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Echellé Spectropolarimeter of the BTA Primary Focus: Purpose and Optical-Mechanical Construction

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Abstract. Here we present an optical layout and construction of the new echellé spectropolarimeter ESPRI of the primary focus of the Russian 6-m telescope BTA. We discuss its science case and state of art. The spectropolarimeter control system is realised based on NI myRIO-1900 controller and Xilinx Zyng-7010 CPU.

1. Reasoning

The Main Stellar Spectrograph (MSS) of the 6-m telescope of the Special Astrophysical Observatory was developed in the early 1970s and has been in permanent operation since 1975. This instrument has been successfully kept operational for a long time by equipping it with modern detectors and significantly upgrading its optical layout (Panchuk et al. 2014a). One of the main purposes of MSS was to obtain long-term observational programs (Sachkov 2014). For the future there is a request of astronomers to equip the 6-m telescope with a new instrument which will exceed MSS spectral resolution and a number of spectrum elements that can be observed simultaneously. The important requirement is to take into account a rotation of the field of view of the Alt-Azimuth system of BTA as well as linear polarisation effects on the third BTA mirror. This is the case why the new instrument should be installed onto the moving table of the primary focus cabin of BTA. Based on our experience with the primary focus echellé spectrograph PFES (Panchuk et al. 1998) (spectral resolution $R \approx 14\,000$) we developed a new primary BTA focus echellé spectrograph (Panchuk et al. 2016) with polarimetric mode for linear and circular polarisation measurements. There will be a possibility to observe relatively faint supergiants of the late evolution stages with spectral resolution $R \approx 30\,000$ that are unaccessible for NES instrument (Panchuk et al. 2009) as well as make linear and circular polarisation measurements of selected objects with spectral resolution $R \approx 20\,000$.

The proposed instrument will also be used during ground support observations of the World Space Observatory - Ultraviolet mission (Boyarchuk et al. 2013; Shustov et al. 2014; Panchuk et al. 2014b; Malkov et al. 2011). We refer the interested readers to articles (Sachkov et al. 2014a,b,c) to track the instrumentation evolution of the project.

2. Optical Layout and Construction

Based on our experience of observations with BTA we argue that a new instrument should have a capability of quick switching between both modes, high resolution and spectropolarimetric, depending on weather conditions. In the proposed ESPRI instrument this is realised by two controlled units, polariser analyser carriage and cross disperser grating mechanism. The ESPRI optical layout is presented in the Figure 1.

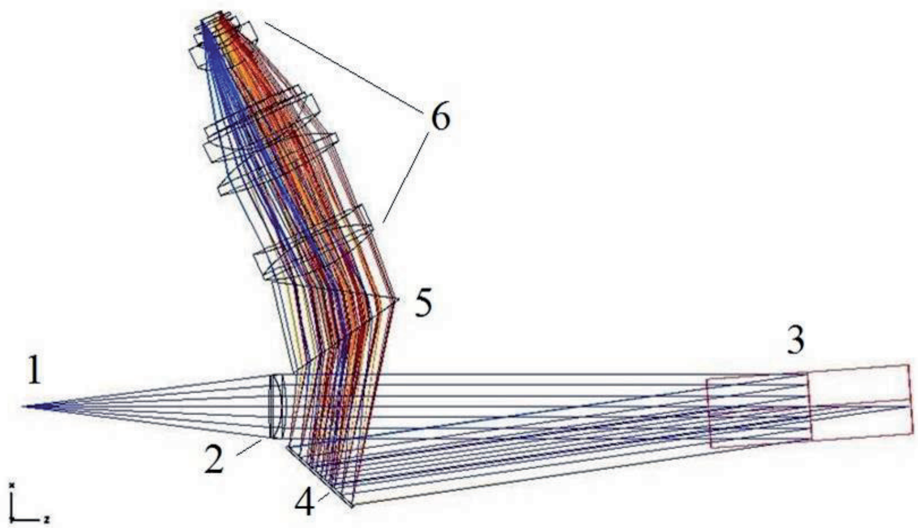

Figure 1. Layout of ESPRI main elements. 1 – slit (decker) position, 2 – lens collimator, 3 – echellé grating, 4 – cross disperse grating, 5 – cross disperse prism, 6 – lens camera optics. Calibration optics, autoguide system and optics of polariser analysers are out of this Figure.

For the quasi equidistant spectral order distribution on the detector plane we use a prism with attached transparent grating replica (see as example (Panchuk et al. 2015)). The prism is useful for shorter wavelength spectral order part of the image and at the same time a grating is useful for that of longer wavelength. The use of both a prism and a grating as cross dispersers allows to make the ESPRI instrument compact enough to be installed in the BTA primary focus cabin. This also increases the stiffness of the ESPRI structure (Figure 1). The prism position is fixed but the grating may be adjusted into two positions, for observations in spectral range of $\lambda\lambda$ 3800......8100 Å and $\lambda\lambda$ 4400......10000 Å. In both cases the distance between spectral orders is large enough for spectral as well as for spectropolarimetric observations. The parameters of the optical elements are as follows: collimator focus F_{coll} = 280 mm, collimator diameter D_{coll} = 70 mm; echellé 37.5 groves per mm, $\tan\theta_b = 3$; camera focus F_{cam} = 200 mm, camera diameter D_{cam} = 111 mm. The detector size is 2048×2048 pixels.

The relative position of the ESPRI elements is shown in the Figure 2. The design of the pre-slit unit is presented in the Figure 3.

We use the same technical solution for the polariser analyser unit as it is described in the paper by Panchuk et al. (2015).

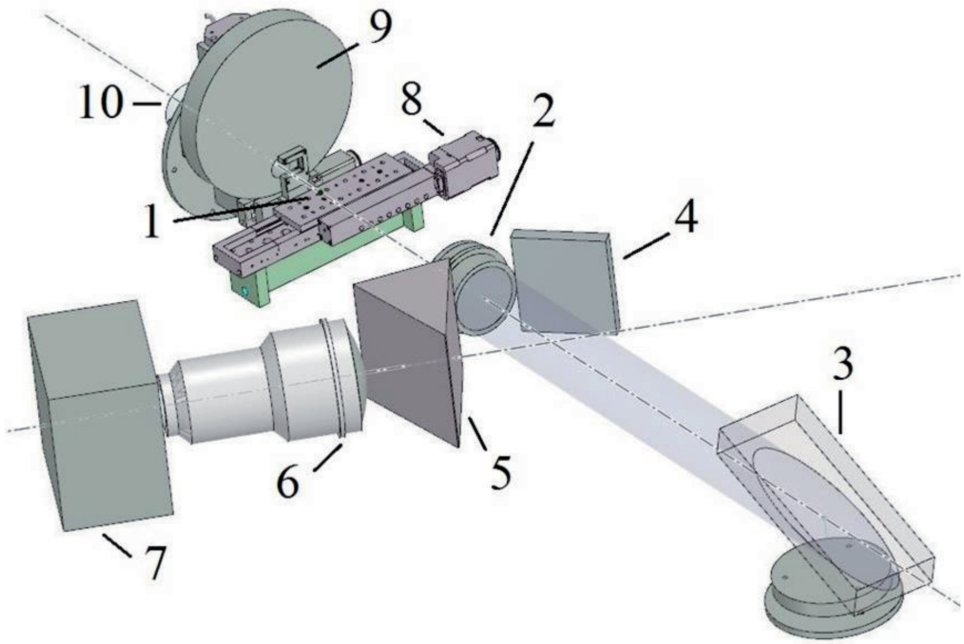

Figure 2. Elements of the ESPRI structure. 1 – BTA primary mirror focus position, 2....6 – the same as on the Figure 1, 7 – detector unit, 8 – decker change mechanism, 9 – polarimetric unit, 10 – local corrector of the image position at the spectrograph entrance.

3. Control System

The ESPRI control system is based on the NI myRIO-1900 controller with Xilinx Zyng-7010 CPU of CPU clock of 667 Mhz with numerical and analogue inputs and outputs. The control system consists of: a) a unit of image position correction on the slit; b) a spectropolarimetric unit with calibration; c) a cross dispersion grating rotation unit; d) decker change unit; e) decker viewer based on CCD camera; f) continuum and line spectral calibration unit; g) objective camera focusing mechanism.

4. State of Art

ESPRI optical elements are manufactured. The optical-mechanical structure is under assembly. The instrument control unit design is finished.

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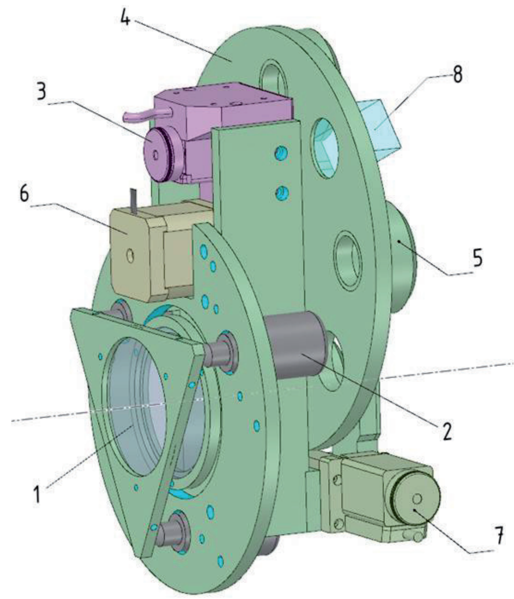

Figure 3. Pre-slit unit design. 1 – corrector plate, 2 – step actuators, 3 – drive mechanism of the touret (4) of the phase-shift changing plate (5), 6 – drive mechanism of changing the angle of plate optical axes, 7 – polariser analyser input unit, 8 – calibration channel mirror.

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