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A 23 x 25.9cm^2 RGB color CMOS Imager System for Digital Photography

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This paper presents a custom-developed 23 x 25.9cm^2 CMOS-based RGB-color digital back for previewing images on a 8"x10" Sinar camera. This is a custom development for a world leading photographer, for which an existing CMOS image sensor design for X-ray applications was modified in size by changing the number of stitched blocks, and was provided with color filters. Four imagers are butted together to form the focal plane array of the 'digital intermediate' back.

This digital back "MAXBACK" is a replacement for the Polaroid film used in combination with a 8" x 10" Sinar P2 camera, applied for scene composition and lighting adjustments before registering the final image using conventional (but expensive) 8" x 10" silver halide slide film.

The starting point for the development of this CMOS detector is an existing CMOS pixel design developed for medical X-ray applications using the same design concepts as presented in [1]. Each individual 8" wafer-scale sensor is composed of six identical 'independent' slices, each with their own inputs and analog output, as shown in Fig.1. One slice is 256 pixels wide and 1728 pixels high, resulting in an active image format of 115 x 129 mm^2 for six slices together. All readout and control circuitry is placed at the bottom side of the imager, and the row drivers are distributed within the active columns. The resulting three-side buttable design enables the assembly of (X-ray) detectors of e.g. 2x2 tiles with an active area of 23 x 25.9 cm^2. The performance is summarized in Table 1.

For this application, RGB color filters are applied to the CMOS-sensors at a specialized foundry.

Four 8" wafer scale image sensors are then butted together to form a single 23x26cm^2 focal plane array, Fig. 2. The maximum inter-sensor spacing corresponds to a single pixel pitch, allowing for butting gap corrections using advanced custom interpolation routines. These routines also take care of the irregularity of the RGB pattern around the butting areas, inherent to the concept of the design, see Fig. 3. For the five areas "1" to "5" a modified RGB reconstruction method was developed.

The edges of the wafer-scale imagers have special structures to allow precise mechanical dicing without chipping. Fig, 4 shows the edge of a similar imager but without color filters after dicing. Fig. 5 shows the butting gap after assembly for a similar assembly of devices without color filters.

The detector housing was designed to fit the standard mechanical cassette interface of the Sinar camera, balancing requirements for rigidity (sensor butting) and handling (weight). A custom-designed ND/IR-filter was used as coverglass to obtain nominal ISO100 sensitivity and correct color response.

Fig. 6 shows the assembled CMOS detector. Fig. 7 shows an image obtained in the lab, Fig. 8 shows an image obtained by the customer. The performance is summarized in Table 2.

In conclusion, a custom "XXL" butted RGB color imager was successfully manufactured by re-using design, assembly and hardware concepts for large medical X-ray detectors.

Item	Value	Comment
Image format	115 (H) x 129 (V) mm^2	Butting to 2(H) x 2(V) for MAXBACK
Resolution	1536(H) x 1728 (V)	
Number of Pixels	2.65M	
Maximum charge capacity	385 000 e-	
Amp conversion factor	3.75 µV/e-	Matched to maximum charge capacity
Readout Noise	135 e-	Sufficiently low for original application that is X-ray photon shot-noise limited
Image lag	< 0.01%	2nd frame
Optical sensitivity of columns with distributed row driver	50% … 60% of standard columns	
Dark signal	6500 e-/pix.s	40°C
Dynamic Range	69.1dB	
Linear Dynamic Range	67.6dB	Linear range defined as <2% deviation from linear fit
Input clock frequency	40 MHz	Maximum
Data Rate (6 outputs)	240 MHz	Maximum

Table 1: Specification of 8" wafer-scale color CMOS imager used four times in MAXBACK.

Item	Value	Comment
Image format	23 (H)x 25.9 (V) cm^2	Butted to 2(H) x 2(V)
Resolution	3072(H) x3456 (V) pixels	
Number of Pixels	10.6M	
Butting gap	74.8 µm +/- 10µm	One pixel
ISO sensitivity	100	Obtained by custom-designed ND/IR filter in front of digital back
Power consumption	24W	Total system
Total number of outputs	24	
Output Data Flow	2 x 14 bits @ 60MHz	By re-arranging signals of 24 outputs
Control signals	Tint, trigger, flash sync	
Image processing	RGB reconstruction & defect pixel, row and column correction	

Table 2: Specification of digital back composed of four wafer-scale color CMOS imagers

References

[1] "A wafer-scale CMOS APS imager for medical X-ray applications", L. Korthout et al, ISSW 2009

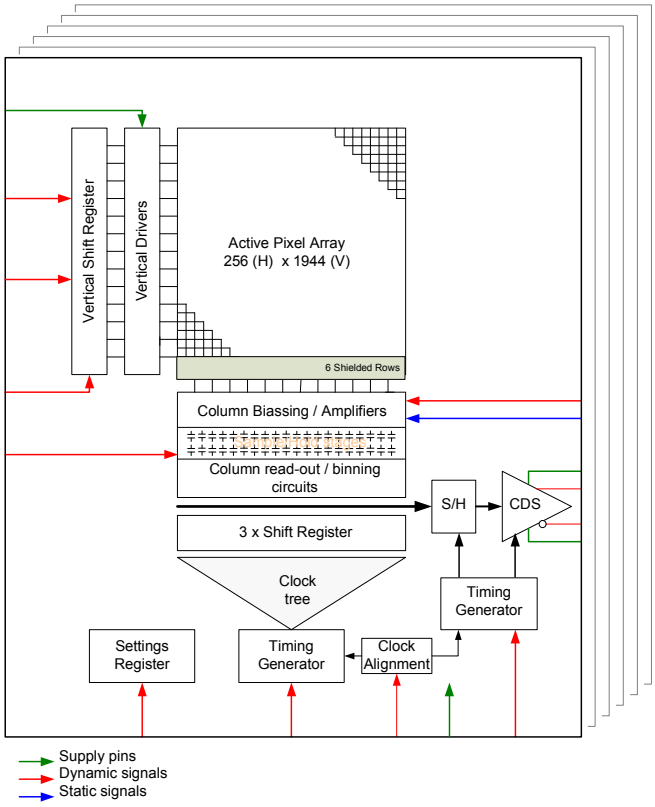

Fig1. Schematic of one CMOS Image Sensor used as starting point for "MAXBACK". Each 8" wafer-size CMOS imager is composed of 6 slices.

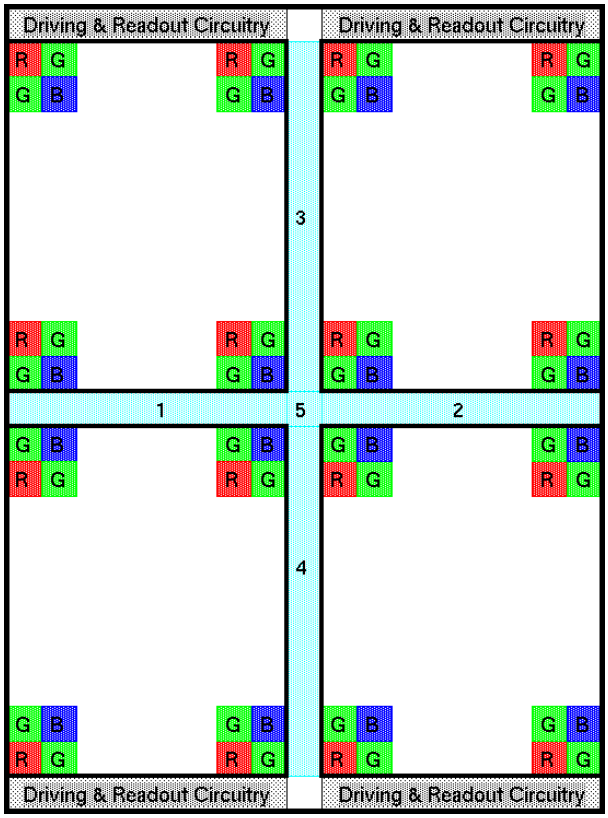

Fig.3. RGB Color pattern at butting locations

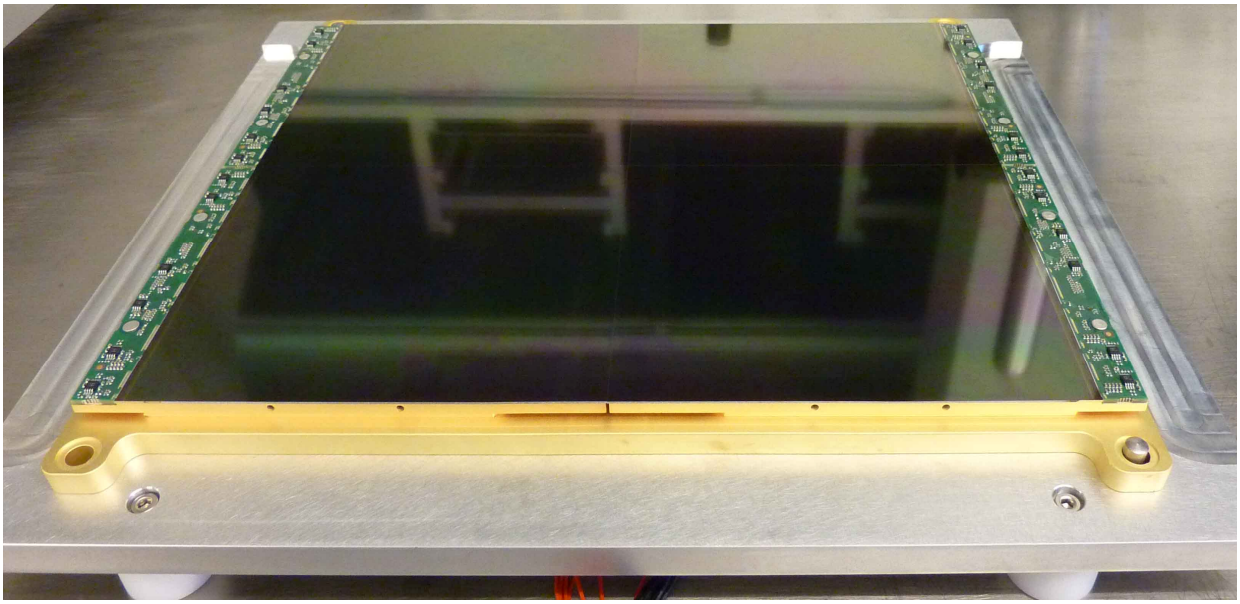

Fig.2 Four 8-inch wafer scale image sensors butted together to form a single 23x25.9cm^2 focal plane array

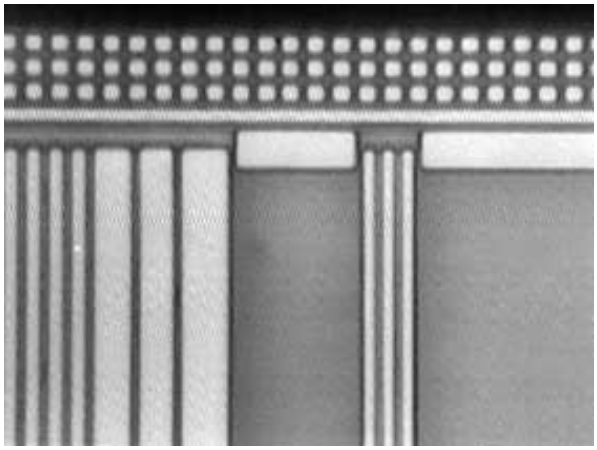

Fig 4. Edge of wafer-scale imager after dicing (similar imager without color filters)

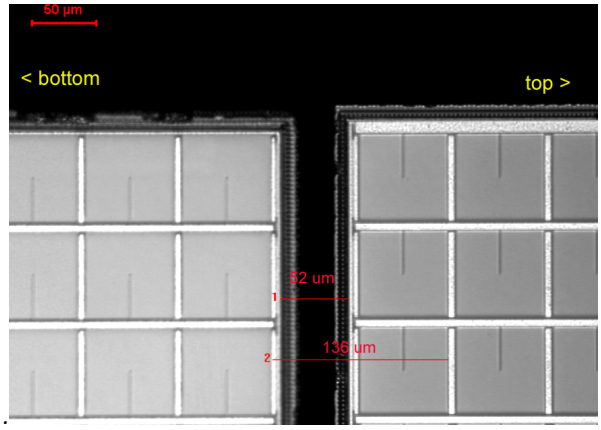

Fig.5. Detail of two sensors butted together on one substrate (example of similar imager without color filters)

Fig.6. Detector assembly "MAXBACK"

Fig.7. Image obtained in the lab

Fig.8. Image taken by the customer