ESRF	**Experiment title: Anisotropy of structure under a magnetic field in dense ferrofluids and ferroglasses**	**Experiment number**: SC1937
Beamline: ID02	**Date of experiment**: from: 13th April 2006 to:16th April 2006	**Date of report**: 20th March 2007
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Our aim was to understand the anisotropic structure of well-defined magnetic colloidal dispersions (ferrofluids) obtained under a constant magnetic field. We studied a series a samples constituted of magnetic nanoparticles of maghemite (γ-Fe_2O_3) dispersed in water. The interactions between the nanoparticles were tuned by several parameters : the size d of the particles, the volume fraction Φ and the ionic strength I. This allows to vary the magnetic dipolar interaction as well as the repulsive interations [1].
As the iron strongly absorbs (absorption edge at 7.11 keV), we used an energy higher than the edge (12keV) in order to decrease absorption. The measurements were performed with two configurations (distances 2m and 10m). The resulting q-range was : 2.10^{-3} Å^{-1} – 0.2 Å^{-1}. The measurements were performed without field and with magnetic field (up to 1 T). We checked that the scattered intensity was the same without the magnets and with the magnets at the maximum gap (very small field).

After our studies using neutron scattering, the following questions remained, for which the answer could be obtained only with X-Rays.

1/ does the most probable distance between particles (q of the maximum of S(q)) change under field ? And is this distance different parallel and perpendicular to the field ?

Thanks to the good resolution of X-rays, we can conclude that there is indeed a shift of the abscissa of the maximum of the structure factor if the particles are big enough and if the volume fration is high enough. An example is given in Figure 1a : $q_{max\ //H} > q_{max\ H=0} > q_{max\ \perp H}$. The difference between $q_{max\ //H,\perp H}$ and $q_{max\ H=0}$ is less than 5%, thus very difficult to observe with neutrons. It means that the most probable distance between particles is smaller in the direction parallel to the field than in the direction perpendicular to the field, in good agreement with the larger attractions parallel to the field, and also the less defined structure (the peak of $S(q)_{//}$ is smoother).

2/ How is the anisotropy under field at small q for large volume fractions ?

With X-rays, the anisotropy under field at small q is the same whatever the volume fraction : $I_{//H} < I_{H=0} < I_{\perp H}$. This means that the compressibility is smaller parallel to the field, and that there are more repulsions parallel to the field at this large scale. This result is in agreement with the results obtained from neutron scattering for low enough volume fractions ($\Phi < 15\%$) [2]. However, for concentrated samples ($\Phi > 20\%$), the result is different from the observations using neutrons. This observation associated to detailed comparisons of the same samples measured using X-Rays and neutrons proves that the magnetic signal that exists with neutrons pollutes the small q region for the measurements with H=0. This can be seen in Figure 1b: the scattered intensity at small q is higher with neutrons due to the magnetic signal. Therefore, for these concentrated samples, neutrons are not appropriate. Moreover, X-Rays prove that the behavior under field is qualitatively similar whatever the volume fraction.

3/ Is there a remanence of the anisotropy and how does it relax if it exists ?

For the larger particles and high concentrations, a remanence of the anisotropy induced by the magnetic field was indeed observed after removing the magnetic field thanks to the short acquisition time per spectrum. The anisotropy relaxes on a scale of several minutes.

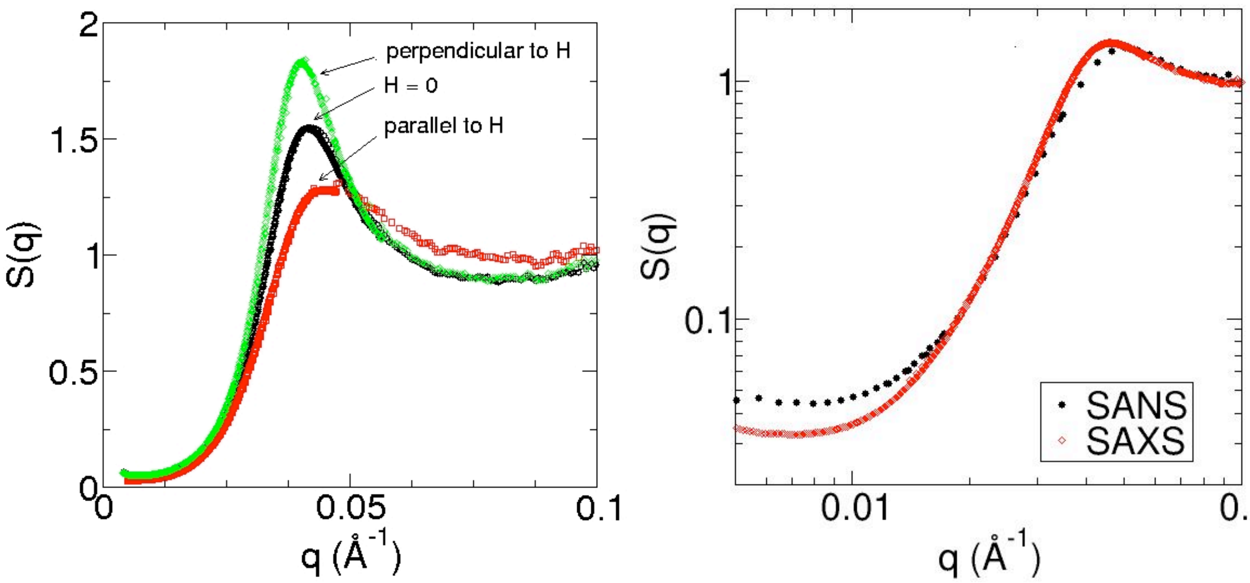

Figure 1 : (a) S(q) for a repulsive concentrated fluid sample (Φ=24%) in H=0 and H= 1T, in the directions parallel and perpendicular to the field; (b) S(q) for a repulsive concentrated fluid sample (Φ=22%) without field with X-Rays and neutrons (measurement in H_2O).

This first study of the structure using X-Rays opens new possibilities for concentrated ferrofluids, which are glass forming fluids, the translational dynamics of which can be studied by XPCS [3]. Dynamical measurements of the relaxation of the structural anisotropy while removing the magnetic field will allow to follow the change of structure and couple it to the rotational dynamics measured by magneto-optical techniques.

References :

[1] F. Cousin, E. Dubois, V. Cabuil, Phys. Rev. E 68, 021405-1 à 9 (2003)

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