Low Resolution Spectropolarimeter with Broadband Achromatic Plate and Special Wollaston Prism

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Abstract

A general concept and merits of the new ground-based spectropolarimeter, is briefly discribed. The two principal new units of the device are:

1) a superachromatic (covering spectral region from 360 nm to 900 nm) revolving retarder containing from 5 to 7 plasic plates to measure all four Stokes parameters. These phase plates were firstly proposed by V.A. Kucherov.

2) a complex Wollaston prism with decenterted and deformed surfaces which allows to obtain the two spectra with mutual orthogonal polarization. This unit replaces ordinary two-block unit containing a normal Wollaston prism to split the light into two (ordinary and extraordinary) beams and grating or glass prism to produce the spectrum.

Due to minimum of free surfaces the loss of light in the device is very low. The device possess the merits of filtered and grating/prism polarimeters and allows to observe objects of about 15 mag with time resolution of parts of hours which is much better in comparison with that for existing devices. It is expected that this spectropolarimeter will provide polarization data in the whole optical spectral region without changing phase plate.

1 Introduction

Up to now the measurements of polarization were carried out by either polarimeters, selecting a spectrum range by filters, or with slit spectrographs. To each of them the disadvantages are inherent, lowering efficiency of devices and essentially enlarging time of measurements.

Really, polarimeters with a consecutive change of filters to study spectral dependence of polarization parameters are time consuming. To reduce this time multichannel devices with selective reflecting coatings are used. But thus with increasing a number of channels losses of light in a device increase too.

Spectropolarimeters on the basis of slit spectrographs have large losses of light on an entrance slit and optical elements - collimator, grating and camera. It causes their low efficiency, essentially hindering their application to study for weak objects.

2 OPTICS OF SPECTROPOLARIMETER

Low resolution spectropolarimeter with a broadband achromatic phase plate and a deformed Wollaston prism (Fig.1) makes it possible to expand essentially an opportunity for spectropolarimetry of weak objects.

The main advantage of this device is a minimum of optical elements, that sharply reduces losses of light in it. Its other advantage is a possibility to measure simultaneously both linear and circular polarization in a very wide spectral range.

At development of a spectropolarimeter the following purposes were set:
- Recording all four components of a Stokes vector.
- Minimum power losses.
- High quality of the image.

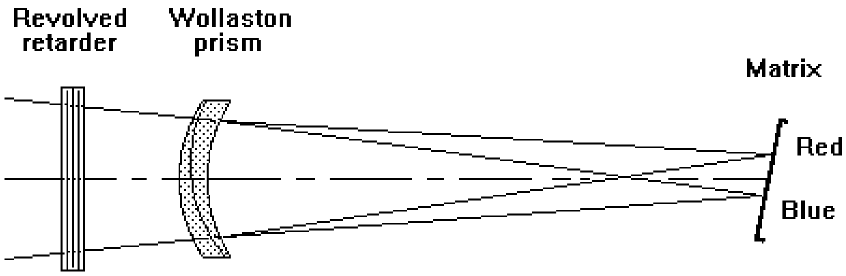

Figure 1: Layout of the high efficiency spectropolarimeter with a deformed Wollaston prism.

- Simplicity and technological efficiency to manufacture a device.

The two principal new units of the device are:

1) a superachromatic retarder, which provides for a constant phase shift with a deviation less than 3 angular degrees in wide spectral band. The technology permits to get 5- and 7-component plates of the high optical quality, stable for a long time and working in a range of temperatures from -20 to +40C (Fig2).

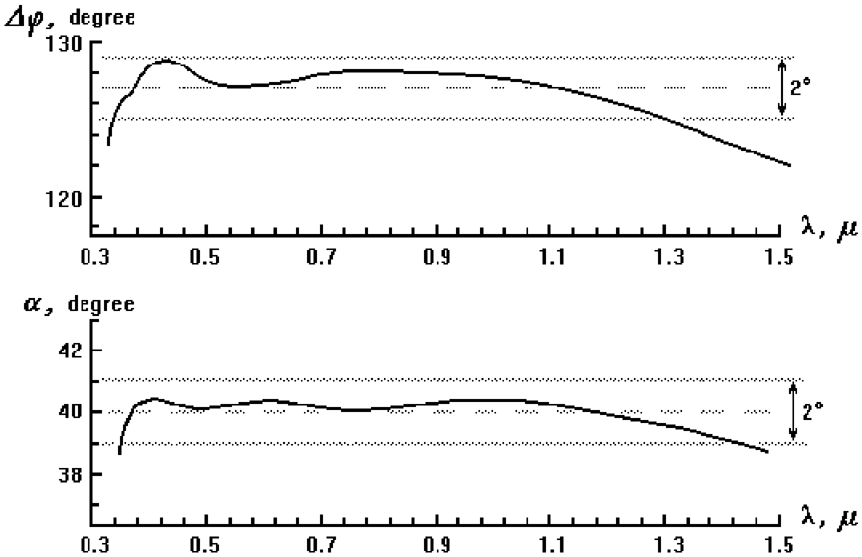

Figure 2: Phase shift and main axis deviation for crystalline Kucherov's retarders

2) a complex Wollaston prism with decentered and deformed surfaces which allows to obtain the two spectra with mutual orthogonal polarization. This unit replaces ordinary two-block unit containing a normal Wollaston prism to split the light into two (ordinary and extraordinary) beams and grating or glass prism to produce the spectrum (Fig.3).

Deformations and inclinations of the prism surfaces are equivalent to enter into the system artificial parameters, which make possible to correct the aberrations at

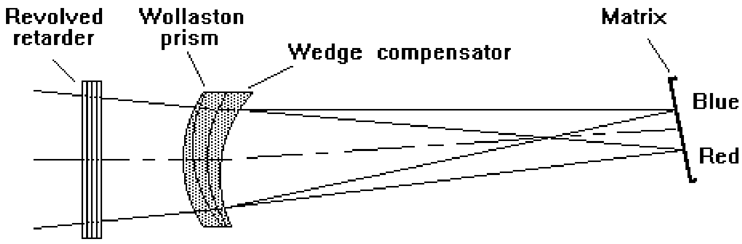

Figure 3: Layout of the spectropolarimeter with a compose deformed Wollaston prism

a minimum of a quantity of optical elements. At such a design each surface executes the correction functions and separates two spectrum with orthogonal polarization.

The decenterings of spherical surfaces are equivalent to the setting i n the system wedge-shaping elements, that leads to a characteristic "prism-made spectrum", with stretched "blue" and compressed "red" regions.

Such the simplest designs are suitable in a limited spectral range or, for example, in a vacuum UV, where the choice of transparency materials is extremely limited. However, at research of wide sample of the objects more uniform dispersion is desirable. Such a correction of dispersion is easily reached by the adding just one more wedge from a material with a special course of the dispersion. The deformation both the Wollaston prism and a dispersion prism permits to minimize the number of elements down to two blocks. The characteristic spot size on the spot diagram (Fig.4) is 10 - 20 μ, with rather uniform dispersion. This design is especially suitable for the devices of a low spectral resolution and of the faintest limiting magnitude threshold.

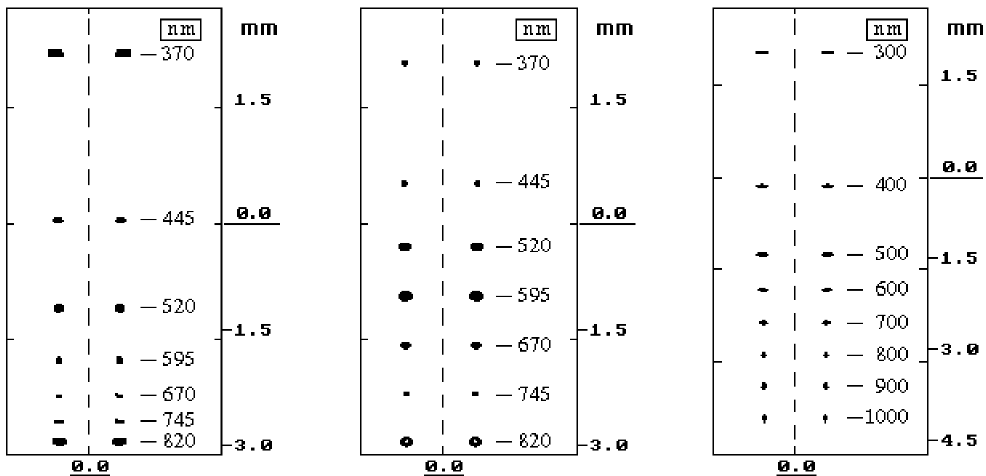

Figure 4: Spot diagram from deformed Wollaston prism: a) - simple prism, b) - compose prism, c) - MgF2-fused silica prism with special glasses.

It is expected that the spectropolarimeter on 125 cm reflector will allow to measure the polarization of the objects of about 15 mag without changing phase plate, with time resolution of parts of hours which is much better in comparison with that for existing devices.

The dependencies of statistical error s in per cent on exposure **t** for objects with brightness from 8 mag to 20 mag are shown in Fig. 5.

For complete determination of all Stokes parameters the number of frames must be increased depending on specific mode of operation. In further estimations of an exposure time for observations of various astrophysical objects the exposure per single frame is given to estimate the statistical error of measurement of the degree of polarization only.

The calculations show that the contribution of dark current and reading noise is perceptible only at the area of very short exposure times (less than one minute) for objects fainter than 12 mag, increasing as it is low (worse than 3-5 %) accuracy of such observations. As accepted statistical error of estimation of the degree of polarization must be not worse than 1-2 %, where the contribution from dark current and reading noise are practically non appreciable, their influence on the estimation of the limiting magnitude may be ignored.

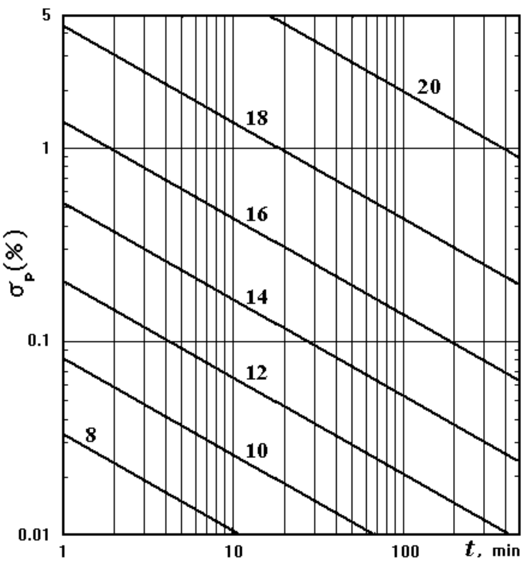

Figure 5: Statistical errors of the measurements by spectropolarimeter on 125-cm telescope.

A flexibility of this device is exceptional. The quality of the image is high, almost diffraction like; the characteristic size of monochromatic spots on the spot diagram ignoring the seeing is 2 - 6 μ at the relative telescope aperture up to F/3. The spectral resolution is from units up to hundreds spectral elements. The device permits to work in an extraordinary wide spectral band (Fig.4c). The analysis shows that proposed device is rather technological, the tolerances to the quality of the optical surfaces and to an adjusting are rather soft.

3 Conclusion

The proposed spectropolarimeter allows a great freedom to choose the spectral resolution at high efficiency, has a minimum of optical elements and is simple in manufacturing. The information capacity of the device exceed the known sets by an order of magnitude. It will provide the useful "raw" information as much as a number of kilobytes/s, even from faint objects. The consideration carried out above allows to conclude, that proposed device can be applied to solve a great majority of scientific problems connected with polarimetry of point-like objects.