A Study of the Non-Linear Optical Properties of Low-Dimensional Materials

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Introduction

The Z-scan technique is a method used to determine the non-linear optical properties of materials, such as their non-linear refractive indices.

The refractive index of a material describes the propagation of light through the medium, calculated using the ratio of the velocity of light in a vacuum and the velocity of light in the material being investigated.

When using light of high intensity, such as a laser beam, the refractive index varies non-linearly- this means it changes in a way that is proportional to the optical intensity.

For materials considered thin on an atomic scale, light of very high intensity is required to effectively measure some of their optical properties.

Aim

The aim of the research undertaken was to construct a modified Z-scan set-up, i.e. a measurement tool with the ability to determine the optical properties of very thin materials.

The Z-Scan Set-up and Method

The traditional Z-scan technique was modified using a highly focused intense laser beam as the probe. A motor was connected to a high speed stage, this was then attached to a specifically designed sample holder.

The material under investigation was attached to the sample holder and moved back and forth in front of the photodetector. A lens was affixed in front of the sample in order to focus the laser beam. The initial movement of the sample triggered the oscilloscope and the data was then recorded.

To check the measurement tool was functioning as intended, a blank microscope coverslip and a sample of graphene oxide were investigated using the set-up. The data from both samples were then filtered to reduce noise, and the resulting graphs were analysed for the predicted trends.

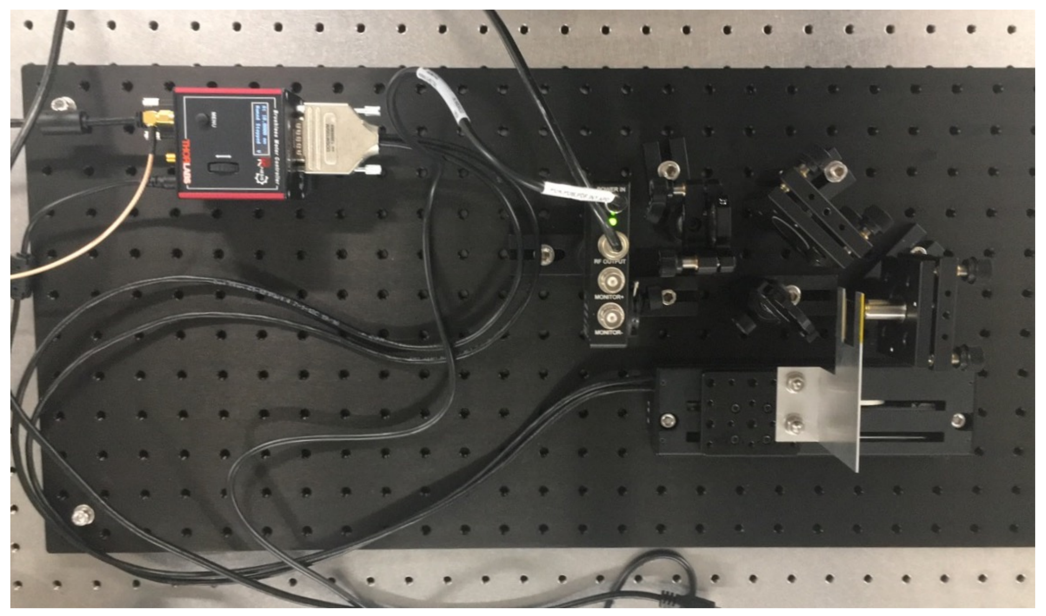

Figure 1: Partial view of the modified Z-scan set-up

Results

Blank coverslip

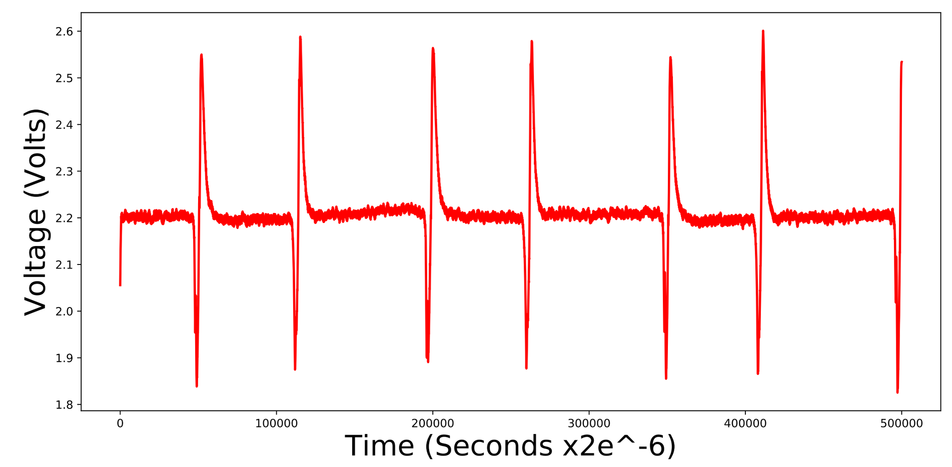

Figure 2: A filtered voltage-time graph for a blank coverslip

Graphene Oxide

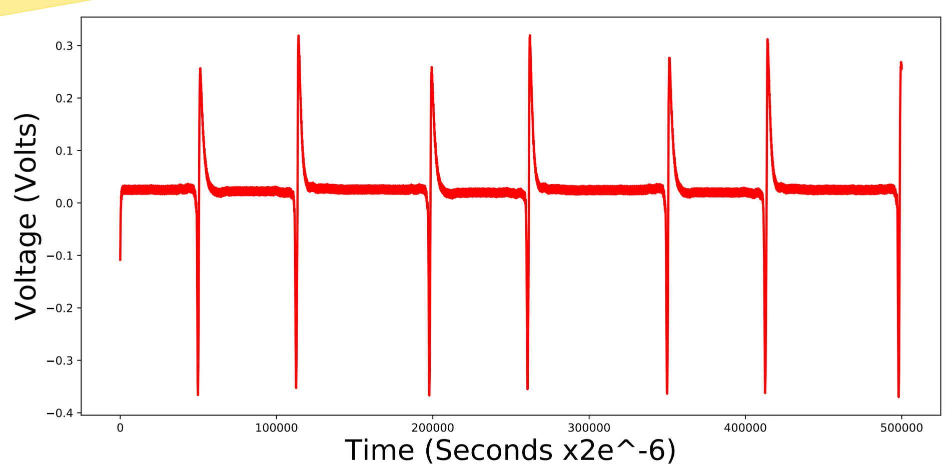

Figure 3: A filtered voltage-time graph for graphene oxide

Discussion

The filtered data shows a repeating pattern which corresponds to the sample being moved through the beam waist- the part of the laser beam with the smallest radius. The peak-valley repetition is the expected form of this technique.

By converting the time axis to distance, the separation between peaks corresponded to the focal length of the lens. This confirmed the functionality of the produced measurement tool.

Conclusion

Applications of this research include optical switching and optical limiting, both of which have wide ranging applications in photonics and optoelectronics, and can be used to help fabricate non-linear optical devices.

The measurement tool produced over the course of this project could be improved by adding an extra high-speed stage so the sample could move along two axes. This would allow more precision and efficiency when positioning the sample directly in line with the laser beam.

Most significantly it would allow more low-dimensional materials to be investigated using this technique, therefore the set-up could be used on a wider scale.

References

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[2] Z-Scan for the Characterization of Transparent Optical Materials, https://www.newport.com/medias/Z-Scan-for-the-Characterization-of-Transparent-Optical-Materials-App-Note-34.pdf (accessed 10 August, 2017).