New Si PIN photodiodes S10783 and S10784
Highlights

SOLID STATE PRODUCTS

10 Red LED for POF Data Communications

ELECTRON TUBE PRODUCTS

28 75W Xenon Lamp Series

SYSTEMS PRODUCTS

38 Cooled CCD Camera ORCA-R²

Content

4 Company News

SOLID STATE PRODUCTS

6 CCD Signal Processing Module NEW
7 Back-thinned TDI-CCD Image Sensor
8 InGaAs linear Image Sensor
9 Si PIN Photodiode NEW
10 Red LED for POF Data Communications NEW
11 Red LED for Optical Link
12 MPPC (Multi-Pixel Photon Counter)
16 MPPC Module
18 Article: Geiger-mode APD Arrays detect low light
21 Encoder Module

CRL PRODUCTS

22 QUANTA-OEM

ELECTRON TUBE PRODUCTS

23 Photosensor Modules
24 High Voltage Power Supply
25 3.5-Inch Diameter Head-on PMT
26 High QE Photomultiplier Tube
27 Photosensor Modules
28 75W Xenon Lamp Series
29 Image Intensifier Unit
30 UV Tron Driving Circuit
31 Immunochromato Reader
32 Photoionizer/Four-head Type Controller
33 MCP Assembly

SYSTEMS PRODUCTS

34 ImagEM-1K
35 Camera line-up for Solar Cell inspection
37 InGaAs Camera
38 Cooled CCD Camera ORCA-R²
39 High speed Digital CCD Camera
40 Optical NanoGauge
41 Imaging Based Reader NEW
42 NanoZoomer-RS Digital Pathology
43 Article: Hamamatsu TiGA Center
44 TDI Camera

SERVICE

45 Fax Reply
46 Exhibitions 2008/09
47 Hamamatsu Photonics Europe
MPPC®
(Multi-Pixel Photon Counter)
Array Type

- Large active area:
  4 (H) x 1 (V) mm (1 x 4 ch array)
  6 (H) x 6 (V) mm (2 x 2 ch array)
- Buttable structure – minimum dead space between chips
- Suitable for radiation measurement when combined with a scintillator
Hamamatsu Photonics honoured at the CERN LHC Industry Awards day October 20th 2008.

The prestigious Industry Award Day was held on the 20th October 2008 in Geneva, as part of CERN’s official inauguration ceremony of the LHC Experiment, to honour industries that have made outstanding contributions to the construction of the LHC and its experiments.

Hamamatsu Photonics’ sensors were used for all the larger experiments around the LHC ring and in different sub-detectors, and we are proud to announce that we have received awards for four of the sub-detectors.

The decision criteria for all four awards were very similar:
- Good collaboration during the R&D phase and meeting the challenge to push the boundaries of sensor/detector technology
- Delivery of uniformly excellent quality products, which exceeded the technical specifications of the contract
- Meeting the strict delivery schedules and costs.

During the Industry Award Day, as part of the official inauguration of the LHC, Hamamatsu Photonics was awarded a plaque in front of the CERN building 40 where the offices of the major experiments are located. Director General Mr. Robert Aymar personally unveiled the award on behalf of the HEP community and presented us with his thanks for our contribution to CERN.

CMS 200 m² Silicon-Tracker – Crystal Award
Hamamatsu Photonics received the Crystal Award for the delivery of more than 20,000 large area silicon strip sensors representing 210 m² active Detector – the largest silicon detector ever built. The strip failure rate was < 0.01% defective strips, significantly lower than the < 1% demanded by CERN specifications.

LHCb Award for Hamamatsu Photomultiplier Tubes
Hamamatsu Photonics were proud recipients of the LHCb Award for the supply of the R7600-M64 multichannel photomultipliers, which were specifically developed to meet CERN’s requirements for their LHC-b pre-shower detector.

ATLAS Silicon Tracker – Supplier Award
Quote from the Award Ceremony: “ATLAS Supplier Award for Hamamatsu Photonics supply of silicon microstrip sensors for the ATLAS Semiconductor Tracker”.

Hamamatsu Photonics has supplied 17,028 of the p-in-n single-sided silicon microstrip sensors that make up the detecting element of the ATLAS SemiConductor Tracker. The sensors are of six different shapes, each having 768 ac-coupled readout strips at a pitch close to 80 µm. The final design details and specifications were developed during several years of collaborative R&D between Hamamatsu Photonics and ATLAS Institutes. The challenge was to produce sensors with high strip quality and efficiency that could withstand the high radiation levels to be experienced in ATLAS, operating at high bias voltages after type-inversion. The sensors supplied were of uniformly excellent quality, well in excess of the requirements of the technical specification. They were delivered over a three-year period to the agreed schedule and cost. The ATLAS collaboration greatly appreciates the help, the flexible attitude and the enormous contribution of Hamamatsu Photonics to the experiment.
CMS ECAL for Large surface, radiation hard APD’s
A total of 130,000 APD’s (Avalanche Photodiodes), each with a size of 5x5 mm, fully tested, had to be delivered at a rate of 6,000 pieces per month. CERN demands a survival rate of >99% after 10 years of operation of LHC. The major challenge for this project was to achieve radiation hardness whilst maintaining good performance of a large surface, low capacitance blue enhanced APD. CERN, PSI and Hamamatsu Photonics met that challenge and the ECAL is fully installed today.

These combined efforts exceeded standard business practices and led to the development of extraordinary products for the industry, such as the "MPPC" Silicon based photon counting detector. The MPPC is at the forefront of such development and is seen as the key detector for the next generation of TOF-PET Scanners and, in combination with high magnetic field MRI instruments, will lead to high sensitivity images to reveal human body functions with higher precision for better understanding and treatment in the near future.

Author: Marco Mayer, Hamamatsu Photonics Switzerland

---

Hamamatsu Photonics Norden and Hamamatsu Photonics UK celebrated their 20th Anniversary in September 2008.

As part of their continued expansion Hamamatsu Photonics K.K., in September 1988 established two new European Subsidiaries to provide locally based expert technical and customer support for Hamamatsu Photonics products and technology and to create closer working relationships with customers. The two new offices were Hamamatsu Photonics Norden (HPN) to support customers in the Nordic and CIS countries and Hamamatsu Photonics UK Limited (HPUK) for UK and Ireland.

Since their establishment in 1988 both offices have shown substantial growth, HPN establishing a satellite office in Russia and HPUK providing local-level support in Southern Africa.

Mr. Atsushi Tsujimura, Managing Director, Hamamatsu Photonics UK and Mr. Max Skoglund, Managing Director, Hamamatsu Photonics Norden wish to thank their customers for their business and support over the last 20 years and both they and the staff at HPUK and HPN will continue to provide the highest levels of customer service for many years to come.

Hamamatsu Photonics supports the advancement of industry and research, through discovery of new opportunities using photonics technology. Building strong working relationships is central to this philosophy and Hamamatsu Photonics aims to create partnerships with our customers, enabling us to provide the best possible service now and in the future.
Designed for Hamamatsu Photonics CCD image sensor S9840, suitable for spectrometers

The C10416 signal processing module can be used in a spectrometer when combined with the S9840 CCD Image Sensor. Including CCD driver circuit, analog video signal processing circuit and power supply.

Features
- Built-in 14-bit A/D converter
- Interface of computer: USB 1.1/2.0
- Adjustable offset/gain
- Signal frequency: 1 MHz

Related products
Back-thinned CCD image sensor for spectrometers S9840

Features
- Optimized structure for full line binning (1D operation)
- High quantum efficiency in UV region
- Stable UV sensitivity
- Low dark current (MPP operation)
- No image-lag
- High-speed response: signal output frequency 5 MHz Max.

Specifications (Typ. Ta=25°C, unless otherwise noted)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel size</td>
<td>14 (H) x 14 (V)</td>
<td>µm</td>
</tr>
<tr>
<td>Number of active pixels</td>
<td>2048 x 14</td>
<td>pixels</td>
</tr>
<tr>
<td>Active area</td>
<td>28.6 x 0.196</td>
<td>mm</td>
</tr>
<tr>
<td>Spectral response range</td>
<td>200 to 1100</td>
<td>nm</td>
</tr>
<tr>
<td>Horizontal clock phase</td>
<td>2 phases</td>
<td></td>
</tr>
<tr>
<td>Vertical clock phase</td>
<td>2 phases</td>
<td></td>
</tr>
<tr>
<td>CCD node sensitivity</td>
<td>4.0</td>
<td>µV/e-</td>
</tr>
<tr>
<td>Dark current</td>
<td>500</td>
<td>e-/pixel/s</td>
</tr>
<tr>
<td>Readout noise*</td>
<td>25</td>
<td>e- rms</td>
</tr>
<tr>
<td>Full well capacity</td>
<td>1.30</td>
<td>ke-</td>
</tr>
<tr>
<td>Dynamic range</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Readout noise</td>
<td>5200</td>
<td></td>
</tr>
<tr>
<td>Window material</td>
<td>Quartz</td>
<td></td>
</tr>
</tbody>
</table>

*= At 2 MHz readout

Spectral response (without window)
Back-thinned TDI-CCD Image Sensor
S10200-02, S10201-04, S10202-08, S10202-16

Dramatically enhanced sensitivity by TDI mode

TDI-CCD captures clear and bright images even under low-light-level conditions. During TDI mode, the CCD captures an image of a moving object while transferring integrated signal charges synchronously with the object movement. This operation mode dramatically boosts sensitivity to high levels when capturing fast moving objects. Our TDI-CCD uses a back-thinned structure to achieve higher quantum efficiency over a wide spectral range from the UV to the near IR region (200 to 1100 nm).

Features

- TDI mode gives high sensitivity
- High-speed, continuous image acquisition
- Back-thinned structure ensures high sensitivity from UV to near IR
- Multiple ports for high-speed line rate

Applications

- Sequential imaging of high-speed moving samples
- Inspection tasks on electronic parts production line
- Semiconductor inspection
- Flow cytometry

Integrated exposure by TDI mode

TDI mode provides integrated exposure while synchronizing object movement with the signal charge transfer timing. The signal charge is integrated a number of times equal to the number of vertical stages (128 stages on our TDI-CCD), therefore TDI mode yields enhanced sensitivity about 128 times higher than ordinary linear image sensors.

Selection guide

<table>
<thead>
<tr>
<th>Type No.</th>
<th>Pixel size (μm)</th>
<th>Spectral response range (nm)</th>
<th>Number of active pixels (H) × (V)</th>
<th>Number of ports</th>
<th>Pixel rate (MHz/port)</th>
<th>Line rate (kHz)</th>
<th>Vertical transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>S10200-02</td>
<td>12×12</td>
<td>200 to 1100</td>
<td>1024×128</td>
<td>2</td>
<td>30</td>
<td>50</td>
<td>Bidirectional</td>
</tr>
<tr>
<td>S10201-04</td>
<td>2048×128</td>
<td></td>
<td>4</td>
<td>4</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10202-08</td>
<td>4096×128</td>
<td></td>
<td>8</td>
<td>8</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10202-16</td>
<td>4096×128</td>
<td></td>
<td>16</td>
<td>16</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

High sensitivity over the entire UV to near IR region

The back-thinned structure ensures higher sensitivity in the UV through the near IR region, than front-illuminated types.

Spectral response

Fast line rate

Using multiple amplifiers (multiple output ports) allows parallel image readout at a fast line rate (50 kHz or more).
InGaAs linear Image Sensor  
G10768-1024D(X)

High-speed (41000 lines/s max.) and large number of pixels (1024 ch) for near IR

The G10768-1024D is designed for applications such as medical diagnostic equipment and foreign object screening where a multichannel high-speed line rate is required. This image sensor has 1024 pixels yet delivers a high-speed line rate of 39000 lines/s Typ.

Applications
- OCT (optical coherence tomography)
- Foreign object screening
- Near infrared spectroscopy

Features
- Peak sensitivity wavelength: 1550 nm
- Large pixels: 1024 pixels
  (pixel size: 25 x 100 µm)
- High-speed line rate: 39000 lines/s Typ. (41000 lines/s Max.)
  High-speed data rate: 5 MHz Typ. (6.3 MHz Max.)

Signal processing circuit uses CTIA (capacitive transimpedance amplifiers) that allow signal readout while simultaneously integrating signals in all pixels via sample-and-hold circuits. A high-speed line rate is achieved through 8 output ports.

Equivalent diagram

Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak sensitivity wavelength</td>
<td>λₚ</td>
<td></td>
<td></td>
<td>1.55</td>
<td></td>
<td>µm</td>
</tr>
<tr>
<td>Saturation charge</td>
<td>Qsat</td>
<td>V=5 V</td>
<td>-</td>
<td>0.5</td>
<td>-</td>
<td>pC</td>
</tr>
<tr>
<td>Dark current</td>
<td>Iₒ</td>
<td></td>
<td>-</td>
<td>0.5</td>
<td>2</td>
<td>pA</td>
</tr>
<tr>
<td>RMS noise voltage (readout noise)</td>
<td>N</td>
<td>Standard deviation Sample number: 1000</td>
<td>-</td>
<td>2</td>
<td>6</td>
<td>mV</td>
</tr>
<tr>
<td>Saturation voltage amplitude</td>
<td>Vₛat</td>
<td>Integration time 30 µs</td>
<td>-</td>
<td>2.5</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>Defective pixel</td>
<td></td>
<td>CE=770 nV/e- (worst-case condition)</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>%</td>
</tr>
</tbody>
</table>

(Ta=25°C, fₜ=5 MHz, Vdd=5 V, INP=3.5 V, Vref1=Vref2=Vref3=2.5 V, CE=770 nV/e- per 1 element)
High-speed receiver built-in a plastic package for auto power control

Features
- High-speed response
  300 MHz Typ. (λ = 650 nm, V_r = 2.5 V)
  250 MHz Typ. (λ = 780 nm, V_r = 2.5 V)
- High sensitivity
  S10783: 0.46 A/W Typ. (λ = 650 nm)
  S10784: 0.45 A/W Typ. (λ = 650 nm)

Applications
- Laser diode monitor in optical disk drive (High-speed APC)
- Sensor for a red laser diode

Electrical and optical characteristics (Typ. Ta=25 °C, unless otherwise noted)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>S10783</th>
<th>S10784</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral response range</td>
<td>λ</td>
<td></td>
<td>Min. 3.50 to 1040</td>
<td>Max. 1040</td>
<td>nm</td>
</tr>
<tr>
<td>Peak sensitivity wavelength</td>
<td>λ_p</td>
<td></td>
<td>- 760</td>
<td>- 760</td>
<td>nm</td>
</tr>
<tr>
<td>Photo sensitivity</td>
<td>λ_S</td>
<td>λ = 660 nm</td>
<td>0.41</td>
<td>0.46</td>
<td>A/W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>λ = 780 nm</td>
<td>0.47</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>Dark current</td>
<td>I_d</td>
<td>V_r = 2.5 V</td>
<td>- 0.01</td>
<td>1.0</td>
<td>nA</td>
</tr>
<tr>
<td>Temp. coefficient of I_d</td>
<td>T_Cd</td>
<td></td>
<td>- 1.15</td>
<td>- 1.15</td>
<td>times/°C</td>
</tr>
<tr>
<td>Cut-off frequency</td>
<td>f_C</td>
<td>V_r = 2.5 V</td>
<td>150</td>
<td>300</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R_in = 50 Ω</td>
<td>125</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Terminal capacitance</td>
<td>C_T</td>
<td>V_r = 2.5 V</td>
<td>- 4.5</td>
<td>9</td>
<td>pF</td>
</tr>
<tr>
<td>Noise equivalent power</td>
<td>NEP</td>
<td>V_r = 2.5 V</td>
<td>- 3.5 x 10^-13</td>
<td></td>
<td>W/Hz</td>
</tr>
</tbody>
</table>
Red LED for POF Data Communications  NEW  L10762

RC (Resonant Cavity) LED for POF (plastic optical fiber) data communications

The L10762 is a red LED designed for POF (plastic optical fiber) data communications. A microball lens is bonded to the LED chip to enhance fiber coupling efficiency.

Features

- Improved fiber coupling efficiency
  A microball lens is bonded to the LED chip surface to enhance the coupling efficiency to optical fibers. Fiber end output power *1 was increased around about 7 times higher than our conventional type (L9907).
- High-speed response, $f_c = 70$ MHz Typ.

Fiber coupling characteristics

X, Y directions

<table>
<thead>
<tr>
<th>Distance from cap center X, Y (mm)</th>
<th>Relative fiber end output (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>0.5</td>
<td>90</td>
</tr>
<tr>
<td>1.0</td>
<td>80</td>
</tr>
<tr>
<td>1.5</td>
<td>70</td>
</tr>
<tr>
<td>2.0</td>
<td>60</td>
</tr>
</tbody>
</table>

Z direction

<table>
<thead>
<tr>
<th>Distance between fiber end and cap surface Z (mm)</th>
<th>Relative fiber end output (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>100</td>
</tr>
<tr>
<td>1.0</td>
<td>90</td>
</tr>
<tr>
<td>1.5</td>
<td>80</td>
</tr>
<tr>
<td>2.0</td>
<td>70</td>
</tr>
</tbody>
</table>

Specifications  

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak emission wavelength</td>
<td>$\lambda_p$</td>
<td>640</td>
<td>660</td>
<td>670</td>
<td>nm</td>
</tr>
<tr>
<td>Spectral half width</td>
<td>$\Delta \lambda$</td>
<td>-</td>
<td>15</td>
<td>25</td>
<td>nm</td>
</tr>
<tr>
<td>Fiber-end output *1</td>
<td>$P_f$</td>
<td>0.7</td>
<td>1.0</td>
<td>-</td>
<td>mW</td>
</tr>
<tr>
<td>Forward voltage</td>
<td>$V_F$</td>
<td>-</td>
<td>1.9</td>
<td>2.4</td>
<td>V</td>
</tr>
<tr>
<td>Cut-off frequency *2</td>
<td>$f_c$</td>
<td>60</td>
<td>70</td>
<td>-</td>
<td>MHz</td>
</tr>
</tbody>
</table>

*1: Plastic fiber: 1 mm in core diameter, 1 meter in length, and Z (distance between cap surface and fiber end) = 0.3 mm

*2: Frequency at which the radiant output drops by 3 dB relative to the output at 100 kHz.
RC-LED for 156 Mbps POF (plastic optical fiber) communications

The L10881 is designed for high-speed POF communications. The device is moulded into a miniature plastic package with lens, allowing easy and efficient coupling to a POF.

Features
- Red RC-LED for POF data link
- Peak emission wavelength: 660 nm (suitable for POF communications)
- High-speed response: $f_c=70$ MHz Typ.
  High-output power: $P_o=-2$ dBm ($I_f=20$ mA, $\Phi=1$ mm, POF)
- Designed to be used with the S7727 (receiver photo IC)

Applications
- Plastic optical fiber communications (FA, office machinery, home automation, LAN)
- Data transmission in locations subject to high electromagnetic noise

Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward voltage</td>
<td>$V_F$</td>
<td>$I_f=20$ mA</td>
<td>-</td>
<td>1.9</td>
<td>2.4</td>
<td>V</td>
</tr>
<tr>
<td>Peak emission wavelength</td>
<td>$\lambda_p$</td>
<td>$I_f=20$ mA</td>
<td>640</td>
<td>660</td>
<td>670</td>
<td>nm</td>
</tr>
<tr>
<td>Spectral half width (FWHM)</td>
<td>$\Delta \lambda$</td>
<td>$I_f=20$ mA</td>
<td>-</td>
<td>-</td>
<td>25</td>
<td>nm</td>
</tr>
<tr>
<td>Fiber coupled optical power</td>
<td>$P_o$</td>
<td>*</td>
<td>-</td>
<td>-2</td>
<td>-</td>
<td>dBm</td>
</tr>
<tr>
<td>Pulse distortion</td>
<td>$\Delta T$</td>
<td>*</td>
<td>-2.5</td>
<td>-</td>
<td>2.4</td>
<td>ns</td>
</tr>
<tr>
<td>Cut-off frequency</td>
<td>$f_c$</td>
<td>$I_f=20$ mA + 1 mAp-p</td>
<td>60</td>
<td>70</td>
<td>-</td>
<td>MHz</td>
</tr>
</tbody>
</table>

Vertical axis: 30 mV/div., Horizontal axis: 5 ns/div.
(Ta=25°C, Vcc=5.00 V, $R_1=100\Omega$, $R_2=300\Omega$, $C_L=20$ pF)
MPPC®
(Multi-Pixel Photon Counter)

The MPPC is a new type of photon-counting device made up of multiple APD pixels operating in Geiger mode. The MPPC is a small semiconductor detector that operates at room temperatures and has an excellent photon-counting capability. In addition to the current MPPC line up, Hamamatsu Photonics will release surface mount type MPPCs.

Newly developed surface mount type MPPC

Hamamatsu Photonics newly developed MPPC is sealed in a plastic moulded package suitable for surface mounting. Supplied in a compact package to minimise dead space. Available in two active area types, 1 x 1 mm or 3 x 3 mm.

Active area: 1 x 1 mm type

<table>
<thead>
<tr>
<th>Parameter</th>
<th>S10362-11-025P</th>
<th>S10362-11-050P</th>
<th>S10362-11-100P</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chip size</td>
<td>1.5 x 1.5</td>
<td>1.5 x 1.5</td>
<td>1.5 x 1.5</td>
<td>mm</td>
</tr>
<tr>
<td>Effective area</td>
<td>1 x 1</td>
<td>1 x 1</td>
<td>1 x 1</td>
<td>mm</td>
</tr>
<tr>
<td>Number of pixels</td>
<td>1600</td>
<td>400</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>Pixel size</td>
<td>25 x 25</td>
<td>50 x 50</td>
<td>100 x 100</td>
<td>µm</td>
</tr>
<tr>
<td>Fill factor *1</td>
<td>30.8</td>
<td>61.5</td>
<td>78.5</td>
<td>%</td>
</tr>
<tr>
<td>Spectral response range</td>
<td>320 to 900</td>
<td>320 to 900</td>
<td>320 to 900</td>
<td>nm</td>
</tr>
<tr>
<td>Peak sensitivity wavelength</td>
<td>440</td>
<td>440</td>
<td>440</td>
<td>nm</td>
</tr>
<tr>
<td>Recommended operating voltage</td>
<td>70 ± 10 *2</td>
<td>70 ± 10 *2</td>
<td>70 ± 10 *2</td>
<td>V</td>
</tr>
<tr>
<td>Gain</td>
<td>2.75 x 10^9</td>
<td>7.5 x 10^9</td>
<td>2.4 x 10^9</td>
<td>-</td>
</tr>
</tbody>
</table>

Active area: 3 x 3 mm type

<table>
<thead>
<tr>
<th>Parameter</th>
<th>S10931-025P</th>
<th>S10931-050P</th>
<th>S10931-100P</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chip size</td>
<td>3.5 x 3.5</td>
<td>3.5 x 3.5</td>
<td>3.5 x 3.5</td>
<td>mm</td>
</tr>
<tr>
<td>Effective area</td>
<td>3 x 3</td>
<td>3 x 3</td>
<td>3 x 3</td>
<td>mm</td>
</tr>
<tr>
<td>Number of pixels</td>
<td>14400</td>
<td>3600</td>
<td>900</td>
<td>-</td>
</tr>
<tr>
<td>Pixel size</td>
<td>25 x 25</td>
<td>50 x 50</td>
<td>100 x 100</td>
<td>µm</td>
</tr>
<tr>
<td>Fill factor *1</td>
<td>30.8</td>
<td>61.5</td>
<td>78.5</td>
<td>%</td>
</tr>
<tr>
<td>Spectral response range</td>
<td>320 to 900</td>
<td>320 to 900</td>
<td>320 to 900</td>
<td>nm</td>
</tr>
<tr>
<td>Peak sensitivity wavelength</td>
<td>440</td>
<td>440</td>
<td>440</td>
<td>nm</td>
</tr>
<tr>
<td>Recommended operating voltage</td>
<td>70 ± 10 *2</td>
<td>70 ± 10 *2</td>
<td>70 ± 10 *2</td>
<td>V</td>
</tr>
<tr>
<td>Gain</td>
<td>2.75 x 10^9</td>
<td>7.5 x 10^9</td>
<td>2.4 x 10^9</td>
<td>-</td>
</tr>
</tbody>
</table>

*1: Ratio of the active area of a pixel to the entire area of the pixel.

*2: For the recommended operating voltage of each product, refer to the product datasheet.
Preliminary MPPC arrays

Hamamatsu Photonics is developing MPPC monolithic arrays for large area photon detection. The array type MPPC can be used in combination with a scintillator for measuring radiation such as gamma rays.

1 x 4 ch array MPPC (1 x 1 mm active area per channel)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>S10984-025P(X)</th>
<th>S10984-050P(X)</th>
<th>S10984-100P(X)</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective active area</td>
<td>1 x 4</td>
<td>1 x 1</td>
<td>-</td>
<td>mm</td>
</tr>
<tr>
<td>Effective active area/channel</td>
<td></td>
<td></td>
<td>-</td>
<td>mm</td>
</tr>
<tr>
<td>Number of pixels/channel</td>
<td>1600</td>
<td>400</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>Pixel size</td>
<td>25 x 25</td>
<td>50 x 50</td>
<td>100 x 100</td>
<td>µm</td>
</tr>
<tr>
<td>Fill factor *1</td>
<td>80.8</td>
<td>61.5</td>
<td>78.5</td>
<td>%</td>
</tr>
<tr>
<td>Spectral response range</td>
<td>320 to 900</td>
<td></td>
<td></td>
<td>nm</td>
</tr>
<tr>
<td>Peak sensitivity wavelength</td>
<td>440</td>
<td></td>
<td></td>
<td>nm</td>
</tr>
<tr>
<td>Recommended operating voltage</td>
<td>70 ± 10 *2</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Gain</td>
<td>2.75 x 10^10</td>
<td>7.5 x 10^10</td>
<td>2.4 x 10^10</td>
<td>-</td>
</tr>
<tr>
<td>Package</td>
<td>Plastic (Surface mount type)</td>
<td></td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

*1: Ratio of the active area of a pixel to the entire area of the pixel.
*2: For the recommended operating voltage of each product, refer to the product datasheet.

2 x 2 ch array MPPC (3 x 3 mm active area per channel)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>S10985-025C(X)</th>
<th>S10985-050C(X)</th>
<th>S10985-100C(X)</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective active area</td>
<td>6 x 6</td>
<td>3 x 3</td>
<td>-</td>
<td>mm</td>
</tr>
<tr>
<td>Effective active area/channel</td>
<td></td>
<td></td>
<td>-</td>
<td>mm</td>
</tr>
<tr>
<td>Number of pixels/channel</td>
<td>14400</td>
<td>3600</td>
<td>900</td>
<td>-</td>
</tr>
<tr>
<td>Pixel size</td>
<td>25 x 25</td>
<td>50 x 50</td>
<td>100 x 100</td>
<td>µm</td>
</tr>
<tr>
<td>Fill factor *1</td>
<td>80.8</td>
<td>61.5</td>
<td>78.5</td>
<td>%</td>
</tr>
<tr>
<td>Spectral response range</td>
<td>320 to 900</td>
<td></td>
<td></td>
<td>nm</td>
</tr>
<tr>
<td>Peak sensitivity wavelength</td>
<td>440</td>
<td></td>
<td></td>
<td>nm</td>
</tr>
<tr>
<td>Recommended operating voltage</td>
<td>70 ± 10 *2</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Gain</td>
<td>2.75 x 10^10</td>
<td>7.5 x 10^10</td>
<td>2.4 x 10^10</td>
<td>-</td>
</tr>
<tr>
<td>Package</td>
<td>Ceramic</td>
<td></td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

*1: Ratio of the active area of a pixel to the entire area of the pixel.
*2: For the recommended operating voltage of each product, refer to the product datasheet.
Developing and producing various types of MPPC

Since the release of the first MPPC in 2007, Hamamatsu Photonics has been developing and producing a variety of MPPC devices to make them even easier to use and beneficial in more applications. This allows you to select the MPPC that best meets your application requirements such as high-precision measurement, space saving, and mass production.

Active area
- 1 x 1 mm type
- 3 x 3 mm type
- Array type
  - (1 x 1 mm  1 x 4 ch)
  - (3 x 3 mm  2 x 2 ch)

Package type
- Metal
- Ceramic
- Surface mount
## MPPC Line up

<table>
<thead>
<tr>
<th>Type No.</th>
<th>Effective active area (mm)</th>
<th>Number of pixels</th>
<th>Pixel size (µm)</th>
<th>Package</th>
<th>Photo</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active area 1 x 1 mm</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10362-11-02SC</td>
<td>1 x 1</td>
<td>1600</td>
<td>25 x 25</td>
<td>Ceramic</td>
<td></td>
</tr>
<tr>
<td>S10362-11-050C</td>
<td></td>
<td>400</td>
<td>50 x 50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10362-11-100C</td>
<td></td>
<td>100</td>
<td>100 x 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10362-11-02SU</td>
<td>1 x 1</td>
<td>1600</td>
<td>25 x 25</td>
<td>Metal</td>
<td></td>
</tr>
<tr>
<td>S10362-11-050U</td>
<td></td>
<td>400</td>
<td>50 x 50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10362-11-100U</td>
<td></td>
<td>100</td>
<td>100 x 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10362-11-02SP</td>
<td>1 x 1</td>
<td>1600</td>
<td>25 x 25</td>
<td>Plastic (Surface mount type)</td>
<td></td>
</tr>
<tr>
<td>S10362-11-050P</td>
<td></td>
<td>400</td>
<td>50 x 50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10362-11-100P</td>
<td></td>
<td>100</td>
<td>100 x 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Active area 3 x 3 mm</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10362-33-02SC</td>
<td>3 x 3</td>
<td>14400</td>
<td>25 x 20</td>
<td>Ceramic</td>
<td></td>
</tr>
<tr>
<td>S10362-33-050C</td>
<td></td>
<td>3600</td>
<td>50 x 50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10362-33-100C</td>
<td></td>
<td>900</td>
<td>100 x 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10931-02SP</td>
<td>3 x 3</td>
<td>14400</td>
<td>25 x 25</td>
<td>Plastic (Surface mount type)</td>
<td></td>
</tr>
<tr>
<td>S10931-050P</td>
<td></td>
<td>3600</td>
<td>50 x 50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10931-100P</td>
<td></td>
<td>900</td>
<td>100 x 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Array type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10984-02SP(X)</td>
<td>1 x 1/ch (1 x 4 ch)</td>
<td>1600/ch</td>
<td>25 x 25</td>
<td>Plastic (Surface mount type)</td>
<td></td>
</tr>
<tr>
<td>S10984-050P(X)</td>
<td></td>
<td>400/ch</td>
<td>50 x 50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10984-100P(X)</td>
<td></td>
<td>100/ch</td>
<td>100 x 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10985-025C(X)</td>
<td>3 x 3/ch (2 x 2 ch)</td>
<td>14400/ch</td>
<td>25 x 25</td>
<td>Ceramic</td>
<td></td>
</tr>
<tr>
<td>S10985-050C(X)</td>
<td></td>
<td>3600/ch</td>
<td>50 x 50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S10985-100C(X)</td>
<td></td>
<td>900/ch</td>
<td>100 x 100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MPPC Module
C10507-11 Series, C10751 Series

Making photon counting smooth and easy

The MPPC module is designed to extract maximum MPPC performance. Despite its compact size, the MPPC module has many features including a USB port for easy connection and photon counting operation via a PC.

Applications
- Fluorescence and fluorescence lifetime measurement
- DNA analysis, bioluminescence analysis
- Environmental analysis, etc.

3 types of output

The MPPC module provides 3 types of output (analog, comparator and pulse). You can monitor output waveforms by connecting the analog output to an oscilloscope and acquire a pulse count by connecting the comparator output to a frequency counter. The pulse count can also be output using the sample software that supplied with the MPPC module.
The MPPC module is designed to deliver maximum MPPC performance. A current-to-voltage converter, high-speed comparator, high-voltage power supply, temperature-compensation circuit, counter, and microcomputer are all assembled on one compact circuit. The MPPC module comes with all basic functions needed for photon counting, so you can start photon counting measurements without preparing external circuits.

The interface supports USB1.1, for easy operation and simple connection to a PC. The MPPC module is driven by power supplied through the bus of the PC, so no external power supply is required. All operations can be performed from the PC while monitoring the measurement data on the PC display.

We offer a variety of MPPC modules which contain an MPPC (S10362-11 series). We also provide the C10751 series MPPC modules which conform to CE marking.

<table>
<thead>
<tr>
<th>Type No.</th>
<th>Number of pixels</th>
<th>Pixel size (μm)</th>
<th>Package</th>
<th>Effective active area (mm)</th>
<th>Type No.</th>
<th>Spectral response range (nm)</th>
<th>Dimensions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C10507-11-025U</td>
<td>1600</td>
<td>25 x 25</td>
<td>Metal</td>
<td>1 x 1</td>
<td>S10362-11-025U</td>
<td>270 to 900 (λp=400)</td>
<td>80 x 55</td>
</tr>
<tr>
<td>C10507-11-050U</td>
<td>400</td>
<td>50 x 50</td>
<td>Metal</td>
<td>1 x 1</td>
<td>S10362-11-050U</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C10507-11-100U</td>
<td>100</td>
<td>100 x 100</td>
<td>Ceramic</td>
<td>1 x 1</td>
<td>S10362-11-100U</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C10507-11-025C</td>
<td>1600</td>
<td>25 x 25</td>
<td>Ceramic</td>
<td>1 x 1</td>
<td>S10362-11-025C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C10507-11-050C</td>
<td>400</td>
<td>50 x 50</td>
<td>Ceramic</td>
<td>1 x 1</td>
<td>S10362-11-050C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C10507-11-100C</td>
<td>100</td>
<td>100 x 100</td>
<td>Ceramic</td>
<td>1 x 1</td>
<td>S10362-11-100C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CE Compliant C10751-01</td>
<td>1600</td>
<td>25 x 25</td>
<td>Metal</td>
<td>1 x 1</td>
<td>S10362-11-025U</td>
<td></td>
<td>90.7 x 77 x 35</td>
</tr>
<tr>
<td>CE Compliant C10751-02</td>
<td>400</td>
<td>50 x 50</td>
<td>Metal</td>
<td>1 x 1</td>
<td>S10362-11-050U</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CE Compliant C10751-03</td>
<td>100</td>
<td>100 x 100</td>
<td>Metal</td>
<td>1 x 1</td>
<td>S10362-11-100U</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

USB port allows easy measurement from a PC

The MPPC module line-up

We offer a variety of MPPC modules which contain an MPPC (S10362-11 series). We also provide the C10751 series MPPC modules which conform to CE marking.

<table>
<thead>
<tr>
<th>Accessories (sold separately)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber adapter A10524 series</td>
</tr>
<tr>
<td>Coaxial connector adapter A10613 series</td>
</tr>
</tbody>
</table>

* Optical fiber is needed separately.
Solid-state photodetectors have evolved in their ability to detect low levels of light. Building upon silicon photodiodes, novel solid-state detectors have been developed to detect increasingly lower levels of light. The latest addition and most sensitive solid-state detector to date is the Geiger-mode avalanche-photodiode (APD) array, which is capable of detecting a single photon.

Silicon photodiodes convert light into an electrical signal. This conversion occurs when photons having more energy than the bandgap of the detector material are absorbed, exciting an electron from the valence band of the semiconductor to the conduction band, where it is read out as signal. Avalanche photodiodes use the same process, but they generate internal gain using an avalanche multiplication process. An avalanche region is produced within the APD, creating an area of very high electric-field strength. When a photogenerated (or thermally generated) electron in the conduction band moves into the avalanche region, the electric-field strength is sufficient to accelerate it to the point at which it can cause “impact ionization” and liberate another electron. Both of these electrons can be accelerated as well, creating an avalanche multiplication. This process results in detector gain. Typical gains for an APD are in the range of ten to a few hundred.

Geiger-mode operation can increase the modest gain of an APD to a more significant level. In a single-photon-counting APD (in Geiger mode), the electric field described above increases with increasing applied voltage, thereby increasing the APD gain. This works only up to a point. At some operating voltage, the semiconductor junction breaks down and the APD will become a conductor. In fact, the APD is stable above this breakdown voltage until an electron enters the avalanche region, resulting in the avalanche region breaking down and the APD becoming a conductor – this is known as a Geiger discharge. The current flow produced by the breakdown is large; therefore, the signal gain is large (more than $10^5$) because a single electron resulted in a large flow of current.

A device that triggers once, however, is not a very useful detector, so a means to stop the breakdown or to reset the APD is required. Typically the reset is accomplished by placing a resistor in series with the detector. When the junction breaks down, large current flows through the resistor, resulting in a voltage drop across the resistor and in the APD. If the voltage drop is sufficient, the APD voltage will drop below the breakdown voltage and be reset. The discharge-and-reset cycle is known as the Geiger mode of operation.

FIGURE 1. A multipixel photon counter is a photon-counting device consisting of multiple APD pixels operating in Geiger mode. Each pixel outputs a pulse signal when it detects photons, and the output of the device is the total sum of the outputs from all the pixels.

FIGURE 2. In two MPPC arrays of 20 x 20 Geiger-mode APDs, shown with an output waveform, the red pixels represent the discharge of the pixel when an incident photon is detected. In the top array a single photon detected resulting in one photoelectron output. In the lower array three simultaneously detected photons resulting in a pulse with an amplitude three times higher.

FIGURE 3. Number of detected photons vs. time.
Geiger-mode APD arrays

A single APD operating in Geiger mode has a limitation: it is essentially on or off. It cannot distinguish between a single photon and multiphotons that arrive simultaneously. One only knows that the APD was triggered; it is not possible to tell if a single photon or multiple photons triggered the Geiger discharge. Single Geiger-mode APDs are suitable for photon counting at very weak light levels only.

Photon counting is a signal-processing technique that converts the output signal generated by a single photon into a digital pulse that is counted. No additional analog-to-digital converters are needed because the photon-counting circuit does the conversion. Photon counting follows Poisson statistics, so the signal-to-noise ratio is simply the square root of the number of signal counts. If one needs to improve the signal-to-noise ratio, the count is extended for a longer period of time (a count four times longer improves the signal-to-noise ratio by a factor of two).

An array of Geiger-mode APDs connected in parallel can overcome the limitation of a single device. These recently developed arrays can distinguish multiple-photon from single-photon events. One example of these devices, generically known as silicon photomultipliers, is the multipixel photon counter (MPPC) from Hamamatsu Photonics (see Fig. 1).

The sum of the output from each APD pixel forms the MPPC output. This allows the counting of single photons or the detection of pulses of multiple photons (see Fig. 2). When photon flux is low and photons arrive at a time interval that is longer than the recovery time of a pixel, the MPPC will output pulses that equate to a single photoelectron. The pulses can be converted to digital pulses and counted as described above. When the photon flux is high or the photons arrive in short pulses (pulse width less than the recovery time), the pixel outputs will add up, as shown in Fig. 2, as the 2-photoelectron and 3-photoelectron pulses. In this case, the MPPC is behaving in a pseudo-analog manner because it can measure the incident number of photons per pulse—not possible with single photon counting APDs.

One of the biggest advantages of the MPPC is that it’s a solid state device. It is compact, rugged, easy to use (70 V operation), and low cost—making low-level-light detection possible in mass-produced instruments for applications such as point-of-care. Furthermore the MPPC is capable of high photon detection efficiency (PDE), in excess of a typical photomultiplier tube (PMT; see Fig. 3).

Additional advantages of the MPPC are high gain and low multiplication noise (noise added by the multiplication process). The high gain makes detection of a single photon possible—a single detected photon produces a measurable signal. While single photon counting APDs could also detect single photons, they require cooling down to -30°C or -40°C. Furthermore, the active area of these devices is very small (typically less than a few hundred microns). The MPPC has an active area of 1 x 1 mm or 3 x 3 mm and can count photons at room temperature.

While the MPPC has many advantages, it is not perfect. One disadvantage is its sensitivity to temperature changes. Geiger-mode operation reduces the temperature sensitivity, but temperature stabilization or compensation is still required for any application using MPPCs.

The dark counts produced by the MPPC are much higher than for a similar PMT due to the lower work function of silicon. However, dark counts are not the same as dark noise. Since photon counting follows Poisson statistics, the standard deviation in the number of counts is simply the square root of the number of counts. This means that an MPPC with 400,000 dark counts has a dark noise of 632 counts. In principle, one could get a meaningful signal-to-noise ratio from about 1000 detected photons.

![Figure 3. The photon detection efficiency (PDE) is a product of the APD's quantum efficiency, fill factor, and Geiger avalanche probability. The PDE data shown for three multipixel photon counters with differing numbers of pixels include the effects of crosstalk and afterpulsing.](https://example.com/figure3)
Applications of the MPPC

Photon counting and the MPPC in particular can be used in a variety of applications. In a flow cytometer, for example, the major components are a fluidics system, a laser, optics, photodetectors, and electronics. As cells pass single-file through the laser beam, they scatter light and possibly fluoresce. The forward-scattered light indicates the size of the cell, while the side-scatter light indicates its structural complexity. The fluorescence of any fluorophores bound to the cell indicates the presence of a specific cellular structure or biomolecule. In flow cytometry, light from scattering and fluorescence are typically collected by photodetectors, usually PMTs. However, multipixel photon counters can be used as an alternative. They offer high photon detection efficiency, high gain, and detection limits near those of a PMT. The high dark count of an MPPC is not an issue because flow cytometry uses threshold levels — effectively cutting off the contribution from dark counts and only allowing higher signals to be detected. The dynamic range of the MPPC could be an issue though.

Another MPPC application is high-energy or particle physics, which studies subatomic particles like neutrinos. As neutrinos travel through space, they oscillate between three types or “flavors”: $\nu_e$ (electron neutrino), $\nu_\mu$ (muon neutrino), and $\nu_\tau$ (tau neutrino). While the conversion of $\nu_\mu$ to $\nu_\tau$ has been studied, much is still unknown about the conversion of $\nu_\mu$ to $\nu_e$. The Tokai-to-Kamioka (T2K) experiment in Japan is intended to shed light on the nature of this phenomenon with the MPPC playing a vital role. Next year, the Japan Proton Accelerator Research Complex (Tokai, Japan) will send an intense neutrino beam to the Super Kamiokande (Kamioka, Japan) 295 km away. By measuring and comparing the amounts of $\nu_\mu$ and $\nu_e$ at the start and end of the beam’s journey, physicists hope to observe the disappearance of $\nu_\mu$ and the appearance of $\nu_e$ as the neutrinos oscillate.1, 2 The initial and final measurements will be performed by near detectors (ND280) and the Super Kamiokande, respectively.

To detect neutrinos, the ND280 detectors will use thousands of scintillators coupled to photodetectors by wavelength-shifting fibers. The MPPC from Hamamatsu Photonics was chosen as the photodetector for the ND280 because it fulfills most of the requirements. The MPPC is compact and can withstand the 0.2 T magnetic field. It also has gain greater than $5 \times 10^5$, and its PDE is higher than the quantum efficiency for a typical PMT. Although the combined crosstalk and afterpulses in an MPPC is higher than the ideal 10%, the measured values in 300 devices (13% to 22%) are still low enough to allow the MPPC to be used.3 About 55,000 pieces of MPPC will be delivered for the ND280 particle detectors.

The MPPC represents a revolution in solid-state detection. It is now possible to count photons in very compact and low-power applications at room temperature.

Author: Earl Hergert and Maridel Lares, Hamamatsu Photonics Corp.

References
1. T2K Neutrino Experiment website (http://nu-nov01.kek.jp/public/t2k/)
2. T2K-ND280 website (www.nd280.org/info)
7. Multi-Pixel Photon Counter catalog from Hamamatsu Photonics K.K.

Reprinted with permission © Laser Focus World 2008
Small and high-resolution encoder module

P10210 is an optical encoder module that consists of a photo IC and red LED. The photo IC incorporates a 4-element photodiode and a 2-phase digital signal output circuit.

**Features**
- **High resolution: 0.05 mm (2-phase output)**
  This encoder module allows high-resolution measurement when combined with a code plate that has 0.2 mm pitch slits. Signals from 1 pair each of the 4-element photodiode inputs are compared and discriminated to output a 2-phase digital signal.
- **Small package**
  A smaller package than conventional products reduces the component mounting area.

**Applications**
- Laser diode monitor in optical disk drive (High-speed APC)
- Sensor for a red laser diode

**Electrical and optical characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input (LED)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward voltage</td>
<td>( V_f )</td>
<td>( I_f = 20 ) mA</td>
<td>-</td>
<td>1.9</td>
<td>2.4</td>
<td>V</td>
</tr>
<tr>
<td>Reverse current</td>
<td>( I_r )</td>
<td>( V_r = 5 ) V</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>( \mu ) A</td>
</tr>
<tr>
<td>Peak emission wavelength</td>
<td>( \lambda_p )</td>
<td>( I_p = 10 ) mA</td>
<td>-</td>
<td>650</td>
<td>-</td>
<td>nm</td>
</tr>
<tr>
<td>Output (photo IC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating supply voltage</td>
<td>( V_{cc} )</td>
<td></td>
<td>3.0</td>
<td>-</td>
<td>7.0</td>
<td>V</td>
</tr>
<tr>
<td>Low level output voltage</td>
<td>( V_{ol} )</td>
<td>( I_{ol} = 1 ) mA</td>
<td>-</td>
<td>-</td>
<td>0.4</td>
<td>V</td>
</tr>
<tr>
<td>High level output voltage</td>
<td>( V_{oh} )</td>
<td></td>
<td>4.5</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>Supply current</td>
<td>( I_{cc} )</td>
<td>( V_{cc} = V_{ol} = &quot;L&quot; )</td>
<td>-</td>
<td>6.0</td>
<td>10</td>
<td>mA</td>
</tr>
<tr>
<td>Transfer characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duty ratio</td>
<td>( t_{AH}/t_{AP} )</td>
<td>( I_f = 5 ) mA, ( f = 10 ) kHz</td>
<td>35</td>
<td>50</td>
<td>65</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>( t_{BH}/t_{BP} )</td>
<td>( I_f = 5 ) mA, ( f = 10 ) kHz</td>
<td>35</td>
<td>50</td>
<td>65</td>
<td>%</td>
</tr>
<tr>
<td>Phase difference</td>
<td>( \varphi_{AB} )</td>
<td>( I_f = 5 ) mA, ( f = 10 ) kHz</td>
<td>60</td>
<td>90</td>
<td>120</td>
<td>degrees</td>
</tr>
<tr>
<td>Rise time</td>
<td>( \tau )</td>
<td>( I_f = 5 ) mA, ( C = 10 ) pF</td>
<td>-</td>
<td>0.5</td>
<td>2</td>
<td>( \mu ) s</td>
</tr>
<tr>
<td>Fall time</td>
<td>( \tau )</td>
<td>( I_f = 5 ) mA, ( C = 10 ) pF</td>
<td>-</td>
<td>0.04</td>
<td>0.3</td>
<td>( \mu ) s</td>
</tr>
<tr>
<td>Maximum response frequency</td>
<td>( f_{max} )</td>
<td>( I_f = 5 ) mA</td>
<td>50</td>
<td>-</td>
<td>-</td>
<td>kHz</td>
</tr>
</tbody>
</table>

Note: Connect a capacitor of 0.1 F or larger capacitor between \( V_{cc} \) and GND.
Infrared needle in a haystack

The QUANTA-OEM module is designed as an easy to use workhorse in infrared industries and laboratories. It has plug and play function, i.e. just connect the power supply and the laser head will work. The laser is integrated into a complete, cell phone sized, laser head called QUANTA-OEM including the necessary driver and controller. It is suitable for industrial and lab purposes and provides electrical and thermal control. The module allows lasers to be exchanged.

Quantum Cascade Lasers

The QUANTA-OEM uses state of the art pulsed room temperature quantum cascade lasers (QCL). The concept of QCL enables production of diode lasers in the range of 4 µm to 12 µm that work at room temperature. The lasers are offered in Single or Multi Mode. For the basic application of gas measurement Single Mode quality is necessary. In these type of measurements the spectral very narrow laser light scans over a characteristic gas absorption line as the wavelength is continuously shifted within the pulse.

Two types of operation

The laser head works in 2 ways: It can be operated just by connecting power. In this case, the controller will use the factory selected settings made by potentiometers. Status LEDs do report operation status. The QUANTA-OEM provides separate current and voltage monitor output and a combined trigger in/out port. Secondly, the QUANTA-OEM is designed for remote control via an analog interface. This interface can be addressed via a 15 pin SUB-D connector. Remote settings can be made by applying an appropriate voltage. The setting range is 0 … + 5V.

Author: Johannes Kunsch, Laser Components GmbH

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Ratings</th>
<th>Units</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser current</td>
<td>I</td>
<td>1.5 … 9</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Pulse width</td>
<td>t_p</td>
<td>21 ... 310</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Rise / fall time</td>
<td>t_r</td>
<td>&lt; 8</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Repetition frequency</td>
<td>f_re</td>
<td>≤ 200</td>
<td>kHz</td>
<td></td>
</tr>
<tr>
<td>Laser temperature</td>
<td>T</td>
<td>-10 ... +40</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Duty cycle</td>
<td>DC</td>
<td>typ. 0.1</td>
<td>%</td>
<td>DC max = 24 mA</td>
</tr>
<tr>
<td>Recommended input voltage for pulsed current</td>
<td>U_i</td>
<td>0 … 5</td>
<td>VDC</td>
<td></td>
</tr>
<tr>
<td>Recommended input voltage for pulsed width</td>
<td>U_w</td>
<td>0 … 5</td>
<td>VDC</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>m</td>
<td>230</td>
<td>g</td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td>l x w x h</td>
<td>85 x 53 x 36</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>Housing material</td>
<td></td>
<td>Al</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Applications

- Tunable Diode Laser Absorption Spectroscopy
- Infrared Alignment Laser
- Characterisation of Infrared Optics
- Detector Testing
- Look through materials that are not transparent in VIS and NIR
- Replacement of small CO2 lasers
A new high speed Photosensor module is presented with a high sensitive new Super Bialkali Cathode.

Hamamatsu Photonics presents the new high speed, very sensitive and compact series of TO-8 photomultiplier modules.

All modules have extraordinary fast rise time of 570 ps, also a new Super Bialkali cathode having cathode radiant sensitivity of 120 mA/W with a detecting wavelength range from 280 nm – 700 nm. The peak sensitive wavelength is at 390nm.

All modules are supplied with divider sockets and high voltage power supply, needing only a input voltage of 4.5 V – 5 V.

H10721-110 has direct signal out from the anode, whereas H10722-110 and H10723-110 were supplied with preamplifiers.

H10722-110 has a bandwidth of DC – 20 kHz and H10723-110 from DC – 200 kHz.

The applications for this photomultiplier modules are seen in the medical, analytical and industrial field.

Typical applications are fluorescence and luminescence detection, absorbance measurements, scintillation measurements and fast process monitoring.

Author: Dr. Klaus Peter Aicher, Hamamatsu Photonics Germany

Features
- Super bialkali cathode
- Compact size (22 mm x 22 mm x 50 mm)
- Fast rise time (570 ps)
- Modules with preamplifier available
- Including high voltage power supply

Applications
- Time resolution fluorescence detection
- Luminescence detection
- Absorption measurements (e.g. by MTP reader)
- Analyzing combustion processes
- Detection of radioactive processes using scintillation measurement

Specifications
- Detection range 280 nm – 700 nm
- Peak sensitive wavelength 390 nm
- Anode radiant sensitivity 120mA/W
- Cathode radiant sensitivity 48 A/mW (current type), or 48 V/nW (voltage type with preamplifier)
- Input voltage 4.5 V – 5 V
- Active area 8 mm dia.
A new low cost and compact high power supply is presented

Hamamatsu Photonics developed a new high power supply.

C10689 is a low cost and compact power supply for 0 – 1250 V with output current of 25 mA max.

The ripple noise is extremely low with 10 mV p-p (typ.) and a long time drift of +/- 0.01 %/h (typ.). The temperature coefficient is +/- 0.005 %/°C (typ.).

C10689 is a fully encapsulated highly reliable power supply.

C10689 series is compact and has only a dimension of 112 mm (W) x 160 mm(D) x 44 mm (H).

C10689-02 supplies – HV, whereas C10689-52 can be used for + HV.

C10689 can be used as power supply for photomultipliers, phototubes and APDs.

Author: Dr. Klaus Peter Aicher, Hamamatsu Photonics Germany

Features
- Low cost
- High reliability
- Fully encapsulated
- Low ripple noise
- Compact and light weight

Application
- Power supply for photomultipliers, phototubes and APDs

Specifications
- Input voltage 24 Vdc +/- 5 % by 2.0 A typ.
- Output voltage 0 – 1250 V
- Output current 25 mA max.
- Ripple noise 10 mV p-p typ.
- Output control voltage 0 – 5 V
- Drift +/- 0.01 %/h (typ.).
- Temperature coefficient +/- 0.005 %/°C (typ.).
- Dimension 112 mm(W) x 160 mm(D) x 44 mm(H)
- Operating temperature 0 – 50 °C at 85% RH max
- Storage temperature 0 – 60 °C at 85% RH max
- Weight 700 g
3.5-Inch Diameter Head-on PMT for Scintillation Counting

Introducing the new R10233, a 90 mm (3.5 inch) diameter head-on photomultiplier tube (PMT) from Hamamatsu Photonics, designed primarily for scintillation counting and incorporating a bialkali photocathode to match the spectral output from most common scintillators.

The R10233 is designed to meet the needs of applications requiring PMTs larger than our current 3-inch diameter, but where 5 inch PMTs were prohibitive in terms of size and cost.

The key features and attributes of this new PMT make it ideal for high energy physics experiments and for applications in the Medical field.

Author: Robin Smith, Hamamatsu Photonics UK

Features
- New convenient size
- Low Dark current
- Fast time response

Applications
- High Energy Physics
- Medical research
- Academic Research
High QE Photomultiplier Tube
R10699

High QE Multialkali Side-on PMT

The R10699 is a new 28mm (1-1/8 Inch) Side-on Photomultiplier Tube (PMT), incorporating the latest multi-alkali photocathode technology, to give the optimum sensitivity to near IR radiation.

Featuring high quantum efficiency (QE) across a wide spectral response from 185 nm to 900 nm, providing high sensitivity even in the difficult NIR region. The R10699 also features a high gain value of $1.3 \times 10^7$ and combined with the high QE gives this new PMT very high sensitivity and good signal to noise ratio.

The R10699 is pin compatible with Hamamatsu Photonics existing range of 28 mm side window PMTs, such as the industry standard R928, and can therefore be used with our wide range of PMT accessories such as divider socket assemblies, integrated power suppliers, photon counters and PMT coolers.

Author: Jenny Brown/Tim Stokes, Hamamatsu Photonics UK

Features
- High sensitivity
- Wide spectral response
- High signal to noise ratio

Applications
- Biomedical analysis
- Environmental monitoring
- Spectroscopy

Specifications
- High quantum efficiency:
  - At 600 nm 20% (typ)
  - At 780 nm 10% (typ)
- Luminous sensitivity: 650 µA/Im (typ)
- Radiant sensitivity:
  - At 600 nm: 97 mA/W (typ)
  - At 780 nm: 63 mA/W (typ)
- Wide spectral response: 185 nm to 900 nm
- High gain: $1.3 \times 10^7$
- High signal to noise ratio
Photosensor Modules
H10425, H10426

Module integrating Head-on PMT with high-voltage power supply circuit

Hamamatsu Photonics has developed new PMT modules to meet market demand for cost effective detectors for low light level applications, in applications such as luminescence measurements, fluorescence measurements and astronomy.

The H10425 and H10426 integrates a 25mm (1") or a 28mm (1 – 1/8") head-on PMT with high-voltage power supply circuit, offering large effective photocathode area of 22mm or 25mm diameter together with high speed response.

They both are indicated for applications into visible range, are easy operated with input Voltage from +11.5V to 15.5V and offer sensitivity adjustment range of 1:1000 by easy methods as reported in here following scheme.

Hamamatsu Photonics also offers a wide line up of modules adaptable to various kind of applications and measurements, with various characteristics and shapes, analog or digital outputs, CPU and interfaces for control and data transfer with computers and gating function too.

For a complete description of our range of modules please refer to our Photomultiplier Tube Modules catalogue available also in our website.

Author: Roberto Calcaterra, Hamamatsu Photonics Italy

<table>
<thead>
<tr>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>22mm diameter effective photocathode area (H10425)</td>
</tr>
<tr>
<td>25mm diameter effective photocathode area (H10426)</td>
</tr>
<tr>
<td>Fast time response (Rise time 1.5ns Typ. H10425)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminescence measurements</td>
</tr>
<tr>
<td>Astronomy</td>
</tr>
<tr>
<td>Fluorescence measurements</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral response from 300nm to 650nm</td>
</tr>
<tr>
<td>Peak sensitivity wavelength 420nm</td>
</tr>
</tbody>
</table>

Sensitivity Adjustment Method

Voltage Programming

POWER SUPPLY

+15 V
GND

SIGNAL OUTPUT
LOW VOLTAGE INPUT (RED)
GND (BLACK)
Vref OUTPUT (BLUE)
Vcont INPUT (WHITE)

Control Voltage

- Electrically insulate the reference voltage output.
- Adjust the control voltage to adjust the sensitivity.

Resistance Programming

MONITOR
POTENTIOMETER (10 kΩ)

When using a potentiometer, adjust sensitivity while monitoring the control voltage.
75W Xenon Lamp Series
L10725/-01, L10726/-01

It has been a long time now since Hamamatsu Photonics first released the Super Quiet Xenon lamps integrated in different types of instruments. For some specific applications like semiconductor inspection, life time is an important criteria to be considered because such instrument is constantly working on a 24 hours’ basis.

Hamamatsu Photonics use new anode and cathode design that provides a guaranteed long service life, two times longer than previous models.

Author: Lorraine Roland, Hamamatsu Photonics France

Features
- Long Life
  - Guaranteed life: 2000 h
  - Average life: 3000 h
- High Stability
- Point light Source

Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>L10725</th>
<th>L10725-01</th>
<th>L10726</th>
<th>L10726-01</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window Material</td>
<td>Fused Silica (185 nm to 2000 nm)</td>
<td>Ozone-free Silica (240 nm to 2000 nm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamp Rating</td>
<td>Approx. 75 W</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arc Length</td>
<td>1.0 mm +/- 0.1mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamp Current</td>
<td>5.7 A +/- 0.3 A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamp Voltage</td>
<td>Approx. 13.5 V</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Light Output Stability         | Fluctuation: 1.0 % p-p (Max)  
                                  | Drift: +/- 0.5 % (Typ) |
| Operating Guaranteed life      | 2000 h |
| Average Life                   | 3000 h |
| Orientation                    | Vertical +/- 15 degree or horizontal +/- 15 degree |
| Cooling Method                 | Converging Cooling |
| Anode Metal Base Diameter      | dia 9 mm |
| Cathode Metal Base Diameter    | dia 9 mm  
                                | dia 7.5 mm |
| Weight                         | Approx. 15 g |

Applications
- Semiconductor Inspection
- Equipment Light Source
- Scanner Light Sources
- Microscope Light Sources

Spectral Distribution (Typical Data)
The new C10880-03 intensifier unit has been specifically designed for applications where the light signal intensity for a high speed CMOS camera is too low or where short gating times are required when acquiring high speed image sequences.

The unit can be easily mounted in front of most high speed cameras by standard C- or F-mount.

When combining an intensifier to a high speed camera, it becomes important to assure that the light intensity of the intensifier output is strong enough to produce an image with good dynamic range on the CMOS camera side. This requires a special stacked image intensifier configuration as realized in the C10880-03, consisting of a high speed gateable image intensifier with an image booster type intensifier.

The C10880-03 can be either operated by manual operation or by remote control from a PC. On the input side the standard unit has a multialkali photocathode, on request other photocathodes (e.g. with GaAsP photocathode) can be provided.

Author: Hubert Ortner, Hamamatsu Photonics Germany

Features
- High speed gating up to 10 ns gating time
- High luminous gain

Applications
- High speed imaging under low light level conditions
- LIF-laser induced fluorescence applications

Specifications
- Photocathode: Multialkali
- Spectral range: 185 to 900 nm
- Gating time: DC, 10 ms – 10 ns
- Resolution: 38 lp/mm
- Input side diameter: 24 mm
- Output side diameter: 16 mm
Compact power supply and signal processing circuit for UV tron detectors.

Hamamatsu Photonics has developed a new improved driver circuit to our UV-tron detectors, which match our goal of high performance. Using this new C10423 circuit together with UV TRON R9454 it's possible to detect a small 25 mm flame from a cigarette lighter up to a distance of 5 m. The supply voltage is 12 to 24 V DC. The circuit also has an integrated background subtraction which cancel discharges from cosmic rays, solar UV, etc, that otherwise would have been detected as noise. The size is only half of the previous driving circuit C3704-series, by using a double-sided printed circuit board.

Author: Jan Eriksson, Hamamatsu Photonics Norden

Applications
- Fire alarms
- Flame detector for gas and oil lighters
- Combustion monitors for burners
- Electric spark detector

Features
- Compact size due to double-sided PCB (printed circuit board)
- Background subtraction built in circuit (cosmic rays, solar UV, etc)
- Low current consumption, max 4 mA
- High-sensitivity for UV when used with R9454 (UV tron)
- Low DC voltage supply

Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description/Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV TRON Supply Voltage</td>
<td>400 V</td>
</tr>
<tr>
<td>Quenching Time</td>
<td>Approx. 25 ms</td>
</tr>
<tr>
<td>Operating ambient temperature</td>
<td>-10 to +50 °C</td>
</tr>
<tr>
<td>Input Voltage (DC)</td>
<td>12 - 24 V</td>
</tr>
<tr>
<td>Current consumption</td>
<td>4 mA</td>
</tr>
<tr>
<td>Weight</td>
<td>Approx. 12 g</td>
</tr>
<tr>
<td>Suitable UV TRON</td>
<td>R9454</td>
</tr>
</tbody>
</table>
Overview

The C10066 Immunochromato-Reader makes rapid, high-sensitivity, quantitative measurements of color intensities for immunochromatography reagent kit. Since measurement data is saved as a CSV file, it can be analyzed on commercially available spreadsheet software, and calibration curve and time-course graphs then easily drawn. The C10066 Immunochromato-Reader is an optimal tool for R&D work as well as quality control of immunochromatography reagent kits.

Author: Oliver Roesler, Hamamatsu Photonics Germany

Features

- High-sensitivity measurement with high repeatability
- Compatible with different reagent housing configurations
- Color sample provided to check the C10066 main unit makes daily and periodic inspections easy.
- Automatic color line position detection and color intensity calculation (mABS)
- Calibration curve function can be calculated
- Lot measurement and time-course measurement modes selectable

Applications

- Immunochromatography Reagent
  - Development
  - Quality control

Specifications

- Input Voltage (AC): 100 to 240 V
- Power Consumption: Max. 3 VA
- Interface: USB 2.0 (cable supplied) or RS-232C (dedicated cable optional)
- Light Source: Green LED
- Light Detection: Silicon photodiode
- Measurement Object: Colloidal gold color line
- Dimensions (W x H x D): 215 x 92 x 235mm (excluding projecting parts)
- Weight: Approx. 1.6 kg
Advanced electrostatic remover

The L9490 is a safe and clean electrostatic removal unit that can be used on a large variety of manufacturing lines, including those for electronic components, lightweight plastic components, film, large glass, and powdered products. Soft X-rays are emitted by the L9490 to produce ions over the entire volume exposed. The ions produced near the surface neutralize the electrostatic build-up within charged objects.

The high ion density achieved over the entire area of exposure allows a faster and more effective removal of electrostatic charge than with a corona discharge method. Other problems of the corona discharge method – such as air flow, ozone generation, unbalanced ion production, dust particles and electromagnetic noise – are also avoided.

The L9490 has two main components: a compact source head (soft X-ray emitter) and a controller unit. A new controller unit, the C9991, can operate 4-photoionizer heads in parallel which can be convenient for customer who wants to make synchronisation on the manufacturing lines.

Author: Xavier Drouet, Hamamatsu Photonics France

Features
- High ion density
- No ozone generation
- No air flow
- Balance null
- No dust particles and electromagnetic noise generation.

Applications
- High speed moving objects (films, printed matters, etc.)
- Packing of powdered products
- Large size glass
- IC/LCD/PDP screen process lines
- PCB mounting, chip mounter

Specifications (L9490)
- Soft X-rays (3 to 9.5keV)
- Compact: 30 mm x 50 mm x 96 mm (Head)
- Worldwide compatible power supply: accepts 100V to 240V AC.
- CE marking compliance
- Simple soft X-ray shielding required during operation
High Time Resolution TOF-MS Detector

Beside the channel diameter, the flatness of microchannelplate detectors contributes to better time resolution in time of flight mass spectrometry. As warping effect is considered to be predominant, Hamamatsu Photonics focuses on reducing warp influence.

Thus, the F9892-21 and -22 show a typical time response of only 0.9ns FWHM.

Compared to other MCP assemblies of F9892 series with similar diameter, the typical time response is 1.2ns. This means a reduction of 25% while keeping the same small negligible ringing of 3% typ and small dark count rate of 3s-1cm-2 maximum.

Although the effective area diameter is 42 mm, flatness is in the range of +/– 10µm typically.

This excellent flatness is achieved by applying selected materials and a sophisticated manufacturing process.

Both, F9892-21 and -21 are suitable for high voltage floating operation at 10kV MCP-IN.

Author: Siegfried Schmidt, Hamamatsu Photonics Germany

Features
- Very high-speed gating time down to 250 ps
- DIC mode for capturing 2 consecutive images with 300 ns interval
- Captures 12-bit digital images with low noise
- High sensitivity with quantum efficience of 50%

Applications
- Visualisation of discharge and plasma phenomena
- Observation of fuel spray and combustionstate in engine
- Time-resolved measurement of OH-radicals in combustion engines
- Study of laser ablation
- Observation of shock waves

Specifications
- Spectral response from 185 nm to 850 nm with multiakali photocathode
- Spectral response from 360 nm to 920 nm with GaAs photocathode
- Resolution: up to 64 lp/mm
- DIC (dual image capture) interval: 300 ns with 10 ns gate time
- Minimum gate time: 250 ps
- Maximum repetition rate: 200 kHz
The high resolution Back-Illuminated EM-CCD camera

Hamamatsu Photonics has launched the new ImagEM 1K digital EM-CCD camera. It extends our product line of ImagEM electron multiplier CCD cameras with back illuminated CCD by a high resolution type. Its basic concept and feature layout is similar to the world leading EM-CCD camera ImagEM enhanced. The main difference is the large size detector with 1024 by 1024 pixel and a pixel size of 13 x 13 µm.

The ImagEM 1K has multiple operation modes which allow to adapt the camera to a great variety of low light level applications in scientific and industrial applications.

It can operate in a conventional CCD mode where the electron multiplying function is switched off. In EM mode the camera can work with 3 different frame rates, at a maximum of 9.5 frames per second at full resolution. By binning and subarray readout the frame rate can go up to 200 Hz and higher.

The ImagEM 1K is enclosed in a hermetic vacuum-sealed head and reaches temperatures down to -80°C. The maximum EM gain is 1200 x.

Digitisation is carried out by the 16 bit A-D converter, and image enhancement is possible using analogue gain and offset controls.

ImagEM 1K and ImagEM enhanced are optimized for long time operation for quantitative image analysis. This required Hamamatsu Photonics to develop a highly stabilized cooling circuitry, as EM-gain is strongly depending on sensor chip temperature. Additionally an automated gain calibration mode has been developed and implemented which compensates the gain degradation which happens by using EM CCD over longer operation periods. By these means a user can assure to have stable operation conditions for repeated measurements.

The ImagEM camera series is the camera of choice for a range of applications, such as fluorescence microscopy, where high sensitivity and high frame rate and resolution are essential.

Author: Hubert Ortner, Hamamatsu Photonics Germany

Features
- High sensitivity back-illuminated EM-CCD
- 1 megapixel
- High frame rate
- 16 bit data output
- High dynamic range
- High stability

Applications
- Fluorescence microscopy
- Ratio imaging
- TIRF Microscopy
- Semiconductor and solar cell inspection

Specifications
- Resolution: 1024 x 1024 pixel
- Detector cooling: -80°C, stabilized
- Frame Rate: 9.5 Hz in fast scan mode, full resolution
- A/D converter: 16 bit data output

Web-address for further information www.imagemccd.com

Spectral Response

This sample is typical of the CCD characteristics, not guaranteed.
Electro- and photoluminescence analysis

Recently electro- and photoluminescence analysis on solar cells and solar panels has proven to be a powerful method for device characterization and device quality analysis.

In electroluminescence analysis the cell or panel is typically driven by a forward biased current and a camera detects the recombination radiation which is then emitted from the device. For some studies the DUT can also be operated in reverse biased mode. In photoluminescence analysis the cell is illuminated by light and then again the recombination radiation is detected by a sensitive camera.

While electroluminescence requires a fully (electrically) operating device, the photoluminescence analysis can be done on a still uncompleted device, as no electrical connection is required.

In case of Si-based solar cells the recombination radiation is typically emitted in a small spectral band with a maximum at 1100 nm. This requires to use cameras with a high sensitivity in the near IR range. The emission intensity in a photoluminescence set-up is typically low when compared to an electroluminescence set-up. Therefore photoluminescence requires highly sensitive cameras while electroluminescence can be detected with moderately sensitive cameras.

The analysis can be used for device characterization, e.g. for carrier lifetime analysis or serial resistance analysis. But it can also be used for a broad range of quality analysis tasks, e.g. delamination can be easily detected by electroluminescence, shunts and opens can be seen, microcracks can be detected. Electroluminescence is already successfully used for routine quality inspection tasks in cell and module production lines.
Hamamatsu Photonics offers a broad line of cameras suitable for electro- and photoluminescence detection. Depending on the required camera sensitivity the user can choose between following main models (listed from low to high sensitivity order):

**Economy models**
C8484-03 cooled CCD camera with -10°C chip temperature, CCD with 1344 x 1024 pixel, IR enhanced, Hamamatsu Photonics proprietary type ER150 CCD sensor, IEEE1384A (FireWire) interface.

C8800-21 cooled CCD with -20°C chip temperature, CCD with 1024 x 1024 pixel, high IR sensitive CCD, CameraLink interface

**Medium range models**
ORCA-R2 cooled CCD with -35°C chip temperature, CCD with 1344 x 1024 pixel, IR enhanced, Hamamatsu Photonics proprietary type ER150 CCD sensor, IEEE1384B (FireWire) interface.

C9100-02 electron multiplier CCD with 1024 x 1024 pixel, front-illuminated CCD, CameraLink interface.

**High-end models**
ImagEM electron multiplier CCD cameras with back-illuminated EM-CCD, two versions are offered with 512 x 512 or 1024 x 1024 pixel, CameraLink interface.

The cameras are designed for industrial environments and are known for their high reliability and stability. This ensures that the cameras can be used for highly quantitative image analysis tasks for off-line and in-line applications.

**Author:** Hubert Ortner, Hamamatsu Photonics Germany
C10633 Near Infrared Camera

The new C10633 Near Infrared Camera uses an InGaAs-CCD sensor with a spectral sensitivity from 900nm to 1700nm. The excellent quantum efficiency of more than 80% at 1500nm leads to superior imaging quality for applications such as infrared reflectometry with paintings and art works or moisture imaging of food or buildings surfaces. This very high quantum efficiency is approximately 8 times higher than of the well known IR-vidicon cameras at 1500 nm. and opens many new applications at low light levels. The perfect linearity of the camera enables precise quantitative intensity measurements and beam analysis for 1550nm laser sources or single mode fibre optics.

Also for IR illuminated night vision applications this new camera is the perfect solution. The camera has a standard video output signal and an USB 2.0 connection for an easy link with a computer with 14bit image resolution. Via the USB interface the exposure time is controllable from 100µs to 15ms. The camera can also be used for Si-wafer analysis and for Solar-cell evaluation in the photo voltaic industry. The small and compact size, lightweight and robust design allows applications in rough industrial environments which requires a maximum of durability and reliability without any limitation of scientific and high performance expectations.

Author: Bertram Lohmüller, Hamamatsu Photonics Germany

Features
- Very good sensitivity between 900nm and 1700nm
- Standard video output (EIA 60Hz or CCIR 50Hz)
- Small size and light weight
- Simple operation and robust design

Specifications
- Resolution: 320(H) x 256(V) pixels
- Pixel pitch: 30µm
- USB 2.0 interface
- Exposure time between 100µs and 15ms (controllable via USB)
- Universal external power supply for 100V - 240V AC

Applications
- Si-wafer internal inspection
- Solar Cell evaluation
- IR-reflectography
- Optical moisture measurements
- Night vision
- Quantitative intensity measurements and beam profiling

C10633 InGaAs-Camera spectral response comparison between IR-Vidicon camera (C2741-03), normal CCD camera and InGaAs-Camera

C10633 InGaAs-Camera linearity curve

C10633 InGaAs-Camera measurement example, beam profile of single mode fibre output at 1550nm
Cooled CCD Camera
ORCA-R²

All at once: High sensitivity + high speed + high dynamic range

Hamamatsu Photonics has launched the new ORCA-R² “Rapid Readout” digital CCD camera. Building on the success of the established, market-leading ORCA AG and based on the same exclusive ER-150 progressive scan interline 1344 x 1024 pixel CCD, the new ORCA-R² is designed to maintain Hamamatsu’s competitive edge for demanding, non-EM CCD applications in the visible to NIR.

The ORCA-R² has two scan speeds; a normal scan speed of 14 MHz and a rapid scan speed of 28 MHz which deliver full resolution 1.37 M pixel images at 8.5 frames/second and 16.2 frames/second respectively. With binning, the ORCA-R² has a maximum frame rate of 64.3 frames/second. Data output is via Firewire IEEE 1394b.

The ER-150 CCD is enclosed in a hermetic vacuum-sealed head, the same as the previous ORCA-AG, but air-cooling has been improved to -35°C and the ORCA-R² also comes with water-cooling connections as standard, for operation at -40°C for applications where low-level signals mean a tighter control of thermal noise is required.

Digitisation can be carried out in either 12 or 16 bit A-D converters, and image enhancement is possible using analogue gain and offset controls.

All this improved ORCA-R² performance has been squeezed into the familiar ORCA-AG camera head size, including an extended range of programmable trigger signal (edge, level, start, synchronous, cyclic) output options.

The ORCA-R² is the camera of choice for a range of applications, such as fluorescence microscopy, where a balance of speed, sensitivity and resolution are essential.

Author: Hubert Ortner, Hamamatsu Photonics Germany

Features
- Proprietary high sensitivity, 1.3 megapixel low noise CCD sensor
- Up to 16 frames per second frame rate at full resolution
- Air Cooling to -35°C
- 16 bit data output
- High dynamic range mode

Applications
- Fluorescence microscopy
- Live cells expressing GFP
- Ratio imaging
- TIRF Microscopy
- Semiconductor and solar cell inspection

Specifications
- Resolution: 1344 x 1024 pixel
- Detector cooling: -35°C (optional -40°C)
- Frame Rate: 16.2 Hz in fast scan mode, full resolution
- A/D converter: 16 bit data output
- Interface: IEEE1394 B

Spectral Response

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Quantum efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>400</td>
<td>10</td>
</tr>
<tr>
<td>500</td>
<td>20</td>
</tr>
<tr>
<td>600</td>
<td>30</td>
</tr>
<tr>
<td>700</td>
<td>40</td>
</tr>
<tr>
<td>800</td>
<td>50</td>
</tr>
<tr>
<td>900</td>
<td>60</td>
</tr>
<tr>
<td>1000</td>
<td>70</td>
</tr>
<tr>
<td>1100</td>
<td>80</td>
</tr>
</tbody>
</table>

This sample is typical to the CCD characteristics, not guaranteed.
Hamamatsu Photonics introduce the C9300-221, a high-speed VGA-format digital camera aimed at the life-science microscopy/bio-imaging market. Providing frame rates up to 150 Hz with full resolution, or 694 Hz with 8 x 8 binning, the C9300-221 enables imaging of fast events with sensitivity across the blue to NIR spectrum with the 12-bit digital output via a standard CameraLink interface.

The camera’s electronic shutter feature allows for acquisitions as short as 33 micro-seconds. Peak Quantum Efficiency approaching 60% and low dark noise from the forced-air cooling means that even low intensity signals can be imaged with good temporal resolution.

Coupling to microscopes can be made with the standard camera C-mount or optionally the camera can be supplied with F-mount. Excellent spatial resolution is delivered by the CCD’s 7.4 micron x 7.4 micron pixels with a dynamic range of 1000:1. The camera is ideally suited to several application areas including IR-DIC, Calcium ion imaging, fluorescent imaging and membrane potential measurement.

Author: James Owens, Hamamatsu Photonics UK

**Features**
- High speed, up to 150 f/s full resolution
- Wide sensitivity range from Blue to NIR
- Peltier cooled for low dark noise
- 12 bit digital output via CameraLink

**Applications**
- IR-DIC imaging
- Calcium ion imaging
  (Fluorescent probe: Fura-2, Fluo-2, Indo-1)
- Bright fluorescent imaging
- Membrane potential measurement
  (Di-8-ANEPPS, DiBAC4)

**Specifications**
- High resolution of 640 x 480 pixels
- High frame rate of 150 Hz at full resolution
- Low readout noise of 20 electrons (r.m.s.)
- Large fullwell capacity of 20,000 electrons
- Wide spectral sensitivity from blue to NIR
- Low dark current due to peltier cooling
- Fast repetition readout mode for PIV
The Optical NanoGauge is a non-contact film measurement system, capable of quick, accurate measurements of films up to 50 µm thick.

This flexible system is compatible with both stand-alone operation (Macro measurement) and as part of a microscope setup (Micro measurement), meaning it has applications across a wide range of diverse industries such as MEMS inspection, real-time in-line thickness checking on film production lines and flat panel display quality control.

Multi-layer films (up to a maximum of 10 layers) can also be quickly measured, which allows for more complex semiconductor wafer film analysis to be carried out. A near infra-red option (up to 1650 nm) will cope with samples that absorb illumination in the visible range.

There are 5 versions of the NanoGauge available, each with a configuration designed to meet a particular need. So whether you want to take a macro or micro view, real-time or snap-shot, and using UV, Visible or Near Infra-Red illumination there is an Optical NanoGauge model that will provide you with the reliable data you require.

Author: James Owens, Hamamatsu Photonics UK

Features
- Rapid and precise results via proprietary analysis algorithms.
- Real-time results
- Remote communication and data transfer with external devices
- High resolution and high stability
- Mapping function

Applications
- Semiconductor thin film
- Flat panel display
- In-line film production
- MEMS

Specifications
- 200nm - 1650 nm measurement sensitivity
- 20nm - 50 microns
- Measurable layer: up to 10
- Software algorithm: FFT analysis
- External communication: RS-232C
Introducing the new FDSS7000 modular and versatile imaging based plate reader from Hamamatsu Photonics, the optimum tool for assay development and high throughput screening.

The versatility of the new FDSS7000 can be seen in features such as the new 1536 dispensing head, and the ability to run both fluorescent and flash luminescent assays in the same instrument. It can also run protocols for assay development and High Throughput Screening.

The FDSS7000 incorporates a set of xenon light sources and filter sets. This is a key benefit for assay development as this allows flexibility on selection of excitation wavelengths. This therefore allows the user to easily develop novel assays and perform HTS with a large variety of dyes such as Fluo-3/4, Fura-2, FRET (VSP).

For optimum performance, the FDSS7000 includes two separate Hamamatsu Photonics detectors, a cooled CCD camera for fluorescence and a photon-counting camera for luminescence. The detectors are optimized to give the best performance for fluorescent applications such as intra-cellular calcium measurements and luminescence applications such as Aequorin.

Also featuring a new sensor, which provides 20 x increased detection sensitivity at 700nm, ideal for weak luminescence applications.

The system has two dispensing heads that can operate independently, to allow the user to perform contamination free agonist/antagonist assays.

The FDSS7000 can achieve throughput as fast as 52 seconds, making it ideal for integration into a robotic platform for large-scale HTS applications.

The new FDSS7000 is the ideal solution for all your screening needs.

Author: Marc Pontoizeau, Hamamatsu Photonics France

Applications
- GPCR assays
- Calcium assays (Fluo 4 and Fura 2)
- Any other ion assays
- FRET, membrane potential assays
- Aequorin flash luminescence assays

Features
- Full 1536 dispensing capabilities
- 1536, 384, 96 compatible
- Superior throughput — as fast as 52 seconds
- Low total cost of ownership
- Dual dispensing head for fast, easy, and no cross contamination agonist/antagonist assays
- Large capacity cell loading for aequorin assays
- Up to 3 washing unit with ultrasonic tips cleaning
- Walkaway stand alone system with 50 plate stackers
- Two optimized cameras: photon counting for luminescence, and deep cooling, high Drange for fluorescence
- Automatic tips mounting
- Robotics compatible

Specifications
- CV % is less than 10 % with 3 µL in 1536 format.
- CV % is less than 5 % with 5 µL in 384
- From 360nm to 720nm in fluorescence and luminescence mode
- Dual dispensing head installed
- Up to 3 washing unit with ultrasonic tips cleaning
- Robotics access or 50 plate stackers
- Throughput as fast as 52 seconds
- Minimum sampling interval is 1 second (up to 9 frame/sec)
A new member enters the NanoZoomer family

The NanoZoomer family of digital slide scanners converts whole pathology slides into digital (virtual) slides fully automatically with high resolution and color fidelity suitable for diagnostic purposes. In contrast to an image taken with a common microscope the magnification of virtual whole slides images (WSI) can be changed while viewing. In addition to this using the z-stack function of the NanoZoomer traveling through the planes similar to focusing a real microscope is possible.

The new NanoZoomer-RS is Hamamatsu Photonics new product approaching the digital pathology field. It features a slide tray for up to 6 standard slides or 2 double sized slides. Whole slides images can now be taken at 10 x, 20 x and 40 x resolution. Utilizing the same advanced TDI sensor technology that is well established with our high-throughput scanning system – the NanoZoomer HT – the RS model achieves the same very high scanning speed and superb image quality with a standard resolution of better than 0.5 µm per pixel with a scanning time of approximately 3 minutes per slide. These virtual slides are stored in local databases with the ability to view, share and manipulate images through PCs on a network or intranet environment or via the internet.

Our new NanoZoomer-RS opens now due to its lower cost the possibility for laboratories with no need for an expensive high throughput scanner to digitize a lower number of cases at the same speed and quality as the HT system, share them with colleagues and show them on conferences. The whole NanoZoomer family can be also used for fluorescent measurements by adding the fluorescence option.

Furthermore Hamamatsu Photonics offers through various cooperation partners software tools for teleconferencing, webinars, TMA and analysis, students education, etc.

Author: Dr. Erk Mennega-Klopp, Hamamatsu Photonics Germany

Features
- High resolution: 0.46 µm and 0.23 µm per pixel as standard, 0.92 µm optional
- High speed scanning by our unique CCD TDI technology: 20 mm x 20 mm in 3 minutes (0.46 µm/pixel resolution)
- Slide formats: either 6 standard slides (25 mm x 52 mm) or 2 double sized slides (50 mm x 52 mm)
- Z-stack scanning
- Barcode reader
- Fluorescence scanning optional
- Ability to view, share and manipulate images through intranet or via internet
- Easy setup and handling.

Applications
- Clinical
  - Telepathology
  - Consultation and Revision
- Research and Education
  - Tissue Banking
  - Teaching and Examination of students
- Drug Discovery
  - Protein Expression analysis in tissues
  - Toxicity assessment
Hamamatsu Photonics and University Heidelberg inaugurate the Hamamatsu TIGA Center for Tissue Imaging and Analysis

Optical technologies enable fundamental insights into biomedical processes and are essential in diagnostics and biomedical research. In collaboration with the Japanese company Hamamatsu Photonics therefore the Hamamatsu Photonics Tissue Imaging and Analysis (TIGA) Center was inaugurated at the University Heidelberg. The TIGA Center is a joint initiative of the Institute of Pathology and the Institute of Medical Informatics and Biometry at the University Hospital Heidelberg. Thereby, both institutes contribute their complementary competencies of pathology and medical informatics. Technical basis of the TIGA Center is the fully automatic microscopy of tissue sections by the “NanoZoomer” imaging robot of Hamamatsu Photonics. TIGA is part of the BIOQUANT, the newly established research center at the University Heidelberg that focus on the quantitative analysis of molecular and cellular biological systems and enables its research partners for the first time the fully automatic evaluation of full tissue slides. This allows novel insights into the pathogenesis of complex diseases like cancer. TIGA Center especially focuses on biomedical applications in pathology.

“The NanoZoomer provided by Hamamatsu Photonics represents a unique technology, which will be of fundamental importance for the pathology of the future” states Dr. Niels Grabe, scientific head of the TIGA Center. Already 1858 Rudolf Virchow, German Medical Doctor and politician, published his renowned work "Cellularpathologie". Thereby, he introduced the microscopic analysis of tissue sections: the histopathology. 150 years after Virchow, histopathology, which is the basis of many diagnostic and therapeutic decisions, is now on the edge of a new era: the fully automatic microscopy of tissue sections by high resolution imaging systems. The computer assisted or fully automatic diagnosis of diseases is now coming in sight which potentially will lead to fundamental changes in pathology.

For Hamamatsu Photonics, novel markets are on the horizon. “We have invested several years in developing the NanoZoomer. Therefore, we are eager to develop new clinical and research applications and together with our two scientific collaboration partners, the Institute of Medical Biometry and Informatics and the Institute of Pathology,” says Hideo Hiruma, Managing Director of Hamamatsu Photonics, Japan. As the NanoZoomer is generating enormous amounts of image data, which have to be evaluated automatically and with high accuracy, this will be especially a challenging computational task. Being an interdisciplinary initiative of Pathology and Medical Informatics and ideally located in BIOQUANT, TIGA Center is in an excellent starting position for addressing the upcoming challenges.

Image shows a microscopically scanned section through human gingival tissue in a fluorescent three color stain. Red shows collagen in the connective tissue, green shows the protein desmoplakin in the individual cell walls while blue stains the DNA in cell nuclei.

© Hamamatsu TIGA Center Universität Heidelberg.
The new models of the exceptional Hamamatsu Photonics TDI-cameras series uses high resolution back-thinned CCD sensors with a resolution of 4096 x 128 pixels. The 8-tap model C10000-601 gives a maximum TDI line rate of 50kHz, the 16-tap model C10000-701 gives a maximum line rate of 100kHz. Due to the very high quantum efficiency of more than 90% in the visible range and the large sensitivity range from UV to NIR, many new applications are possible particular if high speed detection at low light level is required.

The high dynamic range of 1:1000 can be A/D-converted with 12bit or for faster measurements with 8bit resolution. The camera communicates via a standard CameraLink-interface with a computer and incorporates a DSP circuit for fast and reliable image improvements such as real-time shading correction and background subtraction. The analog enhancement gain can be controlled in 16 steps from 1 to 5 times. The new camera models have a compact and light weight design and a robust slim housing and ideally suitable for industrial applications such as high speed inspection on conveyor belts or rotating cylinders for electronics or semiconductor industry and for life science applications in the bio-med field.

**Author:** Bertram Lohmüller, Hamamatsu Photonics Germany

**Features**
- High resolution and high sensitivity, 4096 x 128 pixels with back-thinned CCD
- High speed, line rate up to 100kHz
- Great spectral response from UV-NIR
- 100% Fill factor
- Bi-directional scanning operation
- Frame readout mode for focusing
- DSP for real-time shading correction and background subtraction

**Specifications**
- CCD cell size: 49.16mm(H) x 1.536mm(V)
- Pixel size: 12µm x 12µm
- Dynamic range: 1000:1, A/D conversion 8bit or 12bit
- Binning: 1 x 1 or 2 x 2
- CameraLink-interface
- Lens mount: M72, P=0.75

**Applications**
- High speed imaging for low light applications
- Semiconductor inspection
- Electronics manufacturing and inspection
- Fluorescence and luminescence imaging
- High speed scanning for large size samples i.e. flat panel displays
- Film digitalization

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Quantum efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>400</td>
<td>90</td>
</tr>
<tr>
<td>600</td>
<td>80</td>
</tr>
<tr>
<td>800</td>
<td>70</td>
</tr>
<tr>
<td>1000</td>
<td>60</td>
</tr>
<tr>
<td>1200</td>
<td>50</td>
</tr>
</tbody>
</table>

**TDI (Time Delay Integration):**
Time Delay Integration is a method of scanning in which a frame transfer device produces a continuous video image of a moving object by means of a stack of linear arrays aligned with and synchronized to the movement of the object to be imaged in such a way that, as the image moves from one line to the next, the integrated charge moves along with it, providing higher resolution at lower light levels than is possible with a line-scan camera.
Hamamatsu Photonics is allowed to send information about their products to this E-mail address, until further notice from the addressee. Hamamatsu Photonics will not supply this information to third parties.

☐ My address has changed. Please send me the Hamamatsu Photonics News regularly at the address above.

☐ The present addressee of the Hamamatsu Photonics News is no longer interested in this magazine. Please send the Hamamatsu News in future to the address above.

☐ I want to receive the Hamamatsu Photonics News regularly. Please add me to your distribution list.

☐ Please do not send me Hamamatsu Photonics News in the future.

I am interested in the following products, which are described in the Hamamatsu Photonics News 2008 Vol. 2:

Solid State Products: ☐ 06 ☐ 07 ☐ 08 ☐ 09 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 16 ☐ 21

CRL Products: ☐ 22

Electron Tube Products: ☐ 23 ☐ 24 ☐ 26 ☐ 27 ☐ 28 ☐ 29 ☐ 30 ☐ 31 ☐ 32 ☐ 33

Systems Products: ☐ 34 ☐ 35 ☐ 36 ☐ 37 ☐ 38 ☐ 39 ☐ 40 ☐ 41 ☐ 42 ☐ 44

☐ Please contact me.

☐ I am searching for a solution for the following application:
Exhibitions 2008/09

May 2009
26.05. - 28.05.09
Sensor und Test (Nuremberg / Germany)
www.sensor-test.com

June 2009
15.06. - 18.06.09
Laser 2009 (Munich / Germany)
www.laser.de
04.06. - 07.06.09
93. Jahrestagung der dt. Gesellschaft für Pathologie (Freiburg / Germany)

September 2009
01.09. - 04.09.09
Ineltec/go 2009 (Basel / Switzerland)
28.09. - 30.09.09
Biomedical Science Congress (Birmingham / UK)
www.ibms.org

October 2009
09.10. - 12.10.09
50th Annual Meeting of the European Society for Paediatric Research (Hamburg / Germany)
15.10. - 16.10.09
Photonex (Coventry / UK)
www.photonex.org

November 2009
03.11. - 05.11.09
Vision (Stuttgart / Germany)
www.vision-messe.de
10.11. - 13.11.09
Productronica (Munich / Germany)
www.global-electronics.net

Exhibitions

Sensor und Test
(Nuremberg / Germany)
May 2009
26.05. - 28.05.09
www.sensor-test.com

Laser 2009
(Munich / Germany)
June 2009
15.06. - 18.06.09
www.laser.de
04.06. - 07.06.09
93. Jahrestagung der dt. Gesellschaft für Pathologie (Freiburg / Germany)

Ineltec/go 2009
(Basel / Switzerland)
September 2009
01.09. - 04.09.09
www.miptec.com
28.09. - 30.09.09
Biomedical Science Congress (Birmingham / UK)
www.ibms.org

Photonex (Coventry / UK)
October 2009
09.10. - 12.10.09
www.advancedmanufacturinguk.com
28.09. - 30.09.09
Photonex (Coventry / UK)
www.photonex.org

Vision (Stuttgart / Germany)
November 2009
03.11. - 05.11.09
www.vision-messe.de
10.11. - 13.11.09
Productronica (Munich / Germany)
www.global-electronics.net