

## HIGH LUMINOSITY FABRY-PEROT SPECTROMETER FOR STUDY THE UPPER ATMOSPHERE TEMPERATURE AND DYNAMICS

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**Abstract.** New high luminosity digital Fabry-Perot spectrometer for upper atmosphere temperature and dynamics studies by airglow emissions with piezoelectric scanning, computer control and digital signal processing is presented. The interferometer plate diameter is 150 mm with the distance between the plates being 12 mm. The instrument width is 0.0015 nm. The preliminary Doppler temperature measurements near Yakutsk on 557.7 nm [OI] airglow with 15 s exposition time per step are presented.

One of the widespread methods of the temperature and neutral gas drift velocity measurements in the upper atmosphere is using of the Fabry-Perot interferometers [Ignatyev and Yugov, 1995]. Interferometric method is based on the measurement of the heat broadening and Doppler shifting of the spectral line profiles, radiated by the night atmosphere. At present dozens of modifications of such instrument worked out in the world [Ignatyev and Yugov, 1995; Hernandez, 1970; Hernandez and Mills, 1973; Chect et al., 1986].

We propose a pilot model of Fabry-Perot spectrometer which is intended for the temperature and neutral winds velocities measurement at the heights of the thermosphere (~95–300 km) on a night airglow or aurora on OI 557,7 nm or OI 630,0 nm in field conditions. The main advantage of the proposed instrument is a combination of compactness, simplicity of assembly and stripping on separate blocks, high luminosity possessing, high degree of automation of the control and a possibility to realise a pre-processing by the personal computer.

Constructively instrument is made as separate functional blocks: interferometric head (A); carrying rack with the telescope (B) and photometer (C); block of interface for the link-up with the computer with power sources; He-Ne laser for adjustment and calibration; mirror system for pointing the instrument on a certain sky area. The block diagram of optical part of the instrument is presented in Fig.1. The diameter of the interferometric plates with multi-layer dielectric coating is 150 mm with the reflecting factor for 630,0 nm of 85%.

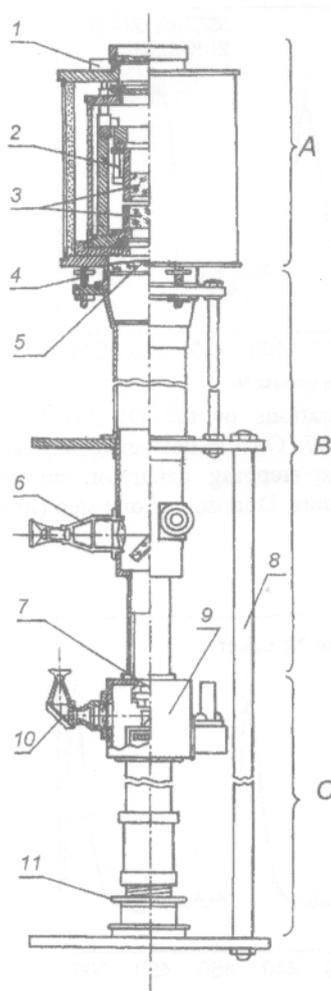


Fig.1.

Interferometric head (A) is a separate thermostatic block which is fixed overhead to the rack of the telescope on three controlling screws 4. It presents itself a carrying body, where holders with interferometric plates 3 are located. The lower holder is a bolt on a special circular rack, which height can change for setting distance between the plates and rest in the body. The upper plate holder rests on three piezoceramic bars 2, attached with the special bracers, bolted to the upper external controlling ring. The plate parallelism is provided by changing the inclination of this ring by adjusting mechanisms 1. An adjustment process can be observed through the lateral eyepiece 6 with the introductory mirror. The fine adjustment of the interferometer is performed by applying an additional voltage to the sides of the piezoceramic bar through potentiometers. The whole interferometric head is comprised in the double camera thermostats. The accuracy of temperature maintenance in the external camera 0,1 .

Telescope (B) is installed in the internal part of the carrying rack 8 . It consists of the correcting lens with the diameter of 200 mm, focal length being equal to 1200 mm, and a light proof pipe. In the focal plane of the telescope there is an aperture diaphragm 7 that passes the central spot an interference fringe. The diameter of the diaphragm for the wavelength of 630,0 nm is 4,2 mm with the field of view of the instrument equal to 0,2 . Coincidence of the interference picture centre with the diaphragm centre is provided by rotating a special handle in two mutually perpendicular directions. Observation of the process of centring the diaphragm is performed through the lateral lens 10 and entrance prism. The light passed through the diaphragm, Fabry lens and interference filter 12 (Fig. 2) is projected on the cathode of the PMT. Interference filters are bolted on special turrets rotated by a motor driven by a command of the computer. The filter rotating mechanism with sensors of position is made as a withdrawal cassette. The diaphragm, filter cassette, Fabry lens, observing device as a separate block 9 are united hard with the body of the photometer and this

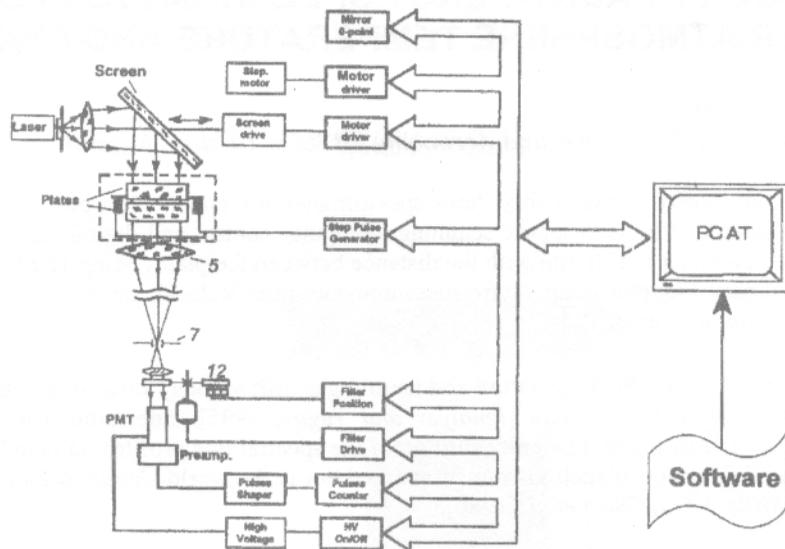


Fig.2.

whole node can be moved on nuts 11 along the optical axis of the telescope for coinciding the plane of the diaphragm with the focal plane of the telescope.

Photometer (C), working in the photon counting mode consists of a light proof cylinder with PMT (FEU-79), provided with a magnetic screen, amplitude - amplifier discriminator, pulse shaper. The amplitude discriminator on the tunnel diode produces cut-off heat (noise) pulses on PMT dynodes.

Laser calibration system consists of the helium-neon laser LG-56, projecting lens and scattering screen. The screen is carried into the field of view of the instrument by a special driver at the computer command during adjustment and writing of an instrumental profile.

For instrument controlling and photometer pulse counting an IBM compatible personal computer is used. For the link-up of the instrument with computer an interface card which is inserted into computer was designed. The card includes two of programming interface chips (580VV55), programming interval timer (580VI53) and auxiliary logic. The first are used for sending commands to the spectrometer and getting signals from the sensors, the second – for photometer pulse counting. The input and output signals enter the external buffer block, where amplifiers of signals and executive relays are located, and TTL-level input signals are formed. In that place are located DAC and output amplifiers of step-like voltage generator and a driver of stepping motor of sky observing.

The software is realised in Borland C++ 3.1 and consists of the user screen interface, where are located the main controlling units, which permit to set initial values of the parameters, e.g., step and exposure duration, filter choice, algorithm of observation, etc., besides there is a

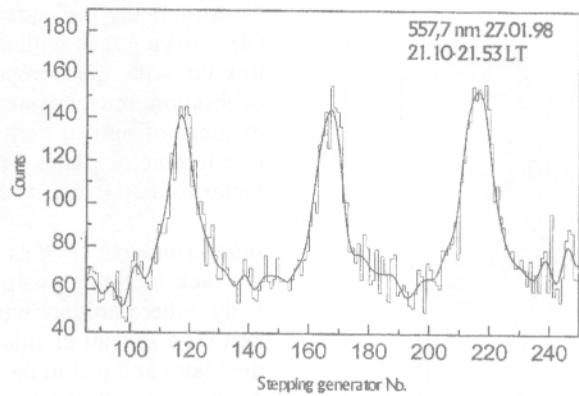


Fig.3. Example of registrations of the OI 557,7 nm airglow profiles on 27.01.97. On the horizontal axis are given the numbers of the stepping generator, on the vertical axis – the PMT counts. Duration of one step (time of accumulation) is 15 s.

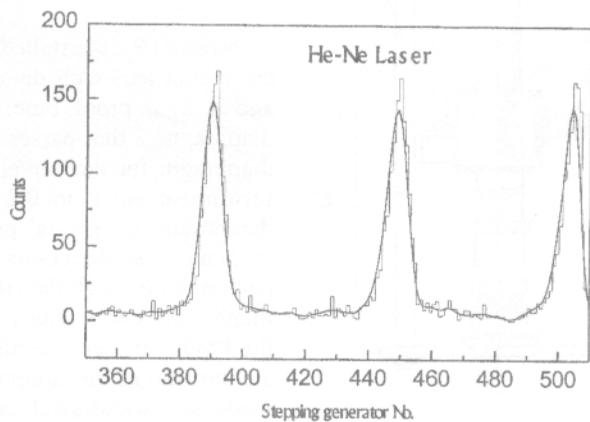


Fig.4. Example of registrations of the He-Ne laser profiles.

screen for watching observed interference profiles in real time. After each scanning cycle, contained of hardware profile of laser emission and three orders of sky emission profiles, the data are saved in the file. Step-like voltage drop is controlled by the program by issues of number sequence from 0 to 255 on digital-analog converter with the endurance, determining the time of accumulation, i.e. for a time of each step of step-like generator is performed opening of the timer gate and the PMT pulses are being counted. The linearity transformation error DAC is about 0,17%. In this case to piezoceramic is applied a step-like drop of the value from 100 up to 400 V. Such voltage is sufficient for scanning of three profiles of the laser line 632,8 nm when the distance between the plates is 12 mm.

Mirror system of focusing is provided in the rotation by the stepping motor and can direct the light from different sky areas onto the input aperture of the spectrometer. For the determination of the initial direction of the mirror there is, so-called, photoelectric sensor of zero position DP. To direct the instrument to a certain area of the sky the first mirror is rolled till finding the initial position, then a necessary number of steps are counted by the computer command.

Free spectral interval at the distance between working surfaces of the plates equal to 12 mm for the wavelength 630,0 nm is 0,0165 nm. Instrumental finesse of instrument is 11. Instrumental width measurements on laser line 632,8 nm distances is equal to 0,0015 nm.

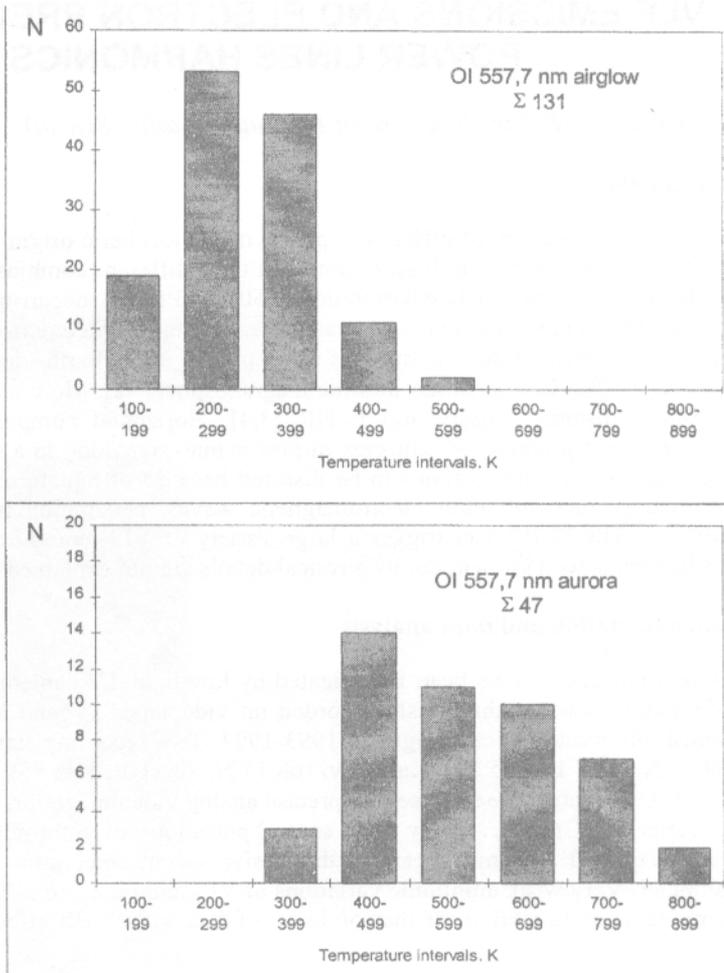


Fig.5. The Doppler temperature distribution histograms of OI 557,7 nm in airglow (a) and in homogenous auroral band (b).

Testing of the instrument at IKFIA optical station "Majmaga" has shown that the luminosity of the spectrometer is sufficient to enable registration of oxygen emissions in the night sky and its spectral resolution allows to investigate variability of temperature and neutral wind velocities at the heights of the subauroral and auroral zones of the thermosphere with the accuracy of 3%. In Fig. 3 and 4 are shown examples of profile registrations of the line 557,7 nm of atomic oxygen in the night sky glow and He-Ne laser, respectively. The data processing method is described in detail in [Ignatyev and Yugov, 1995]. In Fig.5 is presented the distribution of the measured OI 557,7 nm Doppler temperatures at some nights of January-February, 1998. The data in Fig.5a represent the temperatures in airglow in the zenith, and in Fig.5b are presented the data from homogenous aurora form of at the elevation of 30°. So, this distribution shows the consistence of the measured temperatures with the mean real average temperature in the region of the lower thermosphere under quiet conditions without any auroral activity.

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References

Ignatyev V. ., Yugov V. . Interferometrija krupnomashtabnoj dinamiki vysokoshirotnoj verkchnej atmosfery. Yakutsk, YSC SB RAS, 1995. 208 p.  
 Hernandez G. // Appl. Opt. 1970. V.9.N 5. P. 1225.  
 Hernandez G, Mills O. A. // Appl. Opt. 1973. V.12. N 1. P. 126.  
 Chect D.N., Cristensen A.V., Pranke D.V. et. all // Instruments for scientific studies. 1986. 2.. P. 106.