Observation of Brownian Rotation of Iron Oxide Magnetic Nanoparticle under a High Oscillating Magnetic Field.

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Iron oxide magnetic nanoparticles (MNPs) have been used in biosensing, magnetic particle imaging, hyperthermia therapy and so on. These techniques utilize the rotation of magnetization of MNP, but the rotation process required in each technique is different, i.e. Brownian rotation or Néel rotation. For the success of these methods, it is necessary to understand the mechanism of MNP rotation especially in high frequency and high amplitude ac magnetic field. However, it is difficult to distinguish these processes only from a magnetization measurement. In this study, we observed the optical transmittance of MNP dispersion under a damped oscillating magnetic field and it was demonstrated that the only Brownian rotation could be observed separately.

We examined the suspension of maghemite (γ-Fe_2O_3) MNP in water. The magnetic field was applied in Faraday configuration, *i.e.* the magnetic field was parallel to the light propagation. A typical waveform of the transmittance variation is shown in Fig. 1. Accompanied with the application of the magnetic field, the transmittance was increased, and then a comb-like waveform was observed. Since maghemite MNP has an optic axis along its magnetic easy axis [1], the transmittance change can be attributed to the Brownian rotation of MNP. We were able to estimate the averaged orientation angle of the easy axis with respect to the field from the transmittance variation, and its rotational motion under the damped oscillating magnetic field was revealed. The influence of the viscosity was also investigated. Furthermore, we compared the experimental result with a numerical simulation reported by Usov and Liubimov [2].

[1] F. Bentivegna, et al. J. Appl. Phys. **83**, 7776-7788 (1998).
[2] N. A. Usov, B. Y. Liubimov, J. Appl. Phys. **112**, 023901 (2012)

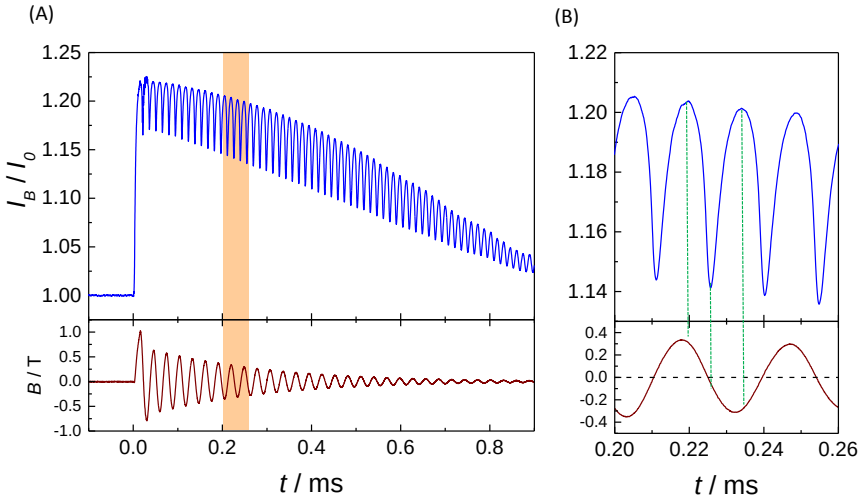

Figure. 1 The variation of the normalized intensity of transmitted light through the MNP dispersion under the damped oscillating magnetic field: (A) The waveforms of the intensity (upper) and damped oscillating magnetic field (lower) and (B) their expansion or the highlighted region in (A).