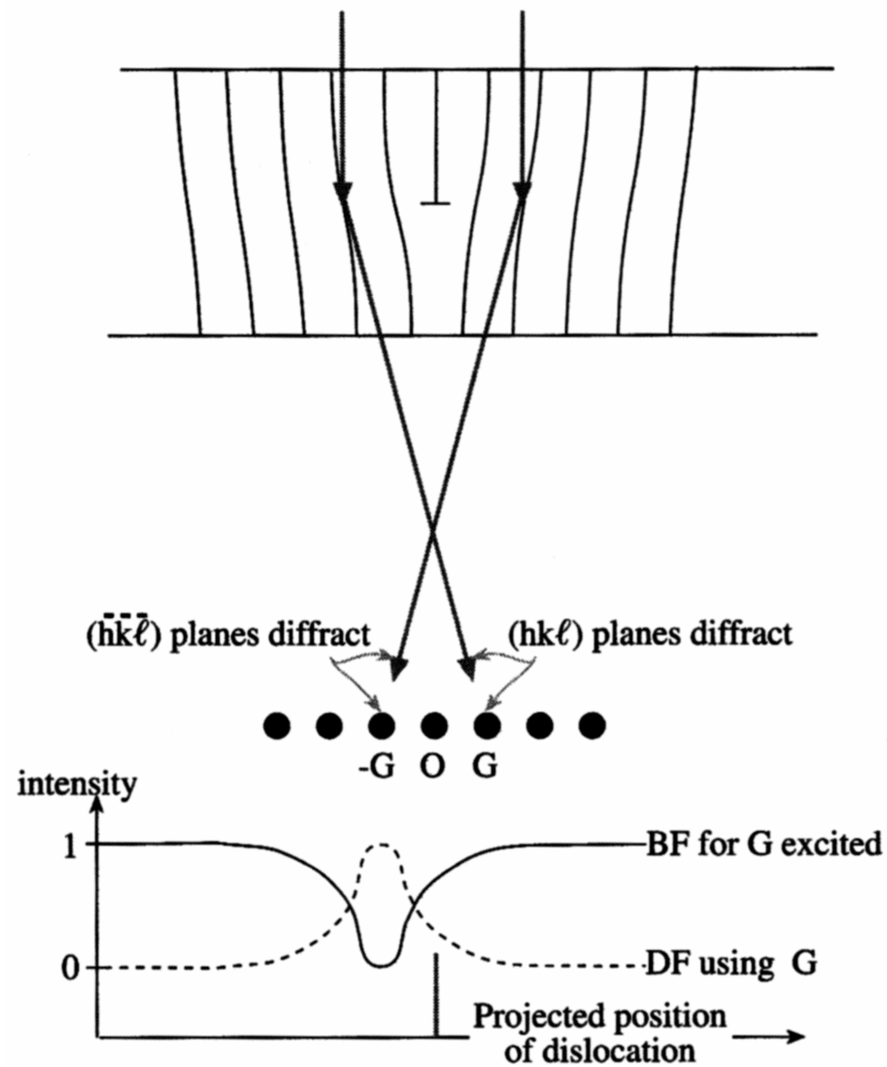

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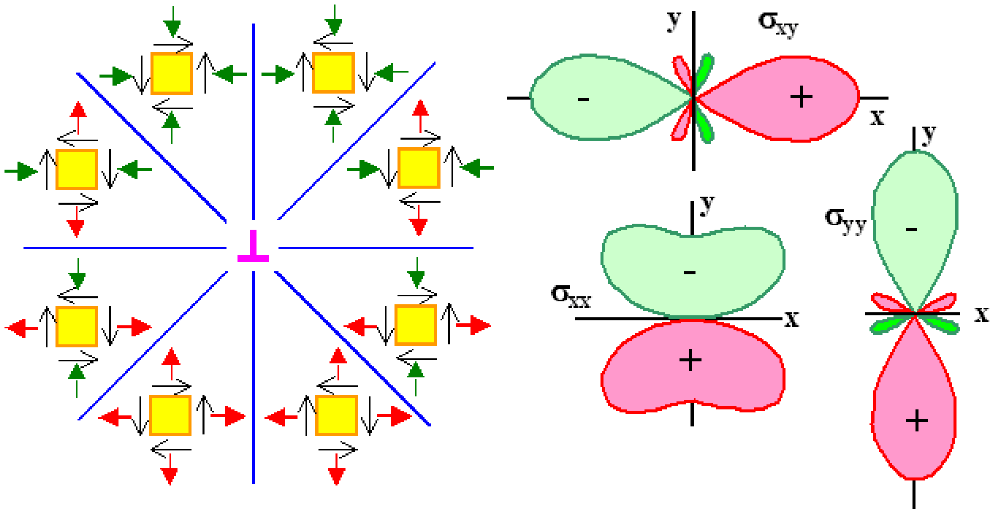


This shows conceptually (left) and fully (right) the strain field around a perfect edge dislocation

The strain field around screw and mixed are a bit more complicated to display …

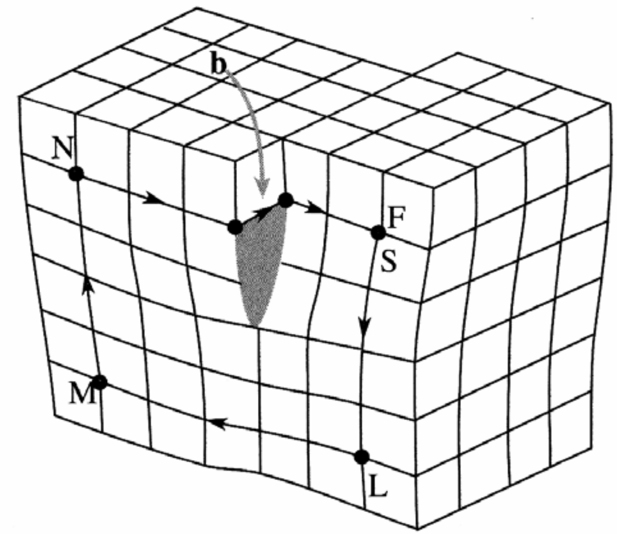
Dislocations

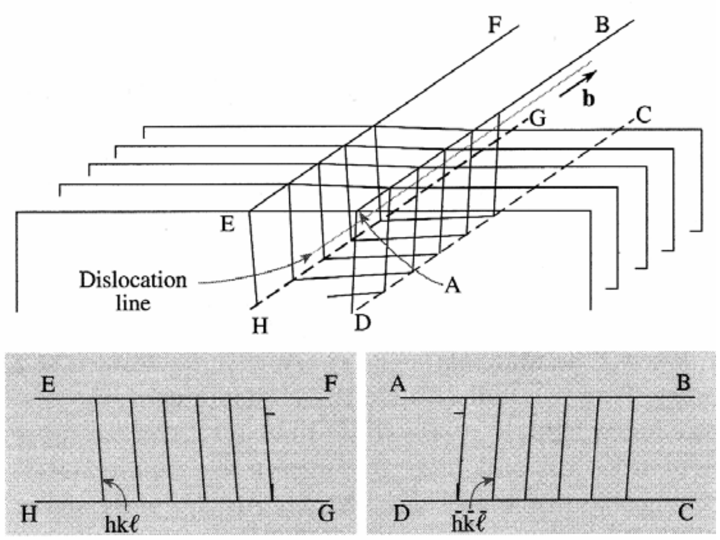
Screw dislocation

- $\vec{b} \parallel \vec{u}$
- Can slip along any plane
- Again, we image the strain field

Mixed dislocation

- $\vec{b}$ neither perpendicular nor parallel to $\vec{u}$
- Thus, each mixed dislocation can be resolved into edge components and screw components

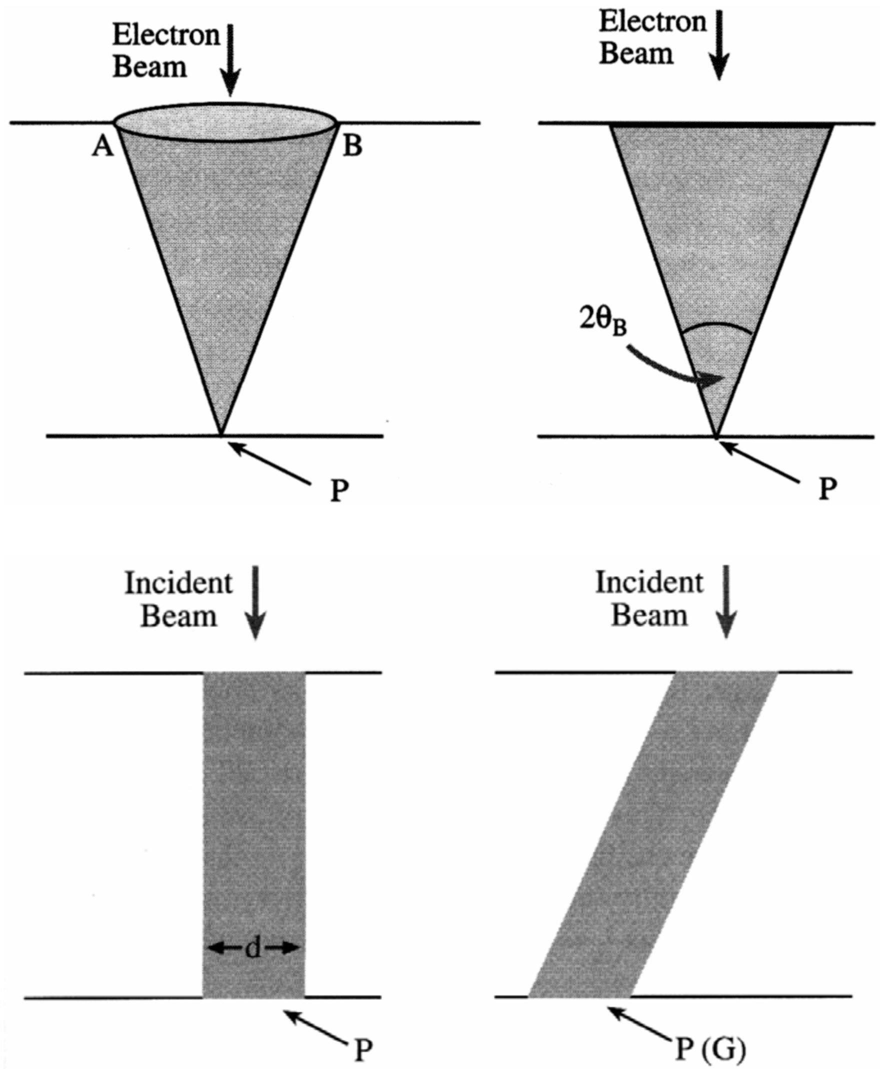




Calculating dislocation contrast

We use the "column approximation"

This is where we said we'd ignore variations in dz with changes in z



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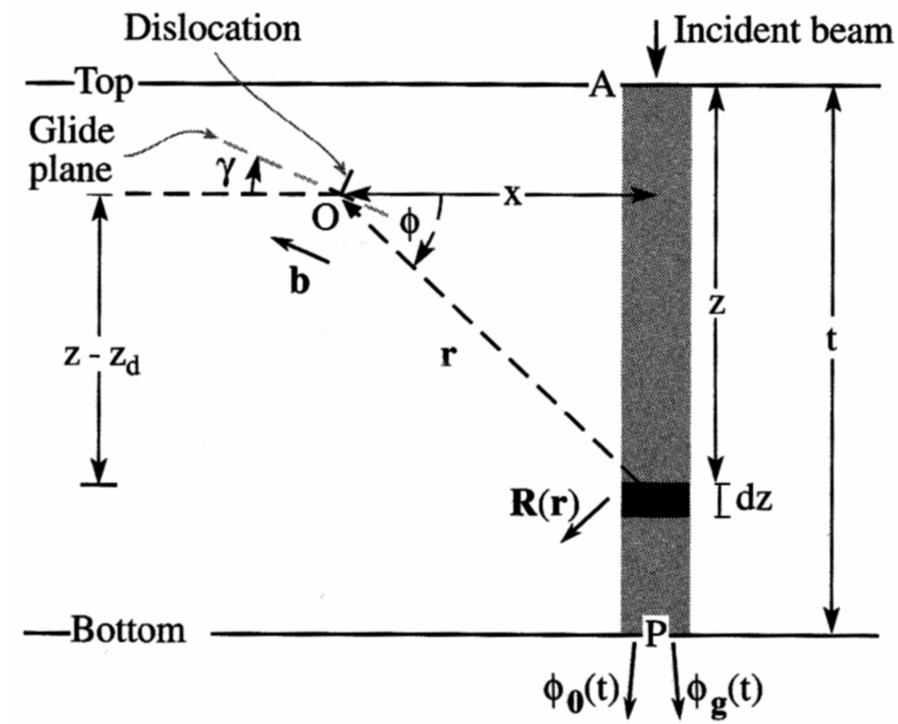
So, divide the sample into narrow columns



Calculate the amplitude of ϕ_o and ϕ_g for each column

What is R?

- Need to go to elasticity theory
- Find:

$$\vec{R} = \frac{1}{2\pi}\left\{\vec{b}\phi + \frac{1}{4(1-\nu)}\left[\vec{b}_e + \vec{b}\times\vec{u}\left(2(1-2\nu)\ln r + \cos 2\phi\right)\right]\right\}$$

- Or if doing computationally, use anisotropic elasticity theory, or simulation output

Dislocation contrast

Consider a pure screw dislocation:

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$$\vec{R} = \vec{b}\frac{\phi}{2\pi} = \frac{\vec{b}}{2\pi}\tan\left(\frac{z - z_d}{x}\right)$$

So: $\vec{R} \propto \vec{b}$

Thus: $\vec{g}\cdot\vec{R} \propto \vec{g}\cdot\vec{b}$

“g dot b” contrast

Table 25.1. Different Burgers Vectors and Different Reflections Give Different g·b = *n* Values[a]

g \ b	$\frac{1}{6}[11\bar{2}]$	$\frac{1}{6}[1\bar{2}1]$	$\frac{1}{6}[\bar{2}11]$	$\frac{1}{3}[111]$
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±(200)	± 1/3	± 1/3	± 2/3	± 2/3
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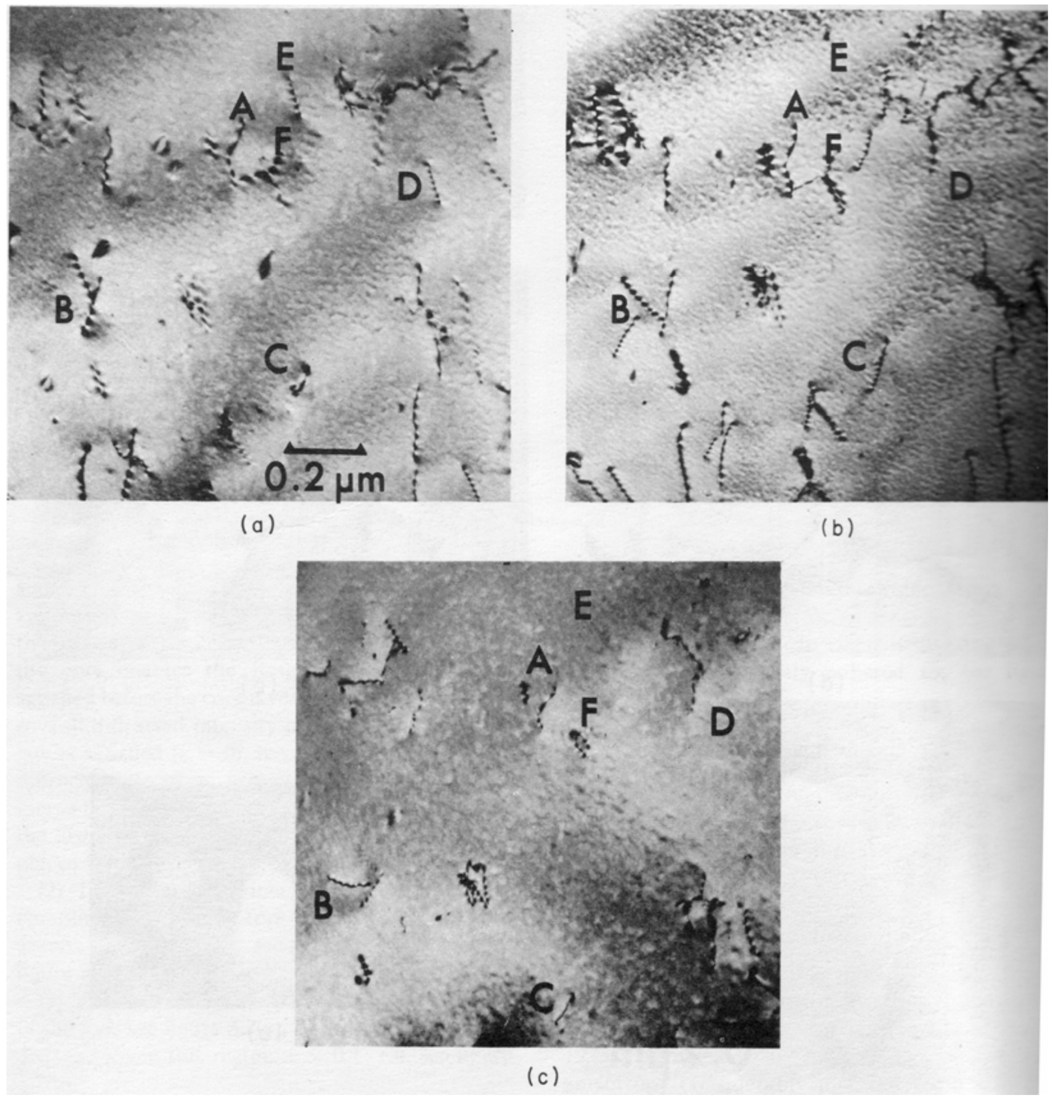

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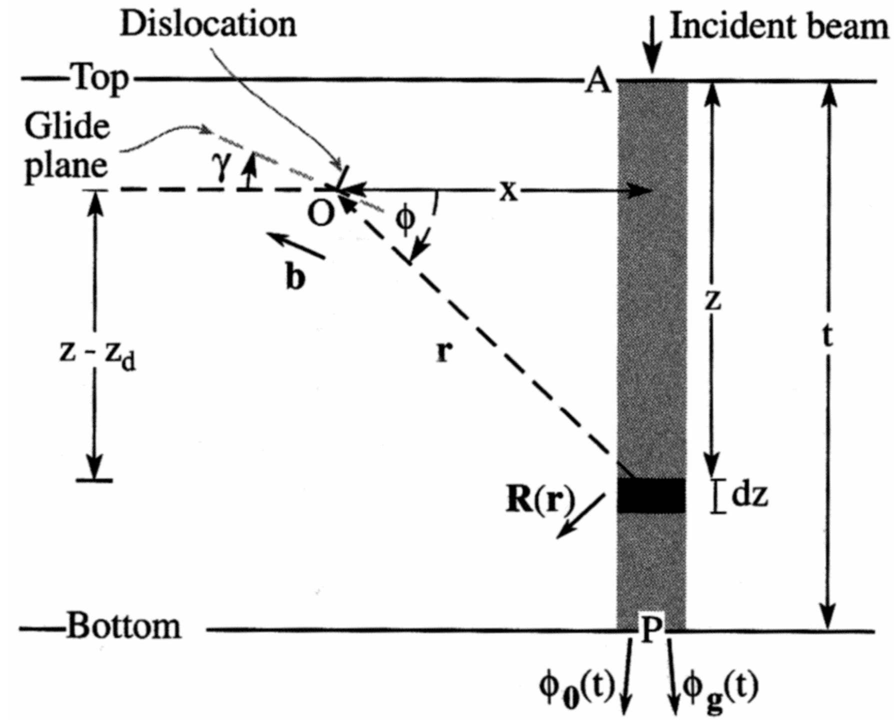
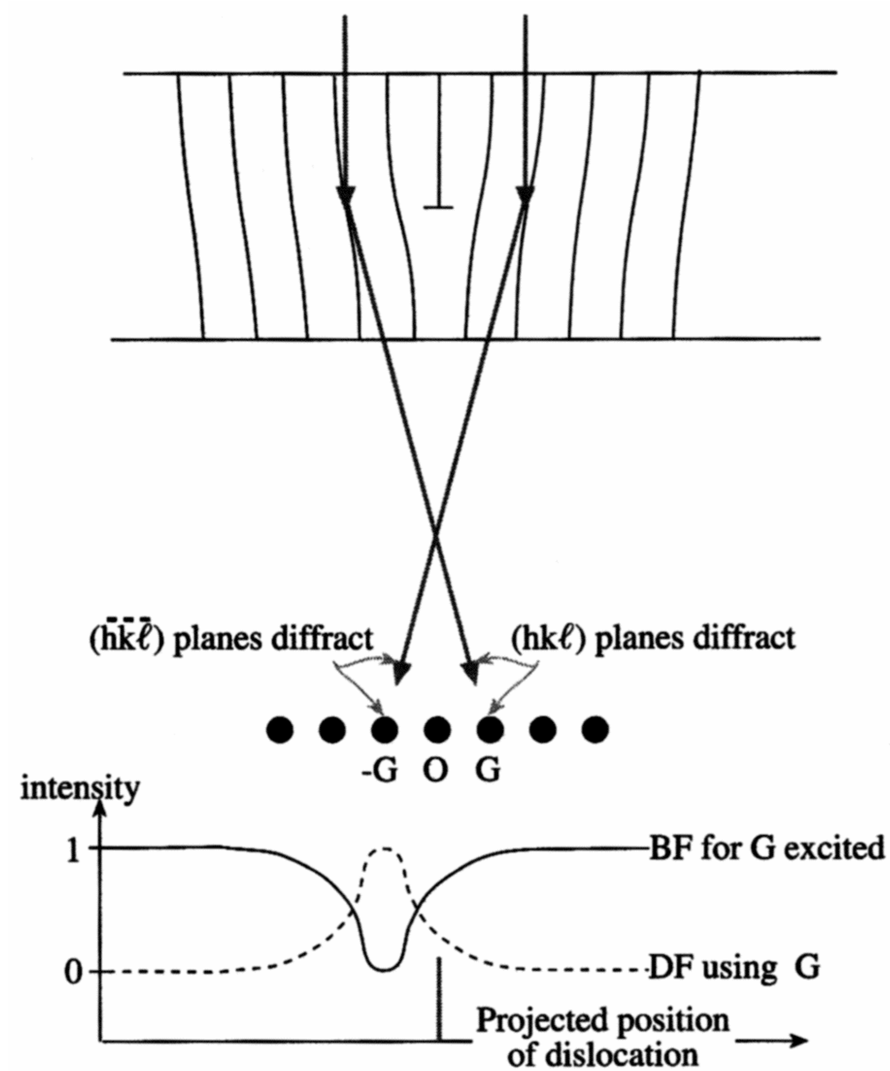


Dislocation contrast

Now for pure edge

$$\vec{b} = \vec{b}_e \;\; ; \;\; \vec{b}_e \times \vec{u} \neq 0$$

So R has both a $\vec{g} \cdot \vec{b}$ & a $\vec{g} \cdot \vec{b} \times \vec{u}$ term



More on 'g dot b' contrast

Often said that when $\vec{g} \cdot \vec{b} = 0$ the dislocation is 'invisible'

This is because the lattice distortion is on diffracting planes parallel to R

– **You won't see it's effect**

Dislocation contrast

More to it (unfortunately)

Firstly, what is 'invisible'?

Generally if $\vec{g}\cdot\vec{b} < \frac{1}{3}$ the contrast is faint

More importantly, even if

$\vec{g}\cdot\vec{b} = 0$ can have $\vec{g}\cdot\vec{b}\times\vec{u} \neq 0$

So, really need to find conditions where both $\vec{g}\cdot\vec{b} = 0$ & $\vec{g}\cdot\vec{b}\times\vec{u} = 0$ if possible

May have to settle for $\vec{g}\cdot\vec{b} = 0$ & $\vec{g}\cdot\vec{b}\times\vec{u} \leq 0.64$