UK Industrial Vision
SWIR Challenges

Ian Alderton

ALRAD IMAGING
ALRAD INSTRUMENTS LTD
ALRAD - Company Profile

- **ALRAD** are a Distribution company for Imaging, Electro Optic, Analytical Components and Instruments including:
  - CCD and CMOS cameras
  - Frame Grabbers and Digital Acquisition Cards
  - LED and Laser Lighting for Machine Vision
  - Imaging and Image Processing Software
  - Optics, Lenses
  - Linear and Area Sensors

- Trading since 1970, 47 years in business.
- Three divisions – Imaging, Photonics and Electronics
• UK Industrial Vision Trade Association
• www.ukiva.org
• Vision In Action
  Association News
• Machine Vision Conference
  Arena MK 16th May 2018
• www.machinevisionconference.co.uk
Spectrum
Historically, solid state area vision sensors are classified as "format" or "type", typically 1/2”, 1/3”, 2/3” and 1”, originally from the front size of a camera tube.

With the advent of the latest CCD and CMOS sensors, new sensor formats appeared, e.g. 1/2.5” 1/1.8” 1/1.2”, as well DSLR and 35mm film equivalents, with different size ratios and pixel sizes. Machine vision systems are now have higher frame rate and resolution available with faster processing and overall system costs have reduced dramatically.

In SWIR the costs have increased as what was a simple replacement camera tube faceplate is now InGaAs or other technologies at significantly higher cost that Silicon sensors and lower resolution than Current CMOS sensors used in most machine vision applications.
Different Camera Vacuum Tube Sensor
with dimensions in mm to illustrate the correlation of Imperial Format Types.

Typical sizes for camera tubes were:
1/2”, 2/3” & 1” diameter.
Different Tubes

Internal layout of Camera Tube.
Small Cameras!

A compact CCTV camera with 2/3” camera tube. VS CMOS 4 megapixel USB 2 Camera
The origin on the Sensor Format

Face view of a Camera Pick-Up Vacuum Tube Sensor with a sensor superimposed on the imaging face, to illustrate the correlation of Imperial Format Types.

Typical sizes for camera tubes were:
1”, 2/3” & 1/2” diameter.
Different Tubes

Face view showing some different faceplates.
Common sensor formats and dimensions

<table>
<thead>
<tr>
<th>Camera</th>
<th>Hor.(mm)</th>
<th>Ver.(mm)</th>
<th>Dia.(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 inch</td>
<td>3.6</td>
<td>2.7</td>
<td>4.5</td>
</tr>
<tr>
<td>1/3 inch</td>
<td>4.8</td>
<td>3.6</td>
<td>6</td>
</tr>
<tr>
<td>1/2 inch</td>
<td>6.4</td>
<td>4.8</td>
<td>8</td>
</tr>
<tr>
<td>1/1.8 inch</td>
<td>7.2</td>
<td>5.4</td>
<td>9</td>
</tr>
<tr>
<td>2/3 inch</td>
<td>8.8</td>
<td>6.6</td>
<td>11</td>
</tr>
<tr>
<td>1 inch</td>
<td>12.8</td>
<td>9.6</td>
<td>16</td>
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</table>
# Extended table of sensor formats

<table>
<thead>
<tr>
<th>Format Type</th>
<th>Aspect Ratio</th>
<th>Ø Dia. (mm)</th>
<th>Diagonal mm</th>
<th>Width mm</th>
<th>Height mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/10&quot;</td>
<td>4:3</td>
<td>2.54</td>
<td>1.60</td>
<td>1.28</td>
<td>0.96</td>
</tr>
<tr>
<td>1/8&quot;</td>
<td>4:3</td>
<td>3.175</td>
<td>2.00</td>
<td>1.60</td>
<td>1.20</td>
</tr>
<tr>
<td>1/6&quot;</td>
<td>4:3</td>
<td>4.762</td>
<td>3.00</td>
<td>2.40</td>
<td>1.80</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>4:3</td>
<td>7.056</td>
<td>4.500</td>
<td>3.647</td>
<td>2.706</td>
</tr>
<tr>
<td>1/3.6&quot;</td>
<td>4:3</td>
<td>7.056</td>
<td>5.000</td>
<td>4.000</td>
<td>3.000</td>
</tr>
<tr>
<td>1/3.2&quot;</td>
<td>4:3</td>
<td>7.938</td>
<td>5.680</td>
<td>4.536</td>
<td>3.416</td>
</tr>
<tr>
<td>1/3&quot;</td>
<td>4:3</td>
<td>8.467</td>
<td>6.000</td>
<td>4.800</td>
<td>3.600</td>
</tr>
<tr>
<td>1/2.7&quot;</td>
<td>4:3</td>
<td>9.407</td>
<td>6.721</td>
<td>5.371</td>
<td>4.035</td>
</tr>
<tr>
<td>1/2.5&quot;</td>
<td>4:3</td>
<td>10.160</td>
<td>7.182</td>
<td>5.760</td>
<td>4.290</td>
</tr>
<tr>
<td>1/2.3&quot;</td>
<td>4:3</td>
<td>10.836</td>
<td>7.66</td>
<td>6.17</td>
<td>4.55</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>4:3</td>
<td>12.700</td>
<td>8.000</td>
<td>6.400</td>
<td>4.800</td>
</tr>
<tr>
<td>1/1.8&quot;</td>
<td>4:3</td>
<td>14.111</td>
<td>8.923</td>
<td>7.163</td>
<td>5.438</td>
</tr>
<tr>
<td>1/1.7&quot;</td>
<td>4:3</td>
<td>14.941</td>
<td>9.500</td>
<td>7.600</td>
<td>5.700</td>
</tr>
<tr>
<td>1/1.6&quot;</td>
<td>4:3</td>
<td>15.986</td>
<td>10.07</td>
<td>8.08</td>
<td>6.01</td>
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<tr>
<td>2/3&quot;</td>
<td>4:3</td>
<td>16.933</td>
<td>11.000</td>
<td>8.800</td>
<td>6.600</td>
</tr>
<tr>
<td>1&quot;</td>
<td>4:3</td>
<td>25.400</td>
<td>16.000</td>
<td>12.800</td>
<td>9.600</td>
</tr>
<tr>
<td>4/3&quot;</td>
<td>4:3</td>
<td>33.867</td>
<td>22.500</td>
<td>18.000</td>
<td>13.500</td>
</tr>
<tr>
<td>1.8&quot;</td>
<td>3:2</td>
<td>45.720</td>
<td>28.400</td>
<td>23.700</td>
<td>15.700</td>
</tr>
<tr>
<td>35mm Film</td>
<td>3:2</td>
<td>n/a</td>
<td>43.300</td>
<td>36.000</td>
<td>24.000</td>
</tr>
</tbody>
</table>
Aspect Ratios, Image Circle, Sensor Size
Image Circle vs. Sensor Format
Linear CMOS VS. NIT HDR
Logarithmic Sensor
What is IR
Benefits of SWIR

- Images are **perceived like in the visible** (reflected light)
  => contrasts, shadows easily understood by user
- **Glass lens transmission is possible** (not in thermal bands)
- **Some plastics or inks are transparent**
- High temperature and some lasers are visible

Inspection

**Fight against counterfeiting**

Liquid level
InGaAs SWIR sensors for WiDy cameras

<table>
<thead>
<tr>
<th>Sensor Model</th>
<th>Sensor Resolution</th>
<th>Pixel size</th>
<th>Sensor size</th>
<th>diagonal</th>
<th>format</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSC0803 Rolling Shutter</td>
<td>320(H)x256(V) QVGA</td>
<td>25 μm</td>
<td>8.00x6.40 mm</td>
<td>10.24 mm</td>
<td>1/1.6in</td>
</tr>
<tr>
<td>NSC1201 Global Shutter</td>
<td>640(H)x512(V) VGA</td>
<td>15 μm</td>
<td>9.60x7.68 mm</td>
<td>12.29 mm</td>
<td>1in</td>
</tr>
</tbody>
</table>
AUTOMATIC WELDING

1. More accurate automatic welding systems

2. Human assisted visualisation still needed

3. Seeing details in extremely high illumination scene

4. HDR is a must

Courtesy Xiris
Semiconductor

- Solar Cell, Microscopy, Inspection
- See Through Silicon or Micro-Packaging
- Low Power Consumption and Form Factor
- Wafer Test, Alignment or Dicing
Art Inspection

- Counterfeit detection/ Masterpiece Authentification
- Art Education
- Portable SWIR camera connectable to laptop or tablet
- Turn key (No set-up, no additional lighting)
Surveillance

- See through Smoke, Haze, Pollution
- The longer distance, the better SWIR performs versus visible
- Maritime, Border Control, UAV
- Active imaging
- Water, Ice detection
NIR Spectroscopy

- Methanol
- Isopropanol
- Ethanol
- Water
- Acetone
Near-IR Spectroscopy & Imaging

Food & Agriculture

Petro-Chemical

Cosmetics & Pharmacy

Glass Textile Plastics

Telecom

Night Vision

Semiconductor

Forensics Medical

NIR Imaging & Spectroscopy
Near-IR Imaging

Night Vision

Firefighting

Telecom

Laser Beam Profiling

Moisture monitoring

Detection

by Benjamin University, Bo Appl. Sci.

Ice detection

Forensics
Available Materials

- Si
- InGaAs
- Ge
- HgCdTe
- InSb
- PbSe

RT operation
Requires cooling

eV
nm
600 700 800 1100 1550 nm 3000 5000 8000 12000
The Future

- **Black Silicon**: commercial developments have been going on since 2012 but no specific lower cost SWIR products on the market yet – modified silicon sensor.

- **Graphene**: 300 – 2000 nm but is a layer on standard silicon sensor using CMOS read out circuits.

- **Organic Photodetectors**: only just beyond silicon with response at 1000 nm but working on SWIR.

- **SWIR** could become much more acceptable if the right material is found or Germanium or specifically InGaAs costs reduce with volume increasing to a lot nearer to that of Silicon sensors.
Water in clear plastic and glass viewed with SWIR
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16 May 2018
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