Ultra high resolution CMOS camera based on advanced pixel shift technology
Introduction

- Application: FPD Inspection, Film Scanning, Wafer Inspection, Document Digitization
- Super resolution up to 1,359 megapixels: Extended resolution by Pixel Shift technology.
- Price of VN camera < Price of stitching multiple cameras-lenses-frame grabbers & PCs
- Reliability of Pixel Shift System is Crucial!
- Speed (4 or 9 images) ↔ Resolution

Main Features of VN series
- Nano Stage Pixel Shift Mechanism
- Extended Resolution up to 1,359 megapixels
- True Color & Extended True Color Images
- Improved Fill Factor
- Defective Pixel Compensation
Features of VN series

- Extended resolution up to 1,359 Megapixels
- Increased fill factor with interline Transfer sensor
- True color with extended resolution
How does “Pixel shifting” work?

- The image sensor is physically & precisely shifted by Piezoelectric Nano Stage to capture multiple images defined by the number of shifts.

- Only one trigger is required to start the pixel shift sequence.

- The captured image sequence is stitched together into a composite super resolution image.
The Role of Aliasing & Fill factor

- **Fill factor**
  - Defined as ratio of the light sensitive area / Total area of pixel
  - Average fill factor of CMOS sensors is approximately 60% with Micro Lens
  - High Fill factor reduces Moiré effect
The Role of Aliasing & Fill factor

Vertex refers to non-light sensitive areas.
About Nano stage

- The minimum spatial resolution: 1nm
- The maximum stroke: 15µm
- MTBF: More than 100 million movements.
- <15nm Repetition Error after 100 million movements
The extended resolution – 4 shot mode (1)
The extended resolution – 4 shot mode (2)

½ Pixel Shift

Camera

Output Image

1 1 1 1
1 1 1 1

PC

4 Shot result Image

1 1 1 1
1 1 1 1

Normal shot
The extended resolution – 4 shot mode (3)

½ Pixel Shift

Normal shot

Output Image

4 Shot result Image
The extended resolution – 4 shot mode (4)
The extended resolution – 4 shot mode (5)

½ Pixel Shift

Output Image

<table>
<thead>
<tr>
<th>1</th>
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4 Shot result Image

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The extended resolution – 4 shot mode (6)

The resolution is increased. But the sharpness is decreased.
The extended resolution – 9 shot mode (1)
The extended resolution – 9 shot mode (2)
The extended resolution – 9 shot mode (3)
The extended resolution – 9 shot mode (4)
The extended resolution – 9 shot mode (5)
The extended resolution – 9 shot mode (6)

2/3 Pixel Shift

Diagram showing a 3x3 grid with numbers from 1 to 6, illustrating the pixel shift process.
The extended resolution – 9 shot mode (7)

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<tr>
<td>7</td>
<td>7</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

2/3 Pixel Shift
The extended resolution – 9 shot mode (8)
The extended resolution – 9 shot mode (9)
The extended resolution – 9 shot mode (10)

< 9 Shot mode >
Example (1)

- Pixel size: 5.5μm
- Object: 3.6μm
- Bright: Black - 0, White - 255

\[
\begin{align*}
(0 + 0 + 255)/3 &= 85 \\
(255 + 0 + 0)/3 &= 85 \\
(255 + 255 + 0)/3 &= 170 \\
(0 + 255 + 255)/3 &= 170
\end{align*}
\]

It is not possible to recognize two adjacent pixels.
Example (2)

It is possible to recognize two adjacent pixels.
The sequence

1. PC assigns memory for combining the pixels shift images
2. PC changes VN camera mode to pixel shift mode
3. Camera is changed from Normal mode to pixel shift mode
4. PC sends a trigger
5. Camera starts to send 4 or 9 images to PC where each image is a different shift
6. Put together creating a higher resolution image.
The extended resolution – Monochrome (1)

1 shot

4 shot

9 shot
The extended resolution – Monochrome (2)
Increased Fill factor reduces Moiré

- Fill factor 60%

< 1 shot >

< 4 shot >
True Color

- Using a single Bayer CFA (Color Filter Array) sensor in a camera designed for pixel shift, one can replicate a color image known as True Color. True Color image is produced by a camera with 3-Sensors camera that creates three separate full resolution images (RGB).
Bayer CFA sensor structure
Realizing True color (1)
Realizing True color (2)
True color with the extended resolution

4shot x True color(4shot) = 16shot
Color resolution improvement (1)

< Original image (Bayer) >

< True color >

< True color + 4shot >

< True color + 9shot >
Color resolution improvement (2)

< Original image (Bayer) >

< True color >

< True color + 4shot >

< True color + 9shot >
## Lens for VN camera

<table>
<thead>
<tr>
<th></th>
<th>VN 25MX</th>
<th>VN 200MX</th>
<th>VNP 604MX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pixel pitch</strong></td>
<td>4.5u</td>
<td>4.6u</td>
<td>3.76u</td>
</tr>
<tr>
<td><strong>Sensor size</strong></td>
<td>18 x 13.6</td>
<td>36.4 x 27.6</td>
<td>53.4 x 40</td>
</tr>
<tr>
<td><strong>Cut off resolution</strong></td>
<td>90Lp/mm</td>
<td>109 Lp/mm</td>
<td>133 Lp/mm</td>
</tr>
<tr>
<td><strong>Pixel shift Resolution</strong></td>
<td>180Lp/mm</td>
<td>218 Lp/mm</td>
<td>266 Lp/mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Company</th>
<th>Lens</th>
<th>MTF(AXIS)</th>
<th>Image Circle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rodenstock</td>
<td>HR-Digaron-S 4.0/100</td>
<td>Above 60% at 80Lp/mm</td>
<td>70mm</td>
</tr>
<tr>
<td>Qioptiq</td>
<td>Inspec.x 2.8/100</td>
<td>Above 50% at 80Lp/mm</td>
<td>43mm</td>
</tr>
<tr>
<td>Schneider</td>
<td>Macro Varon 4.5/85</td>
<td>Above 30% at 100Lp/mm</td>
<td>62mm</td>
</tr>
<tr>
<td>Moritex</td>
<td>ML-LS9040-67M72</td>
<td>Above 38% at 108Lp/mm</td>
<td>67mm</td>
</tr>
</tbody>
</table>

<Focal length : 100mm>
To be Considered

- There must be no vibration.

- Frame rate decreases according to the pixel shift mode.
  - 4 shot = FPS / 4
  - 9 shot = FPS / 9
  - True color + 4shot = FPS / 4 / 4
  - True color + 9shot = FPS / 4 / 9

- FOV increases according to the pixel shift mode.
  - 4 shot = FOV increases by 1/2 pixel to the right, bottom.
  - 9 shot = FOV increases by 2/3 pixel to the right, bottom.
Sample program (Console version)

```
Start
  Please key-in COM : 5
Open com port
Init camera
Init Frame grabber
  Please key-in exposure time (nS) : 500
The original Width: 6576 and Height: 4384
The extened Width: 13152 and Height: 8768
Bit depth: 8
MdigProcess MSEQUENCE
OnSoftwareTrigger
Time Start
WaitForSingleObject
1
2
3
4
SetEvent

Catch 4 Images Time : 2262.000000 mS

Save the combined image into the file
D:\VN_each0_0.raw
D:\VN_each0_1.raw
D:\VN_each0_2.raw
D:\VN_each0_3.raw

Combine Image Time : 93.000000 mS

D:\VN_Final0.raw
MdigProcess MSTOP

Total Time : 2355.000000 mS
EXIT
Press enter key to close
```
Graphic program (Window version)

Nano Stage Pixel Shift Cameras for Extended Resolution up to 260 Megapixels

Pixel Shift ON

Pixel Shift OFF
VN-25M CoaXPress camera

01 CoaXPress Interface (VC-25MX) + 02 Pixel Shifting Mechanism = 03 VN-25M CXP Camera

ONSEMI Vita 25K CMOS Sensor
Mono or Color, 8/10 bits
100MP, 10,240 x 10,240 4 shifts
225 MP, 15,360 x 15,360 9 shifts
VN-200M CoaXPress camera (2)

01 CoaXPress Interface (VC-50MX) + 02 Pixel Shifting Mechanism = 03 VN-200MX CXP Camera

CMOSIS (AMS) CMV-50000 Sensor
Mono or Color, 8/10/12 bits
190 MP, 15,840 x 12008 4 shifts
427 MP, 23,760 x 18,012 9 shifts
VNP-604MX CoaXPress camera

01 CoaXPress Interface (VC-151MX)

02 Pixel Shifting Mechanism

03 VNP-604MX CXP Camera

SONY IMX-411 CMOS BSI Sensor
Mono or Color 8/10/12 bits
604 MP, 28,384 x 21,280 4 shifts
1,359 MP, 42,576 x 31,920 9 shifts
Timing operation (4) Pixel Shifts

Figure 9.13 Timing Diagram when Multi Shot is enabled on Sequence 4 Shot Mode
The combination time on the computer

It depends on your PC performance.
The real image
Actual image

Pixel Shift ON

Pixel Shift OFF
Thank You