Circular Polarisation of Light for Optical Pumping in TRINAT

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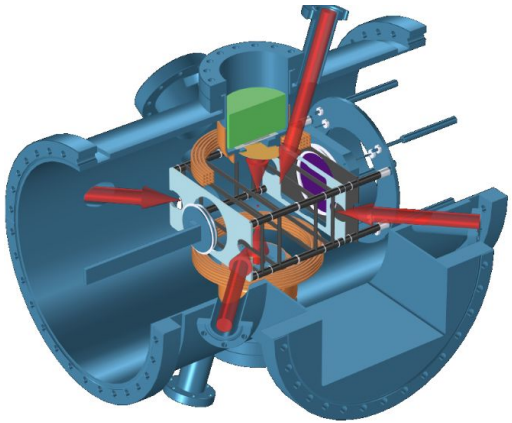
Overview

- TRINAT
- Motivation for Circular Polarisation
- Twisted Nematic Liquid Crystal
- Quarter Wave Plates
- Linear Polariser Mechanical Addition
- Results in Circular Polarisation Improvement
- Optical Fiber Coupling

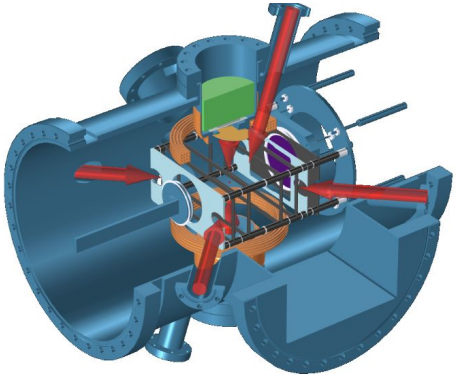
TRINAT

- **TRI**umf's **N**eutral **A**tom **T**rap
- Goal: Measurements of the angular asymmetry of β particles w.r.t nuclear spin from the beta decay of spin polarised nuclei
- Spin polarisation of nuclei achieved by optical pumping in the atom trap



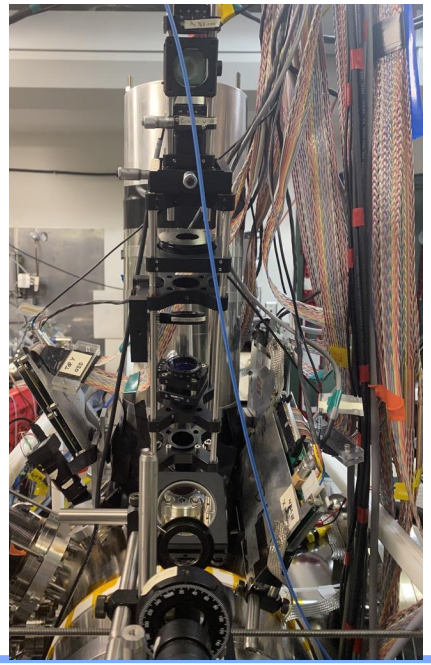
Motivation for Circular Polarisation

- Optical Pumping is done by shining circularly polarized light onto atoms in the trap
- Better nuclear spin comes from better circular polarisation
- To make precise measurements of beta decay we flip the spin every 16 s and take an average of the two measurements



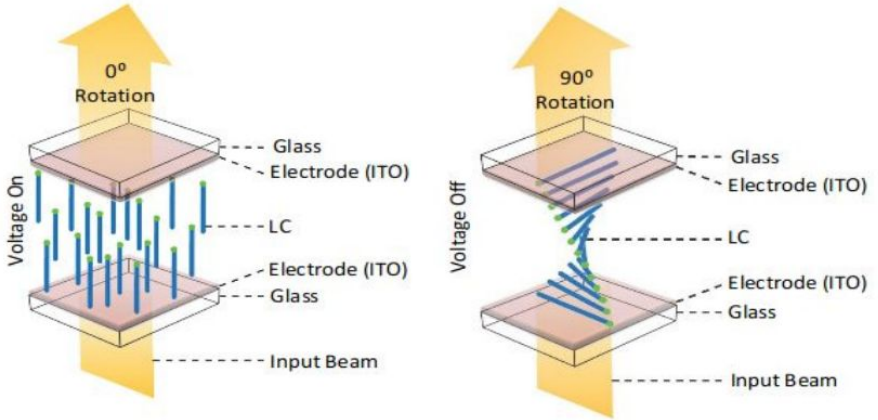
Motivation for Circular Polarisation

- The flipping of the spin requires flipping of the circularly polarised light
- Previously achieved using a Liquid Crystal Variable Retarder
- Now we use a Twisted Nematic Liquid Crystal



Twisted Nematic Liquid Crystal

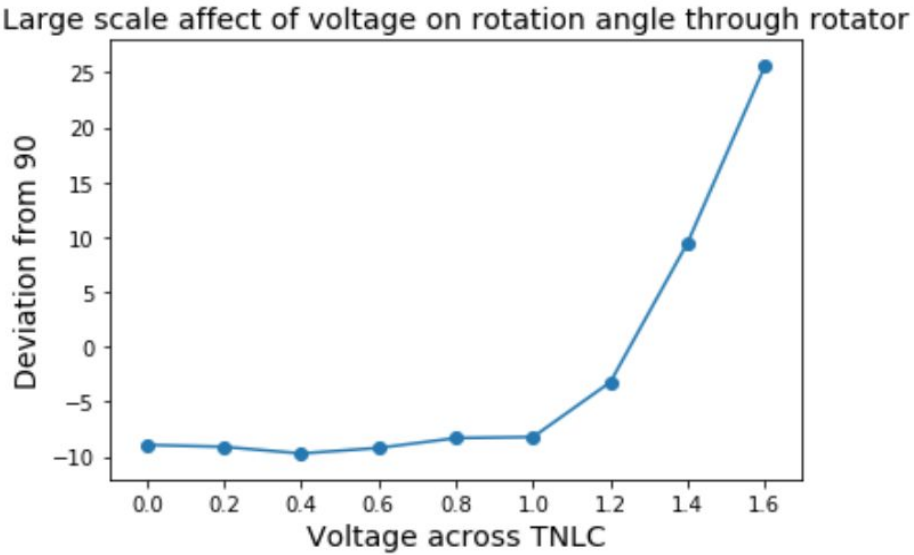
- Two possible states:
- 0° or 90° flip in the linearly polarised light
- Switch between two states by applying a voltage across the crystal
- This light goes through QWP to be circularly polarised



[Meadowlark Optics Binary Liquid Crystal Rotator]

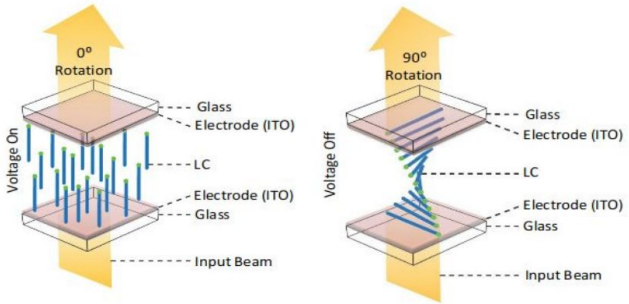
Twisted Nematic Liquid Crystal Results

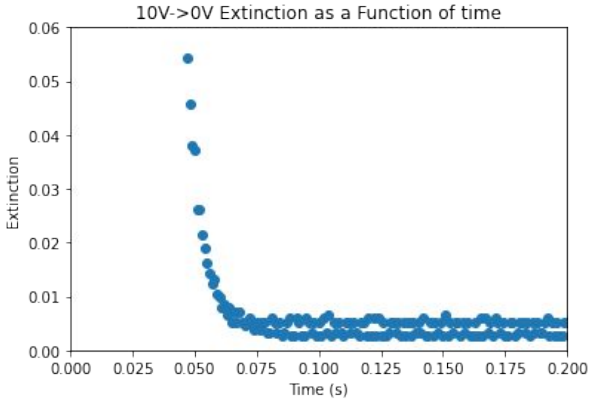
- Does not flip 90 degrees as expected
- Used different voltage combinations to compensate for this
- Voltage drifted over a year



Twisted Nematic Liquid Crystal Time Dependance

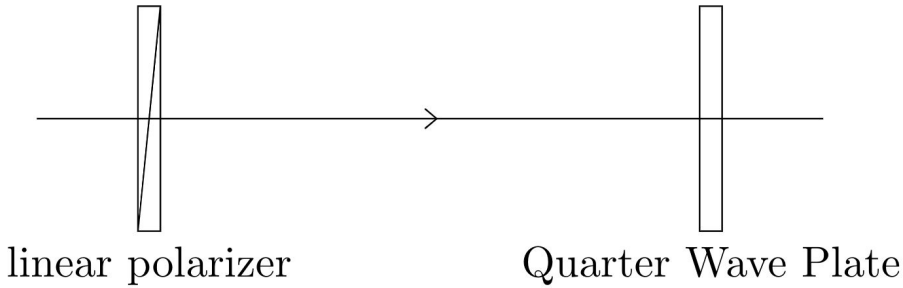
- Low to High Voltage happened very quickly
- High to Low Voltage was much slower





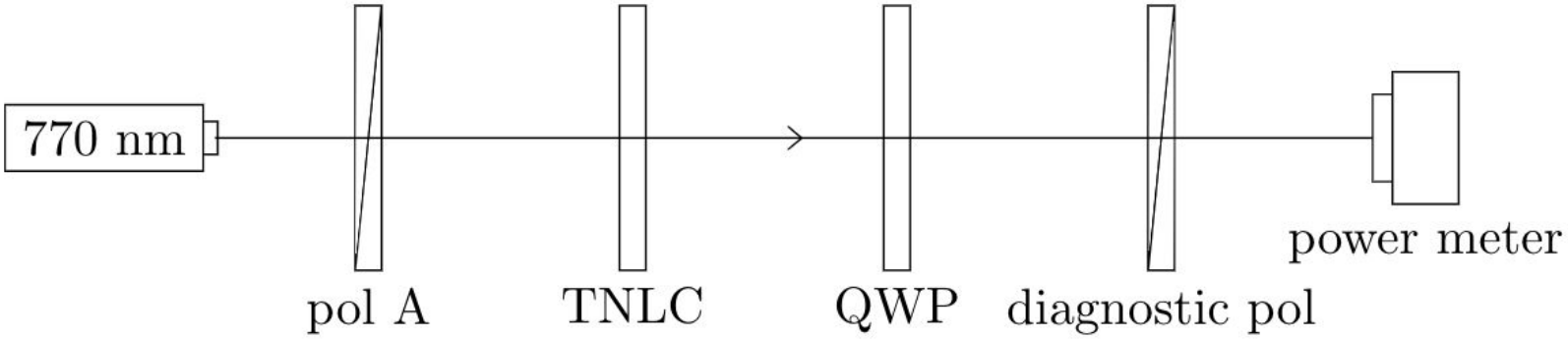
Making Circularly Polarised Light

- Linearly polarised light incident on Quarter Wave Plate (QWP)
- The axis of polarisation should be at a 45° angle from the QWP fast axis



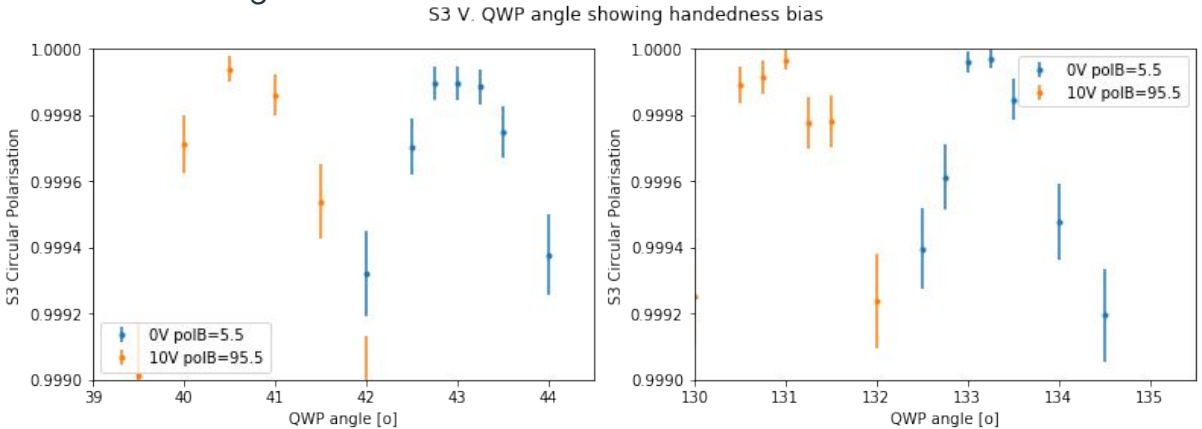
Quarter Wave Plate Analysis

- Investigated the circular polarisation using setup below
- Using Stoke's Parameters : S_3 → **Circular Polarisation**



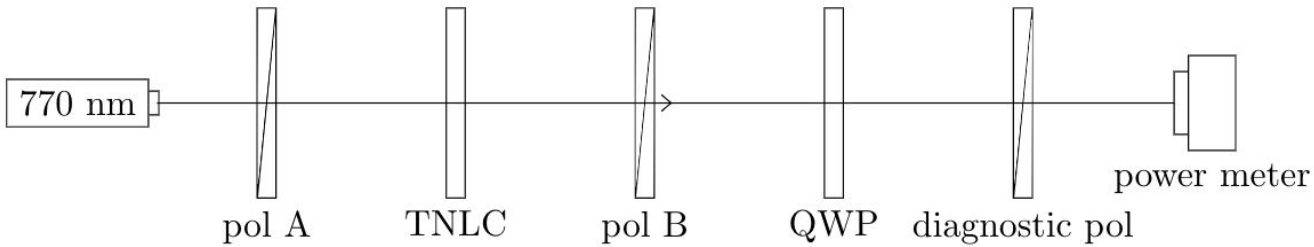
Quarter Wave Plate Peak Separation

- Circular polarisation achieved was excellent compared to previous measurements
- Peaks of the S_3 are not well aligned



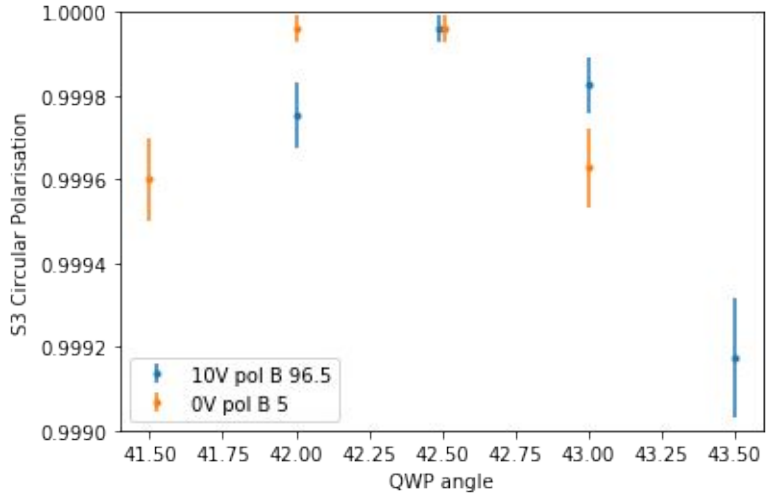
Adding Linear Polariser

- Linear polariser goals:
- Clean up any non-linear light after TNLC
- Compensate for imperfect 90° flip



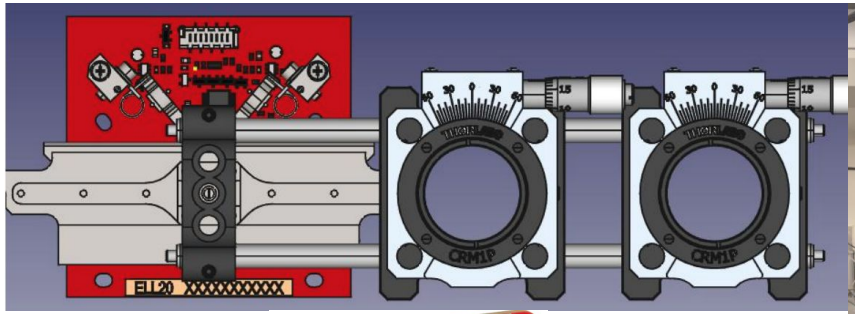
Adding Linear Polariser Results

- Comparison between with and without the linear polariser
- Compensation for TNLC rotation was achieved
- S_3 improved:
- **0.9992** without polariser
- **0.99996** with polariser
- Still need to switch between two states

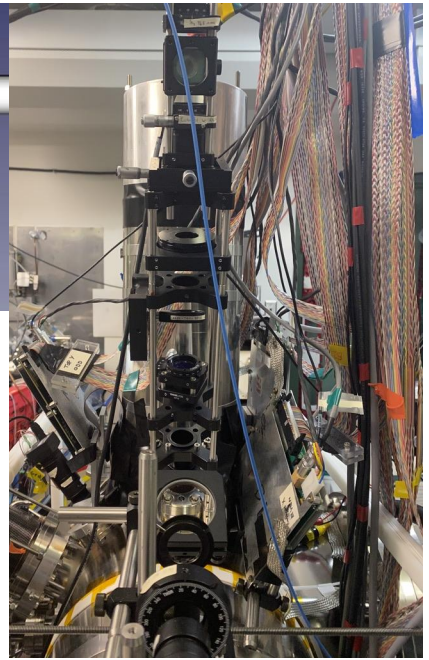


Mechanical Polariser Mounts

Linear Stage:
- "Heavy"
- Unreliable movement

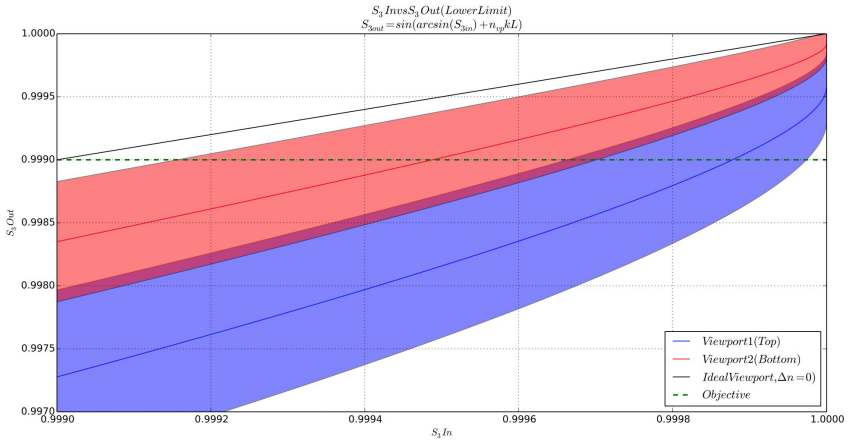


Rotation Stage:
- Light weight
- Reliable rotation



Circular Polarisation Improvement Results

- Taken from Claire Warner's co-op report
- S_3 quality goes down as it passes through viewport
- S_3 in: **0.99996**
- S_3 out: **0.9995**



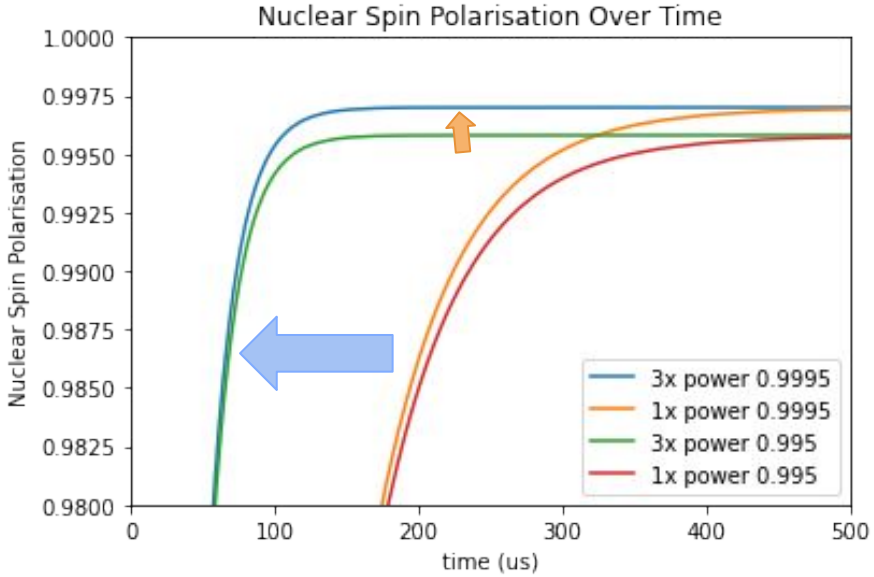
Circular Polarisation Improvement Results

Before

- S_3 in trap: 0.995
- Nuclear Spin Polarisation: 0.9958

After

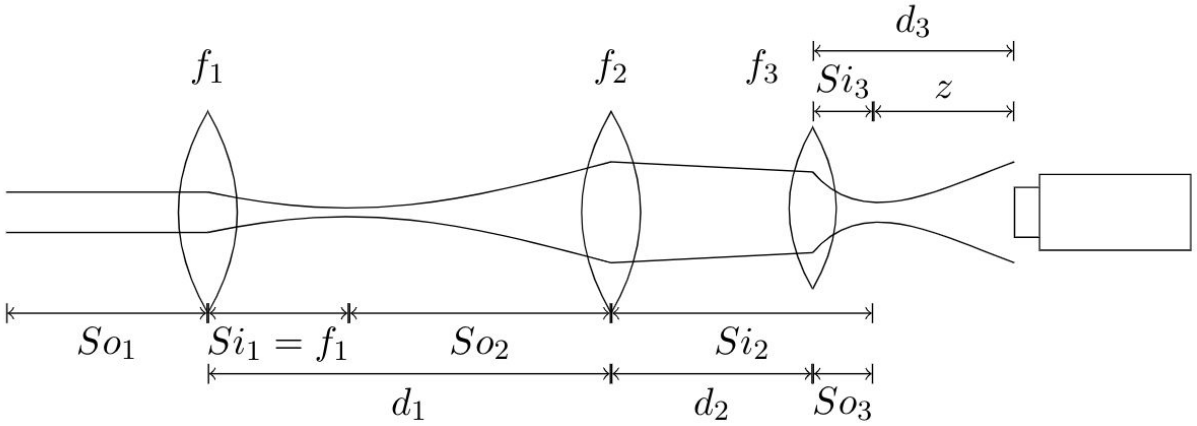
- S_3 in trap: 0.9995
- Nuclear Spin Polarisation: 0.9970



[Ben Fenker, Texas AMU "Optical Bloch Equations"]

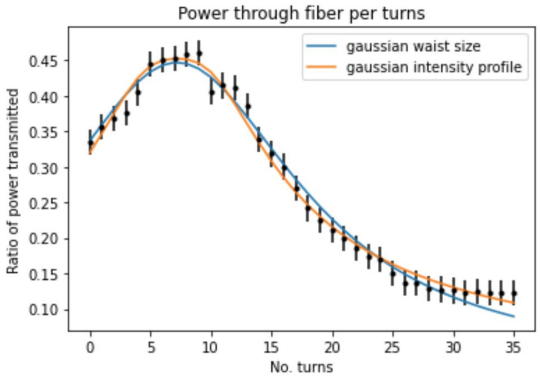
Optical Fiber Coupling

- Light brought to the trap with optical fiber
- Optimized the power through the fiber using set up below



Optical Fiber Coupling

- Laser diode was changed since previous measurement
- 3x improvement in power
- Decreases the time it takes to polarise nuclei



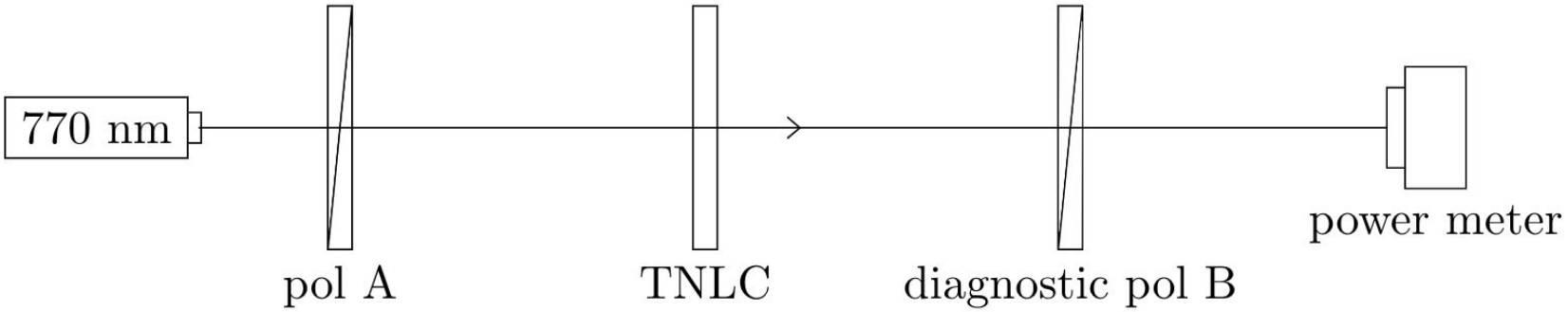
Summary

- Twisted Nematic Liquid Crystals improvement
- Designed a mechanical system to allow for an additional linear polariser
- Circular polarisation improved by an order of magnitude
- Optical Fiber Coupling got 3 x the power transmitted than previously achieved

QUESTIONS?

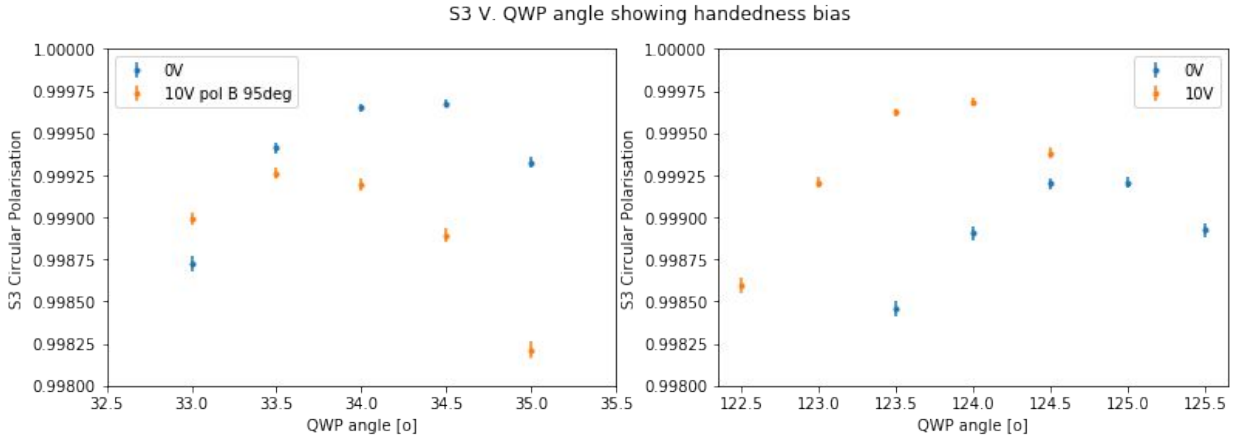
Twisted Nematic Liquid Crystal Testing

- Using a diagnostic polariser, check how well the light is being flipped in the TNLC
- By testing the linear polarisation, get a sense of the circular polarisation quality



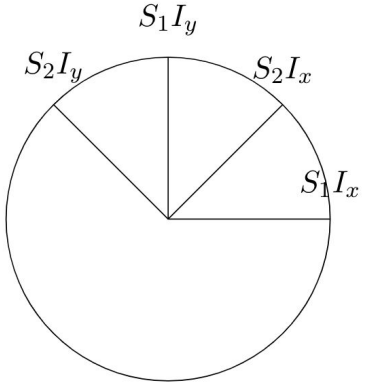
Quarter Wave Plate Handedness Bias

- One orientation is favoured over the other
- Peaks of the S3 are not well aligned



Measuring Circularly Polarised Light

- Using Stoke's parameters, take four power measurements with a linear polariser at 4 angles
- S3 is the circular polarisation of the light
- Previous S3 in the trap was: **0.995**



$$S_1 = \frac{S_1 I_x - S_1 I_y}{S_1 I_x + S_1 I_y}$$

$$S_2 = \frac{S_2 I_x - S_2 I_y}{S_2 I_x + S_2 I_y}$$

$$S_{lin}^2 = S_1^2 + S_2^2$$

$$S_3 = \sqrt{1 - S_{lin}^2}$$

Larmor Precession Limiting

- The Larmor precession is fighting optical pumping
- The spin tries to align itself with the magnetic field
- Nuclear spin polarisation -> 0.9998