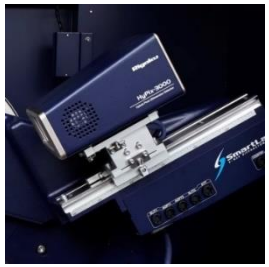
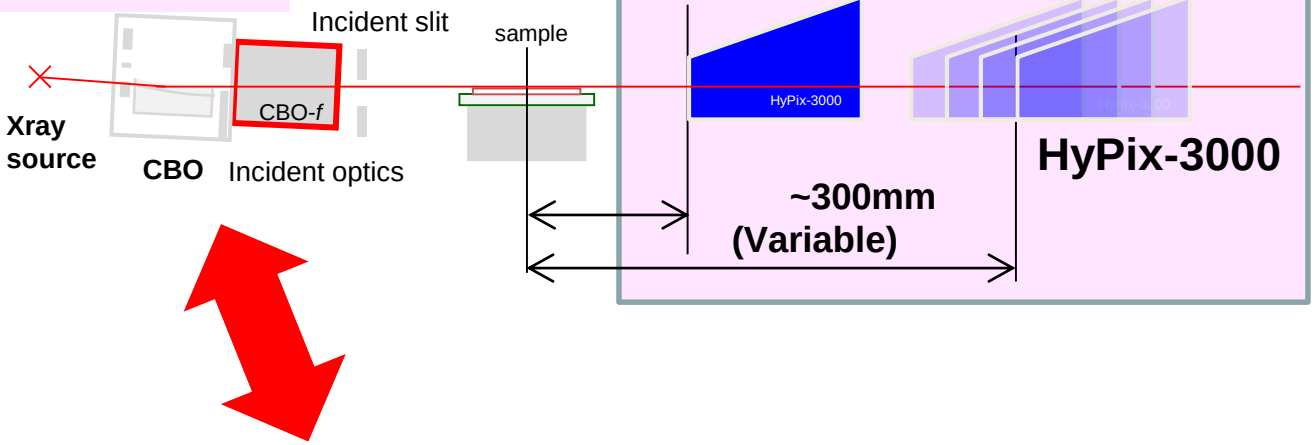
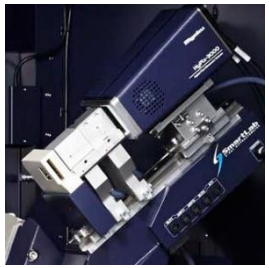
Measurements with HyPix-3000, 2D

Seamless Configuration Switching from 2D to 1D, 0D mode

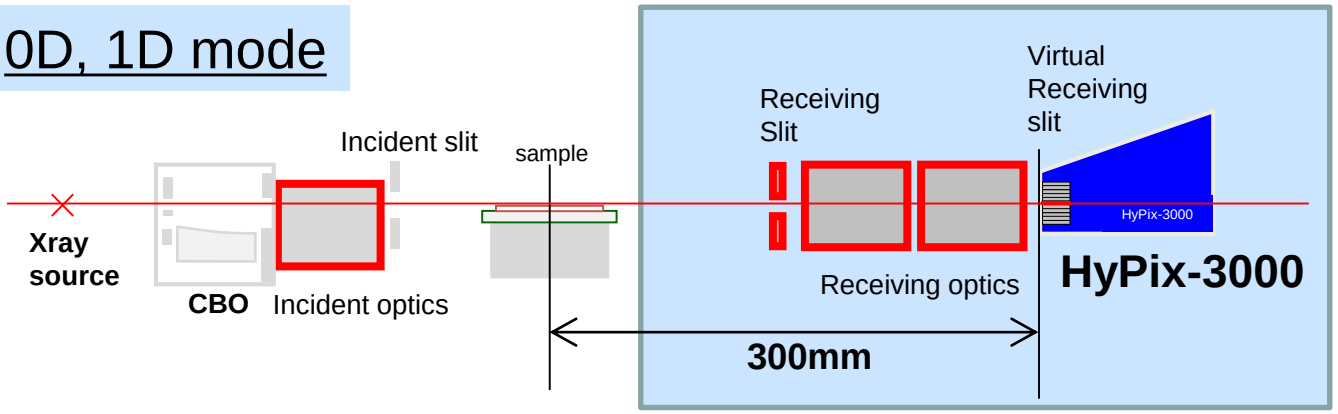


2Dmode





0D, 1D mode

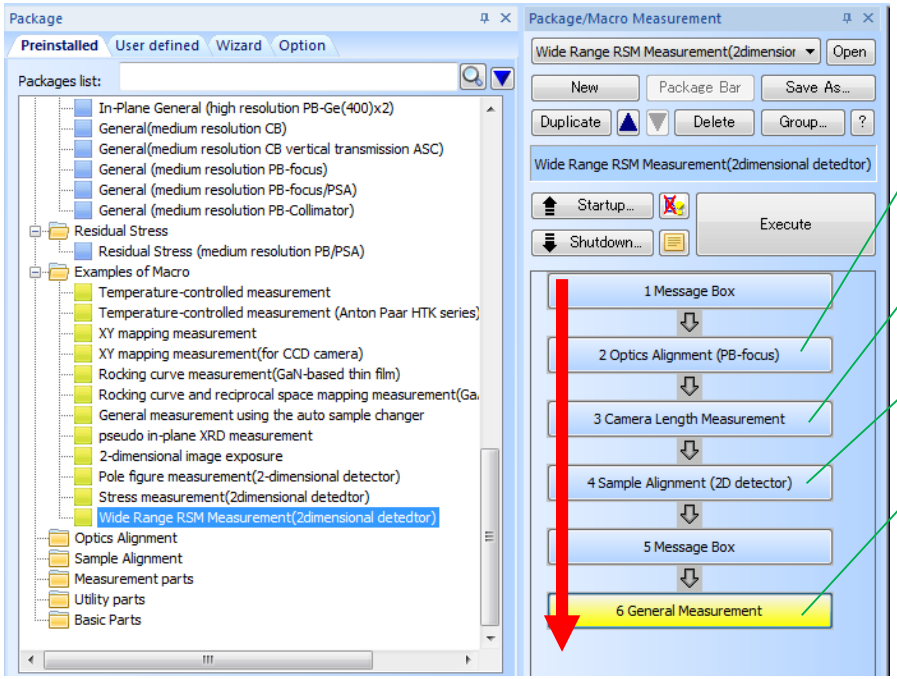


Rigaku

Optics for 2D measurement with HyPix-3000

- PB selection slit + CBO-f + Standard slit box with DHL 0.5 mm
- PB selection slit + CBO-f + PB collimator adapter + Long type Collimator
- PB 0.* mm +PB Collimator adapter + Long/Short type Collimator
- MA + PB Collimator adapter + Long/Short type Collimator
- MA + Standard slit box with DHL 0.5 mm

How to measure the “Wide range Reciprocal Space Map” with HyPix-3000 2D mode



Optics Alignment for 2D measurement (Point beam, CBO-f)

Automatic detector distance and center position alignment

Sample height alignment

Wide range RSM measurement

Exec.	Scan axis	Mode	Range	Start (deg)	Stop (deg)	
1	2-Theta/Omega	Continuous	Absolute	20.0000	80.0000	Chi :0deg
2	2-Theta/Omega	Continuous	Absolute	20.0000	80.0000	Chi :15deg
3	2-Theta/Omega	Continuous	Absolute	20.0000	80.0000	Chi :30deg
4	2-Theta/Omega	Continuous	Absolute	20.0000	80.0000	Chi :45deg

Prepared Example of Macro in SmartLab Guidance software.
Just run from top to bottom like other packages.

Thin Films Evaluation with HyPix-3000

Epitaxial film : Single crystal film grown on single crystal substrate

-2D diffraction image analysis
Orientation information and Mosaic spread (Tilt distribution)

-Wide range reciprocal space map
Orientation relations of each layer,
(and Domains information, unknown phase determination).

2D

Switch from 2D to 0D configuration

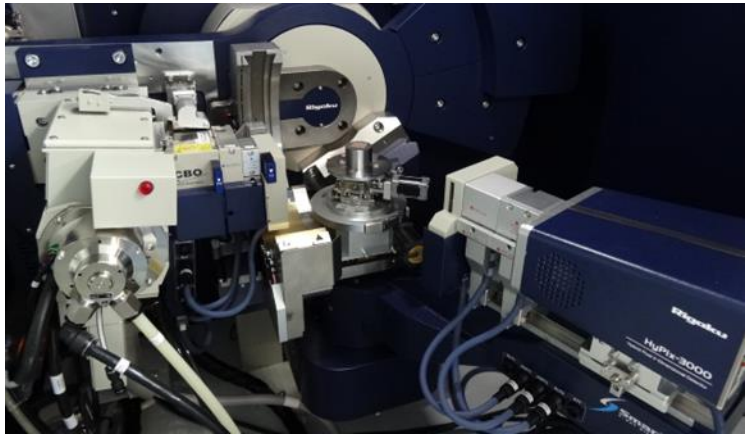
-In-plane XRD
Twist distribution

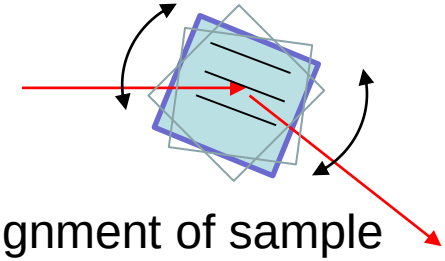
-X-ray reflectivity
Thickness evaluation

0D

In-Plane XRD / Epitaxial film

- Optics alignment
- Sample alignment
  - Z, ω, Rx, Ry
- Axis Alignment (InPlane : reflection)
  Set Conditions *use Manual Control dialog box
    - IS : 0.1 mm
    - RS1, RS2 : 20 mm (open)
    - ω = 2θ : 0.5deg (incident angle)
  - Move to : diffraction angle of investigated material
  - φ scan
    - φ : ±5 deg
    - Step : 0.1 deg
  - Move to the peak top
- Data Measurement
  - 2θχ/φ scan
  - Φ scan





Alignment of sample direction (rotation)

Divergence angle of incident X-ray beam

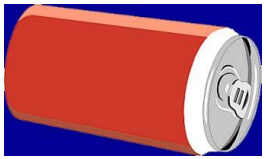
Name	Function	Monochromaticity, $\Delta\lambda/\lambda$	Divergence angle, $\Delta\theta$
Multilayer mirror	Suppression of divergence angle	Cu Kα/Kβ intensity ratio from 100:25 to 1000:1	0.04°
Channel-cut monochromator	Suppression of divergence angle Improvement in monochromaticity	3.8×10^{-4}	0.0083° (Near $\theta = 0°$)
Four-crystal monochromator	Suppression of divergence angle Improvement in monochromaticity	Ge (220) four-crystal: 1.5×10^{-4} Ge(440) four-crystal: 2.3×10^{-5}	Ge (220) four-crystal: 0.0034° Ge (440) four-crystal: 0.0015°

Receiving angle resolution

Name	Function	Slit width (DS, SS, RS)	2θ resolution, $\Delta 2\theta$
Slit	Improvement in 2θ resolution	Open	0.84°
		2 mm	0.34°
		1 mm	0.17°
		0.5 mm	0.084°
		0.2 mm	0.034°
		0.1 mm	0.017°
		0.05 mm	0.0084°
Analyzer crystal	Improvement in 2θ resolution		0.003°
Soller slit	Improvement in 2θ or 2θχ resolution (Depends on direction of insertion)		(Often used for thin-film samples) 1° 0.4° 0.1°

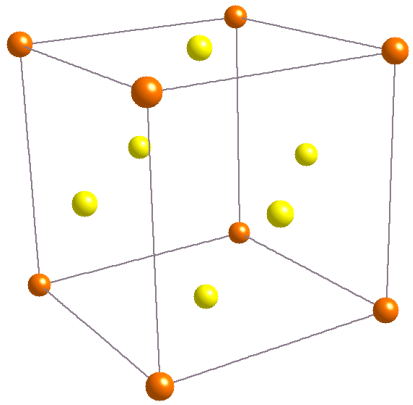
X-rays are useful in daily life

- Soil
- Cosmetics
- Medicine
- Nut
- Plastic bottle
- Fiber
- Juice can
- Pigment

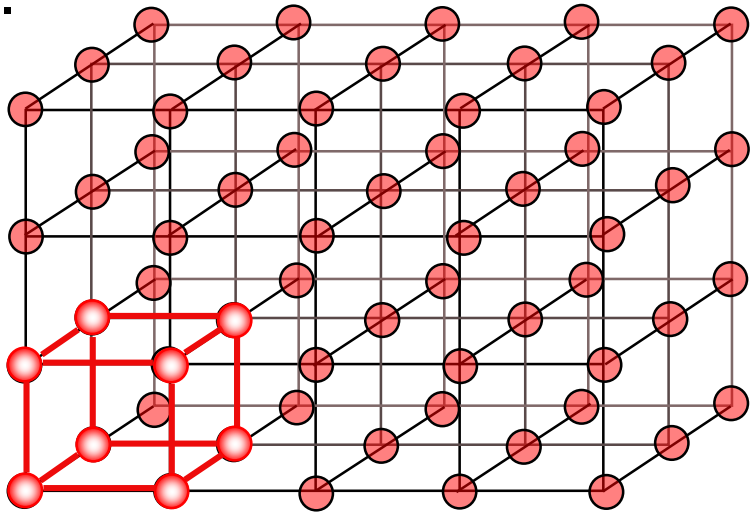


etc.

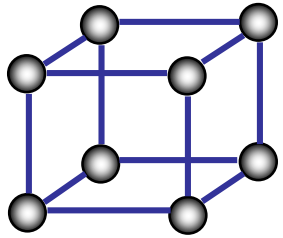
What is a crystal?



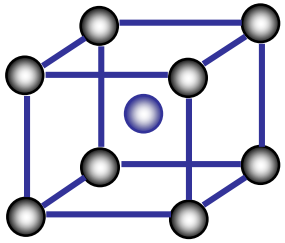
- A crystal is defined as a solid composed of atoms arranged in a periodic pattern in three dimensions
- The smallest repeating unit is called a unit cell.



A unit cell



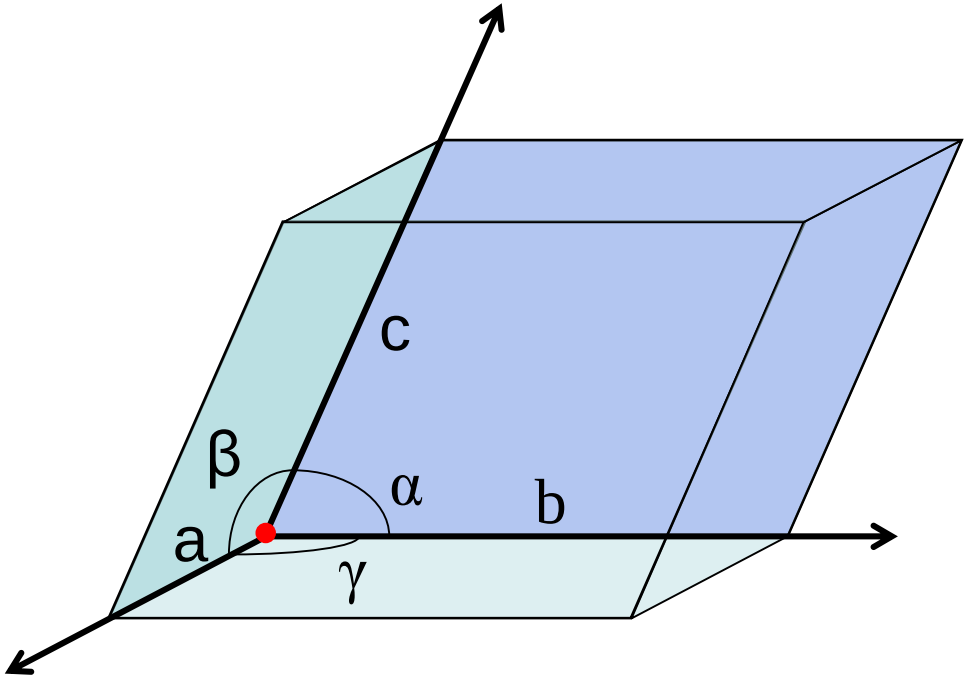
Primitive unit cell



Non-primitive unit cell

Lattice constants

a, b, c are axial lengths;
α,β,γ are axial angles

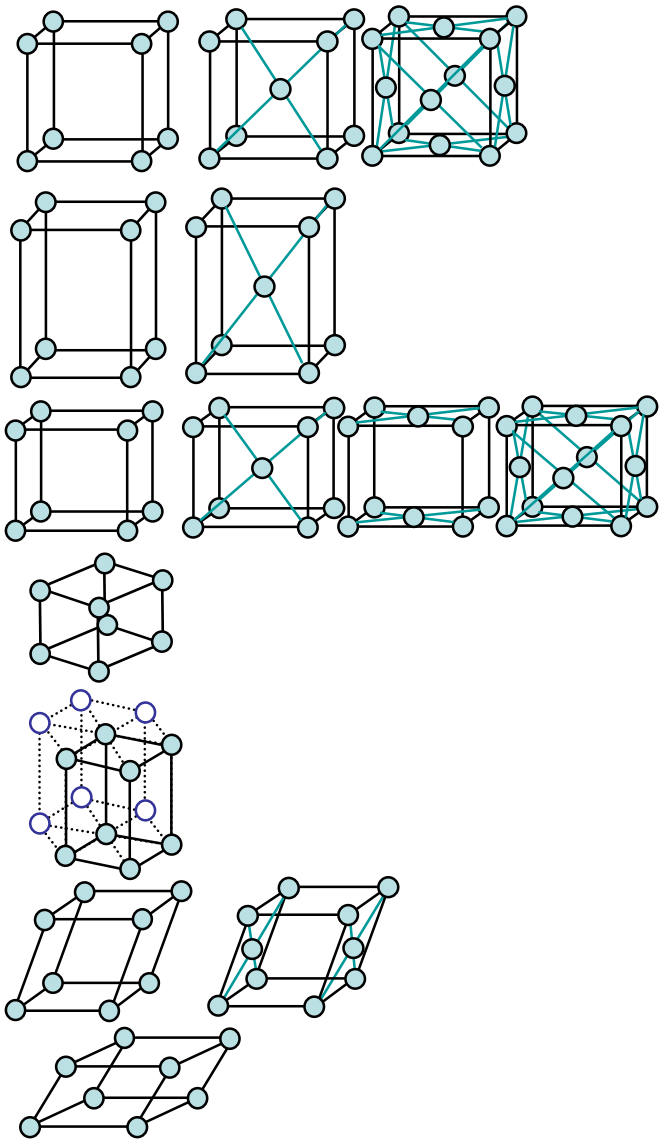


a, b, c may be called crystal axes

From the symmetry classification, there are seven crystal systems. The acquired shapes of lattices are classified into 14 types of Bravais lattices.

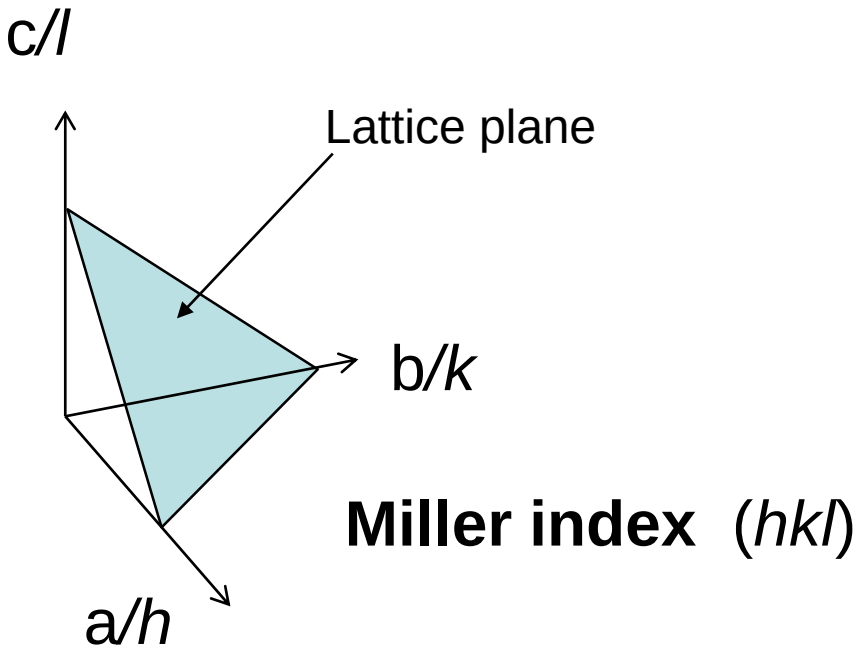
Crystal Systems	Crystal Axes	Bravais Lattices&Symbol Letter
cubic	a=b=c	primitive P
	α=β=γ=90°	body-centered I
		face-centered F
tetragonal	a=b≠c	primitive P
	α=β=γ =90°	body-centered I
orthorhombic	a≠b≠c	primitive P
	α=β=γ=90°	body-centered I
		base-centered C
		face-centered F
rhombohedral	a=b=c	primitive P
trigonal or	α=β=γ≠90°	
hexagonal	a=b≠c	primitive P
	α=β=90° γ=120°	
monoclinic	a≠b≠c	primitive P
	α=β=90° ≠γ	base-centered C
triclinic	a≠b≠c	primitive P
	α≠β≠γ ≠90°	

Characteristic Patterns



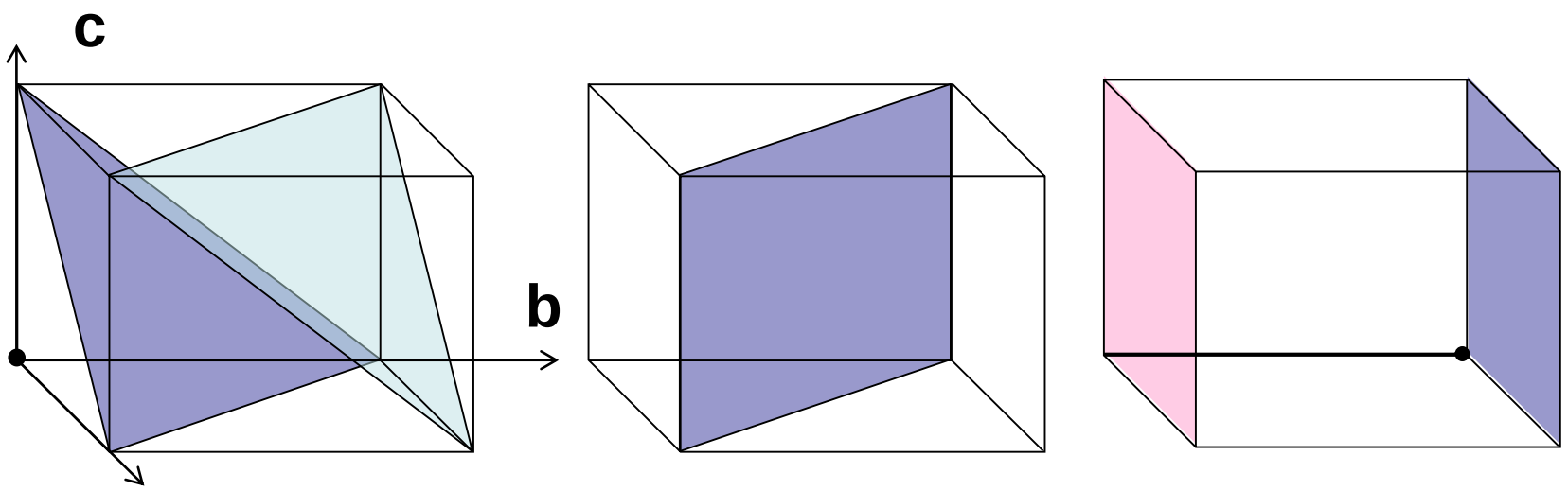
Miller indices

- The lattice plane is defined by the three integer numbers (h k l), which are called Miller indices
- The distance between two lattice planes is called lattice spacing



Examples of the Miller indices

Lattice planes and lattice spacing



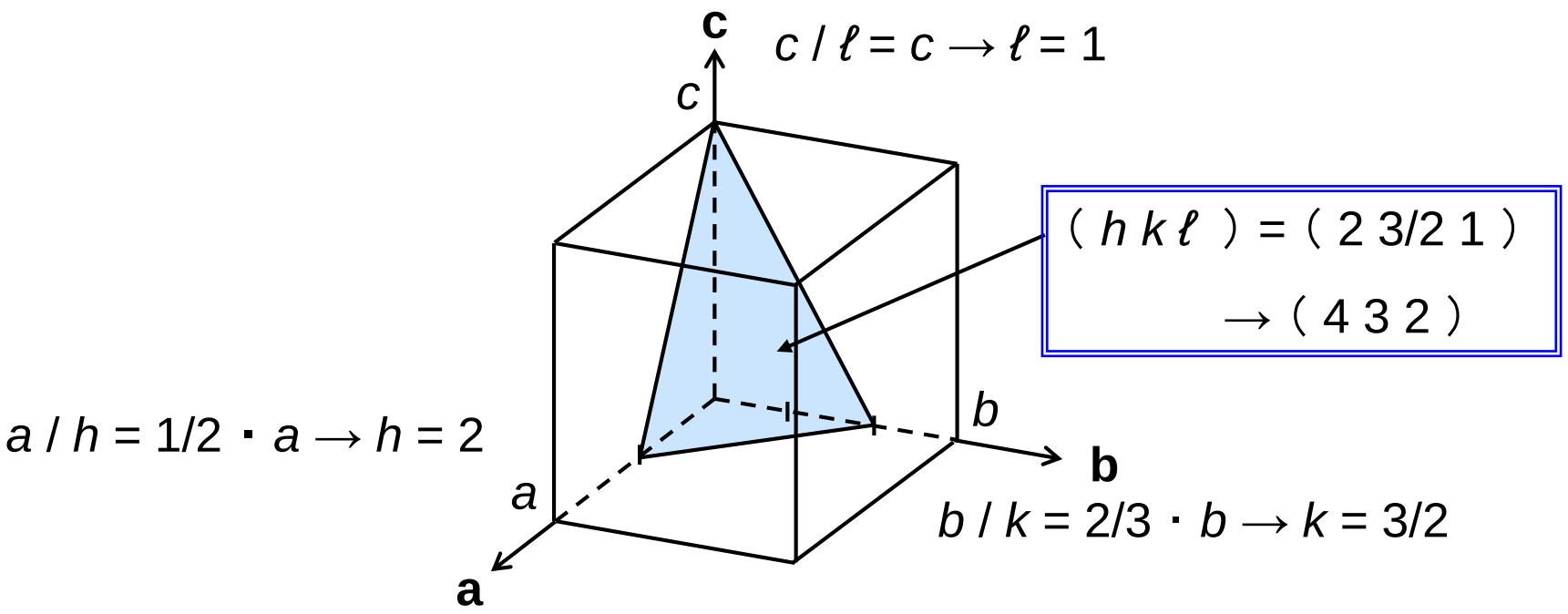
(111)
($\bar{1}\bar{1}\bar{1}$)

(110)

(010)
(0$\bar{1}$0)

Examples of Miller indices

- All lattice points can be positioned on flat plane groups denoted by **Miller indices**



Lattice planes and interplanar spacing

- The **lattice plane** groups of the indicates (*h k l*) are arranged in equal intervals
- This interval is called the **interplanar spacing** and is denoted as $\mathbf{d_{hkl}}$

For the crystal with cubic symmetry:

$$1/d_{hkl}^2 = \frac{h^2 + k^2 + l^2}{a^2}$$