NATIONAL RESEARCH CENTRE
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Изучение киральных магнетиков с помощью рентгеновского магнитного кругового дихроизма

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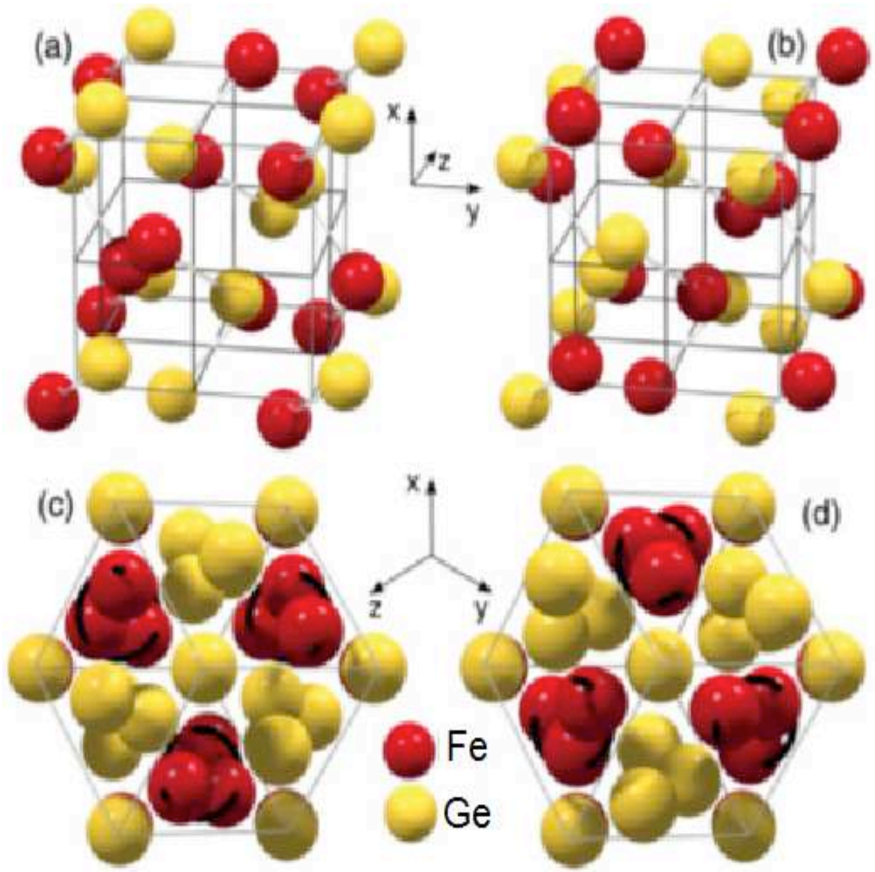
The European Synchrotron | ESRF

OUTLINE

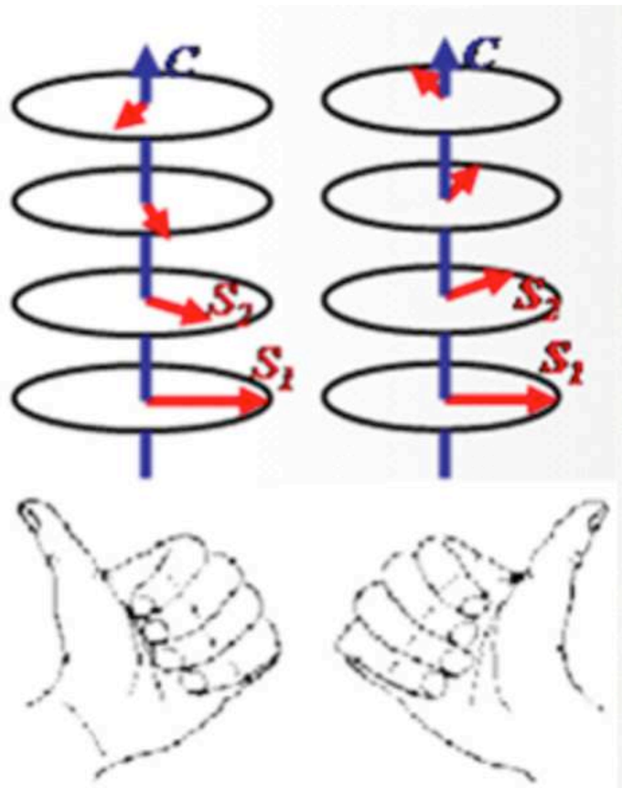
1. Noncentrosymmetric cubic magnets
2. XMCD:two-step model and experiment
3. ID12 beamline
4. Experimental results
5. Conclusions

NONCENTROSYMMETRIC CUBIC MAGNETS (FeGe)

Structural spiral



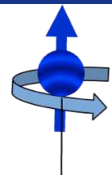
Magnetic spiral



Period of magnetic spiral is longer than period of structural spiral, e.g. FeGe lattice constant is 4.7Å, period of magnetic spiral is 18nm

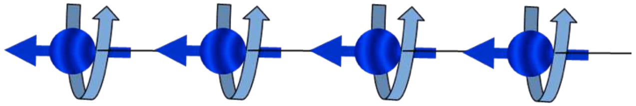
MAGNETIC INTERACTIONS

Atomic spin moment $\vec{S}$

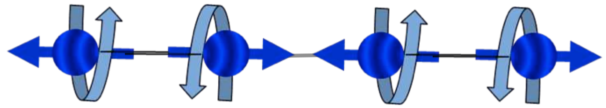


Heisenberg exchange $E_H = \sum_{ij} J_{ij} S_i \cdot S_j$

Ferromagnetism ($J < 0$)



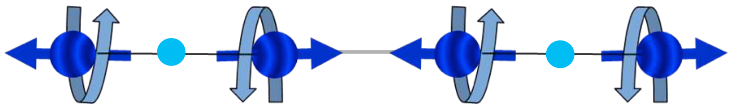
Antiferromagnetism ($J > 0$)



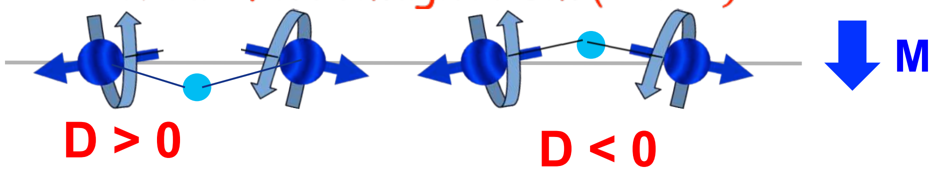
Dzyaloshinskii Moriya interaction $E_{DM} = \sum_{ij} D \cdot (S_i \times S_j)$

Dzyaloshinskii-Moriya interaction is at the origin of weak ferromagnetism, magnetoelectricity, multiferroicity, etc.

Collinear antiferromagnetism ($D = 0$)

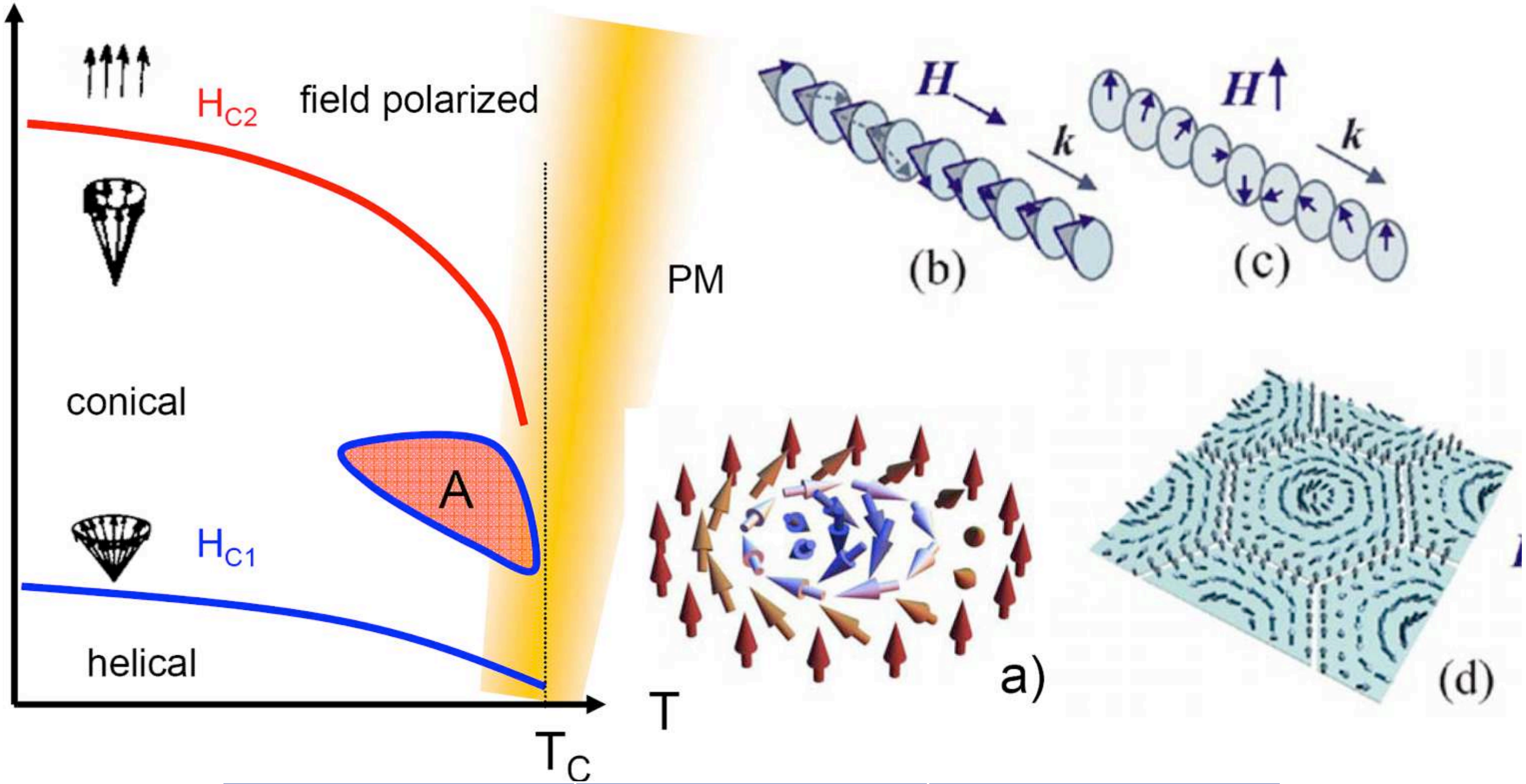


Weak ferromagnetism ($D \neq 0$)

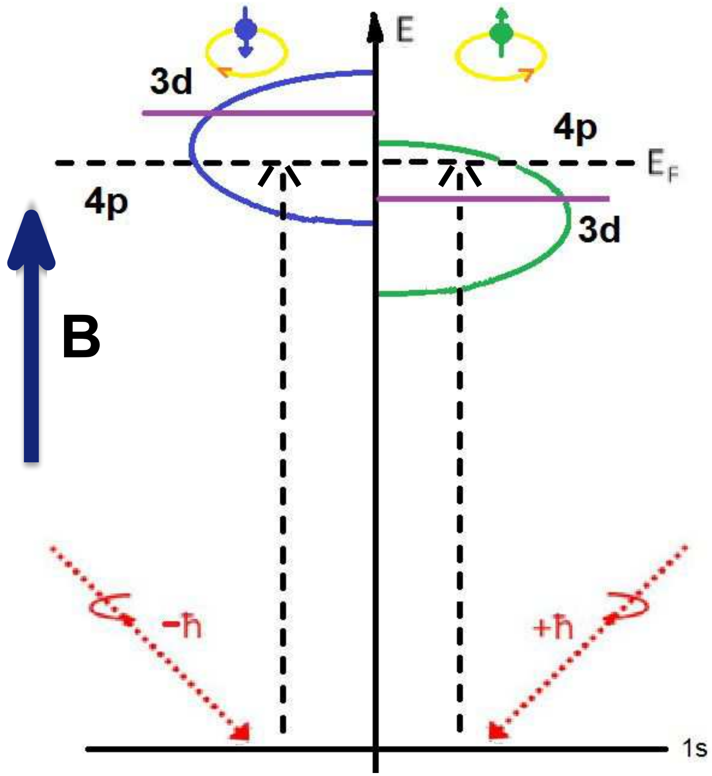


Dzyaloshinskii-Moriya vector D defines the magnetic spiral

PHASE DIAGRAMS OF MONOGERMANIDES OF TM



	FeGe	MnGe
T_c	≈ 270K	≈ 170K
H_{c1}	≈ 0.1T (low T)	≈ 2T (low T)
H_{c2}	≈ 0.3T (low T)	≈ 14T (low T)



LCP photon $\langle L_{ph} \rangle = +\hbar$

RCP photon $\langle L_{ph} \rangle = -\hbar$

Electric dipole selection rules:

$$\Delta m_l = +1$$
$$\Delta m_l = -1$$

$$\sum \left(\vec{L}_{ph} + \vec{L}_{ph-e} \right) = const$$

In the case of the K-edge of transition metals

$$\int XMCD \sim \langle L_z \rangle_{4p} + \varepsilon \langle L_z \rangle_{3d}$$

Advantage: element selectivity

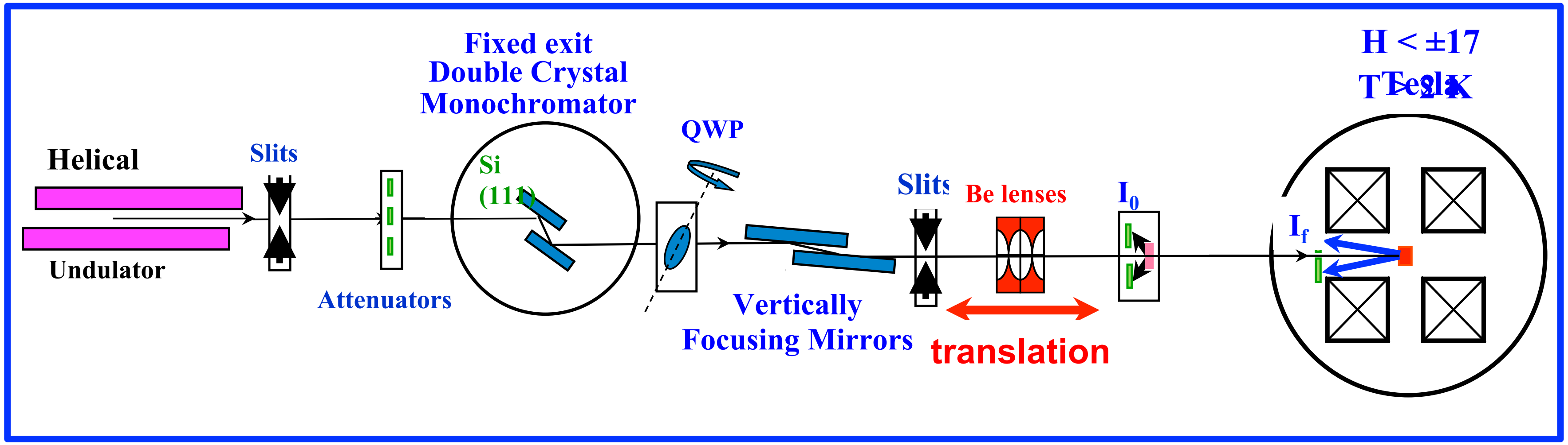
Quantity to measure: $\Delta\mu = \mu^{+} - \mu^{-}$

μ^{+}, μ^{-} => Absorption cross-sections for CP X-rays with
(+) helicity *parallel* to the sample magnetization
(-) helicity *antiparallel* to the sample magnetization

- **Highly performing X-ray detectors**
- **Magnetic field to magnetize a sample**
- **Source of circularly polarized X-rays**

The best possible at the 3rd generation synchrotron radiation facilities

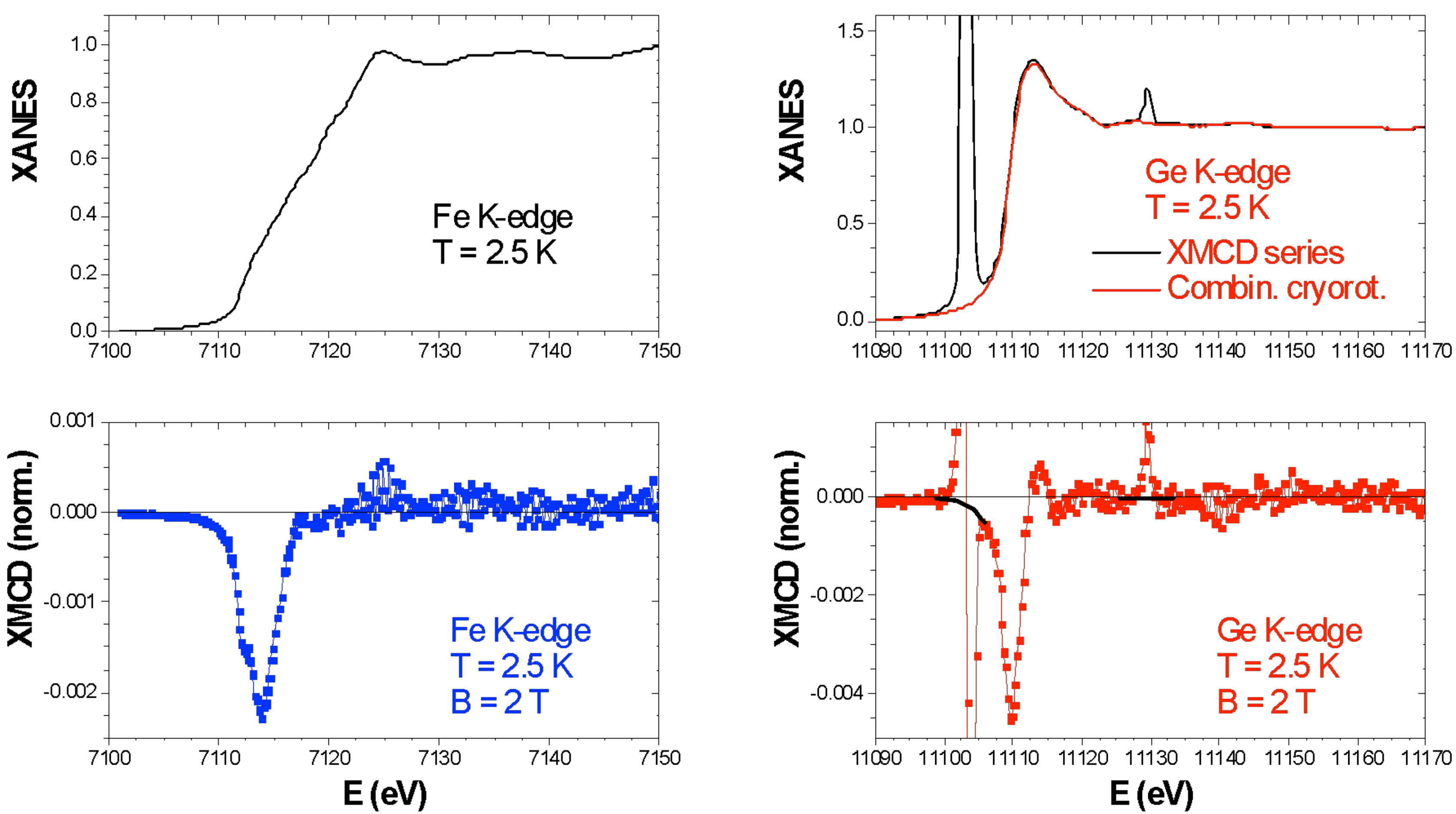
ID12 BEAMLINE



- ➢ Photon energy from 2 to 15 keV
- ➢ Beam size 3µm x 30µm (focused with Be lenses)
- ➢ Source – Sample distance 67 m
- ➢ Quarter wave plate (QWP) is used to measure circular polarization degree
- ➢ Detectors are Si photodiodes

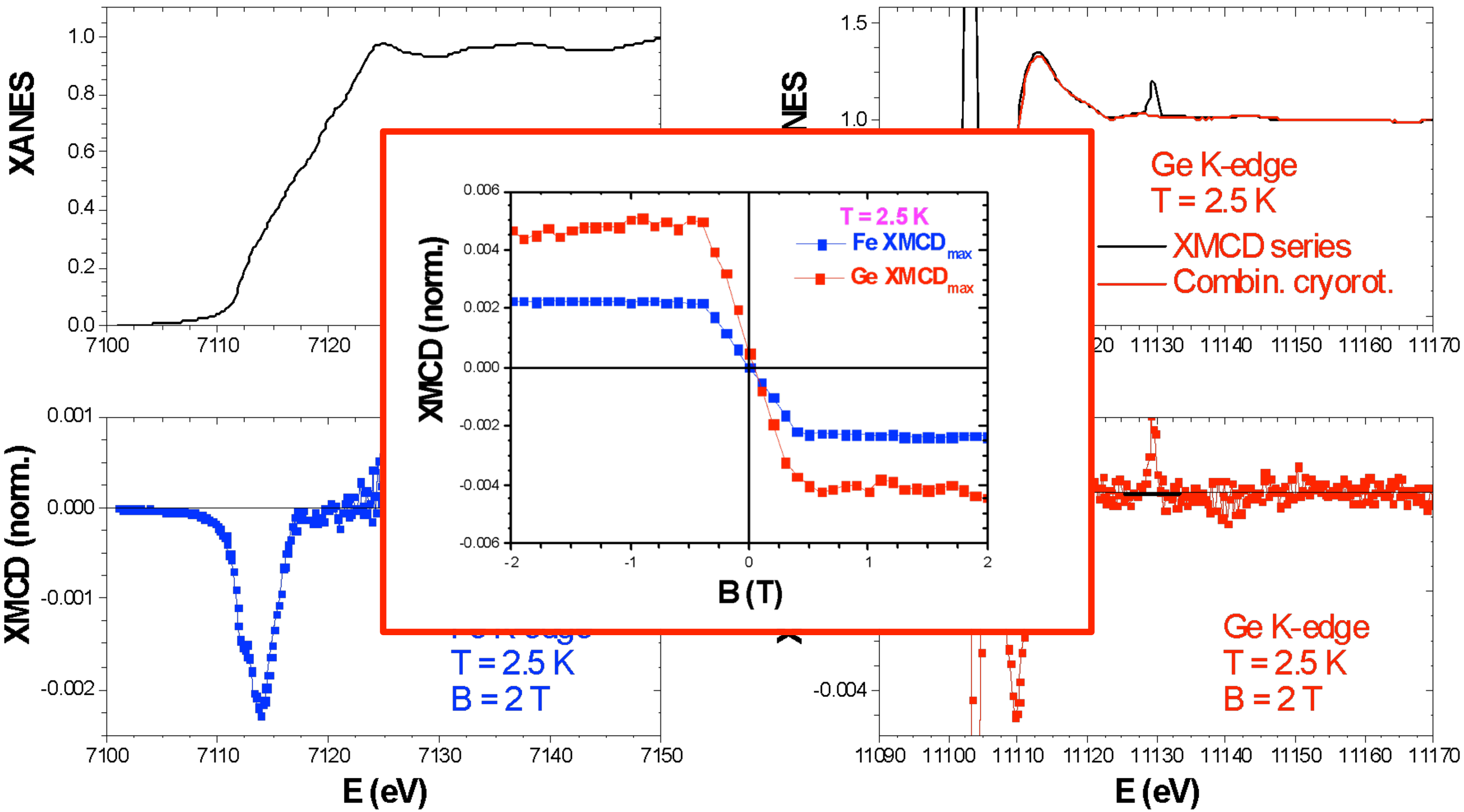
ESRF BEAMLINE ID12 (HIGH FIELD SET-UP)

XMCD ON FeGe SINGLE CRYSTAL



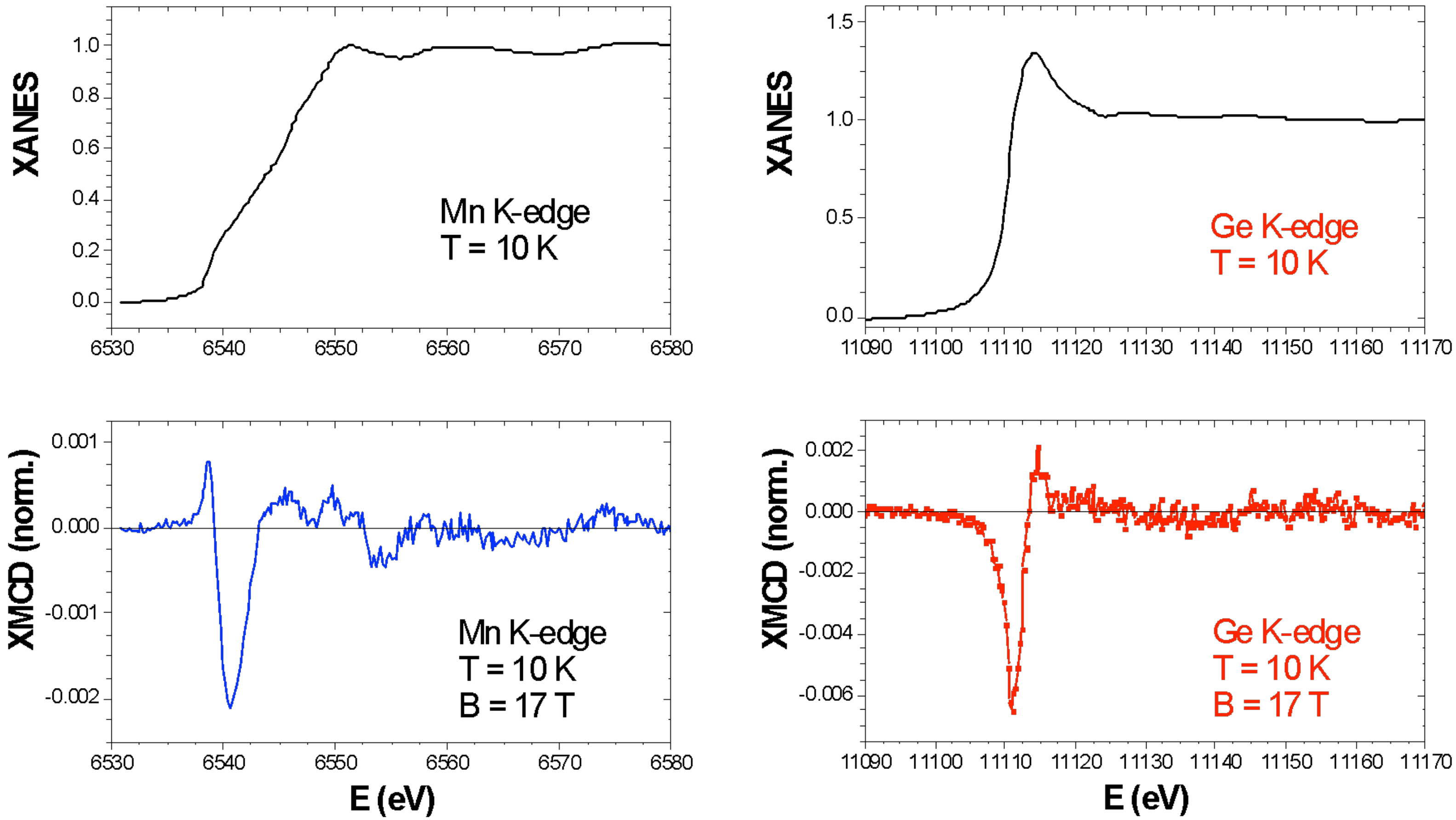
Ge 4p states are magnetically polarized in FeGe via hybridization with 3d states of Fe

XMCD ON FeGe SINGLE CRYSTAL



Ge 4p states are magnetically polarized in FeGe via hybridization with 3d states of Fe

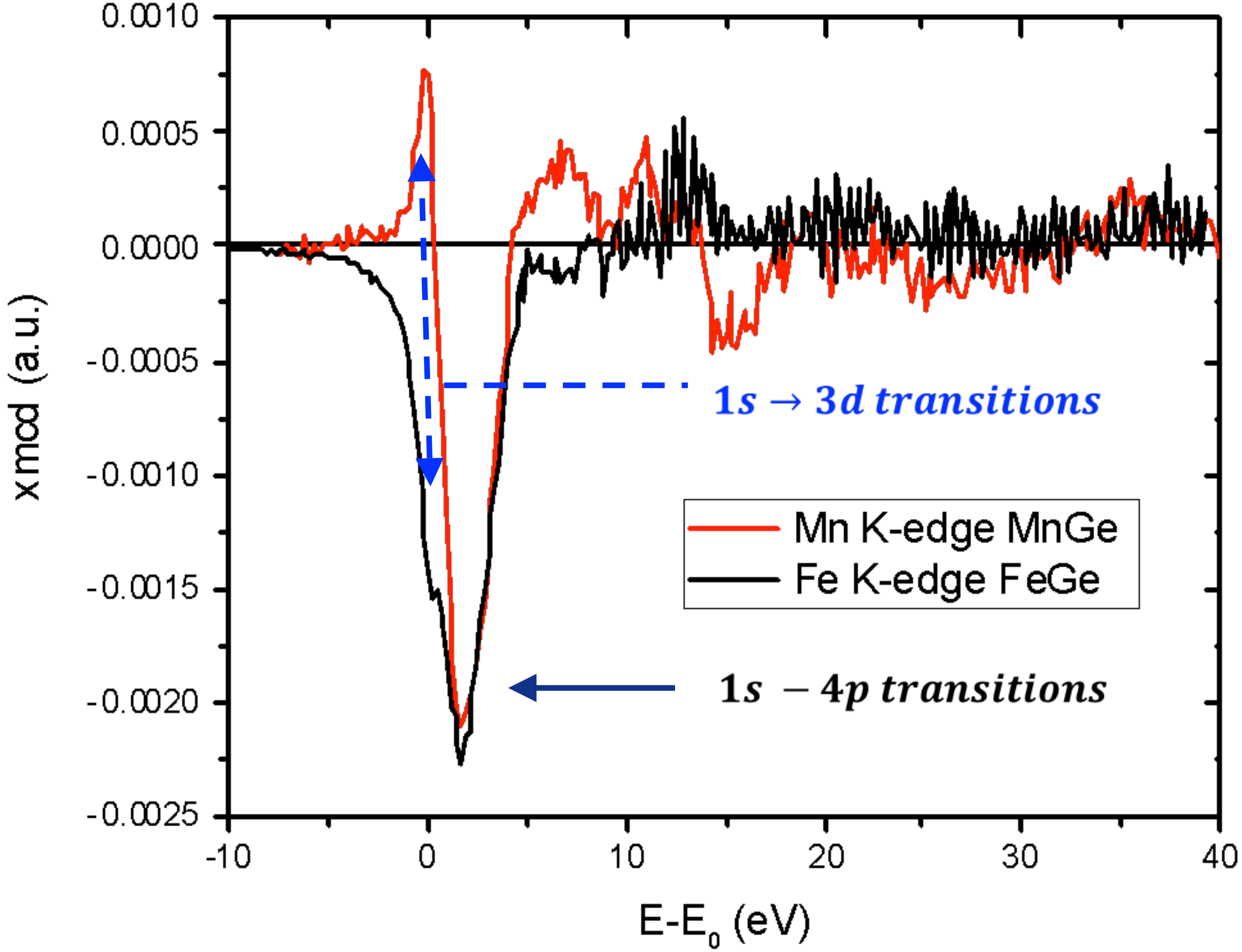
XMCD ON MnGe POLYCRYSTALLINE SAMPLE



XMCD signal at the Ge K-edge follows macroscopic magnetization whereas TM K-edge not

$M_{FeGe} \approx 1\mu_B$/f.u. $M_{MnGe} \approx 1.7\mu_B$/f.u.

XMCD AT THE K–EDGE OF TMs



Note: Sign change of $< L_z >_{3d}$

CONCLUSIONS

- We have measured XMCD spectra at the K-edges in noncentrosymmetric cubic structures MnGe and FeGe
- We have observed an induced magnetic moment on Ge site
- We have obtained the difference between Mn and Fe XMCD-signals due to 3d states in FM state

Спасибо за внимание!