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Cassegrain Echellé Spectrograph

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Abstract. Here we present a basic model of echellé spectrograph CAES for 1-m class telescopes. The aim of such spectrograph creation is bright object monitoring with spectral resolution about 35 000. A slit length allows to take into account a sky background of urban and anthropogenic origin. The spectrograph control system was realised based on available electronic components.

1. Reasoning

Connection of a high resolution spectrograph and a telescope with a help of opto-fiber allows to reach high positioning accuracy with light loose in the fiber and with stabilisation of the spectrograph housing. Still there are astronomical tasks that require to use a classical slit. They are:

- radial velocity of gas movement in atomic and ion lines in different parts of planetary nebulae;
- absorbtion shell radial velocity measurements;
- observation of faint objects to take into account sky background;
- visual binary star doppler measurements when one needs to register both component spectra;
- in survey observations of magnetic stars where one does not need precise zeeman measurements;
- ground base ultraviolet observations (in the range of 300.....400 nm) where light loose in fiber is very significant.

The proposed spectrograph will be used for relatively bright objects program of the Russian 6-m telescope (Klochkova 1997, 2014; Sachkov 2014). The CAES instrument may 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. 2014; 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. Spectrograph Optical Layout and Construction

Main spectrograph element layout is presented in the Figure 1. The spectrograph is designed to be used with telescope of relative apertures of 1 : 13. A convergent beam (1) falls into a slit (2), follows to a mirror collimator of a ʼreverse Newtonian“ layout. A diameter of a flat mirror (3) is inside of a shadow of a telescope secondary mirror in a collimated beam. The collimated beam falls onto the echellé grating (5),than beams follow through cross-disperse prism (6). After the prism beams go to a lens objective (7), spectrum image is focused on the detector (8).

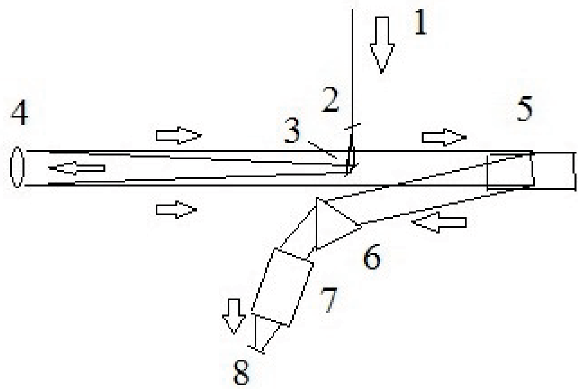

Figure 1. Layout of the main spectrograph elements.

Because of limitations for spectrograph size we use collimator with focus of f_1 = 650 mm and with diameter of d_1 = 49 mm. The blaze angle of the diffraction grating is 63.5 degree, grating period is 75 groves per mm, diffraction area is 120×60 mm^2. To have enough space between spectral orders in short wavelength part we use prism as a cross disperser (refraction angle is $A = 60°$, base length is $T = 70$ mm). This is especially important for cool stars with faint signal in the short wavelength range where scattering light between spectral orders should be taken into account. In the long wavelength spectral region the scattering light can be estimated correctly only if the slit length is no more than $4''$. We use lens objective ($f_2 = 300$ mm, diameter d_2 = 85 mm) as spectrograph camera. The parameter of slit-width is 650 \ 300 = 2.16. If the image scale in the 1-m telescope focal plane is 15.9 $arcsec$\mm, than the scale in the spectrograph detector plane is 34.5 $arcsec$\ mm. For slit width of $1''$ its projection onto the detector is 0.03 mm. For autocollimation scheme (echellé incidence angle is equal to blaze angle) we will have reciprocal linear dispersion of $P \approx 5$ Å\mm at wavelength λ = 5000 Å. If the slit image of 0.03 mm for 3 pixels, instrument function width $\delta\lambda$ = 0.15 Å, hence, the spectral resolution is $R = \lambda \setminus \delta\lambda$ = 33 000. This is a lower limit of the spectral resolution R.

3. Control System

The spectrograph also includes a slit viewer channel and a calibration channel. The slit viewer channel consists of a flat mirror (to send the reflected beam from the slit to the first objective), second objective of the channel, and CCD-camera. Objective parameters are: first objective F=78 mm, D=28 mm; second objective F=85 mm, D=30 mm. CCD-camera is 6×4 mm^2 detector.

The calibration channel consists of a ThAr cathod lamp and a continuum lamp. We use the glass chamber for the ThAr lamp so to get a continuum spectrum calibration one can use an incandescent lamp which light is falling through a ThAr lamp without changing positions of optical mechanical elements of the calibration channel. The only moving controlled element of the spectrograph is the input-output prism unit of the calibration channel. CCD matrix is of 9 micron pixel size and 36.8×36.8 mm^2 sensitive area. The cooling system is Peltier one. It is possible to control the spectrograph via Internet. We plan to add automatic guide unit (Yakopov et al. 2011) to correct telescope control unit inaccuracies.

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