ESRF	**Experiment title:** Structure evolution in hybrid ferrofluids upon magnetic field and shear flow	**Experiment number**: MA 3016
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Report:

Detailed knowledge of the field- and flow-induced microstructure formation in ferrofluidic dispersions is crucial for the understanding of emerging magnetoviscous effects. We propose to perform a combined SAXS/WAXS study of the aggregation behavior in hybrid ferrofluidic dispersions consisting of conventional ferrofluids doped with elongated magnetic nanoparticles. Both the aggregate formation and the shear-induced aggregate rupture was investigated, giving insight into the effect of elongated nanoparticles on the shear-thinning behavior. The expected results are highly valuable in order to understand microscopic impact on the macroscopic magnetoviscous effects may in the long term contribute to an enhanced technological applicability of ferrofluid materials.

Simultaneously, the SAXS/WAXS measurements were carried out at room temperature and ambient atmosphere with applied flow (perpendicular to the beam direction) and horizontal magnetic field up to 500 mT (parallel/perpendicular to the beam direction) using a custom made setup in the **Fig. 1**.

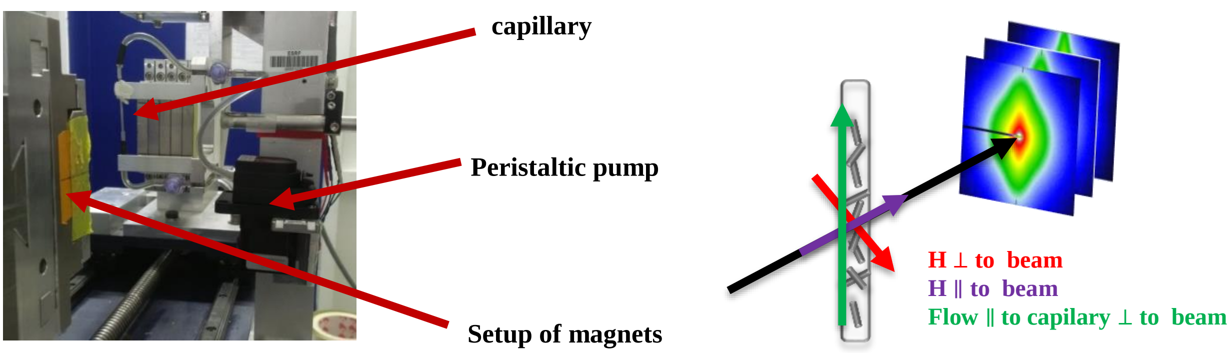

Fig. 1: Setup for the simultaneous measurements of SAXS/WAXS in flow and magnetic fields.

We performed measurements on two pure systems of elongated magnetic nanoparticles (Nickel nanorods with length of 400 nm and hematite spindles with mean length of 368(42) nm). The orientation behavior of nickel nanorods in combined flow and magnetic fields experiments is presented in **Fig. 2**. They are clearly visible that with increase of flow through the capillary the orientation of nickel nanorods changes initially strongly oriented even in small magnetic field of 3mT. Moreover, we performed combined flow/magnetic field measurements on our hybrid ferrofluidic dispersions of nickel nanorods with various concentration of spherical cobalt ferrite nanoparticles. For illustration, the comparison of CoFe12 spherical nanoparticle and Ni-nanorods in several applied static magnetic fields is presented in **Fig. 3**. In the low *q*-range, there is a significant increase of the intensity caused by structure evolution of hybrid ferrofluidic dispersion (spherical particles capsulate the elongated nanoparticles due to the magnetic interactions), this is best seen in the case of magnetic field oriented parallel to the beam (**Fig. 3a**) where the rods are aligned in such a way that effectively one is looking at its face (circumference). Moreover on can show that these anisotropic structures orient differently in applied static magnetic fields than the pure nanorods system. The in-depth evaluation of the data of combined measurements of flow and magnetic field from hybrid ferrofluids is ongoing.

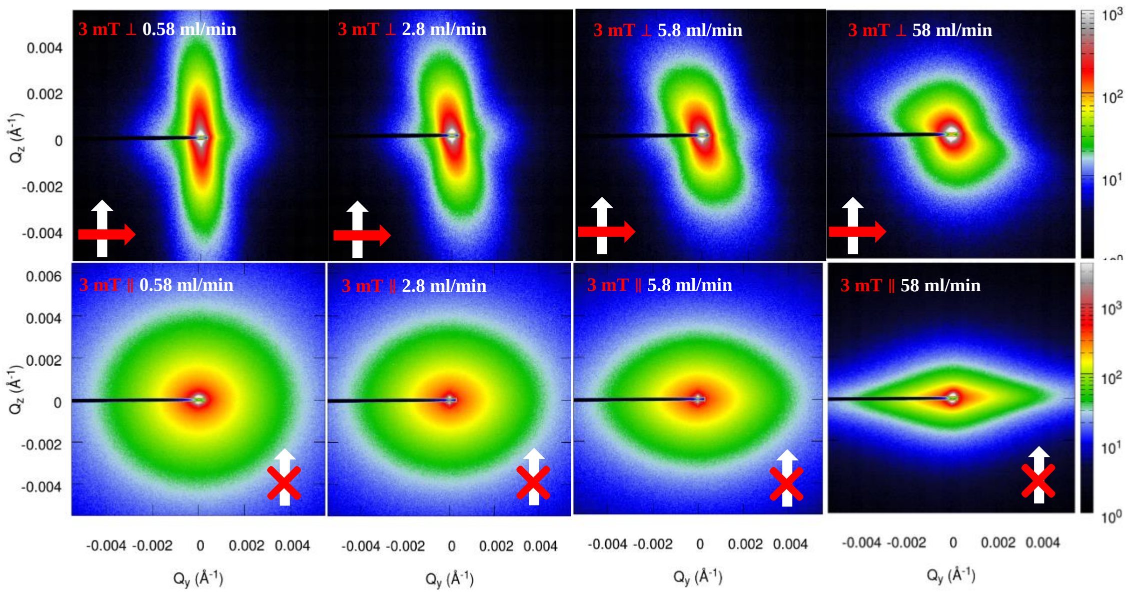

Fig. 2: 2D SAXS measurements of nickel nanorods upon flow and magnetic fields perpendicularly and parallely oriented to the beam, respectively. The arrows represent the direction of field (in red) and flow (in white) with respect to the beam.

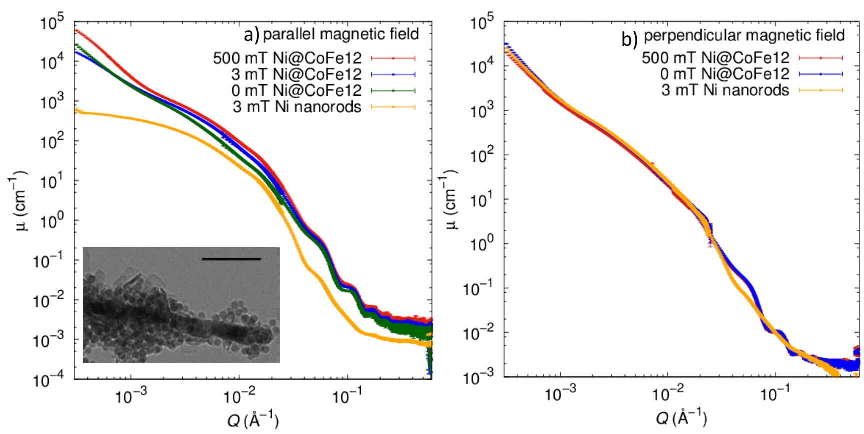

Fig. 3: SAXS measurements of pure nickel nanorods and their hybrid dispersion with spherical NPs in magnetic fields applied a) parallel b) perpendicular to the direction of beam. Inset in a): TEM micrograph of aggregate around Ni nanorod (bar corresponds to 100 nm).