An Efficient modulation scheme for dual Beam Polarimetry and the calibration of Kodaikanal Tower Telescope Polarimeter

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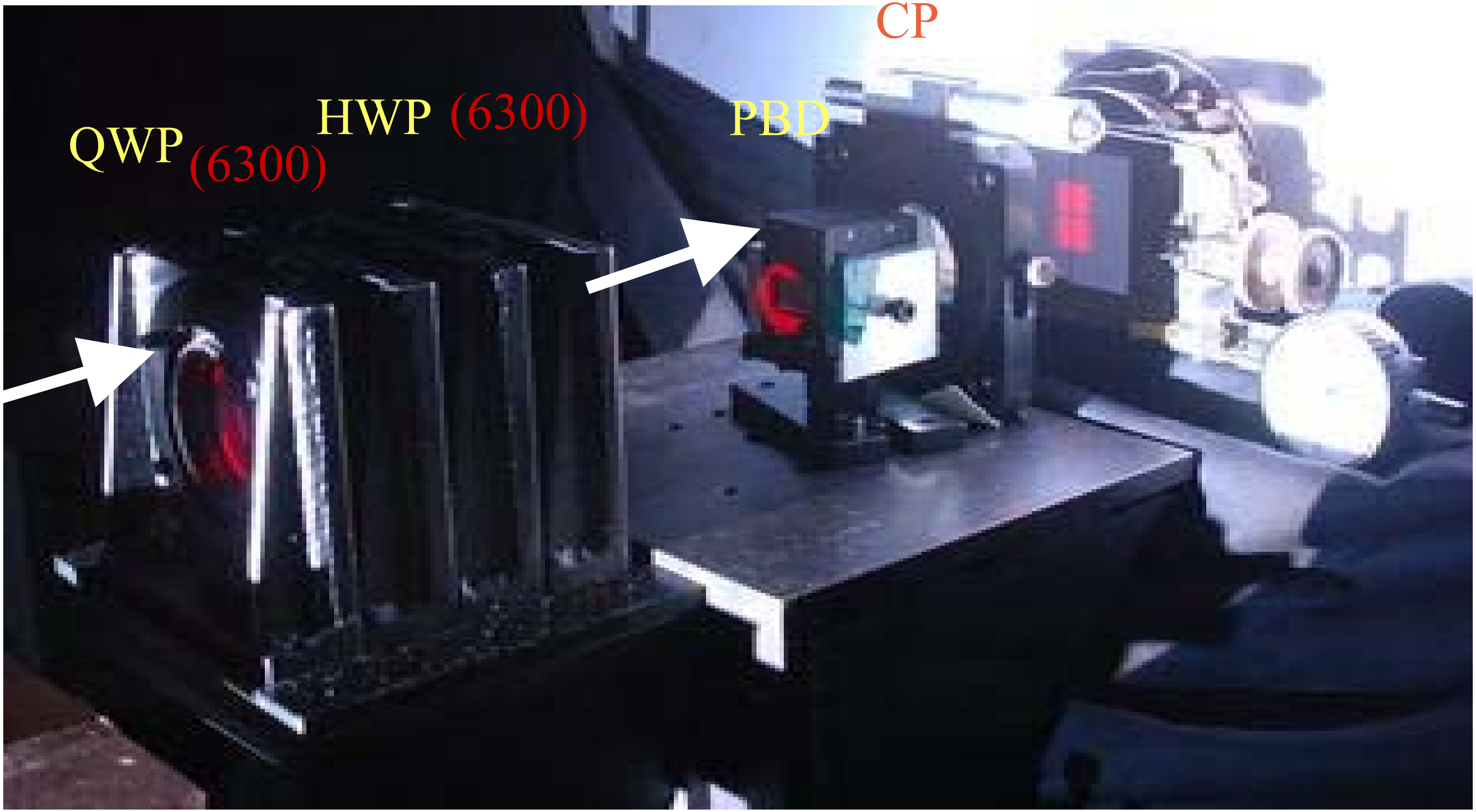
Introduction

- Polarimetric accuracy is one of the most important goals in modern astronomy.
- Most of the optical elements encountered by light alter its polarization state.
- For ground based polarimetry, ‘seeing’ induces large variation. Fast modulation can be used to beat the seeing fluctuations. But the technology is expensive.
- A low cost dual beam polarimeter that we have proposed compromises on time resolution but improves on the accuracy compared to single beam fast modulation systems.
- But we can use a theoretically sound modulation scheme to improve the polarimetric efficiency.

Two beam polarimeter setup at Kodaikanal Tower Telescope



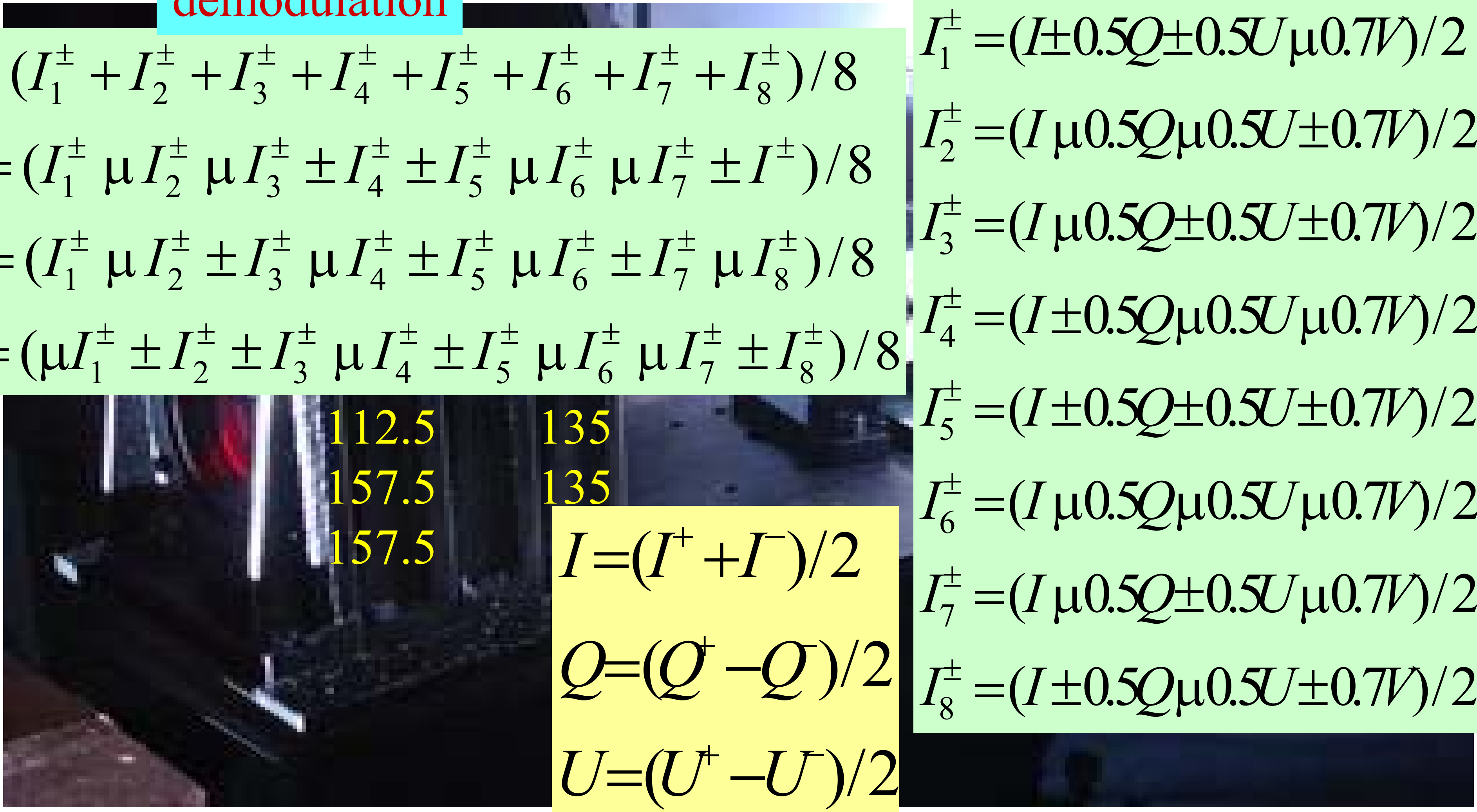
demodulation

$$= (I_1^\pm + I_2^\pm + I_3^\pm + I_4^\pm + I_5^\pm + I_6^\pm + I_7^\pm + I_8^\pm)/8$$

$$= (I_1^\pm \mu I_2^\pm \mu I_3^\pm \pm I_4^\pm \pm I_5^\pm \mu I_6^\pm \mu I_7^\pm \pm I^\pm)/8$$

$$= (I_1^\pm \mu I_2^\pm \pm I_3^\pm \mu I_4^\pm \pm I_5^\pm \mu I_6^\pm \pm I_7^\pm \mu I_8^\pm)/8$$

$$= (\mu I_1^\pm \pm I_2^\pm \pm I_3^\pm \mu I_4^\pm \pm I_5^\pm \mu I_6^\pm \mu I_7^\pm \pm I_8^\pm)/8$$



$$I = (I^+ + I^-)/2$$

$$Q = (Q^+ - Q^-)/2$$

$$U = (U^+ - U^-)/2$$

$$V = (V^+ - V^-)/2$$

modulation

$$I_1^\pm = (I \pm 0.5Q \pm 0.5U \mu 0.7V)/2$$

$$I_2^\pm = (I \mu 0.5Q \mu 0.5U \pm 0.7V)/2$$

$$I_3^\pm = (I \mu 0.5Q \pm 0.5U \pm 0.7V)/2$$

$$I_4^\pm = (I \pm 0.5Q \mu 0.5U \mu 0.7V)/2$$

$$I_5^\pm = (I \pm 0.5Q \pm 0.5U \pm 0.7V)/2$$

$$I_6^\pm = (I \mu 0.5Q \mu 0.5U \mu 0.7V)/2$$

$$I_7^\pm = (I \mu 0.5Q \pm 0.5U \mu 0.7V)/2$$

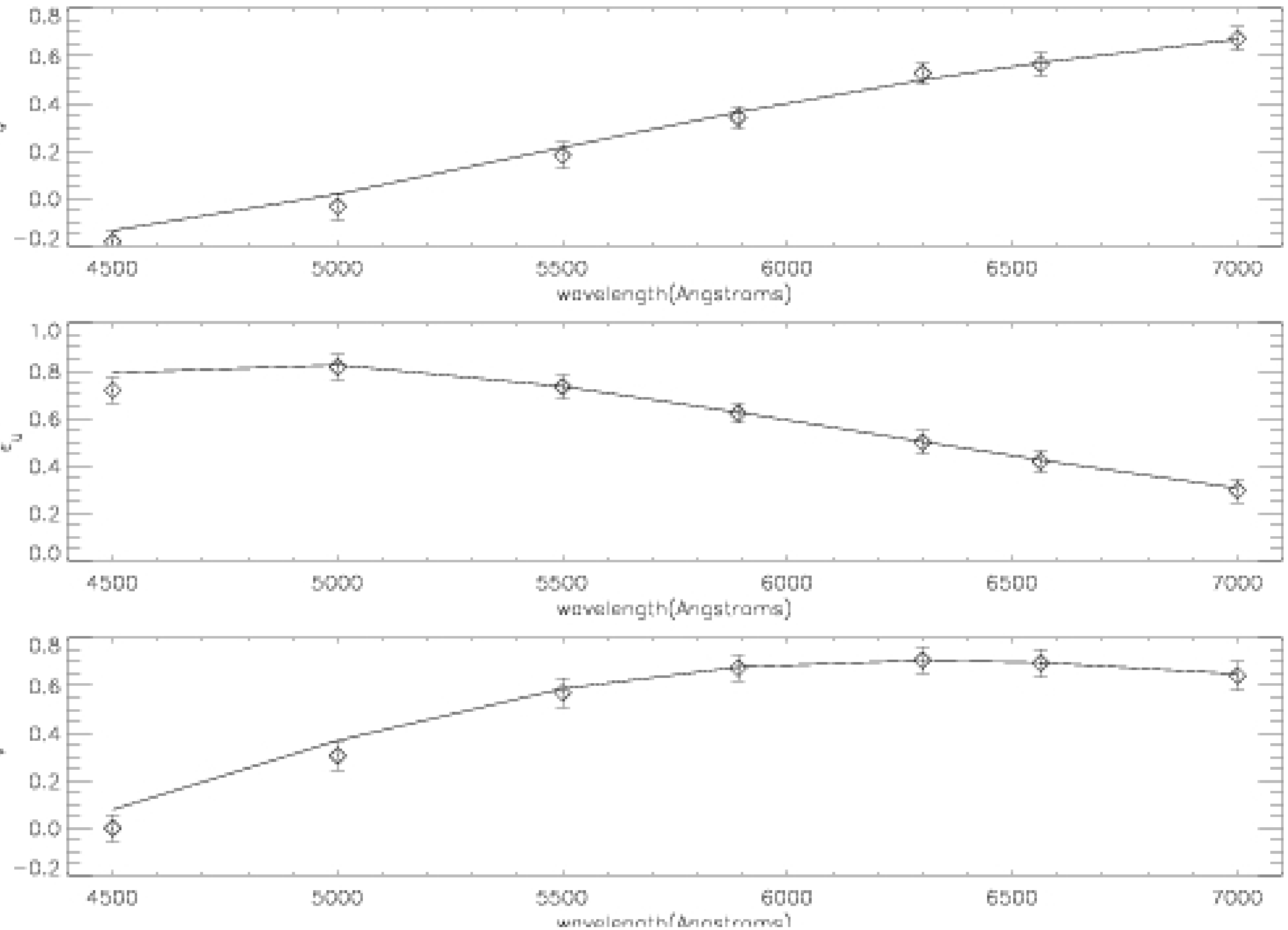
$$I_8^\pm = (I \pm 0.5Q \mu 0.5U \pm 0.7V)/2$$

- The modulation scheme is well balanced because each Stokes parameter is weighted equally in all eight stages of measurements.
- The maximum efficiencies in Stokes I,Q,U and V are ε = (1.0,0.5,0.5,0.707) and so the total efficiency of the scheme is 0.9999.
- For comparison, ASP is (1.0,0.546,0.41,0.659) giving 0.9 and ZIMPOL (1.0,0.474,0.467,0.534) with 0.728 as total efficiencies.

- An experiment was setup to study the efficiencies in different wavelengths because the retarders are not achromatic.

Experiment to study polarimetric efficiency

Wavelength dependence of polarimetric efficiency



Calibration of polarimeter installed at KTT

- To calibrate the polarimeter, a calibration unit consisting of a linear polarizer followed by a quarter wave plate at 6300A was used. We made several sets of measurements on different days to check the stability of the system using Sunlight.
- This gave us the Mullar matrix of the polarimeter to be:

Calibration of the polarimeter

CU unit:
Linear polariser
Retarder

$$S_{meas} = M_{pol} S_i$$

$$M_{pol} = \begin{bmatrix} 1.0 & -0.0066 & 0.0383 & 0.0461 \\ 0.014 & 0.478 & 0.0561 & 0.00 \\ 0.022 & 0.019 & 0.494 & -0.003 \\ -0.0005 & -0.0073 & 0.0007 & 0.669 \end{bmatrix}$$

$$\Delta\varepsilon_Q = 0.4\% \quad \Delta\varepsilon_U = 0.4\% \quad \Delta\varepsilon_V = 0.27\%$$

Conclusions

- The measured total polarimetic efficiency is 0.986 at 6563A wavelength region.
- The eight stage modulation allows beam swapping technique so that the gain terms introduced by various optical components are eliminated.
- It is found from computer simulation that a 14% sky transparency variation can cause 1.8% uncertainty in the elements of the polarimetric response matrix.

Acknowledgments

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