Designing a variable partially-polarizing beamsplitter

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1 Introduction

- A polarizing beamsplitter is an optical device that separates a beam of light into two polarization states, one that oscillates horizontally and one that oscillates vertically.
- A variable partially polarizing beam splitter (VPPBS) allows for the independent control of the transmission and reflection coefficients of each polarization.
- A VPPBS is a very useful tool in photonics because independent control of the polarizations of a single beam is difficult to obtain.
- An operational VPPBS can be used in a quantum logic gate (one of the building blocks of a quantum computer), and a number of other areas of quantum photonics.

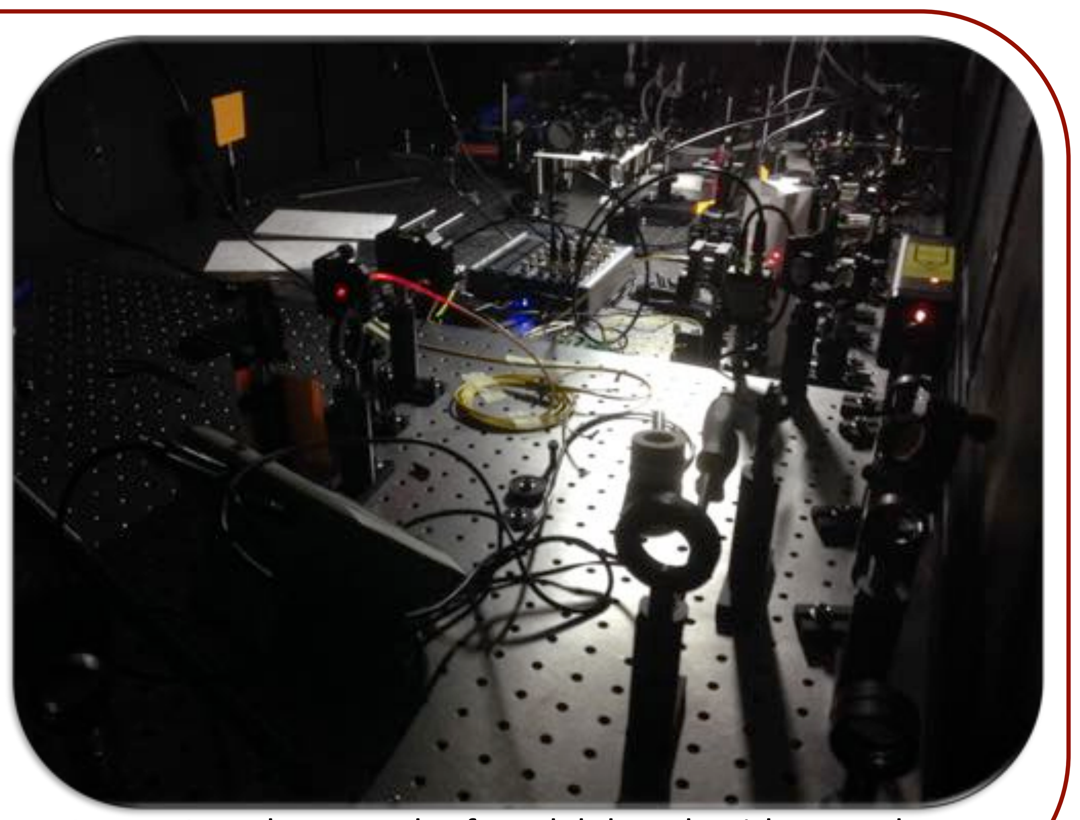

Image 1: a photograph of our lab bench with a number of ongoing experiments. Image credit Nathan J. Carlson

2 Methods

- The VPPBS consists of a displaced Sagnac interferometer with three mirrors and a non-polarizing beamsplitter (NPBS).
- The input beam (shown in black) is split by the NPBS along two paths (shown in blue and red). The two paths intersect back at the NPBS and interfere, creating two outputs (shown in violet).
- The outputs are split into horizontally and vertically polarized light by a pair of polarizing beamsplitters (PBS). This gives us four coefficients R_H and T_H the reflected and transmitted horizontal coefficients, and R_V and T_V the reflected and transmitted vertical coefficients.
- A birefringent crystal (BBO) and glass plate (a microscope slide) are placed in either beam; by rotating them, we can tune the output coefficients to the desired values.

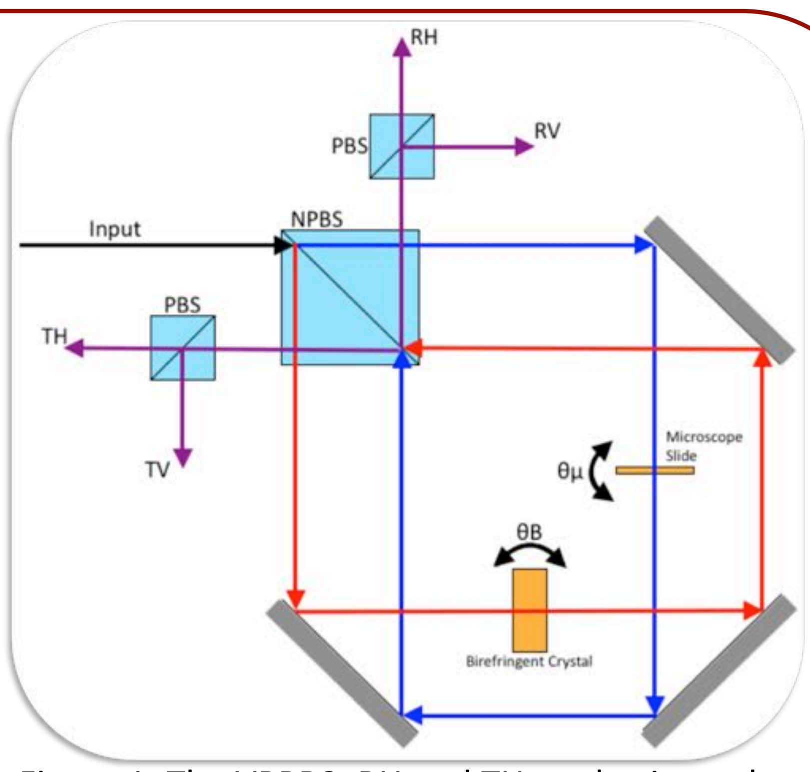

Figure 1: The VPPBS; RH and TH are horizontal components, RV and TV are vertical components

3 Results

- The first step in building a VPPBS is to construct the displaced Sagnac interferometer. Interferometry is a high precision science, requiring miniscule differences in path length of the two beams so that the polarizations meet with certain phase shifts. Much of the first few weeks of the experiment were spent adjusting and readjusting the Sagnac until each output was exhibiting a strong interference pattern.

- When the birefringent crystal (BBO) and microscope slide were first introduced, the initial data showed a low fringe visibility. When visibility is high, the minimum intensities are very nearly zero, which is desired because in some applications we need the intensity of one or more of the polarization coefficients to be zero.

- By adjusting the positions of the many elements involved in the interferometer, the visibility was improved to over 90% as shown in figure 2.

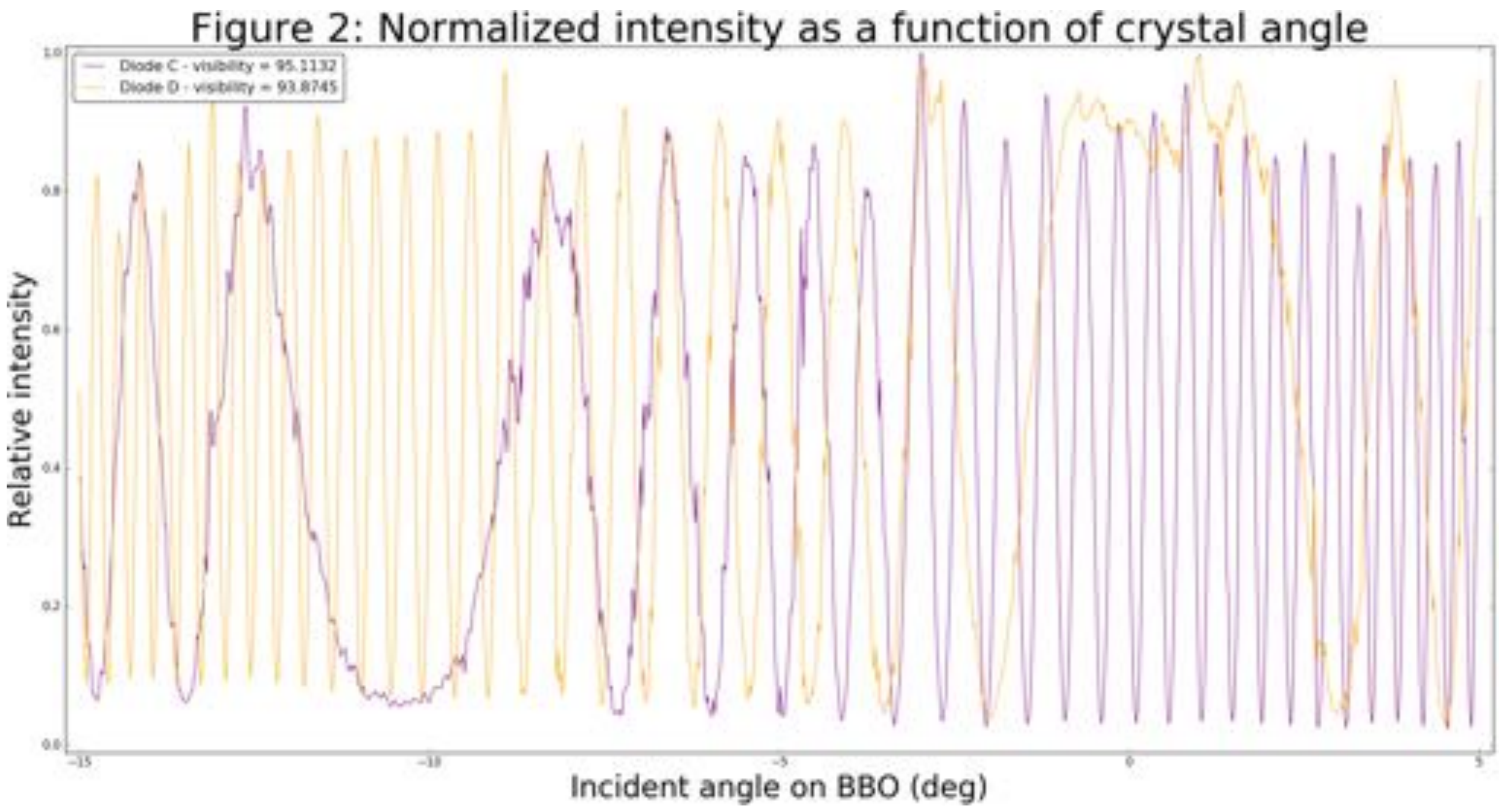

Figure 2: a plot of the normalized intensity of the R_V and R_H output coefficients as a function of the angle of incidence θ_B with the birefringent crystal for a fixed microscope slide.

- A slight oscillation in the height of the intensity peaks was observed (visible in diode C, the violet curve, in figure 2 for the BBO angle between -2.5° and 5°). Assuming that this was the result of a slightly elliptical polarization of the input beam, the wave retarders in the input path were adjusted, and this fluctuation was reduced.

- In figure 2, only the angle of incidence on the birefringent crystal was changed. The final step was to run a trial that measured the intensity of each of the four polarization coefficients for a sweep of BBO angles and microscope slide angles, creating a map of all possible intensities. In doing so, we create an index of microscope slide angles versus BBO angles that allow us to tune the outputs to any combination of intensities.

- A theoretical model was developed to simulate this intensity map, it is shown in figure 3 above. The experiment was then run, those data are shown in figure 4 above.

4 Results & discussion

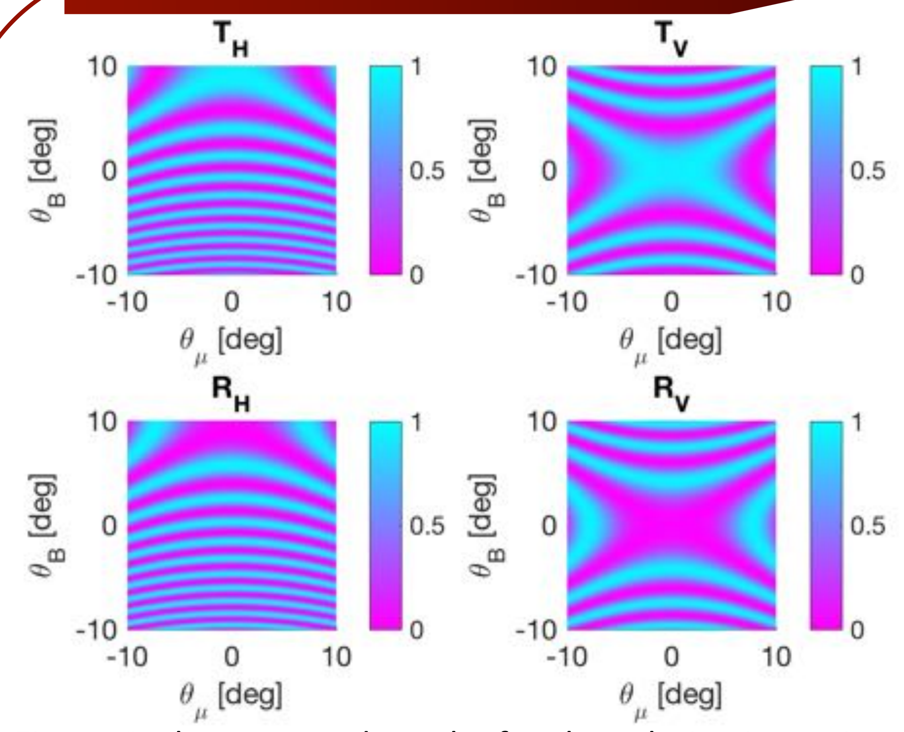

Figure 3: the expected results for the relative intensity of the four polarization coefficients as functions of the angles of incidence on the BBO and microscope slide.

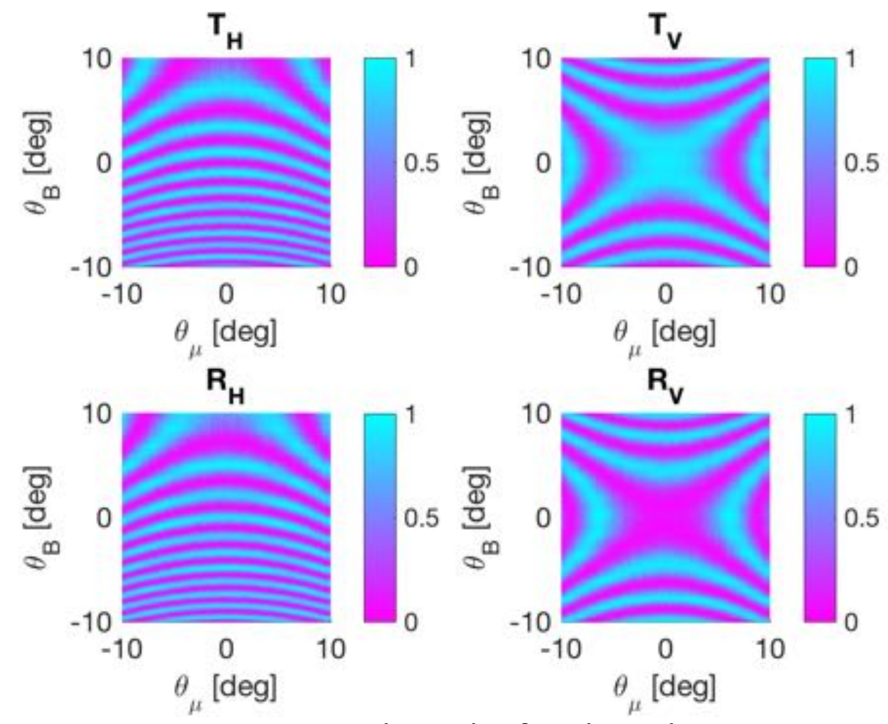

Figure 4: experimental results for the relative intensities of the four polarization coefficients.

As we can see, in experiment the intensities of the polarization coefficients (figure 4) closely match the expected values (figure 3). Because of the asymmetry between the horizontal and vertical coefficients, it is possible to find angles for the BBO and microscope slide that allow us to tune the the coefficients to any values we desire.

5 Conclusion

A variable partially-polarizing beamsplitter was observed, as the output coefficients of the displaced Sagnac interferometer were shown to be independently tunable by rotating the birefringent crystal or the microscope slide. Now that a VPPBS has been constructed, a number of experiments that require independent tuning of polarization coefficients can be performed, including building the logic gate for a basic quantum computer. The VPPBS could be improved by replacing the birefringent crystal and microscope slide with liquid crystal cells. Liquid crystal cells can act as variable wave retarders, controlling the output coefficients by modulating their voltage, avoiding the rotating mounts.

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References

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