WALOP-South: A wide-field one-shot linear optical polarimeter for PASIPHAE survey

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PASIPHAE Survey

Polar-**A**reas **S**tellar **I**maging in **P**olarization **H**igh **A**ccuracy **E**xperiment[1,2] is a collaborative project between IUCAA (India), Caltech (USA), Univ. Of Crete (Greece), SAAO (South Africa) and Univ. Of Oslo (Norway). It aims to create the first large sky optical polarization map using two wide-field, high accuracy optical linear polarimeters called **WALOP** (Wide-Area Linear Optical Polarimeter).

PASIPHAE Survey Outline:

1. Survey Instruments:
   A. *WALOP-South* on 1 m SAAO telescope, South Africa.
   B. *WALOP-North* on 1.3 m Skinakas Observatory telescope, Greece.
2. Cover 4000 square degrees of sky in Galactic polar regions.
3. Measure optical linear polarization of stars with 0.1% accuracy in SDSS-r band.
4. Measure polarization of $>10^6$ stars; current catalogues have 10^4 stars[3].
5. Use stellar polarimetry data in conjugation with distances from GAIA to create a 3-d map of magnetic field and dust clouds of the galaxy[2,4].

- Both WALOP instruments are currently under development in IUCAA. WALOP-South scheduled for commissioning first in 2021.

WALOP-South Instrument Design Goals

Parameter	Design Value
Polarimetric Sensitivity	0.05 %
Polarimeter Type	Four Channel One-Shot Linear Polarimetry
Number of Cameras	4 (one camera per channel)
Field of View (FOV)	30 x 30 arcminutes*
Detector Size	4k x 4k (pixel size = 15µm)
Primary Filter	SDSS-r
Imaging Performance	Close to seeing limited PSF
Stray and Ghost Light Level	Brightness less than sky background

Table 1: Design goals for WALOP-South instrument.
* Obtained field of view is 35 x 35 arcminutes.

Optical Design

The optical model[5] (Fig 1) consists of the following sub-assemblies:

1. *Collimator:* Starts at telescope focal plane, creates a 65 mm pupil.
2. *Polarizer Assembly*: Splits pupil beam into 0^0, 45^0, 90^0 and 135^0 polarization channels. Sends them along +/- x and +/-y directions.
3. Four *cameras:* one for each channel, images the FOV on 4k x 4k detector.

- Expected on-sky Optical Performance: Near seeing limited PSF (FWHM < 1.6 seeing FWHM) for all cameras.

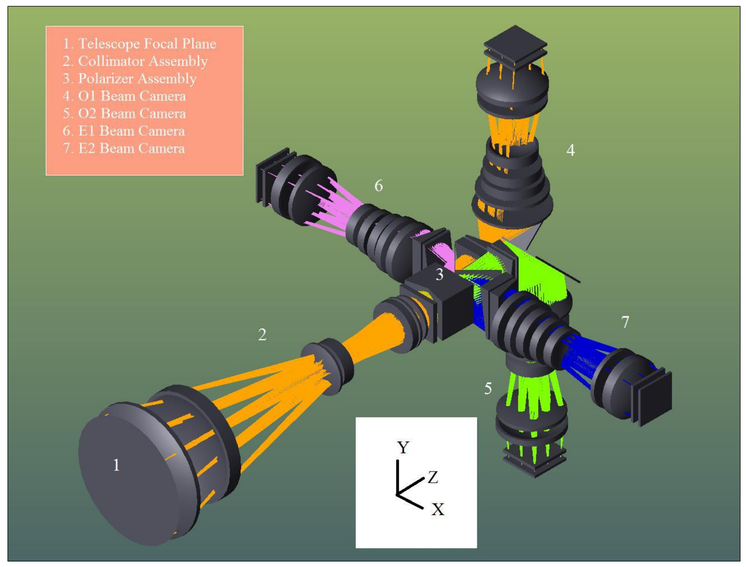

Fig 1. Complete optical model of WALOP-South instrument.

Polarizer Assembly (Fig 2): Most novel aspect of WALOP-South optical design. Functions as the polarization analyser unit. Consists of :

(a) Wollaston Prism Assembly.

1. Two identical large aperture (45 x 80 mm) calcite Wollaston Prisms (WP) with a Half-Wave Plate cemented in front of each WP.
2. Left HWP fast axis at 0^0 wrt WP, does not affect the beam EVPA.
3. Right HWP fast axis 0^0 wrt WP, rotates the EVPA by - 45^0.
4. Left WP separates 0^0 and 90^0 polarizations: to find q.
5. Right WP separates 45^0 and 135^0 polarizations : to find u.
6. BK7 Wedge in front of each HWP prevents vignetting and scattering at interface of the two WPs from off-axis field points.

(b) Wire-grid Polarization Beam Splitters (PBS): PBS' allows 0^0 and 45^0 channels, but fold 90^0 and 135^0 beams along +/- x direction.

(c) Fold Mirrors fold the 0^0 and 45^0 channels along +/- y directions.

Major Challenge in WALOP South Optical Design:
Calcite Wollaston Prisms with large split angle (11.5^0) used. The split beams have large spectral dispersion (R~80). Problem for broadband imaging polarimetry.

- Corrected by placing glass prisms before each camera.

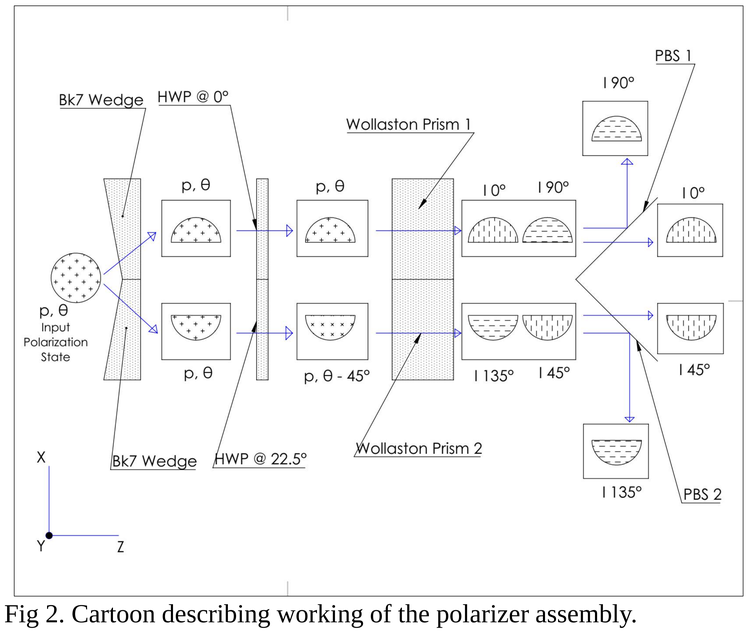

Fig 2. Cartoon describing working of the polarizer assembly.
The polarizations annotated are as seen in x-y plane when seen in z-axis.

Optomechanical Design

An advanced optomechanical design for the instrument has been developed.

- Includes an custom made auto-guider camera for the instrument.
- Incorporates multiple motion, thermal and electrical control systems.
- Many lenses have tight alignment tolerances of around 10-20 µm. Optomechanical design developed taking this into consideration.
- Collimator and the four cameras are designed in form of barrels (Fig 4). Lenses are mounted on a holder and connected using cylindrical spacers.
- Polarizer Assembly is mounted in a box.

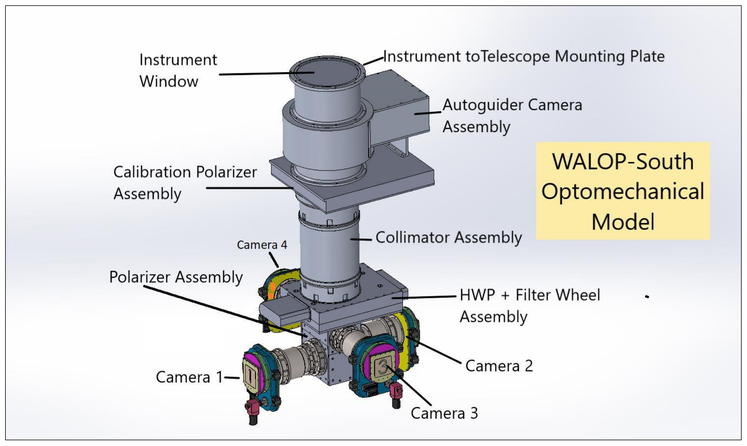

Fig 3: Overall optomechanical model of WALOP-South instrument. Control boxes and connectors are hidden for clarity.

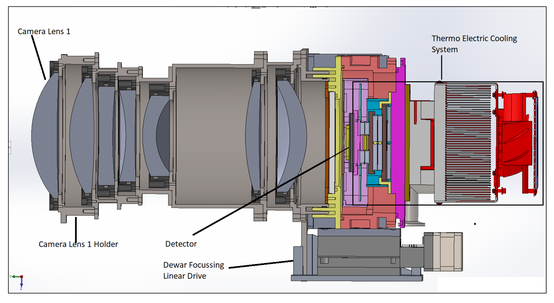

Fig 4: Design of barrel for one of the four cameras.

Summary

1. **We have developed an optical model of instrument capable for four-channel one shot imaging polarimetry.**
2. **Each channel is imaged on a separate camera.**
3. **The optical design corrects for dispersion from Wollaston Prisms enabling wide-field imaging polarimetry in broadband.**
4. **An advanced optomechanical design for the instrument has been developed.**
5. **Scheduled commissioning of instrument in 2021.**

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