Characterization of $Zn_{1-X}Cd_XSe$ Non-Linear Response

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Abstract

The characterization of second-harmonic generation in thin film materials is an important goal for basic and applied sciences. Advances in frequency conversion, optical modulation and optical switching applications depend on robust measurements of second-harmonic generation. Enhanced second-mode and third-mode susceptibilities of thin films are needed to support next generation optical computers. Characterization of the second-harmonic response in a novel series of thin films will provide a clearer understanding of these effects. A family of $Zn_{1-x}Cd_xSe$ ternary thin film alloys has been made available to us for study. The second-harmonic responses are expected to produce a correlation as the value of X increases from 0 (CdSe) to 1 (ZnSe).

The most challenging aspect of identifying second-harmonic responses is to differentiate non-linear from linear effects. A prism coupling technique (PCT) utilizing blue (488 nm) and red (632.8 nm) lasers was used to characterized the linear response. The PCT measures reflectance of light incident on a surface. It is used to identify waveguide modes generated in each thin film sample. Usually a more powerful laser, such as our 1064 nm pulsed IR beam, is needed in order to visibly generate and identify non-linear interactions in a sample. However, we have found what appears to be a clear non-linear response from the $Zn_{1-x}Cd_xSe$ family of thin films using low-power, focused 488 nm and 632.8 nm lasers. Our next step is to use a more powerful laser in order to quantify the second-harmonic light generated by our sample thin films. Since semi conductor films are constructed in a variety of ways, there is no universal method of characterizing non-linear responses. This is our most recent attempt.

Introduction

The linear and nonlinear response of materials is similar to everyday items. In a radio for example, when the volume is turned up, the sound frequencies produced follow a linear fashion. However, when the volume reaches a high level, the sound follows a non-linear response. New frequencies and distortions are found from the addition and subtraction of the current frequencies. A non-linear response can be found in organic and inorganic crystals. Studying these responses can yield valuable information about electronic, magnetic and crystallographic structure. For example, using readily available lasers in the visible spectra, crystals can be probed in the UV or IR spectra using sum and differences frequencies using nonlinear techniques in the investigation of these materials can give more true interaction with the bulk material [4]. Utilizing waveguide modes and the prism coupler technique results in characterization of the non-linear effects.

Experiment

Because the change in pathlength is so small in thin films, Ian Bakk ‘12 found that Maker fringes are not a feasible method to characterize their second harmonic response. We looked to a waveguide prism coupler technique (PCT) as an alternative.

Ian Bakk and Professor Keller built the prism coupler system shown in Figure 1 using the prism with the pneumatically operated coupling plunger which applies 0-40 psi to the back of the sample onto the rear of the prism.

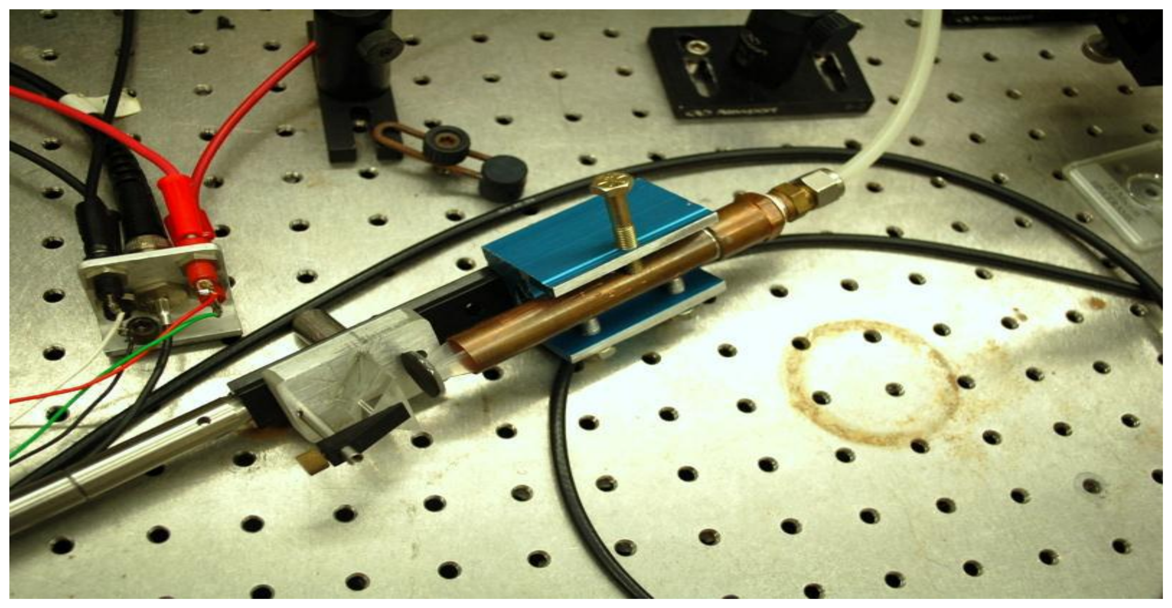

Figure 1. Prism coupling device created by Ian Bakk ‘12. A plunger applies pressure to the rear of the prism in order to keep the thin film firmly pressed against the prism [2].

Experimental Set-Up

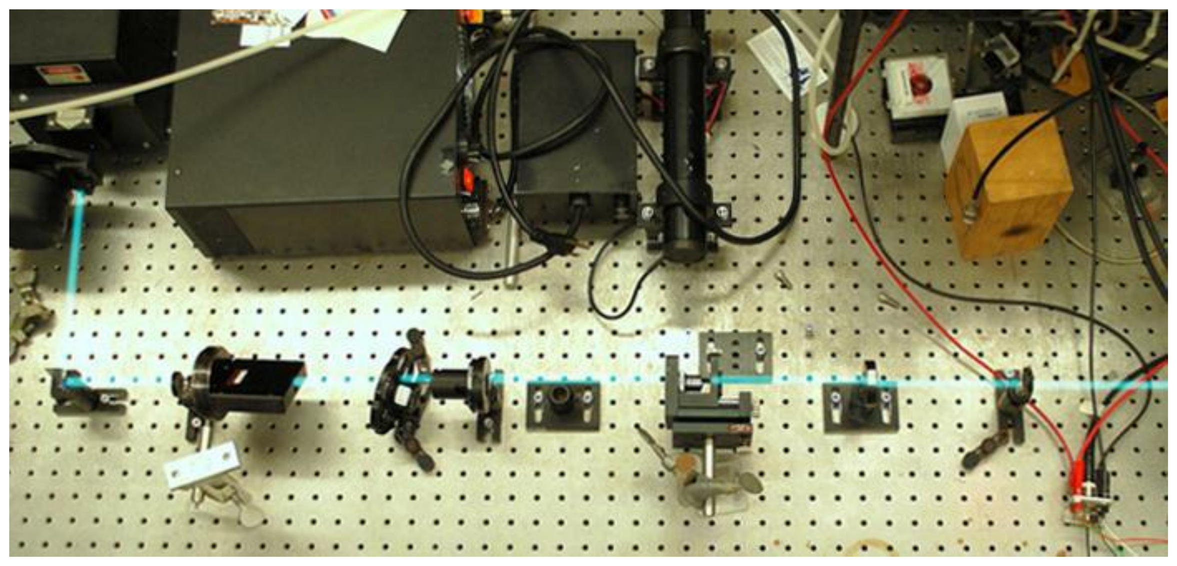

Figure 2. Experimental set-up which included an iris, polarizer, spatial filter, iris, focal lens and the prism coupling device.

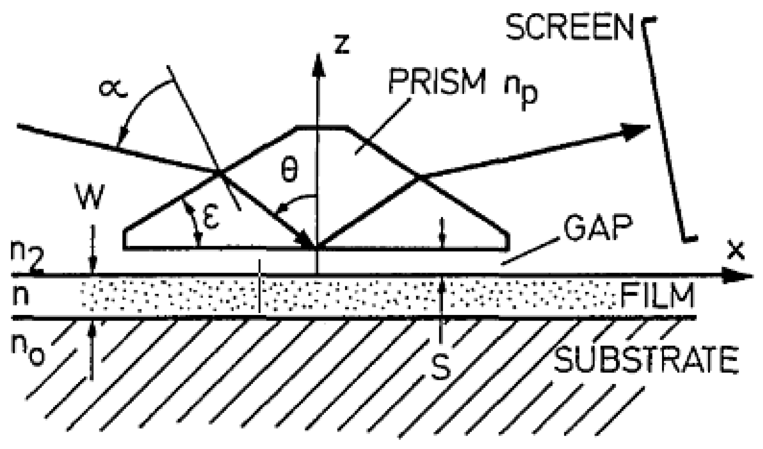

Figure 3. Depiction of the waveguide PCT[3].

Through manipulation of the incoming angle, α, the angle at the prism base θ changes also. At certain angles θ the wave vector parallel to the interface matches (in the x-direction) the supported waveguide modes (Fig. 5). The evanescent wave “tunnels” through the air barrier.

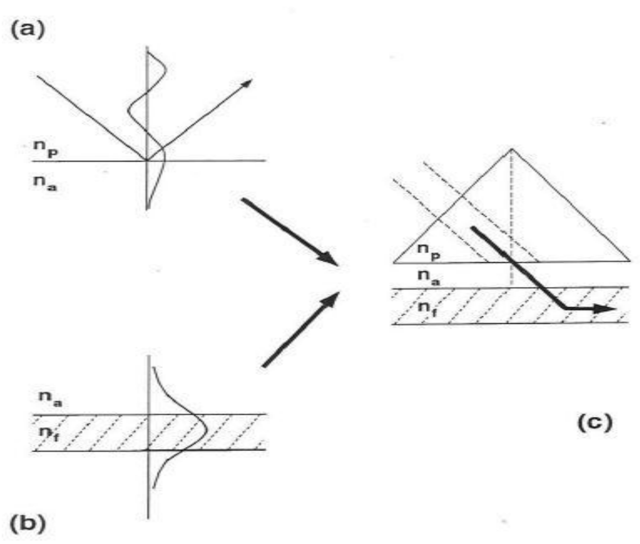

Figure 4. The optical tunneling effect of a waveguide PCT [1].

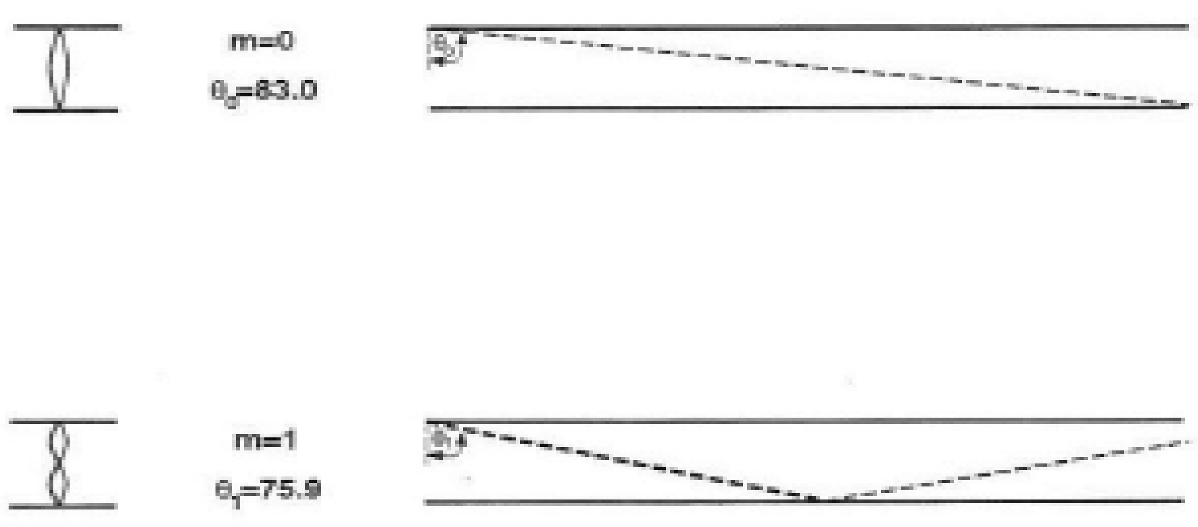

Figure 5. Example of supported modes and corresponding angles in a thin film [1].

Results & Future Work

Snapshot images of red and blue lasers that passed through the experimental set-up yielded multiple modes (Figure 6). Mode amount and position were dependent upon composition and thickness of the individual films.

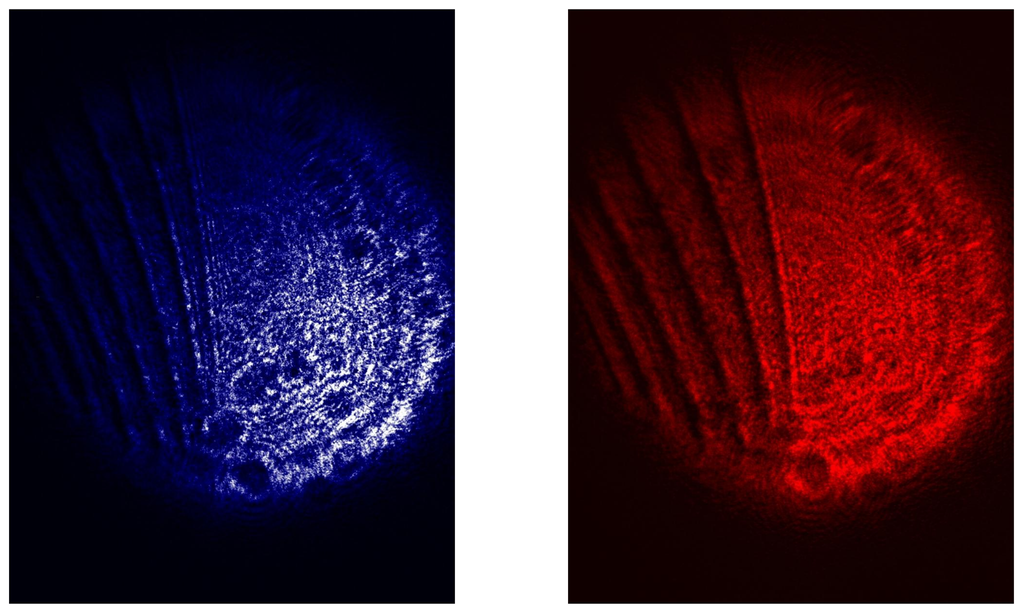

Figure 6. Snapshot images of blue (488 nm) and red (632.8 nm) laser modes after passage through the experimental set-up. Blue shows modes 5-10 (beginning on the right). Red depicts modes 3-7.

When the collected images were analyzed in MaxIM, line profiles were created (Figure 7). The larger “dips” in the line profile indicate the modes pictured in Figure 6. The smaller “dips” indicate that second-harmonic generation is possibly

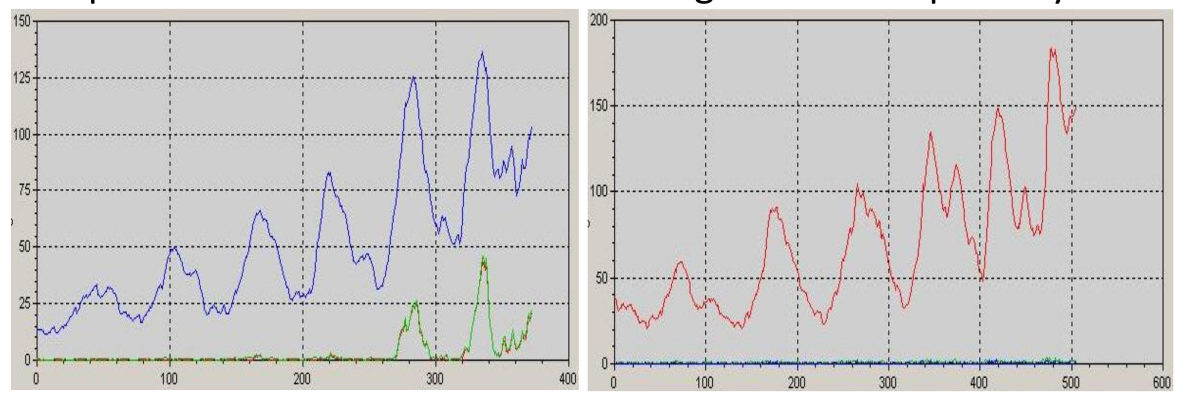

Figure 7. Line Profiles for ZnSe thin films. Large dips indicate modes depicted in Figure 6. Smaller dips reveal the possibility of second-harmonic wave generation.

The possibility of second-harmonic wave generation occurring is exciting and encouraging. We have yet to detect second-harmonic waves around the PCT set-up. Our next step is to move a wavelength adjustable IR laser into the experimental set-up and find the visible second-harmonic wave generation that results.

References

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