In the Fringes: Exploring Thin Films with a Prism Coupler

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Abstract

The design and implementation of optical computers motivates a search for light driven switches to improve and replace discrete components of current devices. Thin semi-conductor films provide a useful platform for the non-linear effects vital to "model" more complex electrical elements such as transistors or relays. Building off of previous research, a prism-coupled apparatus was used to scan many incident angles of a laser beam entering a micron thick zinc-cadmium selenide (Zn-Cd Se) film and to detect those conducted by the wave guide as dark lines on a reflected screen using a camera. Previously, several dark lines outside of the expected pattern were thought to correspond to the generation of the second harmonic inside the thin film, which would result in new wave guide angles. However, new images reveal an extensive pattern of reflection dips that cannot be explained by the second harmonic effect alone. The origin of these unexpected dark lines remains under investigation.

Previous Results

Using the prism coupler system built by a previous student, Jimmy Chapman ‘13 was able to collect images clearly demonstrating the reflection dips expected of wave guide behavior at two different wavelength lasers. Furthermore, another pattern of smaller lines seemed to be in evidence.

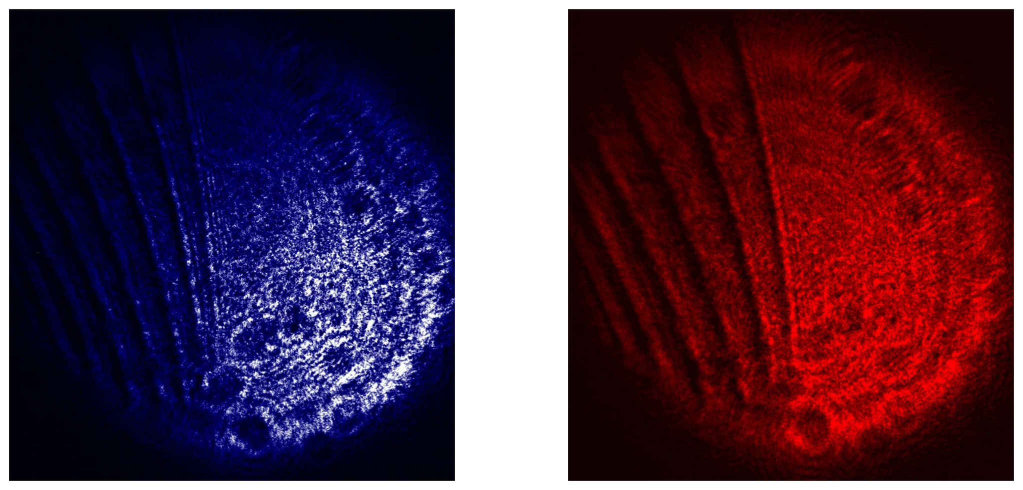
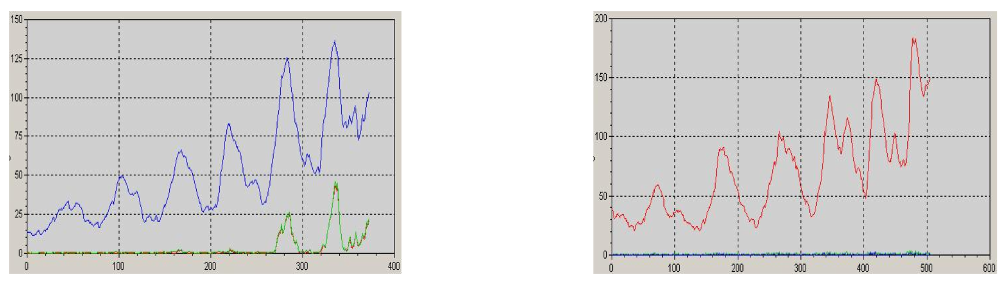


Figure 6. Snapshot images of blue (488 nm) and red (632.8 nm) laser modes after passage through the experimental set-up. Note clear patterns of reflective dips.

Single pixel analysis of the images was used to show the dips in brightness that indicate modes. Due to alignment issues in the apparatus there was a skew to the images which prevented a more rigorous data analysis.



Experimental Set-Up

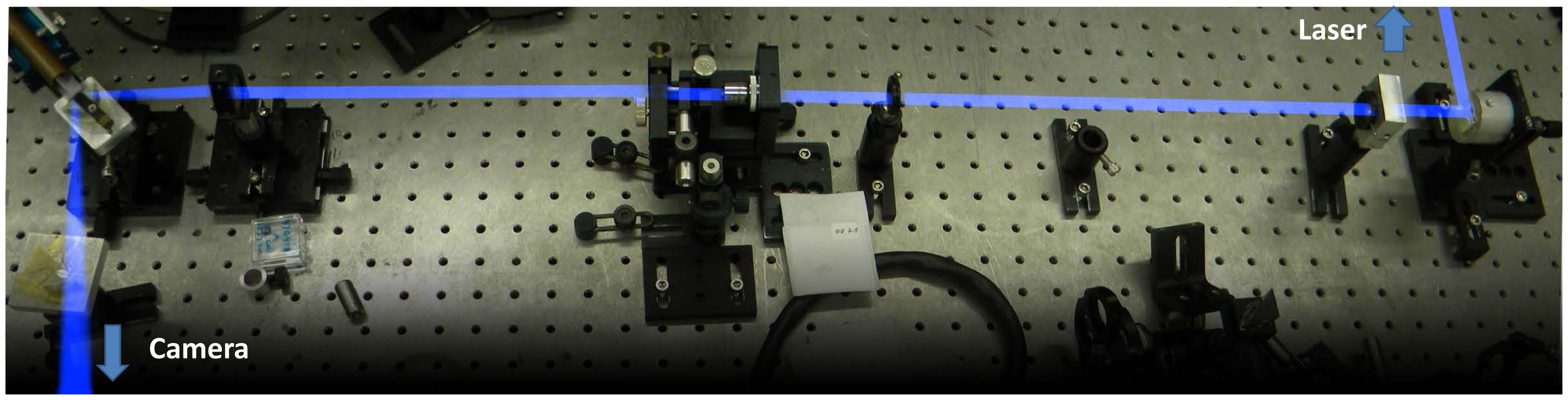
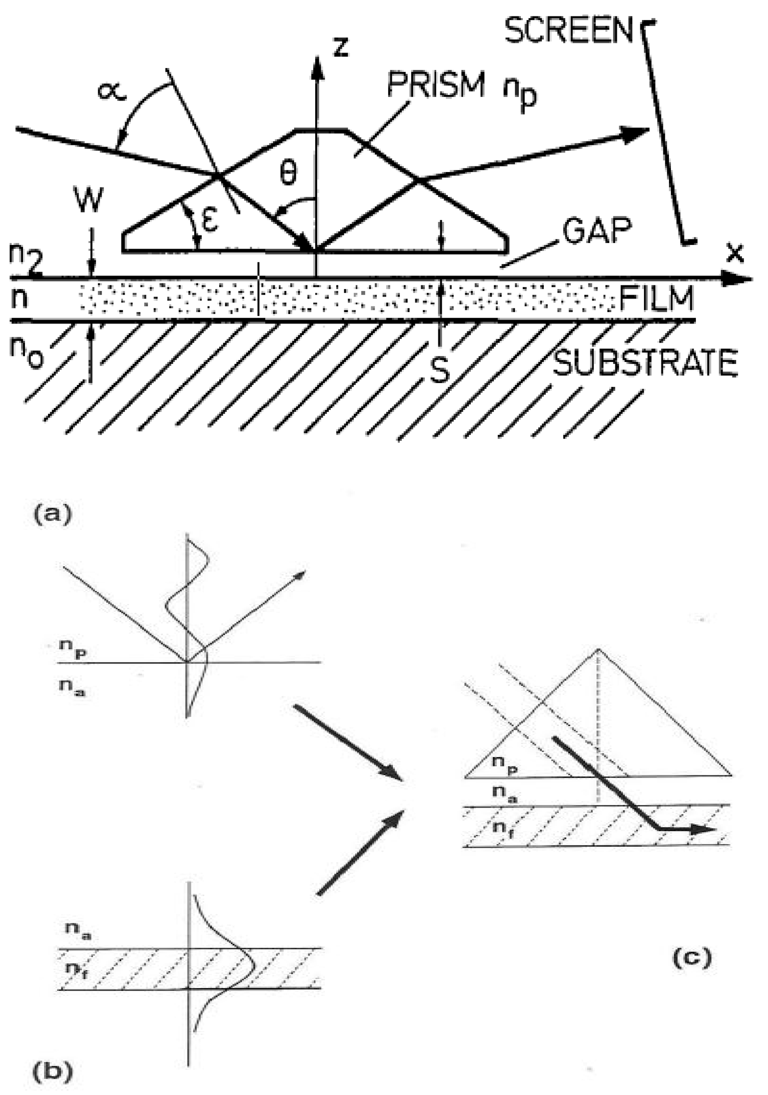


Figure 6. Experimental setup with the laser coming in from upper left to the camera on the lower right. Includes a mirror and two irises for alignment, a spatial filter, focal lens and the prism coupling device.

Theory

In order to detect the generation of the second harmonic it is essential to separate the any linear responses from the signal of interest. A prism coupler allows us to look at the behavior of different incoming angles (α) through their relative geometry reflected onto a screen, or in our case into the lens of a camera. By manipulating the incoming angle, α, we also change the angle at the prism base, θ. For certain values of this base angle, the light gets trapped in the film and travels inside it as a supported waveguide mode(Fig. 5). Tor particular angles α and corresponding θ, some light stays in the wave guide rather than being reflected off the back of the prism resulting in a dip in reflection brightness. The angle at which this occurs is dependent on the index of refraction experienced by the light as it enters the thin film across the air gap.



If second harmonic signals are generated in the film, they will experience a different index of refraction due to their doubled frequency. Therefore different values of θ will become be caught by the wave guide creating a second pattern of dark lines.

Thus by examining the resulting dip in the brightness of the reflection on the screen or image, we can characterize which angles are being sampled by the wave guide and compare them to the theoretical primary and secondary mode angles.

Figure 4. By using optical tunneling the light is able to access the wave guide even through a small air gap [1].

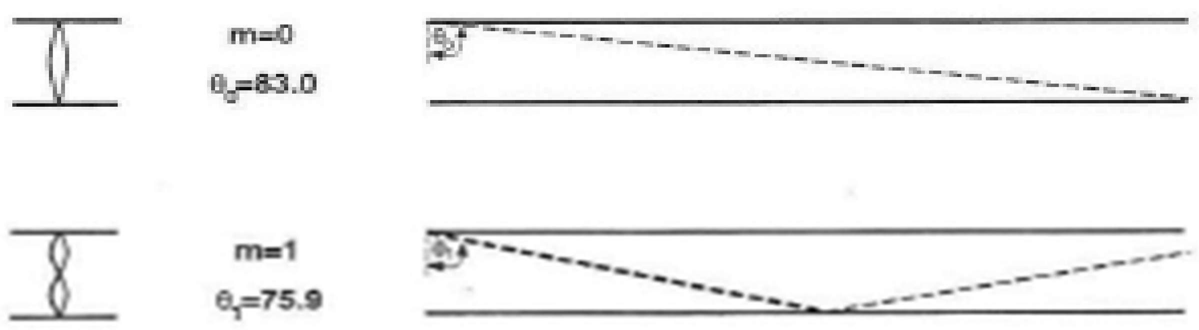


Figure 5. Different angles correspond to the creation of different standing waves in the component perpendicular to the surface of the film. These modes trap the light and create a wave guide along the thin film [1].

Strange New Data

Careful realignment of the set up yielded crisper, higher contrast images of the pattern. Again the primary wave guide modes of the laser are easily visible. However instead of a single additional set of lines that would be expected by the second harmonic contribution, the areas under investigation instead show an extensive pattern of dips reminiscent of an interference pattern.

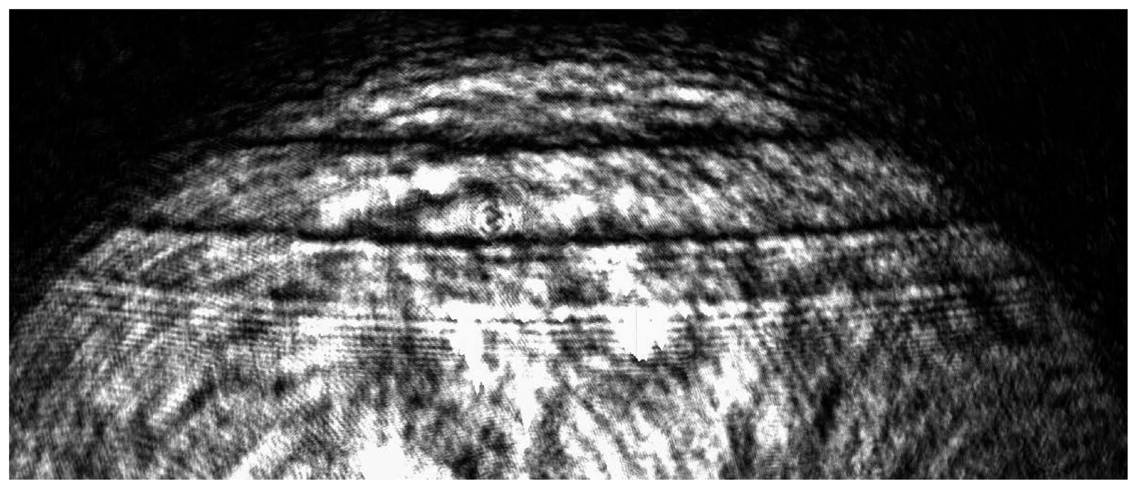


Fig 7. The image clearly shows multiple dark lines “echoing” the primary modes. (488 nm laser)

Hypotheses

Closer inspection of earlier findings of second-harmonic-like fringes reveal the same multi-line pattern seen above (Figure 8). Notably, the pattern is not laser specific, as this past image was taken from a different wavelength laser.

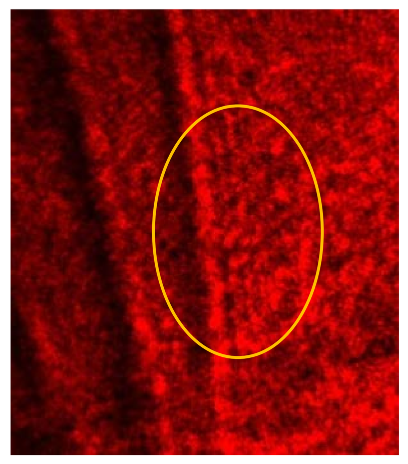


Figure 8.

Several possible origins of this pattern have been explored. While it was quite possible that the film would display dark lines resulting from second harmonic generation, an additional harmonic should not occur readily enough to generate such visible lines, nor should the lines from such effects line up so perfectly with the primary modes.

Another possibility explored was that the echoing lines were the result of thickness variation on the film itself. However the pattern remained invariant as we scanned along the film’s surface effectively disproving that theory. Due to the leakiness of its wave guide properties it was also determined that he gallium arsenide base onto which the film was originally deposited could not be acting as a secondary waveguide.

The search for a way to detect second harmonic generation continues in the lab. The origin of these fringes also remains under investigation.

References

1. Peiris F., Lee S, Bindley U., and Furdyna J. 1998. A Prism Coupler Technique for Characterizing Thin Film II-VI semiconductor system. Journal of Applied Physics 84:9 5194-5197.
2. Peiris F., Lee S, Bindley U., and Furdyna J. 2000. Precise and Efficient *ex situ* Technique for Determining Compositions and Growth Rates in Molecular-Beam Epitaxy Grown Semiconductor Alloys. Journal of Vacuum Scientific Technology 18:3 1443-1447.

Acknowledgements

I’d like to thank Professor Keller for guiding me through this project. I would also like to thank Ian Bakk ‘12 and Jimmy Chapman ‘13 on whose work I was able to build, and Professor Peiris for his work supplying consultation and the thin films used for this project.
Finally, I would like to thank the Summer Science Scholars Program for funding my research.