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CONRAD-2: Cold Neutron Tomography and Radiography at BER II (V7)

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Abstract: V7 has widely been recognized as a versatile and flexible instrument for innovative neutron imaging and has made decisive contributions to the development of new methods by exploiting different contrast mechanisms for imaging. The reason for the success in method development is the flexibility of the facility which permits very fast change of the instrument's configuration and allows for performing non-standard experiments. The ability for complementary experiments with the laboratory X-ray tomographic scanner (MicroCT Lab) offers the opportunity to study samples at different contrast levels and spatial resolution scales.

1 Introduction

V7 (CONRAD-2) is an imaging instrument using low energetic (cold) neutrons. The instrument is installed at the end of a curved neutron guide which blocks the direct view on the reactor core. This reflects in a very low background of high energetic neutrons and gammas. The cold neutron beam provides high attenuation contrast for thin layers of hydrogenous as well as lithium and boron based materials. In this way the visualization of small amounts of water, adhesive and lubricate substances in metal parts can be performed successfully. The wavelength range of the cold neutrons is suitable for phase- and diffraction-contrast imaging like grating interferometry and Bragg edge mapping. The instrument is well suited for high resolution imaging due to the high efficiency of the very thin scintillators used for cold neutrons.

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Figure 1: View of V7. Flight path equipped with containers filled with He gas for loss free transport of the neutron beam to the sample position (left). Sample position equipped with translation, tilt and rotation stages. The detector box with active area of 30 cm x 30 cm is behind the sample stage (right).

2 Instrument application

Typical applications are:

- Energy research (fuel cells and Li-ion batteries)
- Materials research (hydrogen storage materials, phase transitions in metals and characterization of porous media)
- Life science (water uptake in plants and water management in soils)
- High-TC superconductivity (flux pinning in superconductors)
- Magnetism (visualization and analysis of domain networks and visualization of static and alternating magnetic fields)
- Cultural heritage and paleontology

3 Instrument layout

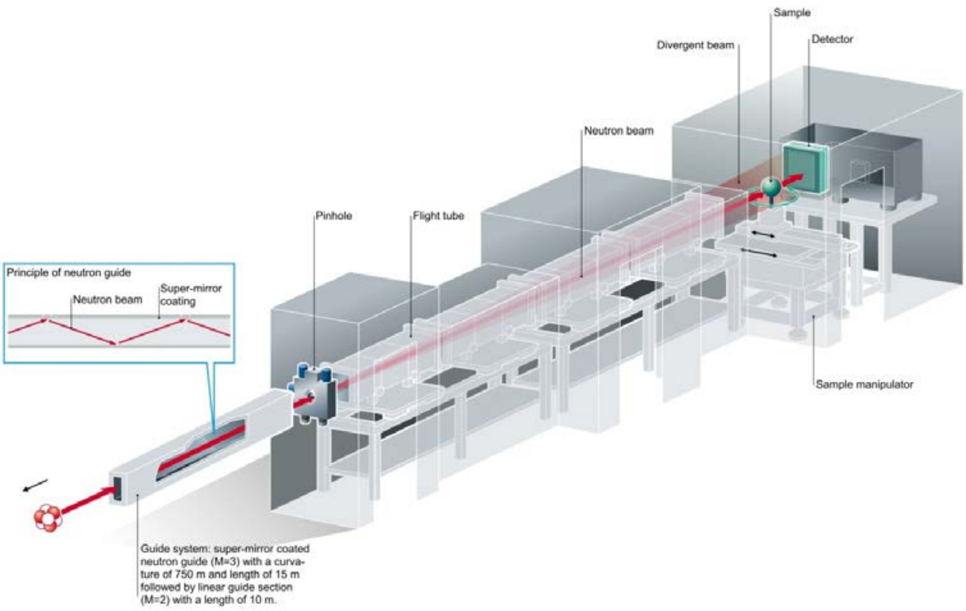

Figure 2: Schematic view of V7.

4 Technical Data

Neutron Guide	NL-1A (m=2,3) with beam cross-section: 125 mm (height) x 30 mm (width) Radius of curvature: 750 m
Pinhole changer	1 cm, 2 cm and 3 cm in diameter
Flight path	10 m flight path, covered by aluminum containers filled with He
Measuring positions	**Position 1** (end of the guide) Flux: $2.6 \cdot 10^9$ n/cm^{2}s @ L/D ca. 70; beam size: 12x3 cm **Position 2** Flux: $7.2 \cdot 10^7$ n/cm^{2}s @ L/D 170; beam size: 15x15 cm **Position 3** Flux: $2.4 \cdot 10^7$ n/cm^{2}s @ L/D 350; beam size: 30x30 cm Flux: $1.1 \cdot 10^7$ n/cm^{2}s @ L/D 500; beam size: 30x30 cm
Double crystal monochromator	Pyrolythic graphite (002) with mosaicity of 0.8° Wavelength resolution: 3 % Wavelength range: 1.5 Å– 6.0 Å
Velocity selector	Wavelength range: 3.0 Å– 6.0 Å Wavelength resolution: 10 – 20 %
Polarizers	2x Solid-state benders 4x Polarised ^{3}He cells and 2x magic boxes
Detectors	CCD camera (Andor, 2048 x 2048 pixels) sCMOS camera (Andor Neo) CMOS camera (PCO 1200h)
Best spatial resolution	20 µm at field-of-view of 13x13 mm
Sample manipulator	Rotation table: 0-360° Translation table: 0-800 mm Lift table: 0-250 mm Maximum weight: 200 kg

Table 1: Technical parameters of V7.

5 MicroCT Lab

The Micro-CT Lab supports users of the neutron imaging instrument CONRAD-2 and gives the opportunity to perform complementary measurements with X-ray imaging techniques. The micro-spot X-ray source produces a cone beam with energies up to 150 keV that allows for a variation of the magnification ratio by adjusting the source-detector and source-sample distances. In this way, the field of view (up to 10 cm) and the spatial resolution (down to 5 μm) are tunable. The short exposure times of a few seconds allow for fast preliminary image tests of samples which are dedicated for neutron tomography experiments. The Micro-CT Lab provides the following experimental methods: dynamic radiography, high-resolution tomography, phase-contrast imaging and laminography. Scientific topics at the laboratory are: Energy research (structural investigations of components of Li-ion and alkaline batteries as well as characterization of PEM fuel cell materials); life science (water uptake in plants by using contrast agent and investigation of soil contamination by heavy metals); biology (investigation of tooth substance and characterization of dental cements); geology (investigation of mineral morphology and crack propagation in rocks); cultural heritage and paleontology (in close collaboration with the local museums).

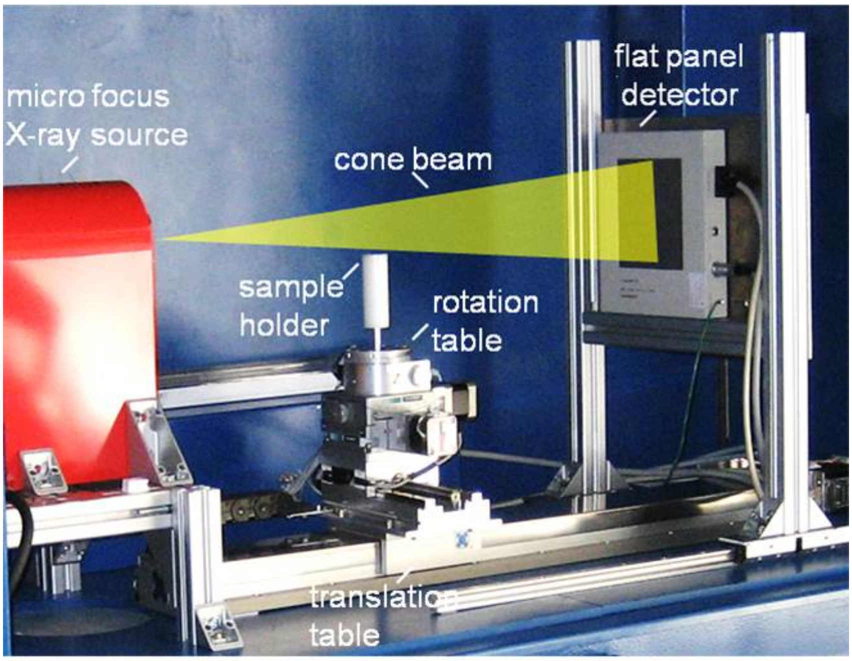

Figure 3: Photo of the MicroCT scanner. The main components are labeled.

Parameters

Micro focus X-ray tube	Hamamatsu L8121-3 Voltage: 40 − 150 kV Current: 0-250 µA @ small spot 7 μm 0-500 µA @ middle spot 20 μm 0-500 µA @ large spot 50 μm
Detector	Flat panel (Hamamatsu C7942SK-05) 2316 x 2316 pixels, pixel size: 50 μm Size: 11.5 cm x 11.5 cm
Magnification	up to 10 times
Best spatial resolution	10 μm at field-of-view 10 mm x 10 mm
Sample manipulator	Rotation table: 0-360° Translation table (along the beam): 60-700 mm Translation table (transverse to the beam): 0-100 mm Maximum weight: 5 kg

6 3D Analytics Lab

The 3D Analytics Laboratory supports users performing imaging experiments at the large scale facilities at HZB. The laboratory is used for complex 2D and 3D analyses of tomographic experiments carried out at the neutron imaging instrument CONRAD-2, in the X-ray Tomography Lab (Micro-CT Lab) and at the synchrotron tomography instrument at BESSY. The 3D Analytics Laboratory consists of a cluster of powerful work stations equipped with state-of-art software for tomographic reconstruction and quantitative analysis of 3D data. In addition, innovative software developed in-house is provided to the users. The laboratory offers the following options: Tomographic reconstruction with innovative mathematical algorithms (parallel beam, cone beam, filtered back projection, etc.); Holotomographic reconstruction algorithms (phase retrieval); Complex 3D image analysis procedures, labelling and individual particle size and shape analysis; Euclidian distance transformations; Watershed analysis and many others. A wide area of scientific topics are covered: Energy research (e.g. quantitative analysis of particles in batteries, 3D structural analysis of diffusion layer materials employed in fuel cells and batteries); life science (holotomographic reconstruction of the cellular structure of plants and woods); biology (porosity determination of bone and tooth substance); geology (morphology analysis of minerals); cultural heritage and paleontology (materials characterization).

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