An Experimental 4K x 2K Color Video Pickup System Based on CMD Imagers

Kohji Mitani, Yoshihiro Fujita, and Hiroshi Shimamoto
Program Production Research Division
Science and Technical Research Laboratories
NHK(Japan Broadcasting Corporation)
1-10-11 Kinuta, Setagaya-ku, Tokyo 157, Japan
Tel. +81-3-5494-2312
Fax +81-3-5494-2309
E-mail mitani@strl.nhk.or.jp

1. Introduction

Recently, very-high-resolution image systems with resolutions greater than that of High Definition Television (HDTV) have been proposed and investigated. These new Ultra-high Definition television (UDTV) and Super High Definition image system (SHD)[1] have been proposed to realize many kinds of applications such as a future television system, telemedicine, virtual museum and electronic publishing. With regard to very-high resolution pickup systems, there are many methods of providing still images[2][3], however a system for providing moving picture has yet to be developed.

This paper gives an overview of our recent work on a very-high-resolution imaging system that provides better resolution than HDTV cameras as a step toward a viable next-generation video pickup system. For such a very-high-resolution pickup system, faster drive capability and increased pixel count will be necessary to develop an image sensor. With today's technology, however, these are conflicting demands since the resistance of buses and the load capacitance become an obstacle to high frequency operation while increasing number of pixels. It was this dilemma that led us to propose an alternative approach of realizing enhanced resolution by increasing the number of imagers incorporated in the pickup system, thereby mitigating the burden on each constituent imager. To confirm the effectiveness of this method, we have developed an experimental system with four 2M-pixel CMDs (Charge Modulation Devices).

2. 2M-pixel Progressive-scan CMD Imager[4]

High resolution and fast drive capability were the two primary performance requirements we sought for the imager incorporated in the experimental pickup system. To demonstrate the concept, we have selected 2/3-inch 2M-pixel CMDs and employed them in our camera system. The schematic diagram and the characteristics of the CMD are shown in Figure 1 and Table 1. The CMD is a type of active pixel sensor and has low power consumption, short reset time and other attributes making them well-adapted for high-speed

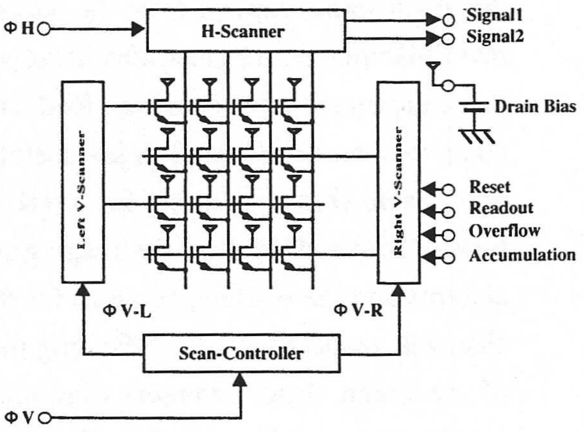


Figure 1. Circuit configuration of 2/3 inch 2M-pixel CMD

drive operation. One of unique features of the CMD is that vertical scanners are provided on both sides of the active image area, thus enabling progressive scan operation. The primary concern with the CMD is that they exhibit fixed pattern noise (FPN) attributed to pixel-to-pixel variations at dark level. However, the offset component of FPN was successfully suppressed by the FPN suppression circuitry incorporated as part of a digital signal processor.

Table 1. Characteristics of a 2/3-inch 2M-pixel CMD at 30 frame/sec progressive scan mode

Optical format	**2/3 inch**
Number of Effective Pixel	**1920(H)×1036(V)**
Optical Aperture Ratio	**34%**
Pixel Size	**5.0μm(H)×5.2μm(V)**
Image Area	**9.6mm(H)×5.4mm(V)**
Saturation Signal	**28μA**
Sensitivity	**760nA/lx**
Resolution	**H:1000 TVL, V:1000 TVL**
Blooming Level	**<-110 dB (V/10 exposure)**
Image Lag	**<0.1% of saturation**
Power Dissipation	**160mW**
Fixed Pattern Noise	**6.0%p-p of saturation**

The present experimental system operated in progressive scan mode at a data rate of 148.5M pixel/sec, double the HDTV data rate. Although the power dissipation in a sensor usually becomes a big problem at such a high driving frequency, the low power consumption of CMD provides a simple solution for reducing sensor temperature. By attaching a small Peltier device to each CMD, the experimental system performed controlled cooling and suppression of white spots caused by dark current in each pixel.

3. Enhanced Resolution Using the Four-Imager Pickup Method

Figure 2 shows a schematic diagram of the new four-imager color-separation optics[5]. Incident light is separated into four color components - two greens, red, and blue (GGRB) - and sent to their respective imagers. Resolution enhancement is then achieved by spatially offsetting the pixels of the two green-light imagers. Since the pixels are offset using optical images of the same wavelength, this reduces the weakening of the pixel offset effect caused by the chromatic aberration and makes it easier to obtain a high-resolution signal. This four-imager method effectively enhances resolution by enhancing the green signal, which makes the greatest overall contribution to the luminance signal.

By adopting the four-imager approach in the present experimental pickup system, the equivalent of a 4K x 2K pixel signal can be derived from the green signal coming from the output of the two CMD imagers for green after being subjected to interpolation processing. Red and blue components are allocated to just a single 2M-pixel each, thus producing 2K x 1K signals. Figures 3 (a) and (b) show the imaging sampling patterns and the Nyquist domains for the color channels, respectively. By offsetting the pixels of the green signal imagers diagonally, the resolution is predominantly enhanced in the horizontal and vertical directions. This method

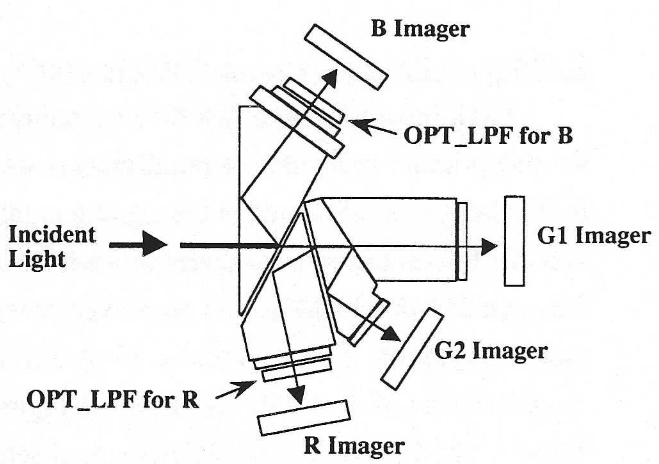
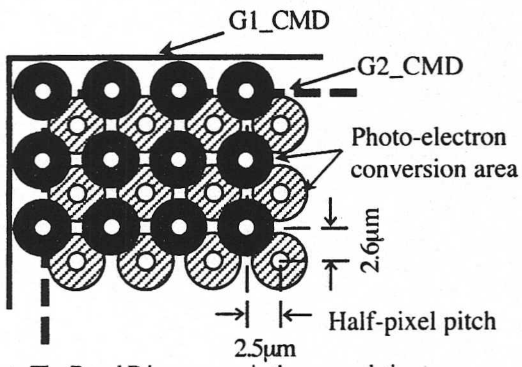
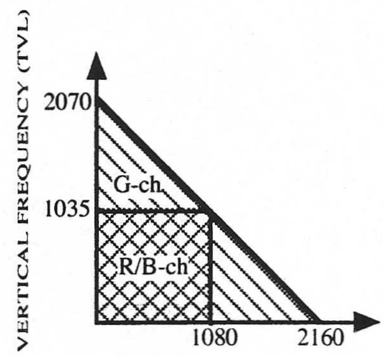


Figure 2. Schematic diagram of the new four-imager color-separation prism

of arranging spatial sampling points in a quincuncial pattern effectively extends horizontal and vertical resolution, which is well suited to the characteristics of human vision. At the same time, however, the horizontal and vertical resolution of the red and blue signals become half that of the green signal. To suppress the resulting aliasing components in the red and blue signals, optical low-pass filters (LPF) are inserted immediately in front of the red and blue CMDs that reduce the response at the horizontal and vertical sampling frequencies (i.e., 2,160 horizontal TV lines and 2,070 vertical TV lines) to zero.



(a): Imaging sampling patterns



(b): Nyquist domain for the color channel

Figure 3. Spatial offset imaging method and Nyquist domains for green, red, and blue channels.

4. Imaging Experiments

Specifications for the experimental pickup system are summarized in Table 2. The basic system we propose has the same 16:9 aspect ratio as HDTV, but doubles the HDTV pixel count in the horizontal and vertical directions to 4K x 2K(exactly, 3,840 pixels x 2,070 lines) which is generated by the interpolation process. The system operates at a frame rate of 60 frames per second in progressive scan mode, seeking to accommodate the image processing capability of computers. The basic frequency clock of the experimental system is set at 297 MHz (four times that of HDTV), and it also accommodates an HDTV image slicing capability to cut the images down from super high resolution to HDTV format.

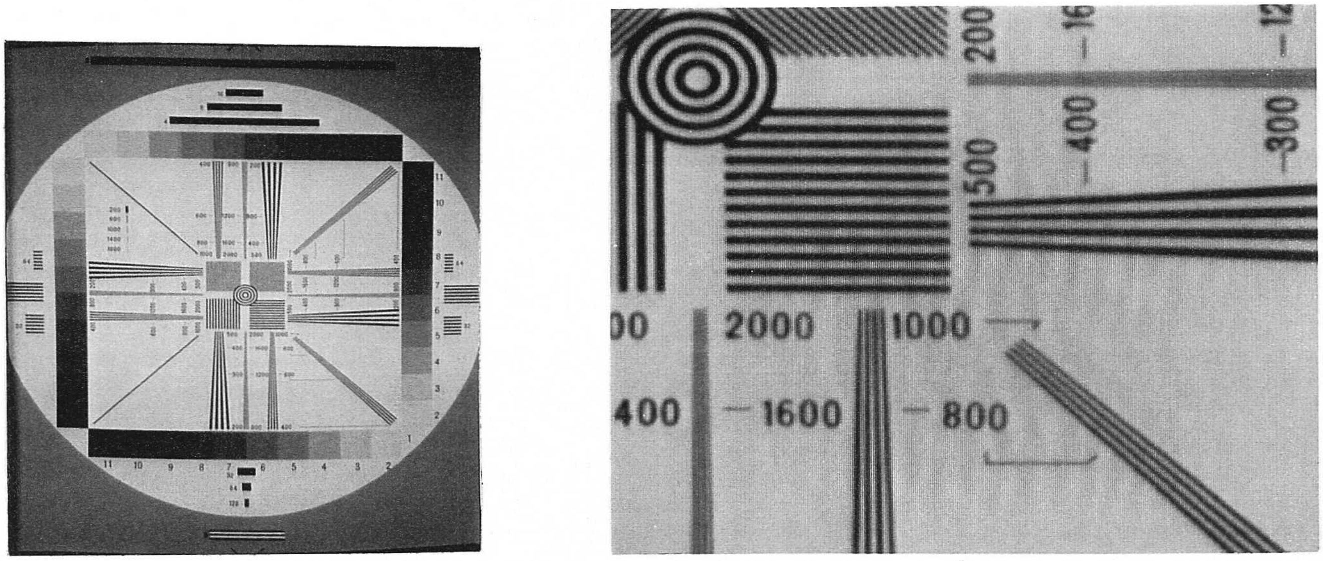
To display 2,000-line images we used the only 2,000-line color display monitor with a 1:1 aspect ratio that is commercially available at the present time. The imaging area of the pickup system has an aspect ratio of 16:9, so half the imaging area in the horizontal direction was masked off to display the images. As the image area (1,920 horizontal pixels x 2,070 vertical lines) with a 8:9 aspect ratio is displayed on the monitor with a 1:1 aspect ratio, the vertical-to-horizontal symmetry of the images was 8-to-9, slightly longer in the horizontal direction.

Figures 4 (a) and (b) show reproduced pictures of HDTV retoma charts displayed on the 2,000-line monitor. From Fig. 4(a) it is

Table 2. Specifications of the experimental pickup system

System	**60 frame/sec** **4K x 2K pixel/frame with 16:9 aspect** **(Gch: 3840 x 2070 pixels by interpolation process;** **R,B ch: 1920 x 1035 pixels)** **Progressive scanning**
Imaging method	**Four-imager pickup method (GGRB)** **(Spatial offset imaging in the diagonal direction applied between the two G channels)**
Imagers	**HDTV 2/3-inch 2M-pixel (1920 X 1036) CMD** **Progressive-scan driven at a rate of 148M pixel/sec** **(74.25 MHz X 2 lines readout)**
Display monitor	**2048 (H) X 2048 (V) pixels color monitor** **(actually 1600 horizontal dots by shadow mask)** **Aspect ratio of 1:1**

apparent that only about half of the total lateral image data is displayed on the monitor. From the enlarged central portion of the image shown in Fig. 4(b), one can see that a limiting resolution of 1,500 TV lines has been achieved in both horizontal and vertical directions. This limiting resolution can be attributed to a number of factors: the number of pixels for the red and blue channels is fairly low, the high-frequency response is diminished by interpolation processing and because the apertures of pixels overlap in the pixel offset method. One should be able to address these problems fairly easily, say with an aperture enhancement circuit that electrically elevates the high-frequency amplitude characteristics.



(a) (b)

Figure 4. Reproduced pictures of HDTV retoma chart displayed on the 2K-line monitor. (a):1,920 (H) pixels x 2,070 (V) lines on a display monitor with a 1:1 aspect ratio. (b):Central portion of (a).

5. Conclusions

This paper describes our implementation of a 4K x 2K pixel experimental pickup system that operates in progressive scan mode at a rate of 60 frames per second. The system adopts a novel four-imager approach that employs four 2/3-inch 2M-pixel CMDs. The experimental system not only fully exploits the inherent advantages of CMDs - high resolution and high-speed drive capability - but it also exhibits a viable method of enhancing resolution by implementing a spatial pixel offset method between two of the four CMD imagers for the green signal channels. A series of imaging experiments demonstrate that the system has a limiting resolution of 1,500 TV lines in both the horizontal and vertical directions. More fundamentally, this work shows that, in the very-high-resolution domain that goes beyond HDTV, the approach adopted here of increasing the number of imagers has inherent advantages, because it enables the capture of very-high-resolution color video using imagers which have relatively fewer pixels and good fundamental imaging characteristics.

REFERENCES

[1] S. Ono et al., "All-Digital Super High Definition Images", Signal Processing: Image Communication, 4, pp.429-444 (Aug. 1992)
[2] S. G. Chamberlain et al., "A 26.2 Million Pixel CCD Image Sensor", Proc. SPIE, Vol. 1990, pp.181-191(1993)
[3] G. Kreider et al., "An mK × nK Modular Image Sensor Design", IEDM Dig. of Tech. Papers, pp. 155 - 158(Dec. 1995)
[4] T. Nomoto et al., "A 2/3-inch 2M-pixel CMD image sensor with multi-scanning function", in ISSCC Dig. Tech. Papers,pp. 196-197, Feb. 1993
[5] M. Sugawara et al., "Four-Chip CCD camera for HDTV", SPIE Proceedings, vol. 2173, pp.122-129, Feb. 1994