Layout and Design of a Neutron Spin Echo Spectrometer for the Spallation Neutron Source (SNS) in Oak Ridge/USA

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The Research Center of Jülich is going to install a new high resolution neutron spin echo spectrometer at the Spallation Neutron Source (SNS) in Oak Ridge/TN USA. The Central Department of Technology is responsible for the technical layout, the detailed design and manufacturing of some of the key components as well as coordination of all technical related interfaces with SNS. During 2004 the general layout of the instrument was developed taking into account space demand as well as all boundary conditions given by SNS. A conceptual design for the neutron guide system, the primary shielding and the spectrometer itself was performed. Of special interest was the feasibility of a magnetic shielded enclosure, a unique feature for this type of instrument allowing to operate at highest resolution in face of external magnetic field disturbance by other instruments or the instrument hall bridge crane. Optimization of correction coils, necessary for achieving highest resolution, was continued. Peak temperature at full power operation was decreased from 130°C to 85°C showing feasibility to finally achieve the maximum allowed temperature of 60°C.

The Research Center of Jülich is going to participate at the Spallation Neutron Source (SNS) in Oak Ridge/TN (USA) by supplying and operating a Neutron Spin Echo Spectrometer. Once built, this NSE will be the neutron scattering instrument with the highest resolution worldwide. The Central Department of Technology (ZAT) has already designed and built two NSE machines for the FRJ-2 (Jülich) and NIST (Gaithersburg/MD) and is responsible for the mechanical design, manufacturing of major parts as well as technical coordination of the construction of the NSE at SNS.

In close collaboration both with SNS and the instrument scientist of our direct neighbor HYSPEC, an appropriate beam line for the instrument was identified. The current general layout of the instrument takes into account the special boundary conditions, the necessary radiation shielding as well as accessibility of the instrument and all of it's components. A special topic of concern was the additional space necessary for the magnetic shielding enclosure unique for this type of instrument.

In order to allow both, the high intensity as well as the maximum scattering angle of at least 60°, a prolong able instrument layout was selected. Using about 9 meter of retractable neutron guide the moderator-detector length can be adjusted from 18 m to 27 m. Figure 1 shows the current status of the general arrangement of the instrument in the high intensity position.

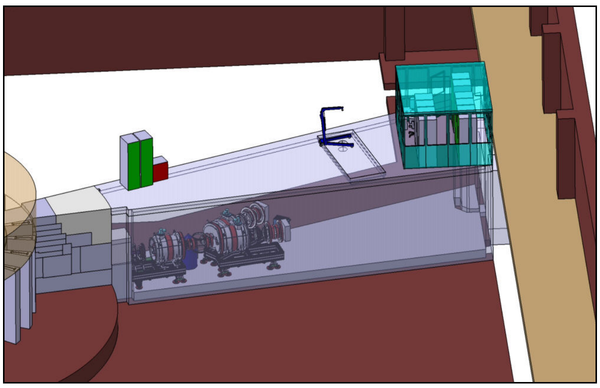

Figure 1. General layout of the NSE at SNS

The primary spectrometer (fig. 2) consists of the neutron guide, the chopper system and a revolver in order to allow switching between three different polarizing benders. A conceptual layout for both the neutron guide and the revolver system was developed in 2004. Main design criteria for the revolver system was the quick exchange of the necessary polarizing bender and at the some time positioning the new bender with an accuracy better than a few tenth of a millimeter. The detailed design and manufacturing of the revolver system will be done in the central department of technology, while the neutron guide was specified to call for tender in 2005. Due to the high energy radiation from a spallation neutron sources the first 11 meters from the moderator have to be heavily shielded using several meters of steel and heavy concrete.

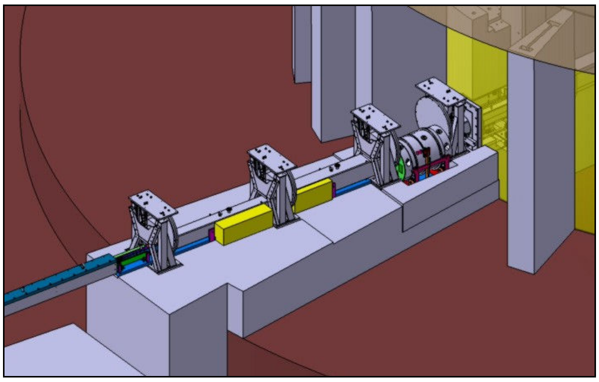

Figure 2. Primary spectrometer with shielding removed

The secondary spectrometer (magnetic part) consists of 32 coils mounted on a carrier system (fig. 3). Both carriers are mounted on air pads allowing both adjustment of the scattering angle as well as changing the moderator-detector length. While the basic layout is similar to the existing spin echo machines already built by ZAT, this new machine will be equipped with superconducting main precession coils. All of the secondary spectrometer will be manufactured by ZAT, except the superconducting coils and the sample stage.

One of the key elements of the new spectrometer are the high current correction coils. These coils are mounted on non magnetic, high precision hexapod drive systems (fig. 4) allowing online adjustment with µm accuracy. These hexapods have been specified and designed together with the vendor. Early in 2005 the first prototype will be available for testing in Jülich.

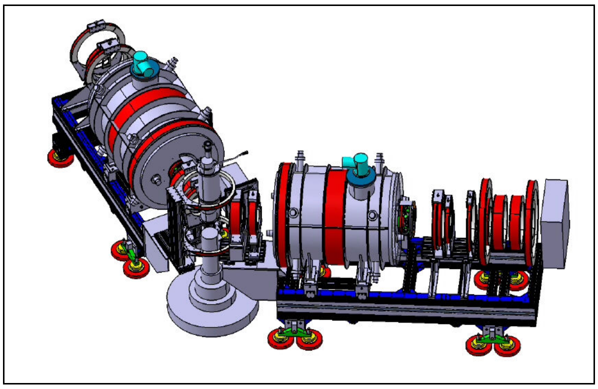

Figure 3. Secondary spectrometer on air pads

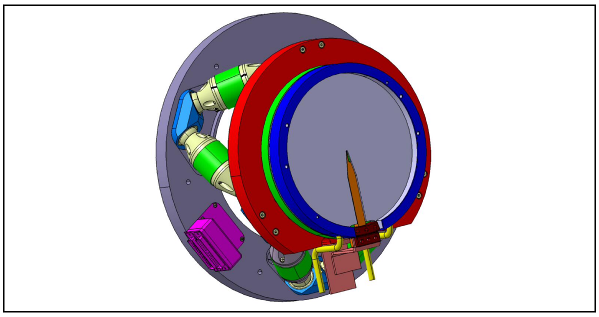

Figure 4. Correction coil on hexapod drive system

In 2004 several correction coils were manufactured and tested up to 300 Amperes. Due to optimization of both the design and the manufacturing techniques the peak temperature was decreased from 130° C to 85°C in the center of the coil (fig. 5). One of these coils was successfully tested to more than 80 full current cycles and over 1360 minutes full power operation. Further optimization will aim at temperatures less than 60 °C. This will reduce the temperature induced geometric distortions to less than 30 µm and therefore fulfill the requirements on the accuracy of the produced magnetic field correction.

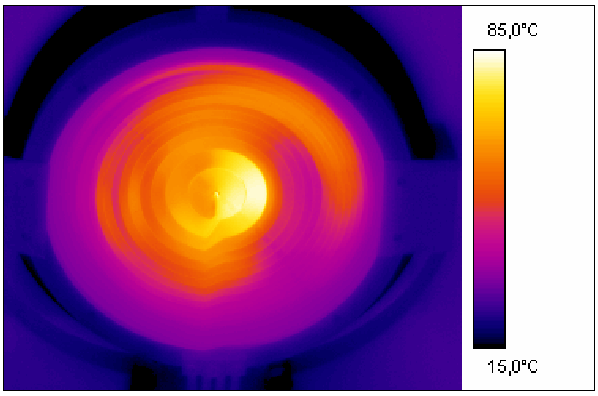

Figure 5. Temperature map of the correction coil at 300 Amperes

Due to its high resolution this spin echo machine is very sensitive to external magnetic fields. These field disturbance could be induced either by the movement of the ferromagnetic bridge crane in the instrument hall or by high field magnets (up to 15 Tesla) used at the sample stage of adjacent instruments. In order to reduce the impact on the spin echo machine the feasibility of a magnetic shielded enclosure was investigated. Of major concern was the retroaction of the high permeable walls of such an enclosure to the field homogeneity of the instrument itself. The maximum allowable field distortion is in the order of 10^{-6} for operation at highest resolution.

The BEM codes MAGNETO and AMPERE provided by IES (Canada) as well as the FEA code ANSYS were used to calculate the change in the field integral along the beam axis within the coil setup due to various wall scenarios. In order to estimate the impact on the homogeneity of the field this calculation was performed for several different neutron trajectories inside the instrument. Figure 6 shows the arrangement of coils for one carrier. The blacks lines representing the neutron trajectories were investigated. For benchmarking and parameter studies analytical calculations for simple scenarios were performed also.

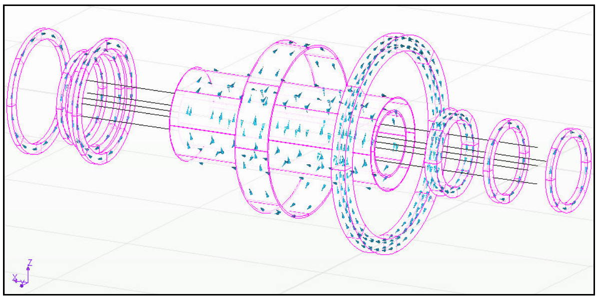

Figure 6. Arrangement of coils for one carrier used in the code AMPERE

Figure 7 shows the change in the field integral along the axis of the coil setup due to a wall made of permeable material. The calculations were performed for different wall to coils distances as well as permeability between 10 and 10^6. For reasonable values of permeability the minimum allowable wall to beam line distance was calculated to be at least 1.2 meters. The error bar for this calculations was estimated to be less than 1×10^{-7} Tm.

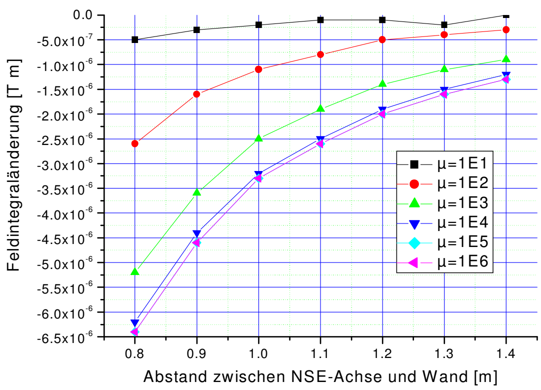

Figure 7. Change of field integral due to high permeable wall adjacent to the coil setup.

Based on these calculations and the geometric boundary conditions a magnetic shielded enclosure is feasible. Further calculations will focus on the expected shielding performance.