INVESTIGATION OF ACOUSTO-OPTIC TUNABLE FILTER OPERATION IN A COLOR DATA READOUT MODULES

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Abstract

Acousto-optic tunable filters (AOTF) are often used for various kinds of image processing. One of the most advanced ways to process image by means of AOTF is selection of the details of certain color or several colors in the total polychromic image. Such kind of processing allows to select the limited amount of information to transmit by the transmission system with limited information transmission capability. We consider two serially proposed devices which solve this problem and discuss their possibilities and compare their characteristics. The distinctive feature of the first configuration is AOTF location in the illumination side of the device and image detection by linear CCD array. The improved configuration includes AOTF in the side of image detection and uses 2-D CCD sensor array. The comparison has shown that the improved configuration of the device provides both bigger signal-to-noise ratio value and better conjugation by the frequency bandwidth with the TV system intended for the processed image transmission.

Keywords: acousto-optic tunable filter, color image processing, signal-to-noise ratio.

1. Introduction

Polychromic image processing plays an important part among numerous applications of acousto-optic tunable filters (AOTF) – Refs. 1,2. Good AOTF selectivity by wavelength which behavior can be described by the same laws as selectivity of the hologram recording medium relatively to the holograms multiplexed by wavelength – Ref. 3.

One of the most fruitful AOTF applications, which deal with images processing, includes the selection of the color image details of certain color (or several colors) among the other details, which compose an image containing very big amount of information – Refs. 4,5.

The image transmission system frequency bandwidth is usually limited so that the real time transmission of multicolor images with high resolution and wide gray scale meets obstacles. One of the ways to overcome such obstacles is to avoid transmission of redundant information, which is contained in almost each image. The problem is how to recognize the data to be transmitted among the redundant data.

The data selection has to be performed according to the certain sign. If the peculiar range of light wavelengths (color) is used as such sign, so AOTF is the optimal device to filter the redundant data. This kind of selection is very close to the hologram selection by wavelength multiplexing.

2. Basic configuration

The problem is to transmit the multicolor image with high resolution and wide gray scale on the paper carrier converting it into electric form. This image can be transmitted in real time using a TV pickup device with very high frequency bandwidth. However, if it is known beforehand that the majority of data contained in the image is redundant, and in order to obtain the adequate representation, it is enough to transmit the data described by several peculiar colors.

The basic configuration of the proposed device is presented in figure 1.

The device, which is schematically shown in fig. 1, was proposed to be composed as a module for color data readout. The set of such modules has to be used for data readout from a large-format document.

The presented configuration involves an illumination unit, which includes a wideband light source with calibrated power spectrum, AOTF with corresponding control unit, Fourier lens, and photodetector linear array such as CCD. In order to provide the best conditions for AOTF operation, the diaphragm is used after the light source (not shown in fig. 1) which limits light divergence by value of 2..3^0.

The electric signal from AOTF control unit excites acoustic waves in AOTF active medium, which provide deflection of light of peculiar wavelengths, corresponding to the colors of the necessary data, which must be selected from the total image. In order to provide recording of only these colors, the non-deflected light can be rejected by the blind.

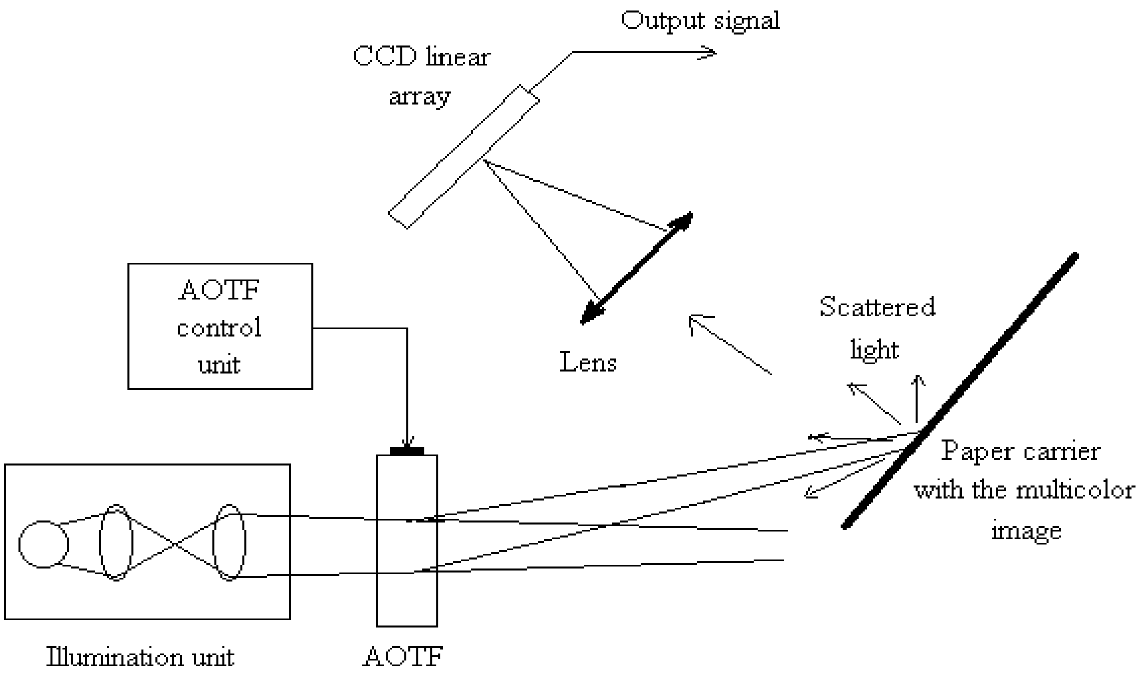

Figure 1. Initial configuration of the color data readout module for single colors selection using AOTF

Light is scattered from the paper with multicolor image, and this image can be seen as “black” in the areas where the other colors than the selected one by AOTF take place, and “white” in the areas containing the selected color. This image in scattered light is recorded by linear CCD array. The signal registered by CCD array can be transmitted further by usual electric way. In order to provide strict correspondence between the color notes and places in the background where these notes are located, the paper can be moved uniformly with the peculiar velocity.

In order to provide the coincidence of the transmitted color details with the necessary coordinates of background in the place where the data are transmitted, it is necessary to use the corresponding reference marks.

The presented configuration, which has been initially developed, has some deficiencies. The most significant are:

1. The limited divergence of light from the source causes too big light power loss.
2. Operation with linear CCD array limits the data processing velocity very much.

In order to avoid these deficiencies, we have proposed the improved device version.

3. Improved configuration

The proposed improved configuration is shown schematically in figure 2.

The configuration presented in fig.2 differs from that shown in fig. 1 by following features:

1. AOTF is removed from the illumination part into the readout part.
2. CCD 2-D sensor array is established instead of linear CCD array.
3. The configuration allows to project the 2-D image to the CCD sensor.

The illumination unit shown in fig. 2 differs from that from fig. 1 by the design providing light divergence inside angle 15…18^0. The rest light is rejected by diaphragm. Evidently, the bigger part of light from the source participate in the device operation in comparison with the previous case. However, the divergence angle must be limited for the optimal AOTF operation.

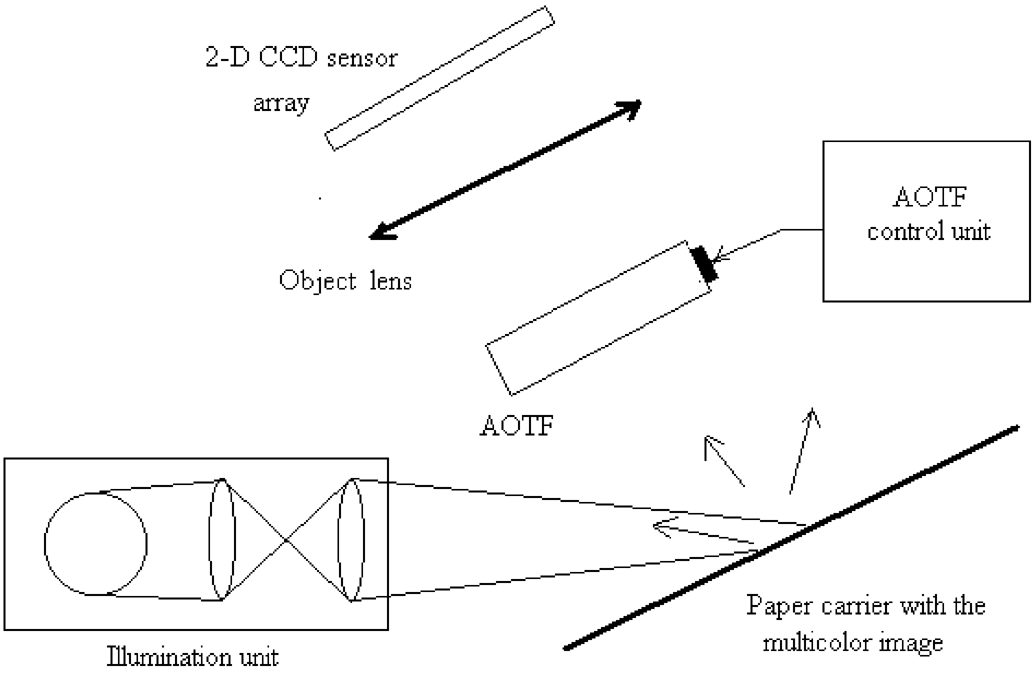

Figure 2. Improved configuration of the color data readout module for single colors selection using AOTF

The optical components of the illumination unit provide illumination of a stripe in the paper carrier surface. Light scatters from this surface according to an indicatrix, which meets Lambert's law. This indicatrix redistributes light power by the propagation direction. Of course, this distribution stays wider than the required divergence of input light for AOTF.

However, in order to conjugate the scattering indicatrix with the required light beam form which is the most suitable for AOTF efficient operation, it is enough to use the correction lens which has to be located between the carrier surface and AOTF (not shown in fig. 2). Such a configuration allows to provide the maximum possible light power use factor. The estimation shows that this configuration provides light intensity 3…4 times bigger than that shown in figure 1.

Another advantage of the improved configuration is connected with the bigger data array, which is processed simultaneously. The improved optical circuit transmits 2-D image located in the paper carrier, and this image is detected by 2-D CCD array. Although number of pixels in this image (in the direction of paper movement) is much less than that in the perpendicular direction (ratio of this numbers can vary from 10 to 100, depending on the required resolving power), the image of this stripe is detected in parallel, which allows to organize the paper carrier movement by much bigger steps than it has taken place in the case of basic configuration.

The experimental studies were performed using the AOTF based on Bragg cell in which non-collinear acousto-optic interaction had been organized. These cells were prepared with tellurium dioxide single crystals; shear acoustic wave in this crystal was excited by means of piezoelectric transducer made with lithium niobate. The crystal orientation deviation from crystallographic axis [110] was close to 6.5^0; this provided acoustic wave runaway from the direction normal to the transducer plane, about 50^0. This configuration allows to provide the necessary resolving power by light wavelength.

Comparison between the two configurations has shown that the second version allows to transmit data with much higher signal-to-noise ratio. Consideration of noise shows that the major noise sources produce additive noise, which does not depend on the signal level (of course, in the link of signal conversion corresponding to this noise appearance). Hence, increasing of the signal level (which takes place in the case of the improved configuration) by the value of order, allows to increase signal-to-noise ratio approximately in 3 times.

Acceleration of data transmission which is provided by the improved configuration, allows to increase information transmission capability of the system up to the values which can be close to that of broadcasting TV systems. Nowadays it can be described by frequency bandwidth of dozens MHz. Hence, we can consider that the transmission capability of the TV system conjugated with the proposed device, will be used practically completely.

References

1. L.J.Denes, M.S.Gottlieb, and B.Kaminsky, «Acousto-optic tunable filters in imaging

applications», *Optical Engineering*, 1998, **37**, No. 4, pp.1262-1267.

2. V.B.Voloshinov, L.A.Kulakov, and O.V.Mironov, «Optical image scanning by acousto-optic light filtering» [in Russian], *Radiotekhnika i Elektronika*, 1988, No. 10, pp. 2177-2182.
3. S.Yin, H.Zhou, F.Zhao, and F.T.S.Yu, "Wavelength-multiplexed holographic storage in a sensitive photorefractive crystal using a visible light", *Optics Communications*, 1993, **101**, pp. 317-321.
4. S.V.Andreyev, A.V.Belyaev, B.S.Gurevich, N.I.Migay, V.I.Popkov, and S.Alymkulov, "Partial image transmission using acousto-optic tunable filters", European Optical Society Topical Meetings Digest Series, 2000, **27**, pp.20-21.
5. B.S.Gurevich, S.V.Andreyev, A.V.Belyaev, V.I.Popkov, N.I,Migay, and M.V.Kaupinen, "Image processing using acousto-optic tunable filters", Proceedings of International Forum on Wave Electronics and Applications, 2001, **1**, pp. 157-161.