THERMAL LENS DETECTION DEVICE USING MACH-ZEHNDER INTERFEROMETER WAVEGUIDE


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ABSTRACT

This paper reports a detection device which realizes the miniaturization of differential interference contrast thermal lens microscope (DIC-TLM) [1]. The device comprises a Mach-Zehnder interferometer using optical waveguide contacting with a microfluidic channel and detects thermal lens phenomenon based on the principle of wave optics. The device is promising for detection of nonfluorescent molecules in micro/nanofluidic channel comparable or smaller than the wavelength of light.

KEYWORDS: Thermal lens microscope, Integrated optics Mach-Zehnder interferometer, Waveguide

INTRODUCTION

Recently, analytical chemistry have targeted micro and nano order space such as micro chemical chip and single cell. Our group have investigated the extended-nano space (10-1000 nm) and developed analytical device such as immunoassay and chromatography. However, in extended-nano space, detection methods based on geometric optics including conventional thermal lens spectrometry are not available. Therefore, we developed DIC-TLM based on wave optics to detect nonfluorescent molecules in nanochannel shorter than the wavelength [1]. Although thermal lens detection device was miniaturized previously [2], it was based on geometric optics. Herein, we developed a thermal lens detection device completely based on wave optics for a microfluidic channel whose optical path length is comparable to the wavelength of light.

THEORY

Concept of the device is shown in Figure 1. Mach-Zehnder interferometer waveguide was fabricated in glass substrate and bonded with a microfluidic channel. A probe beam traveled through the waveguide and came out the device as an interfering light. An intensity-modulated excitation beam was irradiated to a sample and induced a local change in refractive index (thermal lens). The thermal lens was detected by an intensity change of the interfering light.

Figure 1: Concept of the device
EXPERIMENTAL

It is required for the detection that the heat from the sample transfers only to one branch of the waveguide. Waveguide was designed to accomplish this requirement. The waveguide was fabricated by femtosecond laser direct writing that can fabricate Mach-Zehnder waveguide easily [3]. The two glass substrates were bonded by low-temperature bonding method not to break waveguide by heat. We constructed an optical setup for the thermal lens detection, shown in Figure 2.

RESULTS AND DISCUSSION

Waveguide fabrication was confirmed by a phase-contrast microscope. By the experiment described in Figure 3, traveling of the probe beam through the waveguide was confirmed. From these results, it is verified that the waveguide was fabricated and worked as it designed.

We verified the principle of the device using a nonfluorescent sample (Sunset Yellow) with 5 µm microfluidic channel. Signal from the device was detected only if both the probe beam travel the waveguide and the excitation beam irradiate to the sample. The signal was confirmed to be proportional to the concentration of the sample shown in Figure 4. By these results, we verified that the heat from the sample was detected in the microfluidic channel of 5 µm optical path length, which was difficult for the previous thermal lens detection device.

Figure 2: Optical Setup for thermal lens detection

Figure 3. concept of light coupling experiment

Figure 4. Signal vs. concentration of sample
CONCLUSION

We developed a thermal lens detection device with Mach-Zehnder interferometer waveguide and microfluidic channel. The device is miniaturization of DIC-TLM and based on wave optics, so that it is promising for detection of nonfluorescent molecules in micro/nanofluidic channel comparable or smaller than the wavelength of light. In this study, detection in nanofluidic channel was impossible because of low sensitivity of the device. The sensitivity of the device will be improved by decreasing distance between the waveguide and channel and application to nanochannel is also expected.

REFERENCES


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