

# Measurement of the index of refraction of a Flat zinc germanium phosphide wafer in the infrared

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**Abstract:** We have developed and tested a novel application of interferometry to determine the absolute refractive index of individual infrared materials having flat and parallel surfaces without alteration of the sample in any way, and measured  $n_o$  for ZnGeP<sub>2</sub>.

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## 1. Introduction

It is important to know the absolute refractive indices of materials for most optical applications, especially for nonlinear light-matter interactions. Currently, the standard method for refractive index measurements of materials is the minimum deviation method as light propagates through a wedge or a prism. The use of this method presents a unique challenge to the majority of infrared materials, which are manufactured in flat layers. Although refractive index measurements using the wedge/deviation method are highly accurate, they do require the sacrifice of some portion of the material to be precisely, and destructively, ground into that shape. In this talk we present an alternative, non-destructive, sample-specific method for determining the refractive index of flat infrared materials using interferometry.

## 2. Method

The experimental setup for these refractive index measurements is rather straightforward: the flat sample is placed in the beam path of one arm of a Michelson interferometer on a computer controlled rotation stage. As the sample is rotated, the optical path of that arm of the interferometer will change. If the refractive index of the material is greater than 2, the change in optical distance as a function of the rotation angle is

$$\Delta OD(\theta) = 2d(1 + (n^2 - \sin^2\theta)^{1/2} - \cos\theta - n), \quad (1)$$

where  $n$  is the refractive index,  $d$  is the sample thickness, and  $\theta$  is the angle of the surface normal with respect to the incident beam path. A small area of the fringe pattern is recorded as a function of  $\theta$ . The locations of the maxima and minima are extracted from the raw data and fit to

$$\Delta OD(\theta) = m(\theta)\lambda + m_o\lambda, \quad (2)$$

where  $m$  is the relative fringe value, and  $m_o\lambda$  is the initial fringe value for  $\theta=0$ .

## 3. Results and Discussion

The raw data of intensity versus sample angle, measured using a wavelength of 10.611  $\mu\text{m}$  obtained from a low power (700mW) CO<sub>2</sub> laser, is displayed in Figure 1, for an 8×8×2.94 mm sample of ZnGeP<sub>2</sub>. Figure 2 shows the locations of the maxima and minima as a function of the sample angle and fit to equation (2), resulting in a refractive index of the ordinary axis of  $n_o = 3.03 \pm 0.01$ , comparable to that predicted by Zelmon *et al.* of 3.07 [1].

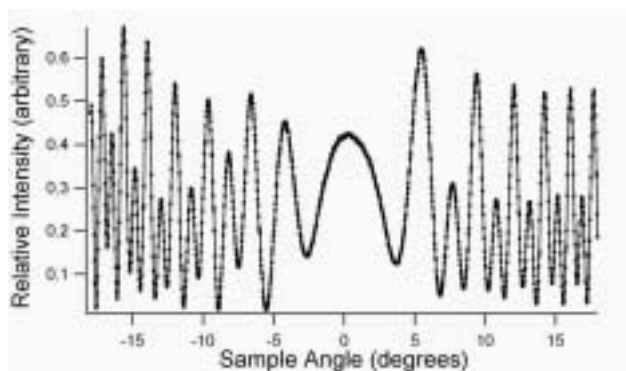


Figure 1. Observed data of the interferometric fringe pattern intensity as a function of the sample angle, for the ZnGeP<sub>2</sub> sample.

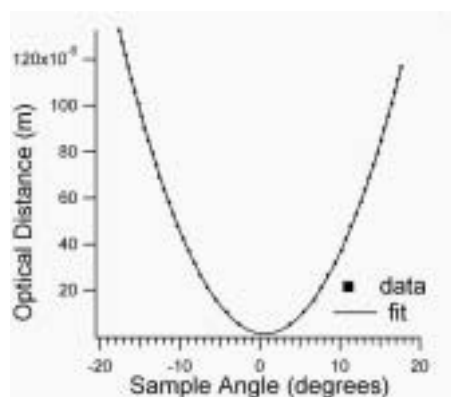


Figure 2. Measured optical distances, and their fit to equation (2).

A calibration check was performed with germanium, yielding  $n = 4.00 \pm 0.01$ , agreeing well with the widely accepted value of 4.003. The major contributor to the error is the uncertainty in measuring the sample thickness of  $\pm 10$  microns. A more accurate measurement of the sample thickness will improve the resolution of this method to 3 to 4 digits of precision. The advantages of this method are: (i) the ability to measure thin ( $\sim 1$  mm) samples, (ii) localized refractive index measurements, and (iii) ease of adaptation of the setup for samples at cryogenic temperatures, which is important for many infrared applications. We will present the results of refractive index measurements for a variety of infrared samples for temperatures of 77K and 300K. To the authors' knowledge this is the first application of interferometry to find the absolute refractive index for LWIR materials.

1. Zelmon, D. E., Hanning E. A and P. G. Schunemann, "Refractive-index measurements and Sellmier coefficients for zinc germanium phosphide from 2 to 9  $\mu\text{m}$  with implications for phase matching in optical frequency-conversion devices", J. Opt. Soc. Am. B **18**, 1307-1310 (2001).