Rheological properties of a ferromagnetic nematic liquid crystal

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It has long been known that suspensions of ferromagnetic nanoparticles in a nematic liquid crystal could induce a ferromagnetic liquid crystal phase [1]. Only recently this phase was successfully experimentally realized [2]. In Refs. [3] and [4], the measurements of the statics and the dynamics were modeled using the existing theory first presented in [5].

The ordering in a ferromagnetic nematic liquid crystal is described by two fields: the director field **n**, which describes an average orientation of the molecules of the liquid crystal and the magnetization field **M**, describing an average orientation of the magnetic moments of the magnetic particles. Unlike for usual nematics, the ferromagnetic phase is sensitive to very small magnetic fields.

To understand the complete dynamic behavior of a ferromagnetic nematic one needs to measure rheological properties of the system. An interesting phenomenon, well-known in usual nematics, is flow alignment, where under the influence of a simple shear flow the director is tilted by a finite angle with respect to the velocity field. Certain liquid crystals nevertheless show a tumbling behavior. Flow alignment can be in these cases restored with a sufficiently strong electric field [6]. We show that in a ferromagnetic nematic the boundary between flow alignment and tumbling can be shifted by using small magnetic fields.

Generally, the measured viscosity of the system depends on the magnitude of the shear rate. To circumvent this dependence, simple experiments were proposed in [7], where the orientation of the molecules is fixed by an external electric or a strong magnetic field. This way, one can introduce in an ordinary nematic liquid crystal three different Miesowicz viscosities. In a ferromagnetic nematic the presence of the magnetization leads to additional dynamic cross-couplings [5]. As a result, the three Miesowicz viscosities for an ordinary nematic are replaced in a ferromagnetic nematic by nine viscosities.

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