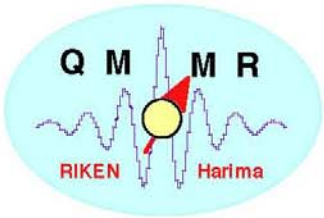
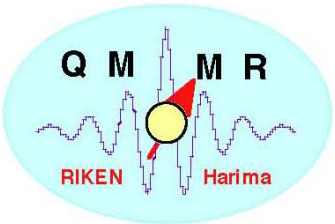


Synchrotron X-ray diffraction studies under extreme conditions

Koichi Katsumata
RIKEN SPring-8 Center, Harima Institute, Japan

1. Introduction
2. Recent results
3. Conclusions



Extreme conditions

- **High magnetic fields**

15 T superconducting magnet, 40 T pulsed field magnet

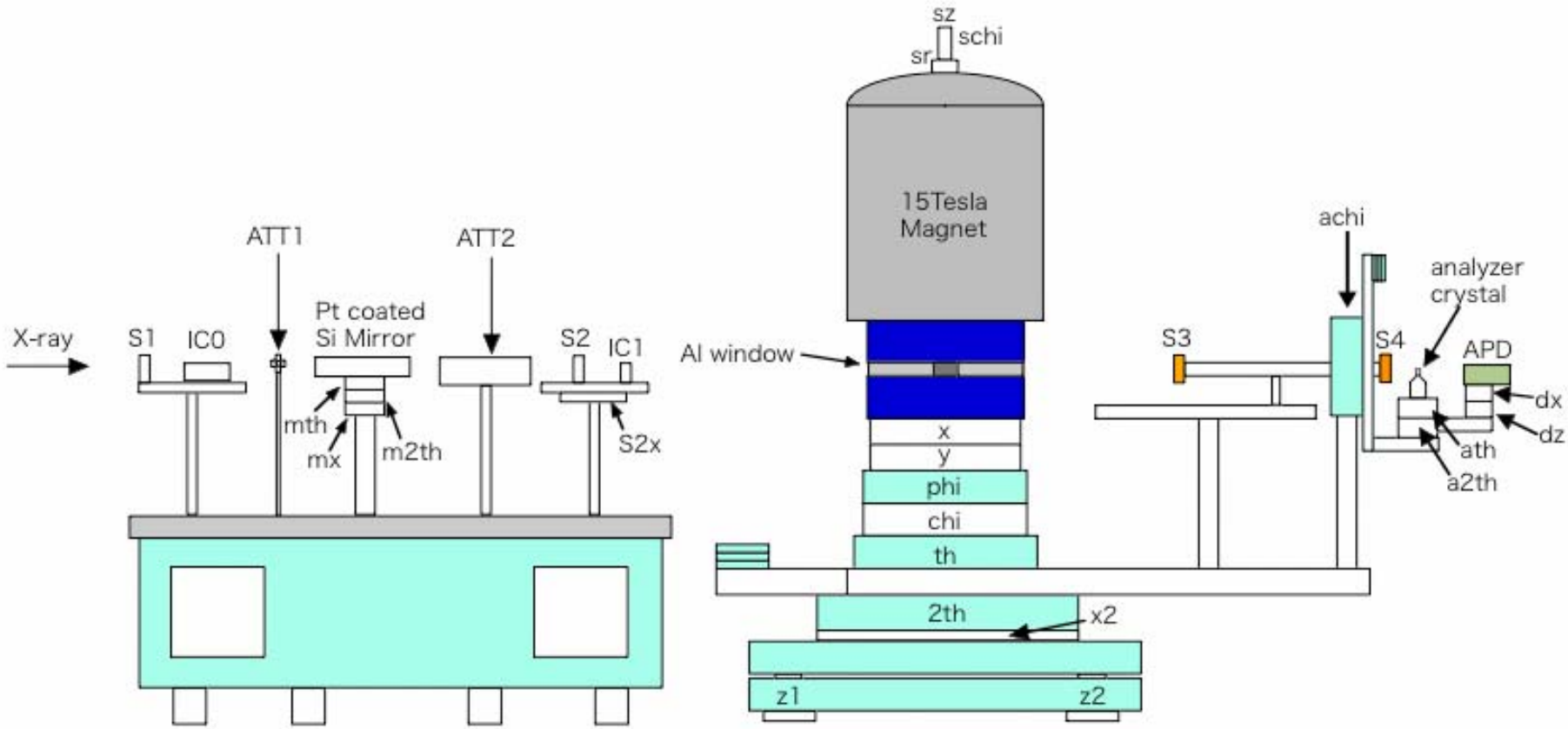
- **Very low temperatures**

30 mK dilution refrigerator

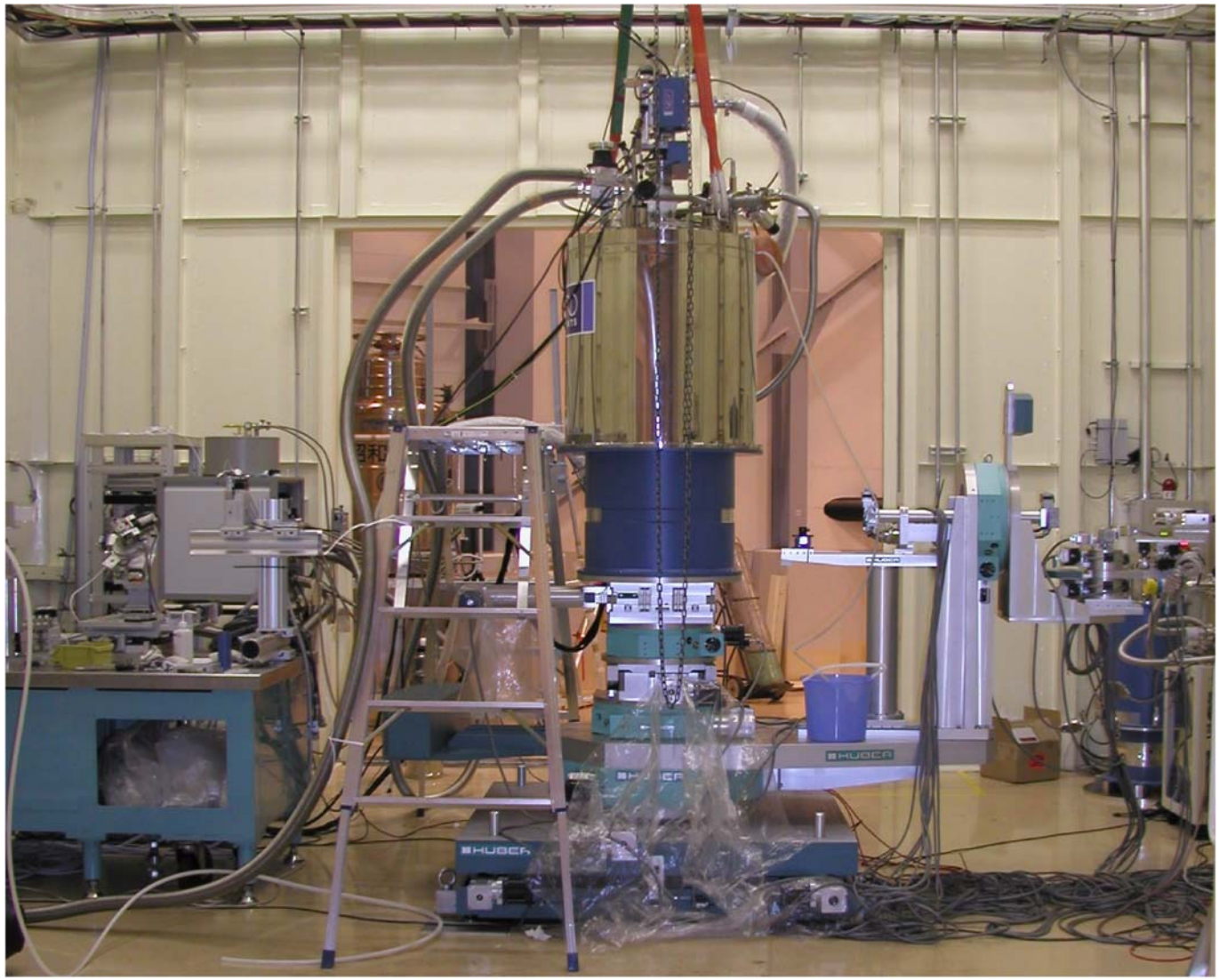
- **Intense high energy X-rays**

The World's strongest hard X-rays @ BL19LXU

Schematic view of the experimental hutch #4 at BL19LXU



A photograph of the magnet on the diffractometer



15 T Superconducting Magnet for X-ray Measurements

(Oxford Instruments, UK)

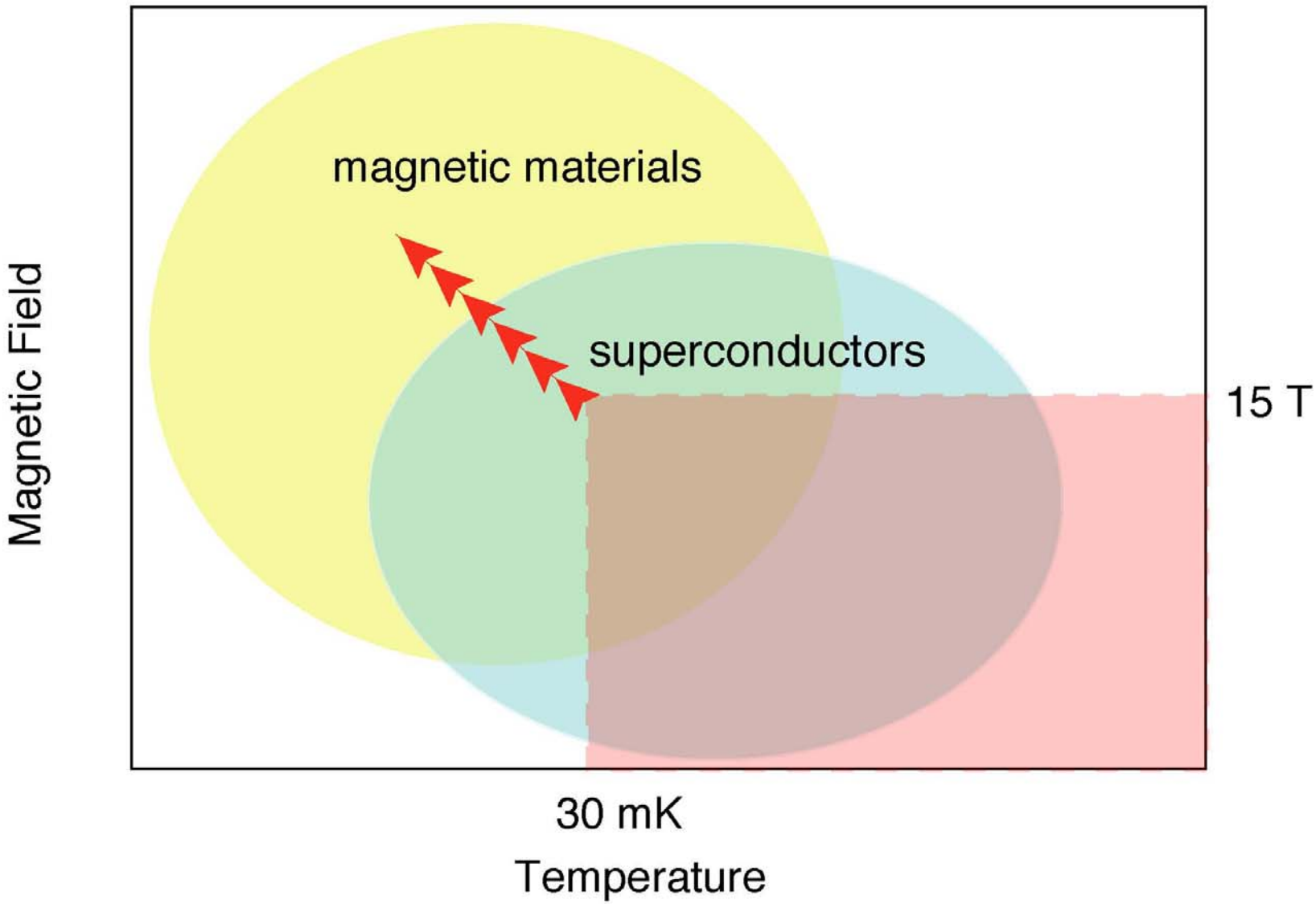
Specifications

Magnetic field	13 T @4.2 K
	15 T @2.2 K

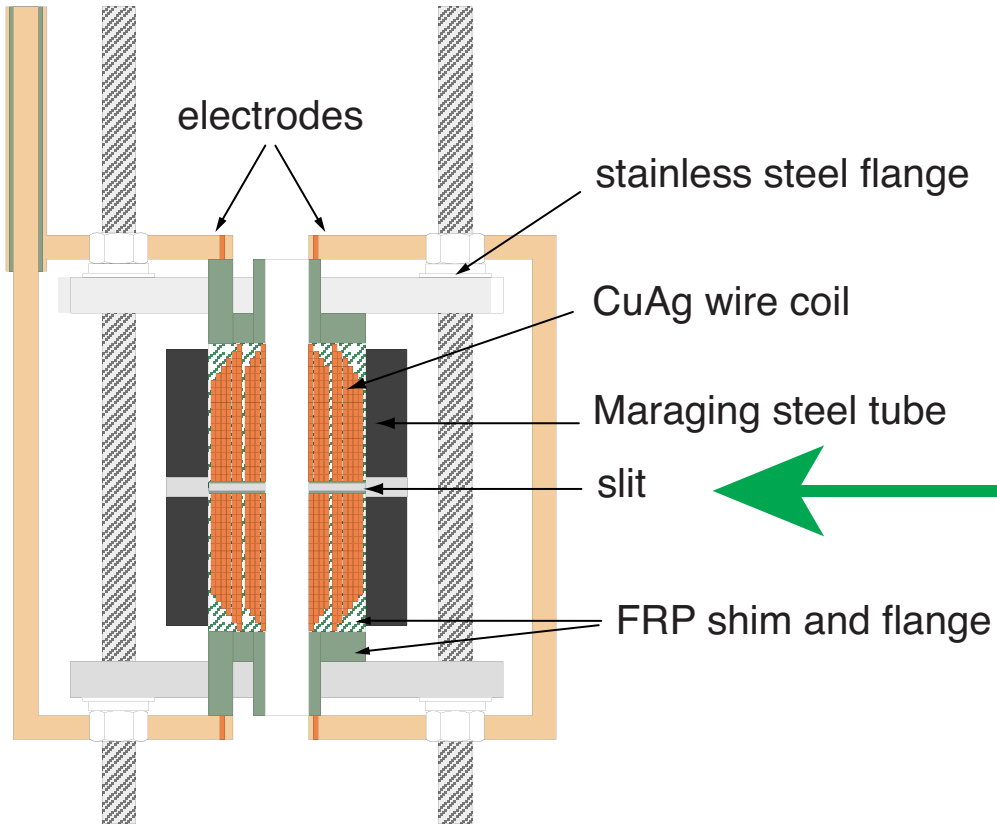
World highest static magnetic field for X-ray diffraction

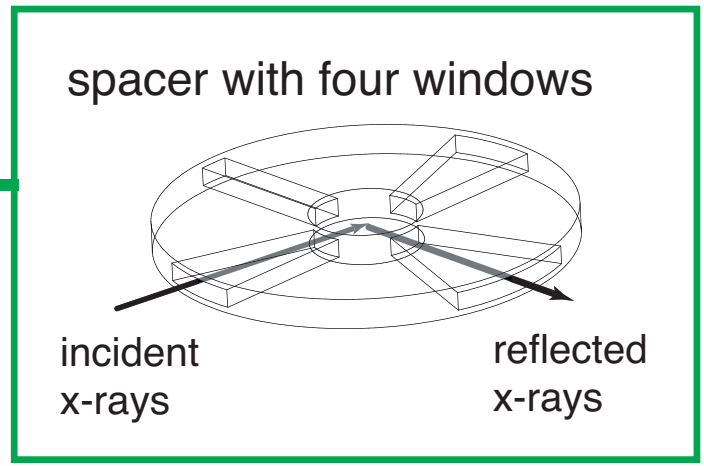
Cold bore	40 mm
Split	10 mm
Homogeneity	0.1 % over 5 mm dsv
VTI	1.5 - 300 K
Dilution insert	30 mK

World lowest temperature for X-ray diffraction


magnetic materials
superconductors
15 T
Magnetic Field
30 mK
Temperature

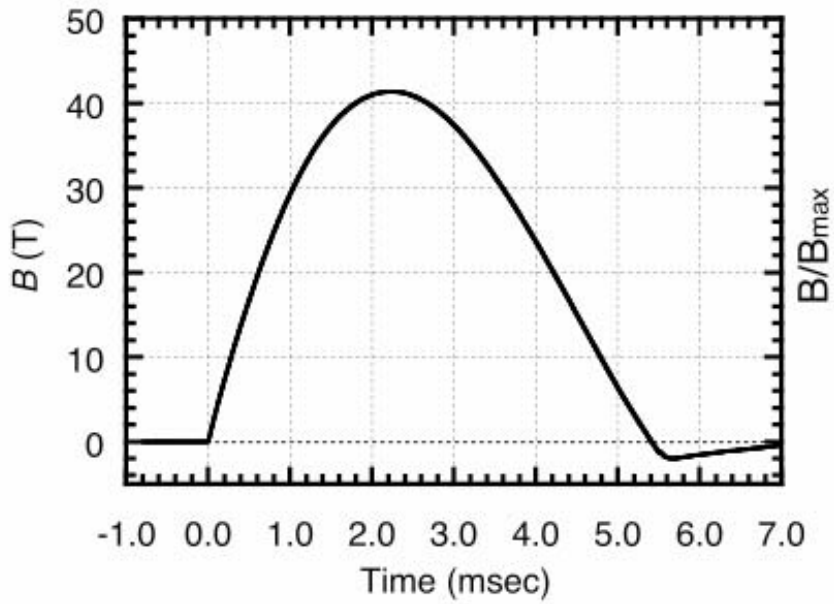
RIKEN Harima + ISSP Univ. Tokyo + KYOKUGEN Osaka Univ. collaboration



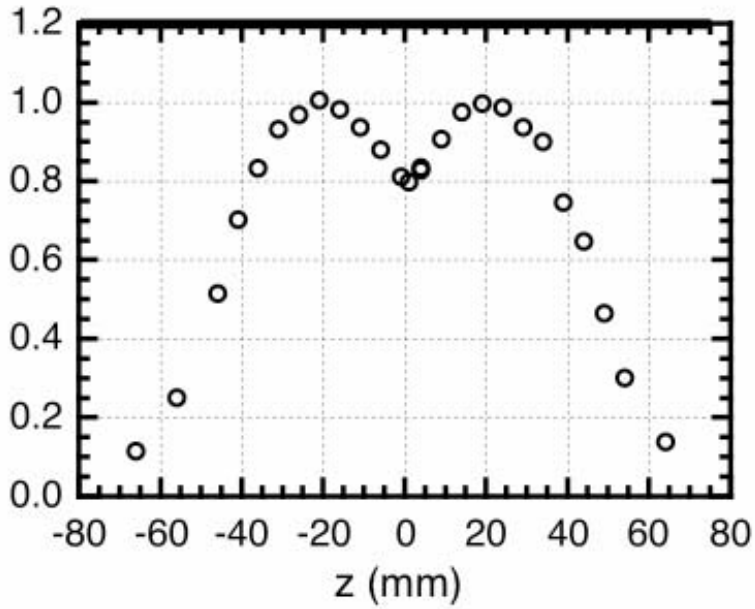


Pulsed field magnet

Field generated

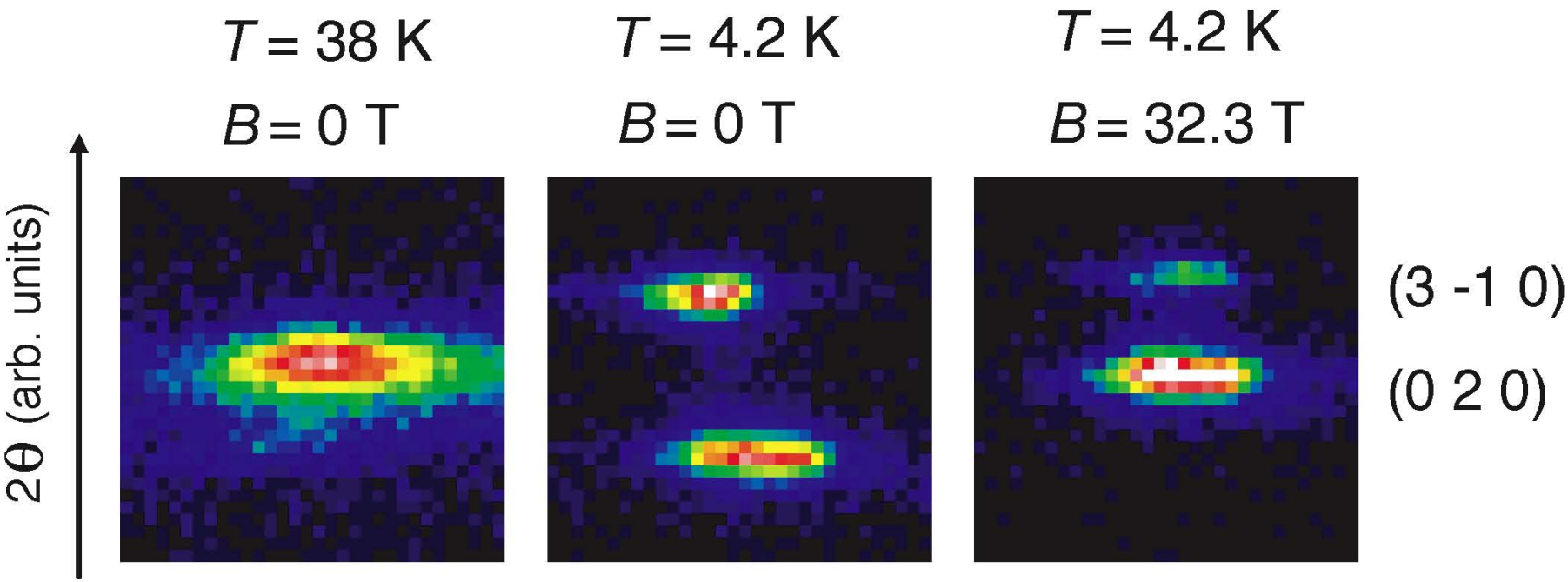


Field distribution



PILATUS 100 K 2D-detector

SLS-JASRI collaboration



Complementary use of static and pulsed high fields for synchrotron X-ray diffraction

Field induced lattice staircase in a frustrated antiferromagnet $CuFeO_2$

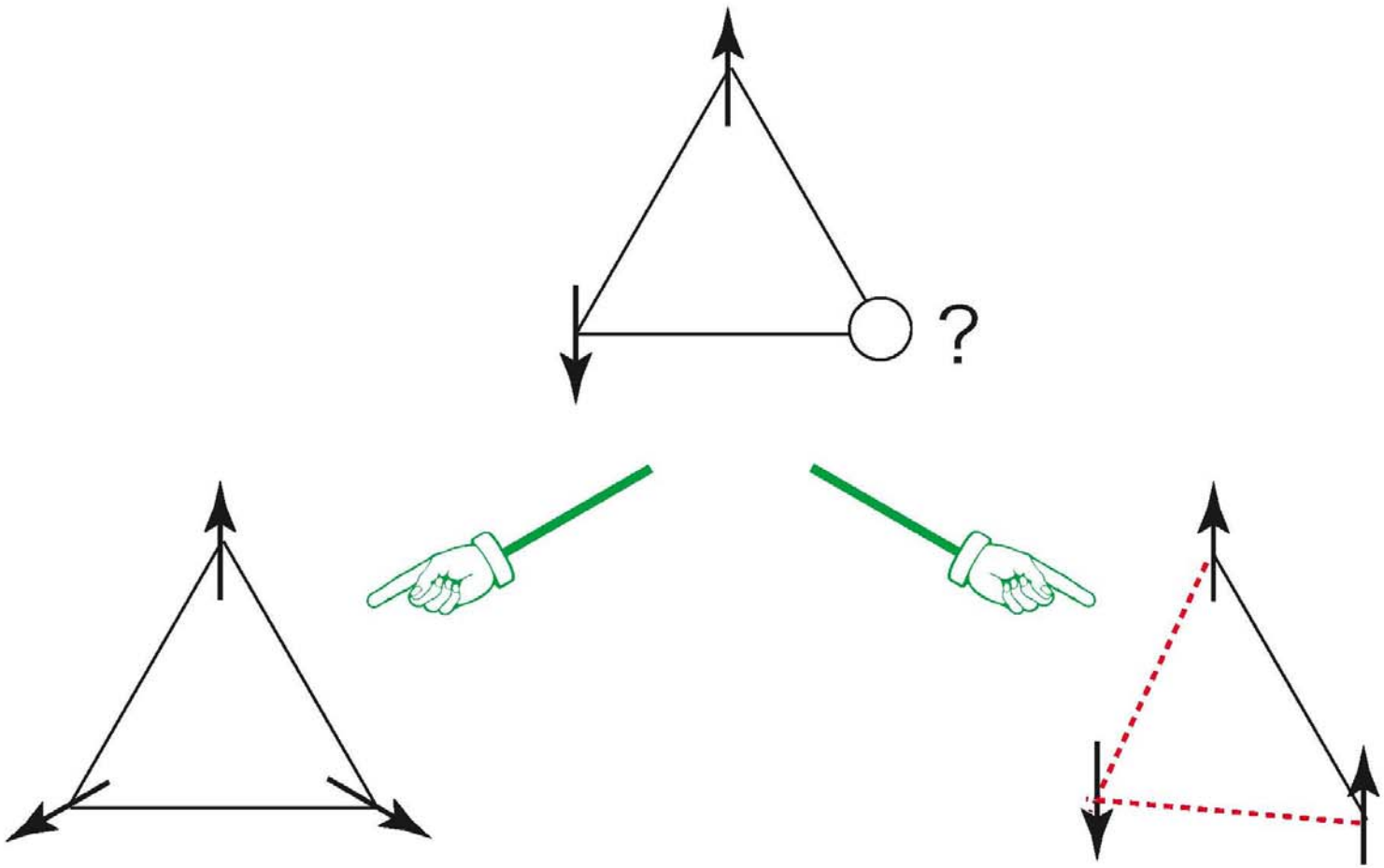
Related presentations

Y. Narumi: Details of X-ray diffractometer in pulsed field

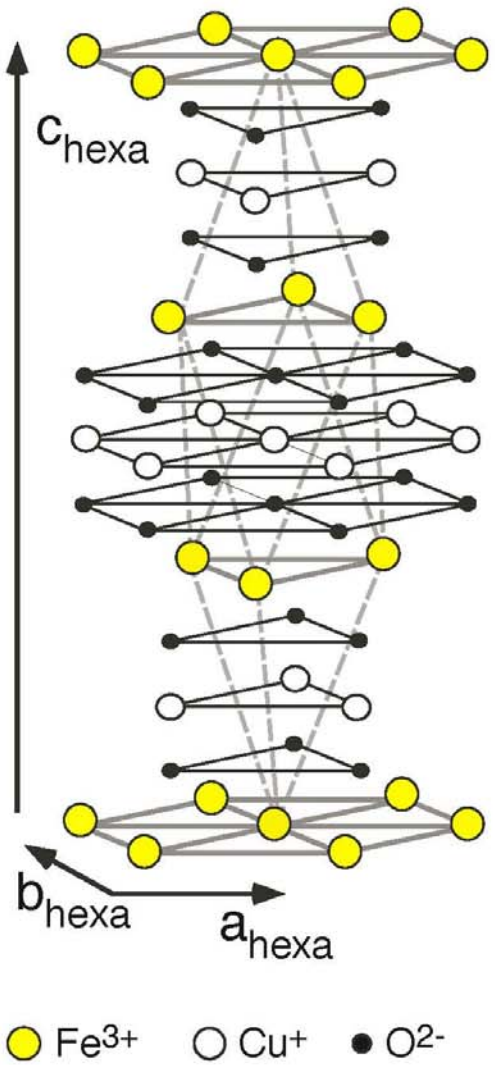
U. Staub: Direct observation of multipolar ordering

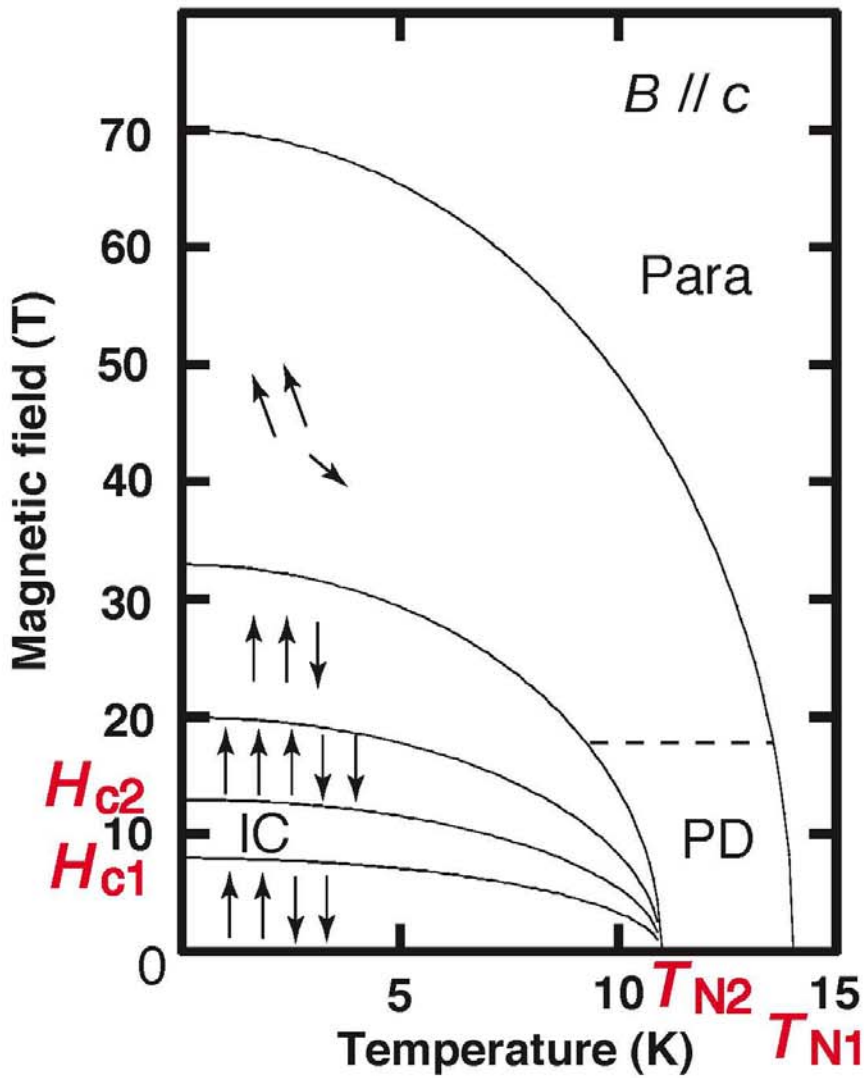
H. Suzuki: X-ray diffraction at very low temperatures

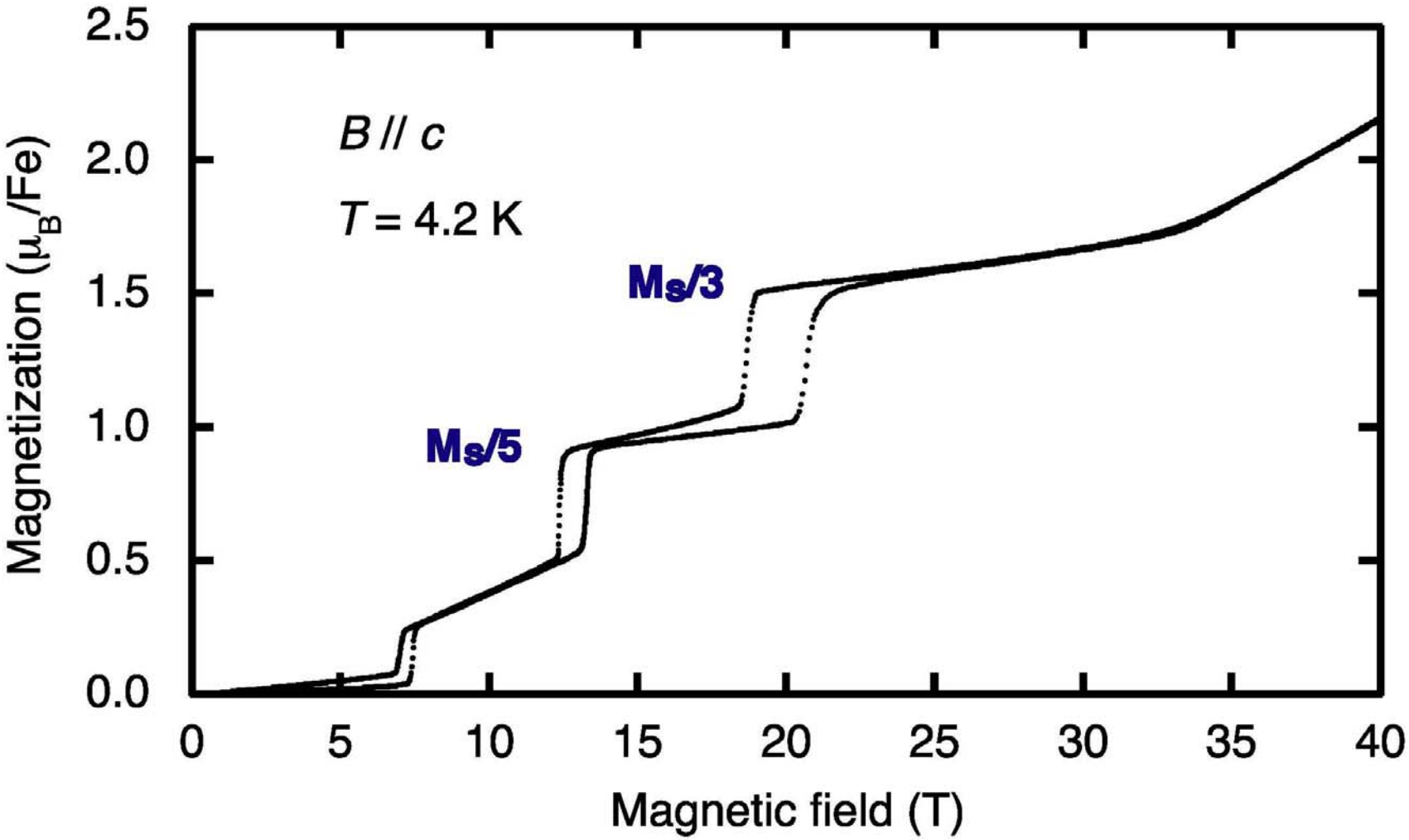
Geometrical frustration in a triangular lattice antiferromagnet



$CuFeO_2$

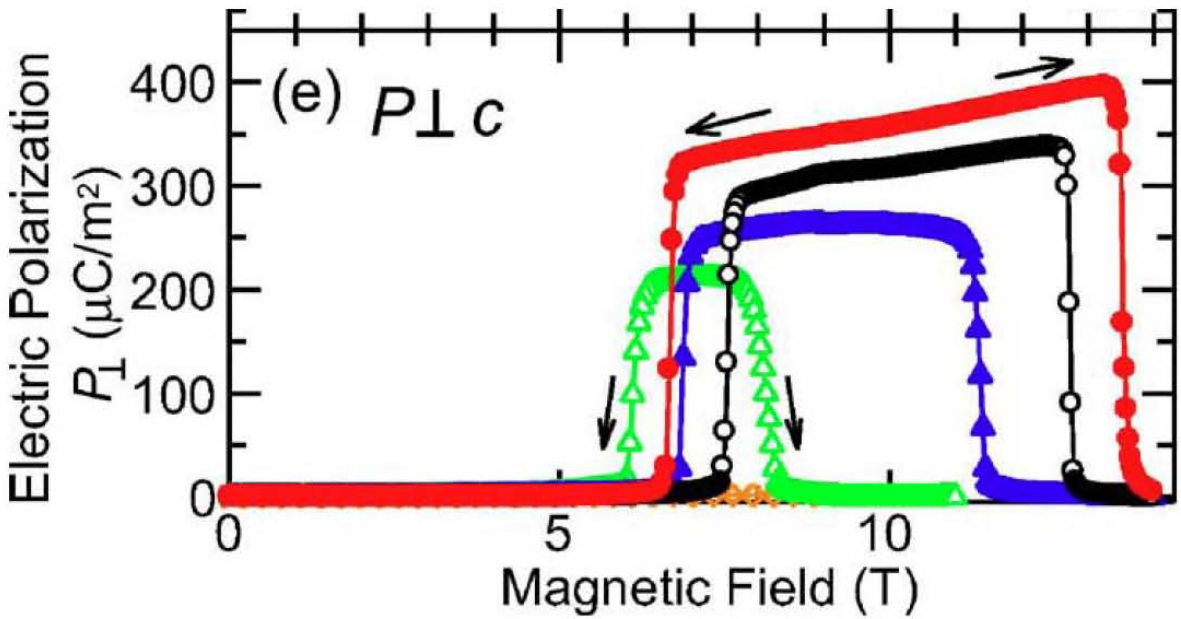

c hexa
b hexa
a hexa
Fe3+
Cu+
O2-


B // c
Para
PD
IC
Magnetic field (T)
70
60
50
40
30
20
10
0
Hc2
Hc1
5
10
15
TN2
TN1
Temperature (K)


B // c
T = 4.2 K
Ms/3
Ms/5
Magnetization (μB/Fe)
Magnetic field (T)
0.0
0.5
1.0
1.5
2.0
2.5
0
5
10
15
20
25
30
35
40

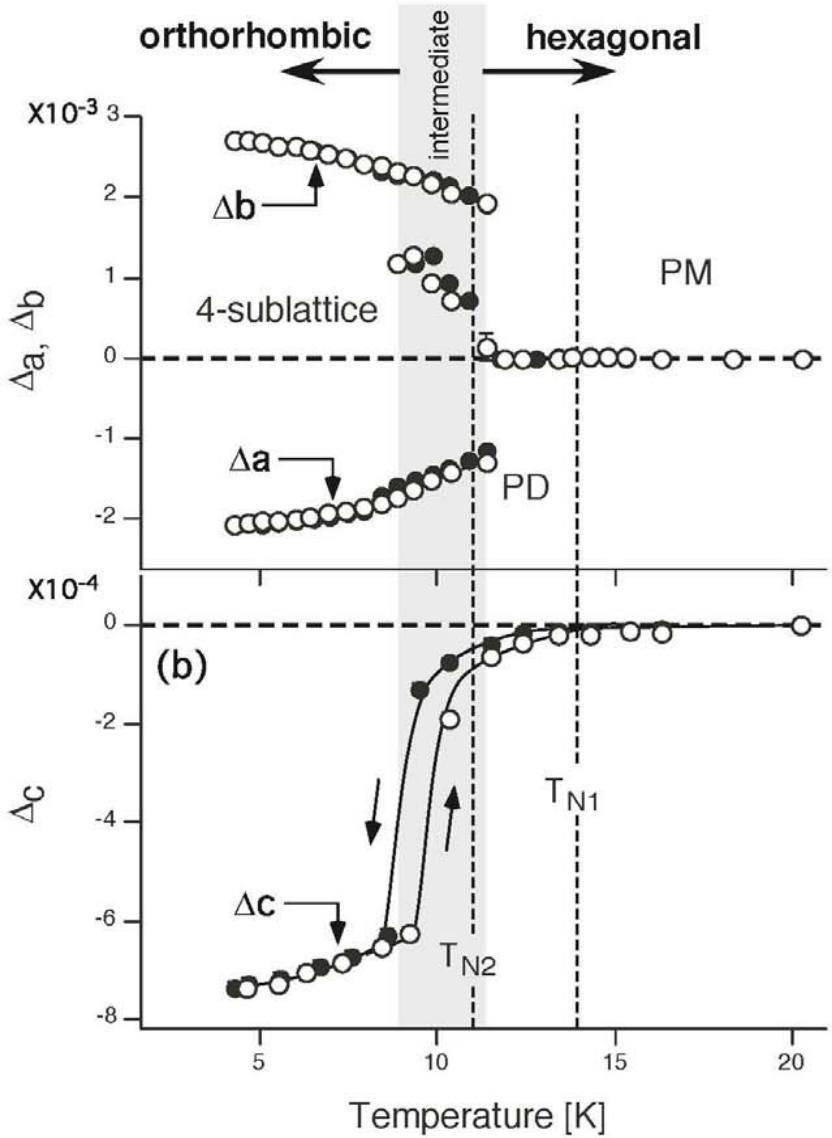
Magneto-electric effect in $CuFeO_2$

T. Kimura et al.: Phys. Rev. B 73, 220401 (R) (2006)



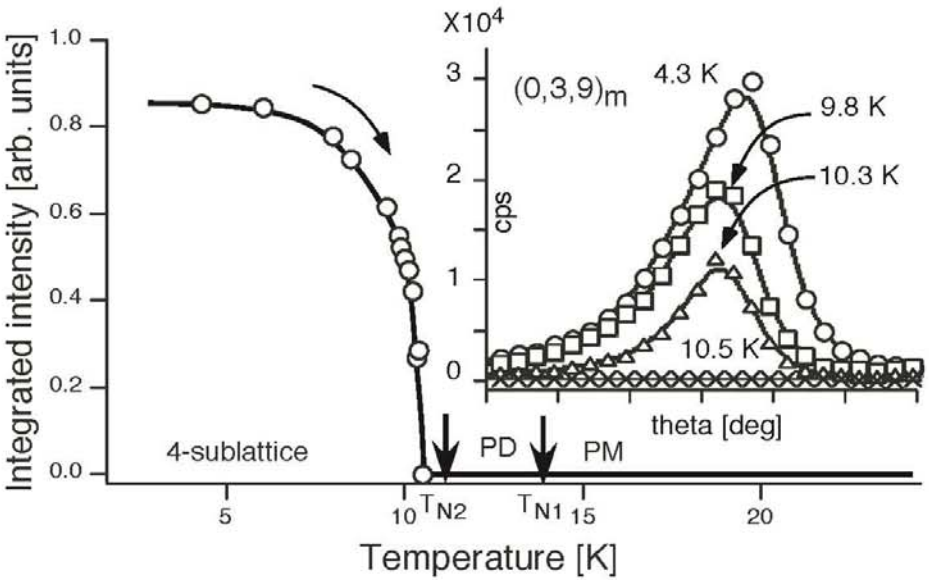
T = 2 K T = 7 K T = 9 K T = 10 K T = 11 K

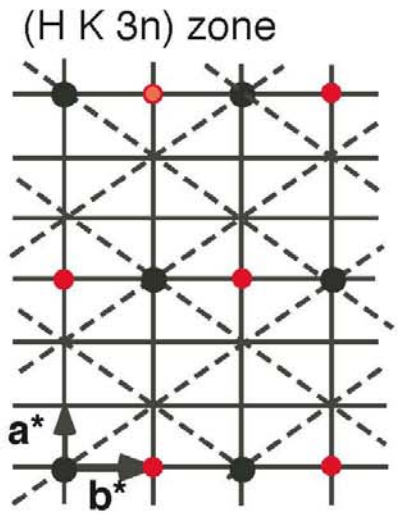
$CuFeO_2$ X-ray diffraction in zero field



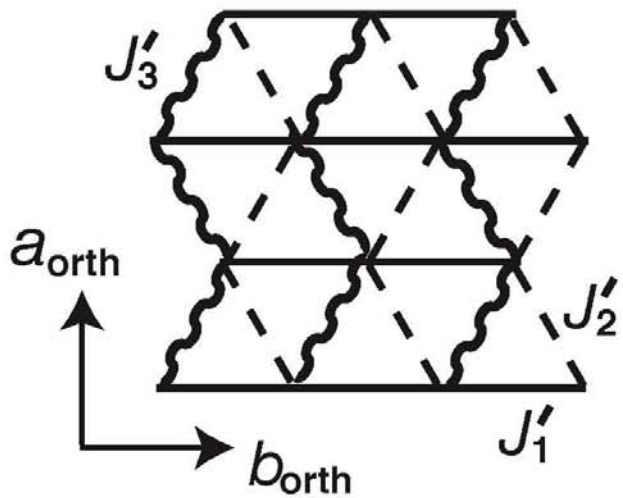
N. Terada et al.:
J. Phys. Soc. Japan 75, 023602 (2006)

N. Terada et al.: J. Phys. Soc. Japan 75, 023602 (2006)



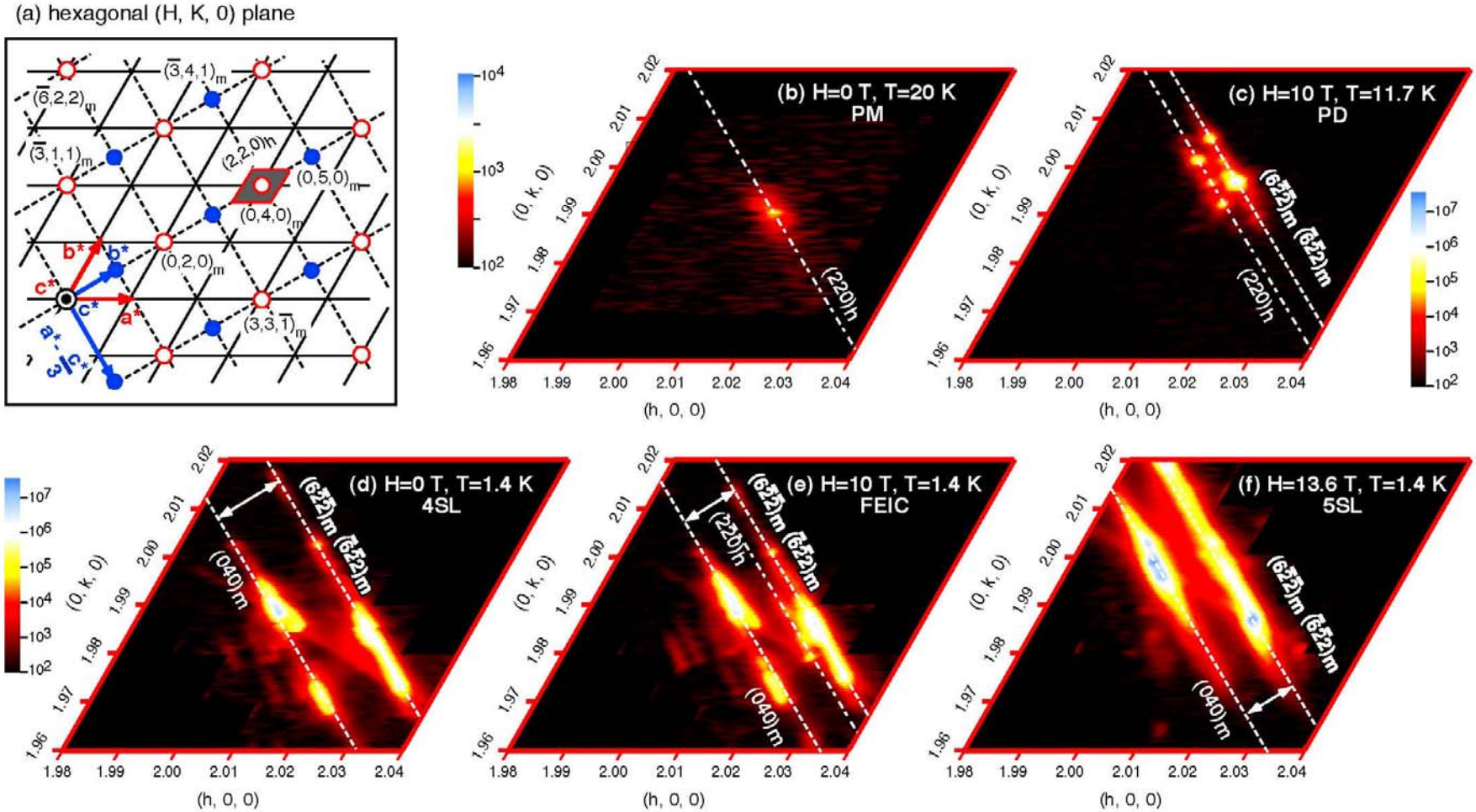


observation of a super-lattice reflection

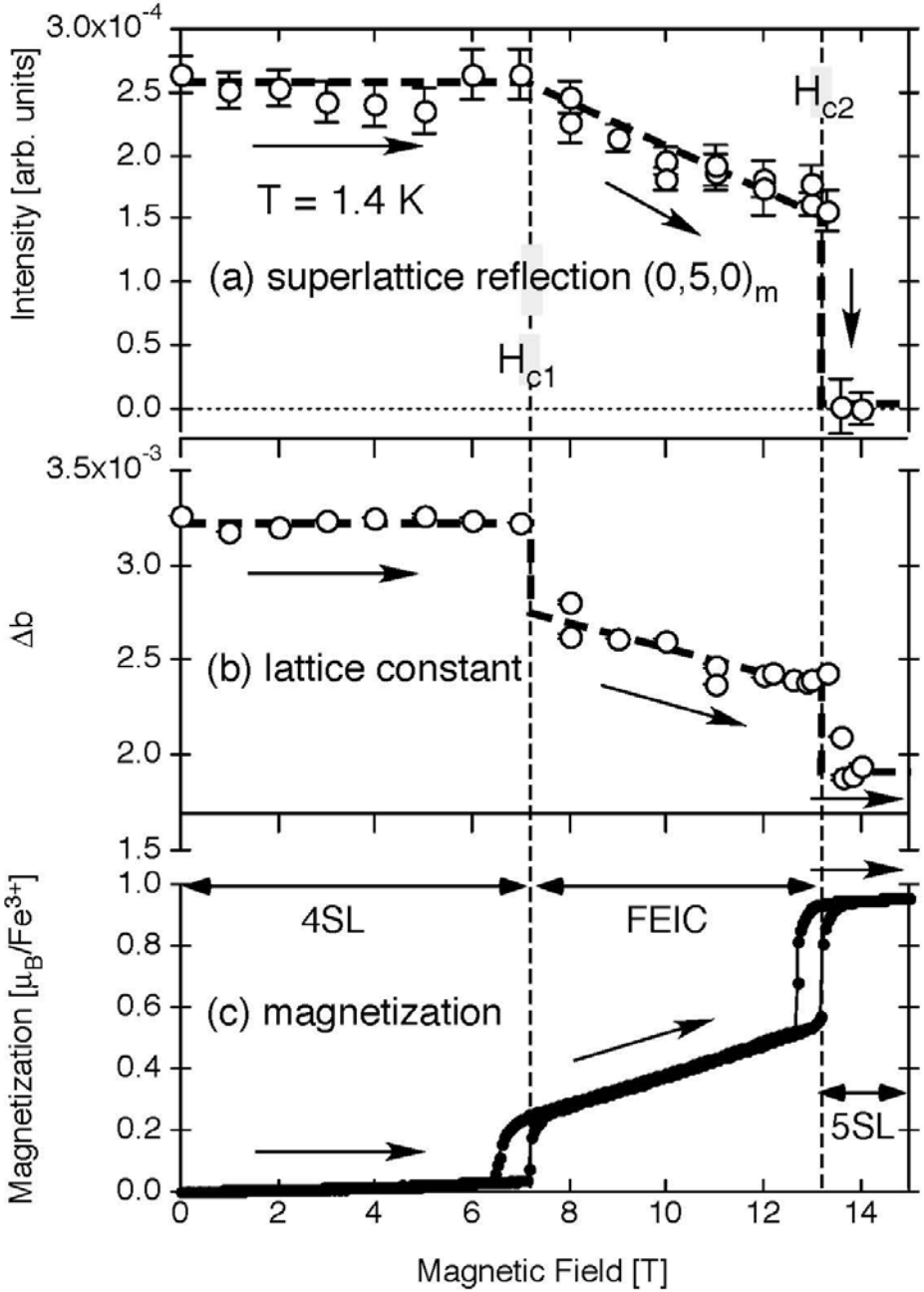


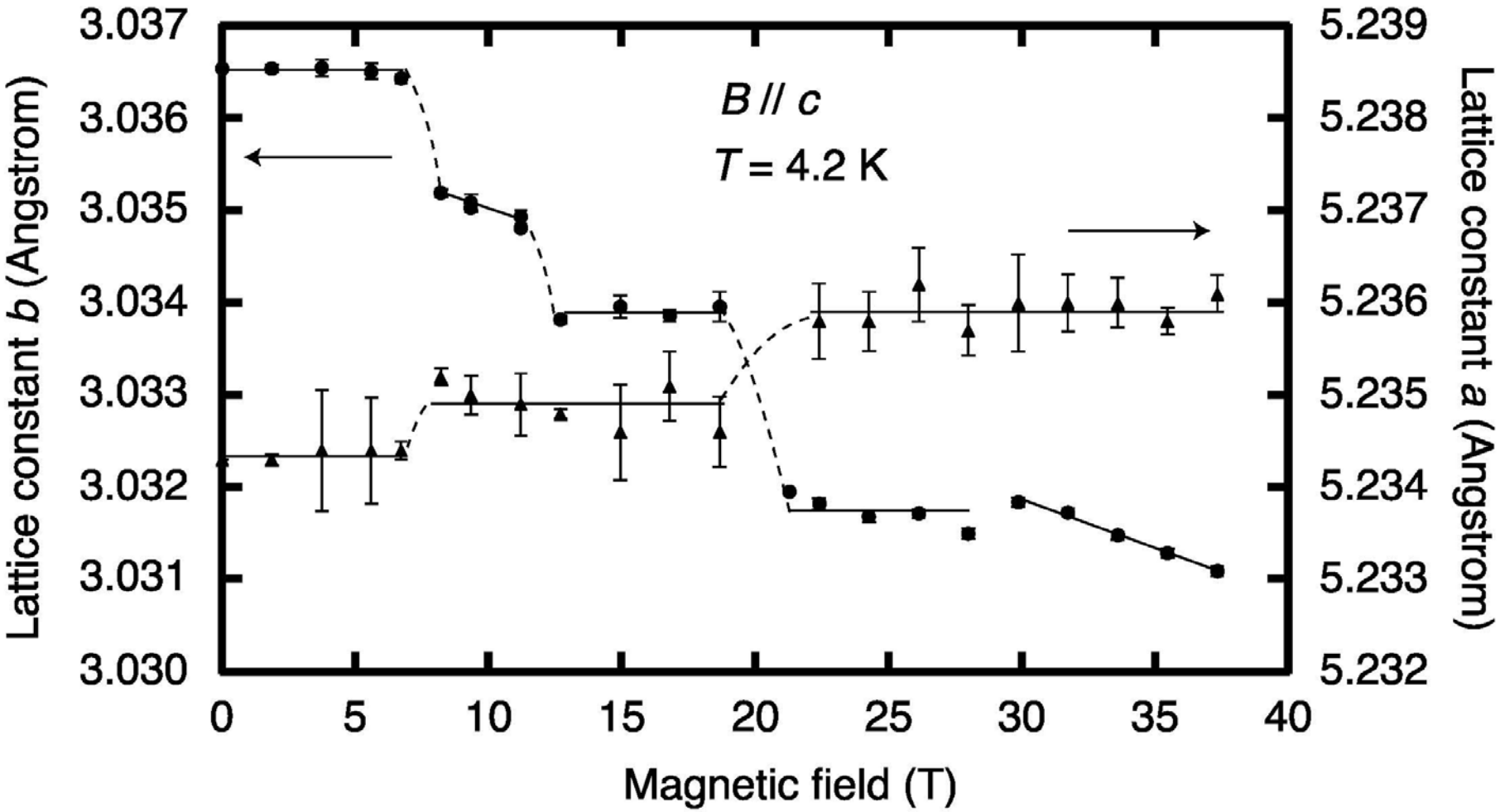
scalene triangle model

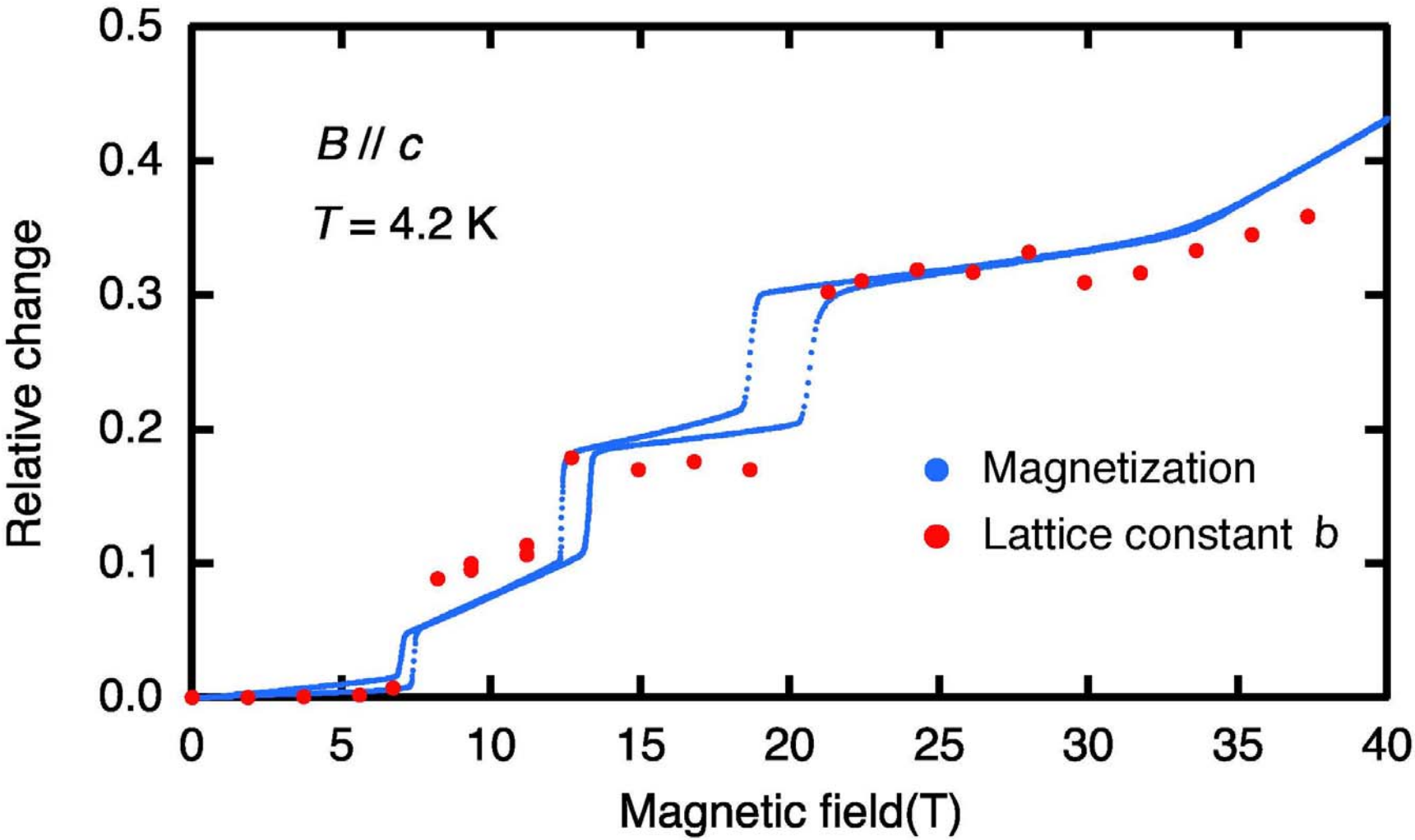
$CuFeO_2$


(a) hexagonal (H, K, 0) plane
(b) H=0 T, T=20 K
PM
(c) H=10 T, T=11.7 K
PD
(d) H=0 T, T=1.4 K
4SL
(e) H=10 T, T=1.4 K
FEIC
(f) H=13.6 T, T=1.4 K
5SL
(h, 0, 0)
(0, k, 0)
(220)h
(040)m

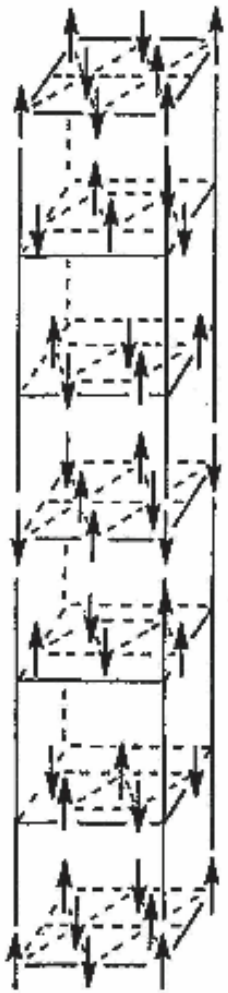
$CuFeO_2$

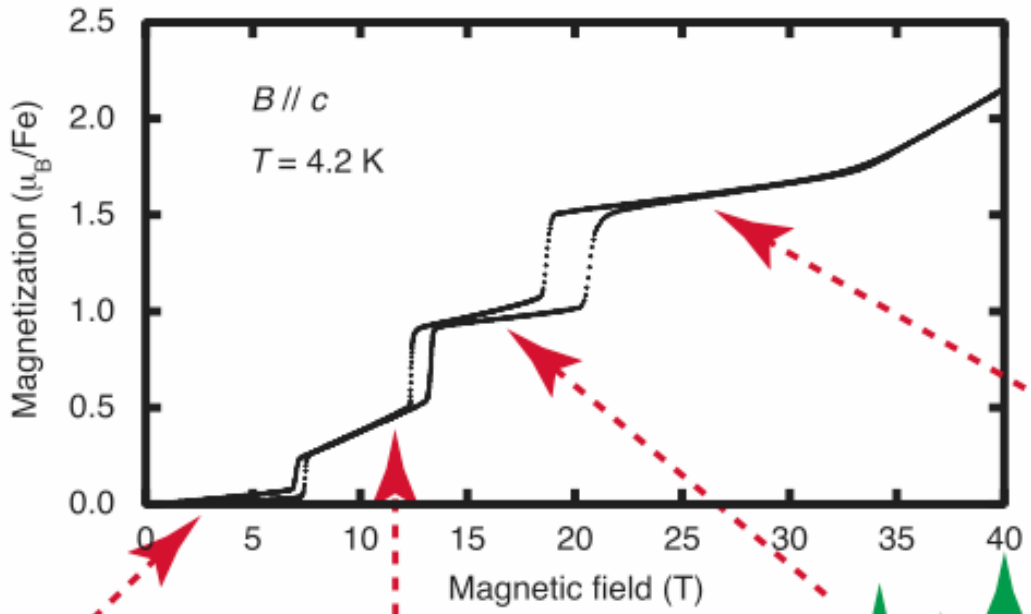

3.0x10^-4
2.5
2.0
1.5
1.0
0.5
0.0
Intensity [arb. units]
T = 1.4 K
(a) superlattice reflection (0,5,0)m
Hc1
Hc2
3.5x10^-3
3.0
2.5
2.0
1.5
Δb
(b) lattice constant
1.0
0.8
0.6
0.4
0.2
0.0
Magnetization [μB/Fe3+]
4SL
FEIC
5SL
(c) magnetization
0
2
4
6
8
10
12
14
Magnetic Field [T]

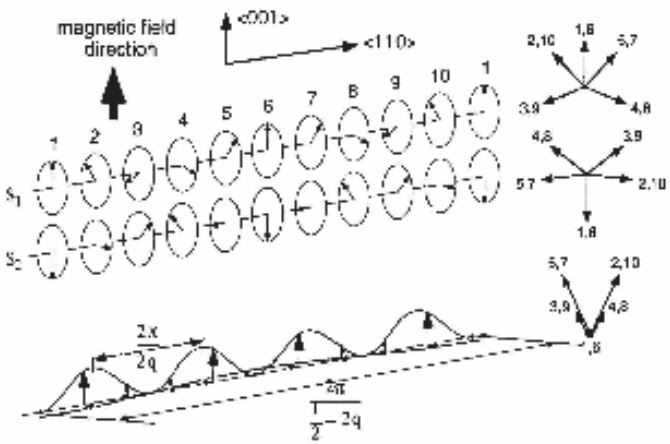

B // c
T = 4.2 K
Lattice constant b (Angstrom)
Lattice constant a (Angstrom)
Magnetic field (T)
3.037
3.036
3.035
3.034
3.033
3.032
3.031
3.030
5.239
5.238
5.237
5.236
5.235
5.234
5.233
5.232
0
5
10
15
20
25
30
35
40

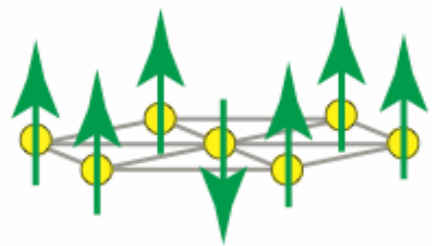

0.5
0.4
0.3
0.2
0.1
0.0
Relative change
B // c
T = 4.2 K
Magnetization
Lattice constant b
0
5
10
15
20
25
30
35
40
Magnetic field(T)

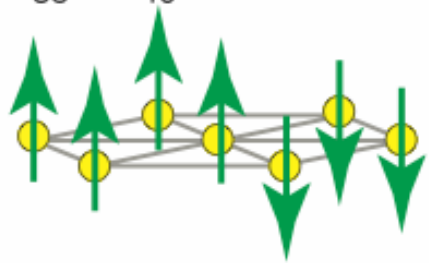
Magnetic structures in $CuFeO_2$





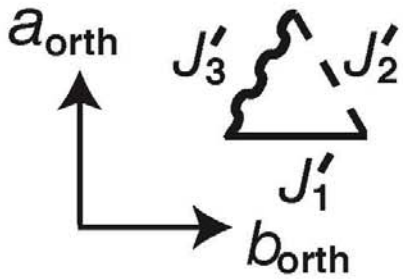






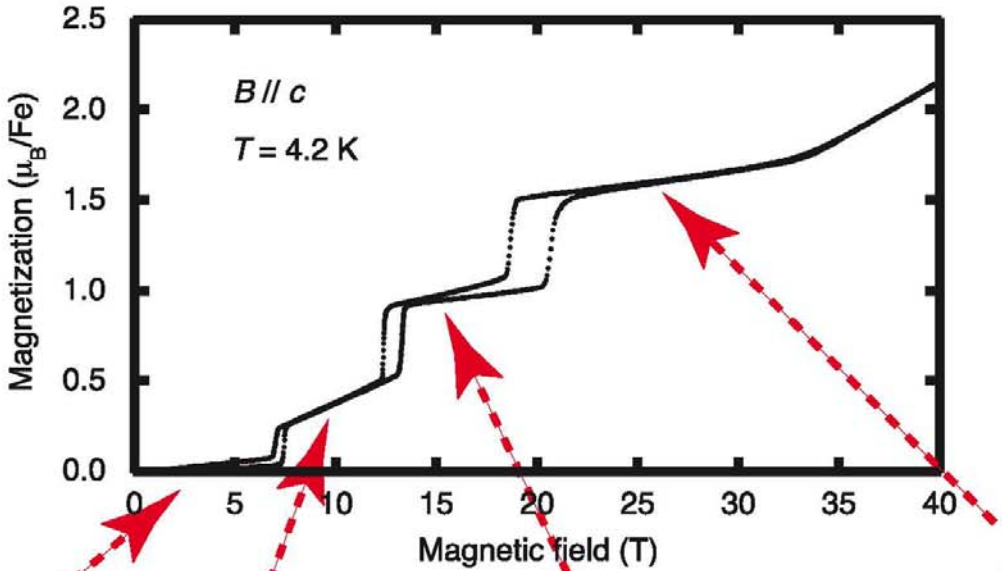
M. Mekata et al.: J. Phys. Soc. Japan 62, 4474 (1993)

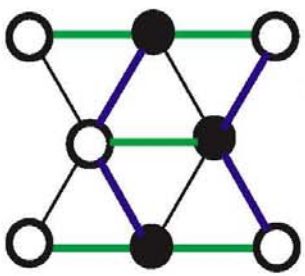
S. Mitsuda et al.: J. Phys. Soc. Japan 69, 3513 (2000)



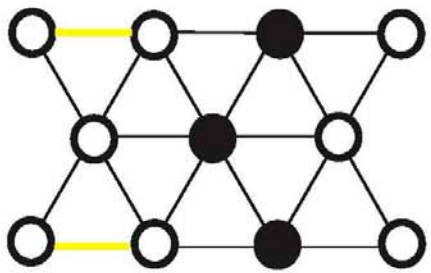
direct exchange: ferro.

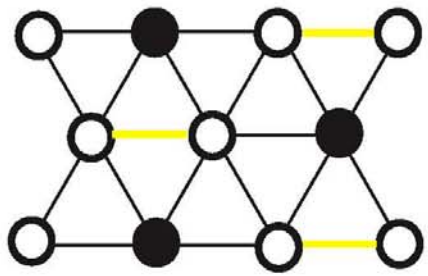
super exchange: antiferro.





elonates





contracts

Summary

X-ray diffraction studies under extreme conditions are successfully in progress

Apparatus;

15 T static field, 40 T pulsed field & 30 mK low temperature facilities

Scientific outputs;

- Stabilizing the high field phase of a spin-Peierls material by strong fields
- First observation of a generalized spin-Peierls transition in a quantum magne
- First observation of a giant magnet-volume effect in α-solid oxygen
- First direct observation of a multipolar ordering in CeB_6
- First observation of a field-induced lattice staircase in a frustrated magnet

DyB_2C_2, $FeCl_2 2H_2O$, α-Gd_2S_3, $HgCr_2O_4$, MnF_2, PrB_6, TbB_2C_2, …….

Collaborators

T. Bizen[1], Ch. Brönnimann[2], S. Goto[1], M. Hagiwara[3], T. Hara[1], I. Harada[4], Z. Honda[5], T. Ishikawa[6], M. Kawauchi[3], A. Kikkawa[6], S. Kimura[3], K. Kindo[7], H. Kitamura[6], M. Kohgi[8], Y. Kuramoto[9], J. E. Lorenzo[10], S. W. Lovesey[11], D. Mannix[12], M. Matsuda[13], T. Matsushita[1], T. Nakamura[1], Y. Narumi[7], Y. Nishiyama[4], H. Ohashi[1], T. Ohata[1], Y. Onuki[14], S. Shimomura[15], U. Staub[2], Y. Tabata[14], K. Takeshita[1], K. Tamasaku[6], T. Tanaka[1], Y. Tanaka[6], N. Terada[6], H. Toyokawa[1], M. Yabashi[1]

[1]SPring-8/JASRI, Japan
[2]Swiss Light Source, Paul Scherrer Institut, Switzerland
[3]KYOKUGEN, Osaka University, Japan
[4]Department of Physics, Okayama University, Japan
[5]Faculty of Engineering, Saitama University, Japan
[6]RIKEN SPring-8 Center, Harima Institute, Japan
[7]ISSP, University of Tokyo, Japan
[8]Department of Physics, Tokyo Metropolitan University, Japan
[9]Graduate School of Science, Tohoku University, Japan
[10]Laboratoire de Cristallographie, CNRS, France
[11]ISIS Facility, Rutherford Appleton Laboratory, UK
[12]ESRF, France
[13]Neutron Science Research Center, JAEA, Japan
[14]Graduate School of Science, Osaka University, Japan
[15]Department of Physics, Keio University, Japan