

## Multipurpose day-sky spectral polarimeter

A.S. Istomin, V.E. Pavlov,\* P.V. Semenko,\*  
D.N. Troshkin,\* and A.S. Shatokhin

*Altay State University, Barnaul*

*\*Institute of Water and Ecological Problems,  
Siberian Branch of the Russian Academy of Sciences, Barnaul*

Received November 28, 2002

A prototype of a day-sky polarimeter operated in short-wave spectral region has been made on the base of a DMR-4 double quartz monochromator. Glan prism is used as an analyzer in this device. Application of microcontroller and PC provides for automatic acquisition of experimental data, their consequent processing, and storage. Spectrograms obtained with the polarimeter are presented to illustrate quality of the device operation.

To perform systematic studies of optical characteristics of the atmosphere in Altay Region, a prototype of a day-sky spectral polarimeter (Fig. 1) has been developed at the Institute of Water and Ecological Problems, SB RAS in collaboration with the Sub-Department of Computer Engineering and Electronics of Altay State University.

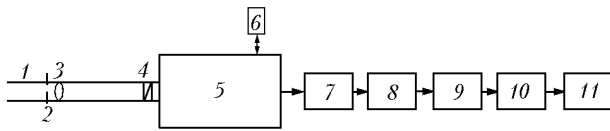
This device is a perfected automated analog of short-wave spectral polarimeter that has been operated at Astrophysical Institute of Kazakhstan Academy of Sciences.<sup>1</sup> DMR-4 double quartz monochromator is used as a base for this device. Double dispersion of light beams provides for high spectral purity therefore this device can be used as a spectrophotometer giving good spectral resolution in ultraviolet spectral region. Applying a FEU-71 PMT it is possible to perform measurements in the wavelength range from 305 to 600 nm, and FEU-62 PMT – in the wavelength range from 450 to 1020 nm. Therefore, this device can serve both as an

ozonometer and meter of water vapor content in atmospheric column. It allows one to carry out measurements of the following optical characteristics of the atmosphere:

- spectral transparency with respect to direct solar radiation;
- absolute brightness phase functions at scattering angles from 5 to 160° and, when using a honeycomb blend, circumsolar halo at angles from 2 to 5°, counted off from solar disk center;
- spectral brightness distribution over the sky in units of solar constant. These data are easily converted into absolute units ( $W/nm \cdot sr$ );
- distribution of degree of polarization over the sky;
- orientation of plane of polarization;
- direct and scattered radiation fluxes on a platform arbitrary oriented in space, when applying heads with cosine transmittance (lactescent plates);
- underlying surface albedo when applying head with Ulbricht sphere.



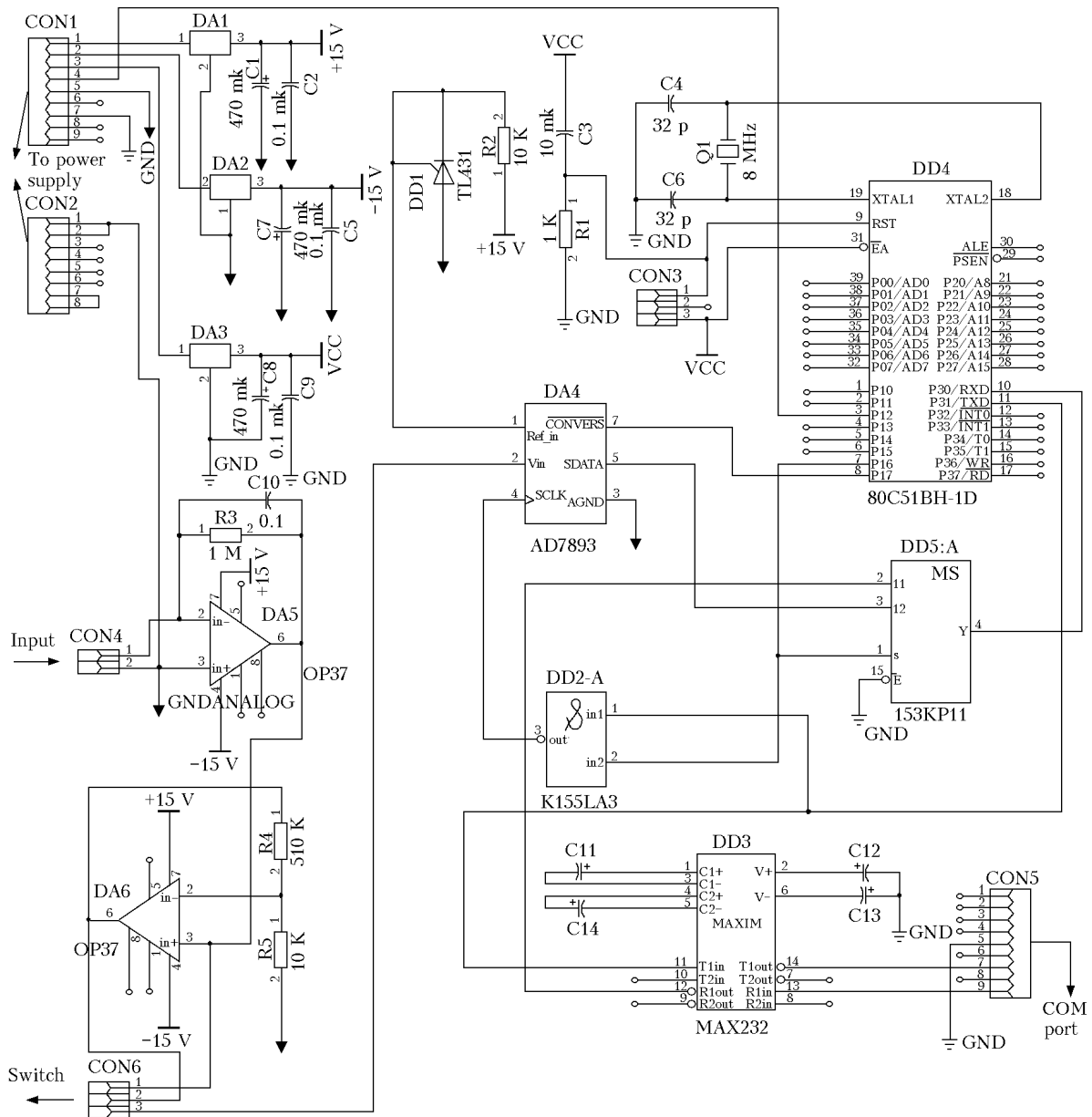
Fig. 1. Day-sky spectral polarimeter.



**Fig. 2.** Schematic diagram of the device: blend 1; accessory diaphragm 2; lens 3; Glan prism 4; DMR-4 monochromator 5; unit for rotation of monochromator head 6; PMT 7; amplifier 8; ADC 9; controller 10; computer 11.

Schematic diagram of the device is presented in Fig. 2. Its optical part includes a blend, a kit of accessory diaphragms, a quartz lens, an analyzer, and a monochromator itself. The blend length is chosen in

such a way that it protects the lens from illumination by direct solar radiation when pointing the device into the sky point situated at angular distance of 5° from the solar disk center. Quartz Glan prism is used as an analyzer. This prism is installed in front of the monochromator slit, it revolves around an optical axis, and can be fixed at three positions in 60° intervals. In other words, to determine the degree of linear polarization and orientation of plane of polarization, V.G. Fessenkov technique<sup>2</sup> is used. Double quartz monochromator provides for achieving spectral resolution of 0.02 nm in the UV spectral region.



**Fig. 3.** Schematic circuit of the controller.

To measure spectral brightness phase functions and angular distribution of brightness over the sky in units of the solar constant,<sup>3</sup> the device is equipped with V-shaped head with two accessory screens made from gray gypsum and magnesium oxide. The latter is used for determination and subsequent monitoring of a gray screen reflectivity.<sup>4</sup> Pointing of the device and V-shaped head to the Sun is realized with the help of two special sights formed by lenses and screens installed on the device and on the head, respectively.

An electronic part includes a PMT with a stabilized power supply, an amplifier, analog-to-digital converter (ADC), a stepping motor with the control unit, and a controller. A circuit diagram of the device's electronic part is shown in Fig. 3.

Anode current of PMT is converted into a voltage that is applied to the amplifier input. Active current-to-voltage converter having conversion factor of  $10^6$  V/A and the amplifier having amplification factor of 52 are made on the base of K140UD17A operational amplifiers. The amplifier pass band is matched with the spectrum scan rate and it is equal to 10 Hz. The dynamic range of this electric circuit with such a pass band is equal to 100 dB. The pass band can be extended or narrowed that results in a change of the dynamic range.

An amplified signal enters the AD7893 12-bit ADC that can be replaced by 14-bit or 16-bit ADC of the same type without any changes in the circuit. The digitized signal is read out to memory of ATME1 89C51 single-crystal computer via serial channel of universal asynchronous transceiver.<sup>6</sup> The data received are transferred into portable PC of NOTEBOOK type<sup>7</sup> via RS-232 serial port. MAX232 chip is used as a signal conditioner for RS-232 interface. Application of PC simplifies reprogramming of the controller, as well as allows one to automate acquisition, processing, and storage of large data arrays including during field measurements.

An executive program for the controller is written on assembler for MK51 microprocessors.<sup>8</sup> The controller operates in command waiting mode under PC guidance. Automatic optical spectrum scanning is fulfilled by means of DShI-200 stepping motor that revolves monochromator's wavelength head. The controller governs operation of the stepping motor. Maximum spectrum scanning rate depends on the pass band chosen and maximum number of revolutions of the stepping motor and at  $f_{\text{pass}} = 10$  Hz it is equal to 2 nm/s.

It is possible to judge on the operational feasibility of the polarimeter from the spectrograms presented below. Figure 4 shows data on spectral fluxes of direct solar radiation  $F_\lambda$  (in relative units) at different zenith distances when correcting power distribution in the observed spectrum using ZhS-20 glass, with the help of which long-wave portion of ultraviolet radiation is suppressed. Exactly such spectral curves are used for determination of total ozone content in the atmosphere in applying

multiwave techniques.<sup>4</sup> Figure 5 presents measurement results for intensity near the calcium H and K emission lines. Studying of their shapes allows one to investigate Raman-effect manifestation in the atmosphere.<sup>5</sup>

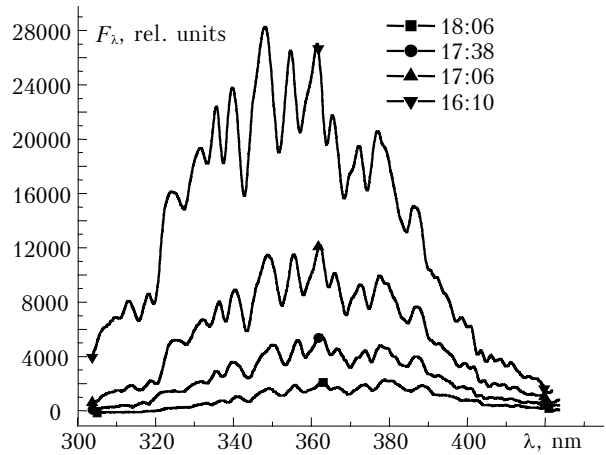


Fig. 4. Solar spectra observed through ZhS-20 glass at different time (diurnal variation).

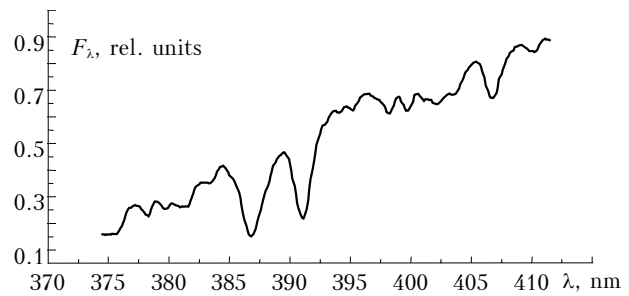


Fig. 5. Solar spectrum near H and K emission lines of calcium.

At present, the device's verification and preparation for routine measurements of optical parameters of the atmosphere are being carried out.

## References

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