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Research Note

Spectrograph design for astronomical telescopes

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Abstract

Many astronomy studies are based on spectral measurements of the stars and heavenly bodies. In this paper, high-resolution spectrograph is designed to be used in the large astronomical telescope. By adding this system, the best use of large astronomical telescope such as national telescope change can be done. Spectrograph slit can be placed in the focal plane of astronomical telescope or the focused beam transferred with an optical system from the focal plane to the slit of spectrograph.

Keywords*:* Spectrograph; Telescope; echelle grating; resolution power

1. Introduction

A high- resolution spectrograph was designed to improve the use of an astronomical telescope. Many astronomical studies are based on spectral measurements of the stars and heavenly bodies. Some applications for a high resolution spectrograph include:

- Measuring the radial velocities of stars
- Chemical composition of the star, star atmosphere analysis
- Search for binary stars and planets outside our solar system
- Historical investigation of nuclear stars

Chemical compositions of the stars need to measure the intensity of the weak lines. The bottom line in low resolution power severely eliminated (Raskin, Winckel, Hensberge et al. 2011; Zerbi, Span`o, et al. 2002).

Therefore a high resolution spectrograph should be used for astronomical studies. Most astronomical studies telescopes have a spectrograph. According to design and construction of the National Observatory and telescope, equipping the observatory with astronomical measuring instruments specifically with high resolution spectrograph is necessary.

In this paper a spectrograph for astronomical studies is designed.

In section 2 spectrograph optics systems are introduced. In section 3 the optical designing of the spectrograph optics system is presented.

Section 4 describes analyzing results for designed optical system. Finally in section 5 conclusions are presented.

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2. Spectrograph optics system

Spectrograph consists of a collimator, echelle grating, dispersive prism, focus lens, detector, and image relay (from foci of the telescope to the spectrograph slit) subsystems. Subsystems specifications are selected with regard to the spectrograph resolution power, spectrograph efficiency, environment conditions and telescope specifications.

Resolution powers equal to the wavelength λ to line width $\delta\lambda$ of the spectrograph

$$R = \lambda / \delta\lambda \qquad (1)$$

The spectral resolving power of a grating is:

$$R = mN \qquad (2)$$

where m is the diffraction order and N is the total number of grooves in the grating.

Use of a grating normally cause light scattering in different modes. The way to deal with this phenomenon is echelle grating (Fig. 1). Echelle grating consists of rows of parallel sloped mirrors. Using these gratings may raise resolution power, but overlapping modes are too large and must be removed by either grating or prism.

In the spectrographs with high resolution power and efficiency, echelle diffraction grating is used (Svanberg 2004).

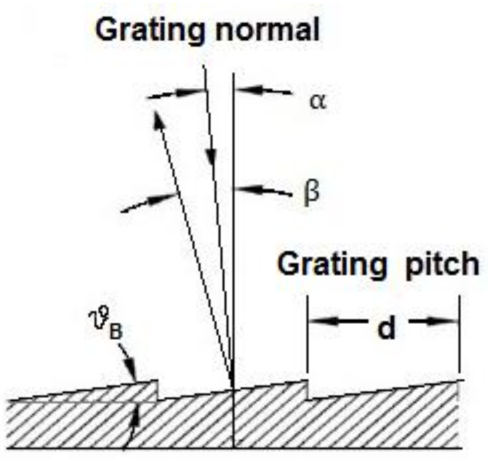

Fig. 1. Echelle grating

3. Design of Optical Spectrograph

Spectrograph design and optimization is done in base vigneting omitting, decreasing optical elements diameter and enhancing image quality and light efficiency. The system is designed with OSLO optical design software.

In this design the task of collimators will be provided with a common mirror. In these two collimators, echelle grating image relays from the center of the first collimator focus to second collimator focus (Buckley, Cottrell, et al. 2004).

Spectrograph slit is placed in the focal plane of an astronomical telescope. The focused beams in the focal plane are transferred by an optical system (as a collection of lenses or a large array of the optical fiber with a set of lenses) to another slit of the spectrograph. This slit is placed in the focus of the collimator mirror. Beams are collimated after the reflection from collimator mirror, and dispersed with echelle grating (Fig. 2). Dispersed beams are recollimated and create a mid-spectrum consisted different diffraction order in collimator focus.

A small mirror near the focus reflects the mid-range monochrome beam to the collimator. The third collimator output beams pass through a prism for eliminating higher modes.

2D dimensional spectra of grating, imaged with a lens set on the CCD detector. This lens set also has low chromatic aberration.

This system resolution power is at least 20,000. Spectrograph covered a wide ranging spectrum from 400 nm to 900nm.

Spectrograph detector is selected according to resolution power, sensitivity and spectral range of spectrograph. In the design of a spectrograph, high quantum efficiency with low read out noise CCD detector (2048 × 4096, 15μm pixels) is selected.

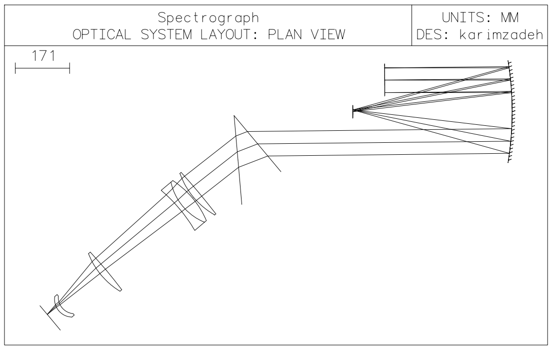

Fig. 2. Spectrograph layout

Slit and the image relay set (lens or fiber with the lens set) from focus to spectrograph slit will be selected and designed according to the specifications of the telescope and spectrograph parameters.

Anti-reflection coatings could be used on surfaces to increase spectrograph transmission.

4. Designed system assessment

To evaluate the image quality, the spot diagram for different wavelengths is studied.

The spot diagram formed from the emitted rays intercept points on the image plane and its smallish scattering spot is criteria for evaluating optical system quality.

The Fig. 3 shows a spot diagram of spectrograph at 550nm. This diagram was provided with the OSLO optical design software.

The designed system surfaces specification are shown in Table 1.

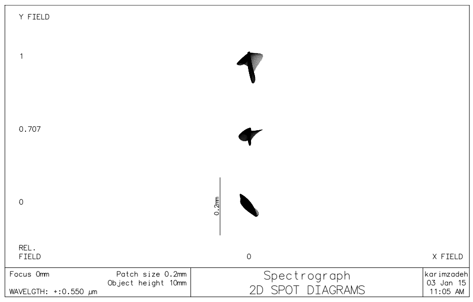

Fig. 3. Spectrograph spot diagram at 550nm wavelength

For enhancing resolution power, output beams from dispersive prism can be divided by a beam splitter in two sections and focused on the CCD with two separate optimized lenses

5. Conclusion

This paper reports the design of spectrograph for the large telescope. In designing echelle grating is used. Optimization performed for high resolution power and efficiency separation is.

Table 1. Surfaces specifications designed spectrograph

Srf	Radius	Thickness	Aperture radius	Glass	Spe note
OBJ	--	500	10	AIR	
AST	--	--	40	AIR	DCX=100
2	-1000	--400	160	REFL	CC=-1
3	--	400	50	REFL	DCX=100 TLA = 67 TLB = -0.8 GOR= -64 GSP=0.019
4	-1000	-500	160	REFL	CC=-1
5	--	500	20	REFL	
6	-1000	-800	160	REFL	CC=-1
7	--	--	100	AIR	DCX= -100 TLB= -40
8	--	-80	115	SF59	
9	--	-160	140	AIR	TLB = 35
10	-2200	-22	85	FK54	
11	239.09	-4	82	AIR	
12	-284.24	-40	82	FK54	
13	177.500	-13	82	LAKN12	
14	-494.87	-300	82	AIR	
15	-1660.9	-22	77	LF5	
16	239.69	-160	77	AIR	
17	51.53	-14	36	SILICA	
18	55.71	-35	42	AIR	
IMS	--	--	50		

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