Recent experiments

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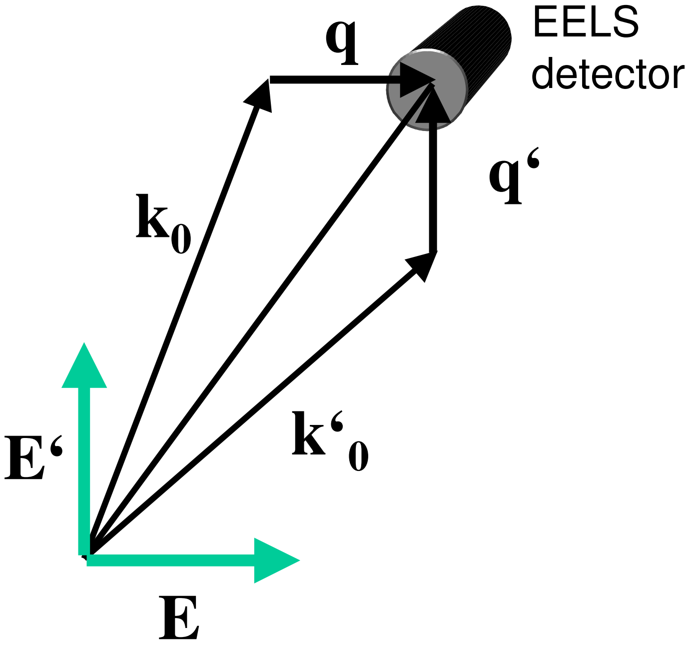
EMCD: theoretical requirements

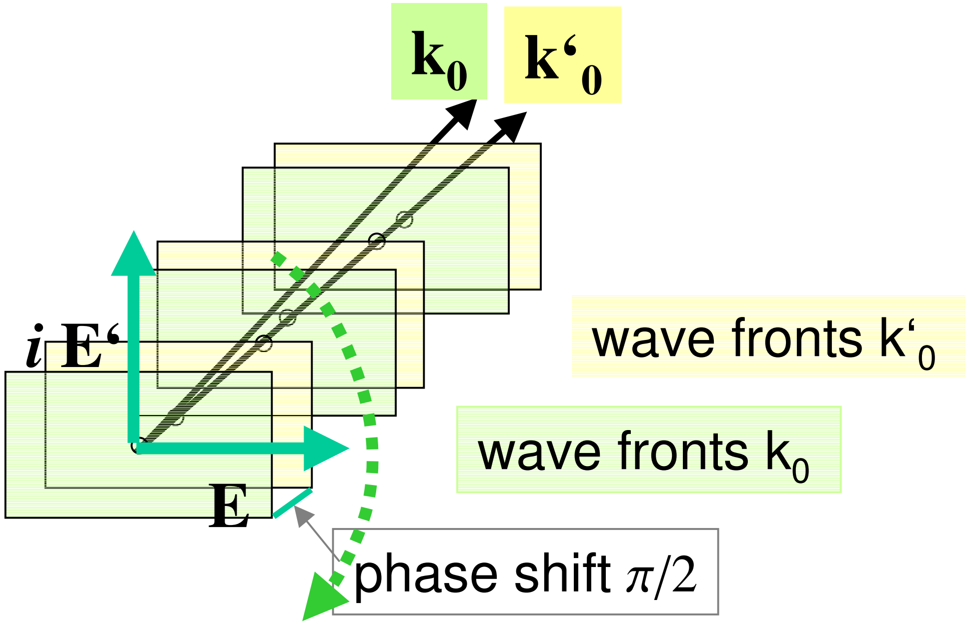
Coherent superposition of incident waves k_0 and k_0‘ ...

... select q‘ $\perp$ q ...



... set phase shift of $\pi/2$ between the resp. wave fronts

Possibility to change helicity.



wave fronts $k‘_0$

wave fronts k_0

phase shift $\pi/2$

EMCD: practical realisations

1. Two beams:

Biprism

Advantages: suitable for any specimen

Disadvantages: requires non-standard equipment

Intrinsic road: Bloch phase lock

Advantages: easy to realize

Disadvantages: requires crystalline specimens

2. Select $\boldsymbol{q}' \perp \boldsymbol{q}$

Contrast Aperture

Advantages: possibility to work in image mode (improved spatial resolution)

Disadvantages: less open to routinisation

Spectrometer Entrance Aperture

Advantages: easy to realize

Disadvantages: limited spatial resolution (determined by SA aperture to >100 nm)

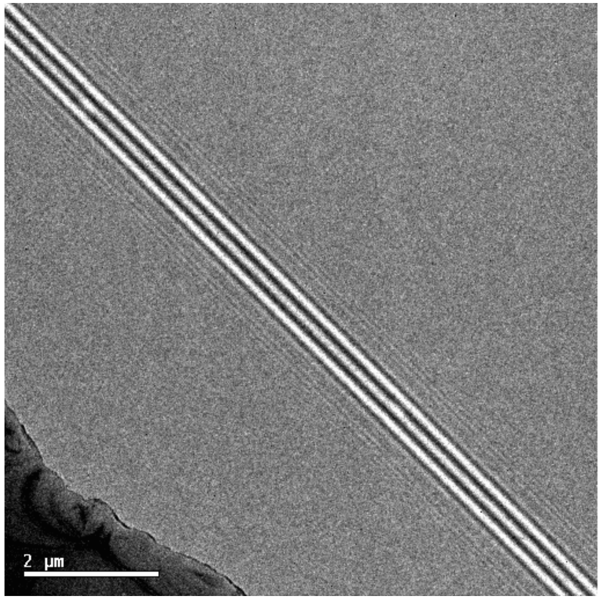
EMCD: practical realisations

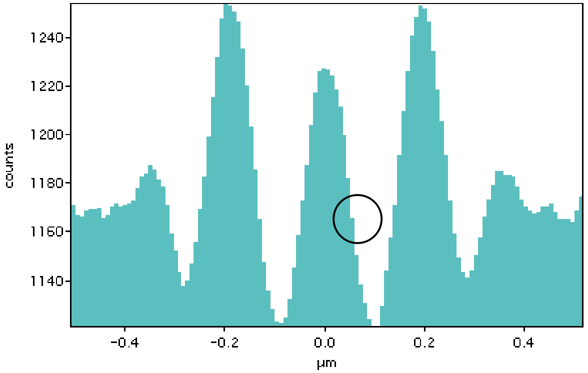
3. Set phase

Biprism: phase is set by moving the fringes

Advantages: immediate

Disadvantages: instability, intensity



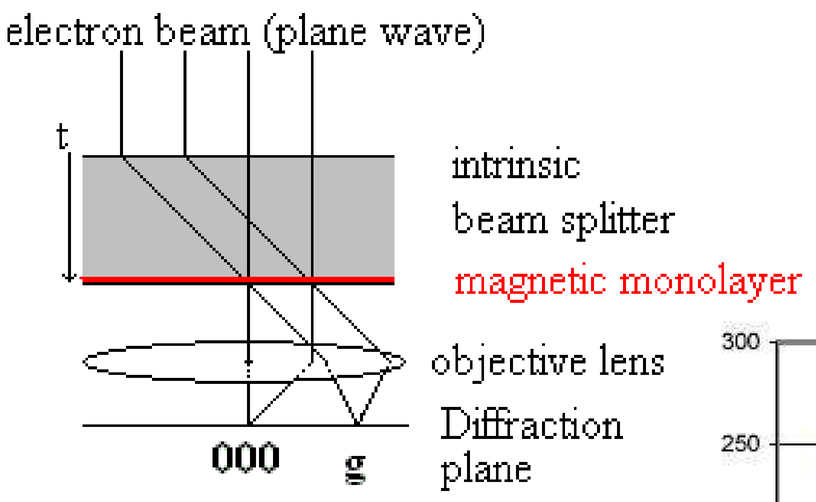


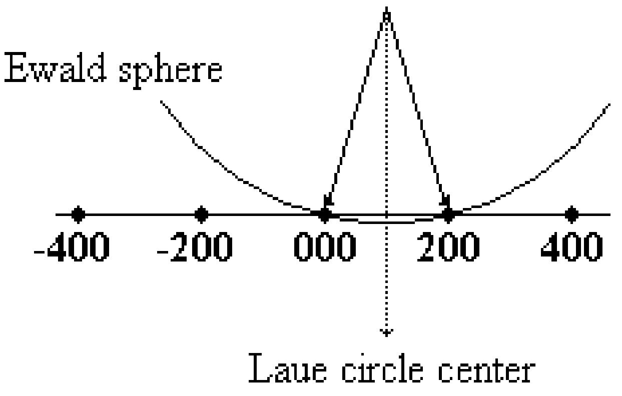
Phase lock: calculated with Bloch Theory

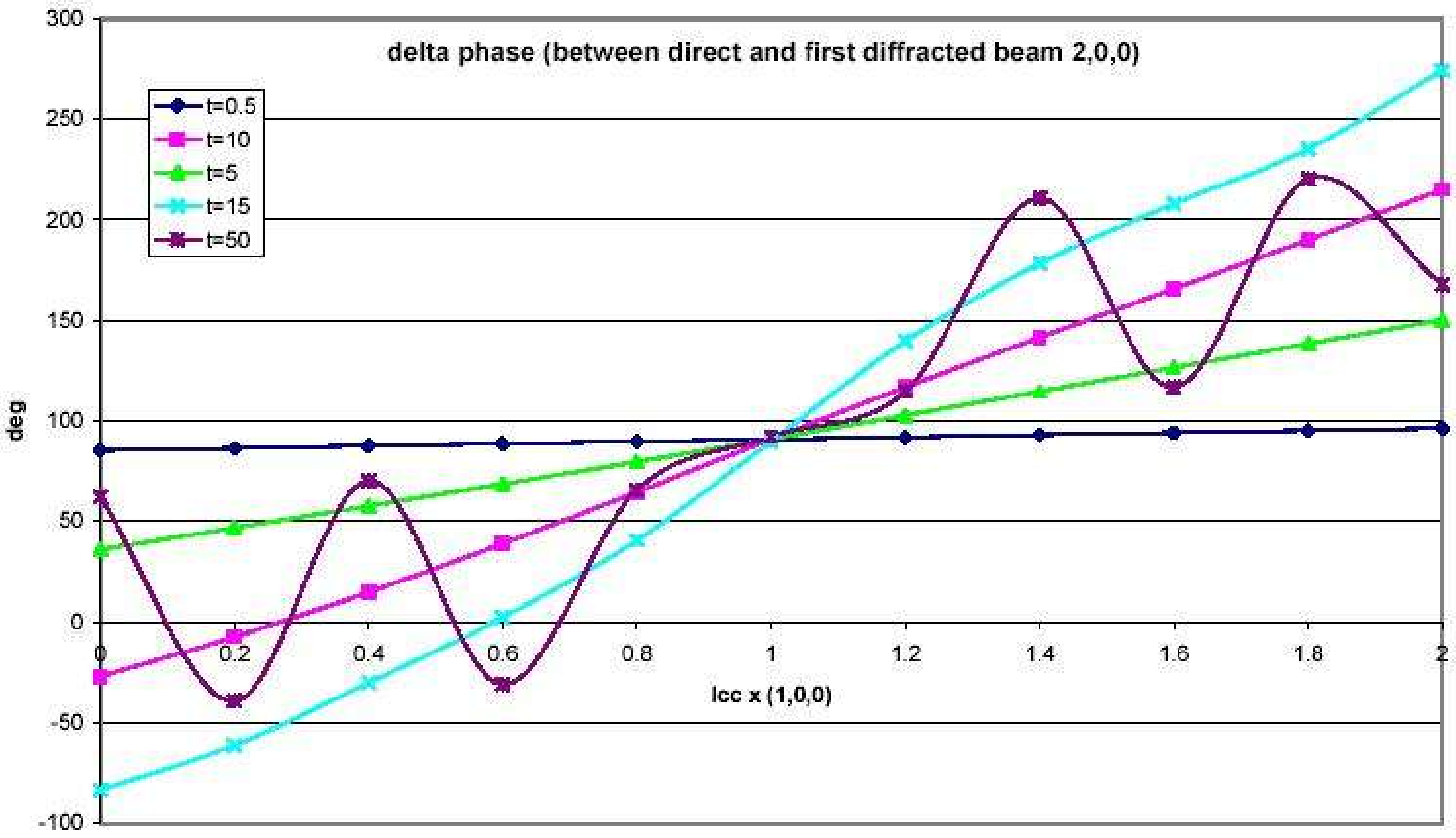
Advantages: it works

Disadvantages: not immediate to see; the use of Kikuchi line to determine Lcc is difficult for thin specimens. It is also dependent on stability of beam tilt and specimen drift (more stable than biprism) and/or good specimen (if it has flat regions).

Phase tuning





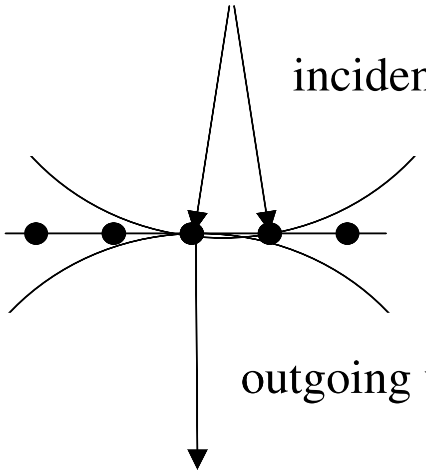


Phase tuning by dyn. diffraction

n-beam case

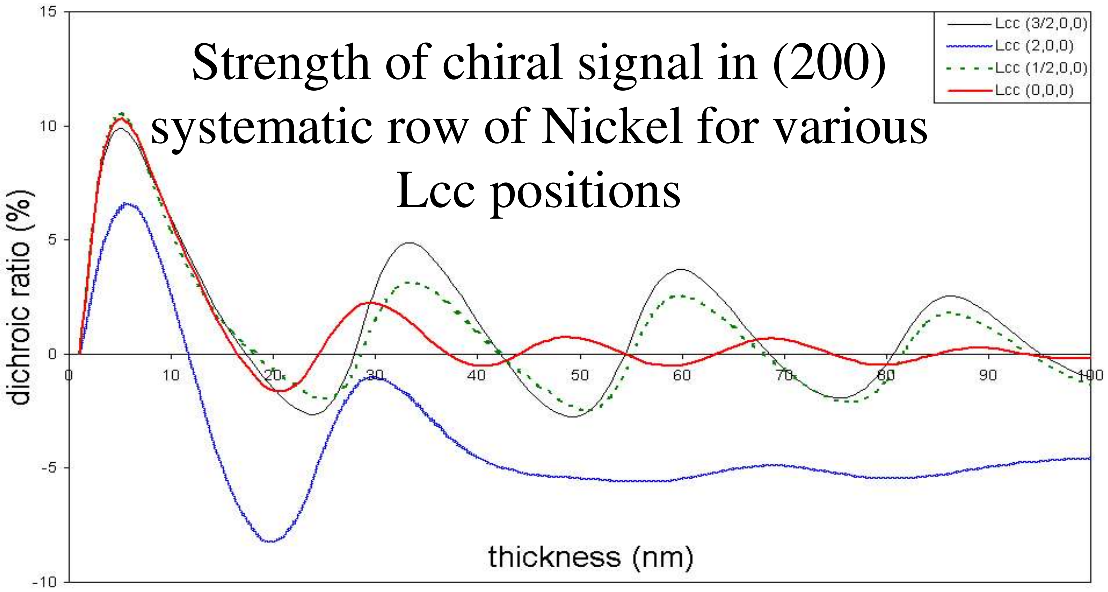
Laue circle centre and thickness determine phase shift

$$\frac{\partial^2\sigma}{\partial E\,\partial\Omega} = \frac{4(1-\beta^2)}{a_0^2}\frac{k_f}{k_i}\left\{\sum_{j=1}^{2n}\frac{DFF(\mathbf{q}_j,E)}{q_j^4} + \sum_{i\neq j} C_{ij}\frac{MDFF(\mathbf{q}_i,\mathbf{q}_j,E)}{q_i^2\, q_j^2}\right\}$$



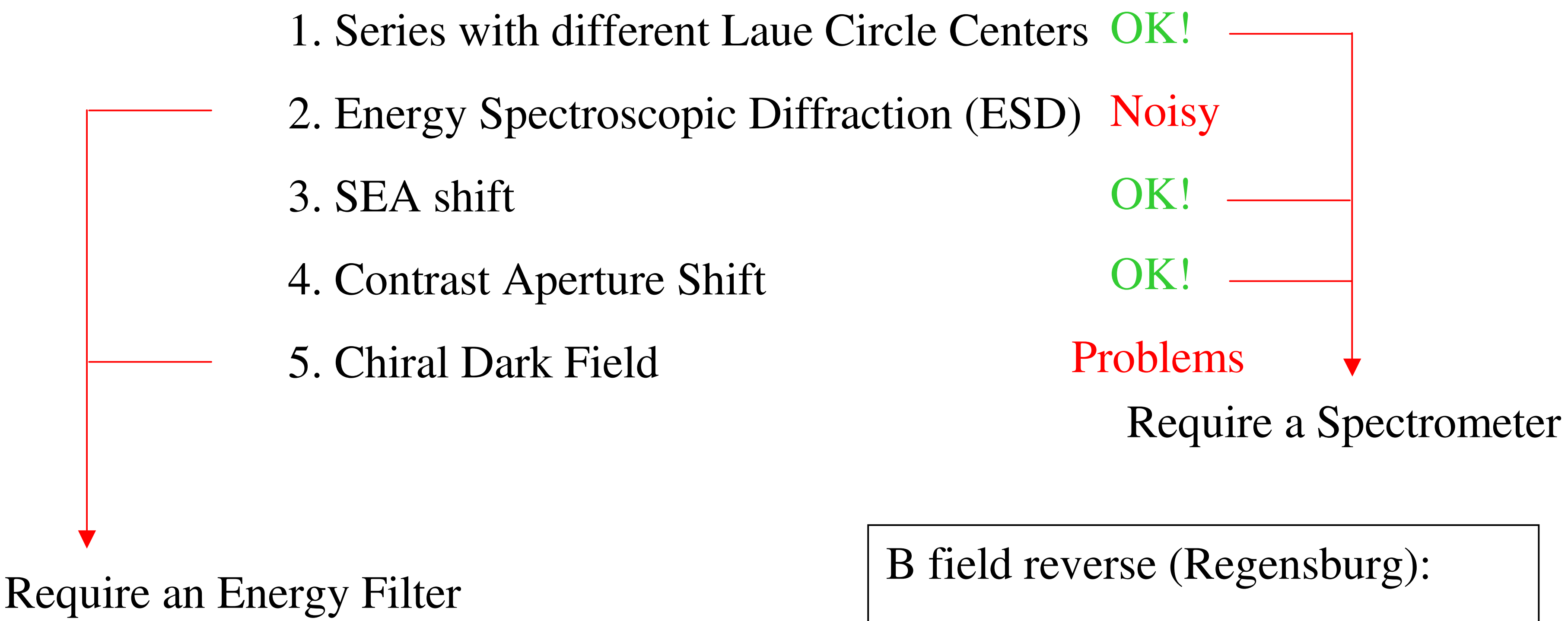
incident wave, s=0

outgoing wave, s < 0



Strength of chiral signal in (200) systematic row of Nickel for various Lcc positions

4. How to change chirality



1. Series with different Laue Circle Centers OK!
2. Energy Spectroscopic Diffraction (ESD) Noisy
3. SEA shift OK!
4. Contrast Aperture Shift OK!
5. Chiral Dark Field Problems

Require a Spectrometer

Require an Energy Filter

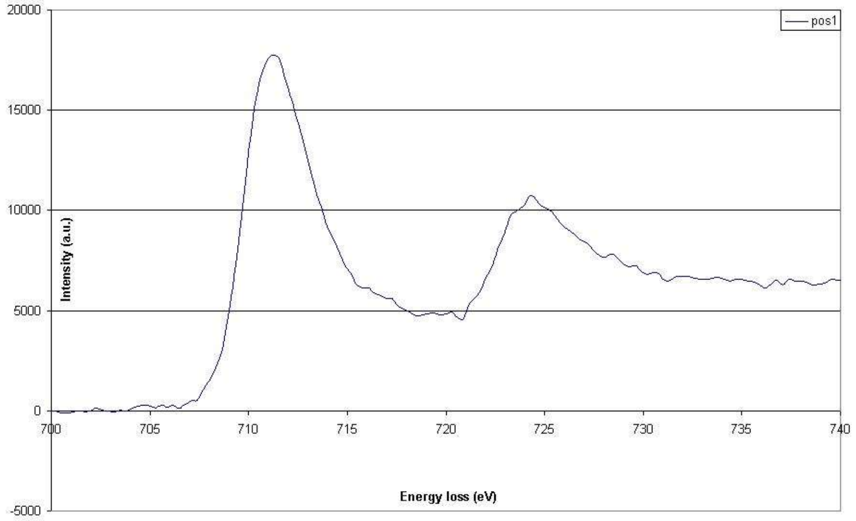
Biprism: shift the fringes

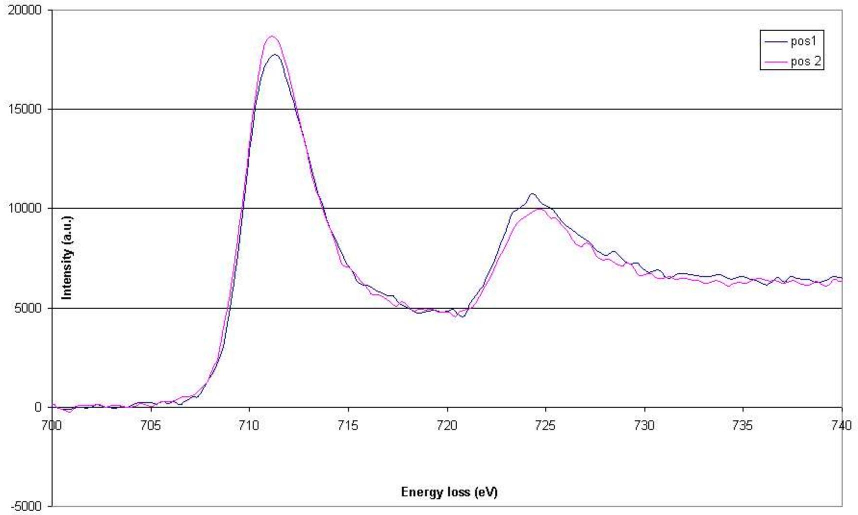
B field reverse (Regensburg):

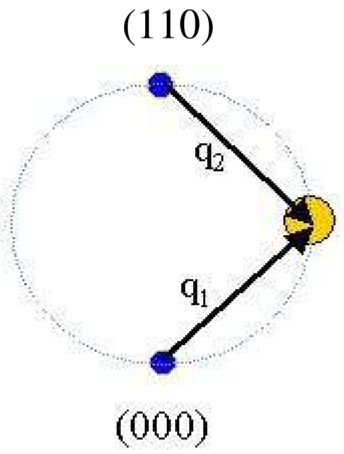
1) Dedicated holder
2) Switch Objective lens current
3) Use magnetic domains

EMCD: spectrometry

Detector shift technique







pos 1 $\Delta\varphi = \pi/2$

q_1^q_2 points out of the figure

pos 2 $\Delta\varphi = \pi/2$

q_1^q_2 points toward the figure

Spatial resolution = SA aperture (~100 nm radius)

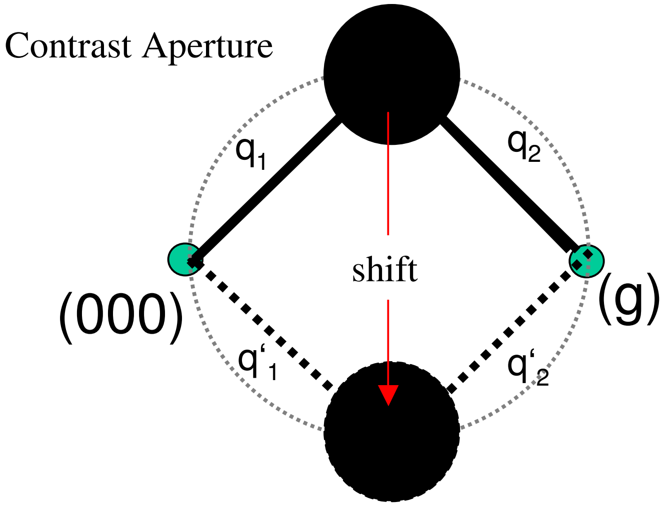
Contrast Aperture Shift

Contrast Aperture to select k_f

↓

work in image mode

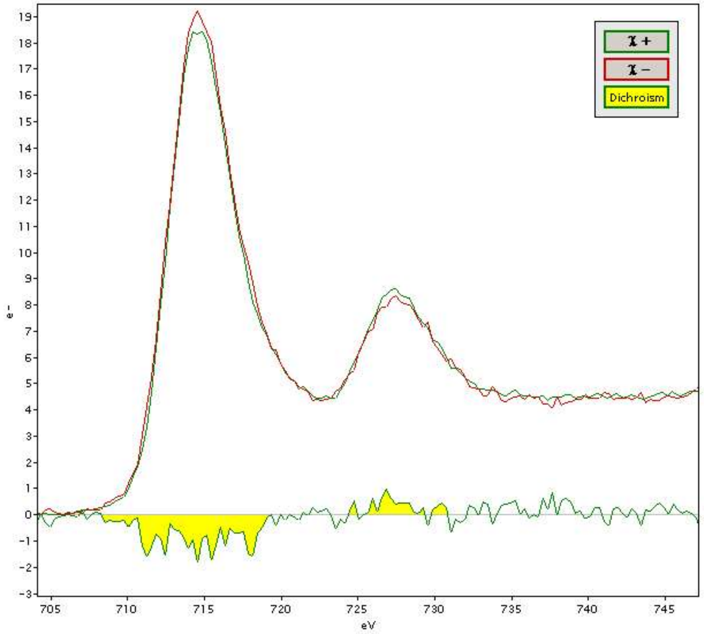
Spatial resolution of a few nm.



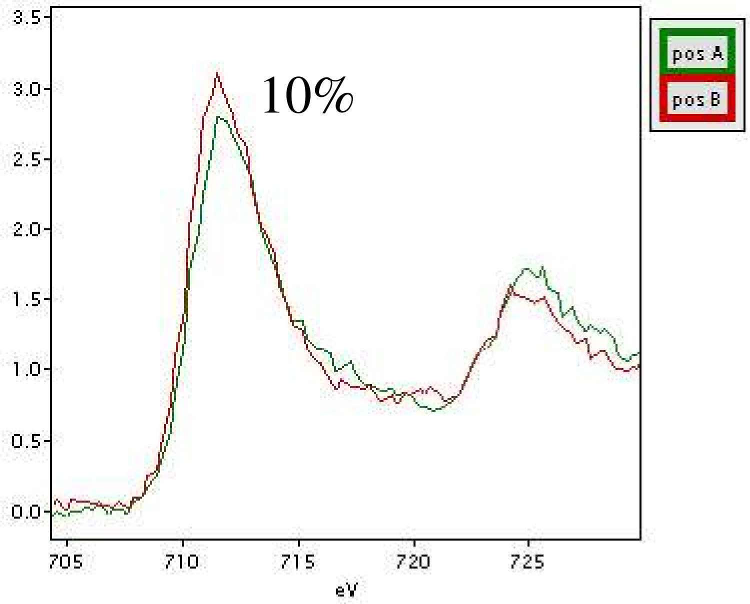
Contrast aperture: 4.8 mrad diam.

d_{110} for Fe is ~12 mrad

Dichroic signal is lower in %

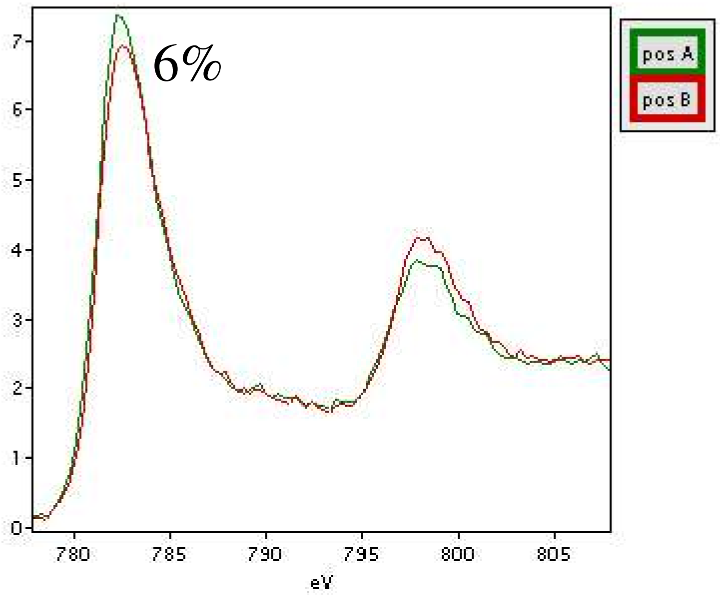


Latest results on Fe, Co and Ni $L_{2,3}$ edge



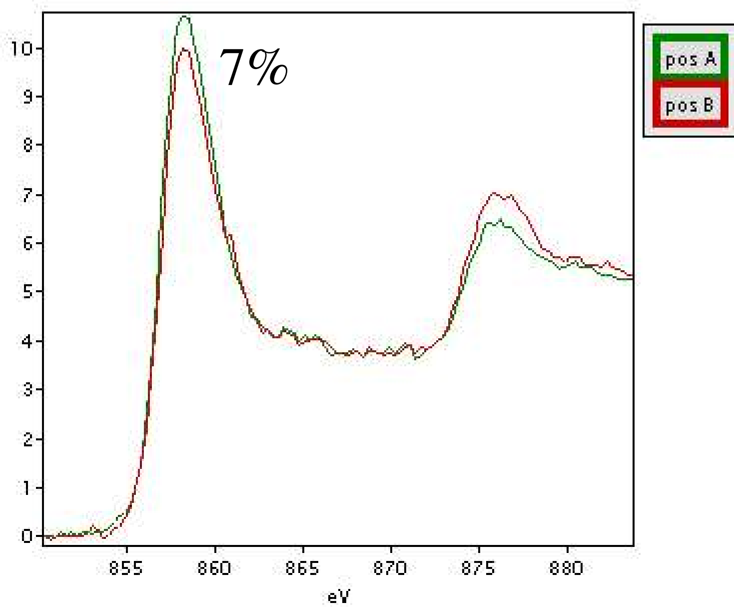
10%

Fe/GaAs



6%

Co

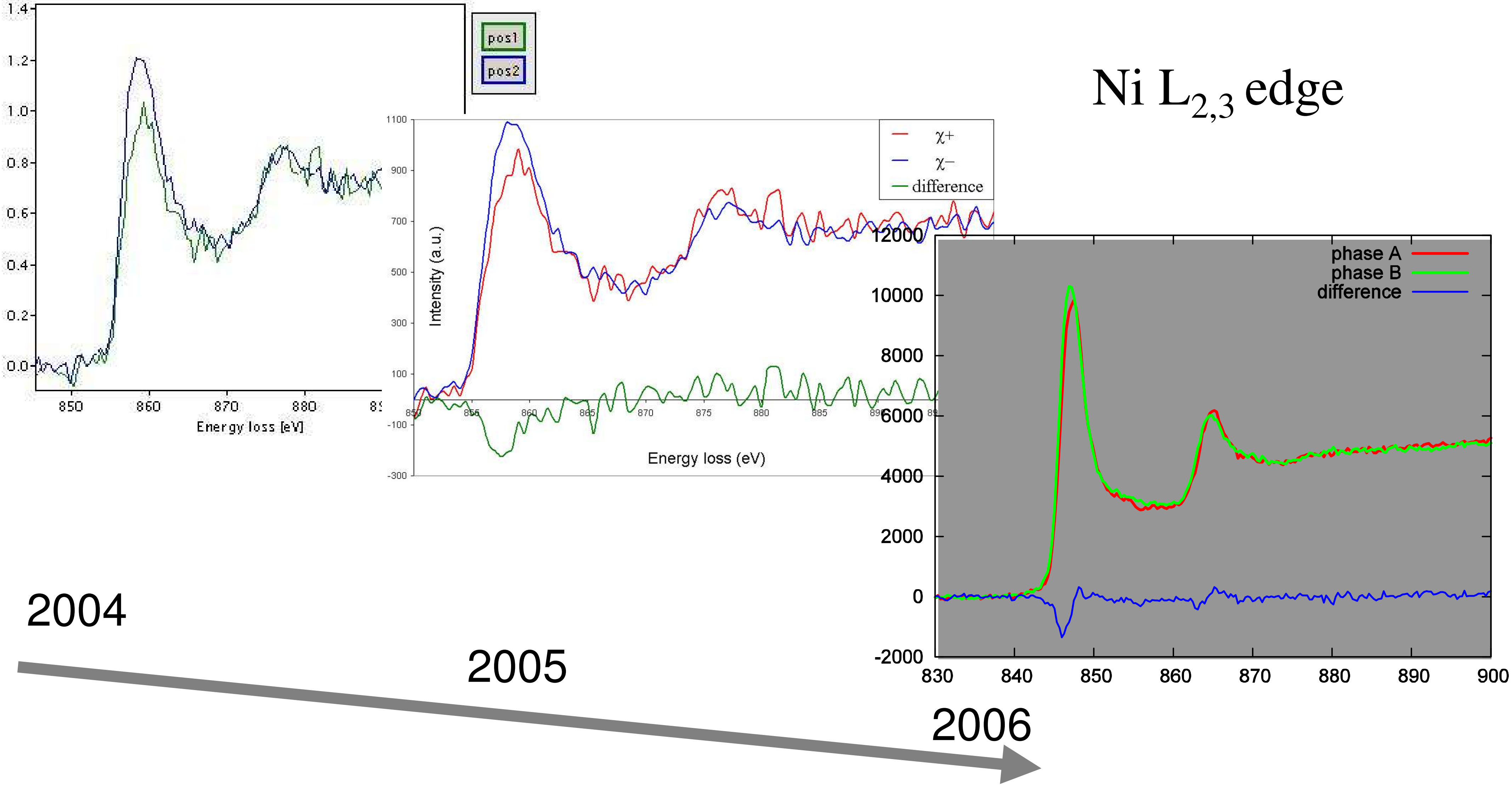


7%

Ni

Improving the S/N ratio

Ni $L_{2,3}$ edge



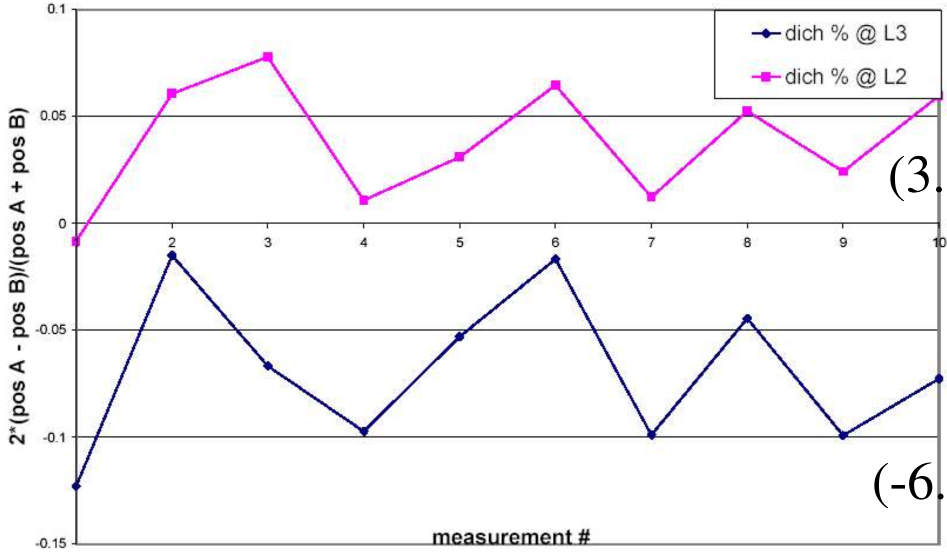
2004

2005

2006

Importance of normalisation

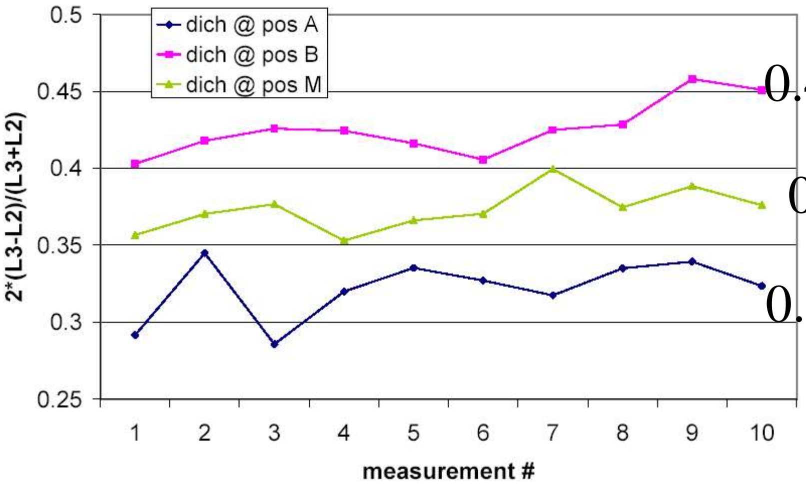
Normal procedure: spectra are normalised to have the same background between the edges. Noise can affect normalisation!



(3.9±2.7)%

(-6.7±3.5)%

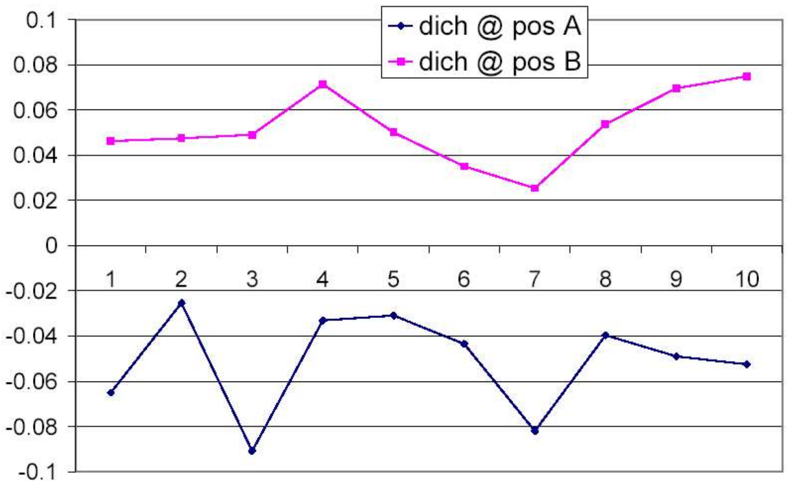
By first calculating the ratio $(L_3-L_2)/(L_3+L_2)$ we can reduce the problem, but we need an extra non dichoric spectrum at position M.



0.425±0.017

0.373±0.013

0.322±0.019

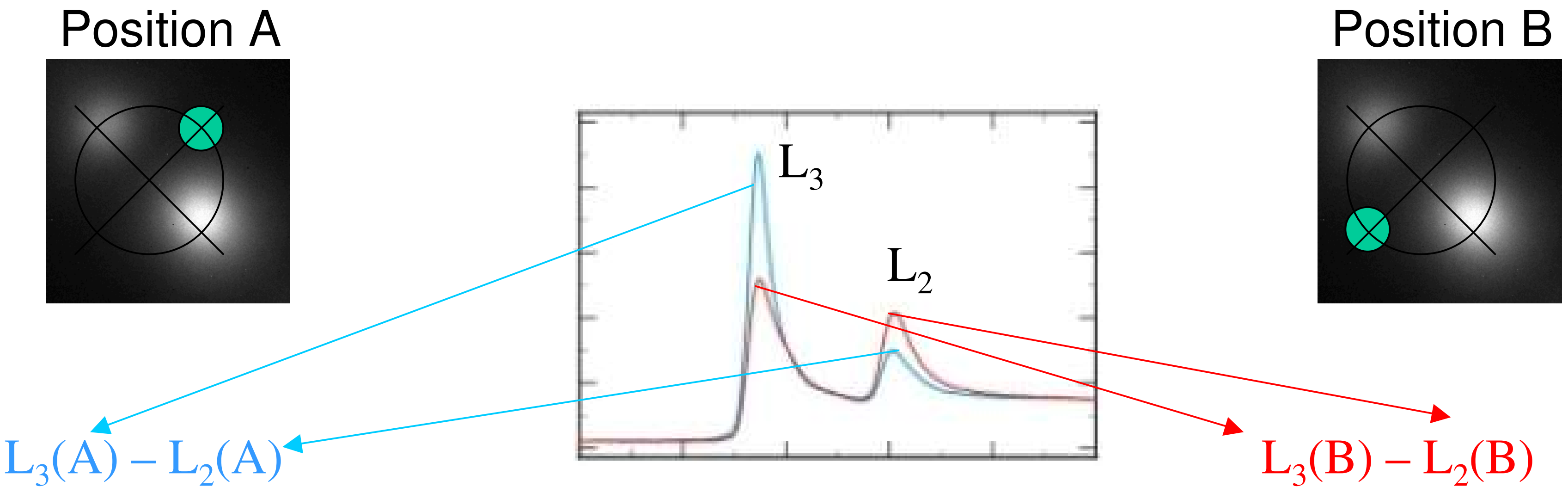


(5.2±1.2)%

(-5.1±2.1)%

EMCD: chiral imaging

Chiral Dark Field



Position A

Position B

$L_3(A) – L_2(A)$

$L_3(B) – L_2(B)$

Advantages: possibility to image magnetic domains

High resolution

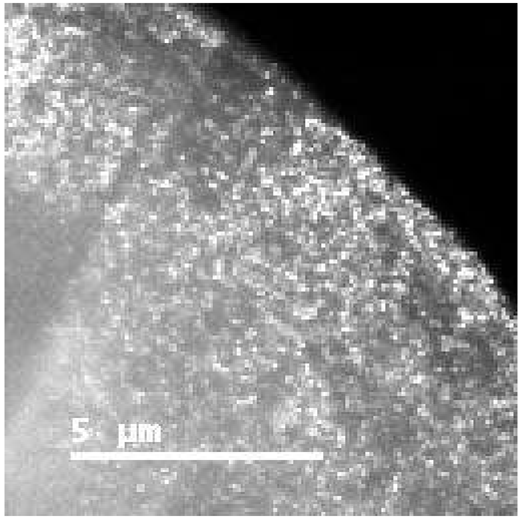
Disadvantages: limited energy resolution (compromise with intensity)

Problems: very low intensity

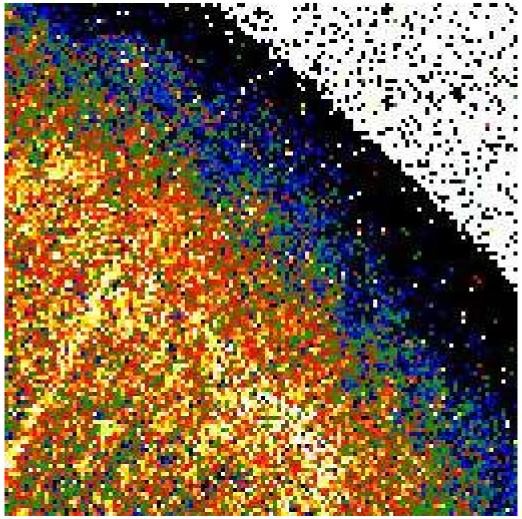
Dark count of CCD is an important source of error!

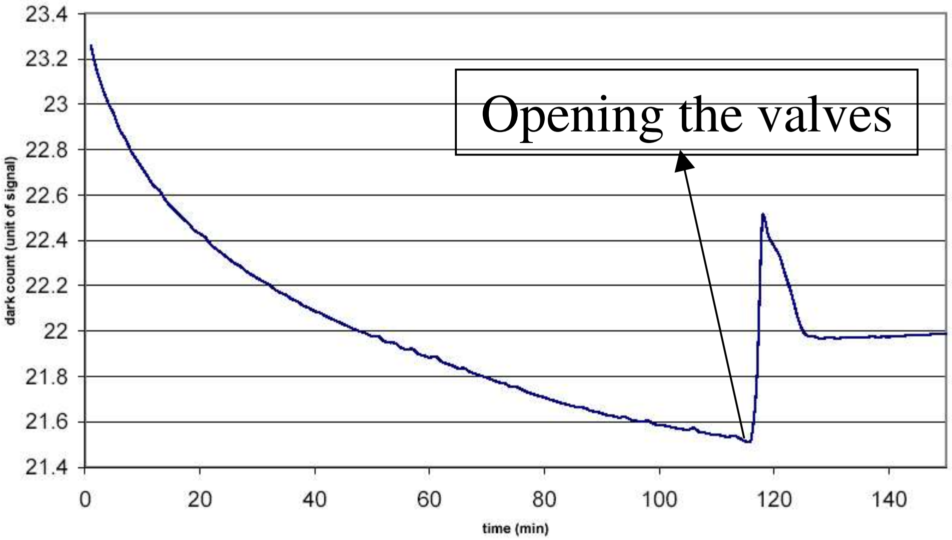
$$L_3(B) - L_2(B) \overset{?}{\sim} -[L_3(A) - L_2(A)]$$

CA @ Position A

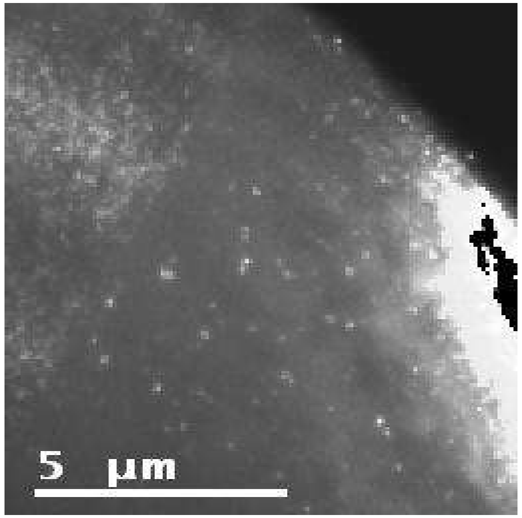


$L_3(A) - L_2(A)$




Opening the valves

CA @ Position B



$L_3(B) - L_2(B)$

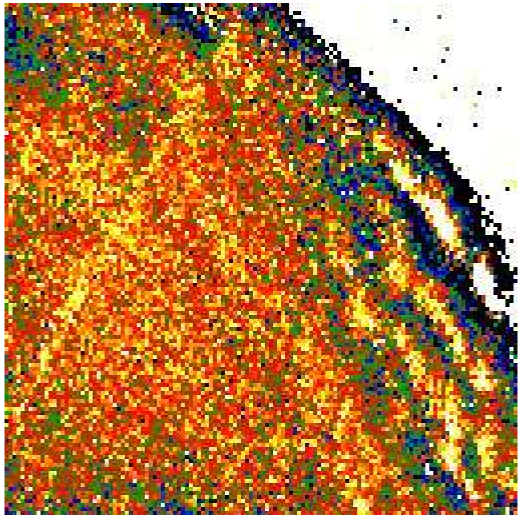
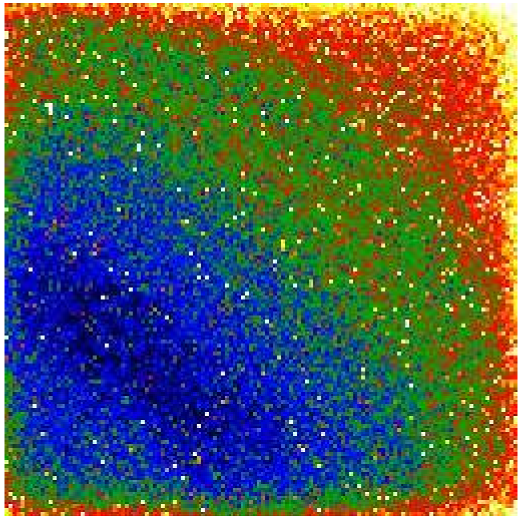
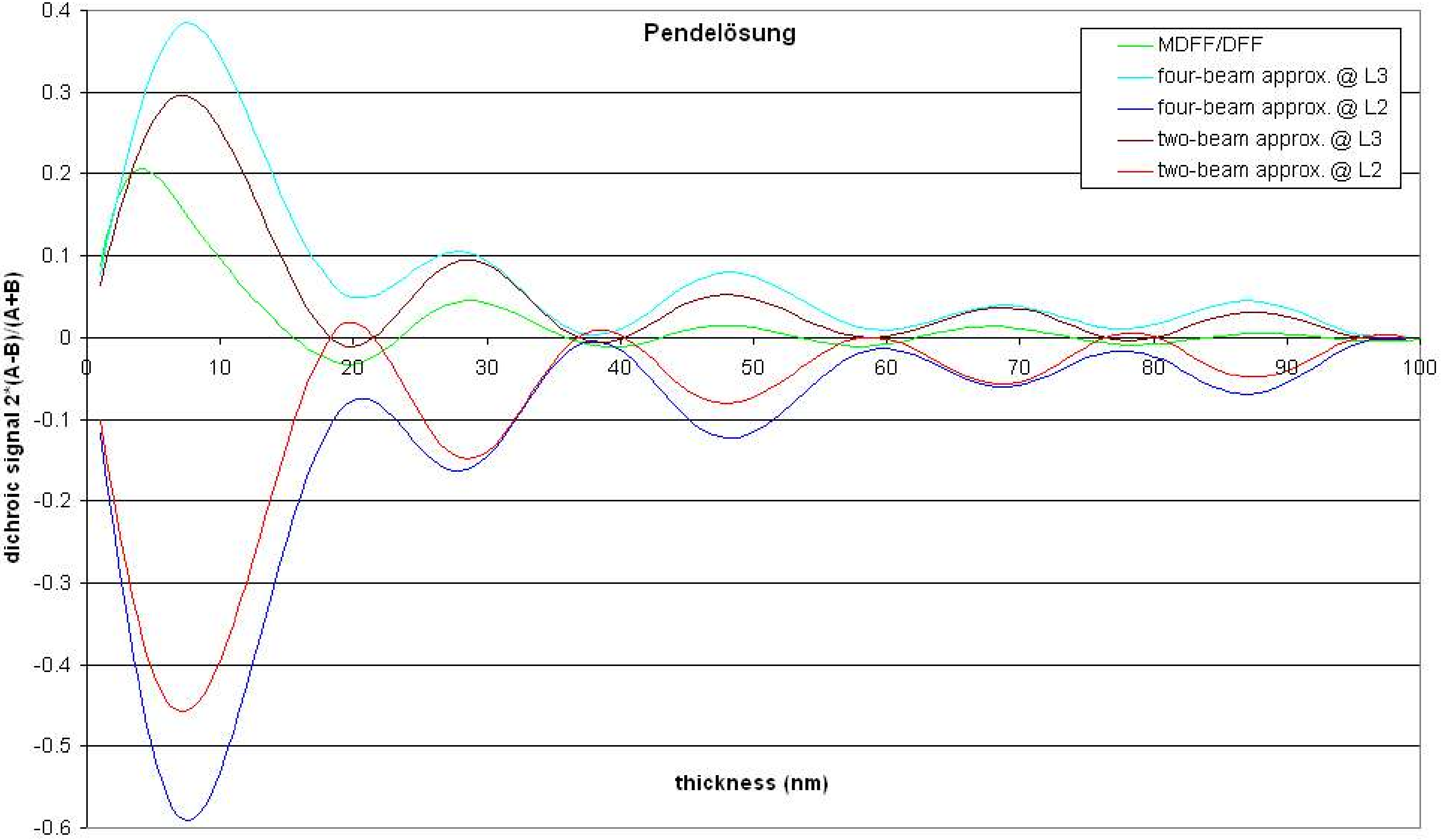


Image of the dark count



Experimenting with simulations...



Thank you!

http://www.chiraltem.physics.at