A Remote I/O (RIO) Smart Sensor Chip Supporting Serial Communications Bus for Small Satellites.

by:

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Abstract. The RIO chip is a general purpose, low power, radiation hardened, mixed analog/digital data acquisition chip for spacecraft/instrument housekeeping and spacecraft control actions, communicating the information over a serial I2C bus or a standard microprocessor bus. It measures eight Temperatures, eight Voltages, and eight currents, digitizes the measurements with an 10-bit A/D and stores the information in an on chip memory. The sensing capability can extend to other physical quantities such as total radiation dose measurements with radFETs etc. The chip contains also four DAC-comparator-counter channels for monitor and control actions. A general purpose 16-bit digital I/O port is also available, which can be configured for monitoring digital status and setting digital conditions to external devices, acting actually as a microcontroller. Four extra I/Os are configured as timer outputs suitable for pulsed or continuous thruster control. The serial communications bus by nature saves a huge amount of harnessing required in a traditional spacecraft design, and allows cascading of many sensors and actuators without additional wiring. It is expected, based on passed experience, that the special care in the design combined with fabrication in a radiation hardened process, will provide a total dose radiation hardness of up to 1Mrad, LET thresholds of ~120 MeV.cm**2/mg, and latch up immunity. This general purpose single die system can revolutionarize the new spacecraft designs, and further more it is a paradigm of a system on a chip, which finally can make reality the concept of the spacecraft on a chip.

MULTIPURPOSE SPECTROMETRIC ZONAL OPTICAL SYSTEM FOR UV AND VISIBLE RANGES "SPECTROZON"

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1.Abstract

Multipurpose spectrometric zonal optical system for registration in two space-matching images of stretching surface in visible (UV- the second channel) wave band is proposed for vegetable cover remote space control and environment and atmosphere ecological monitoring from the board of a small satellite.

Decision the tasks of the vegetable cover control with the help of "Spectrozon" system is based on two-spectral method of reflecting spectrum and polarization registration in characteristic wave length of Chlorophyll ((λ_1 ~ 360 nm è λ_2=560 nm).

Ecological monitoring, relating, in particular, to the definition of the fields, contaminated by oil products, and ozone distribution in the atmosphere, are based on two-spectral registration of fields of brightness in characteristic length of waves λ_1 ~ 340 nm and 450 nm (for oil contamination) and λ_2 ~ 280 nm and 310 nm (for ozone measurement).

Two-spectral method of forest fires detection is based on the two-spectral method of field fires detection in waves length λ_1 ~ 330 nm è λ_2 ~ 560 nm.

The measurement cameras are designed on the base of image amplifiers on microchannel plates and image recorders on the base of CCD structures with sensivity, corresponding to efficiency of the register ~ ten photons per an image pixel. Power consumption of the system does not exceed 40 w, mass - 6.4 kg max, dimensions - 420×400×300 mm max. Such parameters permit to locate the system onboard a small satellite.

2. Introduction

Space monitoring of the Earth surface in the optical spectral range is widely used at the present time for decision the tasks of ecology, antropogenic effects on the environment control as well as for economical tasks decision (agricultural plants yield forecasts, sea and ground fauna state, and other) /1/. On the other hand, the research directions are initiated during last few years on miniaturization of electrooptic images recording instruments together with their sharp (by orders of values) increase of sensivity on account of image brightness amplification in UV and visible ranges /2/.

The given information deals with characteristics of multipurpose UV and visible spectral optical system "Spectrozon" for Earth and atmosphere monitoring, aiming at various economical and ecological tasks decision, the achievements in electrooptic means for images recording are taken into account. The system operates simultaneously in two optically matched spectral channels - UV and visible ranges and it is based on the application of up-to-date electrooptic devices of images amplification and registration, what allows, on one side, to increase observation reliability and information volume, and on the other, to reduce their weight, dimension and power consumption characteristics in order to use such devices onboard small satellites.

3. Destination of the Optical System

"Spectrozon" is a spectral optical system, using two high sensitive matrix-cameras, comprising image brightness amplifiers of UV and visible ranges, band-pass filters, selecting narrow portions of $\Delta\lambda_i$ spectrum, and radiation polarizers.

The system is designed for remote monitoring of the vegetable cover and ecological monitoring of the environment in two matched-in-space images of the stretching surface in visible (the first channel) and in UV (the second channel) waves lengths ranges,

aiming at decision the following tasks:

- classification of agricultural plants, their state and yield estimation:
  - definition of the areas, where crops diseased;
  - forests state classification and estimation;
  - definition of green plantations areas and Chlorophyll mass;

- definition of phytoplankton fields:
  - definition of Chlorophyll concentration in water and Chlorophyll mass distribution;

- definition of the fields, contaminated by oil products:
  - oil products identification;
  - definition of oil products film thickness;

- definition of fires centres and flame distribution areas:
  - definition of burning fields;
  - definition of forest burning intensity;
  - investigation of ozone layer degradation.

4. Primary Methodological Principles, Relating to the Decided Tasks, are Confirmed by the Experimental Data, Described in /3-12/.

4.1. Methodics for agricultural plants and forest recognition and their state and yield estimation.

The methodics is based on registration of space brightness distribution of the stretching surface with a resolution not less than one meter and reflected solar radiation polarization level in two wave lengths - in wave length λ_{01}=560 mcm and λ_{02}=360 mcm. Wave length λ_{01} corresponds to the maximum of vegetable cover reflecting capability r_λ, illustrated by Fig. 1-3 /16/ for agricultural plants reflecting spectra at different phases of growth, as well as mixed and coniferous forests in different seasons. Value r_1 depends on a type of the plants. Measurement of polarization level together with r_2 reflecting capability allows to improve information level and certainty in vegetation classification, control crops growth in different phases, definition of moisture contents in leaves and definition of the areas, suffering from diseases. Methodics of the distinction, based on measurement of polarization and reflecting factor are described in /13-17/.

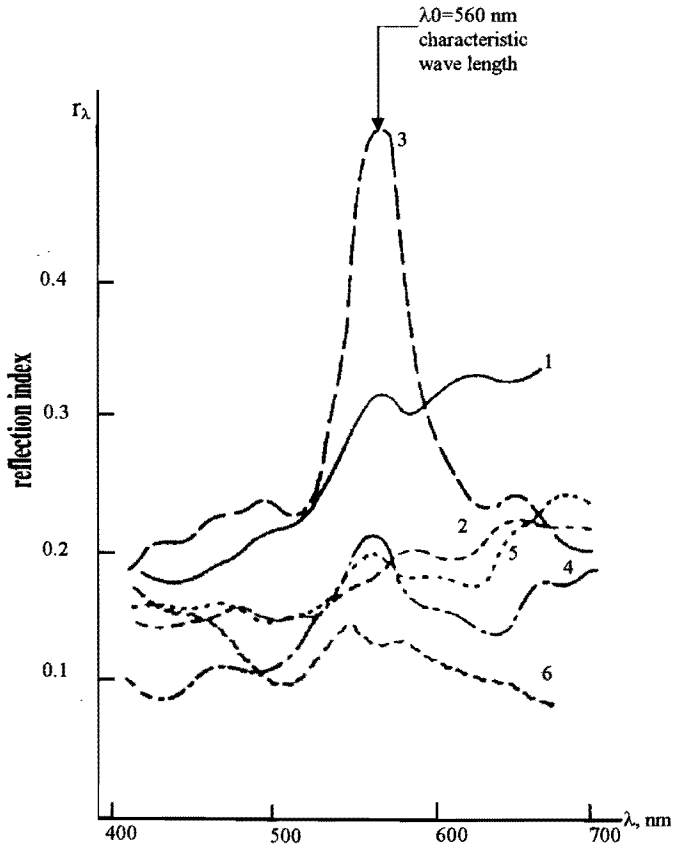


Fig. 1. Agricultural plants spectrum in different growth phases:
1 - winter wheat in a good state;
2 - winter weat with 30% of laying down;
3 - corn in the phase of the 8th leaf (23.06.1988);
4 - the same field - the ripe corn (14.08.1988);
5 - winter barley;
6 - winter barley layed down is 90%.

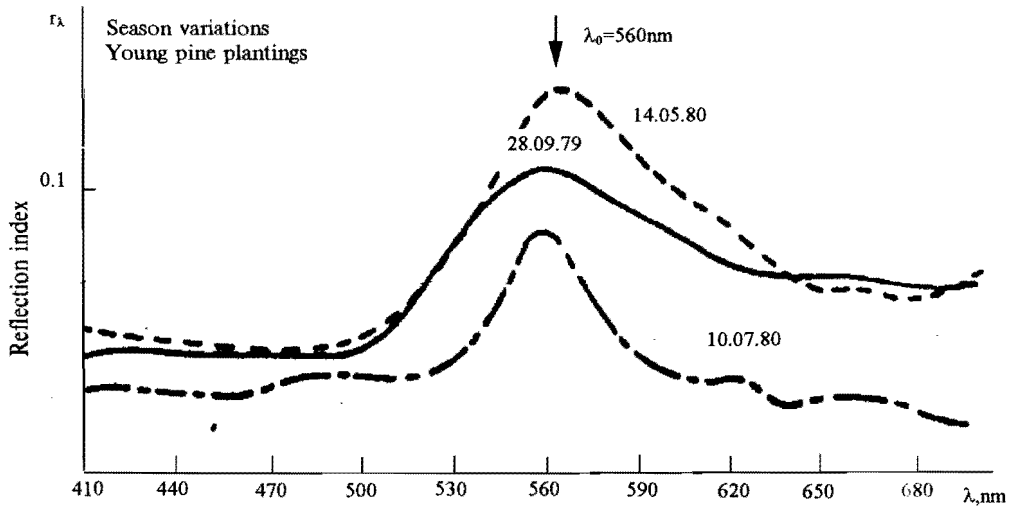


Fig. 2. Season variations of coniferous forests spectral characteristics

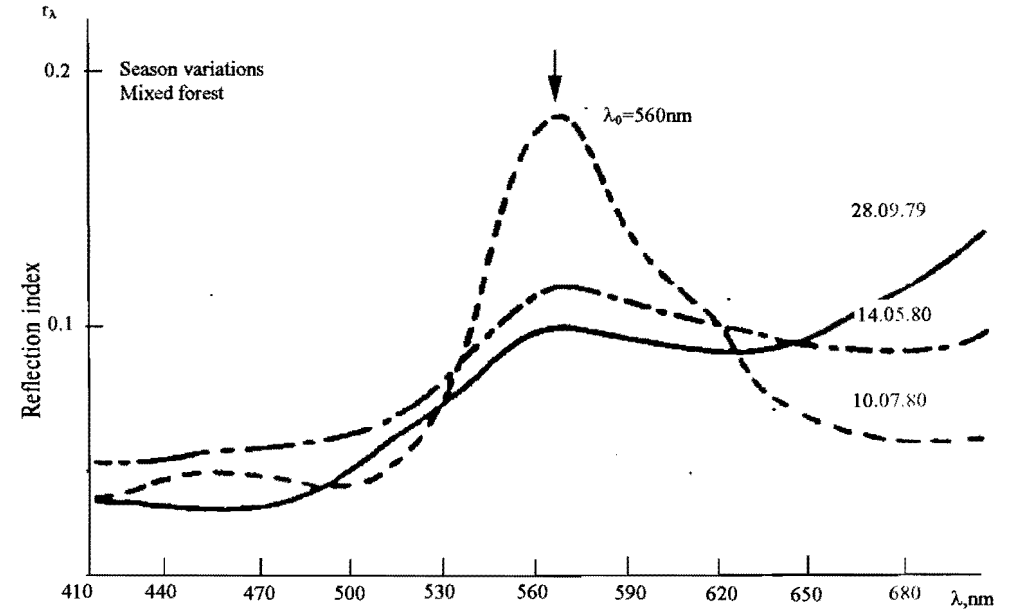


Fig. 3. Season variations of spectral characteristics of mixed forests in Krasnoyarsk region

Wave length λ=360 nm corresponds to the band of Chlorophyll absorbtion, which is the most important component in the process of photosynthesis. Fig.4 illustrates optic constantae of Chlorophyll - the refraction index and the absorbtion index χ /18/.

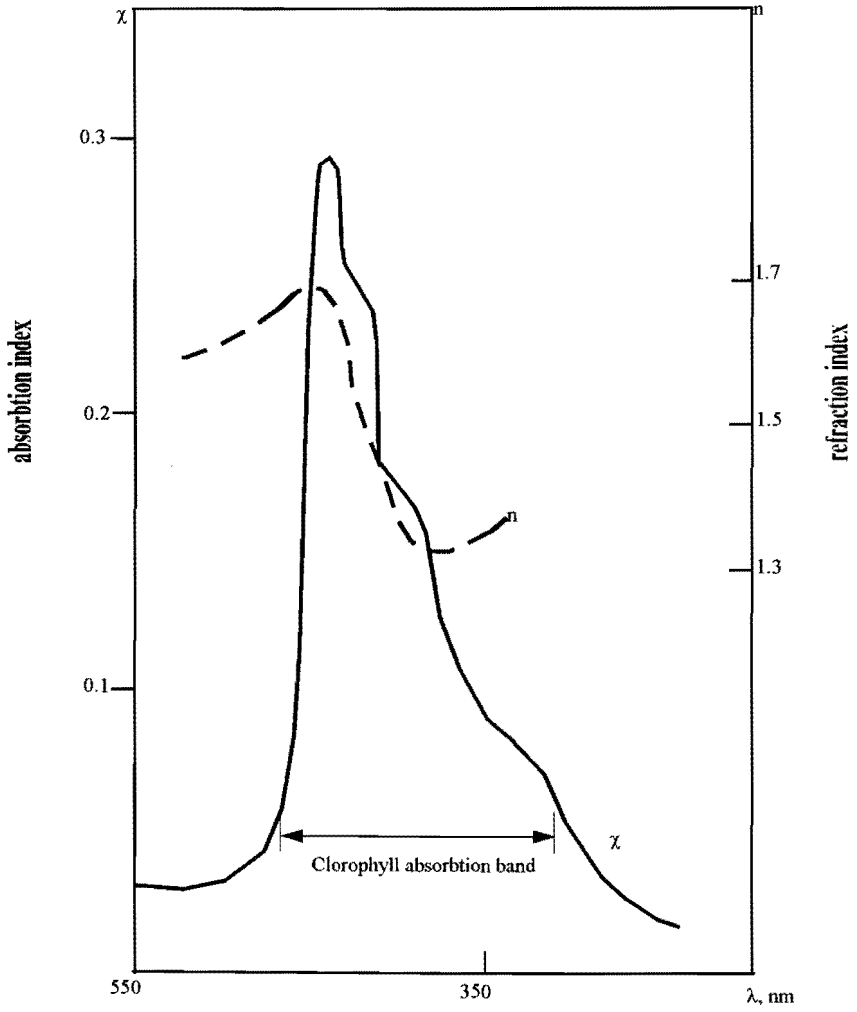


Fig. 4. Spectral characteristics of Chlorophyll

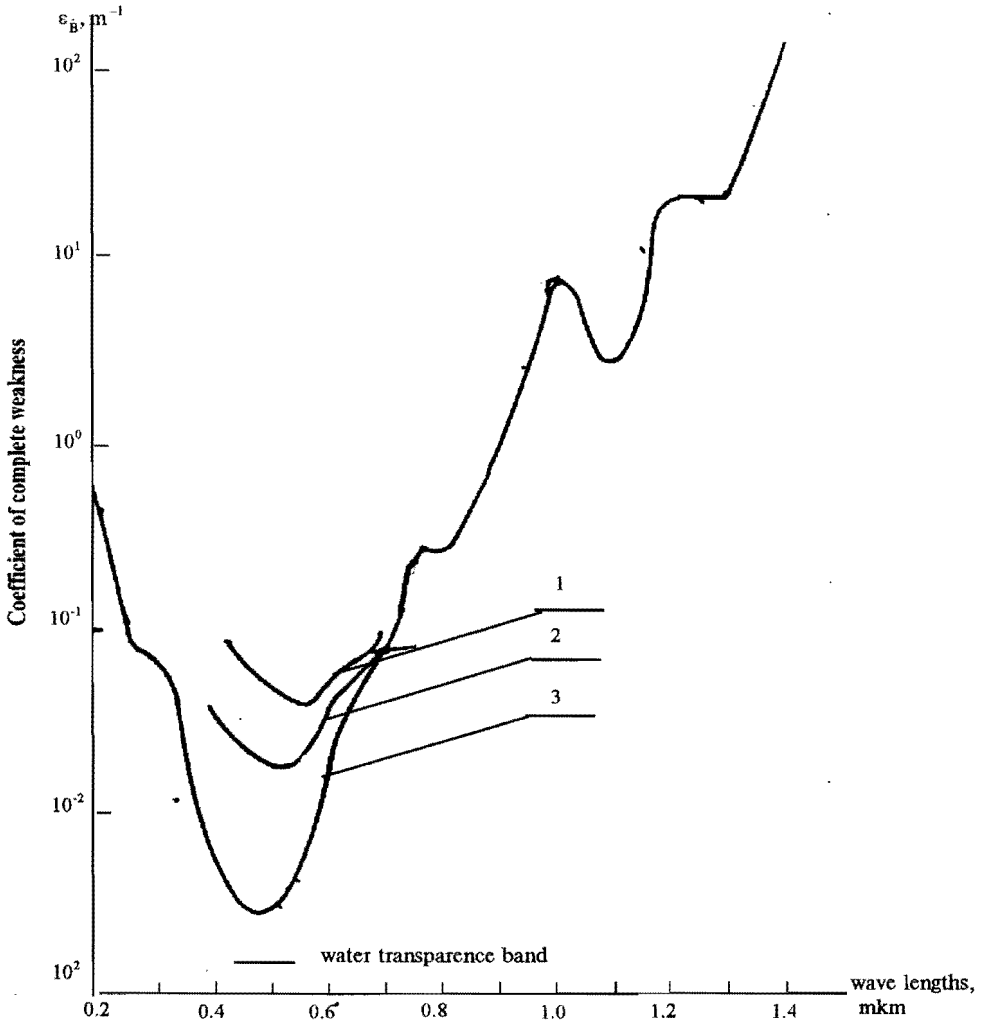
Vegetation leaves, containing Chlorophyll, stand out as a contrast against the Earth background in the absorbtion band 360±3 nm, what allows to define more accurately the effective area of the vegetation mass, absorbing Solar energy.

4.2. Methodics for phytoplankton identification and definition.

The methodics is similar to the methodics, described in p.2.1, as Chlorophyll, contained in water plants and plankton, has the same maximum in absorbtion spectrum and polarization level.

4.3. Methodics for detection and identification of oil products on the water and ground surface and the film thickness definition.

Like in p.3.1, two-spectral registration is used of water surface brigthness distribution and polarization level of ground surface contamination in wave lengths λ_{03}=450 nm and λ_{04}=340 nm. The first one corresponds to the band of a "window" of water transparency, illustrated in Fig.5 /19/. The second - to the band of oil products absorbtion in UV spectral range, illustrated in Fig.6 /20/. The methodics is based on the data of oil contaminations detection research, on measured reflecting factors and polarization level /21/.



1 - Chesapix bay waters; 2 - littoral waters; 3 - distil water

Fig. 5. Coefficient of complete weakness

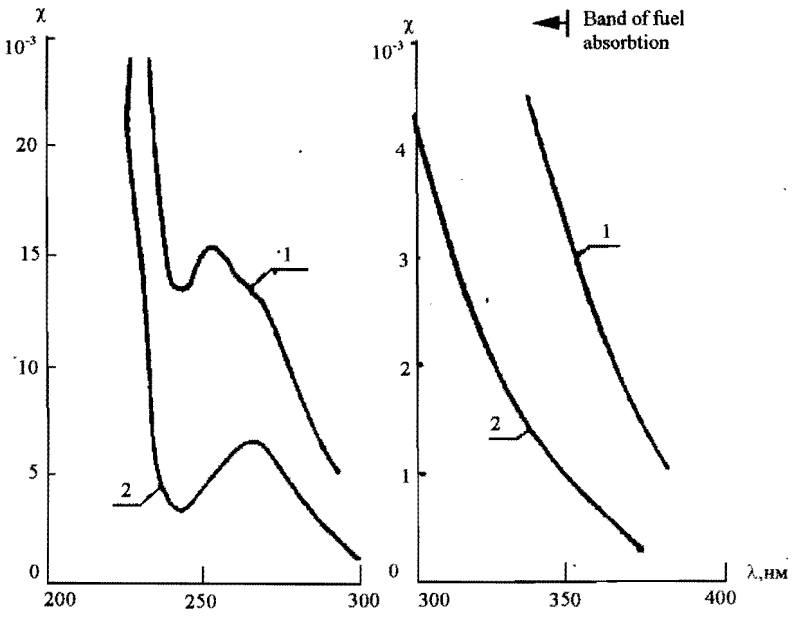


Fig. 6. Diesel fuel absorbtion indexes
1 - insummer; 2 - in winter.

4.4. Definition of fire centres and flame distribution area.

Definition of fire fields and forests fire intensity.

Two-spectral method of detection is used in wave lengths 560 and 330nm. The first channel, in accordance with p.3.1., is used for forest types identification, the second - for identification of burning fields and flame areas during observation in the bands of Hydroxyl 320-340 nm, as the band of Hydroxyl always accompanies flame radiation of Hydrogeneous combustibles.

All the described methods and the main parameters of identification, characteristic wave lengths and spectral intervals of spectral instruments are summarised in Table 1.

Table 1

№ n/n	Stretching surface type and tasks decision.	Identification parameter	λ_{01}	$\Delta\lambda_1$	Channel	Remark
1.	Agricultural plants classification, their state and yield estimation. Definition of the areas, where crops suffer from diseases. Forest state classification and estimation. Vegetation areas and Chlorophyll mass definition.	Chlorophyll	560 360	20 30	1 2	All types of agricultural plants and forests
2.	Oil products on water and ground surface. Contaminated fields definition. Oil product identification. Film thickness definition.	Petrol, Kerosene, Diesel fuels, light and heavy oil. Chlorophyll	450 380	20 30	1 2	
3.	Phytoplankton. Phytoplankton fields definition. Definition of Chlorophyll concentration in water and Chlorophyll mass distribution.	Chlorophyll	450 380	20 30	1 2	
4.	Fire centres and flame spread areas. Fire fields definition. Forest intensity definition.	Hydroxyl OH	560 330	20 20	1 2	
5.	Ozone layer degradation (10).	Ozone O_3	310- 331		4 4	

5. <u>Primary Characteristics of Multipurpose Spectral Zonal Measurement Information Optical System.</u>

Multipurpose spectral zonal optical measurement system of UV and visible ranges comprises two structurally similar measurement cameras and a vidio camera of general application for coordinate-territorial reference of the system.

Each measurement camera comprises four modules: optic - mechanical; electrooptical; matrix video camera; high voltage power supply unit (PSU).

Technical parameters of the system:

Sensitive field, nm	200...400; 400...700
Operational field of view (2W), grad	12
Image brightness amplification factor	$30...3\times10^4$
Brightness amplification adjusting	Smoothly(min...max)
Nominal voltage, V	alternative current - 220
measurement cameras,	12 or 24
accumulator	
Average power consumption, W	40 max
Mass of the system,	6.4 max
including video camera of a general application, kg	1.2
Dimensions of the system, mm	420×400×300 max

The system operates under normal gravity condition and in weightlessness. Operational temperature range is +10°...+40°. The system properly operates in the environment with pressure 450...970 mm and in air environment at the normal atmospheric pressure and humidity within 15...85% (at +20°C). Vibration overloads are up to 10.

Arrangement of UV and Visible Measurement Cameras.

The optical unit is the main element of the measurement cameras. The optical unit is an assembly of the objectives (UV or VI ranges) and electrooptic brightness amplifier (EOA) (UV or VI ranges).

UV or VI images of the objects are formed by the corresponding objective on the surface of photocathodes EOA of UV or VI ranges. EOA output screens of UV an VI ranges form the amplified visible picture of the object, recorded by the video camera, being a component of each measurement camera. EOA is fed by high voltage units, made in a sight of some separate assemblies on the base of high frequency transformers with a smooth ajustment of output voltage for optimal amplification of the image brightness in UV a VI spectrum ranges.

The objectives of the cameras have following characteristics:

Spectral range, nm	200...400 400...700
Angular field of view, grad	12
Geometric relative orifice	1/1
Effective diameter of the input pupil, mm	53.4
Resolution in the centre of field of vision, pairs shtr/mm	40 minimum

Electrooptical brightness amplifier (EOA) has the following characteristics:

Type of device	electrooptical transformer with microchannel amplification and electrostatic focus system with image turning
maximal sensivity area, nm	240...280 540...560
position of maximum luminance of the luminescent screen, nm	550
maximum transformation factor	3×10^3 min
resolution in the centre of field of view, shtr/mm	at least 25

The expendable interferent light filters with a bandwidth 4...20 nm are being installed in front of the objective in the object radiation to select narrow spectral fields (in ranges 0.22...0.35 mcm, 0.33...0.34 mcm, 0.34...0.38, 0.53...0.57 mcm).

The cameras are completed by the corresponding polarizers to separate polarized radiation.

Structurally the system is built as a foundation, on which two coupled units of measurement cameras are fixed, each comprising an optical unit, a video camera and EOA high voltage power units.

The high voltage power unit is connected with the adapter of alternative current of the video camera of the corresponding channel (UV or VI) (AC-V15/V16/V16A) by a cable through a plug-and-socket.

6.Conclusion

The multipurpose spectral system "Spectrozon" is developed with high sensitive construction of the image. One of the specific features of the system is simultaneous matched recording in two tunable spectral regions- in the UV channel and visible channel with coordinate reference to the locality with the help of a specific video camera. Due to up-to-date electrooptic devices for images recording and brightness amplification, sufficient miniaturization of the system is achieved in weight-dimension and power characteristics, suitable for its arrangement onboard small satellites.

Possibilities are considered to use the system "Spectrazon" for decision various ecological and economical tasks, proved its promise as the multipurpose system with high operational characteristics.

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