

Spectropolarimetry with PEPSI at the LBT: accuracy vs. precision in magnetic field measurements

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Abstract. We present the design of the new PEPSI spectropolarimeter to be installed at the Large Binocular Telescope (LBT) in Arizona to measure the full set of Stokes parameters in spectral lines and outline its precision and the accuracy limiting factors.

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1. Spectropolarimeter

The PEPSI *IQUV* spectropolarimeter being designed for the 2×8.4 m LBT (Strassmeier *et al.* 2008) on Mt. Graham in Arizona has the following principal components:

- The PMMA (acrylic glass) super-achromatic quarter-wave retarder (Samoylov *et al.* 2004) in front of the Wollaston prism is to record circular polarization $I \pm V$ in one exposure. A turn of the retarder by 90° swaps the polarity of the two beams.

- The MgF_2 Wollaston prism (with the retarder being retracted from the optical beam) is to record linear polarization $I \pm Q$ in one exposure and $I \pm U$ once it turned by 45° .

- The two polarized beams emerged from the Wollaston prism are corrected for the atmospheric dispersion and focused on two $200 \mu\text{m}$ entrance fibers of the spectrograph ($R = 130,000$). A fixed fiber viewing CCD camera for accurate centering and guiding on the target star sees the residual light rendered from the rotating beam splitter unit with a flexible single mode fiber bundle.

- Two such identical polarimeters mounted at the two Gregorian focuses of LBT are forming four polarized spectra on a 10.3×10.3 k CCD per arm displaced in cross-dispersion alone by the successive échelle orders. Four subsequent exposures with different polarization configurations at three fixed spectral settings result in the Stokes *IQUV* spectra in the range of 450–1050 nm.

- Calibration unit in front of the science retarder: a Glan-Thompson prism, two super-achromatic retarders optimized for the blue and red, and the wedge de-polarizer. The calibration light of the known polarization state allows to model and restore necessary parameters of the polarimeter versus wavelength: phase delay and axis orientation of the retarder, orientation and relative transmission of the Wollaston prism, and transmission modulation function of the fibers.

2. Precision and accuracy

With the 2×8.4 m LBT telescope at $R = 130,000$ and 10% total efficiency in 1 hour integration time, the polarimeter would attain a precision in Stokes *IQUV* measurements of 10^{-4} for a star of 4th magnitude, and 10^{-3} for 9th magnitude. The accuracy of such measurements will be limited by a number of factors:

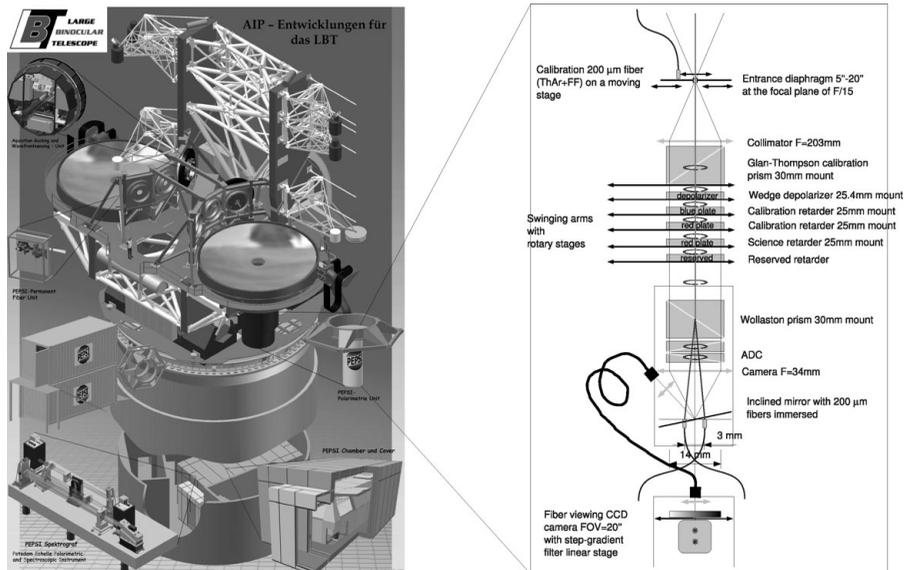


Figure 1. Location of the PEPSI polarimeter on the LBT telescope and its schematic layout.

- The cross-talk between Stokes Q and U induced by a slight misalignment of the Wollaston prism: the relative accuracy in QU of 10^{-3} requires 1 arcmin calibration accuracy of the prism angle.
- The cross-talk between V and QU can be canceled with the turn of the retarder but the residual quadratic terms define the relative accuracy in V up to 10^{-5} if the retardation and axis orientation angles of the retarder are calibrated with the accuracy of 0.1° .
- The entrance collimator lens birefringence can be caused by the mechanical and thermal stresses, anti-reflection coating, and the intrinsic structure of the glass which may lead to a severe cross-talk between Stokes U and V . The use of polarization grade glass (Sun & Adlou 2006) with the path difference less than 1 nm/cm would confine the cross-talk down to 10^{-4} .
- The thermal stability of the polarization elements over a period of time within 1°C is necessary to keep the calibration parameters constant, though, we allow for a slow seasonal variations with the new set of parameters derived.
- Spurious polarization may arise due to CCD fringes and cannot be canceled out: a high quality flat fielding is essential, although, no optical fringes were detected from the PMMA retarders at the level of 10^{-4} .
- The Earth's atmosphere changes the polarization state of the refracted light at large angles of incidence; the effect is of order of only 10^{-5} at zenith distance of 87° .
- The spectrograph stability ($\pm 0.01^\circ\text{C}$ in temperature and $\pm 0.1\text{ mbar}$ in pressure) is essential for the subsequent combination of the polarized spectra obtained in exposures with different configurations of the polarization optics: a drift between two spectra of 10 m/s is equivalent to the Zeeman splitting of a 5G longitudinal magnetic field at 700 nm.

References

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