Next generation Linescan Technology

Stemmer Imaging
Technology Forums 2019

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Overview

- Latest CMOS TDI technology
- High speed
- Multifield/Multispectral Imaging
- Polarization
- “Super Resolution”
- Camera interfaces
- SWIR (= Short Wave InfraRed)
Line Scan Imaging

Single line: simple, easy to use
Dual line: better responsivity and SNR
TDI: best SNR for light starved applications
New Generation CMOS TDI Sensor: Mono/HDR

- Power Configuration
- Main array
- Second array
- 128 rows 5 μm x 5 μm pixel
- 64 rows 5 μm x 5 μm pixel

CDS & ADC
Memory, Summing & Readout
Sensor Performance – latest TDI technology

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>TDI CCD obsolete</th>
<th>TDI CMOS current</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>pix</td>
<td>12k/5.2um</td>
<td>16k/5um</td>
<td></td>
</tr>
<tr>
<td>Linerate</td>
<td>[kHz]</td>
<td>90</td>
<td>300+</td>
<td>Higher throughput</td>
</tr>
<tr>
<td>No. of Stages</td>
<td>[# ]</td>
<td>256</td>
<td>128</td>
<td>Fewer stages simplify setup, alignment and improve MTF</td>
</tr>
<tr>
<td>Peak Responsivity</td>
<td>[DN$_{12}$/nJ/cm$^2$]</td>
<td>4,800</td>
<td>8,000</td>
<td>At 1x Gain</td>
</tr>
<tr>
<td>Read Noise</td>
<td>[e$^-$]</td>
<td>30</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Min. NEE</td>
<td>[pJ/cm$^2$]</td>
<td>0.29</td>
<td>0.14</td>
<td>Light power for SNR=1, low NEE indicates better low-light detectability</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>[dB]</td>
<td>66</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>Max. SNR</td>
<td>[dB]</td>
<td>45.4</td>
<td>44.5 (STD) 47.5 (HFW)</td>
<td>High SNR improves feature separation with high light intensities</td>
</tr>
<tr>
<td>Max. MTF</td>
<td>[%]</td>
<td>65</td>
<td>71</td>
<td>At 100 lp/mm</td>
</tr>
</tbody>
</table>
**HDR: Dual Arrays**

- Store 163 row data and align the images captured from the main and second arrays.
- Spatial correction done in frame grabber.
- More stringent alignment requirements on transport system.
HDR: Selectable Stage Ratio (also available in non TDI cameras)

- Captures two images using different stages and gains
- Option - output one fused image or two separate images
- Fusion algorithm implemented in FG

<table>
<thead>
<tr>
<th>Stage ratio</th>
<th>Main array</th>
<th>Second array</th>
</tr>
</thead>
<tbody>
<tr>
<td>2:1</td>
<td>128</td>
<td>64</td>
</tr>
<tr>
<td>4:1</td>
<td>64</td>
<td>16</td>
</tr>
<tr>
<td>8:1</td>
<td>128</td>
<td>16</td>
</tr>
</tbody>
</table>
## Camera Modes

<table>
<thead>
<tr>
<th></th>
<th>TDI</th>
<th>HDR</th>
<th>HFW</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Array used</strong></td>
<td>Main array: 16kx128</td>
<td>Main+second array: 16kx(128+64)</td>
<td>Main+second array: 16kx(64+64)</td>
<td>Main array 16kx128</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>300kHz</td>
<td>150kHzx2</td>
<td>150kHz</td>
<td>2000 fps</td>
</tr>
<tr>
<td><strong>Imaging</strong></td>
<td>General</td>
<td>Bright/dark scene</td>
<td>Bright scene</td>
<td>Alignment</td>
</tr>
</tbody>
</table>

![Image](image.png)
## High Speed:

<table>
<thead>
<tr>
<th></th>
<th>TDI-ML:</th>
<th>TDI-HS:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Array used</strong></td>
<td>Main array: 8k/16kx4</td>
<td>Main+Second array: 8K/16kx(128+64)</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>300kHz</td>
<td>150kHzx2 (*)</td>
</tr>
<tr>
<td><strong>Status:</strong></td>
<td>Fastest in the market</td>
<td>Fastest in the market</td>
</tr>
</tbody>
</table>

(* = coming soon: 400 kHz)
Multispectral vs. Multifield

**Multispectral:** capture the same object with multiple wavelengths or colours in a single scan

**Multifield:** capture multiple images of the same object at different angles of light in a single scan
Multispectral vs Multifield - part 2

- Capture multifield images with various lighting conditions (e.g. brightfield, darkfield, backlight) in a single scan
- Significantly improve inspection speeds
- Dichroic filters with minimum spectral crosstalk

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Multispectral vs. Multifield – part 3

Imaging using multiple narrowband light sources. Wavelength and angle are defined by light sources and separated by dichroic filters.
Polarization Imaging. Why?

• Most sensitive non-destructive optical technique that improves detectability

• Enhance contrast by detecting “phase shift” for objects that are difficult to distinguish

• Measure physical properties that are not detectable using conventional imaging, e.g. birefringence, stress, and depth, etc.
Polarization Sensor Architecture

- CMOS quadlinear sensor architecture
- Micro-polarizer filters aligned at pixel level
- Polarization filter design:

Area scan: only one native polarization state data per pixel
Polarization - Applications

Glass
Source Emhart glass

Films
Source Dr Schenk

Carbon
Source Synergx
Upcoming: 32k Super Resolution

- Higher detectability for subpixel defects, 4~5x higher SNR
- Effective pixel size ~3.5um
- Standard 16k/5um lens
- Patent pending

<table>
<thead>
<tr>
<th>Defect</th>
<th>Spec</th>
<th>Unit</th>
<th>16k</th>
<th>32k</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 um</td>
<td>Signal</td>
<td>[DN_{px}]</td>
<td>~ 2.8</td>
<td>~ 6.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Noise</td>
<td>[DN_{px}]</td>
<td>~ 1.8</td>
<td>~ 0.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>eff. SNR</td>
<td>[x:1]</td>
<td>1.6</td>
<td>7.5</td>
<td>4.7x</td>
</tr>
<tr>
<td>2.0 um</td>
<td>Signal</td>
<td>[DN_{px}]</td>
<td>~ 4.5</td>
<td>~ 12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Noise</td>
<td>[DN_{px}]</td>
<td>~ 1.8</td>
<td>~ 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>eff. SNR</td>
<td>[x:1]</td>
<td>2.5</td>
<td>12</td>
<td>4.8x</td>
</tr>
</tbody>
</table>
Camera Interfaces:
CLHS: Copper Connection with integrated fiber transmitter and receiver

- PCIe Gen3 x8 framegrabber
- Active optical cable (AOC)
- 3~10Gbps M/X-protocol (8.4GB/s per cable)
Direct fiber connection

- PCIe Gen3 x8 framegrabber
- Quad (4x)/dual (2x) SFP+ (supports up to 4/2 cameras)
- 10~12.5Gbps X-protocol (1.2GB/s per cable)
- Standard telecom fiber-optic cables and SFP+ transceivers
Lower System Cost

• Simpler Cables
  • SFP+ : LC-LC cable cost <$0.5/m
  • CX4 : Up to 8.4GB/s single cable solution

• Repeaters/Extenders not required
  • Up to 300m
  • More reliable data interface
Framegrabber-less interface: NBASE-T

NBASE-T : x5 or x10 faster than GigE Vision, up to 100m cables, low cost of ownership

NBASE-T combines the best of both worlds:
- Cost effectiveness, long cable length of GigE Vision
- Speed of CameraLink interface

NBASE-T is likely to replace CameraLink in the long run
NBASE-T advantages over popular interfaces

Color

“Use thinner, longer, and more flexible cables with NBASE-T than in CameraLink”
- Have more degrees of freedom in equipment cabling design (mostly in large machines)
  - Up to 140kHz for Mono!

Monochrome

“Upgrade your equipment to color imaging without decreasing your inspection throughput”

“Increase x5 speed or resolution of your inspection system without losing cable”
The Future: Short Wave Infrared “SWIR”

- Light in the 900 to 1700 nm wavelength range
  - Can include 700 to 2500 nm range
- Passes through silicon and requires InGaAs detectors

What can SWIR do?
- Image through atmospheric obscurants
- Differentiate between colours that appear identical in the visible spectrum
- Image through glass
- Night vision
- Moisture detection
- Thermal imaging

Variations in mineral content, vegetation, and water cause patterns of light and dark in this near infrared view of the Pijiang Fault in northwestern China. (NASA image by Robert Simmon with ASTER data.)
SWIR Applications

Spectroscopy
(Scientific, Medical, Hyperspectral)

Security
(Haze, Fog, Smoke)

Military
(Night Vision, LASER Detection)

Industrial
(Sorting, Solar Cell, Fill Level, Glass, Telcom)
Possibilities: linescan InGaAs detector development optimized for specific applications.

Differentiation from Existing Products:
• Optimized ROIC design – Qsat, Noise, Linearity
• Multi-Row architecture (2 or 4 rows)
  • Sensitivity
  • MultiSpectral SWIR
  • HDR SWIR (different gain per row)
  • Pixel Replacement (yield and cost)
  • Up to 4x4 binning with square pixels with 4 rows

And future differentiation Opportunities.