White-light Interferometry for Thickness Measurement of Thin Films

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Abstract

Precision measurement is an active area of research in physics and engineering.By using interferometry, minute lengths can be measured precisely and easily. Inour project, we explore the uses of white light Fourier transform interferometryin measuring the thickness of thin optical films. We use MATLAB, LabVIEWand Autodesk Inventor to design and programme our apparatus and test itusing simulated data.

Introduction

nterferometry is a class of techniques used to extract information from the inter-ference patterns produced due to the phase difference between electromagneticwaves. They are well suited for precision measurements of lengths and havebeen used in a variety of experiments in the history of physics. They were thebasis of the Michelson-Morley experiment that sought to prove the existence ofether- the medium of light. The failure of such a precise measurement apparatusto find ether led physicists to explore other solutions to the conundrum of thespeed of light being constant in all frames of reference, contradicting Newto-nian relativity, that culminated in Einstein's theory of relativity. More recently,an advanced version of the same apparatus was used to detect the existenceof gravitational waves at the two LIGO detectors in 2015. In our project, weexplored methods of interferometry for measurement of thickness of films ofoptical material on the order of a hundred microns.

Methodology

Fourier transform spectroscopy relies on the interference of the two waves which gives the sum of waves offset by the phase differences at the point at each point on the spectrometer screen. It is shown how the interferogram (intensity as a function of wave-number) is related to the Fourier transform of the original waveform (intensity as a function of spatial coordinates.

The method of analysis used was Fourier transform interferometry, whichuses the computational method of Fast Fourier transforms to extract data frominterference patterns detected on a spectrometer. We made a simulated of aninterferogram by Fourier transforming two Gaussian-enveloped cosine functionarrays with a predetermined time delay, and storing the absolute value of thetransformed arrays in MATLAB.

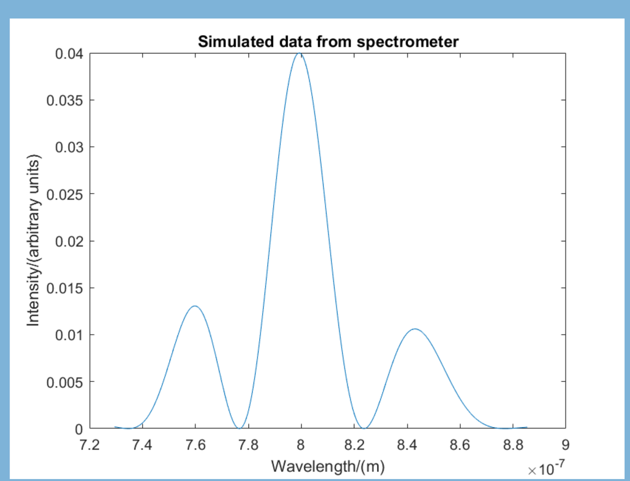

Fig.1: Simulated data in the form of a modulated sine wave. The output t from a spectrometer can be approximated by such a function.

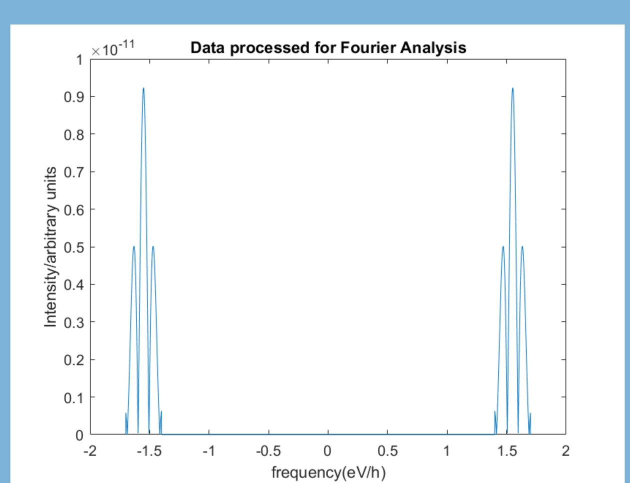

Fig.2: Processing data to make it symmetric so that we can use Fourier Transform to get a real function of the spectrum in the physical space.

Our aim was to reconstruct the delay from the interferogram. After creating the interferogram, the rest of the code had no access to any information apart from the interferogram.
We preprocessed the interferogram by extending the range of lambda value from -max(lambda) to max(lambda) and appending the mirror image of the interferogram to the array since we had to treat the interferogram as the Fourier pair of the time delay, and any real wave's Fourier pair has to have a symmetric real part. Then we transformed it back, from which we got a series of peaks. The distance between the peaks was the initial time delay we had used to create the simulated interferogram.

Results

Our MATLAB code worked to an accuracy of 1% in recreating the time delayfor a realistic range of inputs. The LabVIEW port worked similarly well on sim-ulations. We also successfully interfaced the spectrometer to our LabVIEW codeto retrieve the spectrum array from the light received at the spectrometer.Wedesigned the hinged mount for films of thickness on the order of a hundredmicrons.

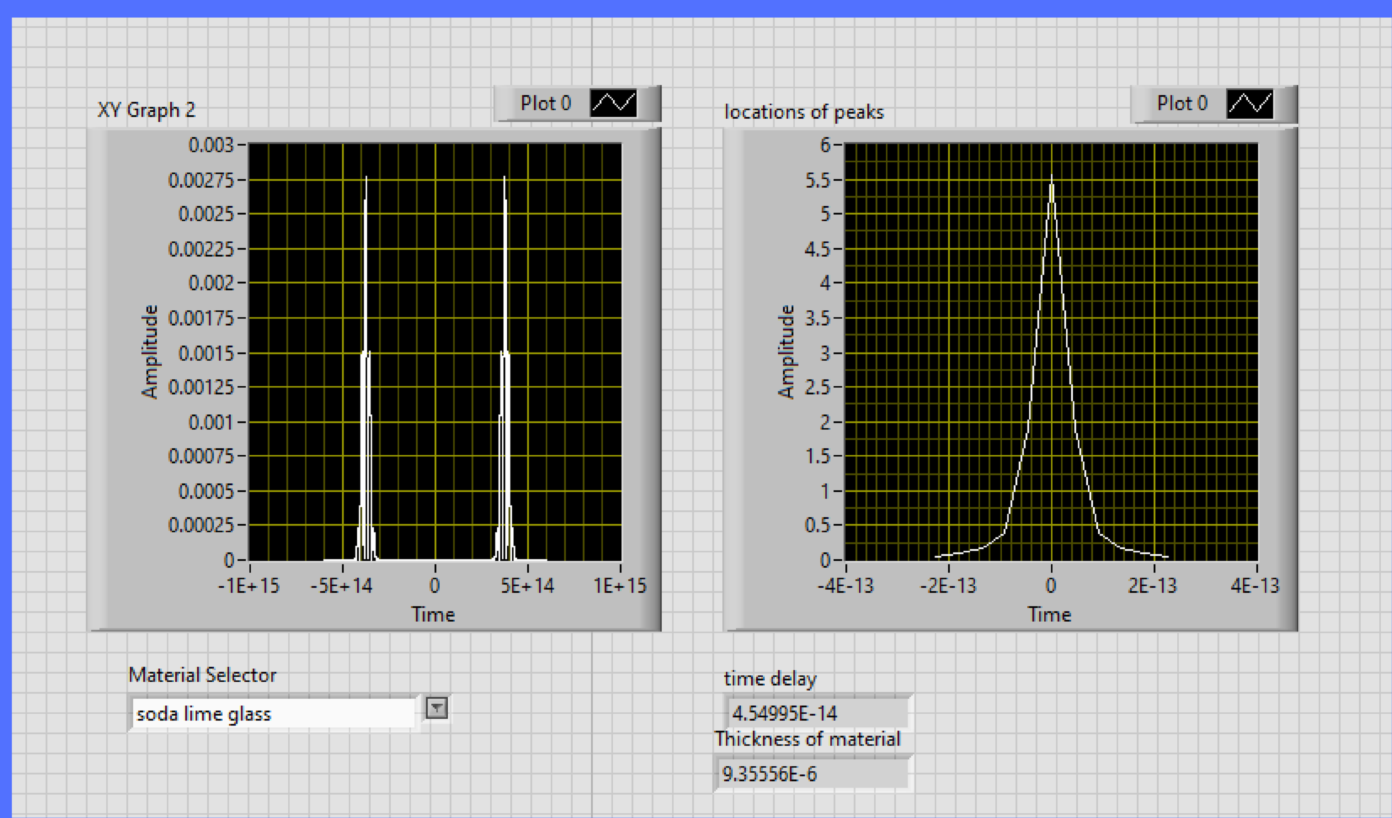

Fig.3: 3 Matlab code ported to LabVIEW and interfaced with spectromemter

Discussion

Our work showed a working model for an interferometer to measure the thick-ness of thin films on the order of a hundred microns with an accuracy close to 1percent. Since our model was rather simplistic, based on assumptions that could reasonably fail in a real scenario, we suggest some improvements for further work in improving our model. We assumed a constant refractive index for the given materials, whereas in general the refractive index is a function of the wavelength of incident light. This is especially valid in the case of white-light interferometry since short pulses of white light necessarily have a broad band-width. This means that the pulse is going to get chirped as it passes through the film, which we haven't taken into account in our work. The next step in our work would then be to include the whole range of refractive index for a givenmaterial in our code.