



## Selected works on the stellar spectroscopy technique

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### ABSTRACT

The paper presents works carried out on the initiative and with the participation of the SAO RAS Laboratory of Astrospectroscopy during the past decade. Taking the changed situation into account, the status of the works, their current state, and prospects are discussed.

**Key words:** diffraction spectrographs, interferometry, crossed dispersion

The development and commissioning of any spectroscopic technique at SAO takes many years; therefore, we have started with the program for advancing methods included in the list of “services” offered to the Big Telescope Alt-Azimuthal (BTA) users. Two instruments with a large collimated beam diameter (hereafter  $D$ ) can be attributed to high-resolution spectrographs. These are the Main Stellar Spectrograph (MSS,  $D = 258$  mm; [Panchuk et al., 2014](#)) and the Nasmyth Echelle Spectrograph (NES,  $D = 235$  mm; [Panchuk et al., 2017](#)). The NES development program has been discussed and is being gradually implemented. Through the reconstruction of almost all the elements of the spectrograph core (the mosaic echelle unit, the collimator unit, the cross-dispersion grating unit, and the units of the pre-slit part), we expect its potential quality to be increased by many times and the remote mode for preparing to observations and for observations themselves to be ensured.

The continuation of the MSS development program, whose key points are the transition of the instrument to a set of diffraction gratings with a format of  $360 \times 320$  mm<sup>2</sup> and equipping the  $F/2.3$  camera with a large-format CCD array, has not been discussed in the past decade. The primary value of the NES and MSS spectrographs lies in their capability to operate in a wide wavelength range, including ground-based ultraviolet, which in the case of the MSS is not systematically used. Given that in recent decades the domestic optical-mechanical industry has failed to produce a single astronomical lens-based spectral camera with an aperture of 100 mm or larger, one must rely on the potential of the catadioptric optics designed and built in the 1970s–1980s. The Laboratory of Astrospectroscopy (LA) has developed proposals for expanding the capabilities of the MSS both for fast spectroscopic and spectropolarimetric tasks using the  $F/1.2$  camera and modern solid-state detectors, as well as for extending the functionality of the  $F/2.3$  camera, currently optimized for only one class of problems.

The second group of methodological works arose as a result of scientific and organizational efforts related to the project on a fiber-fed echelle spectrograph with spectral resolution  $R = 10^5$  (included in the plan of Section 10 “Optical telescopes and methods” of the Scientific Council on Astronomy of the Russian Academy of Sciences in 2001). For the period between 2005 and 2012, this project was assigned to the LA staff. The preliminary design (fig. 1 in [Panchuk et al., 2007](#)) implies the creation of two echelle spectrographs: one ( $R = 20\,000$ ) is at the primary focus, for spectroscopy and spectropolarimetry; and the principal one ( $R = 100\,000$ ), with light transmitted along an optical fiber. This solution (see also [Balega, Panchuk, 2010](#)) was developed on the basis of many-year experience of the LA staff in designing and operating stationary and hanging spectral equipment at the BTA. As a result of the termination of the LA’s work on the project in 2012, the methodological groundwork was transformed into two independent works of secondary importance: the ESPriF echelle spectrograph ( $D = 75$  mm; [Panchuk et al., 2020a](#)) and a fiber-fed spectrograph for a meter-class telescope ( $D = 100$  mm; [Nalivkin, 2022](#)).

During the second decade of the century, the following methodological works were also carried out (key publications are cited):

- 1) numerical simulation of space- and ground-based spectrographs, including the feeding optics ([Yushkin et al., 2016](#));
- 2) ultra-high spectral resolution (Fabry–Pérot interferometer with an open input; [Kulagin, Panchuk, 2017](#));
- 3) slitless echelle spectrophotometer, parallel to the BTA tube ([Panchuk et al., 2022](#));
- 4) telescope and atmosphere (analysis and compensation of quasistationary and low-frequency aberrations; [Klochkova et al., 2020](#); [Tamarov et al., 2022](#));

- 5) broadband spectrograph at the Nasmyth focus of the KST-3 telescope (see fig. 2 in [Panchuk et al., 2019](#));
- 6) interferometer with external post-dispersion ([Panchuk et al., 2021](#)).

Let us assess the prospects of several directions in stellar spectroscopy. We have to admit that the hopes of using lens optics as objectives in domestic astronomical spectrographs have not yet been fulfilled. Replacing them with commercial objectives of smaller aperture leads to reducing throughput in some optical layouts (see, in particular, notes in [Galazutdinov, 2022](#)). The use of “appropriate” commercial optics results in increased variations in the spectrograph hardware function along an order and reduces the accuracy of Doppler measurements through the classical cross-correlation method. Therefore, attention should be paid to the potential of double-beam interferometers, where in a layout with external post-dispersion ([Panchuk et al., 2021](#)), the collimated beam diameter in a medium-resolution spectrograph can be several times smaller. This circumstance opens up the possibility of using relatively inexpensive (owing to the small format) volume-phase holographic gratings that reduce light losses in Doppler measurements.

[Panchuk et al. \(2020b\)](#) noted that implementing a spectroscopic investigation of stars with exoplanets using a multi-program telescope does not justify the cost of constructing a spectrograph with a large collimated beam diameter (where the spectrograph cost is proportional to the third power of  $D$ ). An expensive spectrograph will justify its value more rapidly through continuous use at a specialized spectroscopic telescope, whose cost is determined by the expenses for providing a small field of view. Such works have been initiated at SAO.

The introducing of solid-state detectors with fast readout capability allows for a return to the spectroscopy of short-period phenomena, a field in which interesting results were derived at the BTA during the era of television-type photon counters (see, e.g., [Somov et al., 1998](#)). For this case, the LA staff have developed proposals for the reconstruction of the MSS  $F/1.2$  camera for dynamic spectroscopy and spectropolarimetry.

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