

Electron Irradiation of Polycrystalline Bulk FeSe Superconductors

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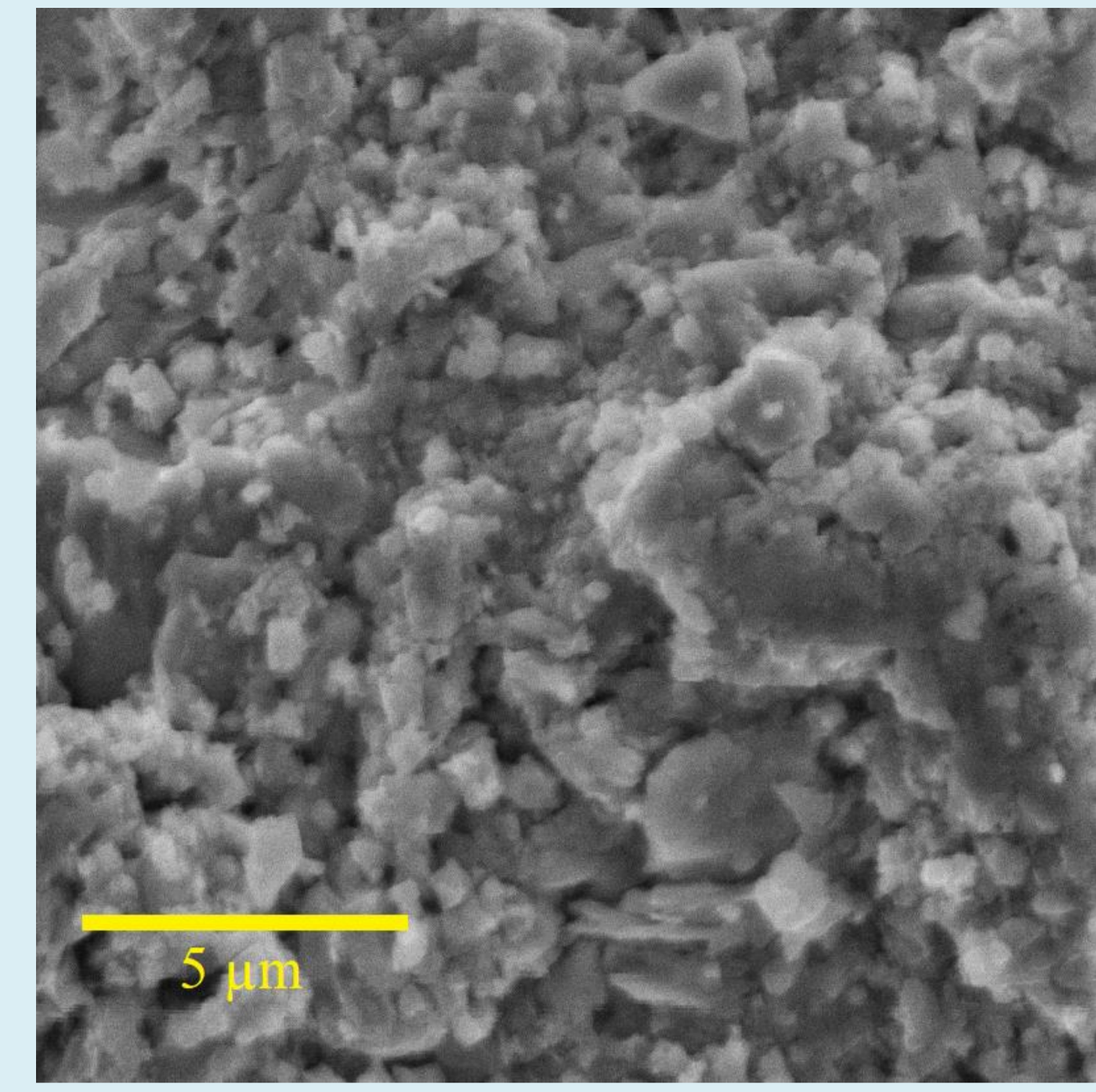
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A polycrystalline iron-based superconductor

- Iron-selenide superconductors:
 - Discovered in 2008 [1]
 - Variable critical temperature: 9 K using bulks, up to 36.7 K under 8.9 GPa [2], above 103 K as monolayer [3]
 - Rare-earth free and non-toxic materials
- Polycrystalline FeSe:
 - Ball milling and sintering at 950 °C
 - Critical current: 8 K
 - Well coupled and randomly oriented grains of the order of 1 μm
 - Presence of a Fe₇Se₈ ferromagnetic phase (40% of the volume)



Critical state model for polycrystalline FeSe

- By removing both diamagnetic and ferromagnetic signal, we can see that a polycrystalline FeSe sample show an asymmetric magnetization loop function of the grains size and the grains coupling.

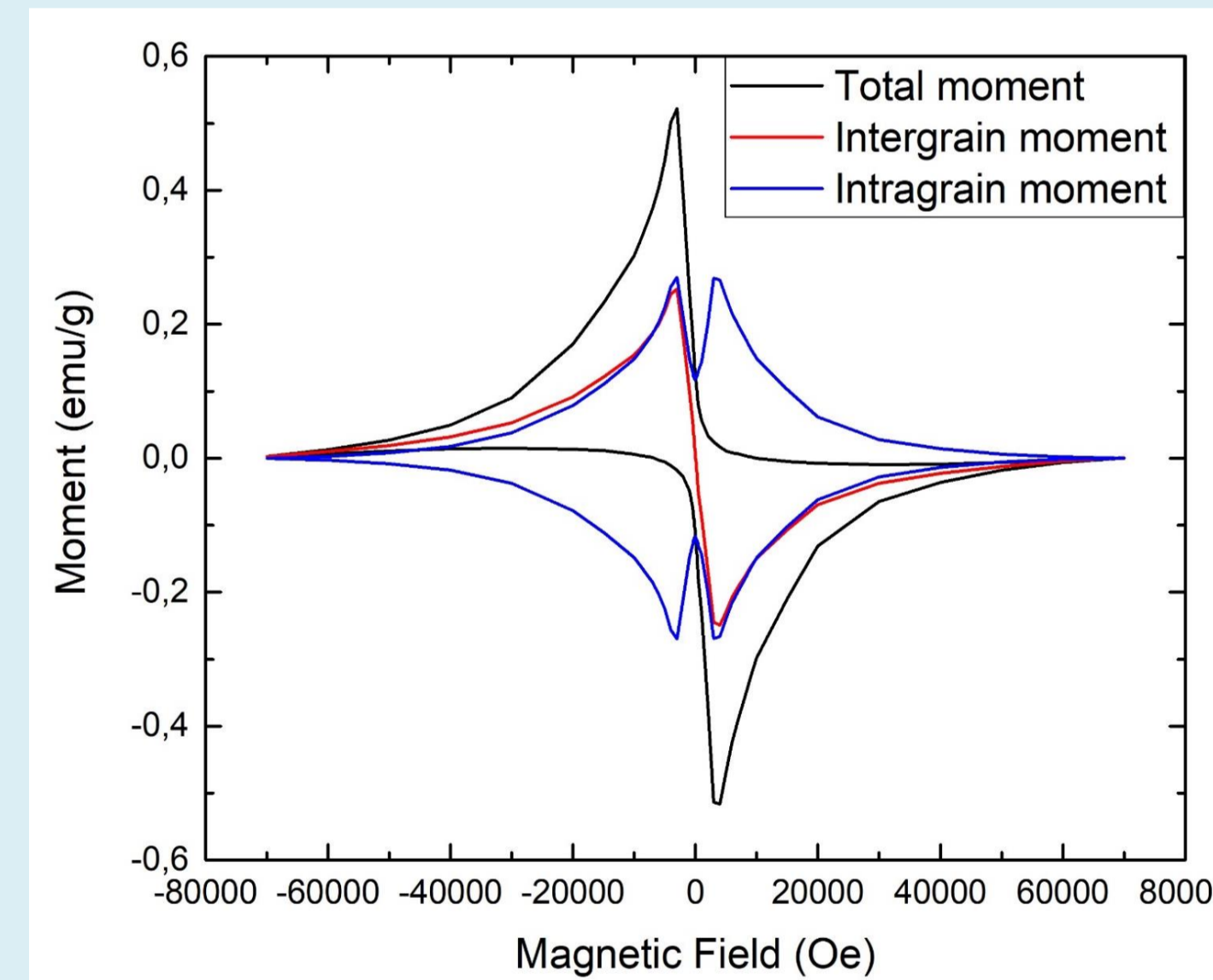


Fig. 2: Magnetization loop of a FeSe polycrystalline sample at 2K

- For an external magnetic field B(T), we can see that: $|M_{intergrain}(B)| = |M_{intragrain}(B)|$. which means 50% of the superconducting volume is allocated for the intragrain current

- This magnetization is created by the sum of an intergrain moment (with a total reversibility) and an intragrain moment (with an horizontal symmetry).

Fig. 3: Intragrain and intergrain magnetization loops of a polycrystalline sample

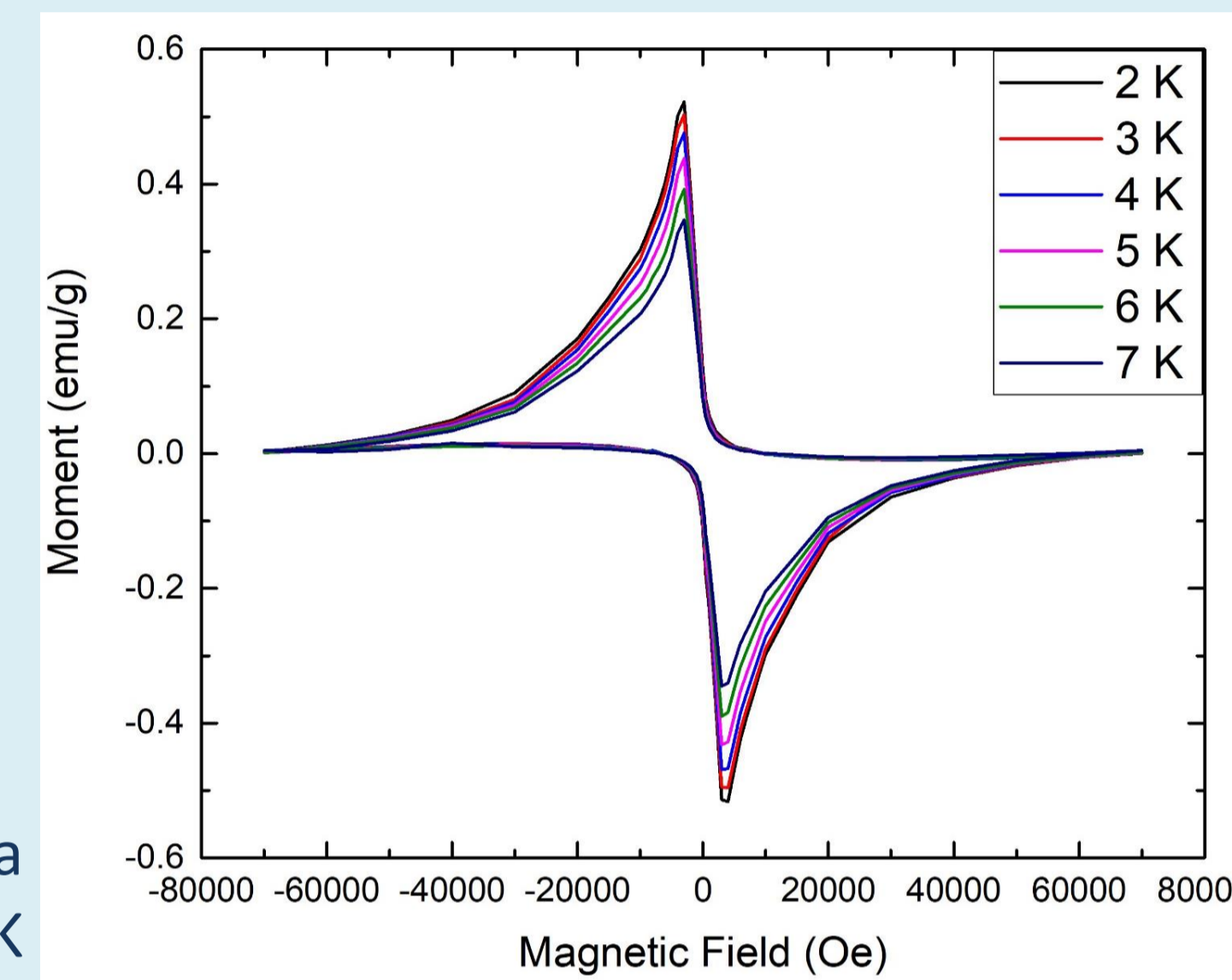
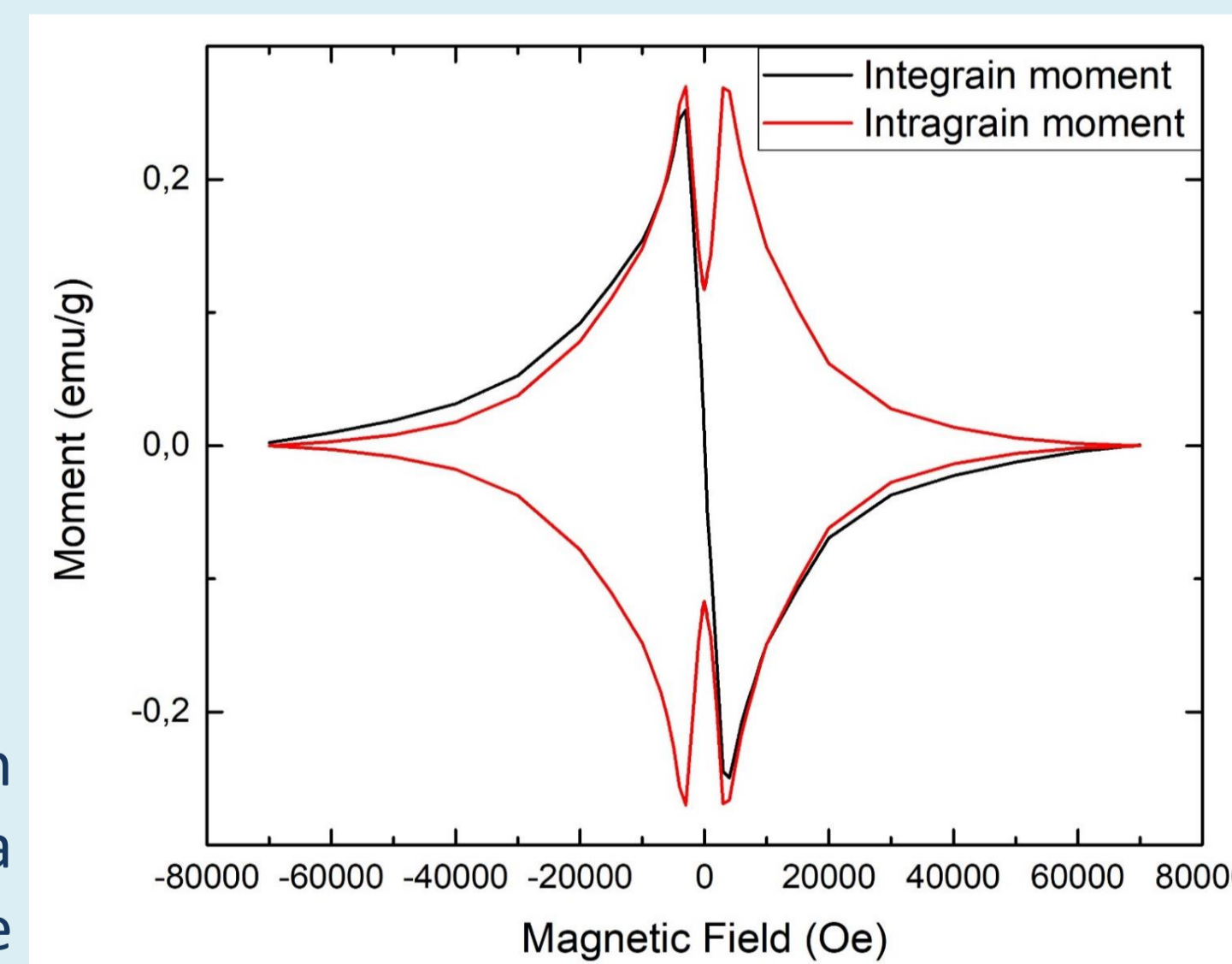


Fig. 2: Magnetization loop of a FeSe polycrystalline sample at 2K



Effect of electron irradiation

- We extract the intragrain moment on 5 samples:
 - 2 irradiated with $4 \times 10^{19} e^-$ (1.27 C): “1.27A” and “1.27B”.
 - 2 irradiated at $2 \times 10^{19} e^-$ (0.655 C): “0.655A” and “0.655B”
 - 1 unirradiated sample: “Unirr”.

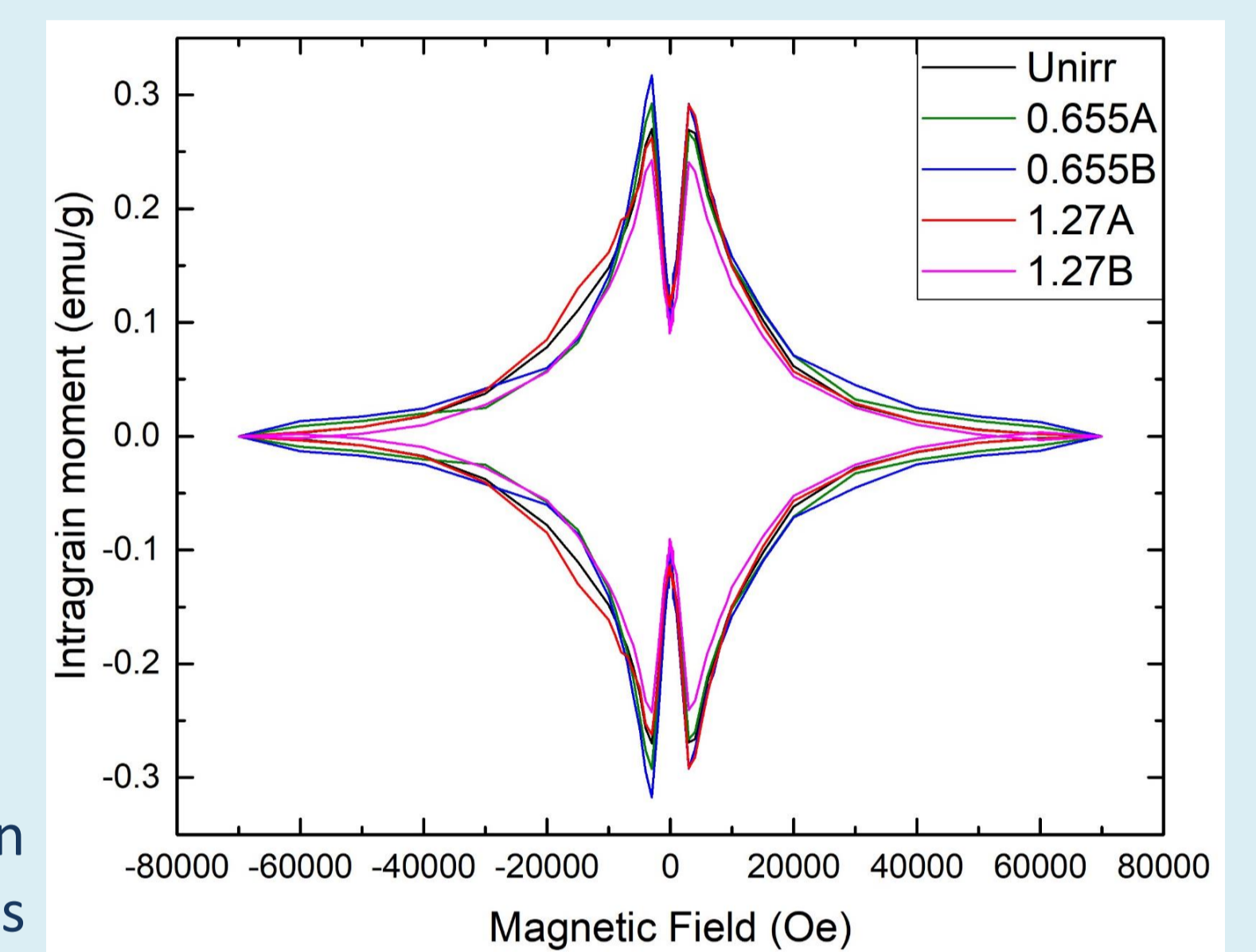


Fig. 4: Intragrain magnetization loop for the 5 samples

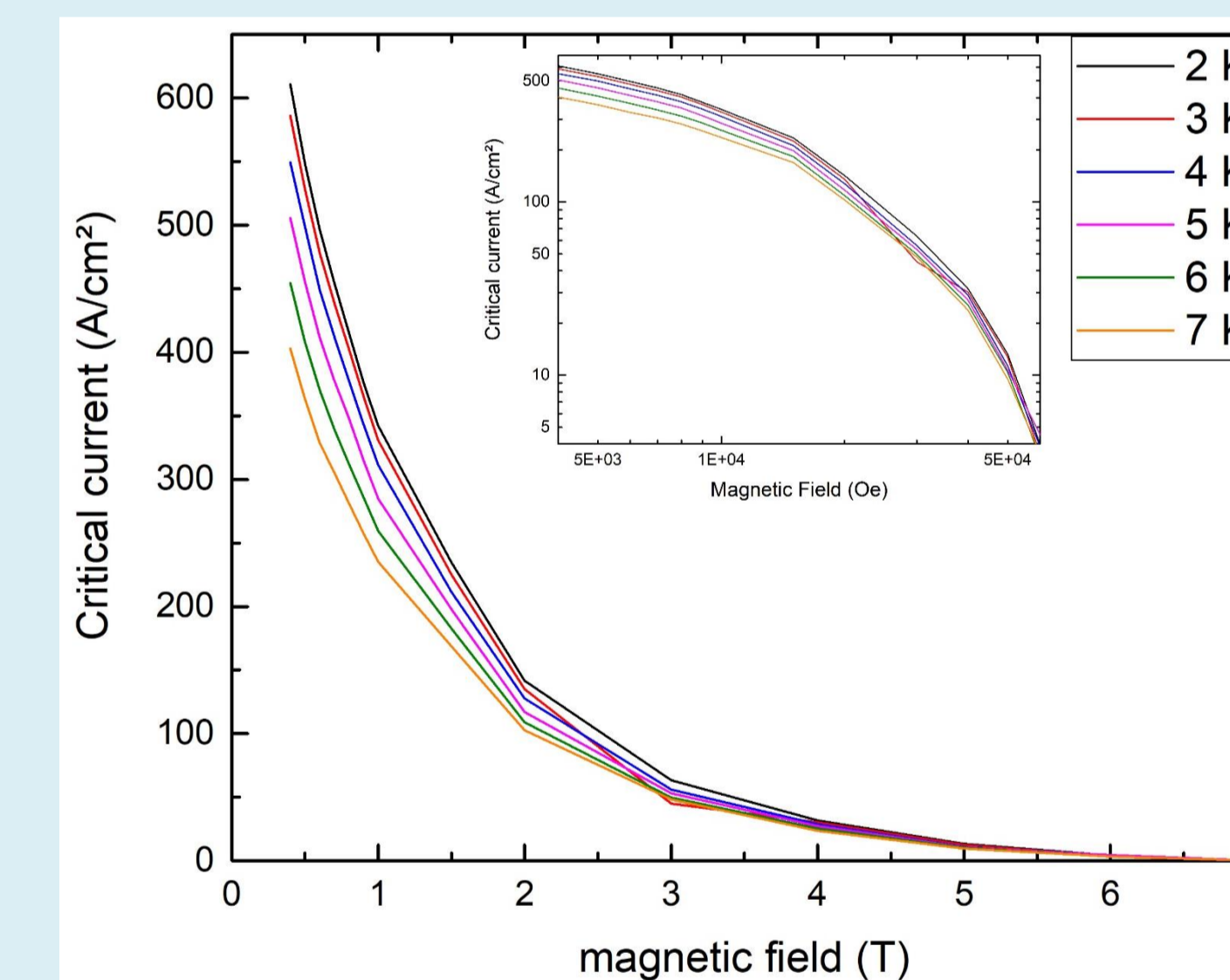


Fig. 5: Critical current of an unirradiated polycrystalline FeSe

- Using the so-called extended bean model we can extract the critical current from the intragrain moment (30% of the sample's volume). Using the following formula [Chen et al., 1989]:

$$J_c = \frac{\Delta M_{intragrain}}{a \left(1 - \frac{a}{3b}\right)} \times \left(\frac{100}{30}\right)$$

- Fig. 6 show an increasing of the critical current for a medium level of irradiation and a lower critical current for a “high” level of irradiation.

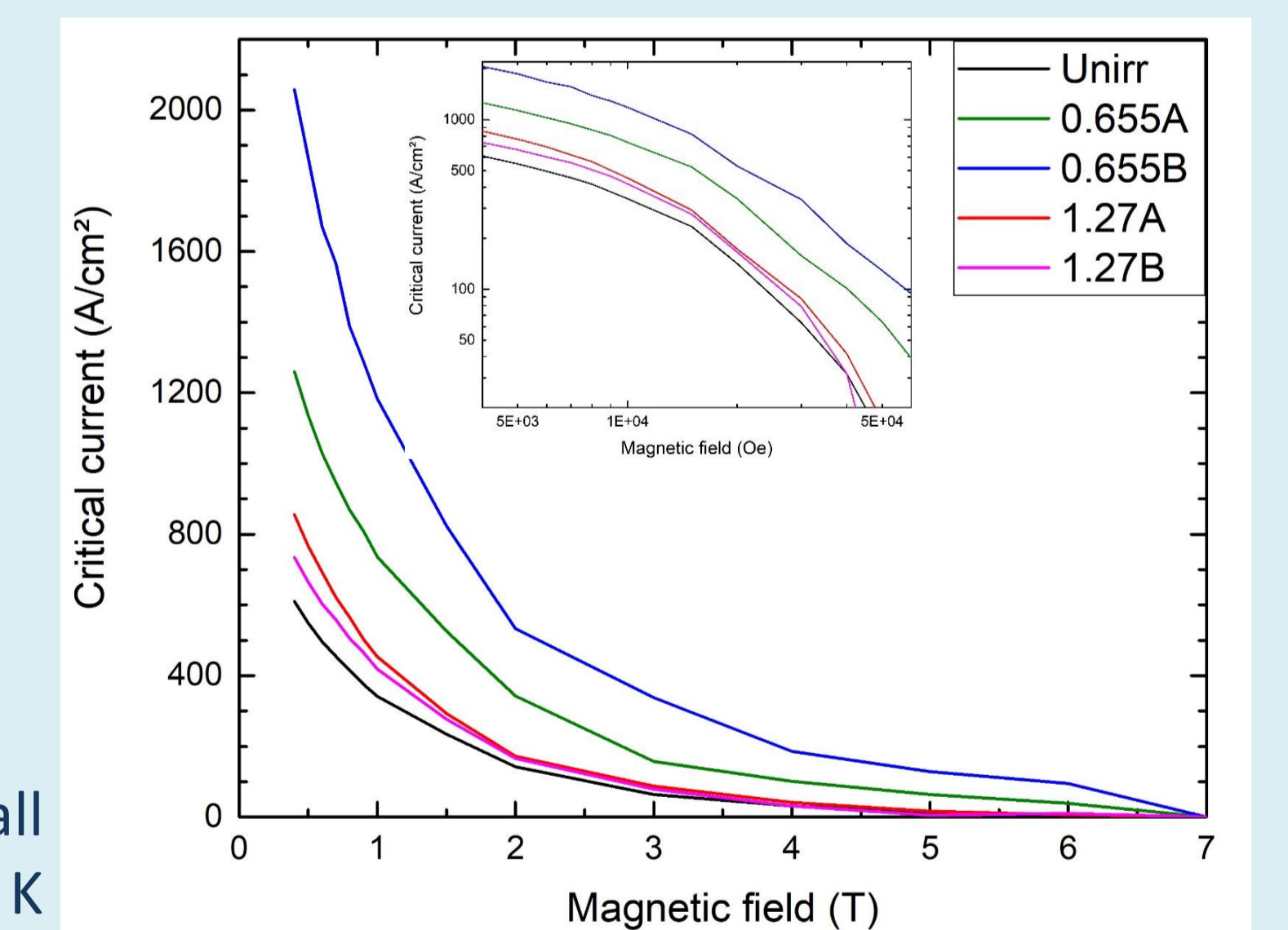


Fig. 6: Critical currents of all samples at 2 K

Electron irradiation using Sirius facility

- Irradiation experiments were done on small cut fragments (around $1 \times 1 \times 0.01 \text{ mm}^3$)
- Samples were irradiated using SIRIUS, an EMIR's facility based at Laboratoire des Solides Irradiés.
- Electron energy of 2.5 MeV and a beam current of 4.6 μA for a total dose of 0.655 C and 1.27 C .
- An electron irradiation adds point-like defects such as voids and interstitial atoms which are useful to trap vortices.

Conclusion

- We developed a new model to extract the critical current of a polycrystalline superconductor
- We have seen the influence of the irradiation on a FeSe polycrystalline sample

What next?

- A new experiment on EMIR facilities using heavy ion irradiations
- Working on the fabrication process to change the ratios Fe₇Se₈/FeSe_{SC} materials and intra/inter grain moments.