D8.7 Magnetic field calculations for compact Larmor devices in ESS designs

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Design criteria

- Make optimal use of the pancake moderator at the ESS
- Short and compact instruments giving high brilliance and tolerating high divergence
- Monochromatic, TOF, white beam
- New magnetic field configurations that lead to compact Spin Echo SANS and Larmor diffraction instruments
- Use the compact instrument as an add-on module, e.g. in SANS

→ SEMSANS

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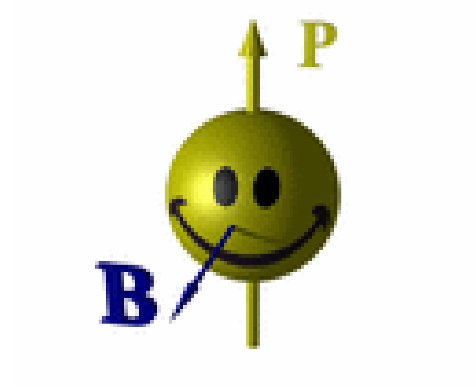
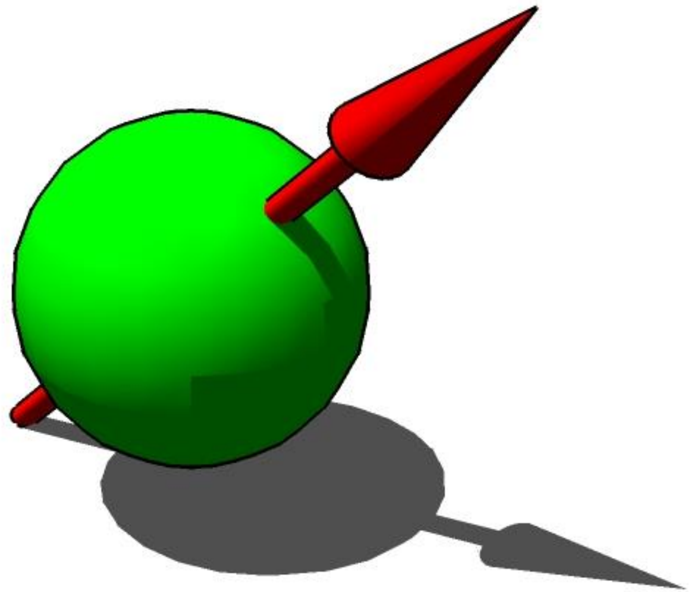
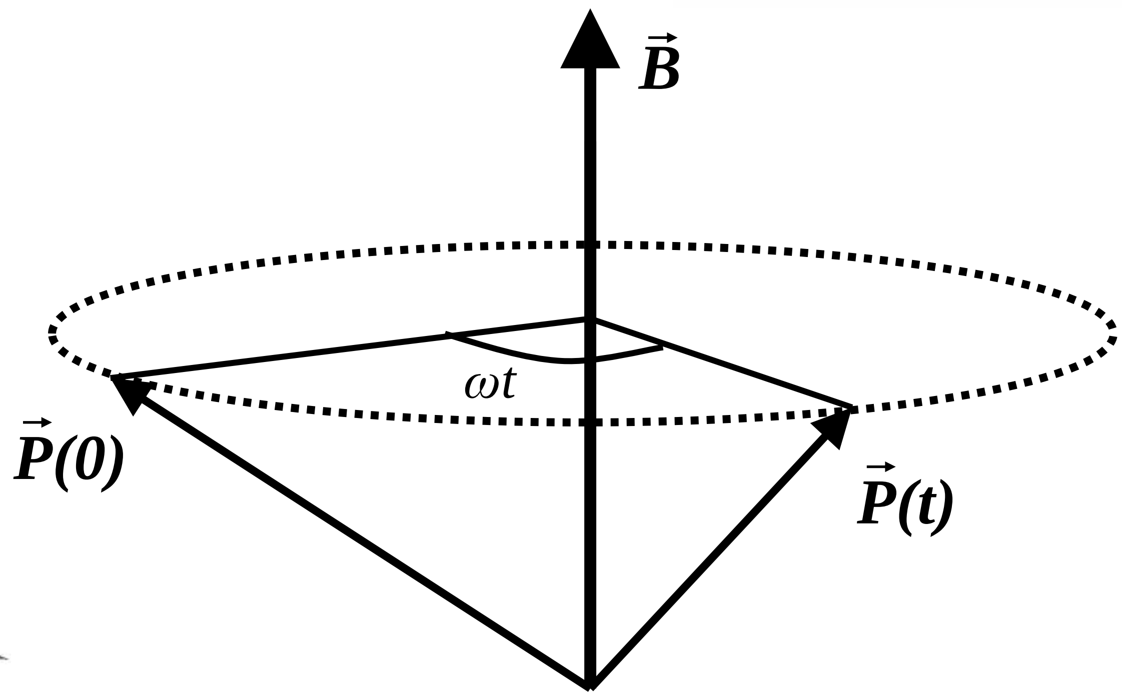
SEMSANS: Concept



All based on Larmor precession





$$\varphi \approx B \lambda L$$

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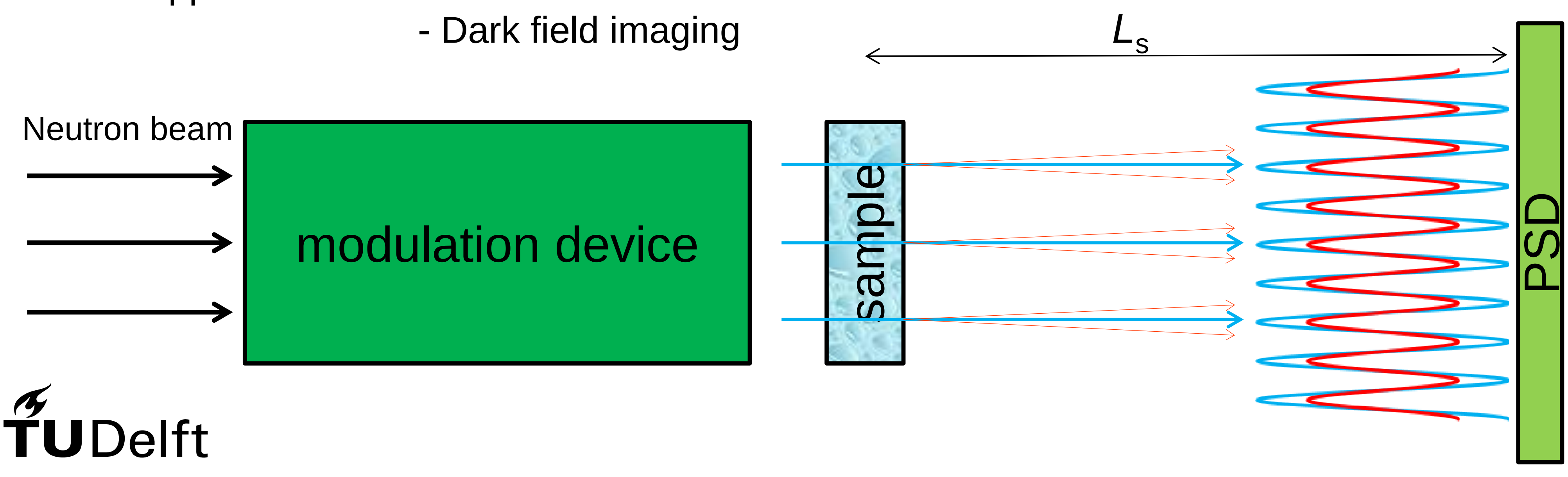
SEMSANS: Concept

- Spin Echo Modulated SANS: spatially modulated intensity in one direction
- Same principles as SESANS, but with spatial information → PSD
- Using RF spin flippers → little material in the beam
- Sample placed after the encoding region: sample → detector distance determines the probed length scale range (10nm → 10μm)
- Scattering signal is within the direct beam: scattering is measured as a decrease in modulation amplitude
- Applications: - Combined SANS + SESANS
  - Dark field imaging



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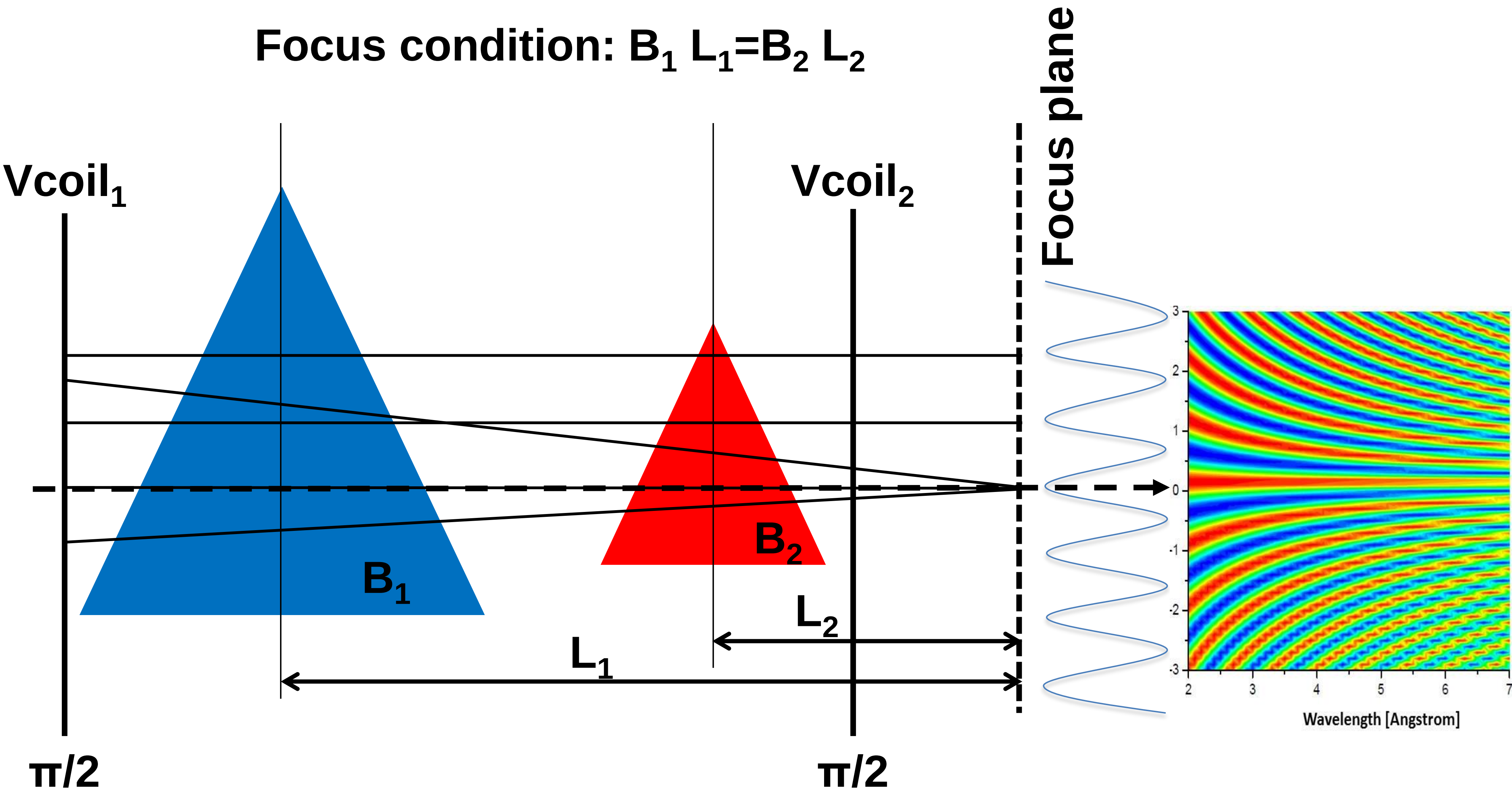
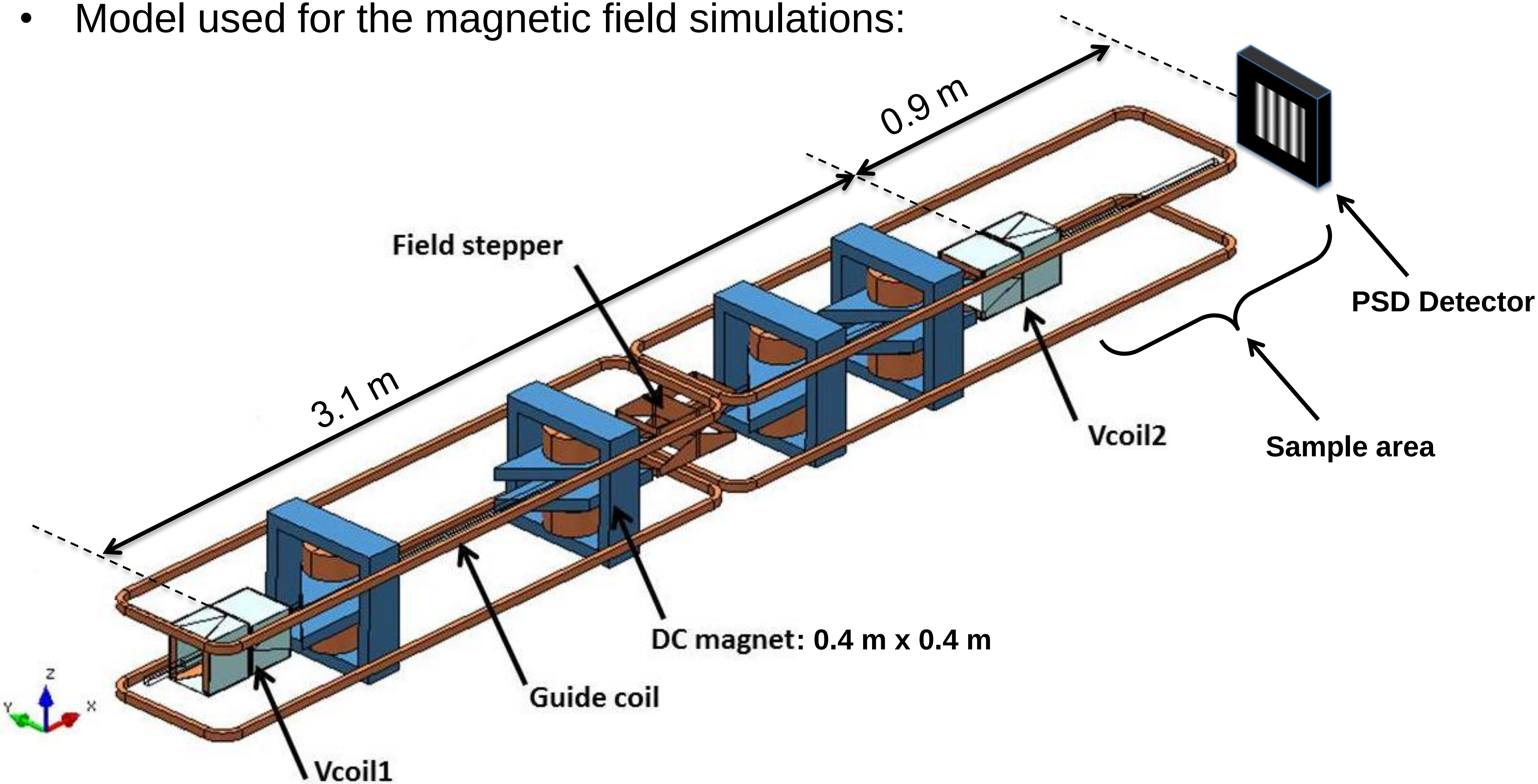
SEMSANS: Concept



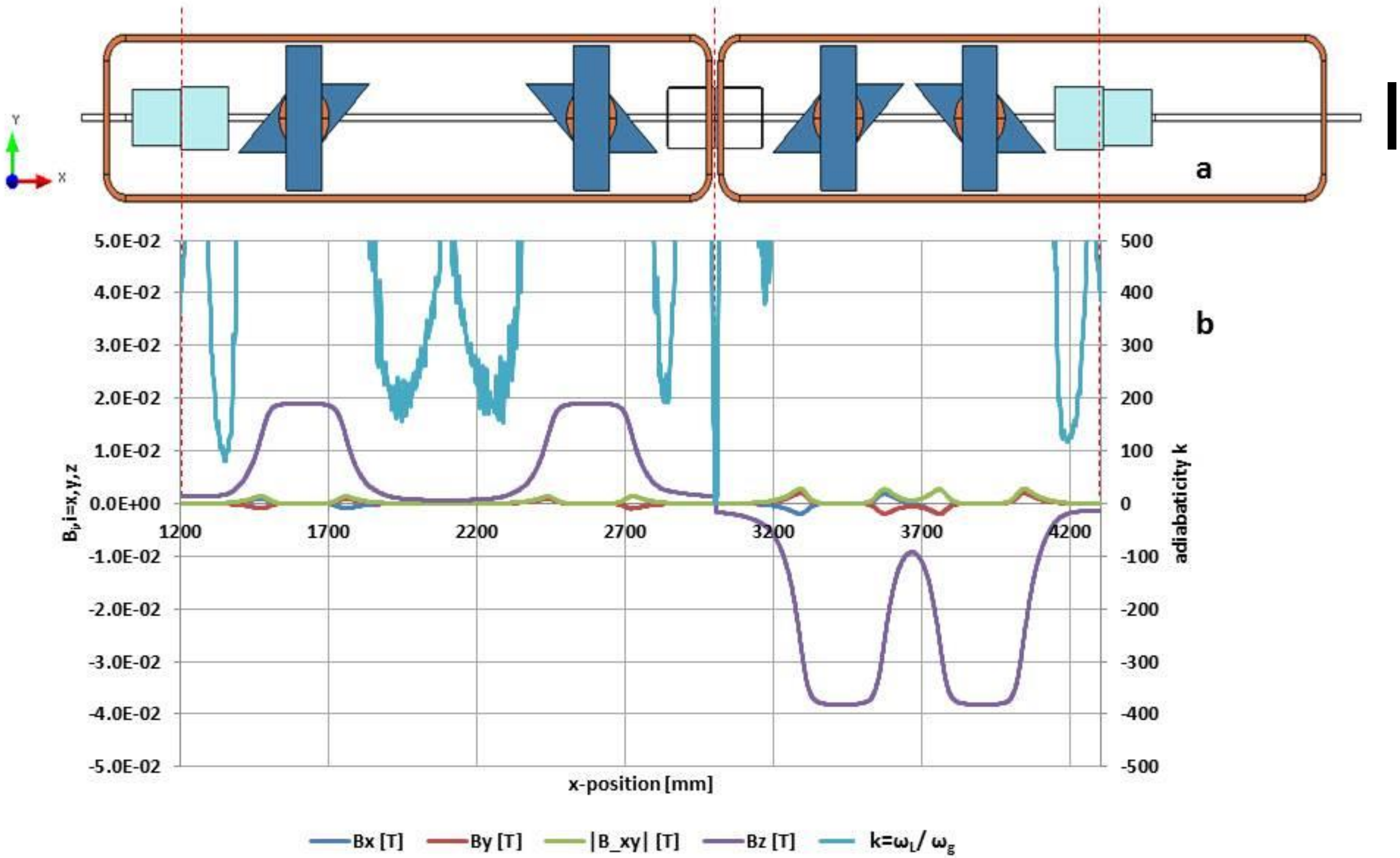
R. Gähler, A certain class of beam modulation techniques and its potential applications, PNCMI Polarised Neutron School, 2006

SEMSANS: Realisation @ HZB

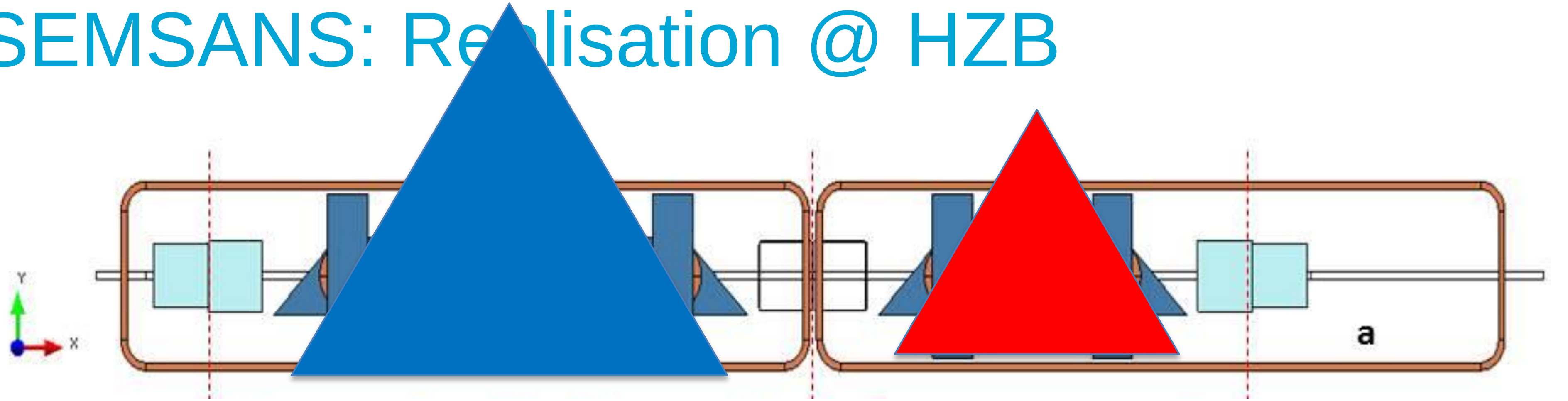
- Build and tested a setup at HZB, Germany
- Model used for the magnetic field simulations:

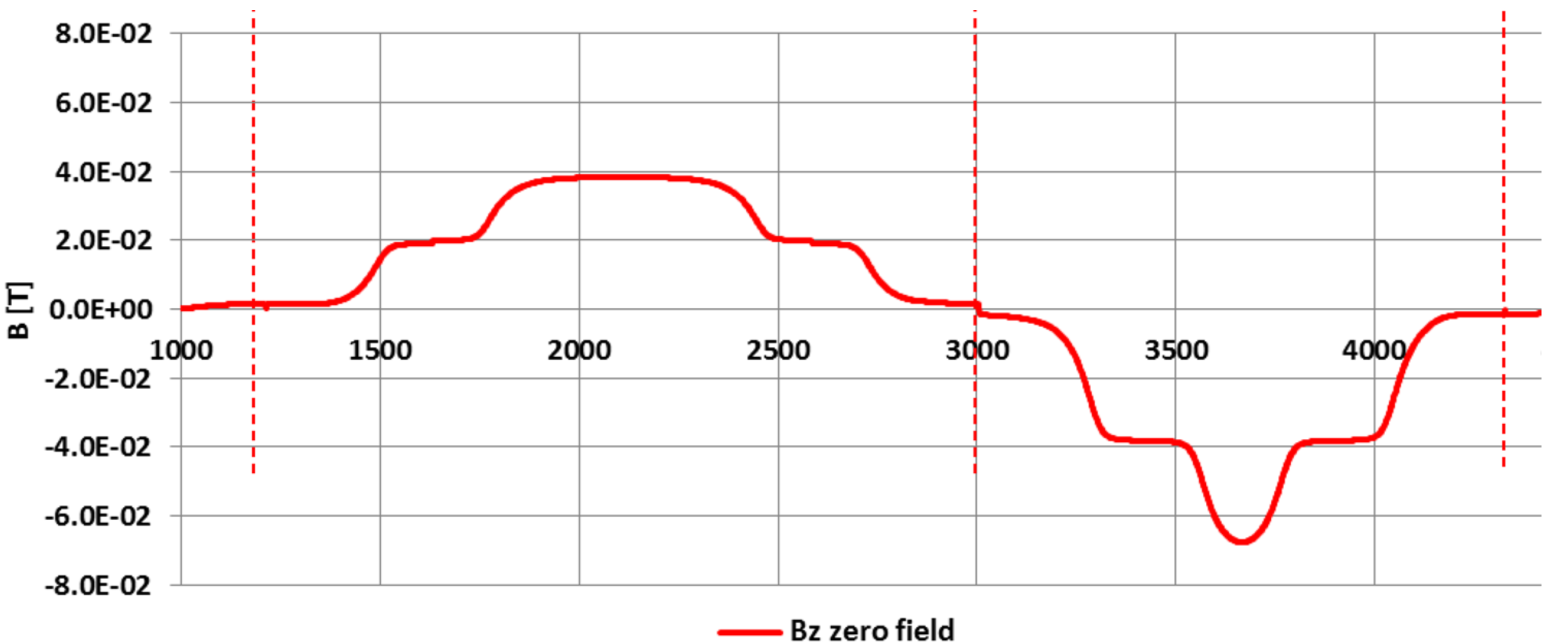


SEMSANS: Realisation @ HZB



SEMSANS: Realisation @ HZB



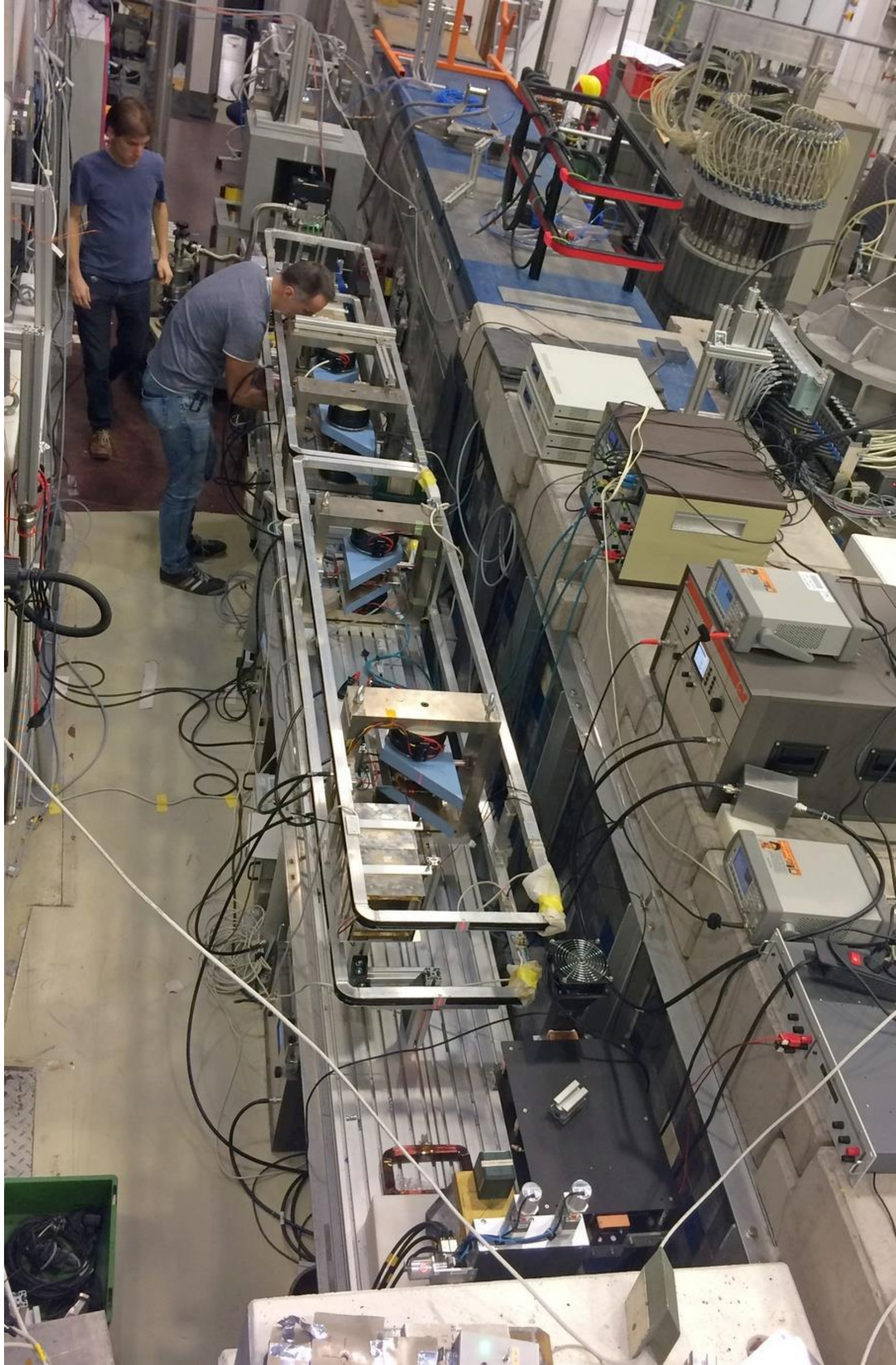


Zero field precession

SEMSANS: Realisation

- Tested at the V20 ESS Test Beam Line at HZB, Germany
- Uses two pairs of parallelogram DC magnets and RF spin flippers
- Each pair simulates a triangular field
- Combined SEMSANS and imaging

In collaboration with Robin Woracek, ESS



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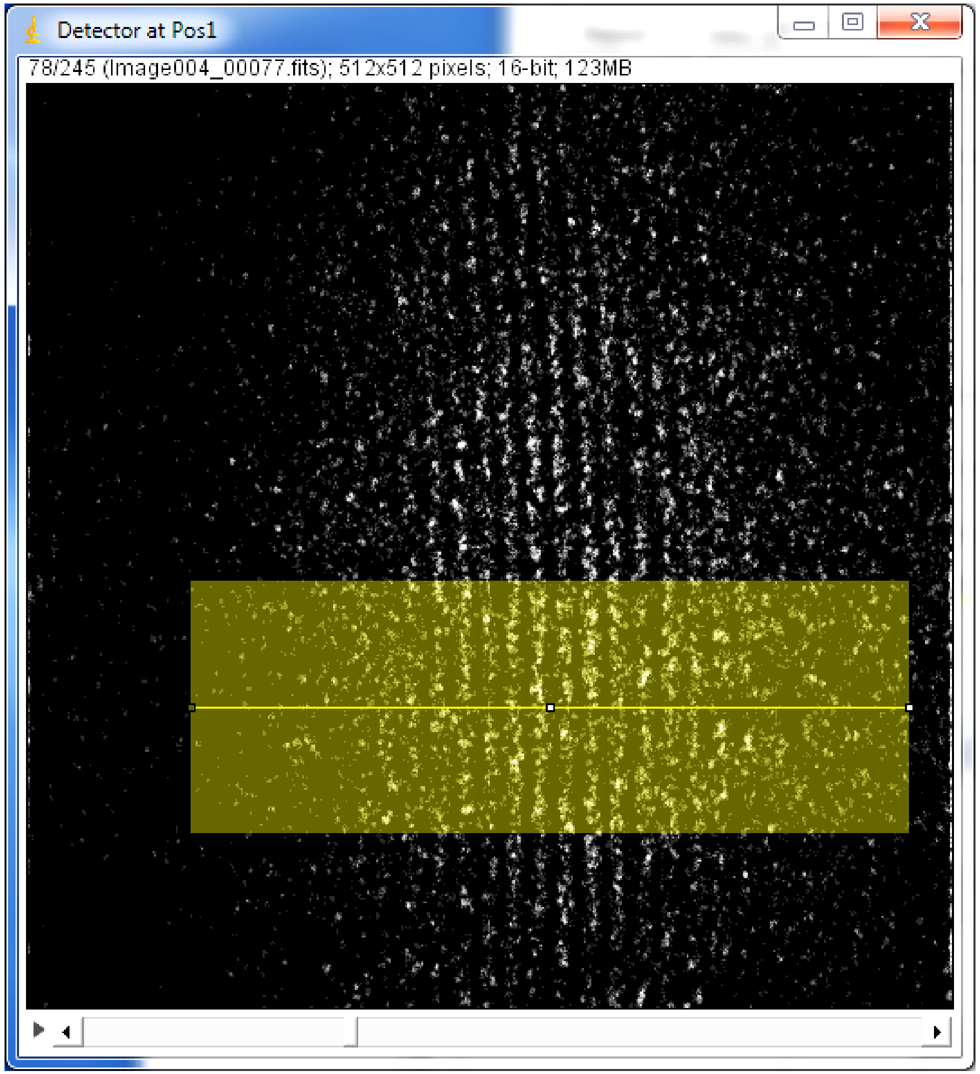
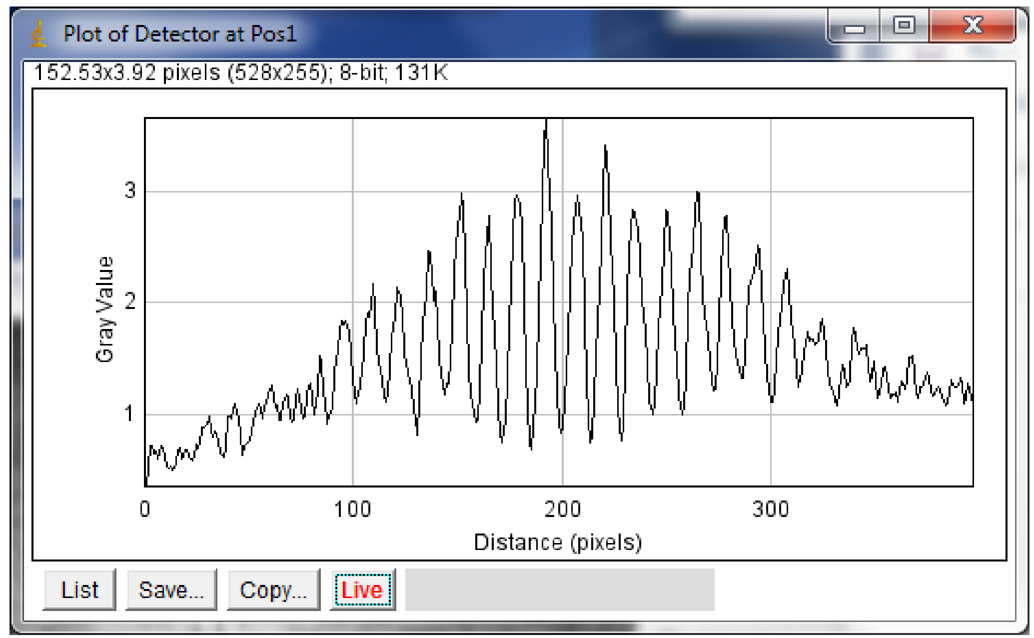
Modulation pattern: TOF single wavelength



512pixels, 28 mm

- Example image:
  - λ = 3 Å
  - Period = 0.8 mm, 15 pixels
- Longer wavelength → more fringes



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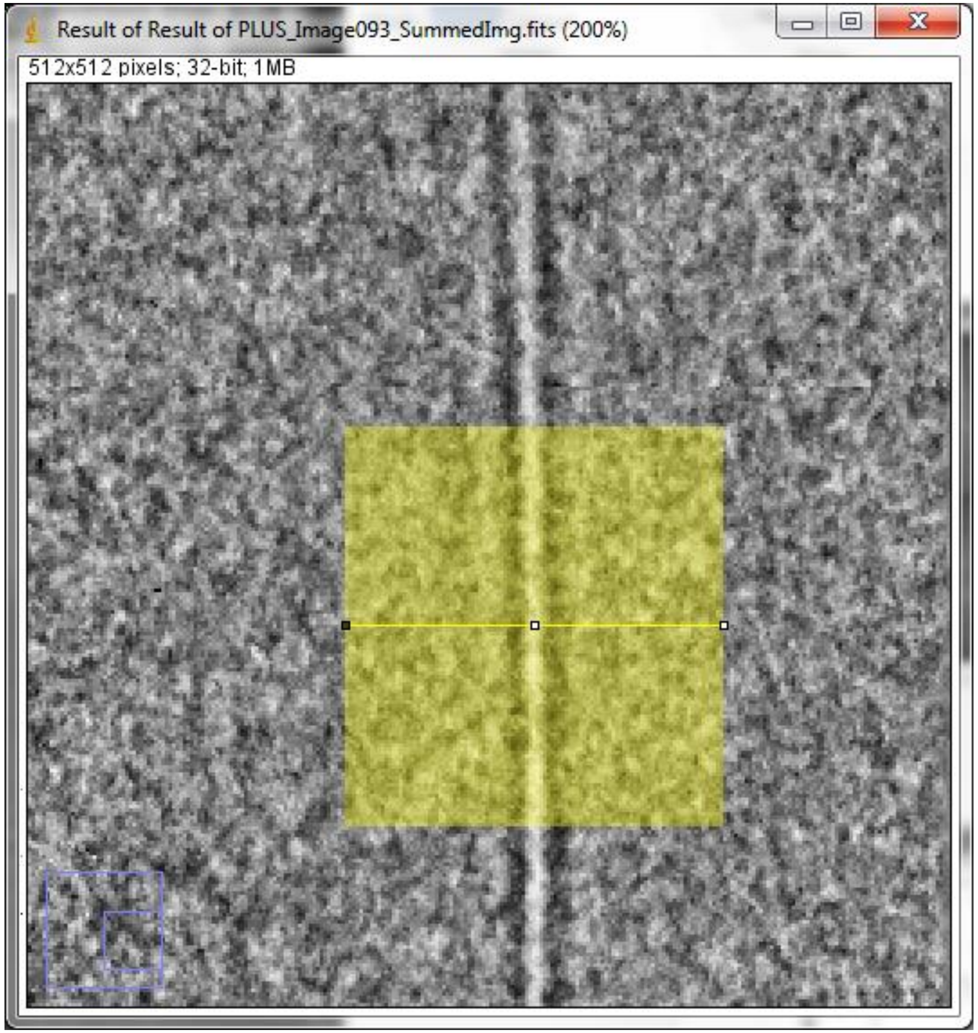
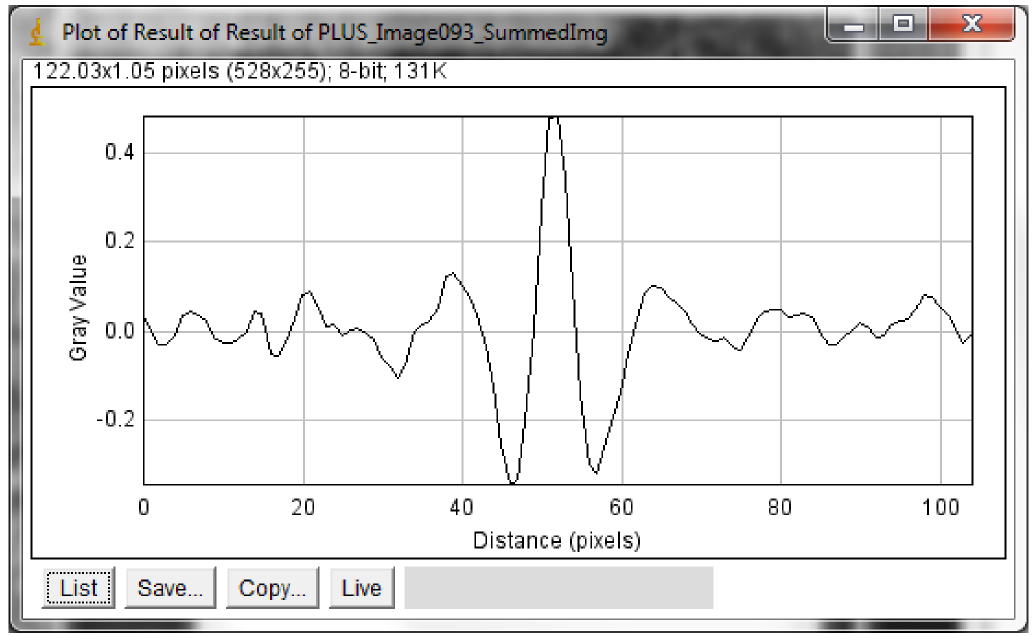
Modulation pattern: White beam



256pixels, 14 mm

- In the centre all wavelengths have spin echo (straight line in Atari plot)
- Outside the centre all modulation periods together smear out to average intensity



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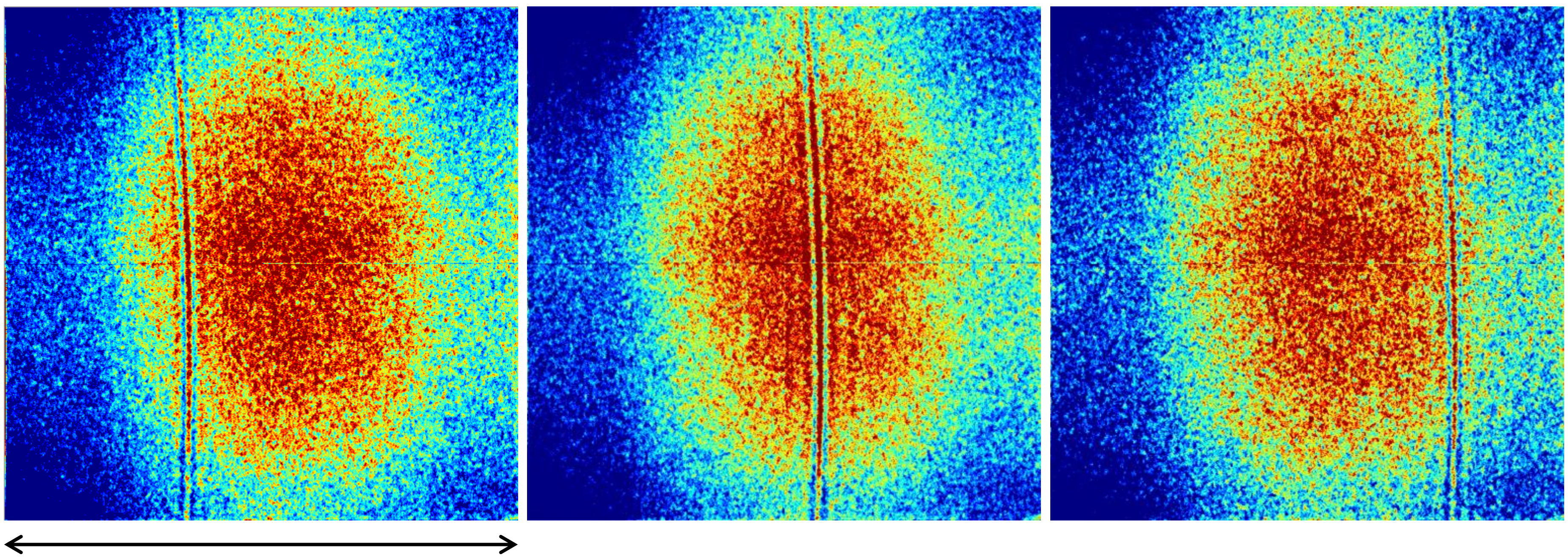
Modulation pattern: Shift

- Shift the spin echo position by tuning the RF frequency in one arm
- Shift also possible by changing B_0 or length of one arm
- Scan the pattern over the sample

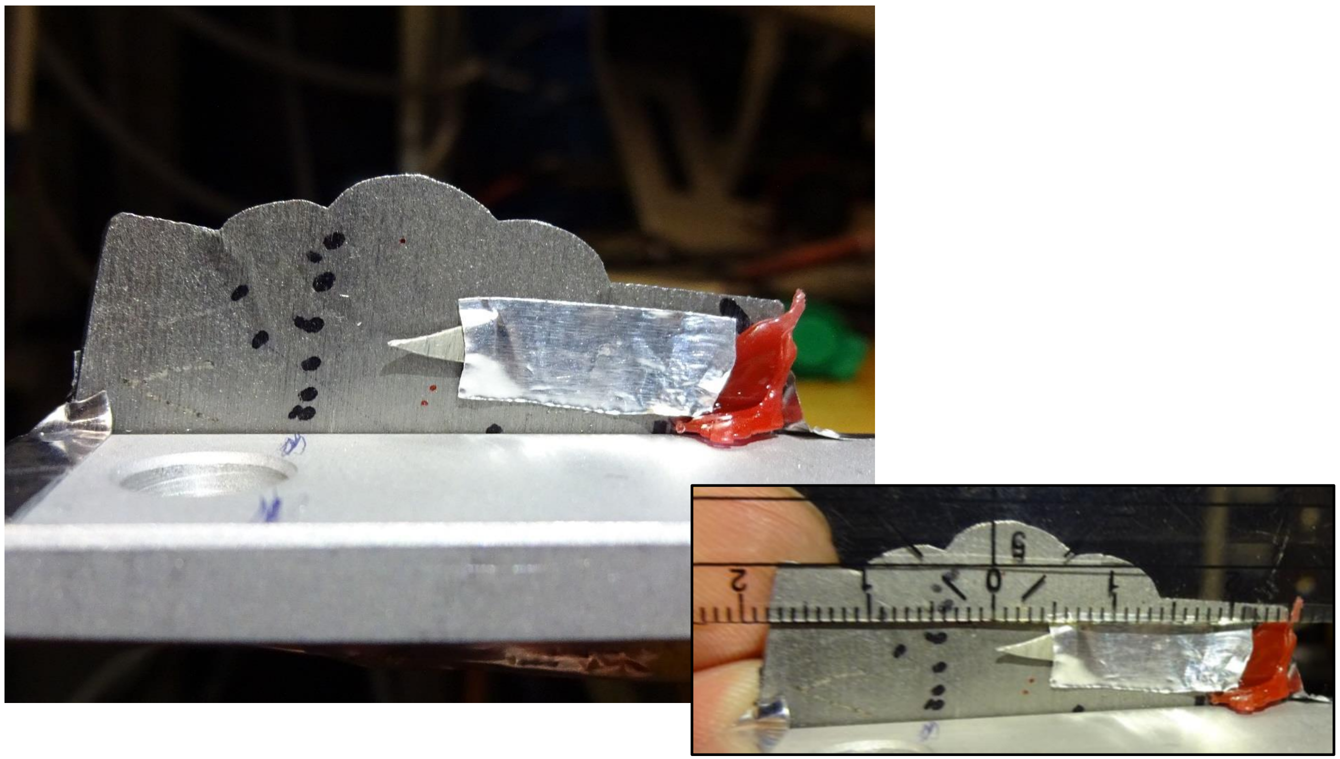
f = 548 kHz | f = 554 kHz | f = 560 kHz

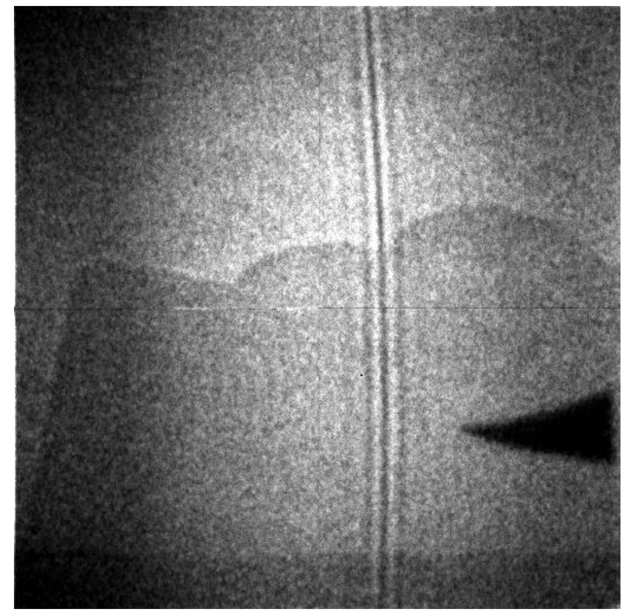


512 pixels, 28 mm

Application: SEMSANS + imaging

- Investigate a weld in a metal plate
- Bragg edge signal from the weld
- Sans signal on every position (>1x1mm² regions)

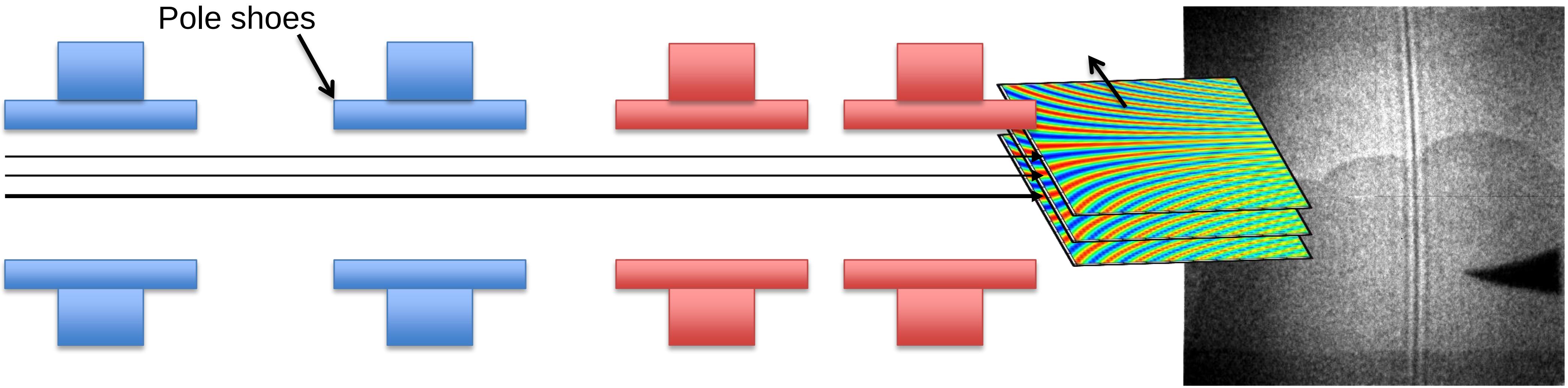




512 pixels, 28 mm

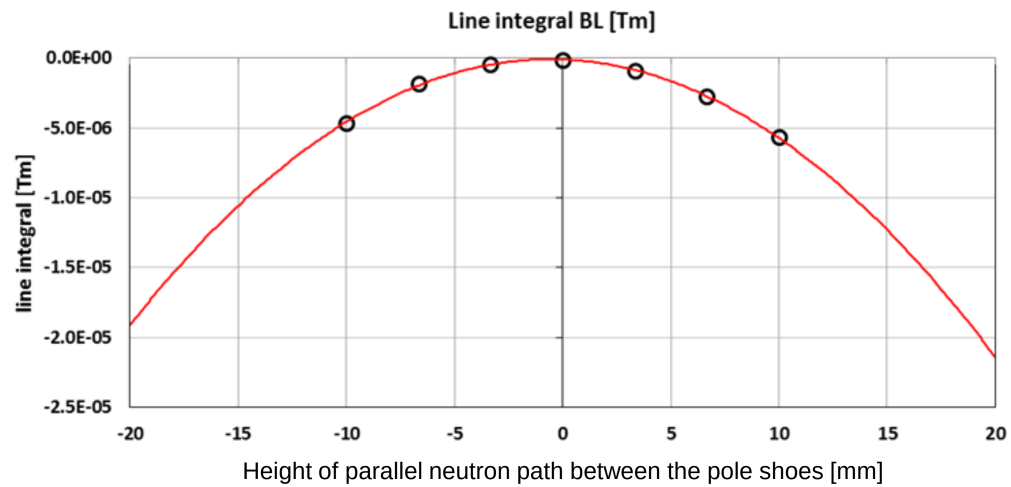
Metal plate with weld, Cd piece for alignment

SEMSANS: curved pattern



Schematic side view. Pole shoe distance: 60 mm, beam height 20 mm

- Not due to alignment
- Field is stronger closer to the pole shoes
- Arm 1 and arm 2 have different field strength and length → different inhomogeneity → extra net phase → ‘Atari plot’ shifts horizontal with height → curved plot



Downscaling the instrument

- Very useful to make conceptual design and use scaling factor with the predictions from the model to adapt a design to a certain beam size without new magnetic field calculations.
- Smaller instrument results in higher intensity
- Building the smaller instrument as an add-on module
- Two simple scaling rules:
    - Scaling the instrument and beam size in all directions, thus maintaining the relative dimensions, has no effect on the fields and aberrations or the modulation pattern
    - Only limit: adiabaticity parameter k scales linear with size. This determines the minimum size from a neutron point of view

Downscaling the instrument

Based on rule 1:

- Beam size at HZB: 20 x 20 mm²
- Beam size at ESS: 5 x 5 mm²

→ Factor 4 smaller

Based on rule 2:

- Adiabaticity parameter *k*:
  Describes how well a neutron can follow a change in magnetic field direction

$$k = \frac{\omega_L}{\omega_g}$$

ω_L: Larmor frequency

ω_g: Gyromagnetic frequency

$k \gtrsim 10$: adiabatic rotation

$k \lesssim 0.1$: sudden transition

Scaling factor: $S = \sqrt{k_{scaled}/k_{original}}$

$k_{original} = 80$ (from slide 7)

$S = \sqrt{10/80} = 0.35$ → Factor 3 smaller

Conclusion

- SEMSANS has a high potential as a compact instrument at the ESS
- The instrument can be scaled following simple rules