

New developments for tomographic imaging at HARWI II

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Since the end of 2002 the GKSS-Research Center Geesthacht has been responsible for running the user experiment for microtomography at DESY. During the construction phase of the HARWI-II beamline attention was given to the optics concept to obtain a high-energy high-flux X-ray beam with a large field of view optimized for materials science applications [1]. Here the new monochromator setup used for imaging applications is described. Furthermore, the new data-management concept and the newly installed computer hardware for microtomography are presented.

Beamline optics

The main components for the beamline optics are the HARWI-II wiggler, the new front-end filter, the monochromator, the beam stop, and the diagnostics table (see figure 1). The design and features of the installed wiggler is presented in detail elsewhere [2]. The main parameters of the wiggler are:

Total length:	4 m	Peak field:	1.91 T
Period length:	110 mm	K:	20.3
Minimal gap:	14 mm	Critical Energy:	26.7 keV.

To reduce the heat load on the first crystal of the monochromator 3 mm carbon is permanently installed as a high-pass filter. For the use of high photon energies, a 7 mm carbon filter and a 1 mm or 2 mm copper filter can additionally be placed into the beam. The sketch of the filter system is given in the inset of figure 1. A detailed description of the system located in the DORIS-DESY injection tunnel 36 m downstream of the HARWI-II wiggler is given elsewhere [3].

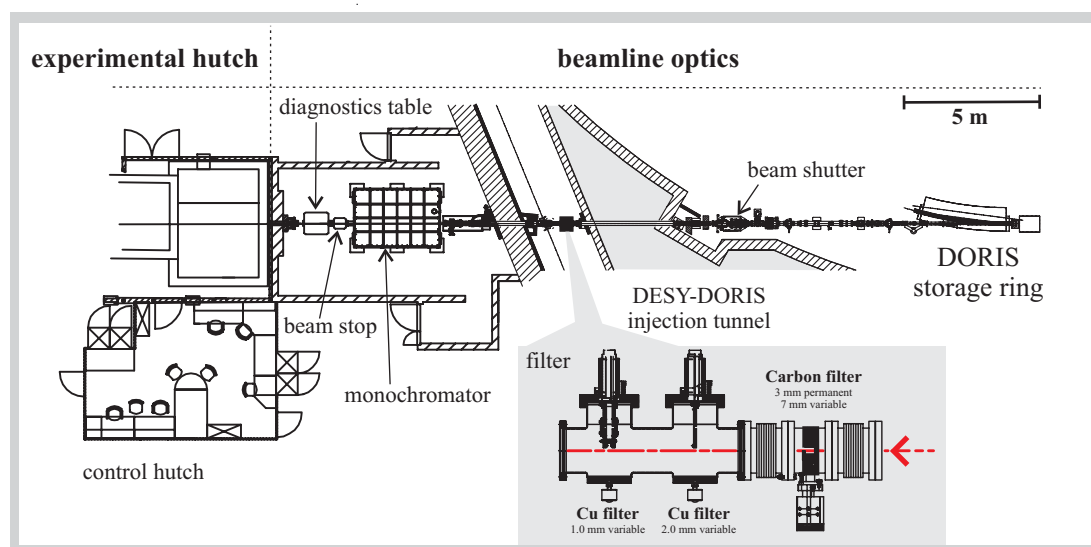


Figure 1: Sketch of the HARWI-II beamline showing the beamline optics. The permanent and optional high-pass filter installed in the DORIS-DESY injection tunnel is shown in the inset. A permanent 3 mm thick carbon filter can be extended by optional 7 mm carbon, 1 mm, or 2 mm copper.

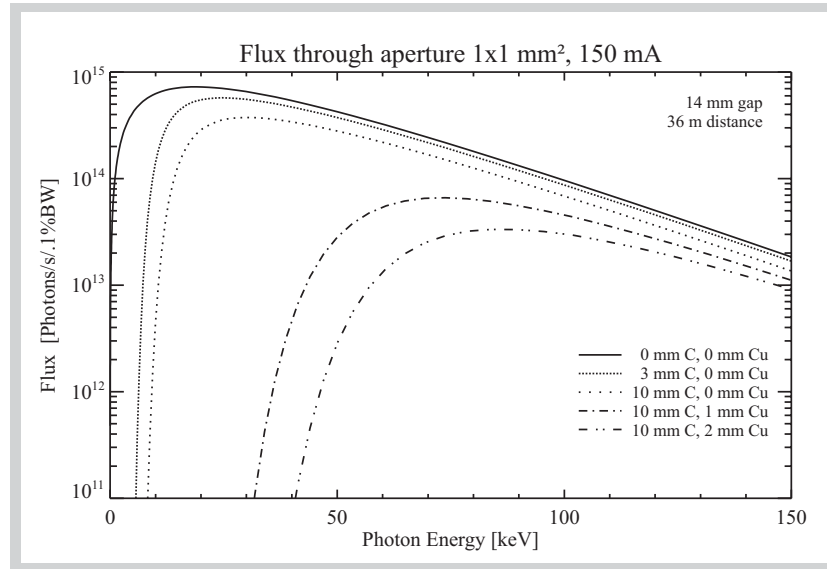


Figure 2: Comparison of the flux of the HARWI-II wiggler at minimal gap of the different filter settings with the unfiltered spectrum at the position of the high-pass filter (36 m distance from the source).

The resulting flux behind the filter system is presented in figure 2. The remaining total power of the white beam ($70 \times 10 \text{ mm}^2$) at minimum gap and minimum filter (3 mm carbon) is about 12.6 kW. To further reduce the heat load on the first crystal, the wiggler gap can be increased. The resulting flux for a gap of 14 mm, 20 mm, and 30 mm is shown in figure 3. By use of different combinations of the filters and wiggler gaps the optimized conditions with respect to photon energy and beam size can be found.

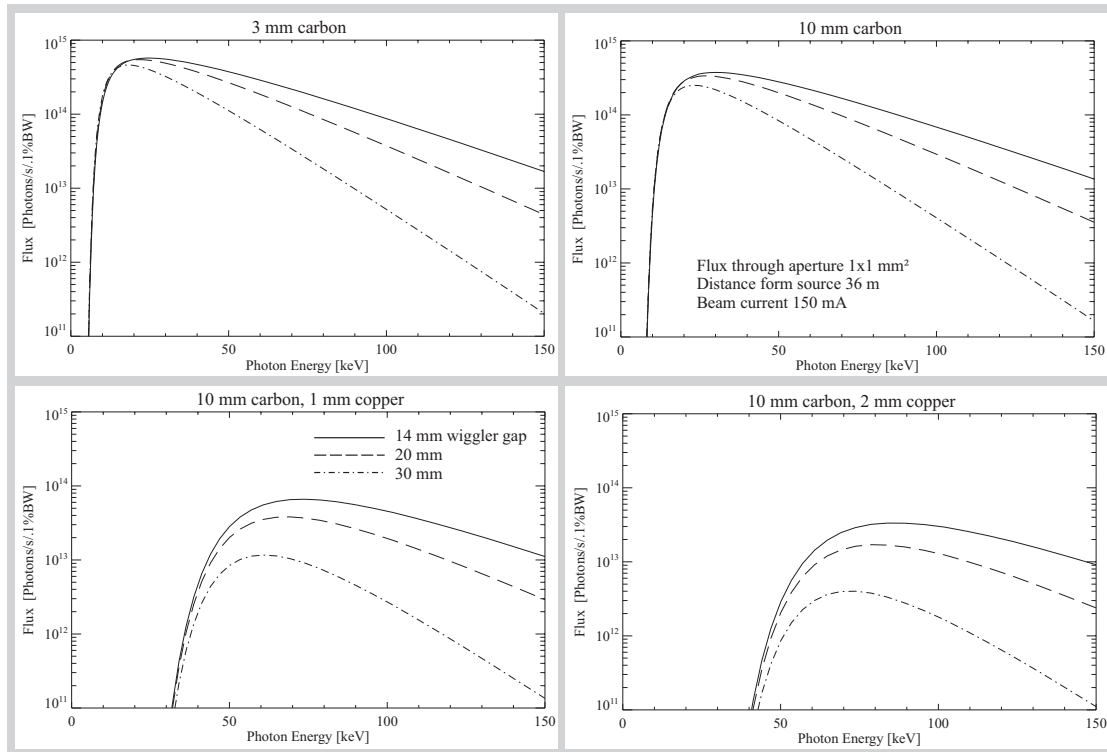


Figure 3: Comparison of the flux for different gaps of the HARWI-II wiggler with respect to different filter settings. Depending on the photon energy range of the monochromator different settings are foreseen. *Left top*: low photon energies (15-25 keV); *right top*: medium photon energies (20-80 keV) and large X-ray beam ($70 \times 10 \text{ mm}^2$); *left bottom*: high photon energies (60-250 keV) and small X-ray beam ($10 \times 10 \text{ mm}^2$); *right bottom*: high photon energies and large X-ray beam.

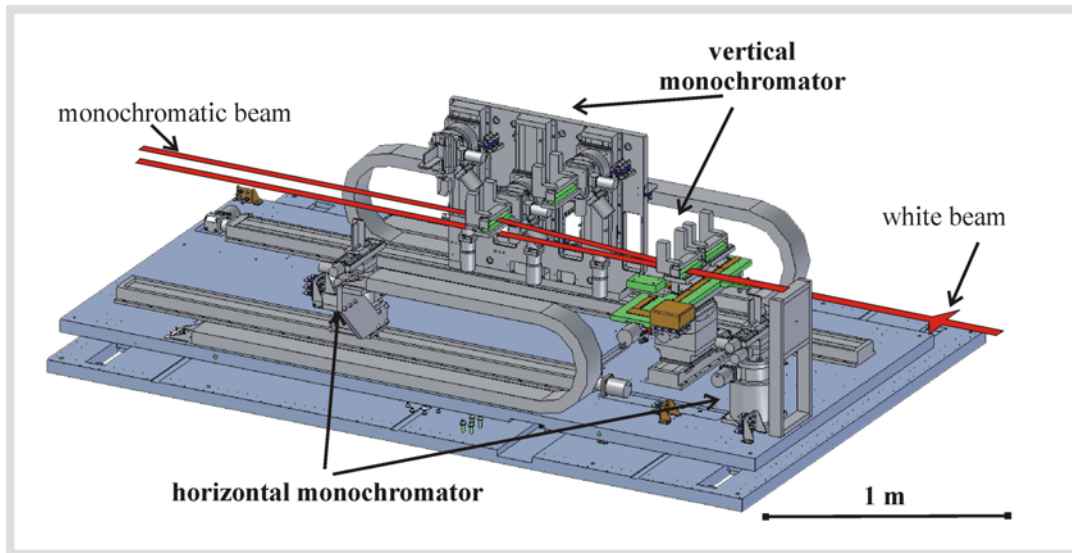


Figure 4: Sketch of the monochromator setup. The user can switch between two different monochromators.

The horizontal monochromator in the foreground and the vertical monochromator in the background are placed into the white X-ray beam by moving the upper plate perpendicular to the beam. The monochromator is installed in the monochromator tank in the optics hutch. The tank is of dimension 3 x 2 x 1 m (L x W x H) and can be evacuated to below 10^{-6} mbar.

The concept of the monochromator setup is presented in figure 4. Two different monochromator systems, one reflecting in the horizontal plane, and one reflecting in the vertical plane, are installed. The horizontal monochromator is mainly used for diffraction applications and provide for an X-ray beam with a size of $10 \times 10 \text{ mm}^2$ from 50 to 250 keV. The vertical monochromator is optimized for imaging applications and will deliver an X-ray beam with a size of $70 \times 10 \text{ mm}^2$ and a photon energy range of 15 to 200 keV. Different pairs of crystals with a new design in Laue-Laue and Laue-Bragg geometry will be installed. Furthermore, the bent-Laue crystals are used to increase the energy band path of the reflected X-ray beam.

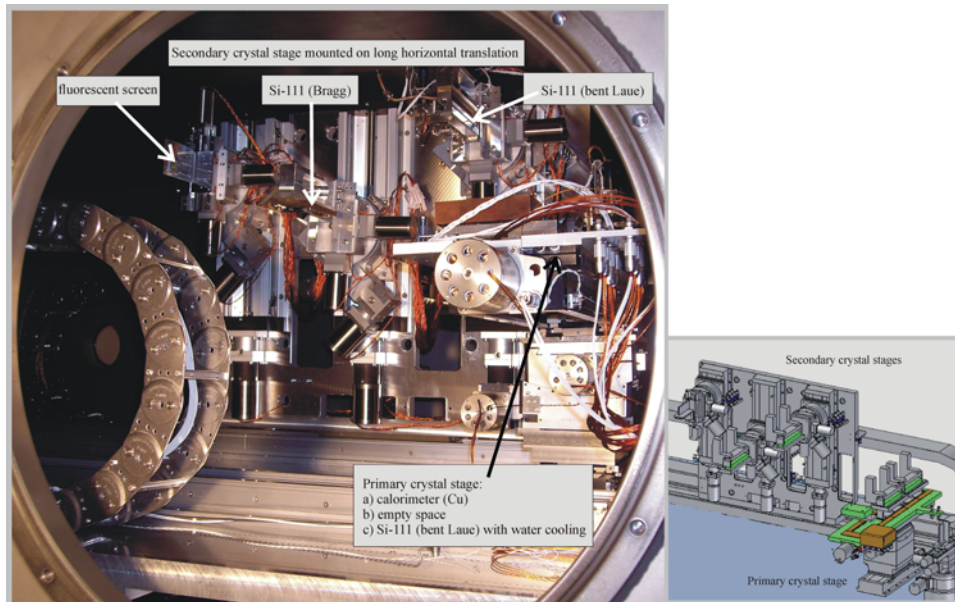


Figure 5: View (left) on the installed vertical monochromator as shown in the sketch (right). The primary crystal stage (right foreground) carries a calorimeter and the first Si crystal. The secondary stage (left background) consists of three stages which allow for combinations of different secondary crystal stages with the first crystal. Here the middle secondary crystal stage is set to a photon energy of 36keV (Si-111). The fixed exit monochromator has an offset of 40 mm.

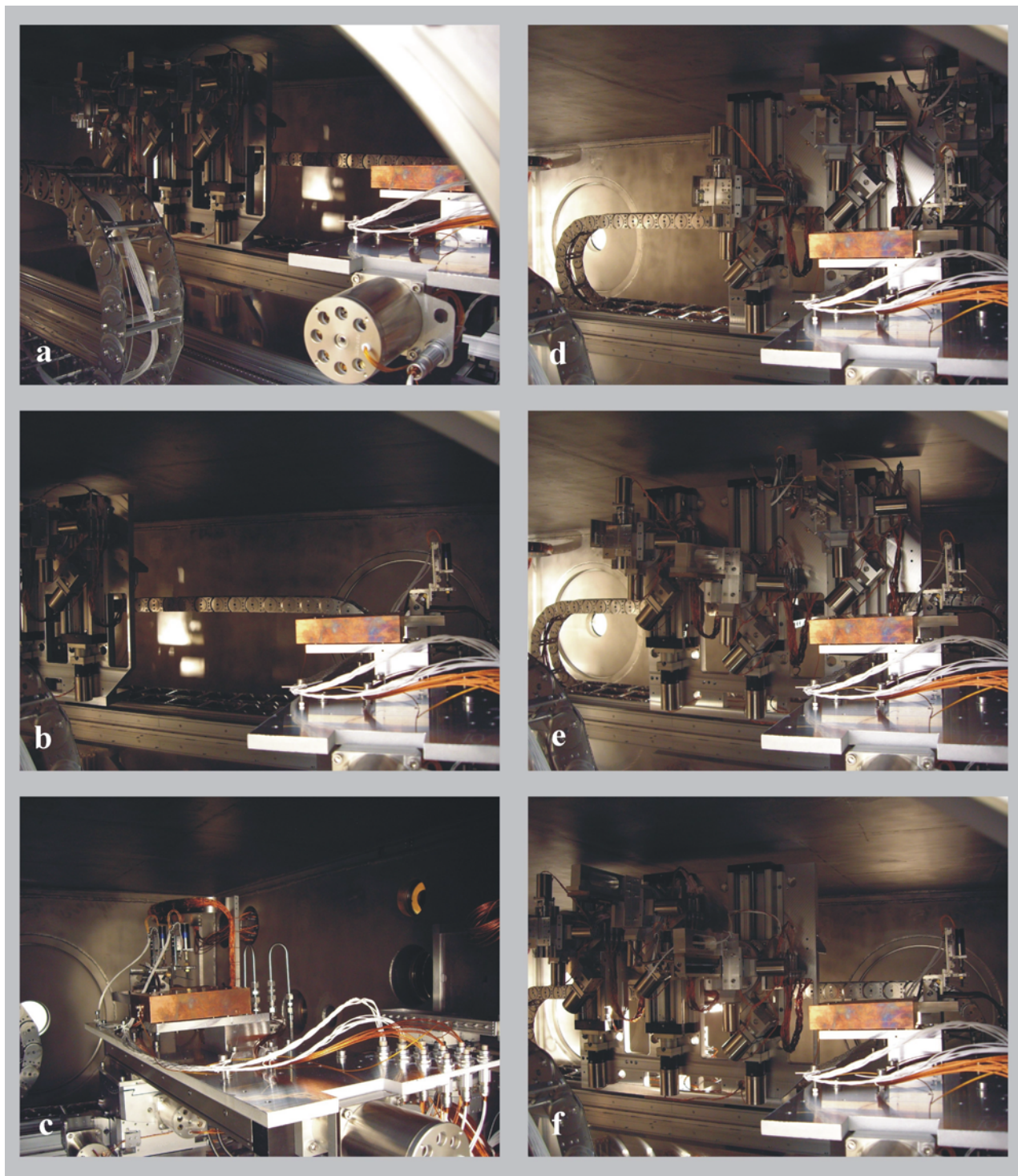


Figure 6: Interior view of the vertical monochromator installed in the vacuum tank. The scheme for the alignment of the monochromator is shown. *a-c*: First the monochromator is aligned relative to the white X-ray beam. Therefore, the secondary crystal stage is placed to its rest position. The calorimeter mounted on the first crystal stage is set into the white beam. After aligning the vertical and horizontal positions of the monochromator the first crystal (Si-111, bent Laue) shown in the background of (c) is moved into the incident white beam. *d-e* The alignment of the fixed exit monochromator (offset 40 mm). In d the fluorescent screen is set to the foreseen position, and the reflection of the first crystal is aligned to the centre of the screen. Then in e the fluorescent-screen stage is replaced by the middle crystal stage (Si-111, Bragg). The bending of the first crystal is then adapted, so that the width of the Rocking curve is minimized. At the end *f* the secondary crystal (Si-111, bent Laue) is used, and the bending of the second crystal is matched to maximise the intensity of the reflection. The photon energy was 36 keV.

In June / July 2006 the vertical monochromator was successfully set up. For the first commissioning phase a fluorescent screen, a Si-111 (Bragg), and Si-111 (bent-Laue) crystal were installed on the secondary crystal stage. The primary crystal stage was equipped with a calorimeter and a water-cooled bent-Laue crystal. Figure 5 shows a view into the monochromator tank revealing the installed monochromator system. Both the sketch and the viewgraph show the same setting. The different steps for alignment of the total system for a photon energy of about 36 keV are presented in figure 6.

For performing microtomography, the microtomography apparatus that was so far mainly used at BW2 was installed onto the lift table in the experimental hutch (see figure 7). The first tomographical scans using the vertical monochromator were successfully performed in July 2006 [4]. Within two weeks of operation 110 tomographical scans were performed in user mode. In the second run for tomography at HARWI II with 3 weeks of user operation another 170 scans were successfully performed using the photon energy range from 16 keV to 64 keV. Due to this huge amount of data the environment for data processing becomes very important. Especially, for running the experiment in user mode it is necessary to directly process the measured data. Therefore, the GKSS decided to renew the hardware for effective data processing.

New data processing chain for microtomography at DESY

For processing of the huge amount of tomographical data a new computing environment was installed by the GKSS at DESY in cooperation with the computer center of DESY. A schematic view of the new computing architecture is shown in figure 8. At beamlines BW2 and HARWI II the control computer of the experiment transmits the data via ethernet to the Sun Fileserver. The Fileserver is connected via fiber channels to the Sun Storage system, which currently have a capacity of 20 TByte. Both the fileserver and storage system are installed at the computer center of DESY. In addition to the fileserver a reconstruction server equipped with 64 GByte RAM and eight dual-core Opteron were set up at the computer center. The 3D-visualization of the tomographic data and the control of the reconstruction process is warranted by a multiprocessor system, which is connected via fiber channels with a 7 TByte RAID system. The backup of the data is supported by a so-called dCache, which is connected to the DESY long-term storage systems. The data exchange to the long-term storage systems is performed automatically and is invisible to the user.

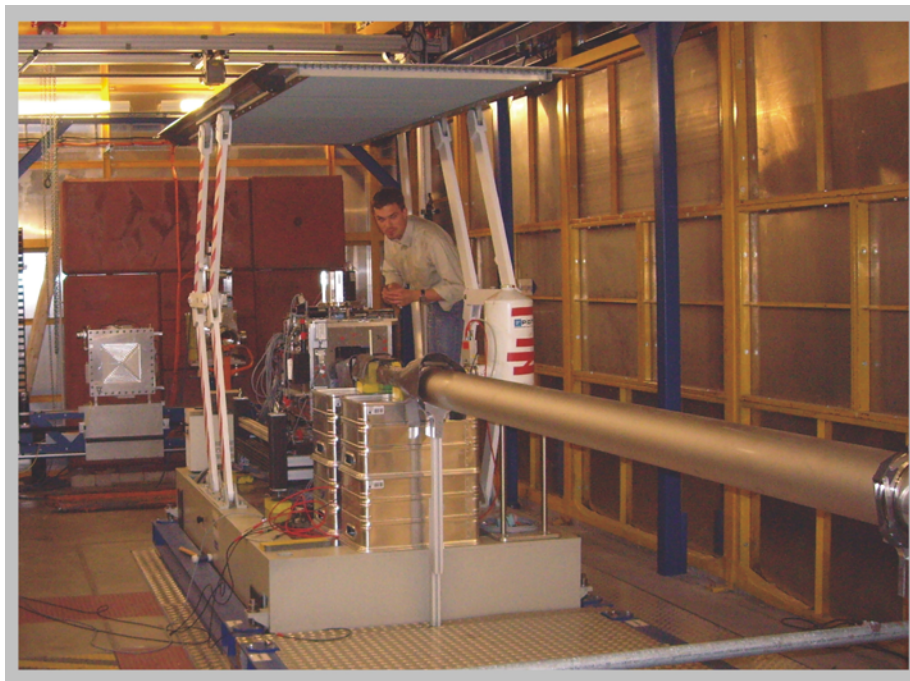


Figure 7: Setup for microtomography at the HARWI-II beamline. The experiment is mounted onto a lift table. The experiment can be lowered by 1.5 m. The pit will then be covered by the shown roof.

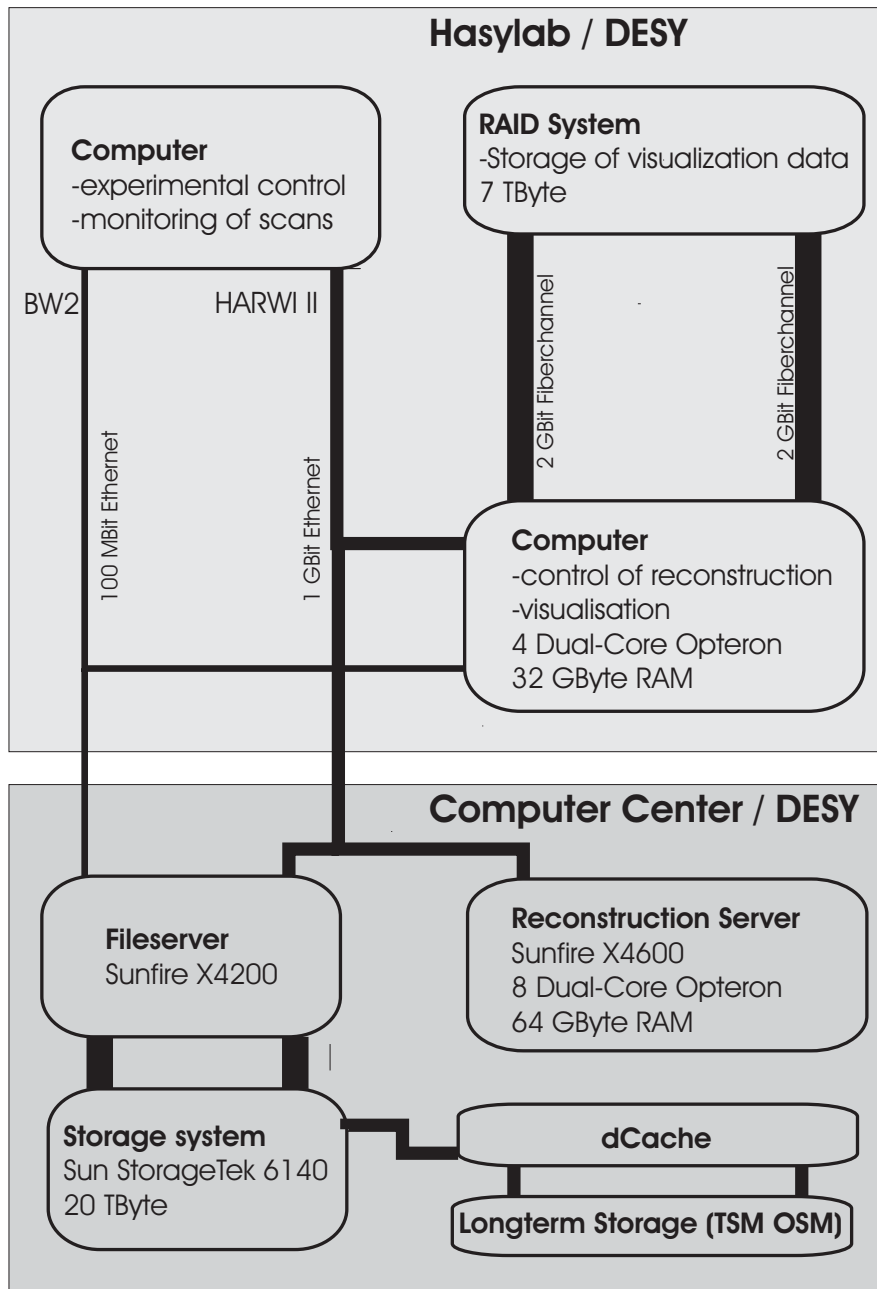


Figure 8: Schematic view of the new computing environment used by the GKSS for running the user experiments for tomography at beamlines BW2 and HARWI II at DESY.

References

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- [2] H. Schulte-Schrepping, and U. Hahn, "Hard x-ray wiggler front end filter design", SRI 2006, Daegu, Korea, AIP Conference Proceedings.
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- [4] F. Beckmann, T. Donath, J. Fischer, T. Dose, T. Lippmann, L. Lottermoser, R.V. Martins, and A. Schreyer, "New developments for synchrotron-radiation based microtomography at DESY", Proc. of SPIE Vol. 6318, 631810, (2006).