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PHASE REFRACTIVE INDEX MEASUREMENTS OF WATER BY WHITE-LIGHT SPECTRAL INTERFEROMETRY

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INTRODUCTION

We constructed an experimental kit consisting of a low-cost supercontinuum white light source delivering diffraction limited light in the entire 450-2400 nm region that performed with the Michelson interferometer in order to determine the group of refractive index and phase refractive index of water. The experimental results showed that the group of refractive index and phase refractive index of water are equivalent to the theoretically calculated results. In addition, the experimental kit can be used to determine the refractive index of the cuvette material as well as the refractive index of other liquids.

THEORY

- The schematic of Michelson interferometer with two beams of light is illustrated in Figure 1.
- The optical path difference between two beams of light in Michelson interferometer (1): $\Delta L(\lambda_0) = L_0 - l$ (1)
- The group refractive index of cuvette material N (λ_0) is given by equation (2): $N(\lambda_0) = 1 + \frac{\Delta L(\lambda_0)}{t}$ (2)
- The optical path difference between two beams of light in the Michelson interferometer, when the cuvette is filled with liquid given refractive index n_l (3): $\Delta'_M(\lambda) = 2(L' - l) - 2t.(n-1) - 2d.(n_l - 1)$ (3)
- When the incident light is white light, the period of fringe spacing measured by interferometer is calculated as follows: $\Lambda(\lambda) = \frac{\lambda^2}{\Delta_M}$ (4)
- The group optical path difference displacement of the equation (3) is written as follows:

$$\Delta'_{M(g)}(\lambda) = 2(L' - l) - 2t\left[N(\lambda) - 1\right] - 2d\left[N_l(\lambda) - 1\right] \quad (5)$$

- The position of mirror M_2 is determined by the following equation (6):

$$L'(\lambda_0) = l + t[N(\lambda_0) - 1] + d[N_l(\lambda_0) - 1] \quad (6)$$

- If $\Delta L'(\lambda_0) = L'(\lambda_0) - L_0 = L'(\lambda_0) - l$ is the distance between mirror M_2 and its initial position, the group refractive index of the water is given by the equation (7):

$$N_l(\lambda_0) = 1 + \frac{\Delta L'(\lambda_0) - t[N(\lambda_0) - 1]}{d} \quad (7)$$

- Finally, the phase refractive index of the water is determined by equation (8):

$$N(\lambda) = n(\lambda) - \lambda\frac{dn}{d\lambda} \quad (8)$$

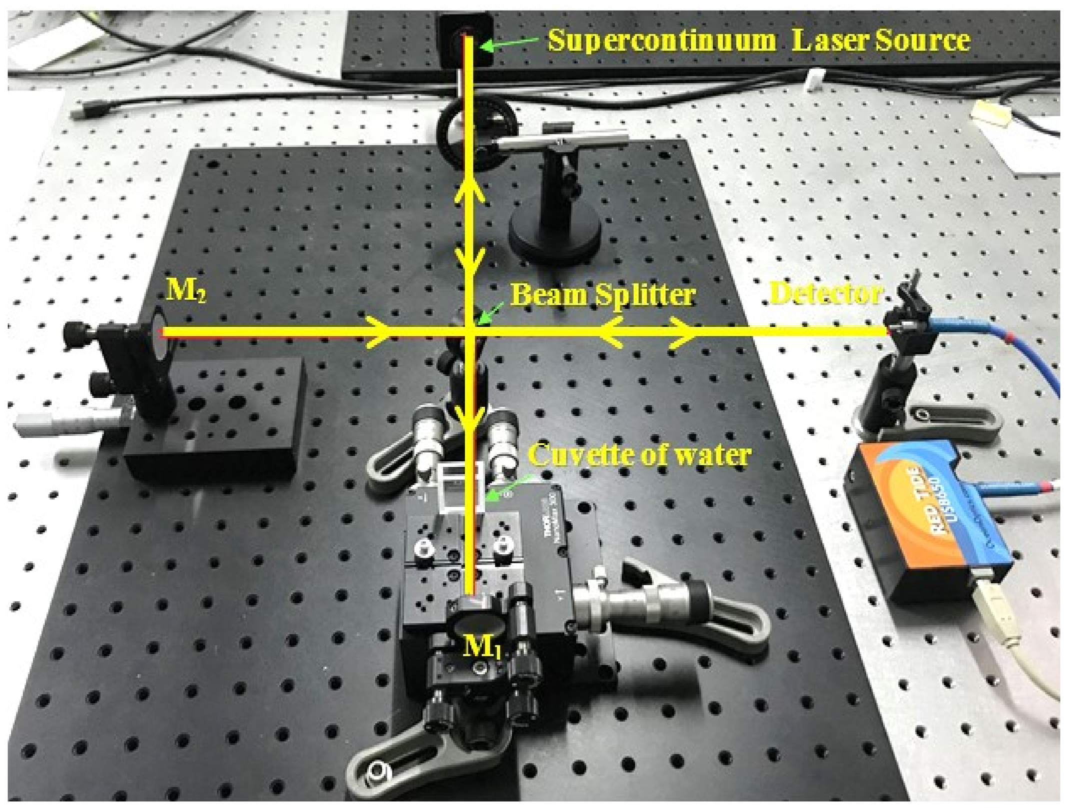

Figure 1. *The schematic of Michelson interferometer with supercontinuum laser source*

where, L_0 is the initial position of mirror M_2; t is the thickness of cuvette; λ_0 is the wavelength in which the central fringe and the initial position are coincident; L' is the optical path of the beam after reflection on the M_2 mirror (the second branch), l is the optical path of the beam after reflecting on the M_1 mirror (the first branch); n is the phase refractive index of cuvett material; d is the thickness of the liquid in the cuvette; $\Delta_M{}'$ is the group optical path difference between two interference branches, N(λ) is the group refractive index of the cuvette, $N_l(\lambda)$ is the group refractive index of water.

RESULTS AND DISCUSSION

To determine group refractive index and phase refractive index of water using interference method with light beams that could change in wavelength, base on the principle diagram (Figure 1), we set up an experiment using the following equipment: 01 SuperK COMPACT Supercontinuum laser can change the wavelength of the transmitter from 0.45 μm to 2.4 μm; 01 optical receiver of Red Tide Spectrometer 0.35 - 1.0 μm and Avantes 1,0 - 1.7 μm; 01 Michelson interferometer.

The results of experiment are shown in Fig 2, Fig 3, Fig 4, which are similar to results of theory. This proves the experimental system to determine the refractive index using Michelson interferometer with a wavelength-changeable light source that we designed has high accuracy and reliability, which can be applied to determine the refractive indices of different properties of materials.

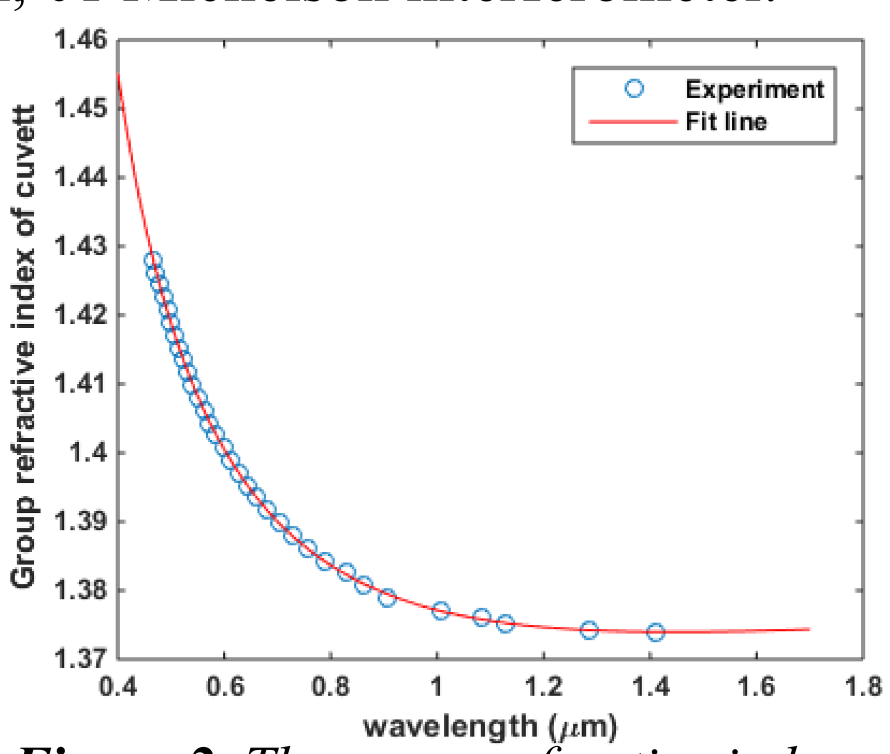

Figure 2*. The group refractive index of cuvette material as a function of the wavelength for the thickness t = 5.49 mm.*

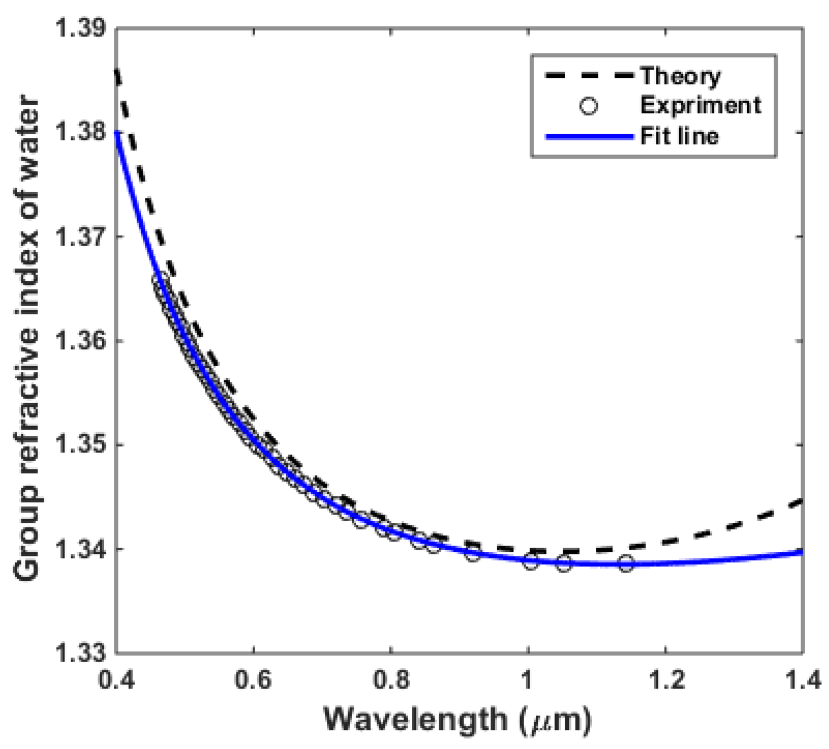

Figure 3*. The measured group refractive index of water as a function of the wavelength.*

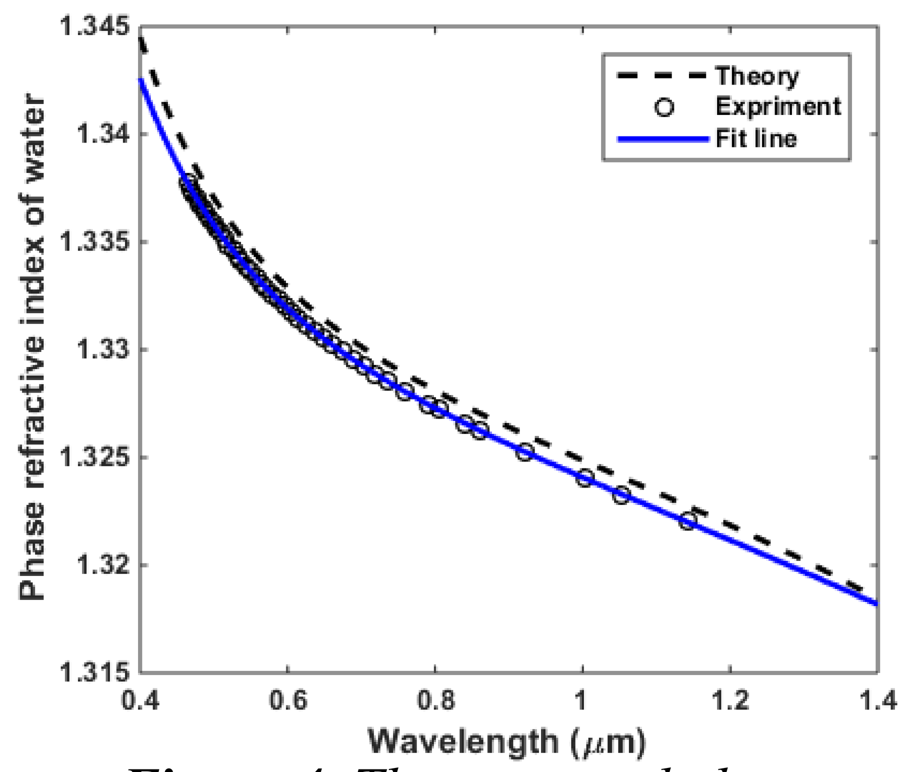

Figure 4*. The measured phase refractive index of water as a function of the wavelength.*

CONCLUSION

We have designed an experiment kit with the Michelson interferometer using a wavelength-changeable light source to measure refractive index of different materials. The obtained results show that there is a match between the experimental results obtained from our experiment kit and the announced theoretical results. This shows that our experiment kit can be used to determine the refractive index of different materials.

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