

Today's Goals

Consolidate our knowledge from previous lectures

Example of graphene

Resolved the crystal structure of a new
200 K superconductor

Structure factor analysis

Discuss different scattering techniques

Instrumentation & Facilities

8 NOBEL PRIZES ON SUPERCONDUCTIVITY AND SUPERFLUIDITY

In 1913, Heike Kamerlingh Onnes received the Nobel Prize in Physics "for his investigations on the properties of matter at low temperatures, which led, inter alia, to the production of liquid He⁴", and the discovery of superconductivity.

In 1962, Lev Davidovich Landau received the Nobel Prize in Physics "for his pioneering theories for condensed matter, specially liquid helium."

In 1972, John Bardeen, Leon N. Cooper and J. Robert Schrieffer received the Nobel Prize in Physics "for the jointly developed theory of superconductivity, usually called the BCS theory."

In 1973, Brian David Josephson received one half of the Nobel Prize in Physics "for his theoretical predictions of the properties of a supercurrent through a tunnel barrier, in particular those phenomena which are generally known as the Josephson Effects.

In 1978, Pyotr Leonidovich Kapitsa received one half of the Nobel Prize in Physics "for his basic inventions and discoveries in the area of low temperature physics," which included the discovery of superfluidity in He.

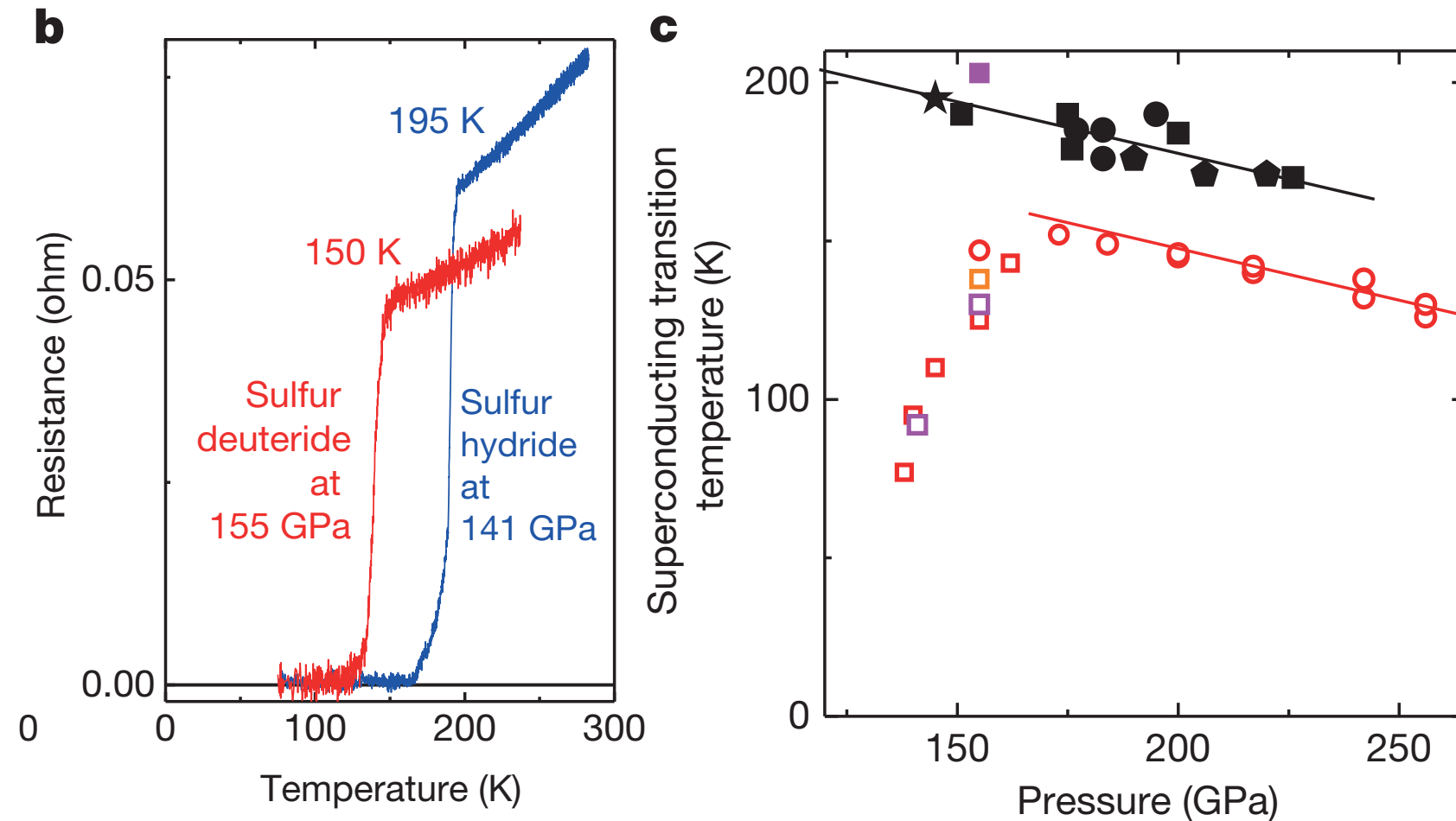
In 1987, J. Georg Bednorz and K. Alexander Müller received the Nobel Prize in Physics "for their important breakthrough in the discovery of superconductivity in ceramic materials."

In 1996, David M. Lee, Douglas D. Osheroff and Robert C. Richardson received the Nobel Prize in Physics "for their discovery of superfluidity in helium-3."

In 2003, Alexei A. Abrikosov, Vitaly L. Ginsburg and Anthony J. Leggett received the Nobel Prize in Physics "for pioneering contributions to the theory of superconductors and superfluids.

2015 – BREAKTHROUGH

Superconductivity above 200 K



Nature **525**, 73–76 (03 September 2015)

2015 – BREAKTHROUGH

What is the crystal structure????

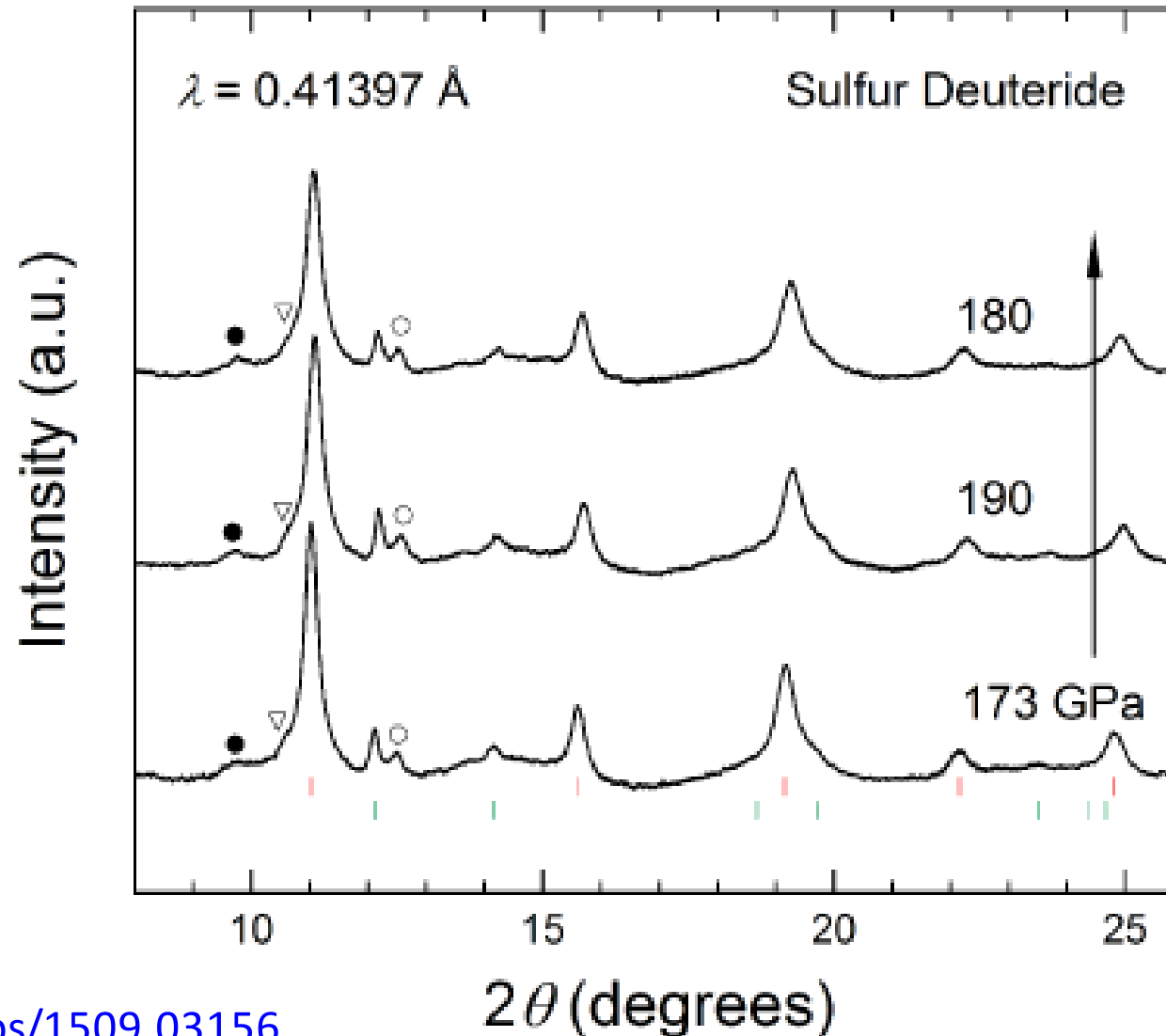


TABLE OF PERIODIC PROPERTIES OF THE ELEMENTS

Percent Ionic Character of a Single Chemical Bond

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Difference in electronegativity | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 |
| Percent ionic character % | 0.5 | 1 | 2 | 4 | 6 | 9 | 12 | 15 | 19 | 22 | 26 | 30 | 34 | 39 | 43 | 47 | 51 | 55 | 59 | 63 | 67 | 70 | 74 | 76 | 79 | 82 | 84 | 86 | 88 | 89 | 91 | 92 |

GROUP IA

| | | |
|----|--------|--------|
| H | 0.32 | 2.10 |
| Li | 0.79 | 0.4581 |
| Na | 14.10 | 0.0585 |
| K | 13.58 | — |
| Rb | 14.304 | 0.1815 |

IIA

| | | |
|----|-------|-------|
| Be | 0.90 | 1.57 |
| Mg | 1.40 | 2.97 |
| Ca | 13.10 | 3.0 |
| Sc | 5.322 | 11.71 |
| Ti | 5.882 | 84.7 |
| V | 1.625 | 2.0 |

IIIA

| | | |
|----|-------|-------|
| Li | 1.32 | 0.98 |
| Na | 2.23 | 48.01 |
| K | 23.70 | 2.601 |
| Rb | 5.139 | 20.1 |
| Cs | 1.23 | 141 |

IIA

| | | |
|----|-------|-------|
| Be | 1.39 | 1.31 |
| Mg | 1.72 | 127.6 |
| Ca | 14.0 | 8.95 |
| Sc | 7.846 | 22.4 |
| Ti | 1.02 | 156 |

DATA CONCERNING THE MORE STABLE ELEMENTARY (SUBATOMIC) PARTICLES

| | Neutron | Proton | Electron ⁻ | Neutrino ⁰ | Photon |
|--|---------------------------|---------------------------|----------------------------|-----------------------|--------|
| Symbol | n | p | e ⁻ | ν | γ |
| Rest mass (kg) | 1.67495x10 ⁻²⁷ | 1.67265x10 ⁻²⁷ | 9.1095x10 ⁻³¹ | ~0 | 0 |
| Relative atomic mass (1 ² C=12) | 1.008665 | 1.007276 | 5.48580x10 ⁻⁴ | ~0 | 0 |
| Charge (C) | 0 | 1.60219x10 ⁻¹⁹ | -1.60219x10 ⁻¹⁹ | 0 | 0 |
| Radius (m) | 8x10 ⁻¹⁶ | 8x10 ⁻¹⁶ | <1x10 ⁻¹⁶ | ~0 | 0 |
| Spin quantum number | 1/2 | 1/2 | 1/2 | 0 | 1 |
| Magnetic Moment | -1.913 μ _N | 2.793 μ _N | 1.001 μ _B | 0 | 0 |

* The positron (e⁺) has properties similar to those of the (negative) electron or beta particle except that its charge has opposite sign (+). The antineutrino (ν̄) has properties similar to those of the neutrino except that its spin (or rotation) is opposite in relation to its direction of propagation.

An antineutrino accompanies release of an electron in radioactive β⁻ (positron) decay, whereas a neutrino accompanies the release of a positron in β⁺ decay.

μ_N=Bohr magneton and μ_B=Nuclear magneton.

VIII

| | | |
|----|-------|-------|
| He | 0.93 | — |
| Ne | 0.49 | 0.084 |
| Ar | 31.80 | 0.021 |
| Kr | 21.87 | — |
| Xe | 5.193 | 0.152 |

IIIB IVB VB VIB VIIB VIII

| | | | | | | | | | | | | |
|---|-------|--------------------|--------|--------|--------|---------|--------|--------|--------|--------|--------|--------|
| B | 0.82 | 2.04 | 0.37 | 2.55 | 0.75 | 3.04 | 0.73 | 3.44 | 0.72 | 3.98 | 0.71 | — |
| C | 1.17 | 507.8 | 0.81 | -7.15 | 0.75 | 2.7929 | 0.85 | 3.4109 | 0.67 | 3.2989 | 0.81 | 1.77 |
| N | 4.60 | 22.6 | 5.30 | — | 17.30 | 0.36 | 14.0 | 0.222 | 17.10 | 0.26 | 16.90 | 0.34 |
| O | 8.298 | 5x10 ¹² | 11.260 | 0.07 | 14.534 | — | 13.610 | — | 17.422 | — | 21.564 | — |
| F | 1.026 | 27.0 | 0.709 | 80-230 | 1.042 | 0.02998 | 0.92 | 0.2674 | 0.824 | 0.0279 | 1.030 | 0.0493 |

Al Si P S Cl Ar

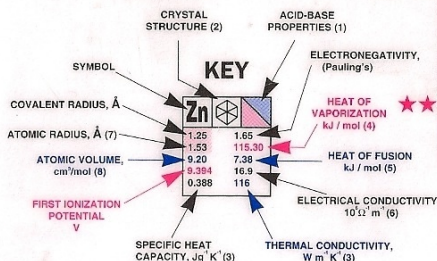
| | | | | | | | | | | | | |
|----|-------|-------|-------|-------------------|--------|------------------|--------|--------------------|--------|--------|--------|--------|
| Al | 1.18 | 1.61 | 1.11 | 1.90 | 1.06 | 2.19 | 1.02 | 2.58 | 0.99 | 3.16 | 0.88 | — |
| Si | 1.82 | 290.4 | 1.46 | 359 | 1.23 | 12.4 | 1.09 | 10 | 0.97 | 10.20 | 0.88 | 6.906 |
| P | 10.0 | 10.7 | 12.1 | 50.2 | 17.0 | 0.53 | 15.50 | 1.73 | 18.7 | 3.21 | 24.2 | 1.188 |
| S | 5.986 | 37.7 | 8.151 | 4x10 ⁴ | 10.486 | 10 ¹⁸ | 10.360 | 5x10 ¹⁴ | 12.967 | — | 15.759 | — |
| Cl | 0.90 | 237 | 0.70 | 148 | 0.769 | 0.235 | 0.710 | 0.269 | 0.48 | 0.0089 | 0.520 | 0.0177 |
| Ar | — | — | — | — | — | — | — | — | — | — | — | — |

IIIA IVA VA VIA VIIA VIIIA IB IIB

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----|-------|--------|-------|--------|-------|--------|-------|--------|-------|-------|-------|--------|-------|--------|-------|--------|-------|--------|-------|--------|-------|--------|--------|--------|-------|--------|-------|--------------------|-------|-------|-------|-------|------------------|--------------------|------------------|------------------|--------|---|
| K | 0.82 | 1.74 | 1.00 | 1.44 | 1.36 | 1.32 | 1.63 | 1.18 | 1.66 | 1.17 | 1.55 | 3.17 | 1.83 | 1.16 | 1.88 | 1.15 | 1.91 | 1.17 | 1.90 | 1.28 | 1.65 | 1.26 | 1.81 | 1.22 | 2.01 | 1.20 | 2.18 | 1.16 | 2.55 | 1.14 | 2.96 | 1.89 | — | | | | | |
| Ca | 2.77 | 76.9 | 2.23 | 154.67 | 2.09 | 304.60 | 2.00 | 425.2 | 1.92 | 446.7 | 1.85 | 339.5 | 1.79 | 219.74 | 1.72 | 349.5 | 1.67 | 373.3 | 1.62 | 377.5 | 1.57 | 300.5 | 1.53 | 115.30 | 1.81 | 266.06 | 1.52 | 334.3 | 1.33 | 32.4 | 1.22 | 26.32 | 1.12 | 14.725 | 1.03 | 9.029 | | |
| Sc | 45.30 | 2.33 | 49.30 | 3.53 | 15.0 | 16.11 | 10.60 | 18.6 | 8.35 | 22.8 | 7.23 | 20 | 7.39 | 14.64 | 7.10 | 18.8 | 6.80 | 17.2 | 7.10 | 13.14 | 9.20 | 7.36 | 11.80 | 5.59 | 13.60 | 31.8 | 13.10 | 27.7 | 16.50 | 5.54 | 23.5 | 5.286 | 32.2 | 1.638 | | | | |
| Ti | 4.341 | 16.4 | 6.113 | 31.3 | 5.54 | 1.5 | 6.92 | 2.6 | 6.74 | 4.0 | 6.765 | 7.9 | 7.435 | 0.5 | 7.070 | 11.2 | 7.95 | 17.9 | 7.695 | 14.5 | 7.795 | 60.7 | 9.394 | 15.9 | 5.999 | 1.6 | 7.899 | 3x10 ¹⁰ | 9.81 | 3.3 | 9.752 | 8 | 11.814 | 10 ¹⁸ | 13.959 | — | | |
| V | 0.757 | 102.5 | 0.847 | 200 | 0.568 | 15.8 | 0.523 | 21.9 | 0.489 | 30.7 | 0.449 | 93.7 | 0.48 | 7.82 | 0.449 | 80.2 | 0.421 | 100 | 0.444 | 90.7 | 0.385 | 401 | 0.388 | 116 | 0.371 | 40.5 | 0.32 | 59.9 | 0.33 | 50 | 0.32 | 2.04 | 0.225 | 0.122 | 0.248 | 0.00949 | | |
| Cr | 2.16 | 0.82 | 1.91 | 0.95 | 1.62 | 1.22 | 1.45 | 1.33 | 1.34 | 1.6 | 1.30 | 2.16 | 1.27 | 1.9 | 1.25 | 2.2 | 1.26 | 2.28 | 1.28 | 2.20 | 1.34 | 1.93 | 1.41 | 1.69 | 1.44 | 1.78 | 1.41 | 1.96 | 1.40 | 2.05 | 1.35 | 2.1 | 1.33 | 2.66 | 1.31 | 2.6 | | |
| Mn | 2.98 | 69.2 | 2.45 | 136.9 | 2.27 | 393.3 | 2.16 | 590.5 | 2.08 | 690.1 | 2.01 | 590.4 | 1.95 | 502.0 | 1.89 | 567.77 | 1.83 | 495.39 | 1.79 | 393.3 | 1.75 | 250.63 | 1.71 | 99.87 | 2.00 | 228.35 | 1.72 | 290.37 | 1.53 | 67.97 | 1.42 | 80.63 | 1.32 | 20.5 | 1.24 | 12.64 | | |
| Fe | 55.9 | 2.34 | 39.7 | 8.2 | 19.80 | 17.15 | 14.10 | 21 | 10.80 | 25.9 | 9.40 | 36 | 8.5 | 21.30 | 8.30 | 25.52 | 8.20 | 16.74 | 8.30 | 16.70 | 10.30 | 11.30 | 13.10 | 6.07 | 16.70 | 3.26 | 16.30 | 7.2 | 18.40 | 19.83 | 20.50 | 17.49 | 25.70 | 7.76 | 4.29 | 2.30 | | |
| Co | 4.177 | 47.6 | 5.895 | 5.0 | 6.30 | 1.8 | 6.84 | 2.3 | 6.88 | 6.8 | 7.099 | 17.3 | 7.28 | 0.001 | 7.37 | 14.9 | 7.48 | 23 | 7.42 | 23 | 8.34 | 10.0 | 7.576 | 62.9 | 6.993 | 14.7 | 5.786 | 3.4 | 7.344 | 8.7 | 8.841 | 2.6 | 9.009 | 2x10 ¹⁷ | 10.451 | 10 ¹⁸ | 12.130 | — |
| Ni | 0.363 | 58.2 | 0.30 | 35.3 | 0.30 | 17.2 | 0.278 | 22.7 | 0.285 | 53.7 | 0.25 | 138 | 0.24 | 50.5 | 0.238 | 117 | 0.242 | 150 | 0.244 | 71.8 | 0.235 | 42.9 | 0.232 | 96.8 | 0.233 | 81.5 | 0.228 | 96.6 | 0.207 | 24.3 | 0.202 | 2.35 | 0.145 | 0.449 | 0.158 | 0.00569 | | |
| Cu | 2.35 | 0.79 | 1.98 | 0.89 | 1.25 | 1.10 | 1.44 | 1.3 | 1.34 | 1.5 | 1.30 | 2.36 | 1.28 | 1.9 | 1.25 | 2.2 | 1.27 | 2.20 | 1.30 | 2.28 | 1.34 | 2.54 | 1.49 | 2.00 | 1.48 | 2.04 | 1.47 | 2.33 | 1.46 | 2.02 | 1.53 | 2.0 | 1.47 | 2.2 | — | — | | |
| Zn | 3.34 | 67.740 | 2.78 | 140.2 | 2.74 | 399.57 | 2.16 | 691.07 | 2.09 | 737.0 | 2.02 | 422.88 | 1.97 | 707.1 | 1.92 | 627.4 | 1.87 | 593.59 | 1.83 | 510.45 | 1.79 | 321.43 | 1.76 | 59.30 | 2.08 | 152.99 | 1.81 | 177.9 | 1.63 | 179 | 1.53 | 120 | 1.43 | 30 ¹ | 1.34 | 18.40 | | |
| Ga | 70 | 2.092 | 39.0 | 8.01 | 22.5 | 11.3 | 26.6 | 21.76 | 10.80 | 36 | 9.53 | 35.40 | 8.54 | 33.05 | 8.43 | 29.29 | 8.54 | 26.36 | 9.10 | 15.66 | 10.20 | 12.36 | 14.80 | 2.292 | 17.20 | 4.27 | 18.30 | 4.77 | 21.3 | 11.0 | 22.70 | 19.0 | 10 ¹⁸ | 10 ¹⁸ | 10 ¹⁸ | 10 ¹⁸ | | |
| Ge | 3.894 | 5.3 | 5.212 | 2.8 | 5.58 | 1.9 | 6.65 | 3.4 | 7.89 | 8.1 | 7.98 | 18.2 | 7.88 | 5.8 | 8.7 | 12.3 | 9.1 | 21.3 | 9.0 | 9.4 | 9.225 | 48.8 | 10.437 | 1.0 | 6.108 | 5.6 | 7.416 | 4.8 | 7.289 | 0.9 | 8.42 | 0.7 | — | — | — | — | | |
| As | 0.24 | 35.9 | 0.204 | 18.4 | 0.19 | 13.5 | 0.14 | 23.0 | 0.14 | 57.5 | 0.13 | 174 | 0.137 | 47.9 | 0.13 | 87.6 | 0.130 | 147 | 0.13 | 71.5 | 0.128 | 317 | 0.140 | 8.34 | 0.129 | 46.1 | 0.129 | 35.3 | 0.122 | 7.87 | — | 20 | — | — | — | | | |
| Se | Fr | Ra | Ac | Rf | Db | Sg | Bh | Hs | Mt | Uun | Uuu | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | | |

The A & B subgroup designations, applicable to elements in rows 4, 5, 6 and 7, are those recommended by the International Union of Pure and Applied Chemistry.

*ESTIMATED VALUES



| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|
| Ce | 1.65 | 1.12 | 1.66 | 1.13 | 1.64 | 1.14 | 1.63 | 1.13 | 1.62 | 1.17 | 1.85 | 1.2 | 1.61 | 1.20 | 1.59 | 1.1 | 1.59 | 1.22 | 1.58 | 1.23 | 1.57 | 1.24 | 1.56 | 1.25 | 1.70 | 1.1 | 1.56 | 1.27 | 1.65 | 1.12 | 1.66 | 1.13 | 1.64 | 1.14 | 1.63 | 1.13 | 1.62 | 1.17 | 1.85 | 1.2 | 1.61 | 1.20 | 1.59 | 1.1 | 1.59 | 1.22 | 1.58 | 1.23 | 1.57 | 1.24 | 1.56 | 1.25 | 1.70 | 1.1 | 1.56 | 1.27 | 1.65 | 1.12 | 1.66 | 1.13 | 1.64 | 1.14 | 1.63 | 1.13 | 1.62 | 1.17 | 1.85 | 1.2 | 1.61 | 1.20 | 1.59 | 1.1 | 1.59 | 1.22 | 1.58 | 1.23 | 1.57 | 1.24 | 1.56 | 1.25 | 1.70 | 1.1 | 1.56 | 1.27 | 1.65 | 1.12 | 1.66 | 1.13 | 1.64 | 1.14 | 1.63 | 1.13 | 1.62 | 1.17 | 1.85 | 1.2 | 1.61 | 1.20 | 1.59 | 1.1 | 1.59 | 1.22 | 1.58 | 1.23 | 1.57 | 1.24 | 1.56 | 1.25 | 1.70 | 1.1 | 1.56 | 1.27 | 1.65 | 1.12 | 1.66 | 1.13 | 1.64 | 1.14 | 1.63 | 1.13 | 1.62 | 1.17 | 1.85 | 1.2 | 1.61 | 1.20 | 1.59 | 1.1 | 1.59 | 1.22 | 1.58 | 1.23 | 1.57 | 1.24 | 1.56 | 1.25 | 1.70 | 1.1 | 1.56 | 1.27 | 1.65 | 1.12 | 1.66 | 1.13 | 1.64 | 1.14 | 1.63 | 1.13 | 1.62 | 1.17 | 1.85 | 1.2 | 1.61 | 1.20 | 1.59 | 1.1 | 1.59 | 1.22 | 1.58 | 1.23 | 1.57 | 1.24 | 1.56 | 1.25 | 1.70 | 1.1 | 1.56 | 1.27 | 1.65 | 1.12 | 1.66 | 1.13 | 1.64 | 1.14 | 1.63 | 1.13 | 1.62 | 1.17 | 1.85 | 1.2 | 1.61 | 1.20 | 1.59 | 1.1 | 1.59 | 1.22 | 1.58 | 1.23 | 1.57 | 1.24 | 1.56 | 1.25 | 1.70 | 1.1 | 1.56 | 1.27 | 1.65 | 1.12 | 1.66 | 1.13 | 1.64 | 1.14 | 1.63 | 1.13 | 1.62 | 1.17 | 1.85 | 1.2 | 1.61 | 1.20 | 1.59 | 1.1 | 1.59 | 1.22 | 1.58 | 1.23 | 1.57 | 1.24 | 1.56 | 1.25 | 1.70 | 1.1 | 1.56 | 1.27 | 1.65 | 1.12 | 1.66 | 1.13 | 1.64 | 1.14 | 1.63 | 1.13 | 1.62 | 1.17 | 1.85 | 1.2 | 1.61 | 1.20 | 1.59 | 1.1 | 1.59 | 1.22 | 1.58 | 1.23 | 1.57 | 1.24 | 1.56 | 1.25 | 1.70 | 1.1 | 1.56 | 1.27 | 1.65 | 1.12 | 1.66 | 1.13 | 1.64 | 1.14 | 1.63 | 1.13 | 1.62 | 1.17 | 1.85 | 1.2 |
|----|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|------|------|------|-----|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|-----|

COMMON CRYSTAL STRUCTURES

BCC - Structure

| Name | Sym | # |
|-------------------|------------|-----------|
| <u>Barium</u> | <u>Ba</u> | <u>56</u> |
| <u>Cesium</u> | <u>Cs</u> | <u>55</u> |
| <u>Chromium</u> | <u>Cr</u> | <u>24</u> |
| <u>Europium</u> | <u>Eu</u> | <u>63</u> |
| <u>Francium</u> | <u>Fr</u> | <u>87</u> |
| <u>Iron</u> | <u>Fe</u> | <u>26</u> |
| <u>Lithium</u> | <u>Li</u> | <u>3</u> |
| <u>Manganese</u> | <u>Mn</u> | <u>25</u> |
| <u>Molybdenum</u> | <u>Mo</u> | <u>42</u> |
| <u>Niobium</u> | <u>Nb</u> | <u>41</u> |
| <u>Potassium</u> | <u>K</u> | <u>19</u> |
| <u>Radium</u> | <u>Ra</u> | <u>88</u> |
| <u>Rubidium</u> | <u>Rb</u> | <u>37</u> |
| <u>Sodium</u> | <u>Na</u> | <u>11</u> |
| <u>Tantalum</u> | <u>Ta</u> | <u>73</u> |
| <u>Tungsten</u> | <u>W</u> | <u>74</u> |
| <u>Vanadium</u> | <u>V</u> | <u>23</u> |

FCC - Structure

| Name | Sym | # |
|--------------------|------------|-----------|
| <u>Actinium</u> | <u>Ac</u> | <u>89</u> |
| <u>Aluminum</u> | <u>Al</u> | <u>13</u> |
| <u>Argon</u> | <u>Ar</u> | <u>18</u> |
| <u>Calcium</u> | <u>Ca</u> | <u>20</u> |
| <u>Cerium</u> | <u>Ce</u> | <u>58</u> |
| <u>Copper</u> | <u>Cu</u> | <u>29</u> |
| <u>Einsteinium</u> | <u>Es</u> | <u>99</u> |
| <u>Germanium</u> | <u>Ge</u> | <u>32</u> |
| <u>Gold</u> | <u>Au</u> | <u>79</u> |
| <u>Iridium</u> | <u>Ir</u> | <u>77</u> |
| <u>Krypton</u> | <u>Kr</u> | <u>36</u> |
| <u>Lead</u> | <u>Pb</u> | <u>82</u> |
| <u>Neon</u> | <u>Ne</u> | <u>10</u> |
| <u>Nickel</u> | <u>Ni</u> | <u>28</u> |
| <u>Palladium</u> | <u>Pd</u> | <u>46</u> |
| <u>Platinum</u> | <u>Pt</u> | <u>78</u> |
| <u>Radon</u> | <u>Rn</u> | <u>86</u> |
| <u>Rhodium</u> | <u>Rh</u> | <u>45</u> |

DIFFRACTION METHODS

Powder diffraction:

Powder sample, monochromatic light, variable scattering angle detection

Single crystal diffraction:

Single crystal sample, monochromatic light, variable scattering angle detection
+ sample rotation

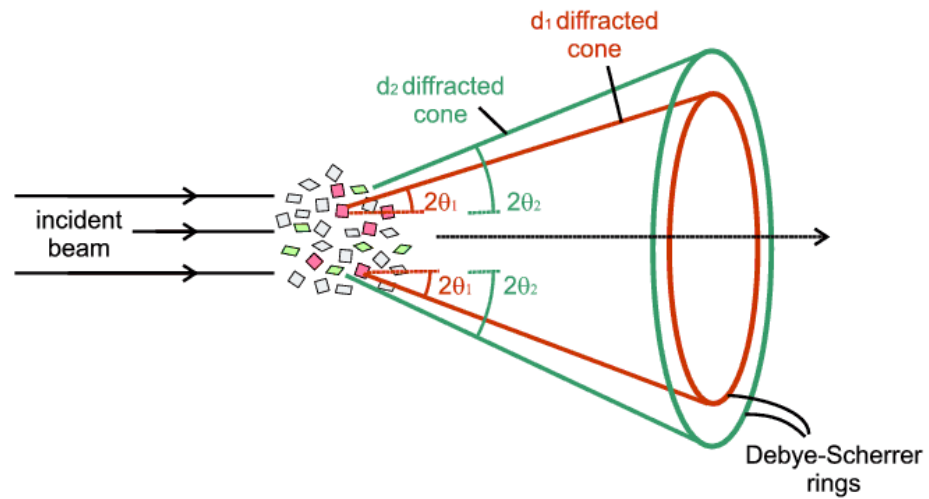
Laue diffraction:

Single crystal sample, polychromatic light (white beam)

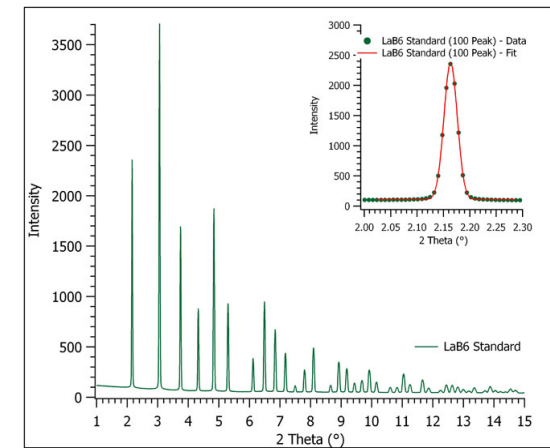
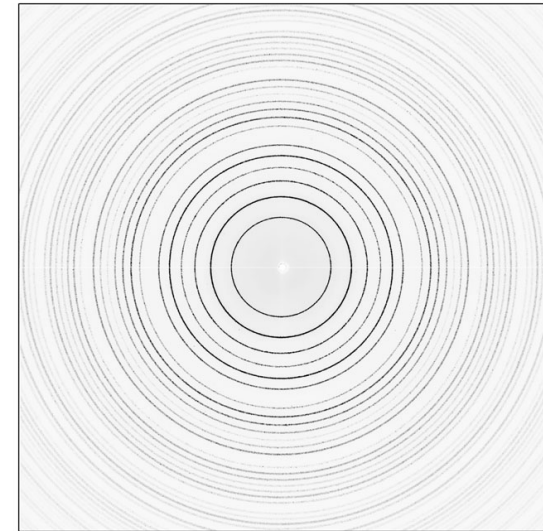
Scattering facilities around Zurich

Paul Scherrer Institute

POWDER DIFFRACTION



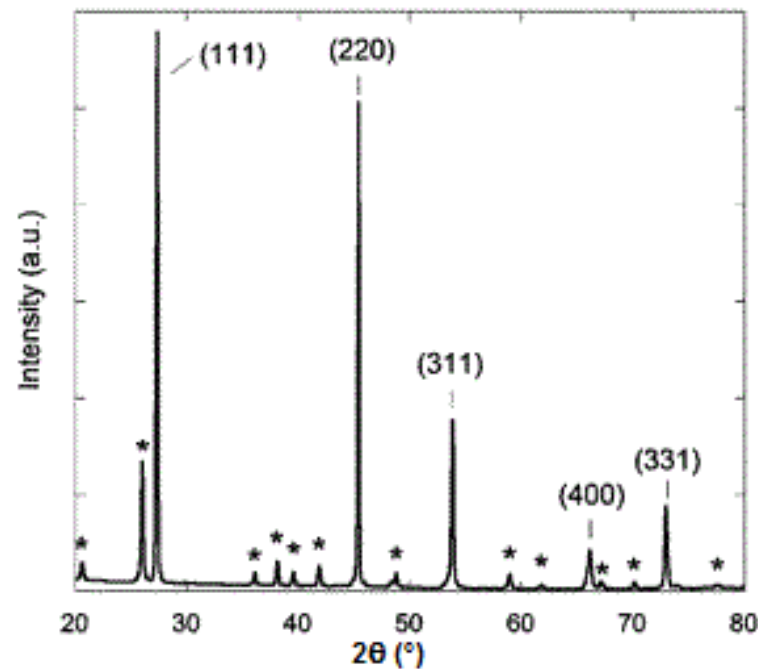
<http://pd.chem.ucl.ac.uk/pdnn/diff2/kinemat2.htm>



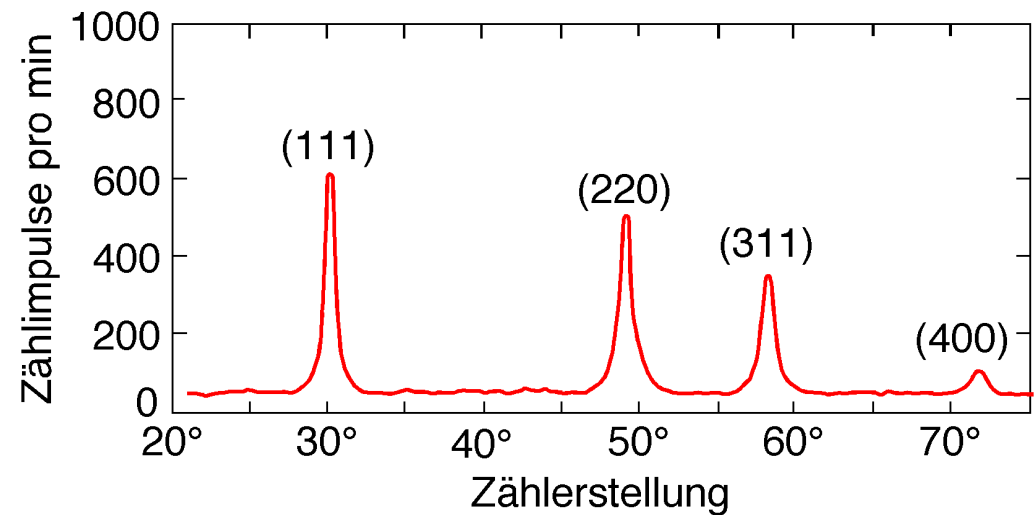
<http://www.diamond.ac.uk/Beamlines/Engineering-and-Environment/I12/applications/diffraction.html>

POWDER DIFFRACTION

X-ray Powder diffraction –
Germanium



Neutron Powder diffraction –
Diamond



Neutronenbeugung an Diamantpulver (nach G. Bacon). Man erkennt Beugungsmaxima an vier Netzebenen-scharen, die mit den kristallographischen Indizes (111), (220), (311) und (400) bezeichnet sind

DIFFRACTION METHODS

Powder diffraction:

Powder sample, monochromatic light, variable scattering angle detection

Single crystal diffraction:

Single crystal sample, monochromatic light, variable scattering angle detection
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Laue diffraction:

Single crystal sample, polychromatic light (white beam)

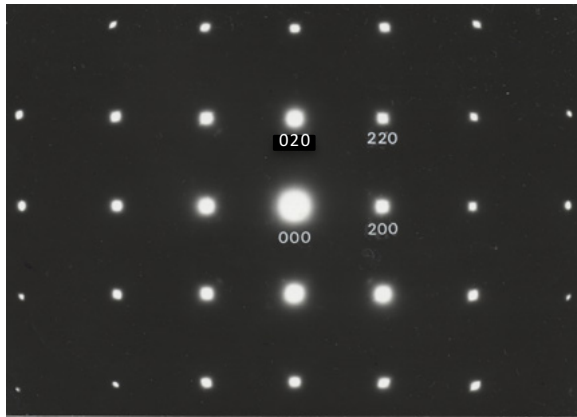
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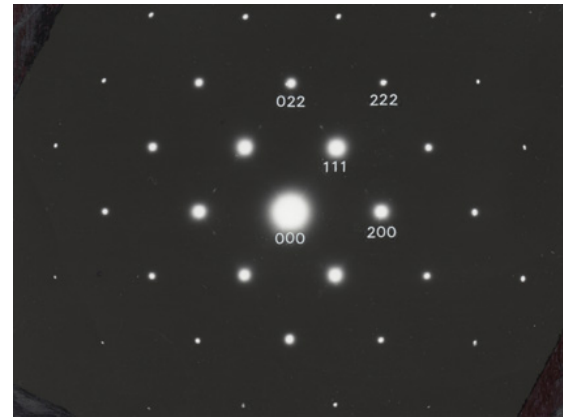
SINGLE CRYSTAL ELECTRON DIFFRACTION

TEM diffraction patterns of a gold-film

Gold film



Scattering plan: (100) & (010)



Scattering plan: (100) & (011)

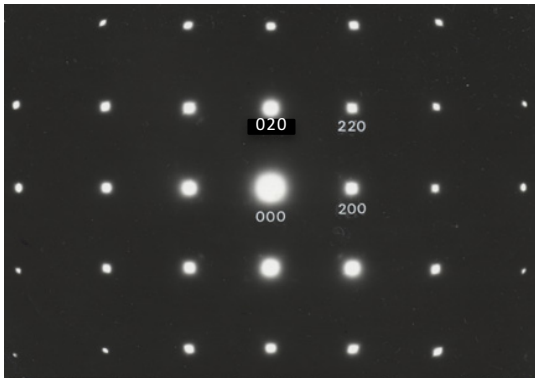
(a) and (b) are $[001]$ and $[110]$ incidence of the electron beam.

<http://www.k5.dion.ne.jp/~inos1936/shozoHP1E.html>

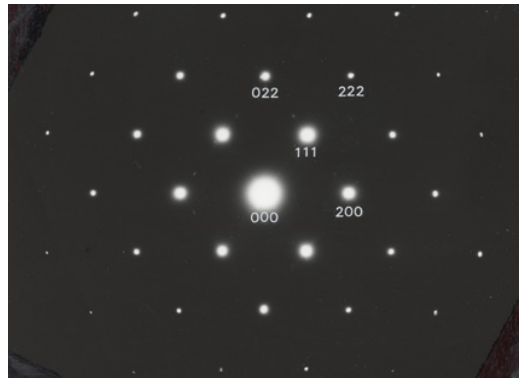
SINGLE CRYSTAL ELECTRON DIFFRACTION

TEM diffraction patterns of a gold-film

Gold film



Scattering plan: (100) & (010)

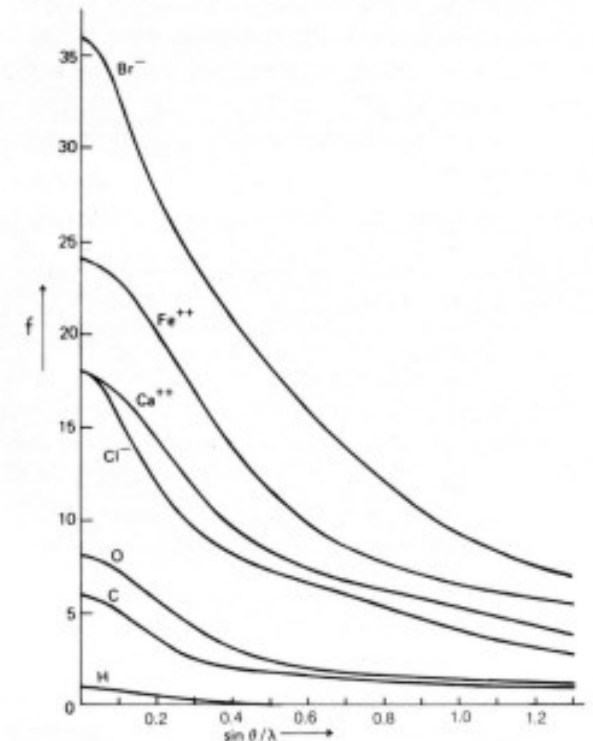


Scattering plan: (100) & (011)

(a) and (b) are [001] and [110] incidence of the electron beam.

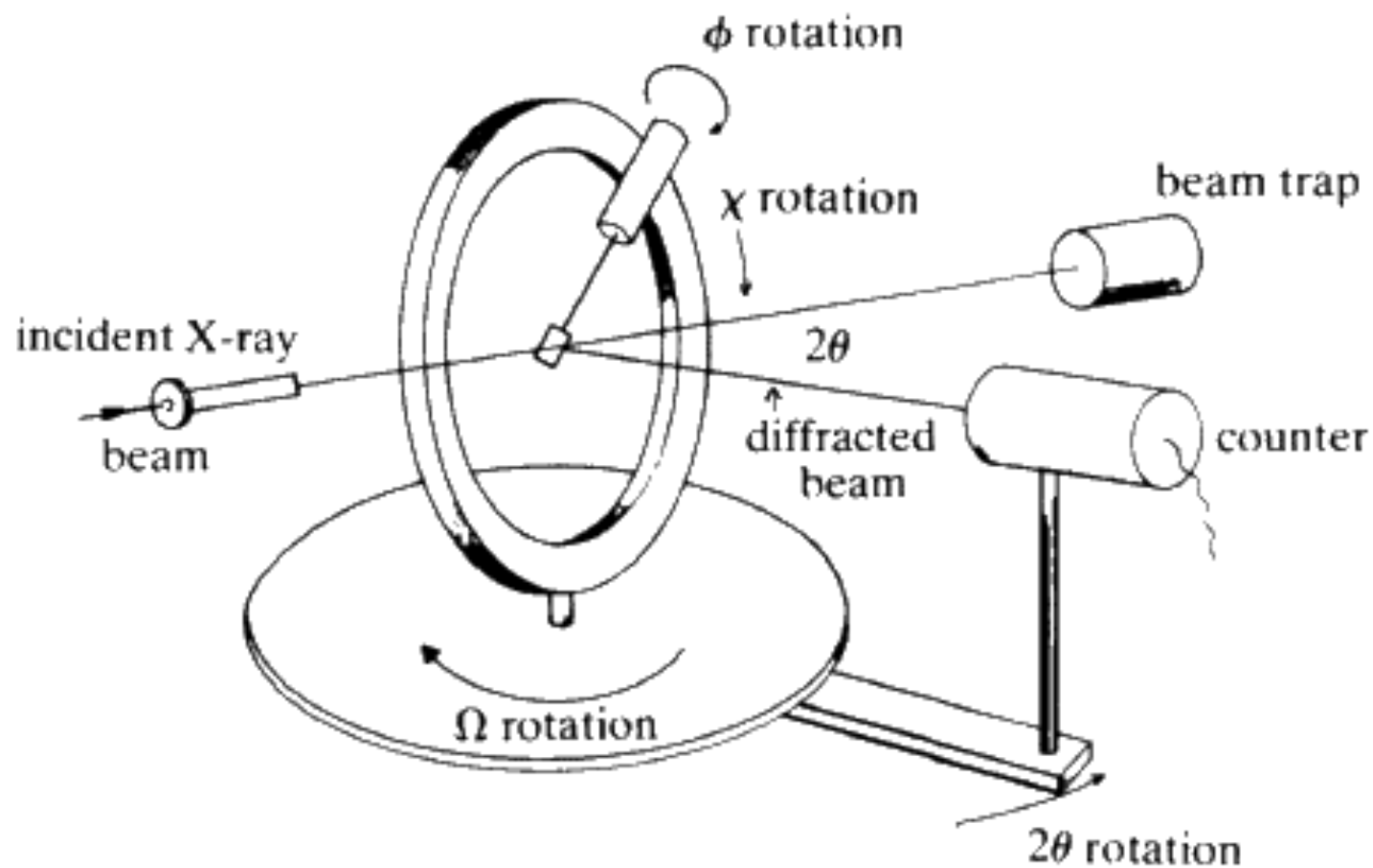
<http://www.k5.dion.ne.jp/~inos1936/shozoHP1E.html>

FORM FACTOR



http://www.xtal.iqfr.csic.es/Cristalografia/parte_05-en.html

Schematic of 4-circle diffractometer



DIFFRACTION METHODS

Powder diffraction:

Powder sample, monochromatic light, variable scattering angle detection

Single crystal diffraction:

Single crystal sample, monochromatic light, variable scattering angle detection
+ sample rotation

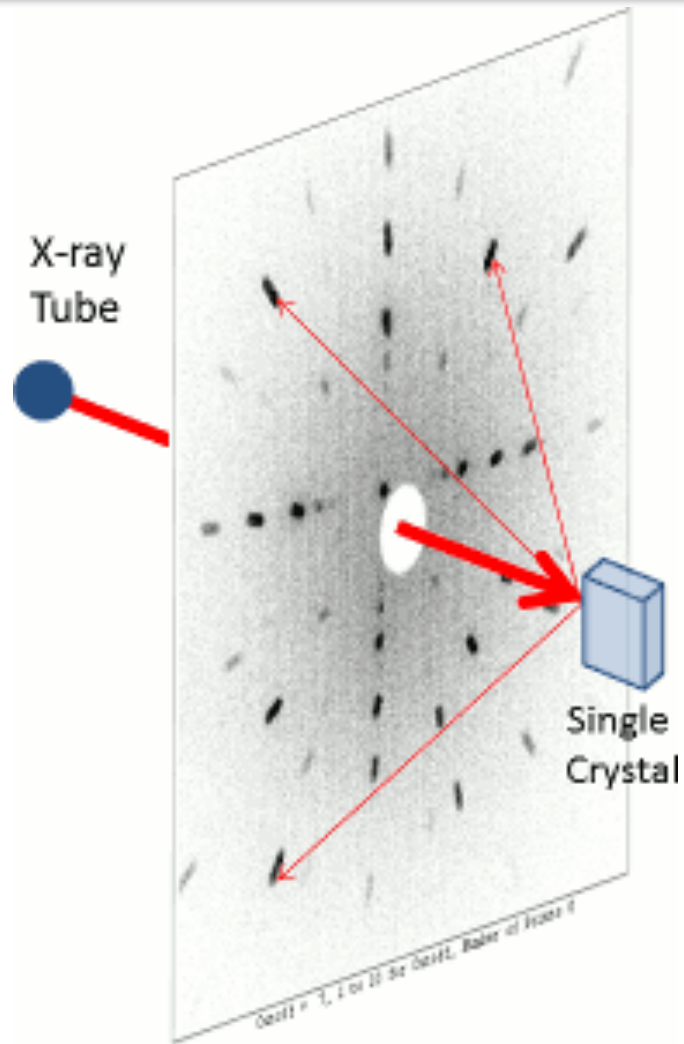
Laue diffraction:

Single crystal sample, polychromatic light (white beam)

Scattering facilities around Zurich

Paul Scherrer Institute

LAUE BACK REFLECTION GEOMETRY



$$2d \sin \theta = n\lambda,$$

DIFFRACTION METHODS

Powder diffraction:

Powder sample, monochromatic light, variable scattering angle detection

Single crystal diffraction:

Single crystal sample, monochromatic light, variable scattering angle detection
+ sample rotation

Laue diffraction:

Single crystal sample, polychromatic light (white beam)

Scattering facilities around Zurich

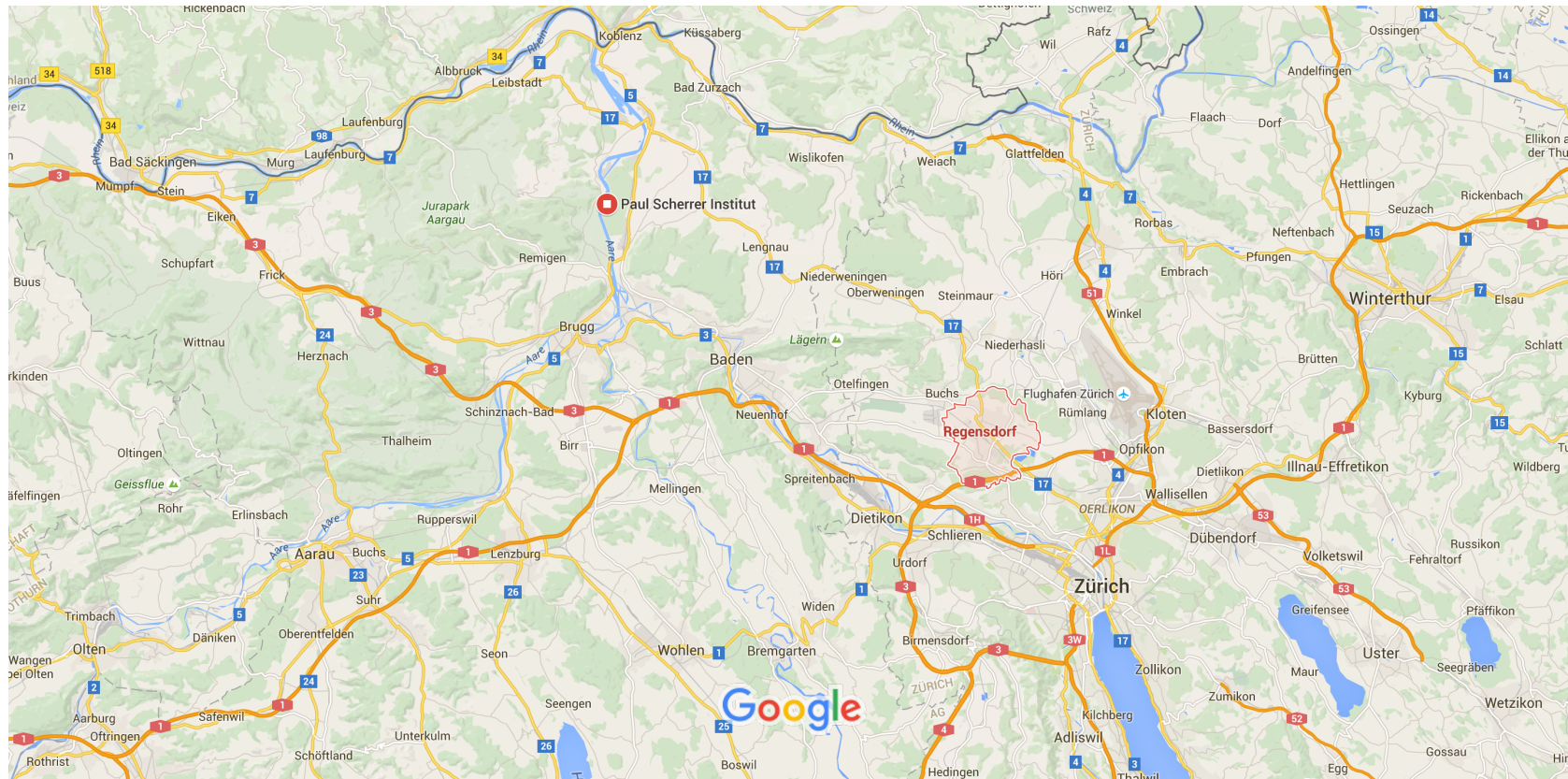
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<https://www.psi.ch>

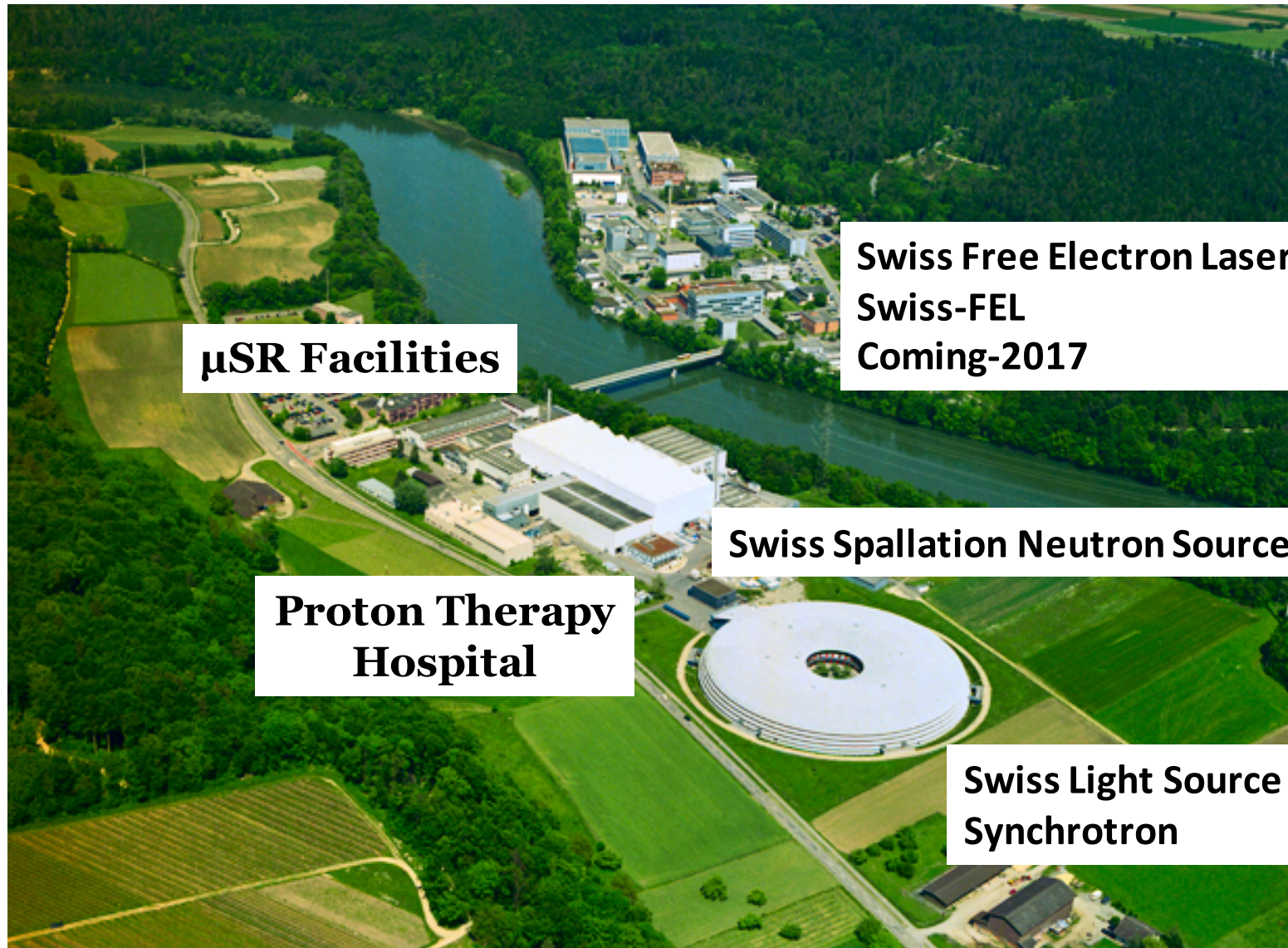
PAUL SCHERRER INSTITUTE (PSI)



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PAUL SCHERRER INSTITUTE (PSI)



μSR Facilities

**Swiss Free Electron Laser
Swiss-FEL
Coming-2017**

Swiss Spallation Neutron Source

**Proton Therapy
Hospital**

**Swiss Light Source
Synchrotron**

Neutron powder diffractometer @ PSI

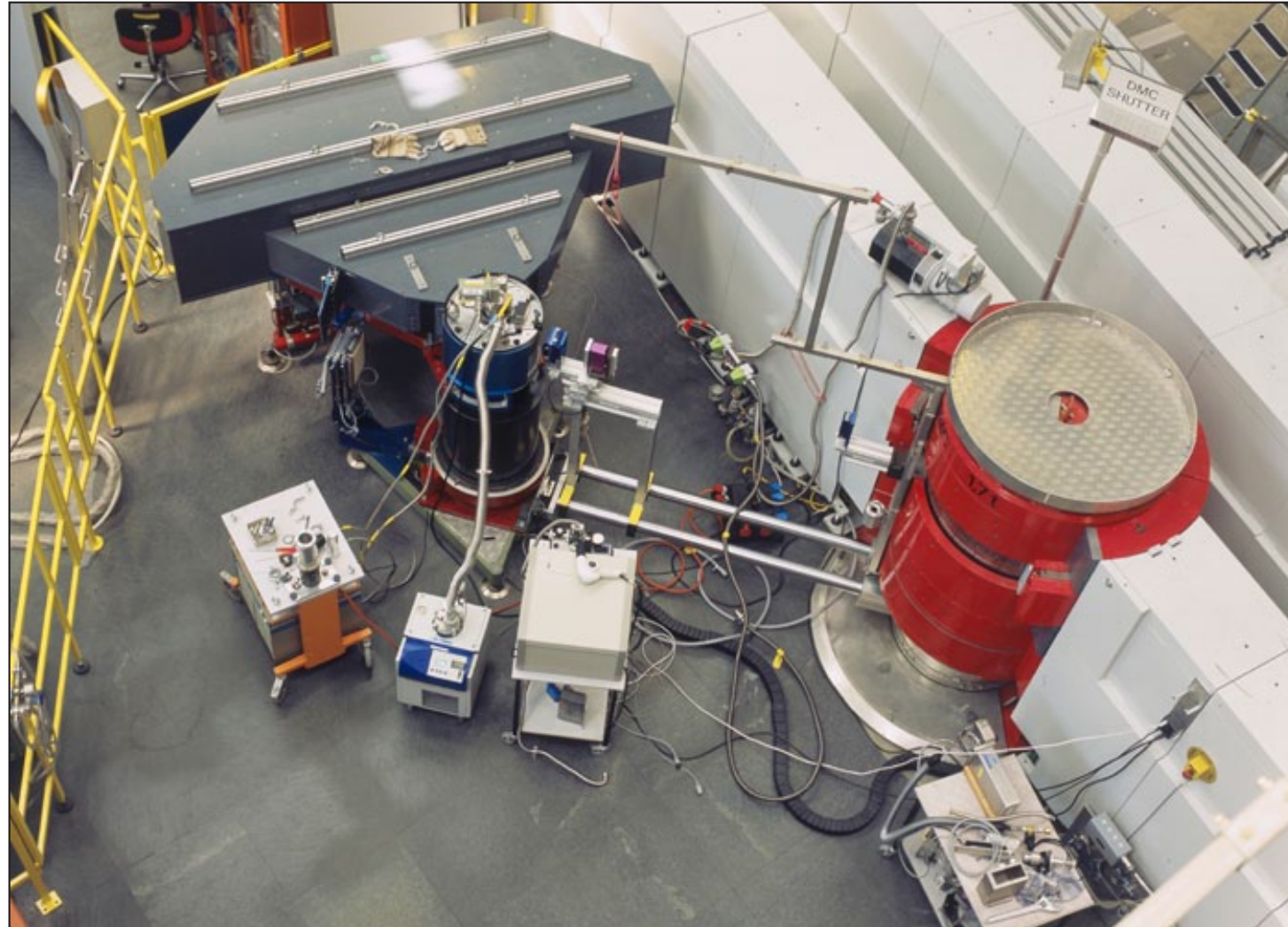
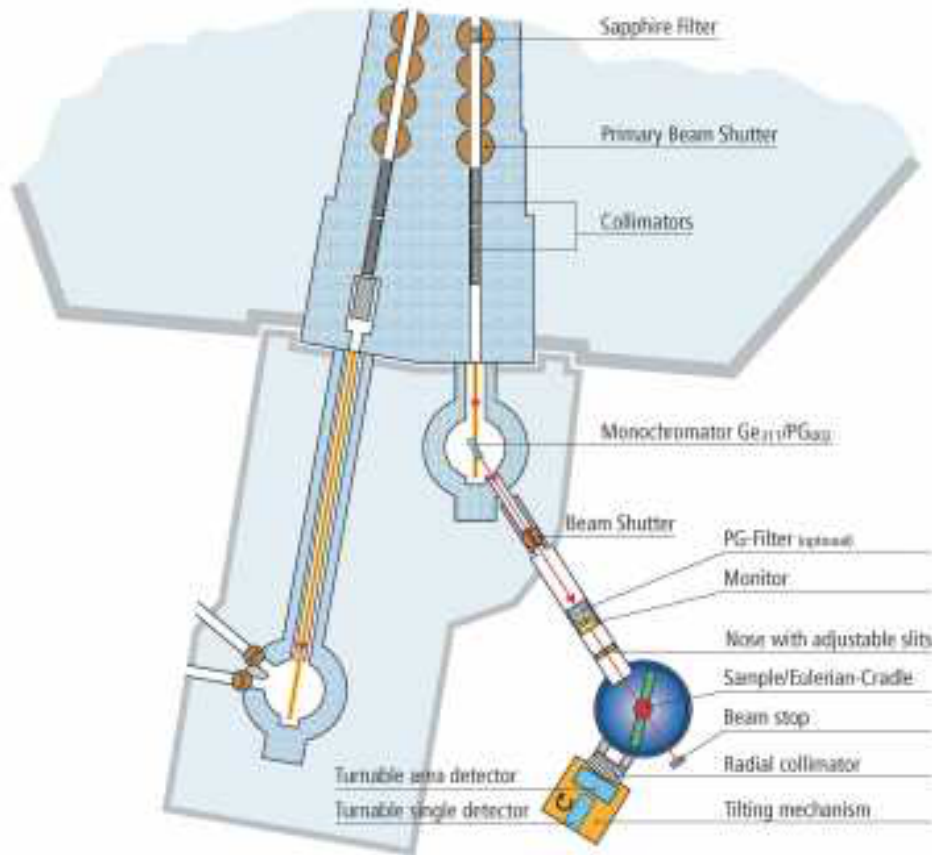


Figure 3: The DMC powder diffractometer is also appropriate for the investigation of magnetic phenomena.

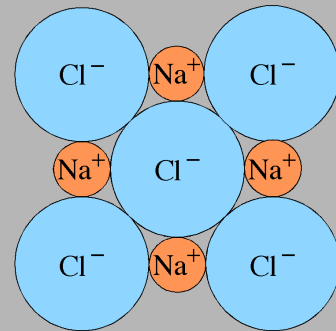
Neutron single crystal diffractometer @ PSI



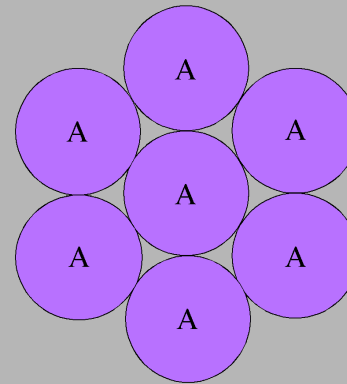
European facilities



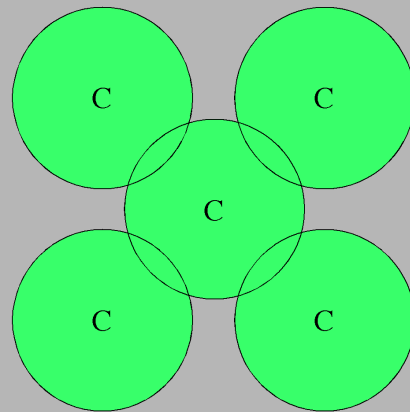
Topic of next week's lecture



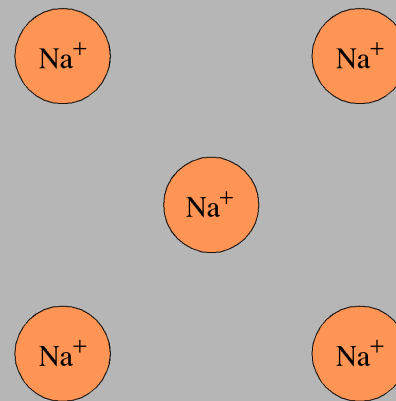
Natriumchlorid
(ionisch)



Kristallines Argon
(van der Waals)



Diamant
(kovalent)



Natrium
(metallisch)