ESRF	**Experiment title:** **Probing spin waves via nuclear resonant scattering**	**Experiment number**: HC 1080
Beamline:	**Date of experiment**: from: 12.12. 2013 to: 18.12.2013	**Date of report**: 05.03.2014
Shifts: 18	**Local contact(s)**: Rudolf Rüffer	*Received at ESRF:*

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Report:

We proposed to study spin dynamics in thin film elements on sub-ns time-scales with sub-nm spatial resolution by means of nuclear resonant scattering (NRS). The influence of a spin wave on the nuclear decay of the nucleus was successfully observed in a former beamtime at beamline P01 of PETRA III, DESY. The time spectra measured under spin wave excitation are clearly altered. The evaluation of the spectra reveals a reduction of the effective magnetic hyperfine field originating from the spin wave. The proposed measurement of the depth profile of spin waves has not been realized. Instead we tried to measure another promising approach to measure the interaction of a spin wave with the nuclear transitions. It relies on an angular Doppler shift of the energy of the photon that is encoded in the polarization of the resonantly scattered photon [1]. The photon polarization performs a continuous rotation during propagation and can be probed by positioning the analyzer crystal in different distances to the sample. The length for a complete rotation of the polarization is inverse to the spin wave frequency. For a frequency of 1 GHz the distance to measure a whole period is 15 cm. The travel range of our analyzer crystal stage is 30 cm.

The reason for changing the experiment was a combined setup time for this experiment and experiment number HC 1360 from 19.11.2013 to 23.11.2013. For experiment HC 1360 a polarimeter, consisting of two channel cut crystals whose alignment is time-consuming, was used for polarization analyses of the scattered photons. The proposed new mechanism also

relies on a polarization analysis. We achieved very good polarization rejection ratios of 10^{-8} and excellent term stability of the setup.

Two kinds of systems were studied. First we started with thin micro structured permalloy ($Ni_{80}{}^{57}Fe_{20}$) films that were excited by high-frequency magnetic fields (up to a few GHz) of a strip line to stimulate spin waves resonantly. The part of the film where spin waves are effectively excited is only 10 μm wide so that focusing with a KB-mirror is mandatory. We used this sample arrangement in earlier measurements with count rates above 100 Hz without the polarimeter. In the present experiment the count rates were below 0.5 Hz. The reason was the combination of the need for focusing and the analyzer crystal of the polarimeter. The angular acceptance of the analyzer crystal is low and strong focusing was not possible. Either we lost intensity due to the low acceptance of the analyzer or due to the missing focus on the sample.

The second system consisted of an iron borat crystal ($FeBO_3$) that was placed in a rotating external magnetic field of 1 mT, strong enough to rotate the magnetization completely. Rotation frequencies up to 200 kHz were realized. Here, the non-resonant driven magnetization mimics a slow spin wave. Concerning count rates this experiment was much more successful. Without enrichment of the iron borat crystal and without focusing we got count rates up to 30 Hz. The expected polarization change at 200 kHz and in the order of one millirad over 30 cm, which is too small to be detectable with the polarimeter directly. We used another approach that relied on a change of the intensity relative to the phase of the rotating magnetic field.
As we are interested in a photon polarization change, we did not recorded time spectra, which is typically done in NRS experiments. A different scheme was used. The timing electronics were not triggered by the bunch clock of the synchrotron but by a trigger signal of the rotating magnetic field. An intensity variation with the quarter periodicity of the rotating magnetic field was observed as expected as shown in figure 1. It originates from nuclear resonant scattering that changes σ to π polarization (only the π polarization is probed by our analyzer) depending on the configuration of the incoming σ polarized photon and the magnetization of the sample. This phase spectrum is expected to change it phasing when the distance of the sample to the analyzer is changed. We measured these spectra at two positions with a distance of 16 m. Here a phase shift of two degree should be visible. The evaluation of the data is in progress.

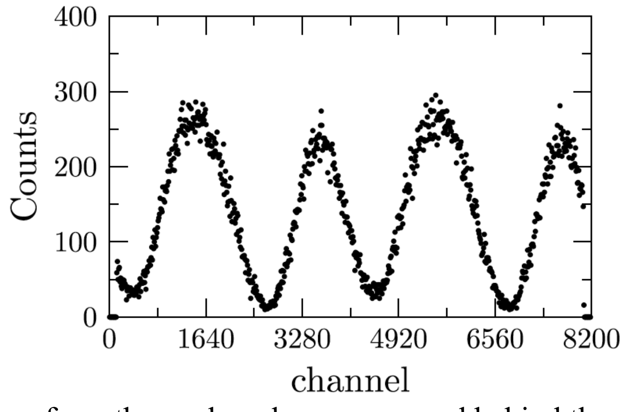

Figure 1: Count rate of photons from the nuclear decay measured behind the analyzer crystal versus channel number of the timing electronics. One period of the rotating magnetic field, here at 100 kHz, corresponds to 8200 channels.

For future experiments a different design of the analyzer crystal is planned. A strong asymmetrical cut of the crystal will increase its angular acceptance and facilitate the use of KB mirrors for focusing. Then the micro-structured samples with frequencies in the GHz regime can be measured and the polarization rotation should be directly detectable with the analyzer crystal over a travel distance of the analyzer stage of 30 cm.

[1] R. Röhlsberger, Phys. Rev. Lett. accepted (2014)