OBSERVATIONAL CAPACITIES OF 1M OPTICAL TELESCOPE ZEISS-1000 AT SAO RAS

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The optical telescope of SAO RAS Zeiss-1000 saw its first light of about thirty years ago. Nowadays it is successfully used to solve a wide variety of astrophysical problems. The main observational programs are photometry of bright quasars and nearby Seyfert galaxies, studies of X-ray binaries, monitoring of AGNs, bright supernovae, binary systems, magnetic survey of main sequence stars, compilation of spectral atlases of bright Ae/Be Herbig stars, studying variability of magnetic peculiar stars etc. We present a brief historical review starting at the time the Zeiss-1000 was manufactured and put into operation. A few words are said about the instruments the telescope was equipped at the beginning and the enhanced ones. Photometric and spectroscopical observational methods realized presently are described in detail. Attention is paid to newly developed devices. When placed in commission they will provide new observational capacities. To raise effectiveness of the Zeiss-1000 operation complex automatization of the telescope control system, update of main mounting components and the telescope optical system adjustment were done. There were increased the telescope pointing accuracy and the tracking quality. The modes of fast-moving celestial bodies' program tracking and of remote observations were realized. The Zeiss-1000 observational time is scheduled and awarded by the Time-Allocation Committee for telescope proposals submitted once a half-year semester.

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1. INTRODUCTION

Zeiss-1000 is a meter-class reflecting telescope with a Ritchey–Chrétien–coudè optical system. The main advantage of such a scheme is a maximum possi-

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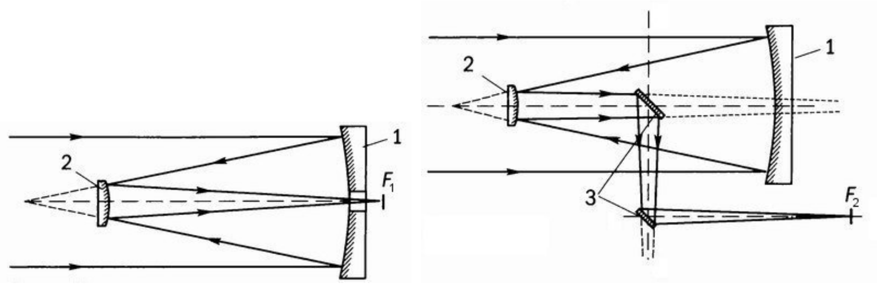

Fig. 1. Optical layout of a RC telescope with the Cassegrain focus F_1 (left) and the coudè one F_2 (right): 1 —primary mirror; 2 — secondary one; 3 — flat mirrors switching light beam to coudè focus F_2

ble versatility at a moderate cost of instrument manufacturing. The Ritchey–Chrétien (RC) system provides both wide field imaging and detailed photometric and spectral studies of individual objects using small-sized attachable instruments in Cassegrain focus(Figure1).

The English mounting "EM-2" used is suitable without design changes for all telescope locations at geographical latitudes between −55 and 55 degrees. In addition, owing to the symmetry of load distribution elastic deformations on the angular deviation of the hour axis is negligible. The mounting "EM-2" makes it possible to redirect light to the coudè focus with two flat mirrors (Figure 1). The placement of fixed instruments of large size in the coudè focus. expands the range of possibilities, allowing to equip the telescope with a high-resolution spectrograph.

Serial production of one-meter optical telescopes was carried out at the Carl Zeiss JENA Enterprise. Orders were made by various countries: Bulgaria, Hungary, Czechoslovakia, China. The USSR acquired eight telescopes for observatories of Dushanbe, Alma-Ata, Crimea, and Maidanak. One-meter optical telescopes of the Ritchey–Crétien system with the English mount "EM-2" have been created since 1968. The first two telescopes of this series were installed in observatories of India. The tenth of 11 Zeiss-1000 manufactured was ordered for the Special astrophysical observatory [1].

After shipping to the location place in 1986 the Zeiss-1000 of the Special astrophysical observatory was installed in close proximity to the Big Telescope Alt-azimuthal (BTA). There was an idea to apply the Zeiss-1000 as an auxiliary tool to test equipments and observational methods for the BTA and conversely to use in part the instruments and techniques of the BTA. This would make the observation time allocation more efficient as pretty lot of observational programs did not require the BTA facilities.

The telescope Zeiss-1000 saw first light in October, 1989. The creation of stationary equipment and respective observational methods laid the foundation of running independent scientific programs. The main ones were studies of binary systems, photometry of bright quasars and nearby Seyfert galaxies, monitoring of AGNs, bright supernovae, x-ray binaries, magnetic survey of main sequence stars, compilation of spectral atlases of bright Ae/Be Herbig stars, studying variability of magnetic peculiar stars, etc. Most of them are effectively continued at present.

2. INSTRUMENTS IN OPERATION AT ZEISS-1000

For more than a quarter-century history of observations with the telescope a variety of instruments were used. Three of them are in operation nowadays being modernized. They are the CCD photometer and the Universal Astronomical Grating Spectrograph in the Cassegrain focus and the Coudè-Echelle Grating Spectrometer.

2.1. CCD photometer

A CCD photometer was one of the first main instruments at the telescope. It was designed for direct imaging of astronomical objects both without a filter, in white light (3600–10000Å), and in the bands of the Johnson–Cousins system U, B, V, R_c, I_c. Presently it is used in monitoring studies of variable objects such as blazars (see [2]), x-ray sources, LBV-candidates, massive SNe, etc.

Table 1. CCD photometer characteristics

Parameters of EEV 40-42 CCD		Limiting magnitude			
		Band	T_{exp}	Seeing	Mag
Format, px	2048×2048	U	300^s	$1.5''$	20.3
FOV, arcmin	7.3×7.3	B	300^s	$2.0''$	21.0
Scale (w/o binning), $''$/px	0.216	V	300^s	$1.8''$	20.3
Gain (low), e^-/ADU	2.02	R_c	300^s	$2.0''$	20.3
Gain (high), e^-/ADU	0.50	I_c	300^s	$1.6''$	19.4
Readout noise (normal), e^-	3.3	R_c	3^h	$1.8''$	22.7

Limiting magnitudes for the detection of faint objects at a 3σ-level and the parameters of CCD EEV 40-42 are given in Table 1.

2.2. Coudè-echelle spectrometer CEGS

The Coudè-Echelle Grating Spectrometer[1)] was designed [3] for high-resolution spectroscopy, $R = 30000$, in a wide spectral range of $3600 - 9000$ Å. The spectrometer is equipped with a circular polarization analyzer and replaceable diffraction echelle gratings providing operation in several observation modes: of high, medium, moderate and low resolution. Their paramemeters are listed in Table 2. The instrument is successfully used in monitoring of long-period magnetic stars (see, e.g. [4]). The limiting magnitude for an hour exposure in good weather conditions is about 7^m.

Table 2. Parameters of CEGS gratings

Grating	Size, mm	Blazing angle, deg	grooves/mm
G37.5	200×300	63.5	37.5
G75	200×300	63.5	75
G600-1	200×200	24	600
G600-2	200×200	8	600

2.3. Universal Astronomical Grating Spectrograph

For long slit spectropy of extended astronomical objects with medium spectral resolution in the wavelength range of 360–1000 nanometers the Universal Astronomical Grating Spectrograph[2)] (UAGS) is used.

The parameters of the UAGS diffraction gratings are given in Table 3.

Table 3. Parameters of UAGS

Grating	grooves/mm	Spectral range, Å	Variance, Å/px	Spectral resolution, Å
R325	325	3700–7500	2.5	7.5
R400	400	3600–8000	2.1	6.3
R1302 ($\phi = 43°10'$)	1302	3880–6300	0.5	1.5
R1302 ($\phi = 53°$)	1302	5750–7050	0.7	2.1

Spectra are recorded using the CCD EEV 42-40 detector (2048×2048 px, $13.5 \times 13.5 \mu m$) mounted on the Schmidt–Cassegrain camera ($F = 150$ mm). The

[1)] https://www.sao.ru/Doc-k8/Telescopes/small/CEGS/cegs.html (in Russian)
[2)] https://www.sao.ru/Doc-k8/Telescopes/small/UAGS/

Fig. 2. CCD images of a comet field (unreduced) and satellite tracking ($T_{exp} = 1^s$), left and right panels correspondingly

spectra are obtained without binning in the 'high' and 'norm' mode, which corresponds to the readout sampling of $0.52e^-$/ADU, readout noise of about $2e^-$ and the scale of $1.35''$/px along the slit. For wavelength calibration a He+Ne+Ar source of line spectrum is used. The main observational programs run with the instrument are search for magnetic stars, spectroscopy of multiply systems, and monitoring of AGNs, blazars and various transients (e.g. [5]).

3. ZEISS-1000 MODERNIZATION AND PROSPECTIVES

Since 2013 the automated control system creation with simultaneous upgrade of the main telescope units has raised Zeiss-1000 to a new standard of observations [6]. Contrary to a large number of existing projects of automation and robotization of telescopes, this has ensured integration of all the telescope instruments with its control system, providing the possibility of remote observations based of fully automated programs[3)]. Replacement of control systems of telescope axes drives, main axis sensors, implementation of calculation and tracking algorithms has yielded a pointing accuracy increase and a significant tracking quality improvement, including the possibility of program tracking of fast-moving celestial bodies (see Figure 2).

In 2015, the telescope optical system was adjusted [7]. Presently it ensures an image quality of about $0.5''$ at 80 per cent of energy level. This significantly expands the observational capabilities of the telescope.

[3)] https://www.sao.ru/hq/vsher/reports/report2014/ (in Russian)

The Zeiss-1000 observational time is scheduled and awarded by the Time-Allocation Committee for telescope proposals submitted once a half-year semester. It is also allocated to observations with "guest" instruments (e.g. MaNGaL [8]).

The Multi-Mode Photometer-Polarimeter (MMPP) has been designed recently [9] to be installed in the Cassegrain focus. It is equipped both with highly effective broadband interferential filters of the Johnson-Cousins system and mediumband filters centered on the wavelengths of basic emission lines of the objects under investigation. In the polarimetric mode there is a possibility of linear and circular polarization studies. MMPP is a modern instrument for a solution of a wide range of photometric and polarimetric tasks (see e.g. [10]). When placed in commission it will provide new observational capacities.

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