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Wavevector dependent damping in nanomagnets

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Nanomagnets are the building blocks of spintronics devices. This makes it important to understand the magnetization dynamics in nanomagnets from an application oriented view. From a more basic research orientated perspective, nanomagnets provide the opportunity to determine, if the localization of spin-wave modes influences their dynamics. We measured localized spin-wave modes in individual $Ni_{80}Fe_{20}$ nanomagnets ranging from 80 nm to 400 nm in size by heterodyne magneto-optical microwave microscopy. We compared our measured spectra with micromagnetic simulations and were able to identify two spin-wave modes, the center-mode and the end-mode. We determined that the Gilbert damping for these localized spinwave modes depends on the size of the nanomagnet and on the respective spin-wave mode. We were able to exclude that the observed damping originates from an area of enhanced damping at the edge of the nanomagnets. A detailed analysis showed that the results can be understood within the model of Bar'yakhtar for damping in ferromagnets, where exchange contributions to the relaxation are considered. These additional contributions depend on the curvature of the dynamic magnetization or, in Fourier space, on k^2, where k is the wavevector of the respective Fourier components of the spatial non-uniformities. We also studied the k^2-damping for perpendicular standing spin-wave modes (PSSWs) in $Ni_{80}Fe_{20}$ films with a thicknesses starting at 75 nm. Our results showed that any k^2-damping contributions must be significantly smaller than what we have found in the nanomagnets. In order to determine if this k^2-damping originates from the interface, we compared the damping in nanomagnets for 3 nm, 10 nm and 15 nm thick $Ni_{80}Fe_{20}$ layers. We found, that the k^2-damping for the nanomagnets decreases with increasing thickness of the ferromagnetic layer. This indicates that the k^2-damping in the studied system has a strong interfacial contribution, which explains, why we were not able to measure any k2-damping for the PSSWs. 1) V. G. Bar'yakhtar et al., Zh. Eksp. Teor. Fiz. 91, 1454 (1986) 2) H.T. Nembach et al., Phys. Rev. Lett., 11, 117201 (2013) 3) M. Schoen et al., Phys. Rev. B, 91, 184417 (2015)