A monolithic 111-M Pixel High Speed, High Resolution CCD

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ABSTRACT

A 111-Mega pixel, 92x92 mm^2, full-frame CCD imager with 9x9 um^2 pixel size has been developed for use in scientific applications. Recent interest for ultra-high resolution imagers for electronic imaging OEM customers in various scientific markets, including biotechnology, microscopy, crystallography, astronomy, spectroscopy, and aerial reconnaissance markets has lead to the development of the STA1600A 111-Mega pixel monochromatic charge-coupled device. Innovative design techniques were utilized in the early development of this device, yielding low RMS noise and high MTF for readout speeds ranging from 1 Mpixel/s to 25 Mpixel/sec. This paper will provide detailed information on the design and performance capabilities of the STA1600A, as well as background information on the commercial uses of this device.

Key Words: Charge Coupled Device (CCD), Charge Transfer Efficiency (CTE), RMS Noise, Quantum Efficiency (QE)

2. STA1600 DEVICE DESCRIPTION

The STA1600 is a 10560 x 10560 image element solid state Charge Coupled Device (CCD) Full Frame sensor. This device is depicted schematically in Figure 1, exhibiting split frame transfer configuration. The vertical clocks are configured such that there are eight individual sections that reduce the overall drive capacitance. This improves the vertical charge transfer efficiency (CTE), as well as reduces the risk of image smear at high frame rates. This CCD is intended for use in high-resolution scientific, space-based, industrial, military, and commercial electro-optical systems. The STA1600 is organized in two halves each containing an array of 10560 horizontal by 5280 vertical photosites. For dark reference, each readout line is preceded by 8 dark pixels. This imager is available in a full frame transfer configuration or a split frame transfer configuration with shield metallization covering half of the imager. The split frame transfer architecture allows higher frame rate operation through four readout quadrants, whereas the single-sided approach allows readout through two readout quadrants. The STA1600 is offered as a backside illuminated version for increased sensitivity and UV response in the same package configuration.

Figure 2 represents an individual imaging subset of the STA1600A. These individually addressable output sections reduce the number of horizontal transfers, thus decreasing the readout and improving the horizontal CTE. The pixel size is 9 x 9 um in the imaging array; however the horizontal register is designed to store two times the vertical full well for binning. The output is a dual stage FET that is operable at readout rates up to 25MHz. This device was fabricated using a three-phase, triple poly, double metal process and the die size is 92 x 92 mm. The STA1600A has the capability of capturing data at a rate greater than 3 frames/second.

One difficulty with this extremely large device (die size 92 x 92 mm or 84.64 cm2) is fitting it within the useable area of a 150mm wafer. Many process areas were altered to improve not only the device yield, but also ensuring performance for a variety of end-users. Figure 3 represents a wafer from the STA1600A lot run. There are a variety of test structures around the 111-Mega Pixel imager, allowing for a timely evaluation of the fabrication process.

This device has undergone wafer level DC characterization and functional testing. The following section will cover a brief synopsis of the characterization techniques, along with detailed experimental results from the STA1600A 111-Mega Pixel imager.

3. STA1600 EXPERIMENTAL RESULTS

Fe55 images are used to calculate RMS noise and charge transfer efficiency. The STA1600A RMS noise values for various readout rates are presented in Figure 4. Figure 5 demonstrates excellent CTE of 0.999999.

Following x-ray characterization of the device are uniform illumination tests. These include PRNU, linearity, and full well measurements. The output linearity and full-well are measured using the photon transfer curve technique.[3] Figure 6 is the photon transfer curve taken with a frontside illuminated STA1600A. This chart shows an output linearity <2%, and a pixel full-well capacity of 80000 electrons. The STA1600 has an SNR value of 78 dB at 1 MHz and 65 dB at 25 MHz.

Along with the previously mentioned specifications, cosmetic quality is of major concern for an imager of this stature. This is important criterion for the astronomical, medical, and biological imaging fields. Currently we have tested multiple STA1600A each containing a limited number of cosmetic defects. Figure 7 is a 10580 x 5280 image containing 3 column defects and 99.9993% good pixels. A column/pixel defect is defined as an area that either has excessive dark current (hot pixel) or one with poor photo-response (dark pixel).

Now that the STA1600A has undergone baseline characterization, efforts will be concentrated on high frame rate evaluation. These tests will be accomplished using the new STA Flex Cam high speed data acquisition system; where the device is currently imaging at 10MHz. This camera is an FPGA based system that utilizes high speed drivers with 40MHz at 3.5A drive capability. The video board uses a CDS analog signal chain with a 14 bit ADC.

6. SUMMARY

The STA1600A 111-Mega Pixel imager has the capability of providing high-end quality imaging for multiple markets. As camera mosaics increase in size the desirability of large scale imagers is becoming more and more evident. These STA Ultrahigh Resolution CCD's will drive down the price of scientific grade detectors by greatly decreasing the number of devices necessary for large mosaics. Also when attempting to populate a multi-gigapixel array, less devices implies a simplification in drive electronics. In conclusion the STA1600A meets the strict electro-optical detector requirements for aerial reconnaissance, thus improving the capabilities and raising the bar for industry standards.

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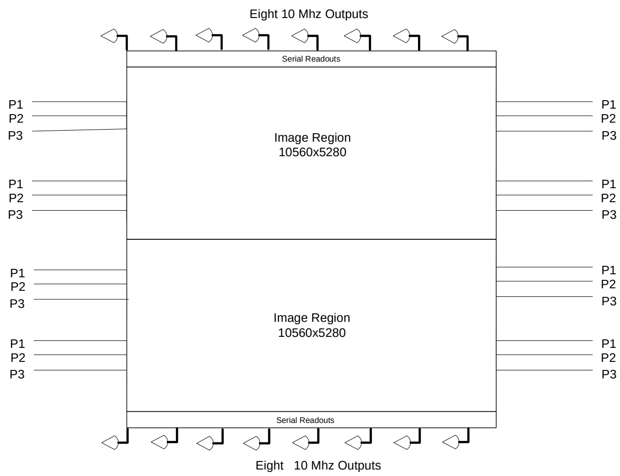

Figure 1 Configuration

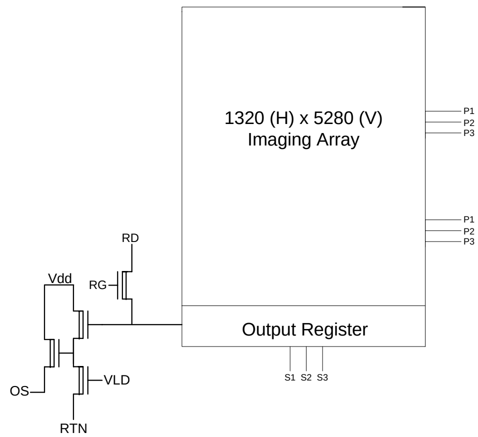

Figure 2 Single

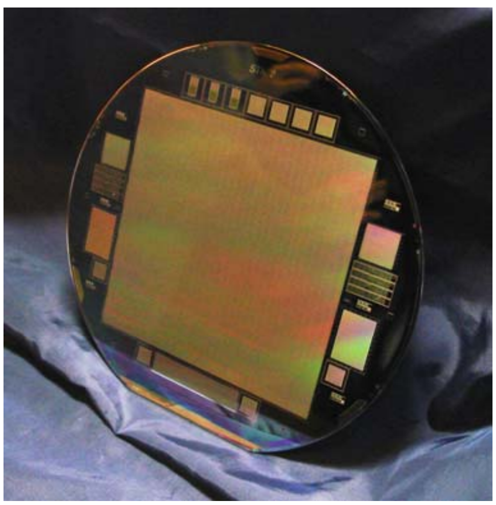

Figure 3 STA1600 Wafer

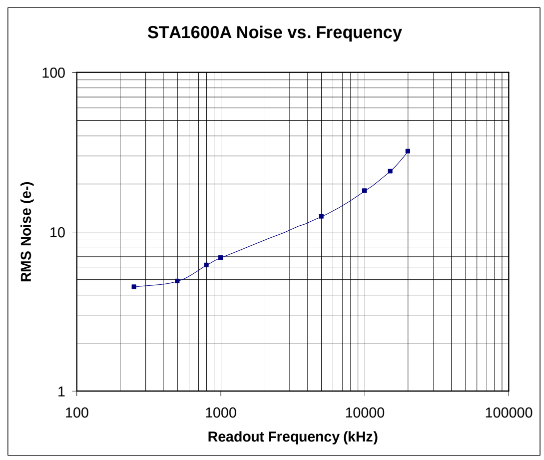

Figure 4 Noise vs

Test Parameter -75C @ 10MHz	Measured Data	Units
Parallel Charge Capacity	>80,000	e-
Serial Charge Capacity	>160,000	e-
Vertical CTE – Fe55	0.999995	per pixel
Vertical CTE – EPER	1.000000	per pixel
Horizontal CTE – Fe55	0.999985	per pixel
Horizontal CTE – EPER	1.000000	per pixel
Non-Linearity	1.0	%
Read Noise	18.2	e- rms
Dark Current	0.31	e- Non MPP
Spatial Resolution	55.56	cycles/mm
Dynamic Range	72.3	dB
Ensquared Energy	0.913	Collection Eff.
Frame Rate	3.5	frames/second

Table 1 Performance summary

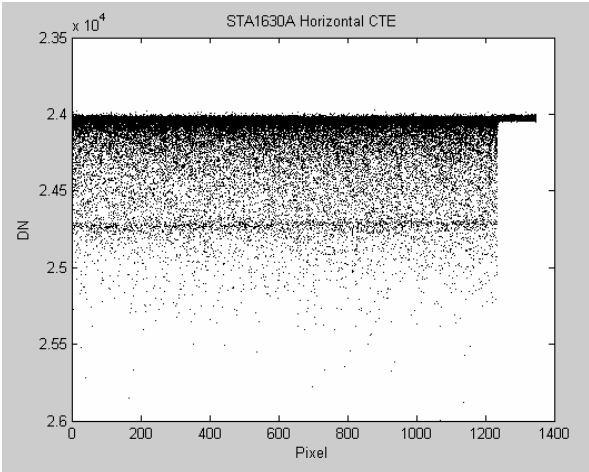

Figure 5 Charge Transfer

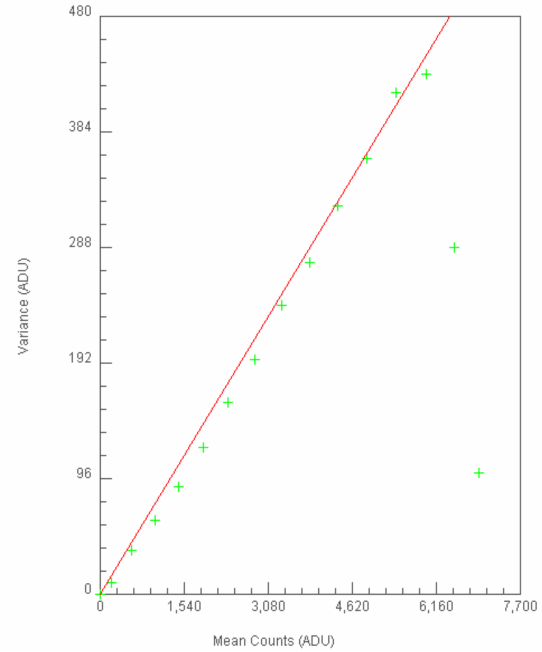

Figure 6 Photon

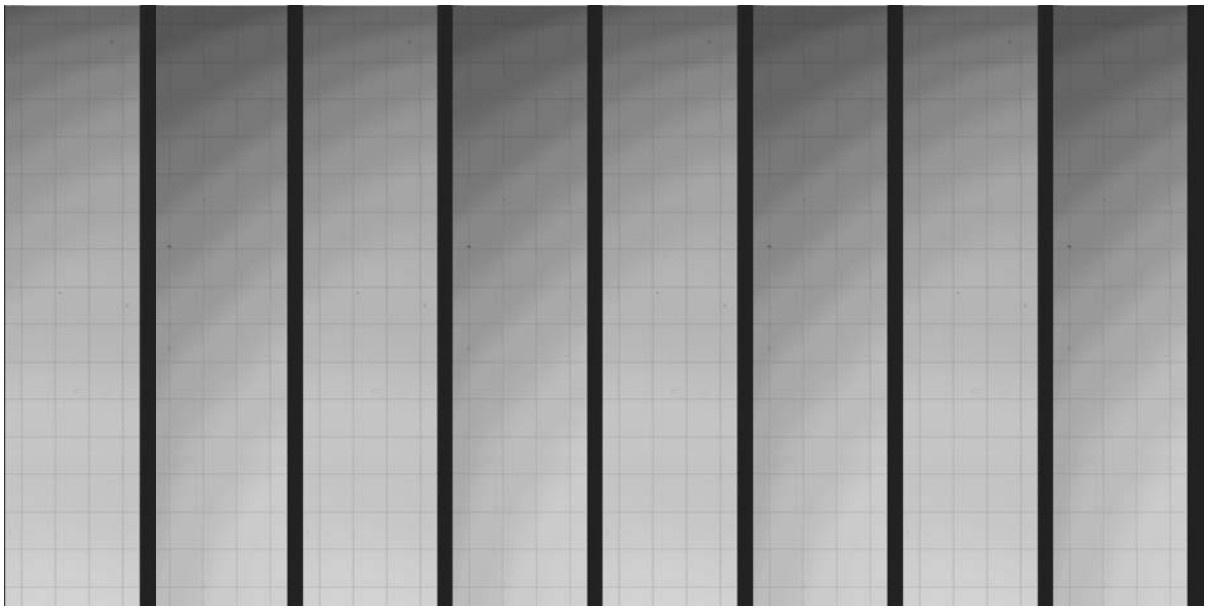

Figure 7 STA1600A 10560 x 5280 Flat Field