High resolution imaging of magnetic flux distributions in superconductors with SXM at low temperatures

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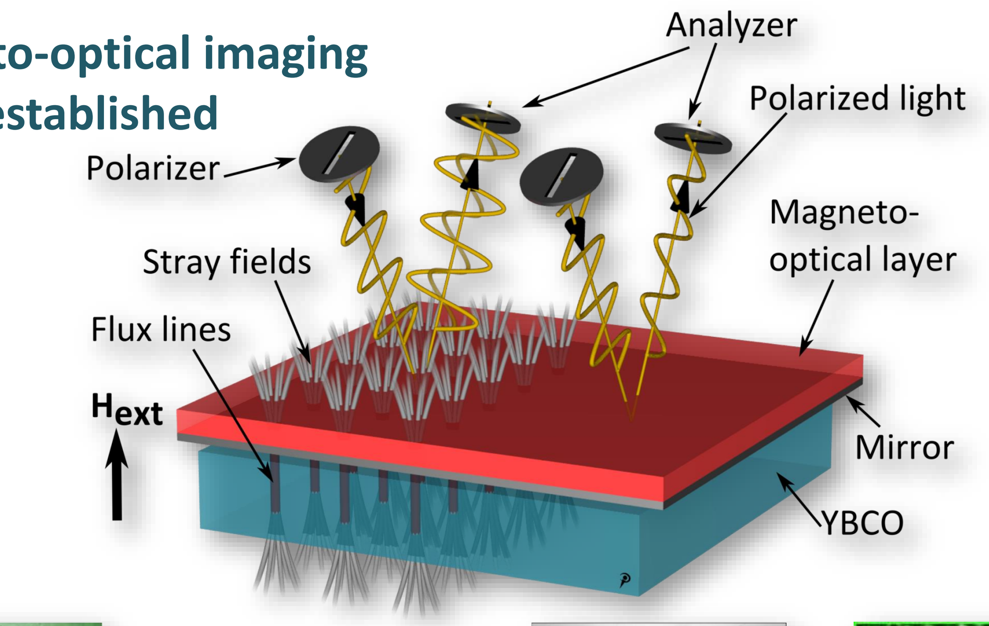
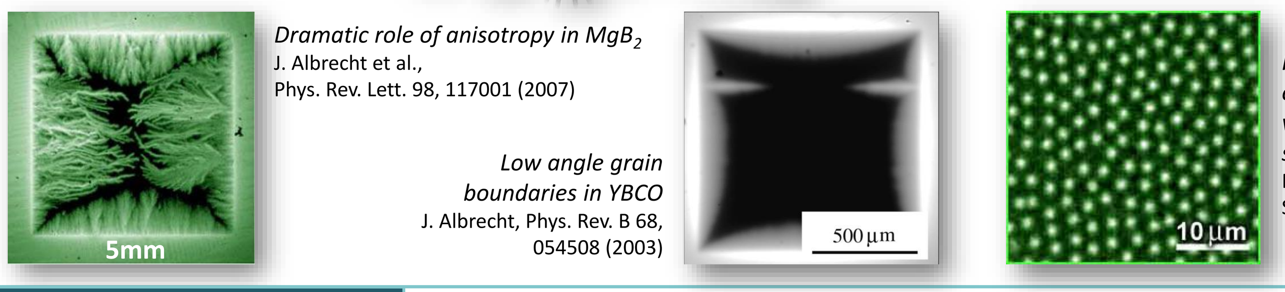
The Idea: Visualization of the Flux Density via XMCD

Magneto-optical imaging – well established





Dramatic role of anisotropy in MgB_2, J. Albrecht et al., Phys. Rev. Lett. 98, 117001 (2007)

Low angle grain boundaries in YBCO, J. Albrecht, Phys. Rev. B 68, 054508 (2003)

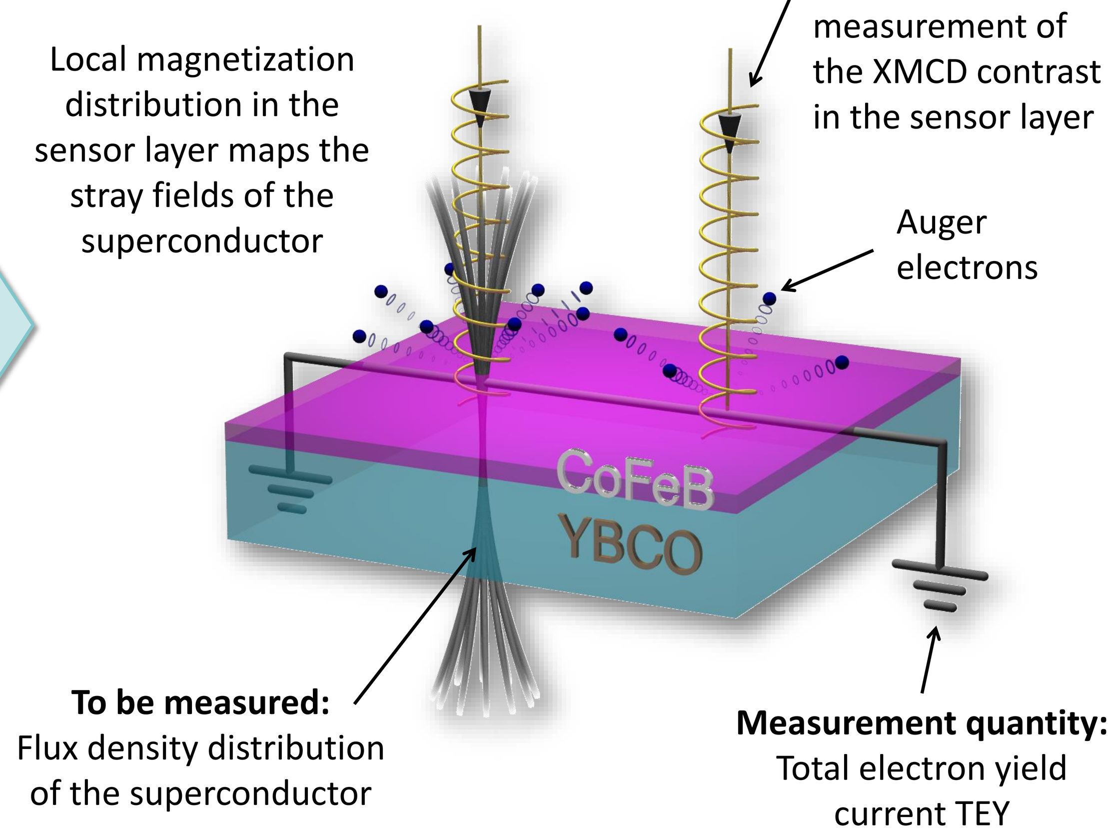
Real-time magneto-optical imaging of vortices in superconducting $NbSe_2$, P.E. Goa et al., Supercond. Sci. Technol. 14, 729 (2001)

Transfer of the technique

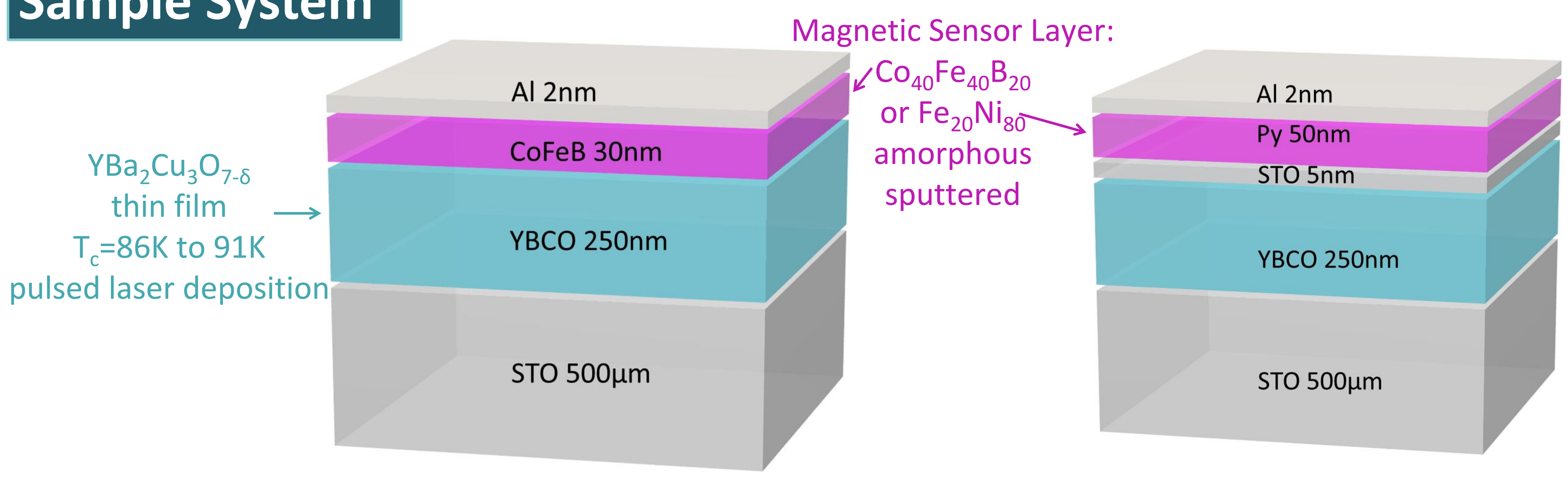
Visible light	→ Soft X-rays
µm resolution	→ nm resolution
Faraday Effect	→ XMCD Effect
Polarization microscope	→ X-ray microscope MAXYMUS
Iron Garnet Indicator	→ CoFeB/Py sensor layer
CCD Camera	→ TEY/Transmission signal
Mercury lamp	→ Synchrotron/Undulator
Linear polarization	→ Circular polarization

Synchrotron Bessy II, Berlin

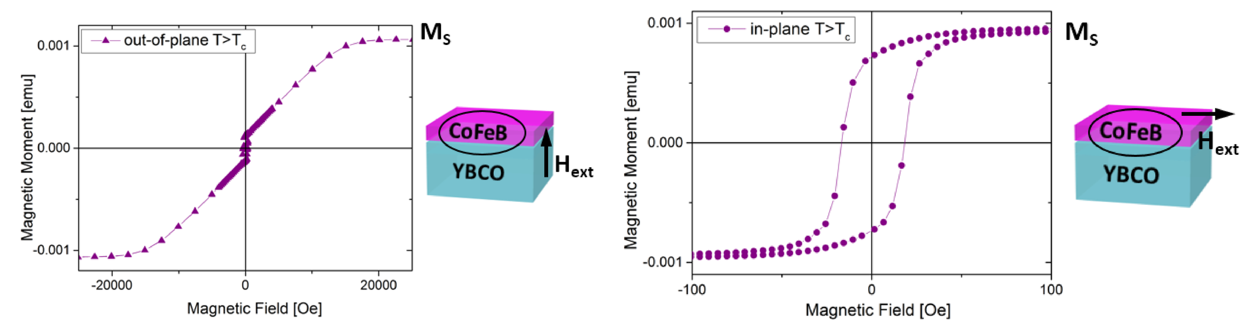
X-ray imaging – concept:



Sample System

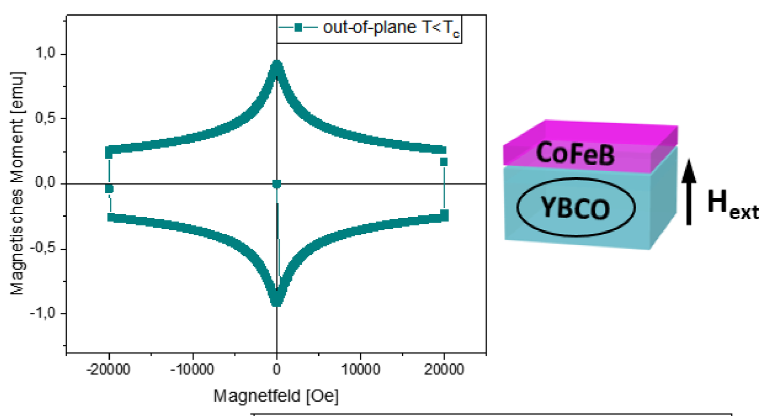


Comparison of magnetic signals



Comparison of magnetic signals:

- Soft in-plane magnetization for CoFeB and Permalloy
- High magnetic moments for YBCO thin film
- Magnetic moment of YBCO two orders of magnitude higher



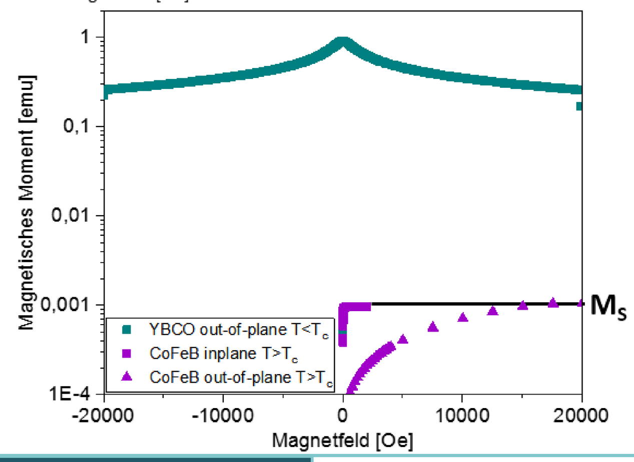
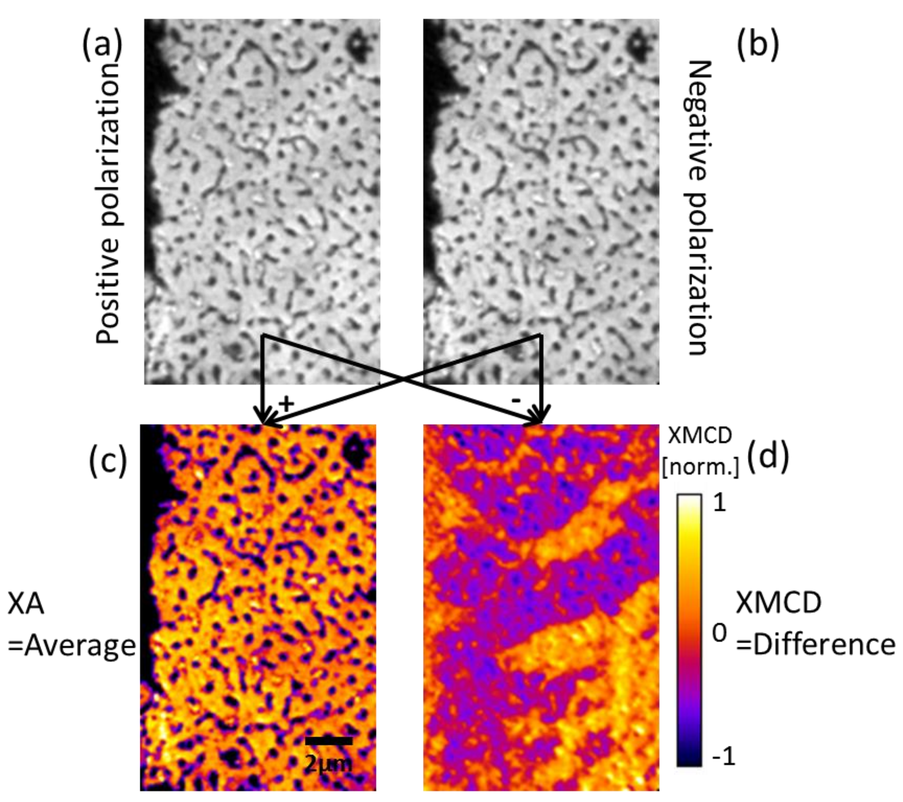


Image processing



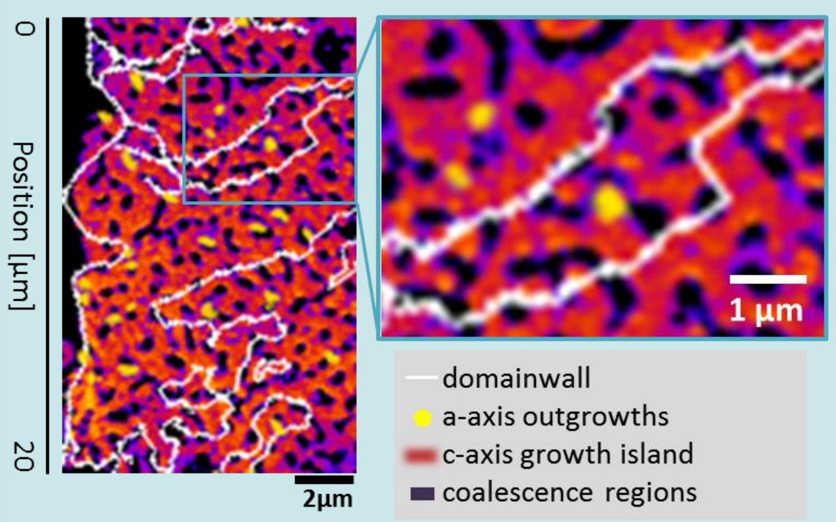
Conclusion image processing:

- Two measurements needed: positive and negative polarization
- Average image enhances structural contrast
- Difference image shows magnetic contrast
- Direct measurement no modelling of sample surface needed

Correlation of microstructure and flux density distribution

TEY

SXM image – state prepared @ 12K- measured @ RT

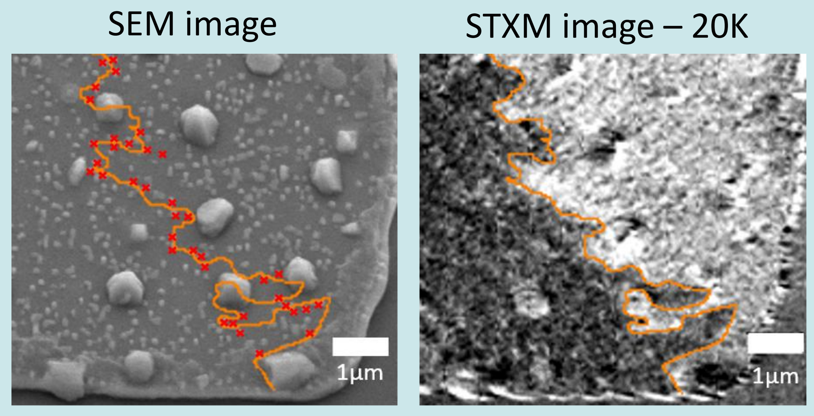


Resolution 100nm/px

Conclusion TEY-measurement:

- No pinning on large a-axis outgrowths
- Domain is pinned alongside coalescence regions

Transmission

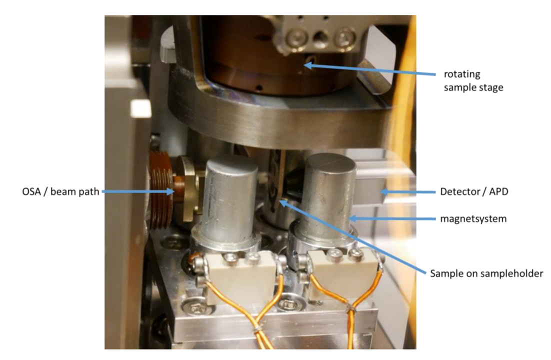


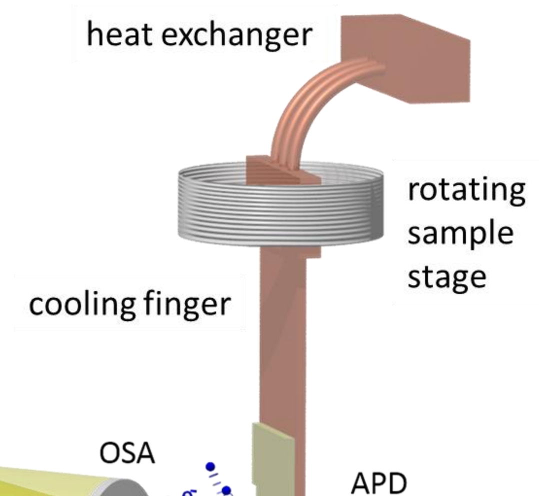
Resolution 50nm/px

Conclusion Transmission-measurement:

- No pinning on large grains
- Small outgrowths pin the domain wall

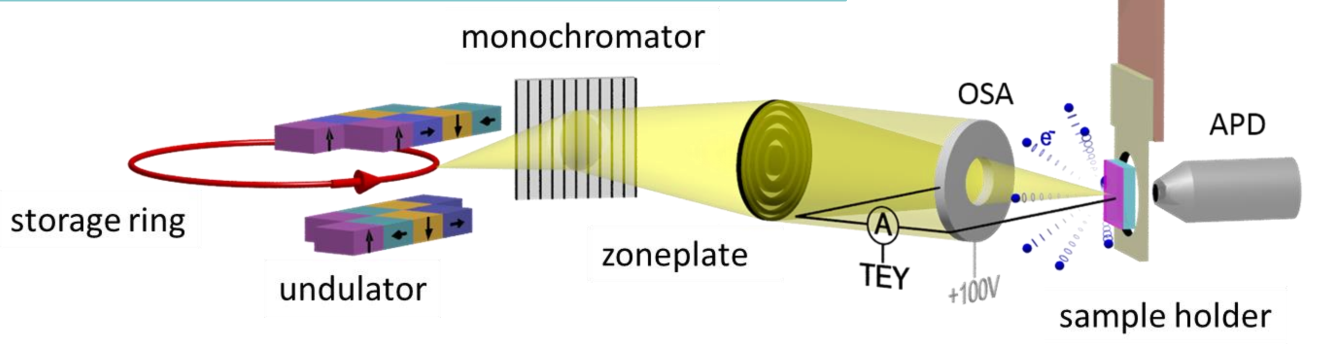
Microscopy Setup





Microscopy setup:

- New Cryostat
- Temperatures down to 20K available
- Transmission and TEY measurements possible

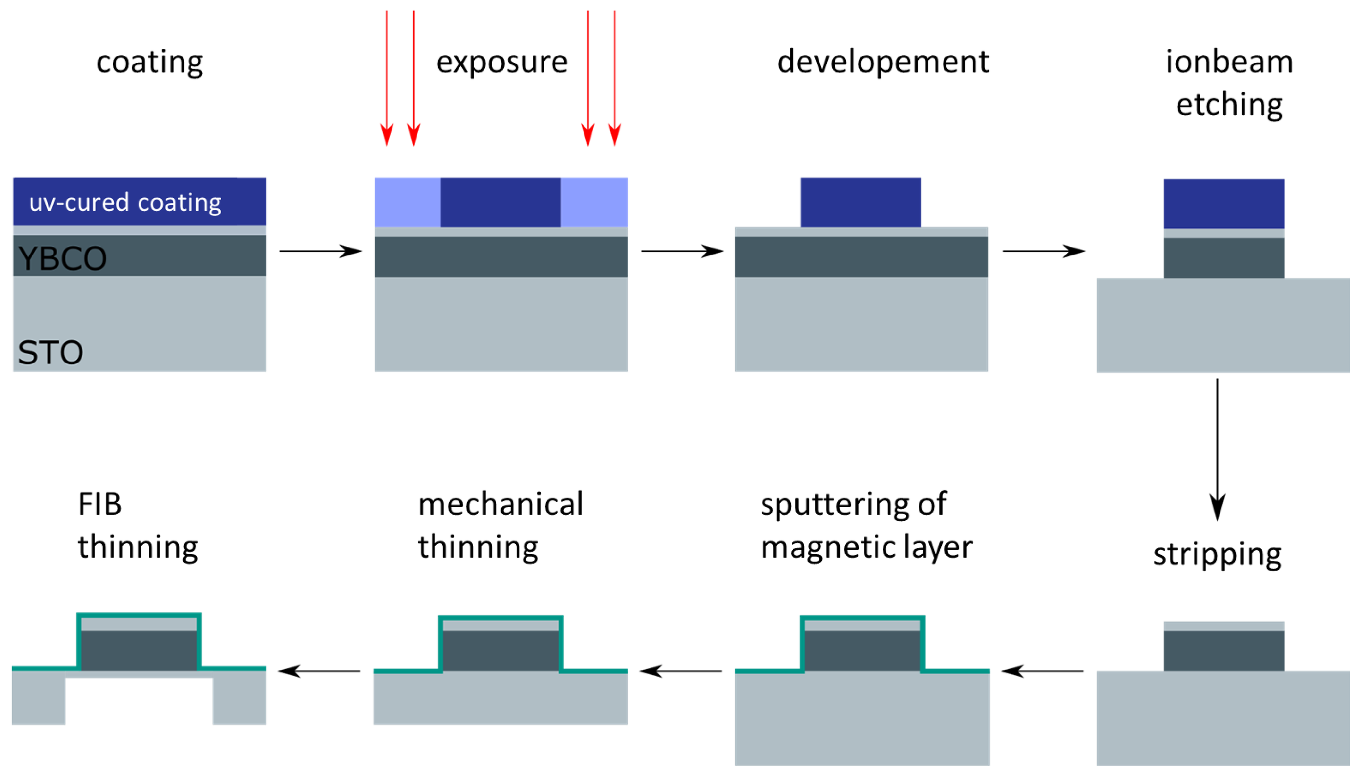


Conclusion and Publications

- Mapping the flux density distribution of superconductors with XMCD microscopy is shown
- The SXM MAXYMUS setup has been upgraded by a helium cryostat
- Correlation of surface structure and magnetic flux density distribution in TEY and Transmission
- Novel technique for the preparation of single crystalline substrates for STXM

S. Ruoß et al., APL 106, 022601 (2015). S. Ruoß et al., NJP 18, 103044 (2016).

Sample preparation for transmission



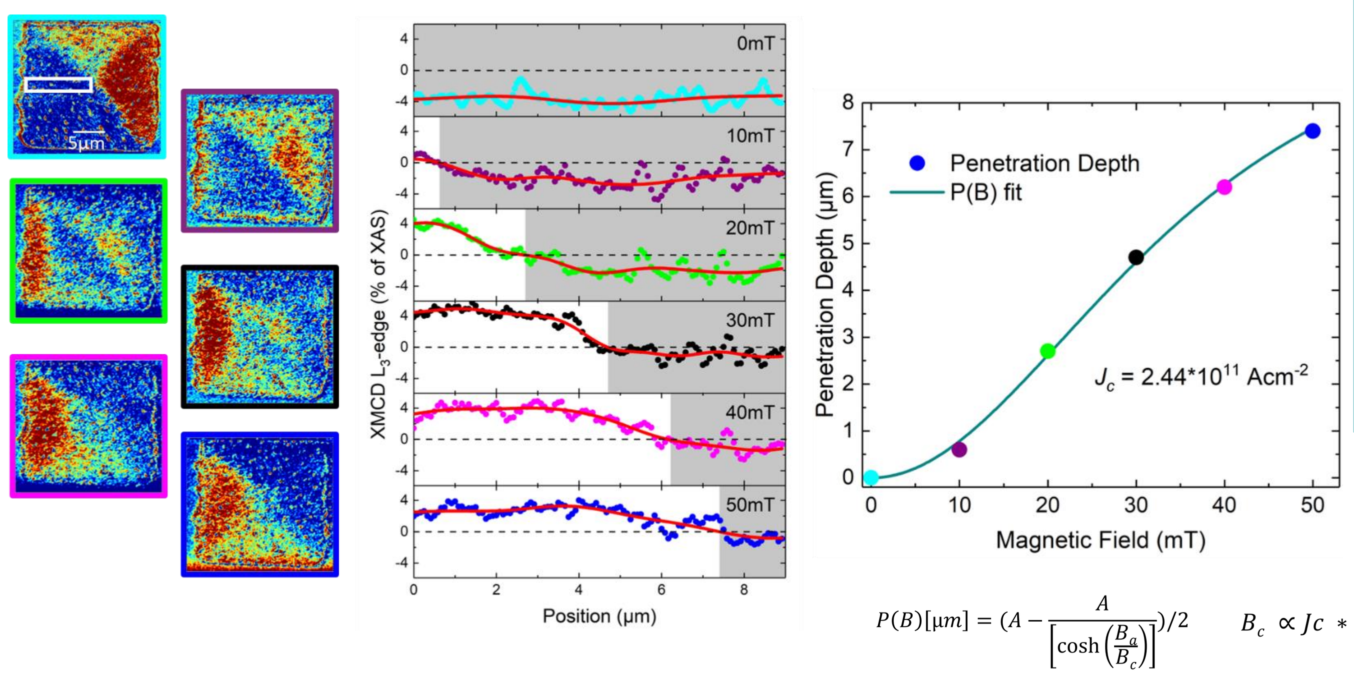
Conclusion sample preparation:

- several steps which can harm the YBCO are necessary
- Mechanical thinning to roughly 20µm
- FIB thinning down to 300-600nm

Issues with sample preparation:

- Thin STO layers inhibit temperature conductance
- Thick STO layers reduce transmitted photons
- Implantation of foreign atoms possible

Transmission measurements: data extraction



$P(B)[\mu m] = (A - \frac{A}{\cosh\left(\frac{B}{B_c}\right)})/2 \qquad B_c \propto Jc * dYBCO * \mu_0$

Conclusion transmission measurements II:

- Flux penetration in small structures behaves macroscopic
- Penetration depth usable to calculate J_c
- Calculation of J_c comparable to large structures

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