SAND2014-17022PE

Introduction and overview

Streak camera meeting
Sandia National Laboratories
August 26-27

Dan Dolan and David Bliss
Sandia National Laboratories

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

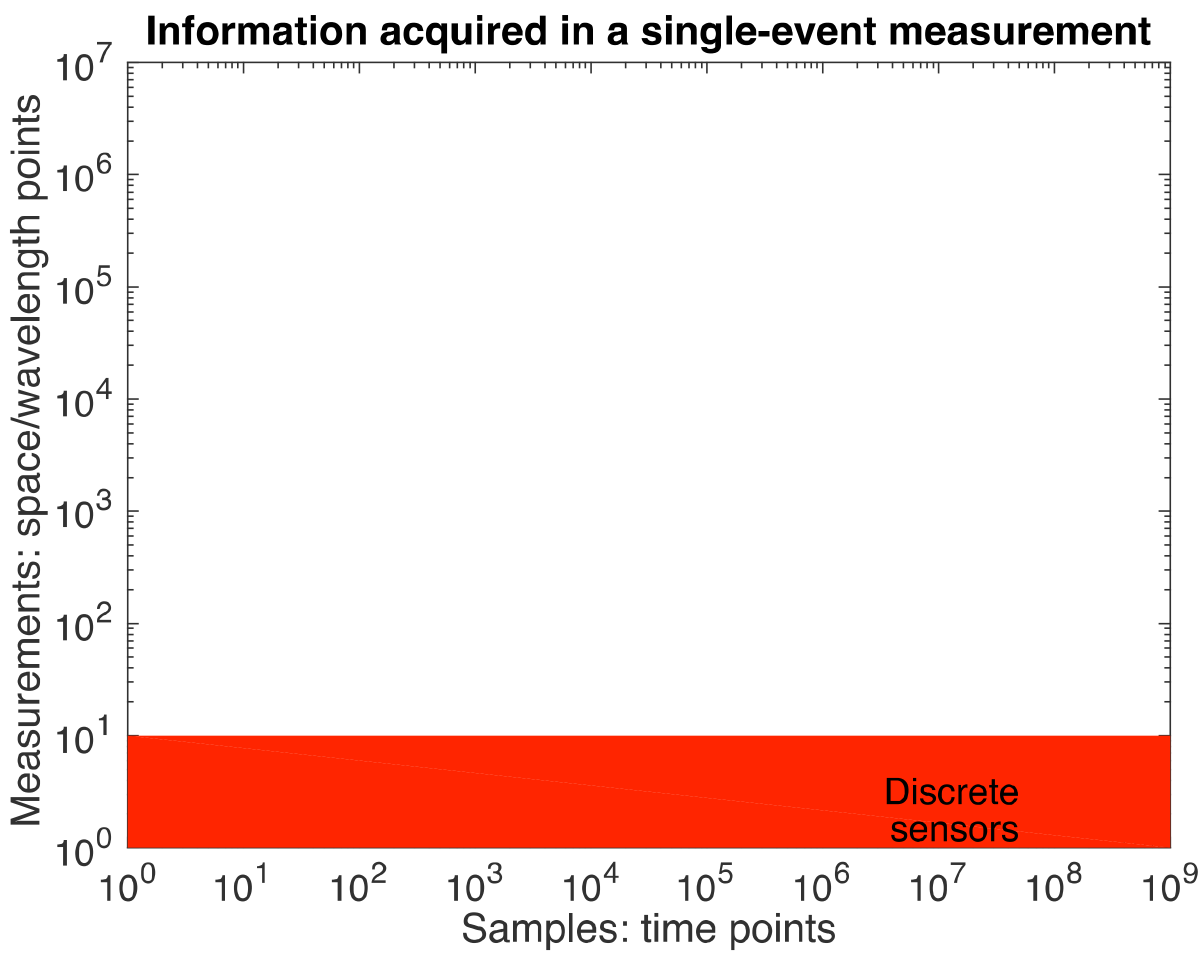
Why are we here?

- **Streak cameras were identified as a potential gap (Diagnostic Workshop, January 2014)**
  - Streak cameras used throughout the NNSA laboratories
  - Concerns about continuing availability of streak tubes
    - Diminishing expertise/production of vacuum tubes
    - No domestic manufacturer
  - Some active cameras are 20+ years old
    - Replacement tubes are no longer available
- **How can we prepare for the future?**
  - Maintain/replace cameras in the short term (<5 years)
  - Invest in new technologies for intermediate (5-10 years) and long term (10+ years)

Why are streak cameras are important?

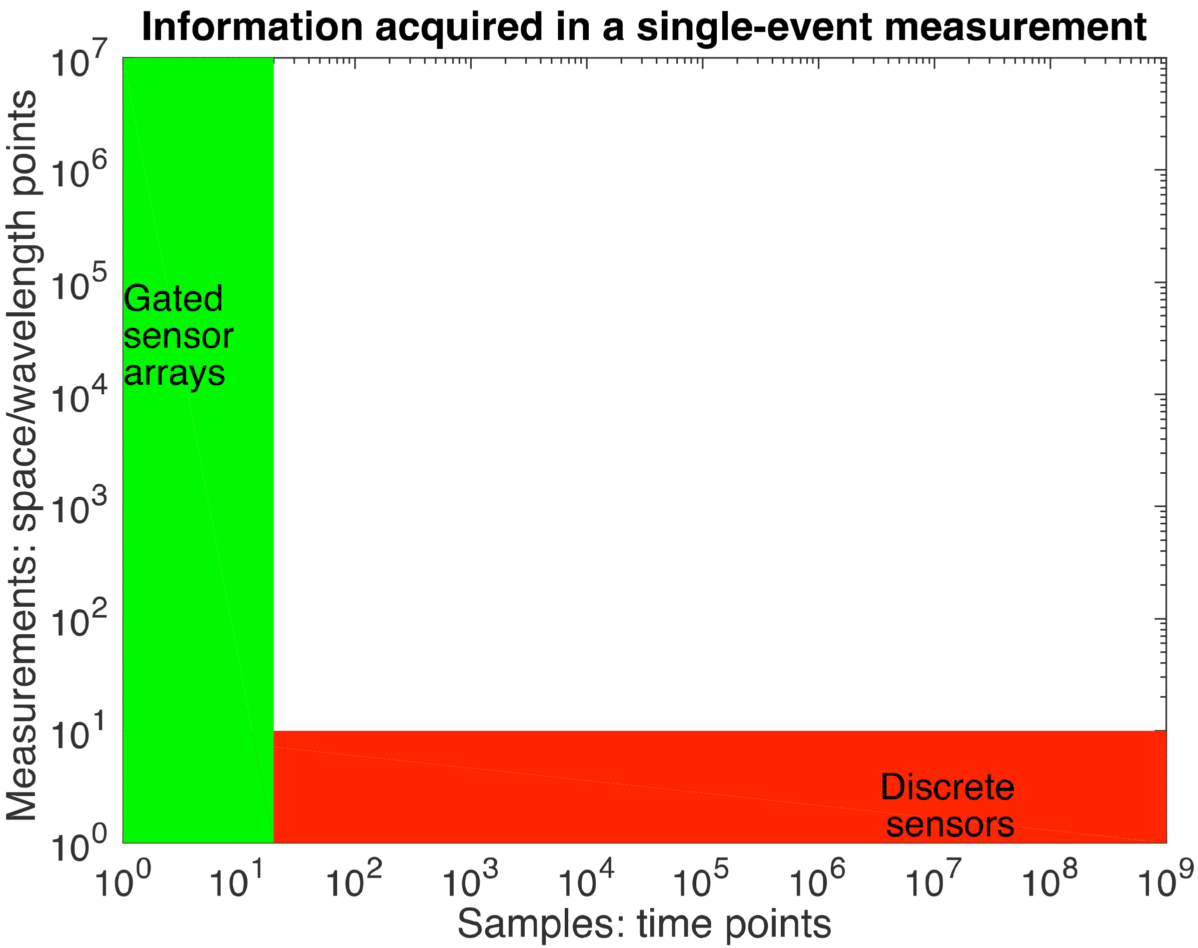
It comes down to information storage in a single-event measurement

Why are streak cameras are important?



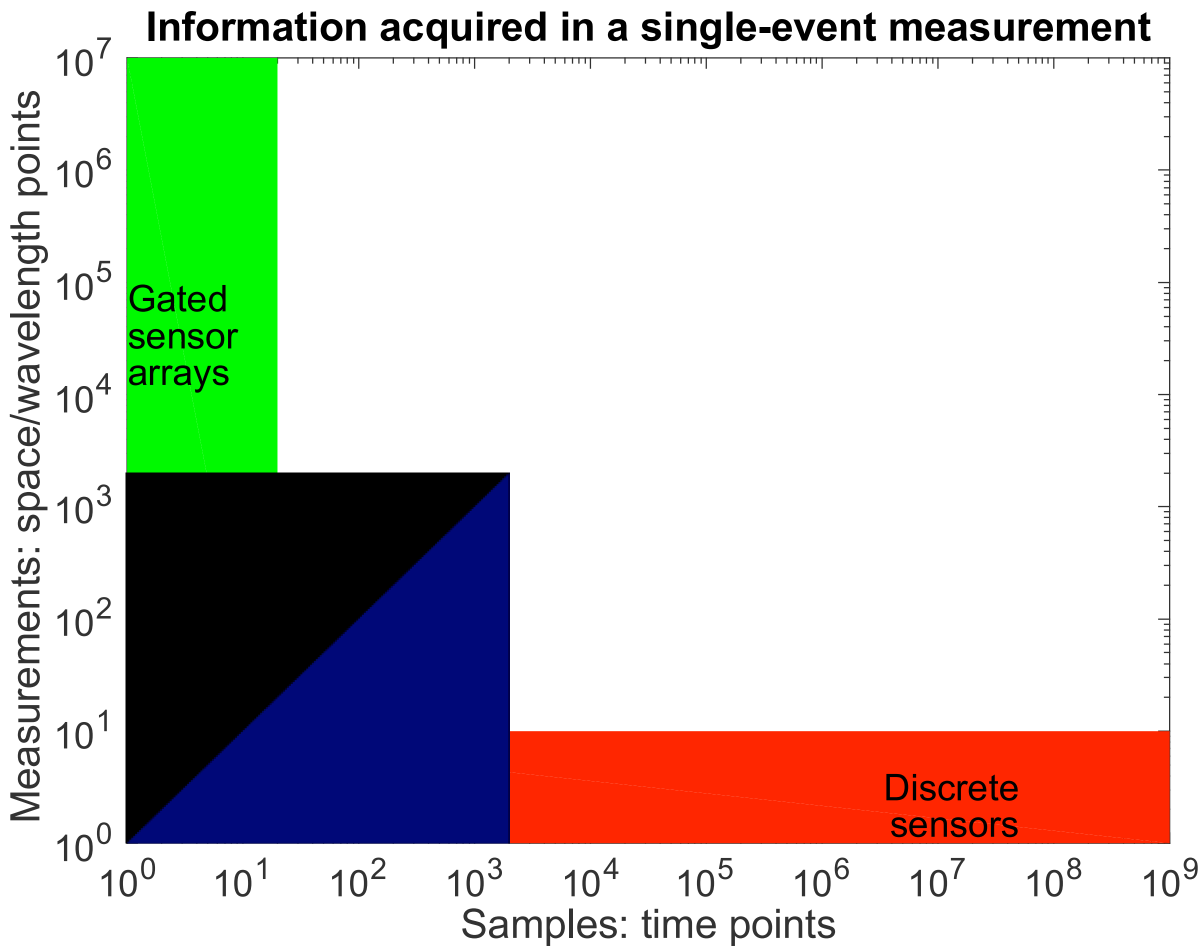
- **Digitizers**
  - Photodiodes
  - PMTs
  - Sensors
- **Many samples**
- **Few measurements**
- **This gets expensive quickly**

Why are streak cameras are important?



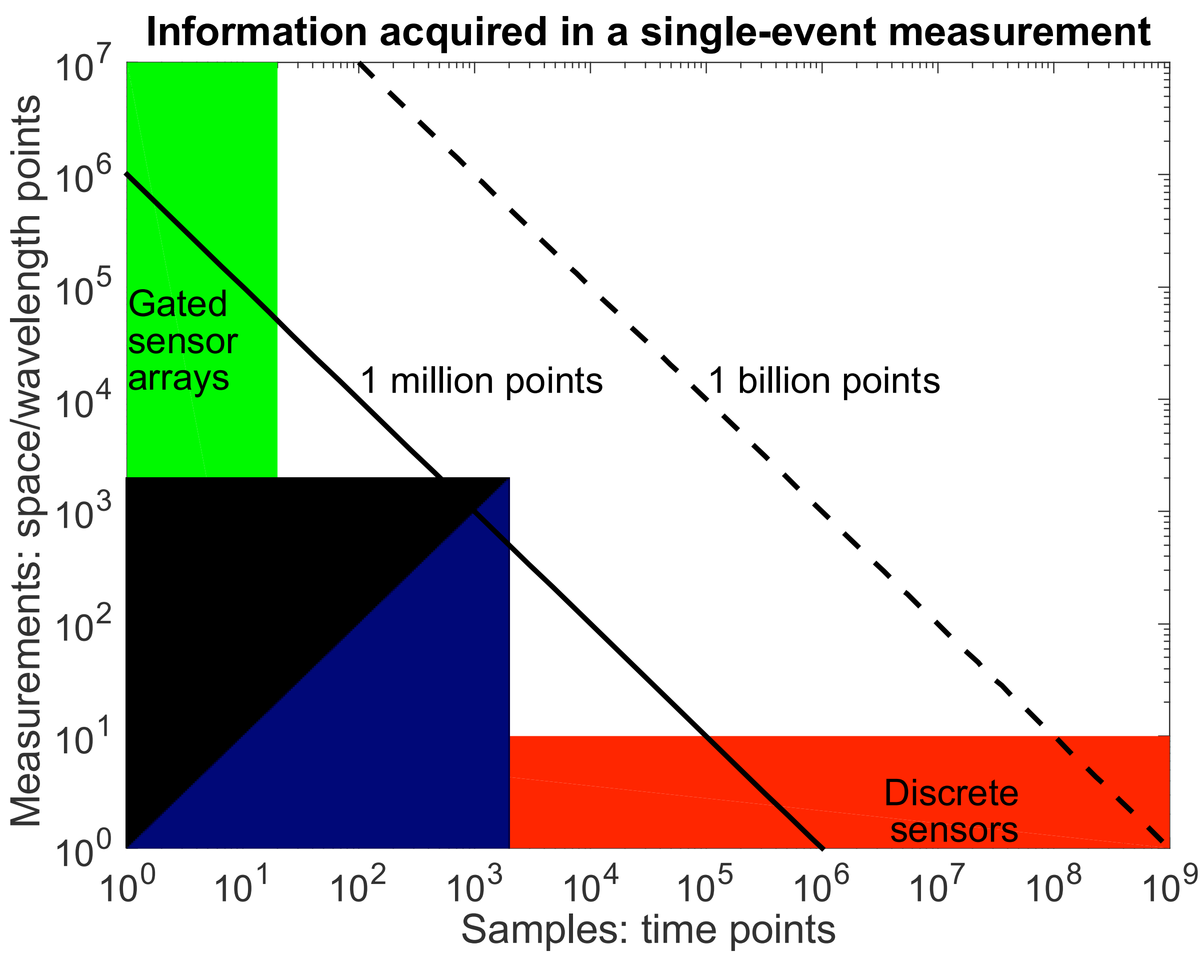
- **Sensor arrays**
  - CCDs
  - Image plates
  - Film
- **Many measurements**
- **Few samples**
- **Dividing measurements becomes difficult**

Why are streak cameras are important?



- **Moderate number of measurements and samples**
  - ~1000x1000 points
  - Not all points are truly distinct

Why are streak cameras are important?



- **Moderate number of measurements and samples**
  - ~1000x1000 points
  - Not all points are truly distinct
- **Total capacity is roughly 1 million points of information**

Streak camera use has changed

- **Shock breakout was once the primary diagnostic in shock-wave physics**
  - Los Alamos shock tables built almost entirely from shock breakout measurements
  - This type of measurement has largely been replaced by:
    - Line ORVIS (streak camera technique)
    - Photonic Doppler Velocimetry (digitizer technique)
- **Streak cameras are rarely used in discrete-probe velocimetry**
  - Fabry-Perot velocimetry is effectively extinct
  - VISAR is typically recorded on digitizers, not streak cameras
  - Multiplexed PDV is expanding (64-128+ points)
- **Spectroscopy is a much larger streak application than it used to be**

Goals of this meeting

- **Discuss streak camera applications across the NNSA labs**
  - Diagnostic types, characteristic operating conditions, etc.
  - What capabilities are the labs looking for?
- **Describe current streak camera capabilities**
  - Survey the commercial market
  - Assess future streak tube availability
- **Consider streak tube alternatives**
- **Begin planning for the future**
  - Identify common requirements and overlapping interests
  - Look for collaborations to accelerate new development
- **A short, informal summary will be presented to NNSA Diagnostic Working Group**
  - Operational decisions remain independent

clear up misconceptions

General schedule

- **Tuesday morning**
  – Streak camera applications at the national laboratories
- **Tuesday afternoon**
  – Current streak camera technology

- **Wednesday morning**
  – New tube developments
  – Solid-state cameras
- **Wednesday afternoon**
  – Other technologies

- **Lots of time for informal discussion**

Miscellaneous items

- **Absolutely no classified discussions allowed!**
- **Some presentations include proprietary information**
  - These talks are meant for the DOE audience only; others will be dismissed
    - Most of the early-morning presentations on Wednesday
    - 1-2 presentations late-morning on Wednesday
  - I will not release presentations to the general audience
    - If there are no objections, presentations will shared with the POC for each laboratory
    - Lab overviews may be shared if speakers concur
- **Consider this meeting as the beginning of an ongoing conversation**
  - A venue for this discussion has been missing since the 2004 High Speed Photography and Photonics Congress

2004 High Speed Photography and Photonics Congress

A solid state streak camera

Stuart Kleinfelder*[a], Kris Kwiatkowski[b], Ashish Shah[a]
[a]University of California, Irvine, CA, 92697-2625,
[b]Los Alamos National Laboratory, Los Alamos, NM, 87545

ABSTRACT

A monolithic solid-state streak camera has been designed and fabricated in a standard CMOS process. It consists of a 1-D linear array of 150 integrated photodiodes, follov chip, 150-deep analog frame storage. Each pixel's front-end consists of an n-diffus complementary reset transistors, and a source-follower buffer. Each buffer drives a lir with each sample circuit consisting of an n-channel sample switch, a 0.1 pF double-pc switch to definitively clear the capacitor, and a multiplexed source-follower readout generation was designed using a self-timed break-before-make operation that insur settling. The electrical analog bandwidth of each channels buffer and sampling circui Sampling speeds of 400 M-frames/s have been achieved using electrical input sign signals has been demonstrated at 100 MHz sample rates. Sample output multiplexin samples (150 pixels times 150 samples per pixel) in about 3 ms. The chip's output ran 3.3V supply voltage, corresponding to a maximum 2.55 V swing at the photodiod measured to be 0.51 mV, rms, at 100 MHz, for a dynamic range of ~11.5 bits, rms. C along with the results of electrical measurements and optical experiments with fast p wavelengths.

1. STREAK CAMERA DESIGN

A photograph of the streak camera chip is shown in Figure 1. In this figure, the arra the right edge of the chip. Two channels, the top and bottom-most, are equipped with to permit easy electrical testing, and these bond-wires are seen to the right. General I/C

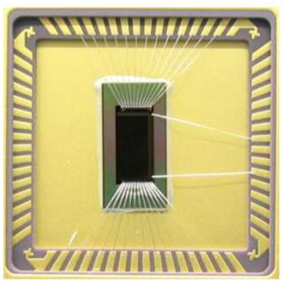


Fig. 1: Photograph of the streak camera prototype. The array of sensor diodes are or

* Email stuartk@uci.edu; Tel: 949-824-9430; University of California, 2225 Engineering Gatew

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Hybrid Image Sensor with Multiple On-chip Frame Storage for Ultra High-speed Imaging

Vincent DOUENCE*, Yibin BAI, Hakan DURMUS, Atul JOSHI, Per-Olov PETTERSSON, Debashish SAHOO, Rockwell Scientific Company, 5212 Verdugo Way, Camarillo, CA 93012
Kris KWIATKOWSKI, Nicholas S.P. KING, Christopher MORRIS, Mark D. WILKE, Physics Division, Los Alamos National Laboratory, Los Alamos, NM 87:

ABSTRACT

A high-resolution hybrid visible imager, that is composed of a CMOS readout integrated circuit (RC photo-detector array, has been designed. The ROIC is fabricated with a standard 0.25 μm CMOS mi with a back-illuminated silicon detector array that is produced at Rockwell Scientific Company (R HyViSI™ process.
The camera system is designed primarily to record images formed on a scintillator used in pulsed p experiments. In such experiments, the repetition rate of the proton beam can be as high as 2.8 M imaging system with the desired 1440x1440 pixels resolution would result in an instantaneous readou 5.79 E12 samples/s. To address this issue we designed a pixel with three-frame in-pixel analog stor deferred slower readout.
The 26 μm pitch pixel imager is operated in a global shutter mode and features in-pixel correlated (CDS) for each of the three acquired frames. The CDS operation is necessary to overcome the integrating node to achieve high dynamic range. A 65 fps continuous readout mode is also providec silicon array has close to 100% fill factor while anti-reflection (AR) coating maximizes its quantun scintillator emission wavelength (~415 nm).
The ROIC is a 720x720, two-side buttable integrated circuit with on-chip 12-bit analog to digital co digital readout. Timing and biasing are also generated on-chip, and special attention has been gi distribution of the pixel-array and snapshot signal buffers. This system-on-chip approach results in a power camera, an important feature to extend the number of imaged frames by synchronizing multiple

Keywords: Hybrid, CMOS, silicon photo-detector, ultra-fast imaging, multi-frame storage

INTRODUCTION

The imager presented in this paper is designed specifically for proton radiography experiments c Alamos National Laboratory. Scientists from Los Alamos and Lawrence Livermore National l developed a technique for dynamic imaging of thick objects. The method is similar to x-ray radiogr are replaced by a highly penetrating proton beam, focused by a series of magnetic lenses [1,2]. Mul going through the object at various angles can be used to reconstruct a 3D image. Finally, since one understand how materials behave under explosively driven pressure and shock waves, multiple images at sub-microsecond scale.

Several methods of detection have been proposed and tested [3-6]. In this paper, the principle us image formed on a ~12cmx12cmx2mm lutetium oxyorthosilicate (LSO) scintillator placed directly ir The LSO scintillator acts as a proton radiation-to-photon converter with an emission spectrum center approximate temporal response is presented in Fig. 1. The 40 ns wide proton burst produces a sharp i flux, which is followed by an exponential decay with a 42 ns time constant. The accelerator allows time to be varied between 10's of µs and 60ns. However, in the past the minimum 358 ns inter-burst i

* correspondence email: vdouence@rwsc.com; web: www.rockwellscientific.com.

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An image sensor of 1,000,000 fps, 300,000 pixels, and 144 consecutive frames

T. Goji Etoh* [a,c], Yuya Hatsuki[a], Tomoo Okinaka[a], Hiroshi Ohtake[b], Hirotaka Maruyama[b], Tetsuya Hayashida[b], Masato Yamada[b], Kazuya Kitamura[b], Toshiki Arai[b], Kenkichi Tanioka[b], Dirk Poggemann[c], Arno Ruckelshausen[c], Harry van Kuijk[d], Jan Bosiers[d], and Albert Theuwissen[d]

[a]Kinki University, Higashi-Osaka, 577-8502 Japan
[b]Advanced Broadcasting Devices, Science and Technical Research Labs, NHK, 1-10-11 Kinuta, Setagaya-ku, Tokyo 157-8510 Japan
[c]Faculty of Engineering and Computer Science, University of Applied Sciences Osnabrueck, Albrecht str. 30, 49076 Osnabrueck, Germany
[d]DALSA Professional Imaging, Postbox WZ05, Prof. Holstlaan 4, 5656 AA Eindhoven, The Netherlands

ABSTRACT

An image sensor for an ultra-high-speed video camera was developed. The maximum frame rate, the pixel count and the number of consecutive frames are 1,000,000 fps, 720 x 410 (= 295,200) pixels, and 144 frames. A micro lens array will be attached on the chip, which increases the fill factor to about 50%. In addition to the ultra-high-speed image capturing operation to store image signals in the in-situ storage area adjacent to each pixel, standard parallel readout operation at 1,000 fps for full frame readout is also introduced with sixteen readout taps, for which the image signals are transferred to and stored in a storage device with a large capacity equipped outside the sensor. The aspect ratio of the frame is about 16 : 9, which is equal to that of the HDTV format. Therefore, a video camera with four sensors of the ISIS-V4, which are arranged to form the Bayer's color filter array, realizes an ultra-high-speed video camera of a semi-HDTV format.

Keywords: high-speed video camera, ISIS, in-situ storage image sensor, ultra-high-speed, high spatial resolution

1. INTRODUCTION

In 2001, the authors developed an image sensor of 1,000,000 fps and a video camera mounting it[1),2)]. The sensor was named "ISIS-V2", the in-situ storage image sensor, version 2. They were a test sensor and a test camera with a relatively small number of pixels, i.e., 81,120 pixels (260x312) and a relatively small number of consecutive frames, i.e., 103 frames. All the pixel of the seonsor has an in-situ memory area with 103 CCD memory elements, and a drain. In an image capturing operation, image signals are simultaneously stored in the in-situ storage at all the pixels. The ultimate parallel recording achieved the ultimate high-speed image capturing. When the in-situ storage becomes full of image signals, the oldest one is drained through the drain to the substrate and the newest one is stored instead. With this overwriting operation, the latest consecutive image signals are always stored in the in-situ storage, continuously draining the old ones. The overwriting operation continues until a target event occurs and a trigger signal to stop the image capturing operation is released to the sensor. Then, the image signals stored in the in-situ storage are slowly readout from the sensor to a buffer memory outside the sensor. The overwriting operation significantly eases synchronization of image capturing with occurrence of the target event, especially for the camera system with a storage area for relatively small number of frames, such as the ISIS camera.

In 2001, an image sensor of 1,000,000 fps for practical use was developed, called ISIS-V4. The pixel count is about

* best2010@civileng.kindai.ac.jp; phone 81-729-28-3130; fax 81-729-95-5192

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Should this type of meeting be revived?