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Report:

We applied the method of nuclear resonant scattering to investigate the depth profile of magnetic properties in exchange bias bilayers of MnF_2/Fe and FeF_2/Fe. The high sensitivity of the method combined with its high spatial resolution allowed us to measure on samples with an Fe^{57} probe layer in the Fe layer, which covers different depths in the FM layer (cf Fig.1).

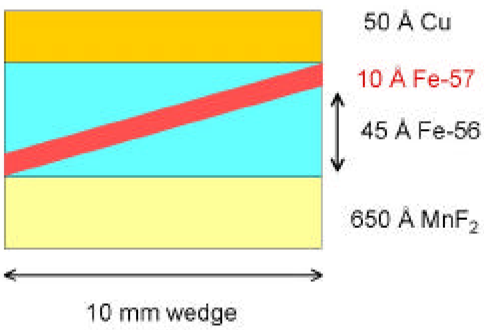

Fig. 1 Sketch of the wedge sample MXJM01. The Fe^{57} wedge layer allows to probe the spin structure in different depths of the same ferromagnetic layer.

In contrast to former experiments where the spin distribution was measured only at remanent field, a major achievements of the present experiment was the measurement of the spin structure of the FM layer through the whole magnetic hysteresis loop, at different depths. This experiment has significant relevance for the controversial discussion on the depth dependence of the FM spin structure in the FM layer, which is neglected in many models of the

exchange bias effect. A further advantage of this experiment is that variation of properties between different samples can be excluded, because the depth dependence could be measured on the same sample.

The results found for MnF_2/Fe can be summarized as follows: At 10 K, below the Néel temperature of MnF_2 (T_N = 67 K), we find a significant depth dependence of the spin structure in the FM layer. Close to the AF/FM and up to a distance of 9 Å we observe a spin structure which was indepent of the applied magnetic field. The NRS spectra of the spin structure could not be fitted by a simple unidirectional spin distribution, which might be interpreted as a more complicated domain or ripple structure. Suprisingly, this spin structure doesn't change even at 110 K, i.e. well above the Néel temperature, but disappeares at RT. The origin of this spin structure could not be solved completely. In particular, the temperature at which the this spin structure vanishes could not be determined, because of limited beamtime. We expect that additional measurement with NRS will solve this unexpected and interesting issue in exchange biased bilayers.

At 10 K and larger distances (22 – 35 Å) we still see a depth dependence of the spin structure in the FM layer which vanishes at 110 K, i.e. above the Néel temperature. Preliminary evaluation of the data points to a spin distribution where the influence by the AFM layer decreases with increasing distance from the interface (Fig. 2). Also this depth dependence changes with the value of the applied magnetic field.

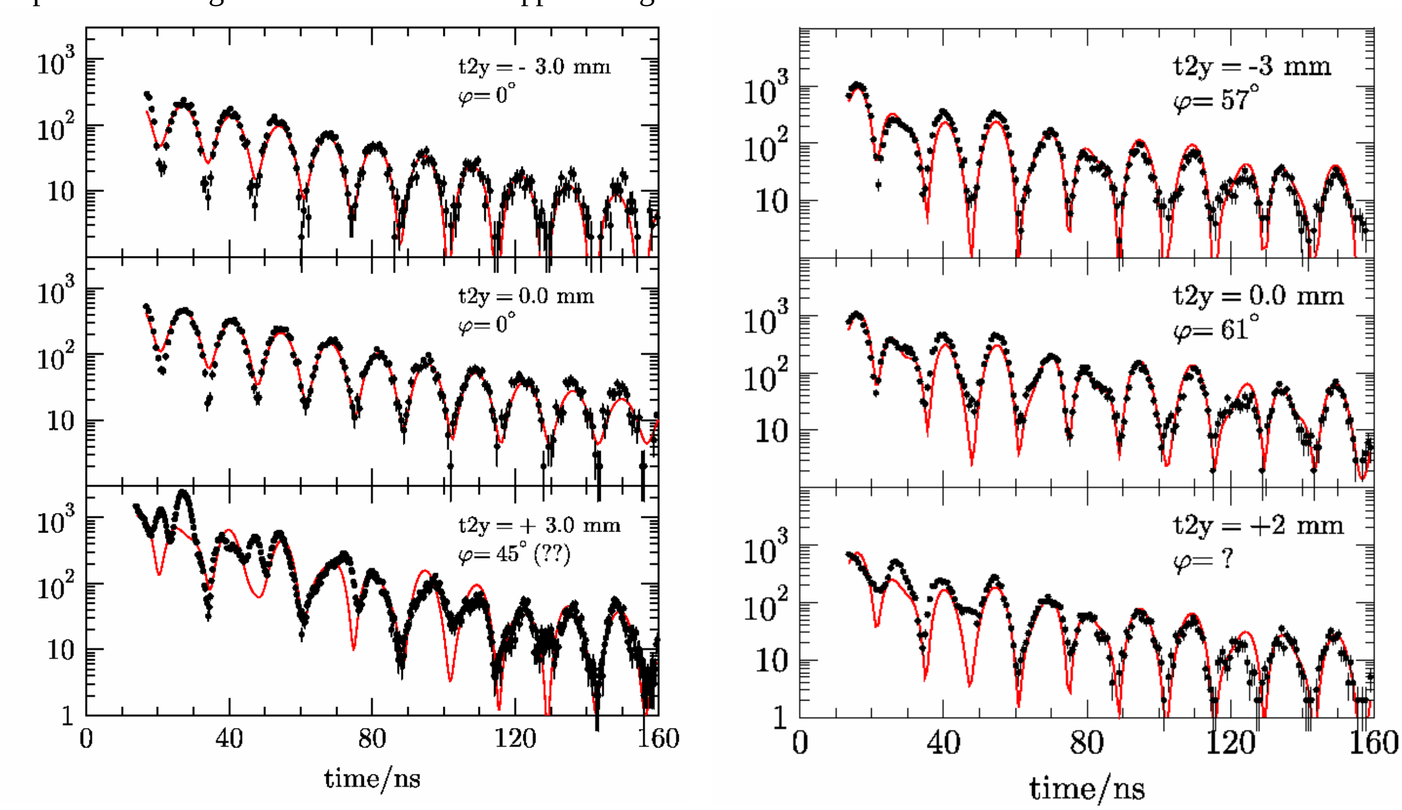

Fig. 2: Time spectra of wedge sample MXJM01at 10 K, below the MnF_2 Néel temperature for different distances from the FM/AF interface. The sample was field cooled in 2kOe perpendicular to the scattering plane and parallel to the sample surface. The coordinate t2y refers to the latereral position of the beam on the sample, i.e. different depths of the ^{57}Fe layer probe layer. The values t2y =-3, 0, 2, 3 correspond distances of 35 Å, 22 Å, 13 Å, 9 Å of the ^{57}Fe probe layer from the interface, respectively. Left: Spectra measured at 500 Oe, i.e. far apart from magnetization reversal. The difference in spin structure is concentrated close to the interface (t2y=3.mm). Right: Spectra measured at -670 Oe, i.e. at magnetization reversal. A depth dependence of the spin structure is also observed at larger distances 22 – 35 Å. The black dots are the measured time spectra and the red solid lines show simulations based on a single-valued unidirectional hyperfine field with the angle j, which is the direction of hyperfine field in respect to the direction of beam. Particularly, at t2y =3 mm and t2y = 2 mm, i.e. close to the interface, the spectra cannot be fitted by by a simple unidirectional hyperfine field. To solve this issue and to investigate the temperature dependence of the additional measurements are required.

Since from magnetization measurement a significant different behavior is expected at temperatures near but still below the Néel temperature, it is desirable to extend the measurement to this temperatures. Because of limited beam time, we had to concentrate on a single sample and only two temperatures, to collect enough data leading to a conclusive picture. However, the other prepared samples, in particular the FeF_2/Fe samples, are ready for measurements, and we hope that we can extend these promising studies to a wider temperature range in the near future.