



## Original research article

## Incident-power-dependent optical transmission properties of magnetic fluid films

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## ABSTRACT

Incident power has an important effect on the optical transmission properties of magnetic fluids. Difference in the effect of the incident power on the optical transmission properties with and without an applied magnetic field was investigated by measuring the transmitted power of the incident light through the magnetic fluid film. In the absence of an applied magnetic field, an approximately linear relationship exists between the incident power and the transmitted power of magnetic fluid films, but the relationship is nonlinear when a magnetic field is applied. Moreover, variation in the optical transmission properties under a magnetic field with various incident powers was measured in experiment. As the magnetic field is enhanced, the transmitted power of the magnetic fluid film first decreases, then increases, and finally reaches saturation. The magnitude of the change in the transmitted power, and the magnetic field range correspond to decreases, increases and saturation are related to the incident power. Therefore, for the sensing applications, depending on the measuring range of the magnetic field and the required variation range of the transmitted power, magnetic fluid film sensors exhibit different characteristics if different incident power values are selected.

## 1. Introduction

Magnetic fluids, which are a type of stable colloidal liquid, possessing both the fluidity of liquids and the magnetic properties of the colloidal magnetic solids, have attracted the interest of many researchers. Magnetic fluids are composed of nanoscale magnetic solid particles, a carrier liquid and surfactants. Many properties of magnetic fluids can be exploited in a wide range of applications, such as the magneto-optical effect [1–5], the thermal lens effect [6,7], and a tunable refractive index [8–12]. Their optical transmission properties are very important for the magneto-optical effect and for optical devices, fiber optic sensors and other applications.

Many researchers have studied the optical transmission properties of magnetic fluids. Horng et al. [13] reported that the evolution of the structure in magnetic fluid films directly causes the change in the optical transmission properties, and the parameters of the magnetic fluid films affect the structural patterns. Rao et al. [14] investigated the effect of the magnetic particle size on the optical transmission properties of magnetic fluid films. The authors found that a significant variation in the transmittance due to the competition between van der Waals and dipole-dipole interactions. Wu et al. [15,16] demonstrated that variations in the optical transmittance using different carrier liquids and particle concentrations are due to the different aggregation abilities of the magnetic particles. Hong et al. [17] designed two optical switch devices wherein the magnetic fluid films were subjected to either a parallel or

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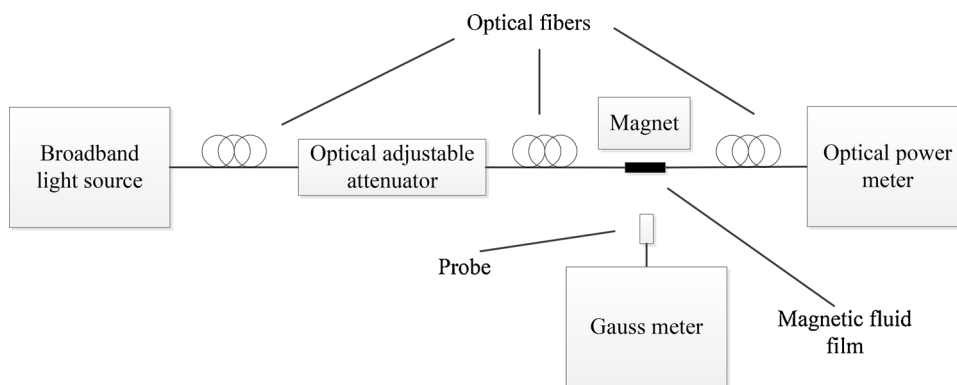


Fig. 1. The experimental setup to investigate the incident-power-dependent optical transmission properties.

perpendicular magnetic field and the magnetic field direction and strength both played a decisive role in determining the transmittance of light. Brojabasi et al. [18] investigated the influence of temperature on the magnetic-field-induced light transmission.

However, previous works have mainly investigated the main factors influencing the optical transmission properties, namely, the magnetic fluid and the external environment. This study considers the incident power dependence of the optical transmission properties of magnetic fluid films, and the transmitted power was experimentally demonstrated to vary with the incident power.

## 2. Experiments

Under the influence of an external magnetic field, the power of the light transmitted through the magnetic fluid changes, because the distribution of the magnetic fluid film nano-magnetic particles changes.

In this experiment, the volume concentration of the synthetic ester-based  $\text{Fe}_3\text{O}_4$  magnetic fluids is 4%, and the average diameter of the magnetic nanoparticles is 10 nm. The magnetic fluid film thicknesses are 200  $\mu\text{m}$  and 400  $\mu\text{m}$ .

The experimental setup to investigate the incident-power-dependent optical transmission properties is shown in Fig. 1, and consists of a broadband light source, optical adjustable attenuator, magnetic fluid film, optical power meter, magnet, Gauss meter and optical fibers. The light emitted by the broadband light source is adjusted to determine the incident power using the optical adjustable attenuator and is incident to the magnetic fluid film. An optical power meter is used to measure the transmitted power of the magnetic fluid film, and the external magnetic field strength applied to the magnetic fluid film is measured by a Gauss meter. The output power of the broadband light source is 34 mW, the optical power meter measures from  $-70$  to  $+30$  dBm, and the magnetic field strength of the Gauss meter ranges from 0 to 20,000 Oe. The incident light is perpendicular to the surface of the magnetic fluid film, while the magnetic field is parallel to the surface of the magnetic fluid film. The structure of the magnetic fluid film is shown in Fig. 2. The capillary is filled with magnetic fluid. The two fibers, which have been precisely machined by cutting, are inserted from both sides of the capillary, and the junctions of the fibers are fixed to the capillary with glue. The distance between the ends of the two optical fibers is the thickness of the magnetic fluid film.

## 3. Results and discussions

### 3.1. Difference in the effect of the incident power on the optical transmission properties with and without an applied magnetic field

In the absence of an applied magnetic field, the relationship between the incident power and the power transmitted through the 200 and 400  $\mu\text{m}$  magnetic fluid films is shown in Fig. 3. The variation in the optical transmission properties is due to the effect of the incident power. Each point in the graph is a measured value, and the curve is the result of a linear fitting of the measured values. The incident power is increased stepwise by 0.5 mW in the range of 1–5 mW. The transmitted power increases monotonically with the increase in the incident power for both film thicknesses, and shows good linearity with the incident power. In the absence of a

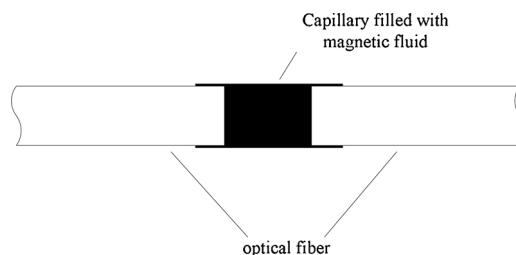


Fig. 2. The structure of the magnetic fluid film.

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