Polarisation and Birefringence

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Contents

- Experimental Setup
- Theory
- Results
- Next Steps
- Conclusion

Introduction

- This experiment investigates how birefringent wave plates affect the polarisation state of laser light.
- We use Jones matrices to model the behaviour of light as it passes through wave plates and polarisers,
- By rotating the wave plates, we can analyse changes in polarisation and measure resulting intensities at the detector,
- The results are compared to theoretical predictions.

Experimental Setup

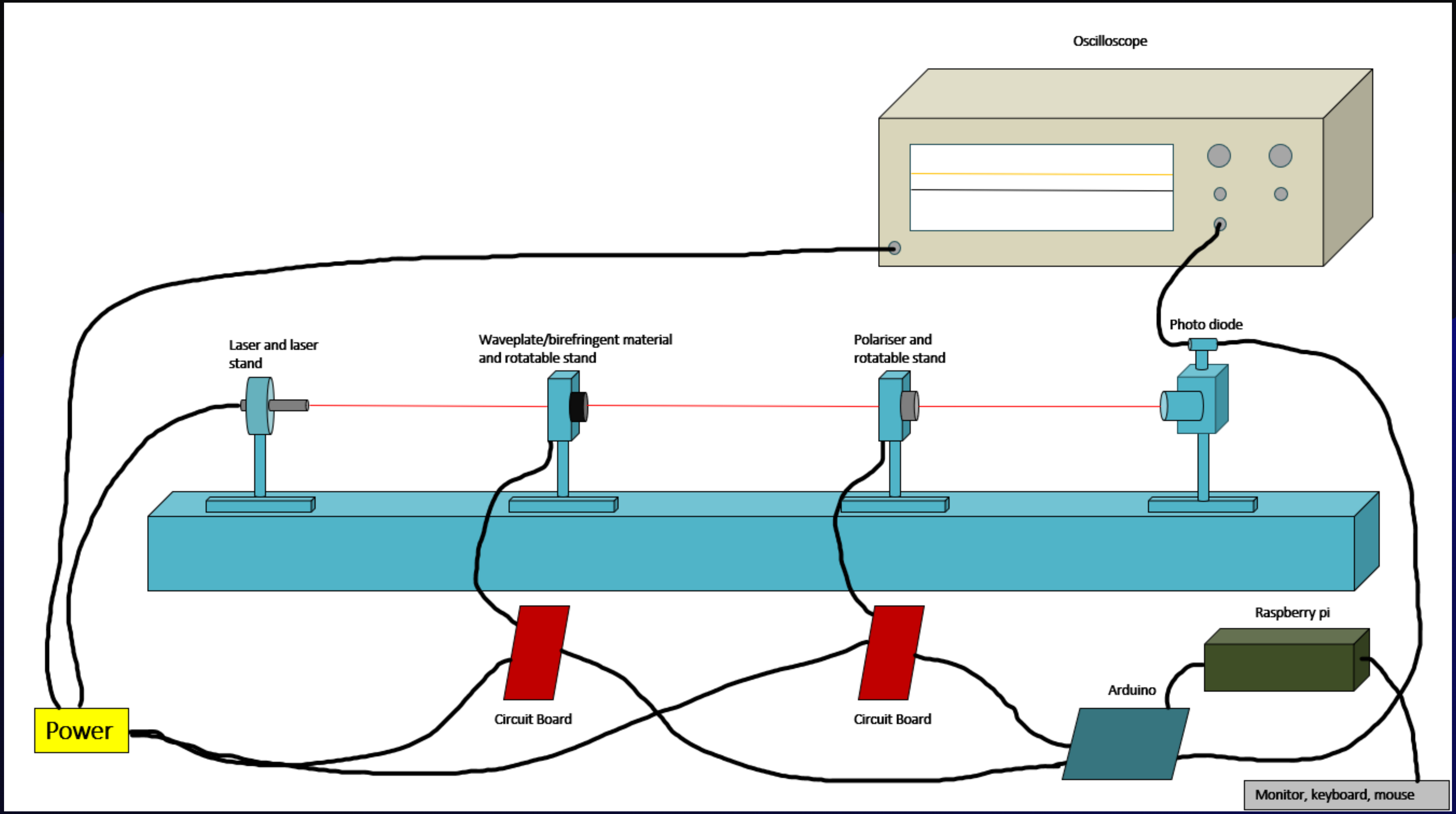

Figure 1

Parameters

- A linearly polarised red laser is used, with wavelength 635nm.
- Custom written code was developed, connected via serial USB to the two piezoelectric motors for the polariser and wave plate.
- Both wave plates investigated have thickness 3.2mm.
- One set of results takes about 10 minutes to record due to response waiting from motors to report back they have rotated, as well as actual rotation times.

Electric Field Vector

$$\boldsymbol{E}_{\text{in}} = e^{i(kz-\omega t)}\begin{bmatrix} E_x \\ E_y \end{bmatrix}$$

- Electric field is a 2D vector in the plane parallel to propagation (transverse).
- Polarised horizontally such that the y component is zero.

Theoretical Prediction

$$\mathbf{D} = \mathbf{J}_P \mathbf{M}_{WP} \mathbf{E}_{in}$$

- Combination of Jones matrices representing the optical components

Wave Plate Matrix

$$\mathbf{J}(\theta, \delta) = \begin{bmatrix} \cos^2\theta + e^{i\delta}\sin^2\theta & (1 - e^{i\delta})\cos\theta\sin\theta \\ (1 - e^{i\delta})\cos\theta\sin\theta & \sin^2\theta + e^{i\delta}\cos^2\theta \end{bmatrix}$$

- A birefringent material has a refractive index dependent on the polarisation of incoming light, different n for the two perpendicular axes (fast and slow)
- Light with components in both perpendicular directions then undergo a phase delay due to the combined waves called the retardence (delta).

Half Wave Plate

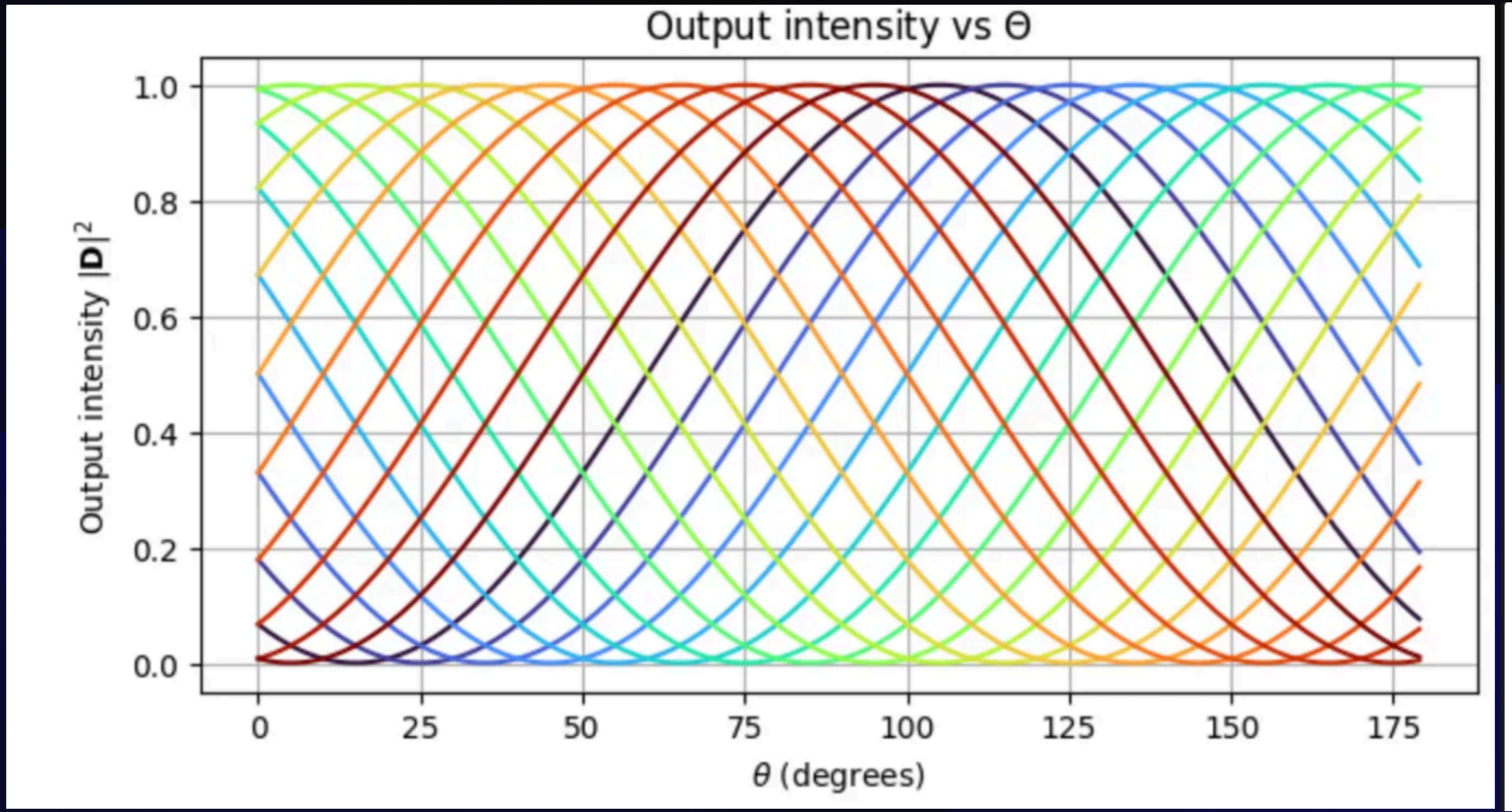

Figure 2: Theoretical

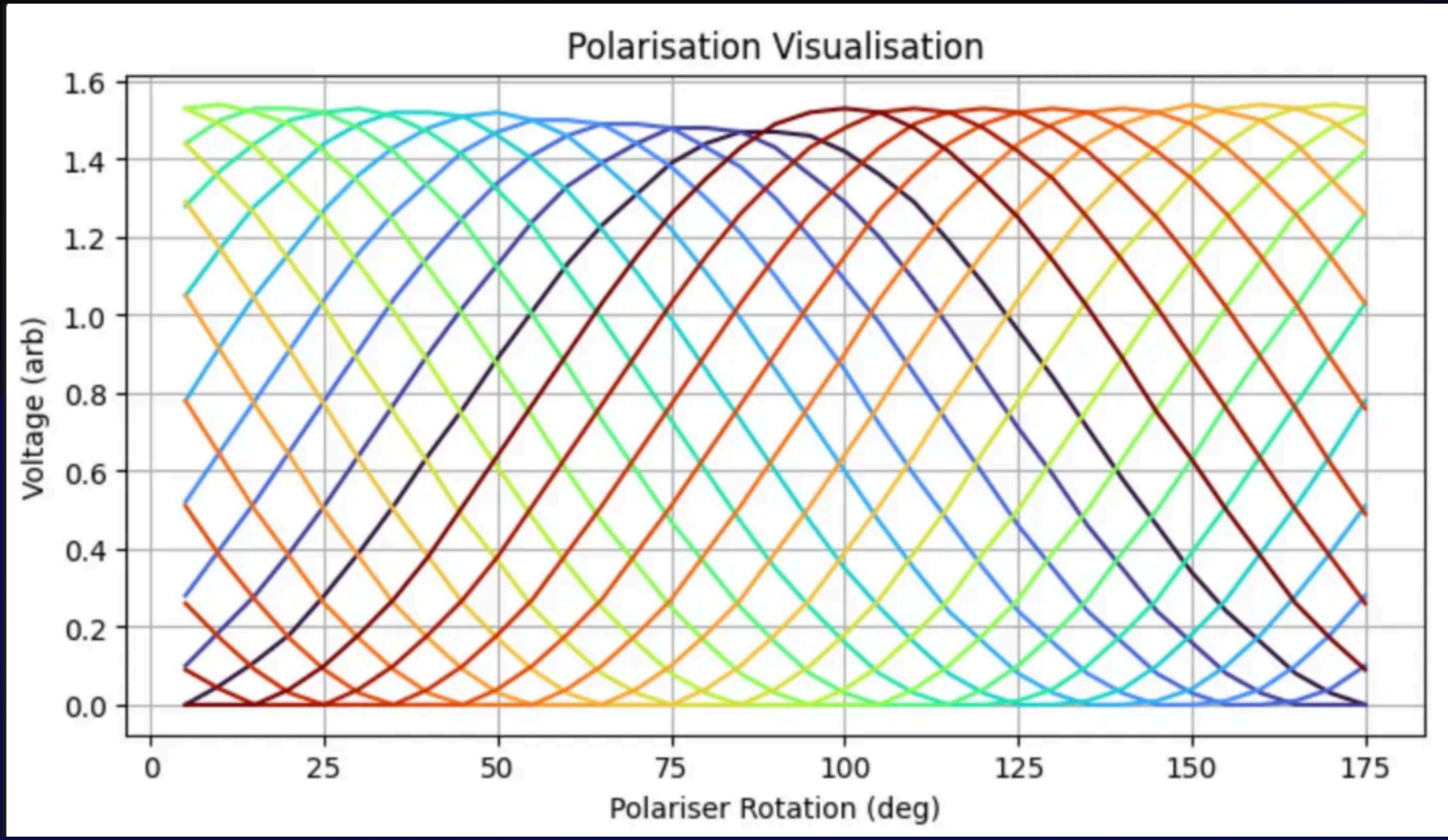

Figure 3: Experimental

Quarter Wave Plate

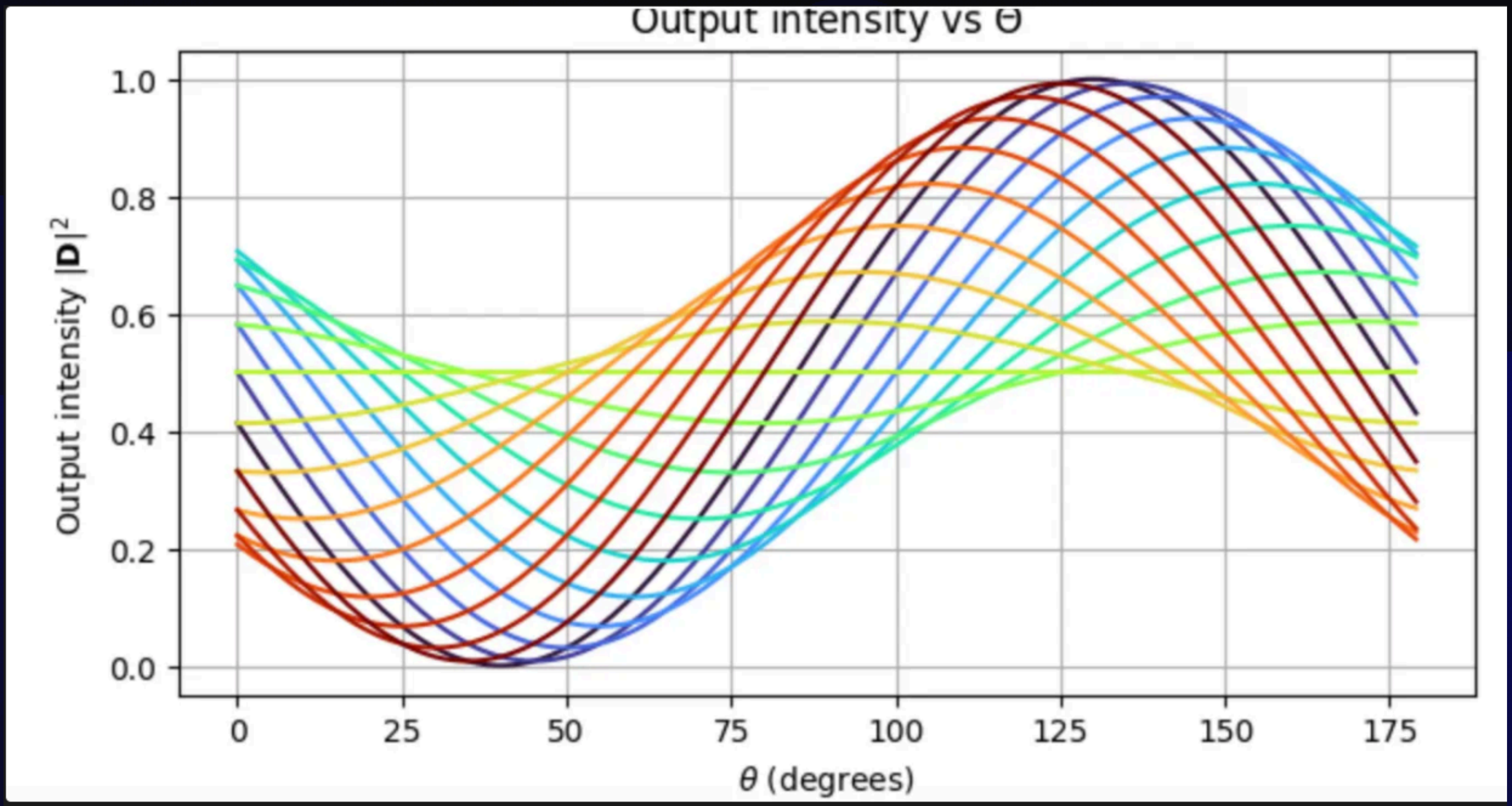

Figure 4: Theoretical

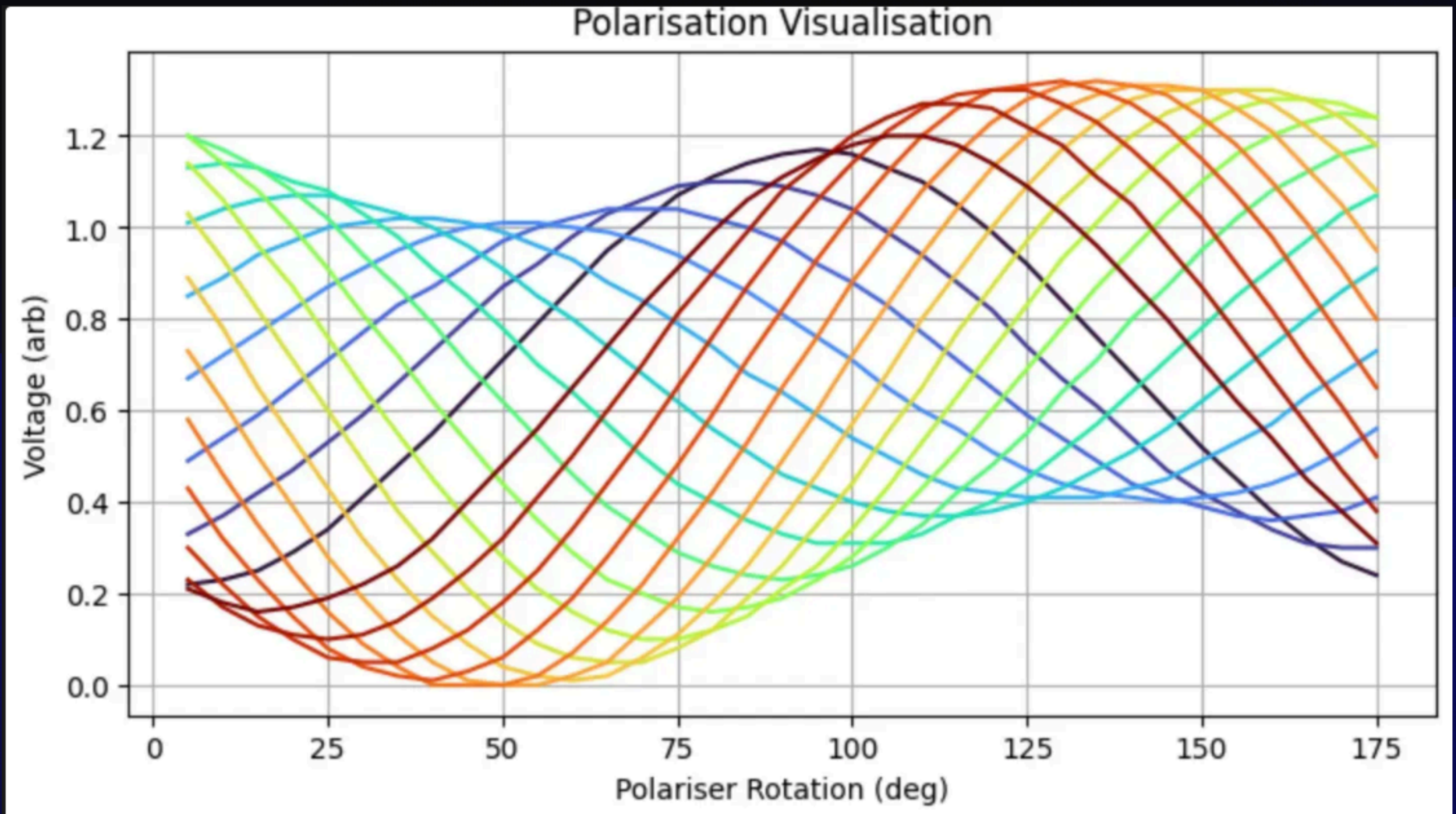

Figure 5: Experimental

Sellotape Results

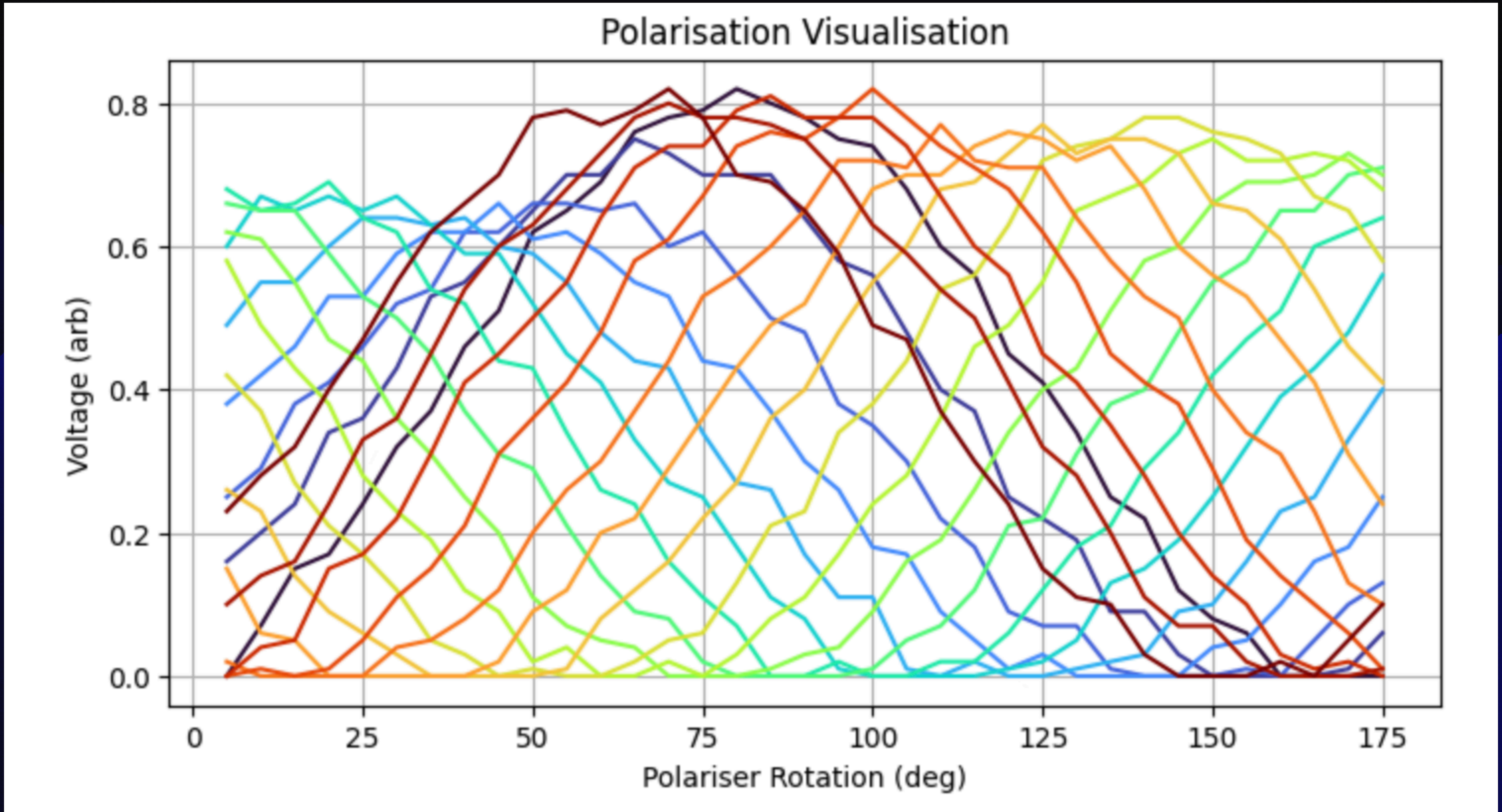

Figure 6

Next Steps

- Determine distinct values for the retardence for birefringent materials,
- Examine data for different angles of incidence,
- Send light through liquids and other possibly birefringent materials,
- Analyse different combinations of wave plates,
- Sellotape stress induced birefringence (photo-elasticity).

Conclusion

- Investigated how birefringent wave plates modify the polarisation of light,
- Observed how data matches the theoretical predictions using Jones analysis,
- Rotating the wave plates produce sinusoidal intensity variation.
- Sellotape shows consistent polarisation effects similar to half wave plates,
- Results validate the power of Jones calculus on modern polarisation optics.