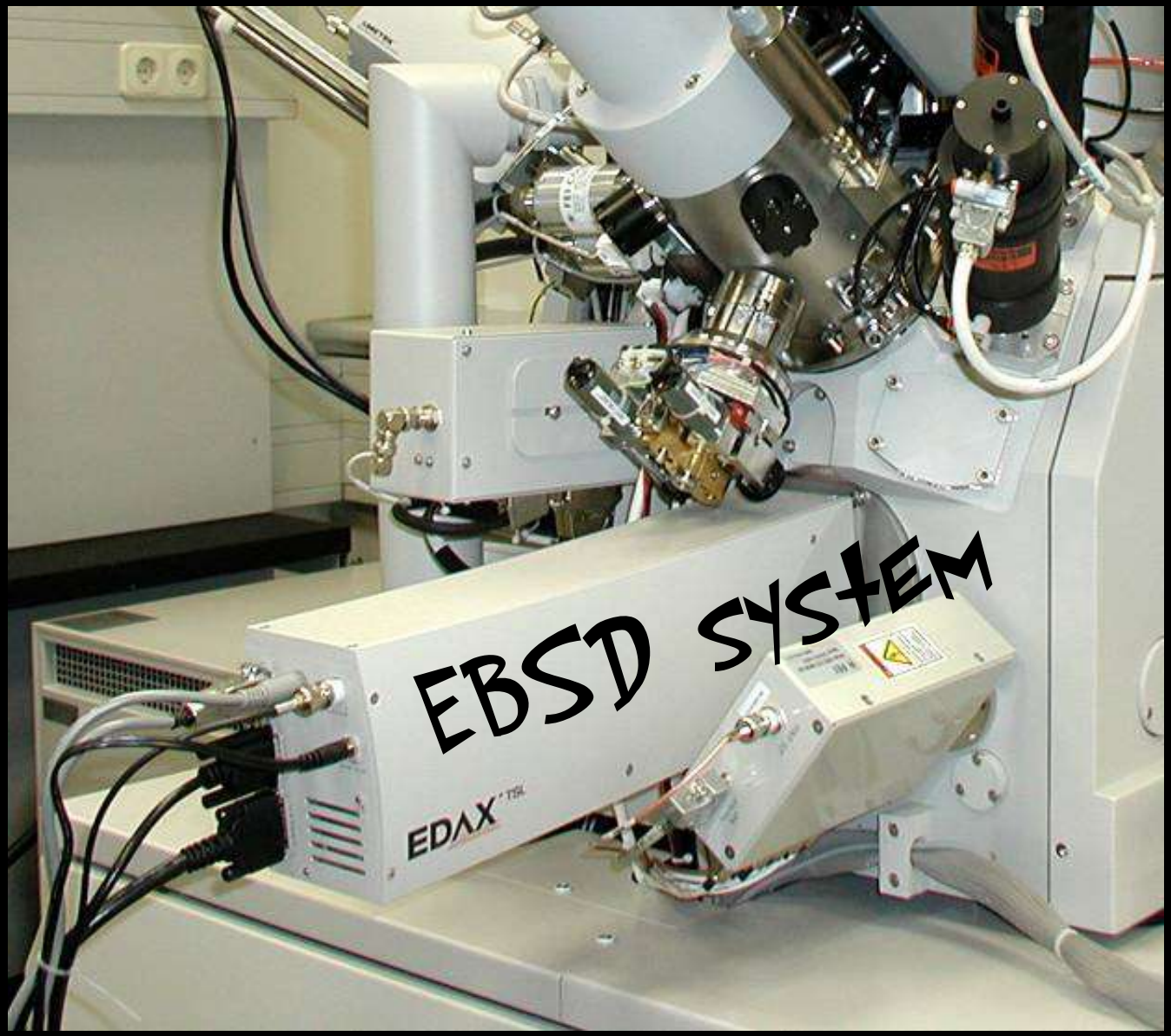
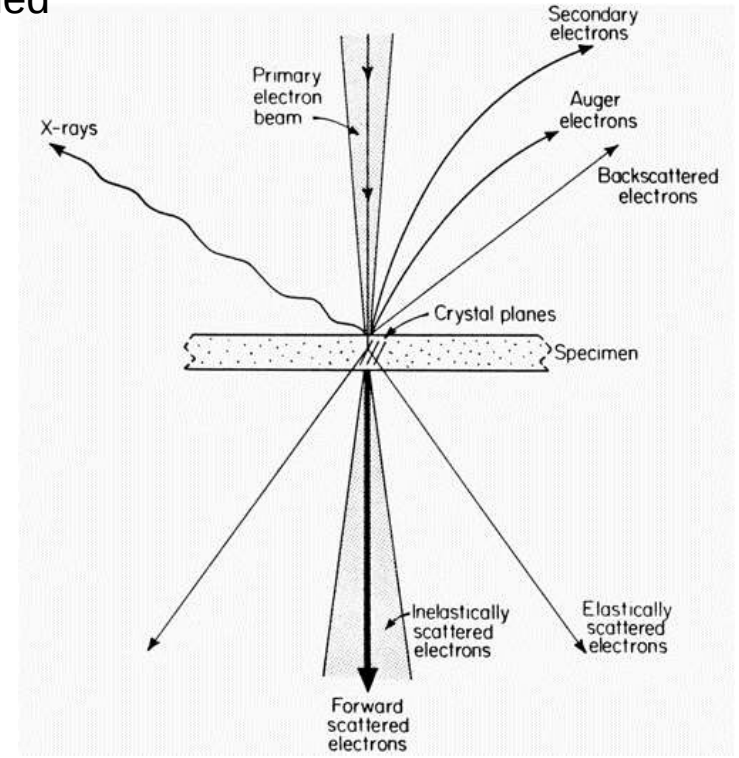

EBSD SYSTEM
EDAX

FEI Quanta 3D SEM/FIB

EBSD system

Between "products" caused by electron-matter interactions:

Elastically scattered electrons: No energy loss,
the *change in direction* is in the *order of degree*. In the case of a crystalline material, the direction is determined by Bragg's law.
TEM diffraction, TEM dark field image,
used by high resolution electron microscopy (HREM)



and

EBSD Electron BackScattered Diffraction
(visszaszórt elektron diffrakció)

EBSD – results of multiple processes: multiple scattering and interference

FEI Quanta 3D SEM/FIB

EBSD system

How It Works?

In case of a thin single crystal sample - diffraction dots (for slightly thicker - Kikuchi lines)

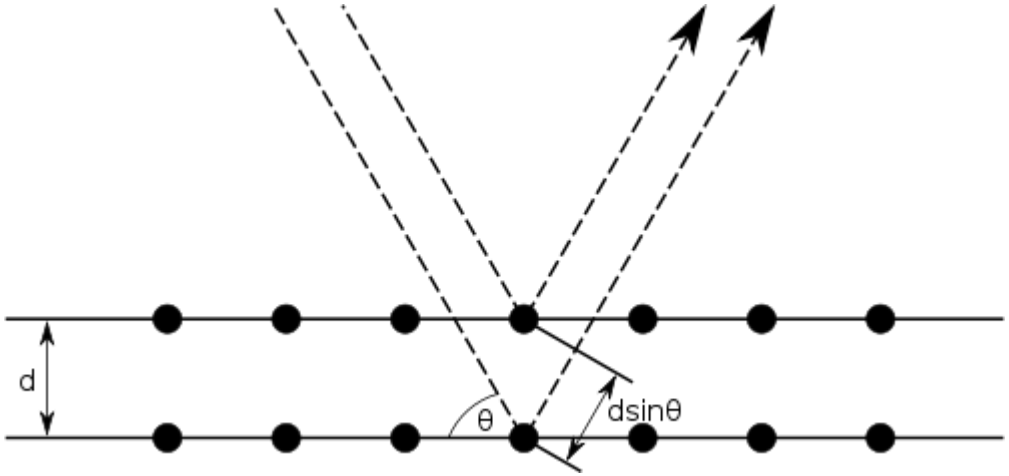
For thick sample and focused beam - Kikuchi bands

- elastic and low energy loss inelastic electron-electron collisions;
- electron Bragg scattering on the lattice planes

elastic scattering

interference

$$n\lambda = 2d \sin \Theta$$



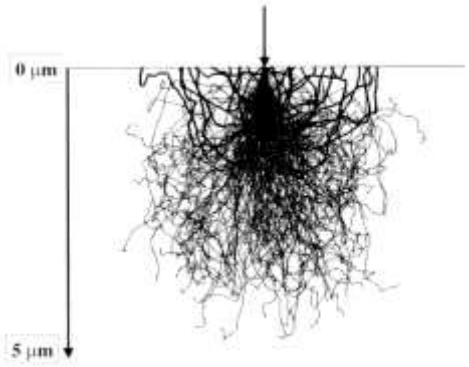
For 20 – 30 keV electrons λ is small $\Rightarrow$ Θ is small too

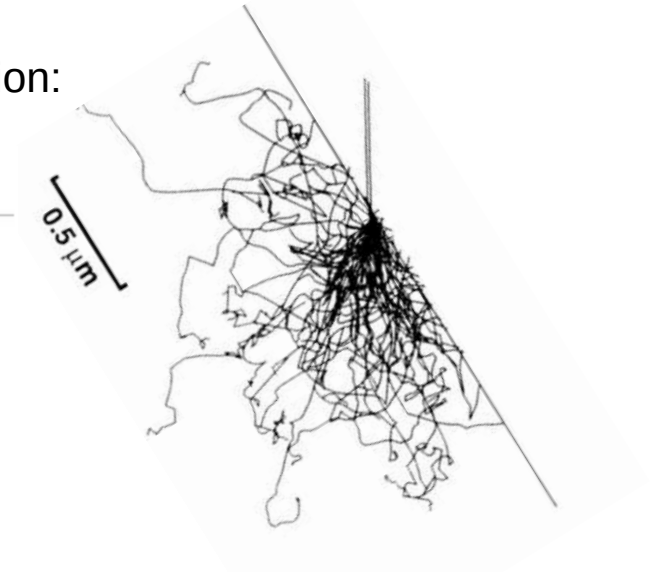
FEI Quanta 3D SEM/FIB

EBSD system

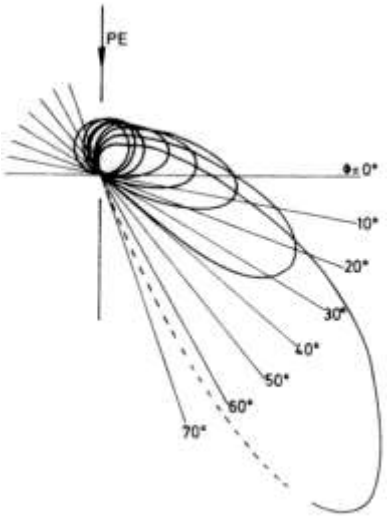
Optimization of excitation

Monte-Carlo simulation:





BSE yield :



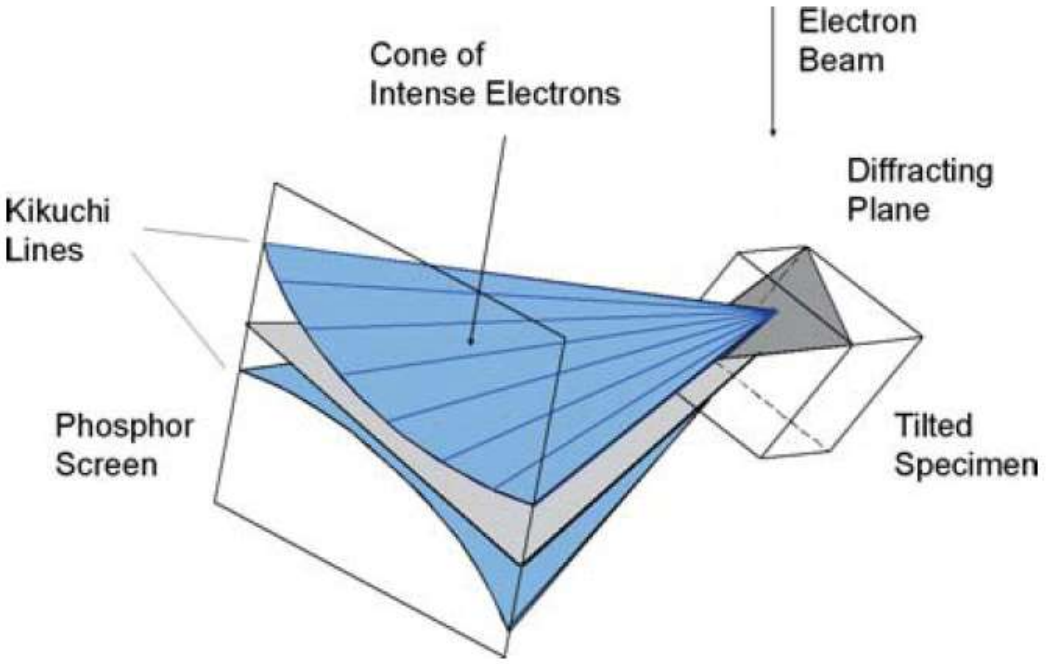
perpendicular excitation

oblique excitation

FEI Quanta 3D SEM/FIB

EBSD imaging

- Bragg diffraction in the upper 20 nm of the surface
- Kossel cones corresponding to the direction of Bragg reflections
- one band belongs to one diffraction plane system
- small phosphor screen relative to the radius of the cone
- Kikuchi bands
- it is a kinematic model - the dynamic one provides a more detailed explanation



FEI Quanta 3D SEM/FIB

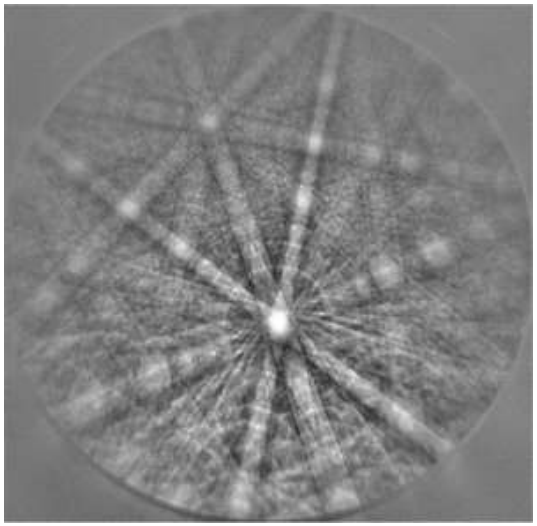
EBSD system

Hikari camera + software

- ***Hikari camera***
  - *vacuum side phosphor surface*
  - *special glass imaging optics;*
  - *advanced CCD chip.*

- ***Software (OIM 7.3)***
  - *fast EBSD data collection;*
  - *triplet indexing option - more accurate indexing;*
  - *integrated camera console;*
  - *adjustable image processing.*

- ***450 pps (indexed patterns per second) image capturing***



EBSD pattern – EBSP

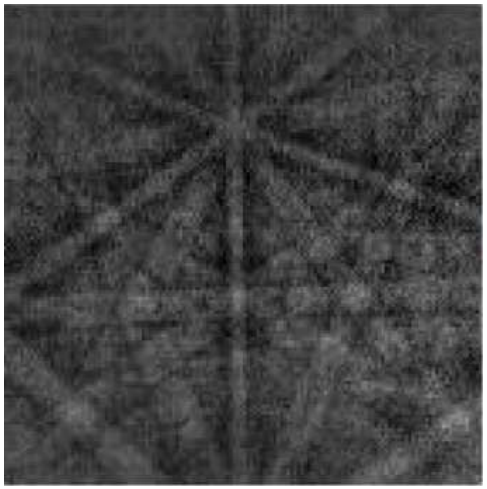
FEI Quanta 3D SEM/FIB

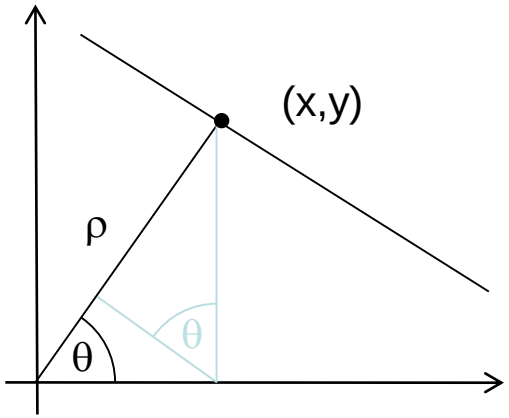
EBSD system

Band Detection

looking for bands – ***Hough transformation:***

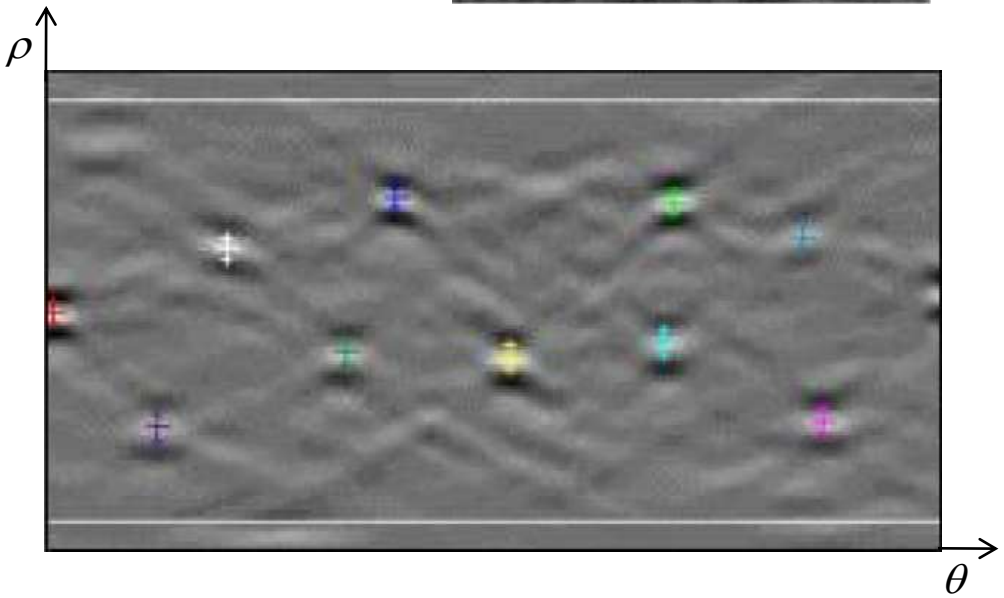
(x,y) plane → *(ρ,θ)* rectangle





$$I_{(\rho,\Theta)} = \sum_k I_{(x_k, y_k)}$$

$$\rho_i = x_k \cos\Theta_i + y_k \sin\Theta_i$$

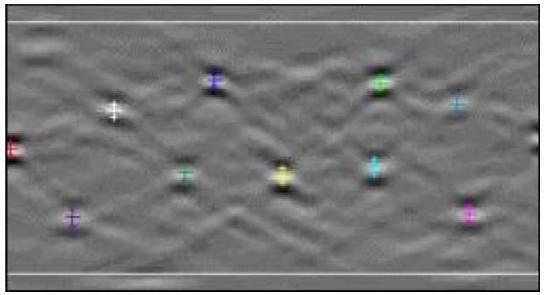


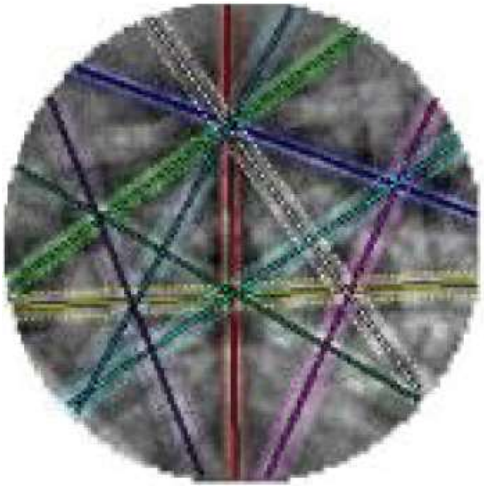
FEI Quanta 3D SEM/FIB

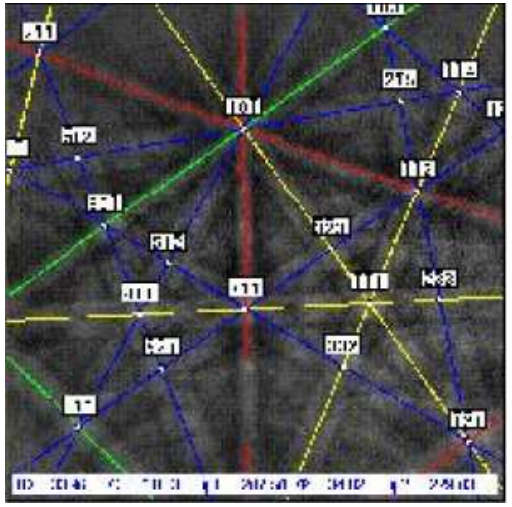
EBSD system

Phase identification I.

- Hough transformation;
- maxima -> bands;
- indexing (crystallographic data)





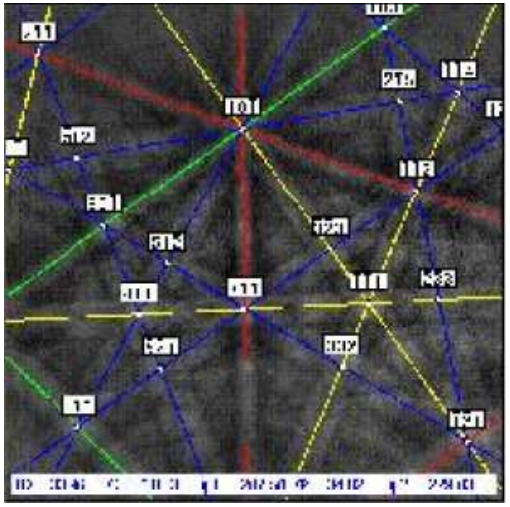


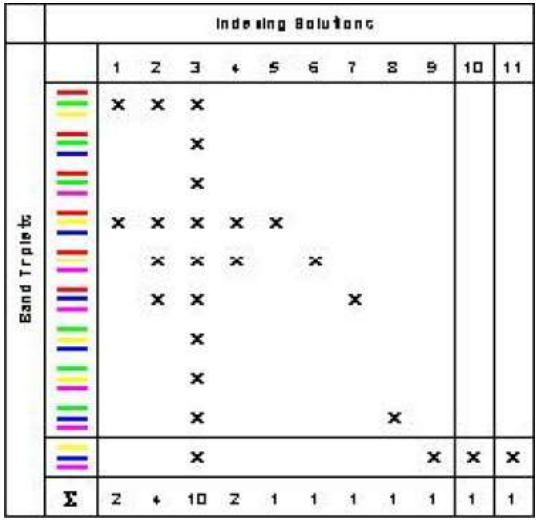
FEI Quanta 3D SEM/FIB

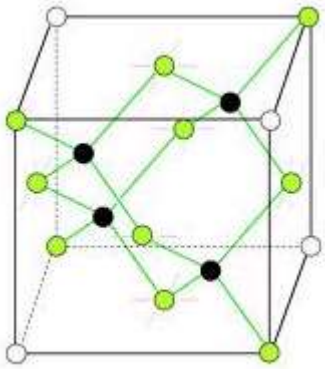
EBSD system

Phase identification II.

- indexing (crystallographic data);
- weighting of possible solutions;
- crystal orientation and phase determination







Voting Table

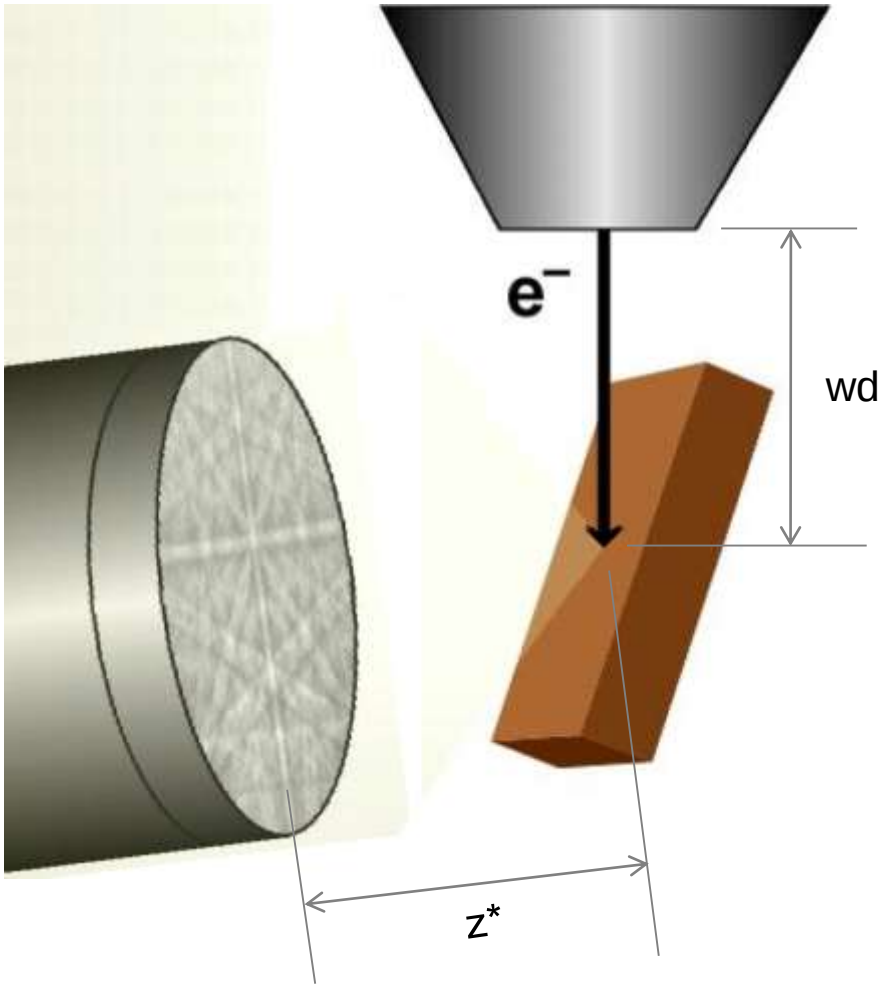
FEI Quanta 3D SEM/FIB

EBSD system

EDAX – FEI setup

Geometric layout :

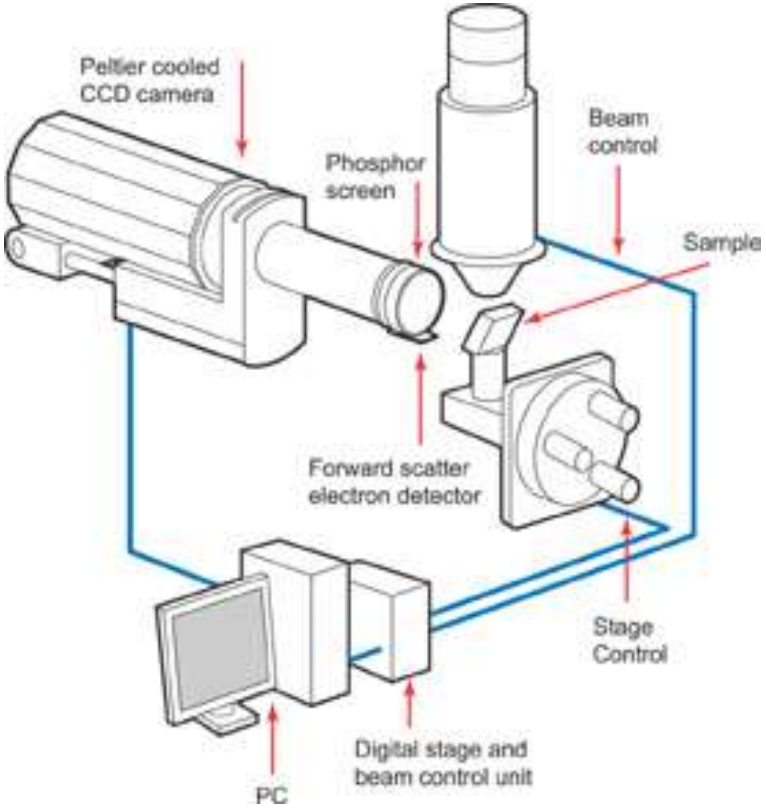
- *70 ° tilted sample;*
- *-7 ° tilted camera;*
- *working distance: wd = 5-25 mm (atomic number dependent);*
- *z * = 30-150 mm camera distance*

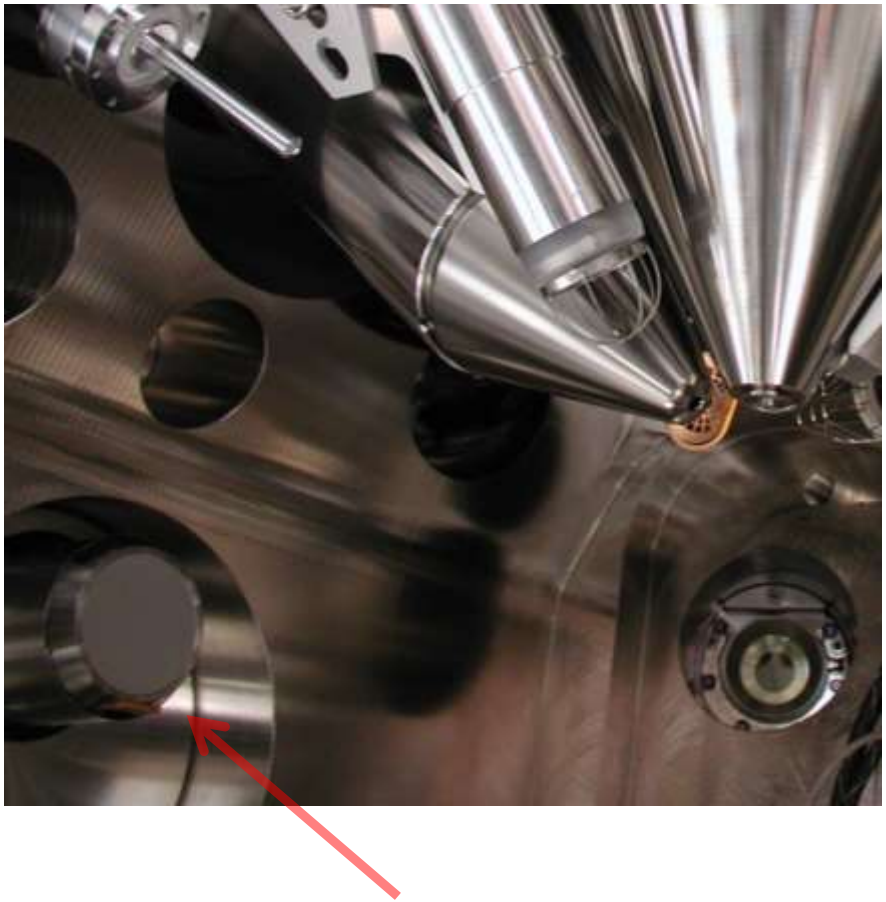


FEI Quanta 3D SEM/FIB

EBSD system

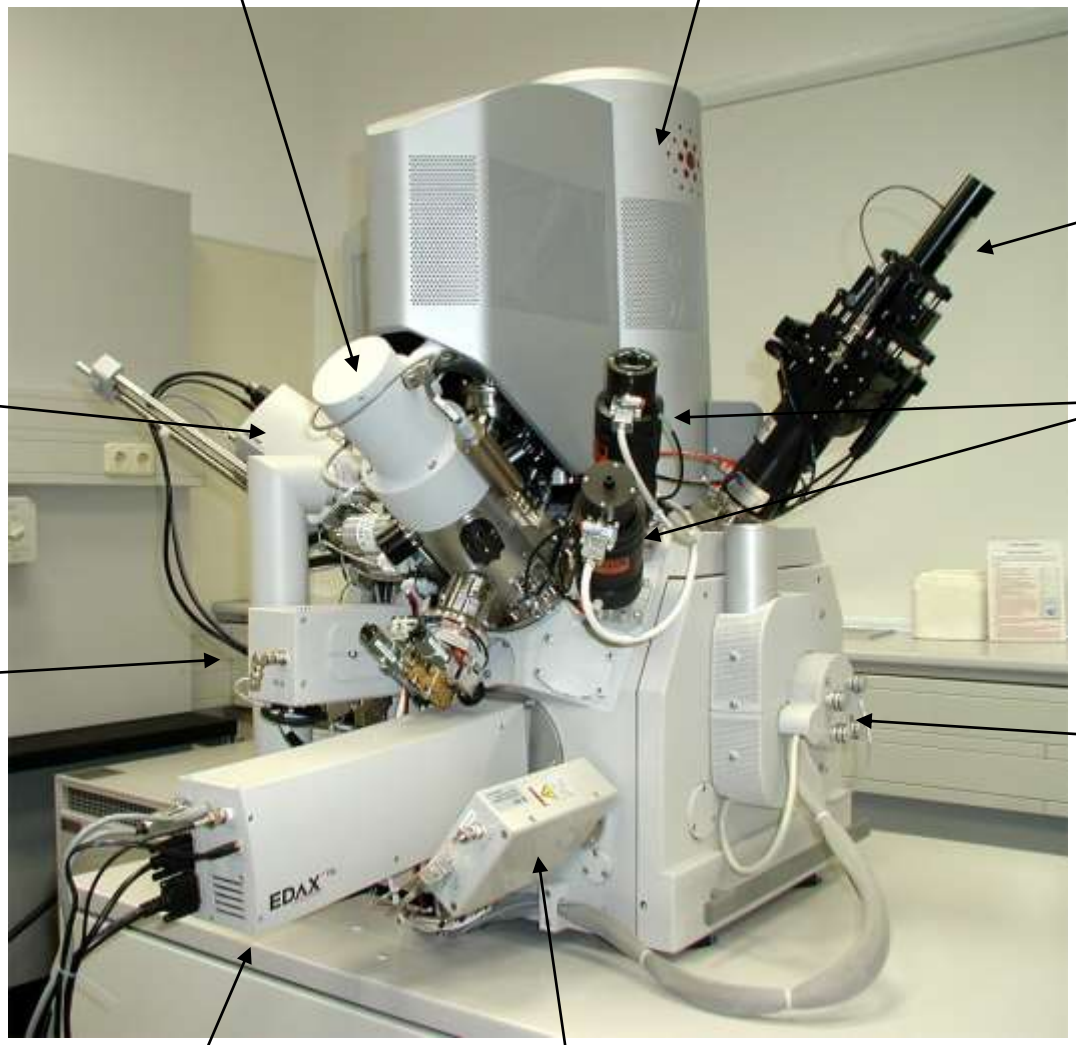
EDAX – FEI setup





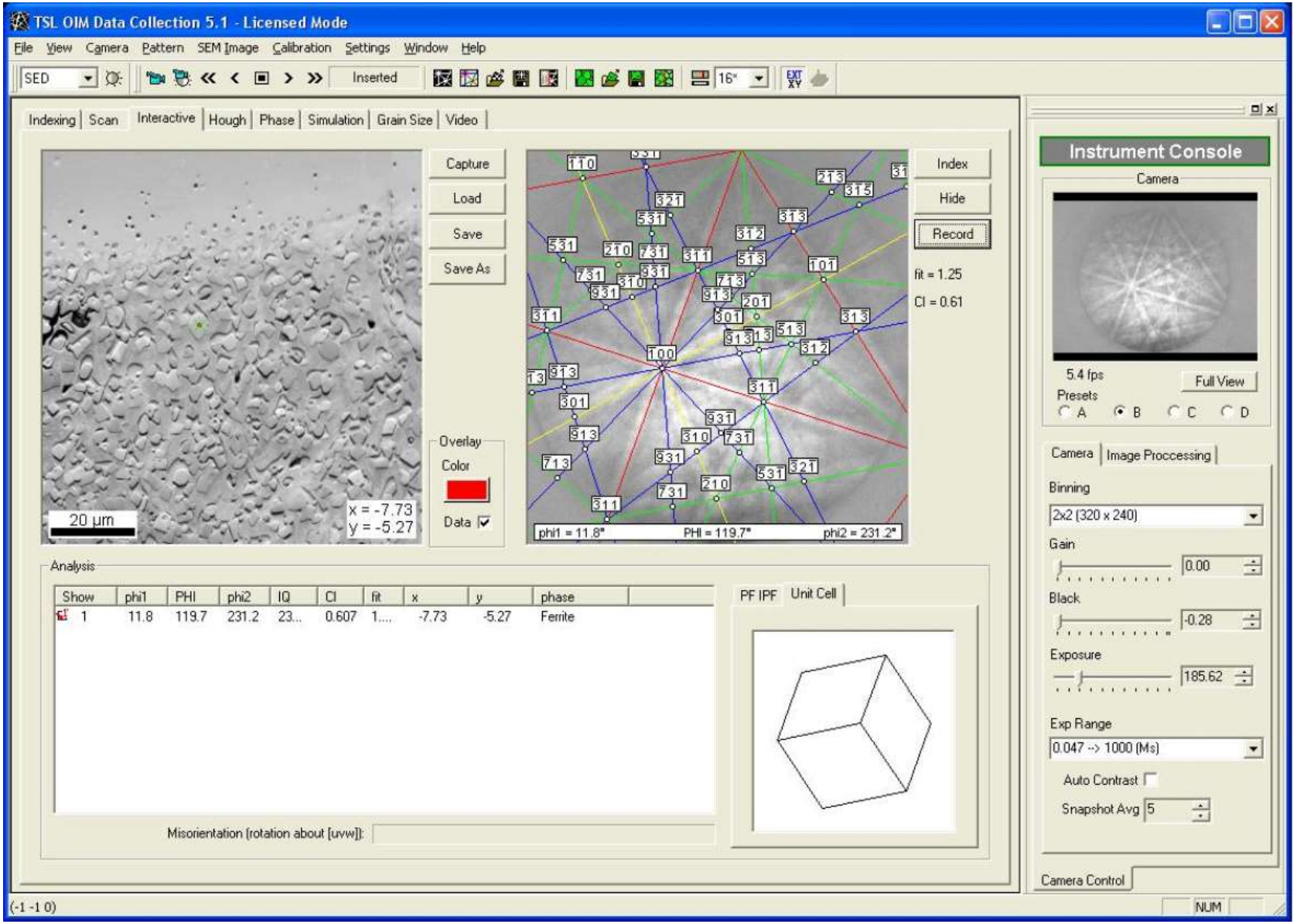
Hikari camera

FEI Quanta 3D SEM/FIB



FEI Quanta 3D SEM/FIB

EBSD system



FEI Quanta 3D SEM/FIB

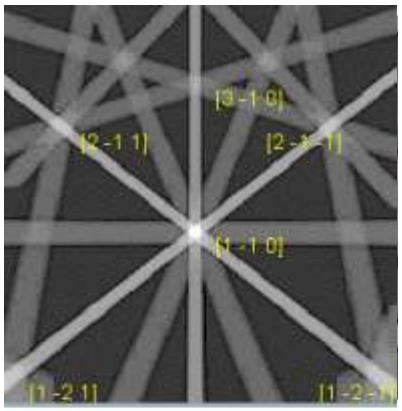
EBSD system

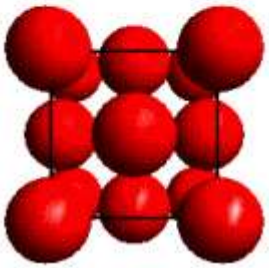
What can it be used for? I.

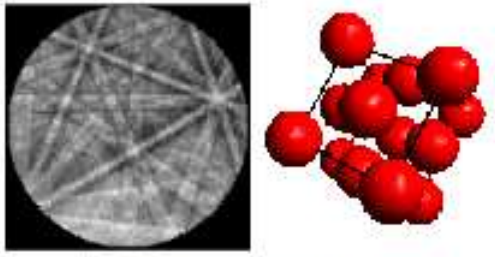
Materials testing technique in SEM:

surface test of bulk polycrystalline (clear and smooth sample)

- Determining the orientation of grains.
- Examination of the distribution of grains over the surface of the whole sample.





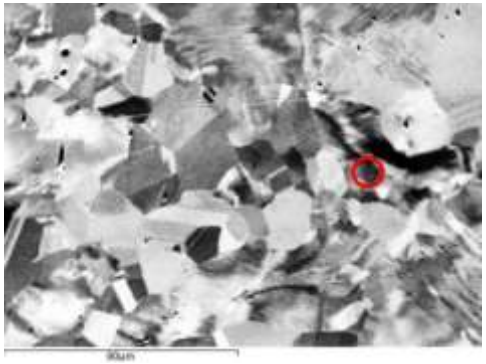


Texture: {3 -1 7}<-4 9 3>

FEI Quanta 3D SEM/FIB

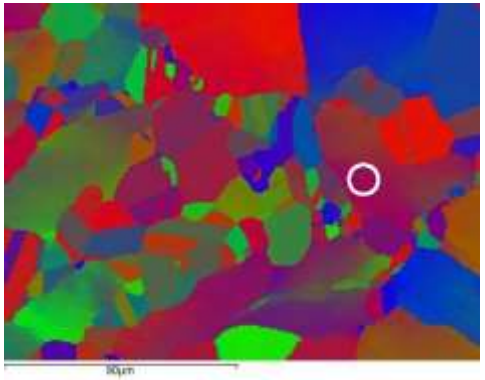
EBSD system

What can it be used for? II.

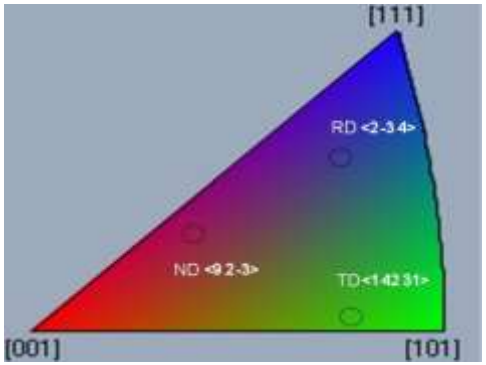


SE image of rolled steel sample

- local texture;
- point-to-point orientation change / correlation;
- phase identification and distribution determination;
- quantitative structure analysis;
- 3D structure discovery (with FIB);
- ~ 50 nm spatial resolution



and grain orientation map

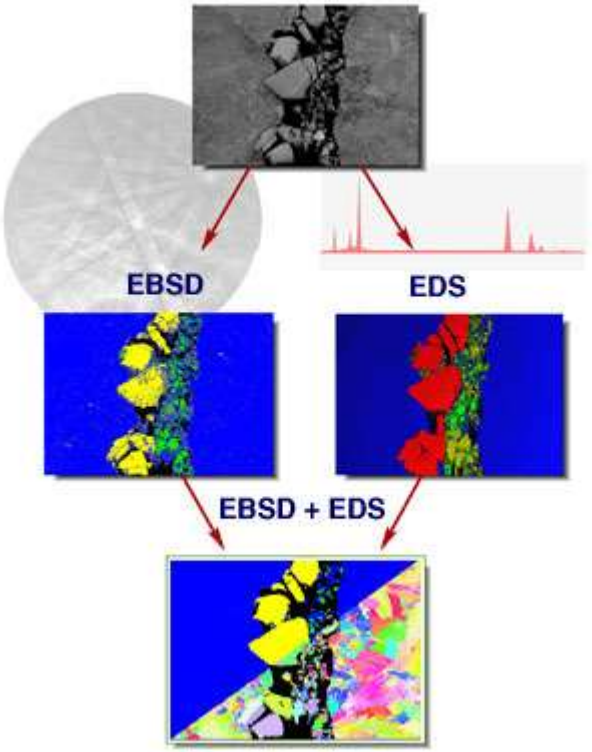


inverse pole figure

FEI Quanta 3D SEM/FIB

EBSD system

If indexing is not sufficient

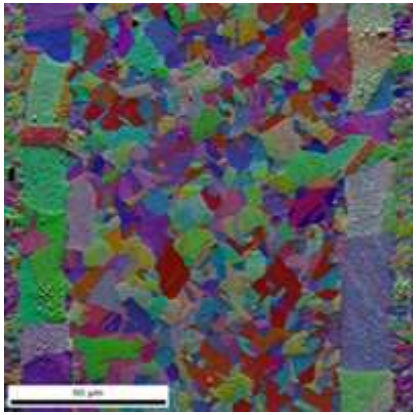


e.g. same phase but different composition

Parallel use of EDS detector:

- recording X-ray intensity of selected elements simultaneously with EBSD data acquisition
- in the case of the same crystal structure, the particle can be determined by its composition

copper-nickel two-phase cubic system (austenite / ferrite)



Orientation map

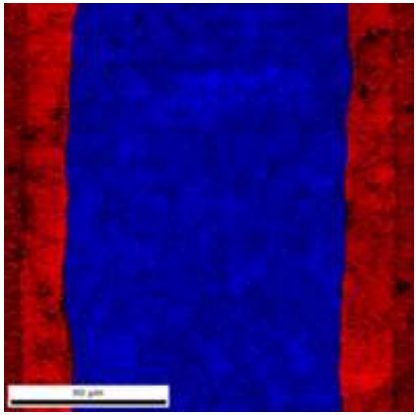


Image Quality and phase map