A new type or imaging spectrometer is proposed, in which tomographic transformation of a two-dimensional image into a one-dimensional image is performed instead of scanning of the original image using the inlet slit. The optical circuits of the device and an experiment at spectral analysis of an image of the Earth’s surface is performed.

Key words: imaging spectrometer, tomographic image, spectral analysis.

The problem of spectral analysis of color images arises in different areas of human activity, beginning with observations of the surface of the Earth and the planets, and astrophysical formations from outer space, and ending with the study of the structure of fluorescent biological microorganisms. Devices used for spectral analysis have been given the name of imaging spectrometers.

The designs of imaging spectrometers used to study different types of objects differ substantially, though the overwhelming majority of the devices may be divided into two groups according to the operating principle.

The operating principle of devices belonging to the first group is based on spectral filtration of the optical signal. A spectral filter, which may be either absorbent, interference, or opto-acoustic in nature, is introduced into an ordinary optical channel used to record images. The absorbent or interference filter is replaced or the opto-acoustic filter is retuned in order to obtain images of the particular object at different wavelengths. The use of a finite number of light filters leads to significant spectral digitization and, as a consequence, a loss of information about the spectral components of the object. If an opto-acoustic filter is employed, it becomes possible to realize smooth spectrum retuning, though because of the conditions of Bragg diffraction that are implemented in such filters it is not possible to simultaneously obtain the high spectral and spatial resolution determined by the filter’s angular aperture. A passband \( \Delta \lambda = 10 \) nm for an aperture \( \Delta \phi = 12^\circ \) is among the best results that may be attained at the present time [1].

Despite these drawbacks, the relative simplicity of the design and the low price are major advantages of imaging spectrometers equipped with light filters.

Devices belonging to the second group are similar in terms of operating principle to traditional spectroscopes. By means of the optical system and input slit, a narrow strip is “cut out” of the image of the object being studied, and this strip is projected onto a diffraction grating and decomposed into a spectrum. The two-dimensional image is recorded and stored in a computer. To obtain a set of spectrally separated images, the object must be scanned by means of a slit and a monochromatic image of the object synthesized on a computer. Such devices are used to create spectro-zonal images of the Earth’s surface from outer space. Scanning is performed as the aircraft travels [2]. These types of imaging spectrometers possess high spatial and spectral resolution, though they are difficult to manufacture and expensive.

A common feature of both types of imaging spectrometers is the fact that they scan the particular object, those in the first group relative to the object’s spectrum while those in the second group, relative to the spatial coordinate. This is
because a two-dimensional color image is a three-dimensional object \( f(X, Y, \lambda) \) in the phase space \((X, Y, \lambda)\), where \( \lambda \) is the wavelength of the optical radiation and \( X \) and \( Y \) the spatial coordinates. The actual function \( f \) describes the spatial distribution of the intensity of illumination. By means of the recording systems that now exist, such as CCD arrays or film, it is possible to record the two-dimensional distribution of the brightness. By scanning the object by means of an imaging spectrometer, it becomes possible to decrease the dimension of the instantaneously recorded file of information to a two-dimensional file. A large number of two-dimensional files is recorded in the process of scanning; these are then synthesized on a computer into a three-dimensional file described by the object \( f(X, Y, \lambda) \). Such digitization of the process of surveying information with respect to space or with respect to spectrum leads to a loss of information and limitations on the length of time the particular object may remain fixed, besides worsening the signal-to-noise ratio.

However, the decrease in dimension that occurs in recording the images of multidimensional objects may be realized by means of integrated probing, as described by a Radon transformation. This procedure is among the basic procedures in modern computer tomography and is referred to as the process of obtaining a tomographic projection [3].

The development of methods of tomographic probing in a space of variables of different physical senses, such as spatial and spectral senses, has made it possible to develop a new class of devices for the spectral analysis of images. In studying a two-dimensional polychromatic object \( f(X, Y, \lambda) \) in such devices it is not the individual cross-sections of the object \( \lambda = \text{const} \) or \( X = \text{const} \) which are simultaneously recorded, as occurs in scanning by means of an imaging spectrometer, but instead two-dimensional tomographic projections. These carry integral information about all the cross-sections of the particular object. Such an approach has served as a basis for a new research trend at the interface between the two branches of modern optics, optical tomography and spectroscopy, and has since been termed spectrotomography [4]. The principle of spectrotomography consists in recording a set of projections containing integral information about the spectral and spatial properties of a particular object, and subsequent tomographic reconstruction of its internal structure [5].

At the present time, studies in the area of spectrotomography are being conducted by several research groups in Russia and abroad. From an analysis of these studies we may note the existence of two tendencies in the development of spectrotomography [6].

The first is that involving the use of spectrotomographic methods for the analysis of the internal spatial and spectral structure of three-dimensional polychromatic objects, for example, different plasma formations. It is only through the use of the tomographic method that it is possible to analyze the spatial structure of three-dimensional objects, hence the spectrotom-