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Journal of Magnetism and Magnetic Materials 297 (2006) 71–75
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Mach–Zehnder interferometer by utilizing phase modulation of transmitted light through magnetic fluid films possessing tunable refractive index

Chin-Yih Hong[a], S.Y. Yang[b], K.L. Fang[b], H.E. Horng[b,*,1], H.C. Yang[c]

[a]Department of Mechanical and Automation Engineering, Da-Yeh University, Chang-Hwa 515, Taiwan
[b]Institute of Electro-optical Science and Technology, National Taiwan Normal University, Taipei 116, Taiwan
[c]Department of Physics, National Taiwan University, Taipei 106, Taiwan

Received 23 September 2004; received in revised form 15 February 2005
Available online 11 March 2005

Abstract

Due to its diverse applications in photonics, bio-sensors, mechanics, etc., Mach–Zehnder interferometer becomes one of important devices. Hence, lots of efforts have been paid to develop advanced Mach–Zehnder interferometers. In this work, we explore new-model Mach–Zehnder interferometer, in which one of arm is consisted of magnetic fluid films. By utilizing the tunable refractive index of magnetic fluid films under external magnetic fields, the traveling phase of a propagating light through the magnetic fluid film is changed. This could lead to a variation in the interfered intensity of the Mach–Zehnder interferometer when an external magnetic field is applied. The modulation in the interfered intensity by the external magnetic field is demonstrated experimentally, and the relevant physical origin is also discussed.

PACS: 85.60.Bt; 75.50.Mm; 78.20.Ci

Keywords: Interferometer; Magnetic fluids

1. Introduction

Mach–Zehnder interferometers are a kind of very important device because of its diverse applications in photonics [1,2], biosensors [3], mechanical sensors [4], etc. Hence, lots of scientists' and engineers' efforts are paid to develop Mach–Zehnder interferometers. The key architecture of a Mach–Zehnder interferometer is the two

*Corresponding authors. Institute of Electro-optical Science and Technology, National Taiwan Normal University, 88, Sec. 4, Ting-Chou Rd., Taipei 116, Taiwan. Tel.: +886 2 29338260; fax: +886 2 86631954.

E-mail address: phyfv001@scc.ntnu.edu.tw (H.E. Horng).

[1]Also with Department of Physics, National Taiwan Normal University, Taipei 116, Taiwan.

0304-8853/$ - see front matter
doi:10.1016/j.jmmm.2005.02.059

jointed arms, which show different traveling phase when two coherent lights propagate through these two arms. As a result, the intensity of the interference light can be modulated by varying the optical phase difference of these two arms. Usually, the variation in the optical phase difference is achieved by changing the refractive index of one arm. The control mechanism depends on the material and its physical intuition of tunable refractive index. For example, by heating one of the Si arms [5,6], the refractive index of this arm is changed to manipulate the phase difference. If the arms are made of electro-optic polymers or liquid crystals, the modulation in the refractive index of one arm can be achieved by applying an external electric field [7,8]. Another method is using photochromic polymers as one arm, which refractive index is reversibly changed under irradiation of lights with various wavelengths [9]. According to most published results, the refractive index of one arm of a Mach–Zehnder interferometer is adjusted via thermal, electric, or optical control. In this work, an alternative way to tune the refractive index of one arm is explored.

2. Experimental details

In our designed Mach–Zehnder interferometer, the light emitted from a He–Ne laser is split into two coherent lights. One of the coherent lights travels in air (referred as path (1)), whereas the other transmits through a magnetic fluid film (referred as path (2)), as shown in Fig. 1. Then, these two coherent lights interfere with each. A typical interference pattern is also shown in Fig. 1. A photo-detector is posited at the center of the interference pattern to measure the intensity.

The magnetic fluid film consists of a glass cell containing water-based lauric-acid coated Fe_3O_4 magnetic fluid. The glass cell is $3 \times 3\,mm^2$ in area and $260\,\mu m$ in depth. The magnetic fluid is fabricated via chemical co-precipitation method. The flow chart to illustrate the synthesis of magnetic fluids is shown in Fig. 2. The distribution in the diameter of Fe_3O_4 particles are measured through dynamic laser scattering technologies. Fig. 3 plots the diameter distribution of the

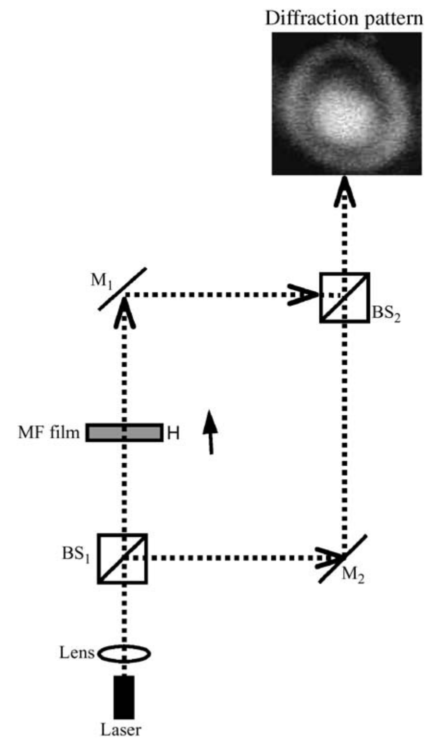

Fig. 1. Scheme of Mach–Zehnder interferometer. A magnetic fluid film is located in one of the arms of the interferometer. The light is normally incident into the film and an external magnetic field is applied along light propagation. BS_1 and BS_2 denote beam splitters, M_1 and M_2 are mirrors.

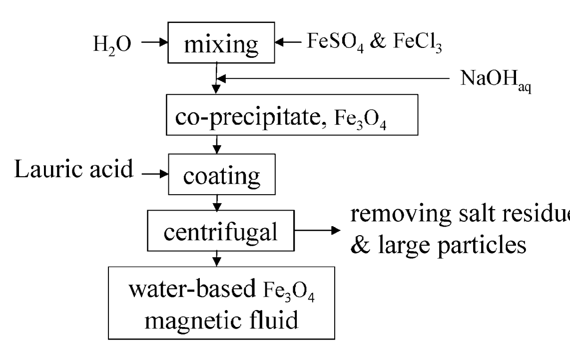

Fig. 2. Flow chart for the synthesis of lauric-acid coated Fe_3O_4 water-based magnetic fluid. The lauric acid is coated on Fe_3O_4 particles as a surfactant to make the particles dispersible in water.

Fe_3O_4 particles used here. The mean diameter and its standard deviation are 63.9 and 14.0 nm, respectively. The magnetic fluid film is located in a