Pseudocoloring with BSO crystals

S. I. Grosz, L. M. Zerbino, and N. Bolognini

Centro de Investigaciones Opticas, CIC, Casilla de Correo
124, 1900 La Plata, B. A., Argentina.

Received 4 April 1989.
0003-6935/90/233337-02$02.00/0.

A new pseudocoloring technique is proposed using photorefractive BSO crystals biased under the influence of an externally applied electric field with coherent or incoherent illumination.

Pseudocoloring of gray level information is a technique of introducing false colors into a black and white image. The importance of this operation is based on the human eye's ability to distinguish between different colors more easily than gray levels.

Over the last few years several analogical optical methods have been proposed, involving holographic techniques, halftone screens, and spatial filtering operations. In some cases it is necessary to use a real-time method, which avoids the spatial filtering steps. Several real-time approaches have been implemented.[1-4]

In recent years the photorefractive effect has become the nonlinear optical mechanism of choice for optical image processing. When the light of a suitable wavelength λ_1 is incident on a crystal, photoelectrons are generated, migrate in the lattice, and are subsequently trapped at new sites. The resulting space charge gives rise to an electric field strength distribution in the material, which changes the refractive index via the electrooptic effect.[5] This property allows the simultaneous recording and reading of a given light distribution to be achieved with time constants suitable to real-time operations.[6] Writing and readout beams wavelengths (λ_1 and λ_2, respectively) and intensities must be adjusted according to the absorption band of the photoconductor to ensure that the written image is not erased.

We propose a new pseudocoloring technique using photorefractive BSO crystals biased under the influence of an externally applied electric field with coherent or incoherent illumination.

The experimental setup is depicted in Fig. 1. A gray level transparency to be pseudocolored is placed at plane Π_1, which is illuminated by a monochromatic λ_1 source S_1 through a condensing lens L_1. Lens L_2 images the Π_1 plane on the Π_2 plane and the Π_2' plane through the beam splitters BS_1 and BS_2. Simultaneously, L_2 images Π_2 and Π_2' (by reflection on mirror M) on the Π_3 plane.

The written image (with wavelength λ_1) in the biased BSO (Π_2 plane) induces birefringence due to the photorefractive effect and is read out with the monochromatic λ_2 source S_2 through lens L_2 and polarizer P_3. Polarizers P_1 and P_2 have their polarization axes parallel and the $\lambda/4$ plate with its axis forming an angle of 45° with those of P_1 and P_2. In this way, the reflected image on the BSO face does not reach the Π_3 plane while the direct mirror reflected image will. Thus, with an appropriate orientation of P_3, we produce a contrast reversed image on Π_3 through L_2 when read out with S_2 (λ_2), the image stored in the BSO crystal. In this way, the direct mirror-reflected image λ_2 superimposed with the photorefractive-induced reversed image gives on Π_3 a pseudocolored image of the original transparency.

Taking into account that the induced birefringence depends on the write-in illumination λ_1 and the applied voltage through the space charge field, a suitable combination of these parameters is necessary to select the resulting colors. A neutral variable density filter was located in front of mirror M for equalizing both intensities (λ_1 and λ_2).

A simplified version is possible without mirror M, beam splitter BS_2, and polarizer P_1. In this case the λ_2 direct contrast image component should be provided by reflection

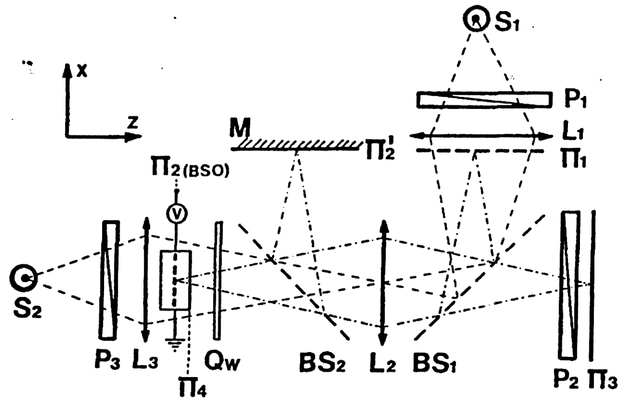

Fig. 1. Experimental configuration of gray level pseudocoloring with BSO crystals: S_1, S_2, illumination sources; P_1, P_2, P_3, polarizers; BS_1, BS_2, beam splitters; L_1, L_3, condenser lenses; L_2, imaging lens; Π_1, gray level transparency plane (input plane); Π_2, BSO image plane; Π_2', mirror M plane; Π_3, pseudocolor image plane (output plane); Π_4, BSO surface plane; QW, $\lambda/4$ plane.

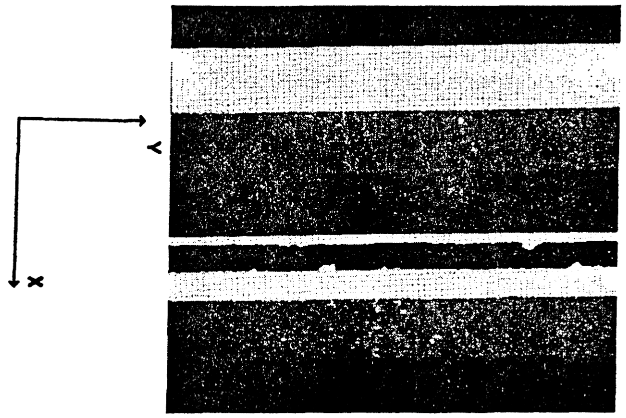

Fig. 2. Gray level original transparency.

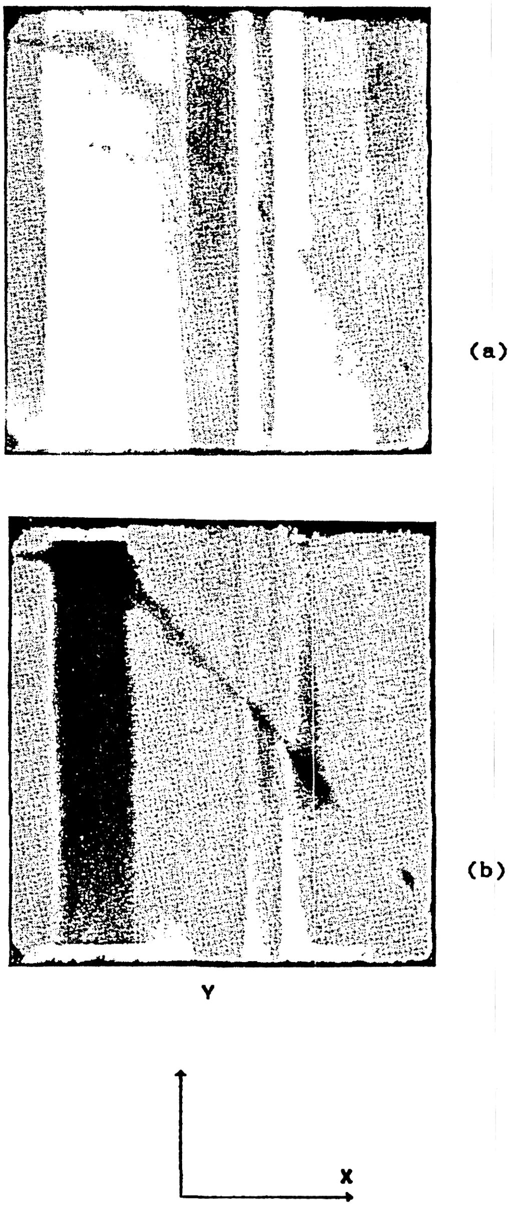

Fig. 3. Black and white pictures of the green (a) and red (b) filtered versions of the pseudocolored image. The faded oblique line across the pictures corresponds to a minute scratch in the crystal surface.

on the BSO surface (Π_4 plane). Nevertheless, in this approach, the equalization also depends on the reflection coefficient of the crystal, and an additional drawback is a misfocusing effect due to the lack of coincidence between planes Π_2 and Π_4. The arrangement of polarizers and mirror M of Fig. 1 provides the λ_2 component at Π_3 plane and eliminates the parasitic misfocused crystal reflection image.

We show an experimental result. In this case the object was a sequence of parallel fringes with different gray levels and widths as shown in Fig. 2. A color picture of the pseudocolored image of this transparency was obtained at the Π_3 plane. Figure 3(a) and (b) are the black and white versions of that colored picture when filtered through a green filter ($\lambda = 5200$ Å, $\Delta\lambda = 100$ Å) and a red filter ($\lambda = 6350$ Å, $\Delta\lambda = 100$ Å), respectively. Both the monochromatic sources S_1 and S_2 were spatially incoherent and were obtained using white light lamps and color filters centered at $\lambda_1 = 5200$ Å and $\lambda_2 = 6350$ Å, respectively ($\Delta\lambda = 100$ Å). The BSO crystal of dimensions $Lx = Ly = 10$ mm; $Lz = 3$ mm (provided by Sumitomo) was operated with an external bias voltage of ~6 kV.

Clearly, S_1 or S_2 or both could be spatially coherent. In this case, similar results could be expected with the additional effect of a speckled final image.

This work was supported under CONICET PID 3081400.

S. I. G. holds a fellowship from the Comision de Investigaciones Cientificas de la Provincia de Buenos Aires.

L. M. Z. and N. B. are members of the Consejo Nacional de Investigaciones Cientificas y Tecnicas.

References

1. F. T. S. Yu, X. X. Chen, and T. H. Chao, "White-Light Density Pseudocolor Encoding with Three Primary Colors," J. Opt. Paris 15, 55–58 (1984).
2. J. A. Mendez and J. Bescos, "Gray Level Pseudocoloring with Three Primary Colours by Diffraction Grating Modulation Method," J. Opt. Paris 14, 69–73 (1983).
3. R. Arizaga, N. Bolognini, H. J. Rabal, E. E. Sicre, and M. Garavaglia, "Real-Time White Light Pseudocolor Density Encoder," Opt. Commun. 43, 12–17 (1982).
4. J. A. Mendez and M. Nieto-Vesperinas, "Light Scattering by Film Grain Noise: Application to Grey Level Optical Pseudocoloring," Appl. Opt. 22, 2068–2074 (1983).
5. P. Gunter and H. J. Eichler, "Electrooptic and Photorefractive Materials," Springer Proc. Phys. 18, 206–228 (1987).
6. A. Marrakchi, A. R. Tanuay, Jr., J. Yu, and D. Psaltis, "Physical Characterization of the Photorefractive Incoherent-to-Coherent Optical Converter," Opt. Eng. 24, 124–131 (1985).