ImagEM®

Electron Multiplying CCD Camera C9100-13, -14

Wide range of applications from
"Real time imaging of low light fluorescence" to "Ultra low light detection"

The ImagEM camera is a newly developed back-thinned electron multiplying CCD camera. This new generation camera incorporates the latest Hamamatsu engineering and technology to provide a high speed readout rate of 32 frames/s at full spatial resolution and 16 bit digitization. Features include maximum QE over 90 % and cooling performance down to –90 ˚C to minimize noise (C9100-13). The ImagEM includes two selectable readout modes for applications such as real time imaging of low light fluorescence and ultra low light luminescence detection.

New features (EM gain protection, EM gain readjustment and Direct EM gain control) significantly improve operational stability and functionality, especially with high gain imaging used for live cell fluorescence. Additional functionality and image improvements are now possible with real time image processing functions. Image processing that previously required software manipulation after readout can now be done in the camera itself at full frame rates.
A high resolution version of the ImagEM, the C9100-14, has been added to the product line-up.

HAMAMATSU

PHOTON IS OUR BUSINESS

ImagEM

APPLICATIONS and FEATURES

Hamamatsu's line-up of advanced Electron Multiplying CCD cameras

- **Choice of CCD formats to suit your application**
- **Shared advanced features and technology**

ImagEM Enhanced EM-CCD Camera C9100-13

- **High frame rate format with 512 x 512 pixels**
- **16 µm pixels suited for high dynamic range imaging**

NEW

ImagEM-1K EM-CCD Camera C9100-14

- **High resolution format with 1024 x 1024 pixels**
- **13 µm pixels suited for high N.A. imaging**

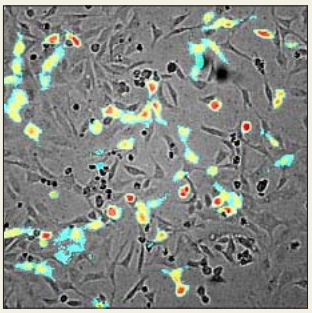
- **Back thinned FT CCD with greater than 90% QE for short exposure times**
- **Precise cooling with water or forced air for low noise and stable gain**
- **EM gain protection and warning features for long life and reliable service**
- **Both EM-CCD and Normal CCD readout for utmost versatility**
- **Multiple readout speeds in each mode to match frame rates to your application**
- **Optimized readout methods for minimum thermal and CIC noise in images**
- **Hermitically sealed vacuum head with lifetime warranty for stable cooling over a wide range of environmental conditions**

APPLICATIONS

- **Fast frame rates and short exposures of living cells with low excitation fluorescence**
- **Protein-protein interaction**
- **Calcium waves in cell networks and intracellular ion flux**
- **Real time spinning disk confocal microscopy**
- **Single molecule imaging with TIRF microscopy**
- **Fluorescence in-vivo blood cell microscopy**
- **Gene expression imaging using luminescence**

Sample of luminescence imaging (C9100-13)

Luminescence imaging of HeLa cells expressing Renilla Luciferase.

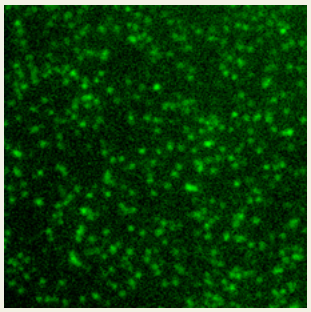


This image is displayed by overlapping luminescence image (pseudo color) and actual image.

- Objective lens: 10x
- Cooling method: Water cooling (-80 ˚C)
- EM gain: 200x
- Exposure time: 5 min

Sample of single molecule imaging (C9100-13)

Single fluorescent molecules in HeLa cells expressing H2B-GFP fusion protein.



- EM gain: 1200x
- Exposure time: 30.5 ms

Data courtesy of:

- Dr. Makio Tokunaga, National Institute of Genetics
- Dr. Kumiko Sogawa, RIKEN RCAI
- Dr. Hiroshi Kimura, HMRO Kyoto Univ. Faculty of Medicine

Wide range of applications from "Real time imaging of low light fluorescence" to "Ultra low light detection"

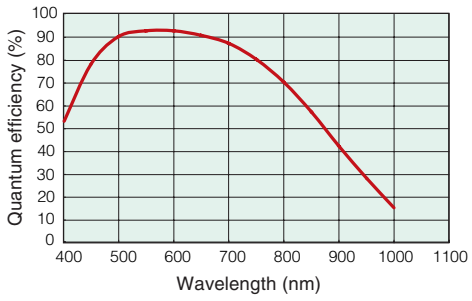
Benefits of ImagEM Cameras

High Sensitivity / *Short exposure and reduced light levels at the sample*

High quantum efficiency of over 90 %

This camera provides QE of over 90 %. It is suitable for visible to near infrared applications.

■ Spectral Response



★ This sample is typical of the CCD characteristics, not guaranteed.

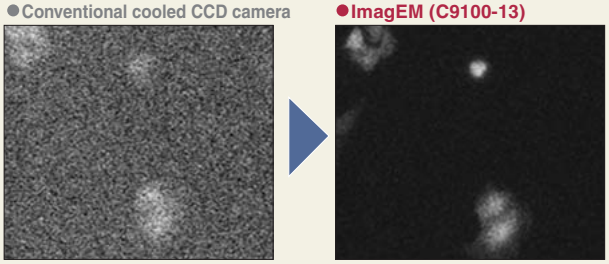
High EM gain of maximum 1200 x

Electron multiplying (EM) gain feature is ideal for live cell imaging because of shorter exposure times and reduced excitation light levels.

■ Comparison of sensitivity with conventional camera
(Exposure time: 30 seconds)

Luminescence imaging of HeLa cells expressing Renilla Luciferase.

● Conventional cooled CCD camera ● ImagEM (C9100-13)



(Water cooling, EM gain 1200x)

Low Noise / *Better detection of weak signals*

Highly stabilized control of CCD temperature with either water or forced-air cooling

Water or forced-air cooling is selectable for any application and optimal cooling temperature can be set in each cooling mode.

Minimal dark noise is another benefit of stable cooling performance

Cooling temperature of C9100-13 is -80 ℃ and C9100-14 is -70 ℃ (Water cooling, water temperature +20 ℃).
Superior cooling performance provides minimum dark noise.

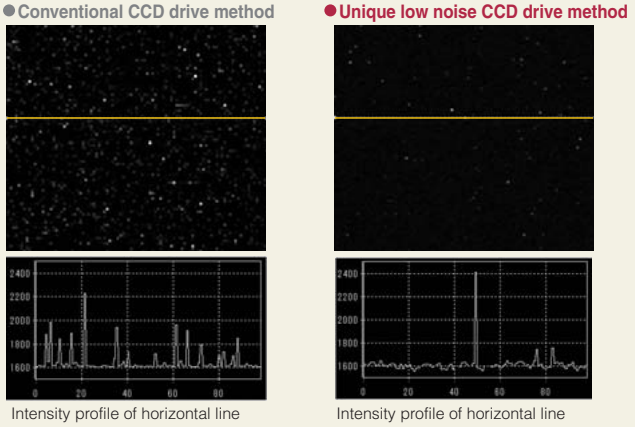
Optimized CCD drive methods significantly reduce the clock induced charge (CIC)

CIC is internally optimized for either fast readout or long term integration by the camera.

■ Comparison of noise (C9100-13)

Comparison of two clock induced charge images (EM gain: 1200 x, Exposure time: 30 ms, no light, enlarged 100 x 100 pixel region)

● Conventional CCD drive method ● Unique low noise CCD drive method



Intensity profile of horizontal line | Intensity profile of horizontal line

ImagEM FEATURES

Great Stability / *Accurate, Repeatable Images and Data*

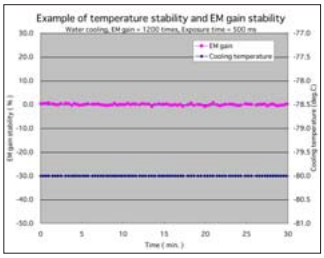
Highly stabilized EM gain by cooling temperature control

Maintaining stable cooling temperature is essential to stable gain settings required for superior performance in long duration imaging and analysis. Very precise control of the cooling temperature in the ImagEM Enhanced is a key benefit.

Examples of temperature stability and EM gain stability (C9100-13)

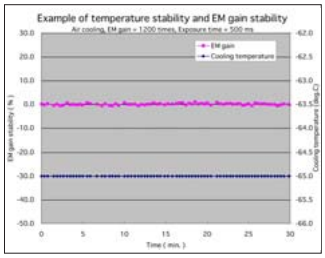
● Water cooled

- Temperature stability : ±0.01 ˚C
- EM gain stability : ±1 %
  - Cooling temperature : –80 ˚C
  - Water temperature : +20 ˚C
  (Operated with circulating water cooler)



● Forced-air cooled

- Temperature stability : ±0.03 ˚C
- EM gain stability : ±1 %
  - Cooling temperature : –65 ˚C
  - Room temperature : Stable at +20 ˚C

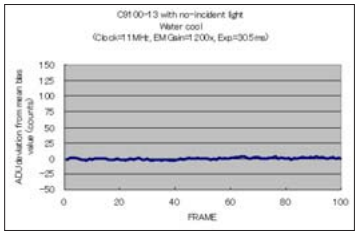


Stability of mean bias value (Digitizer Offset)

The baseline is nearly constant over time providing signal stability for long term measurements.

Example of baseline variance (C9100-13)

- Cooling method:Water cooled
- Clock: 11 MHz
- EM gain: 1200x
- Exposure time: 30.5 ms
- No light



EM gain protection

To maintain performance and help reduce gain ageing from unintentional excessive light conditions, the ImagEM Enhanced can be programmed to send a warning message or audible alarm when too much light is detected.

EM gain readjustment *

If EM gain degradation does occur, a built-in feature of the ImagEM Enhanced readjusts the gain to the original values with a user command.

Direct EM gain control *

Direct control of EM gain multiplying factor using a linear scale is simple, intuitive and quantitative.

*This feature is available when the camera is operated with DCAM-API.
(DCAM-API is software driver which support HAMAMATSU digital cameras.)

Wide range of applications from “Real time imaging of low light fluorescence” to “Ultra low light detection”

Various Imaging Features

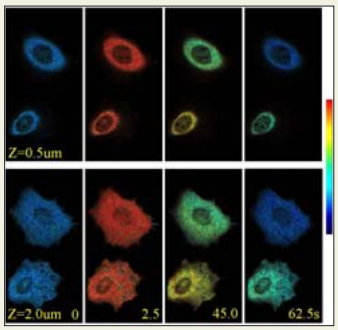
Dual readout mode

Select a readout mode for optimal image acquisition based on the sample brightness or desired frame rate or exposure time.

- **EM-CCD readout** (For short exposure, high sensitivity imaging)
- **NORMAL-CCD readout** (For long exposure, high resolution imaging)

Sample of EM-CCD readout (C9100-13)

Confocal calcium ion imaging of HeLa cell expressing yellow Cameleon 3.6. This image shows changes of histamine stimulated calcium ion with two Z positions and four time lapse.

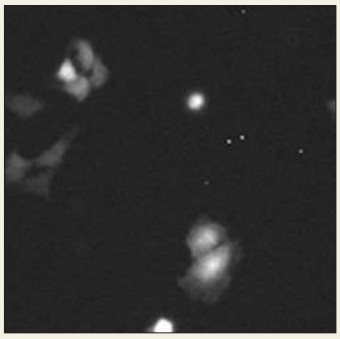


- Objective lens: 100x
- EM gain: 300x
- Exposure time: 100 ms
- Confocal unit: CSU by Yokogawa Electric Co.
- CFP/YFP FRET: 2 wavelength imaging, W-view optics A8509
- Z scan: 19 slices/2.5 s Piezoelectric Z stage

Data courtesy of:
- Dr. Kenji Nagai, Dr. Kenta Saito Hokkaido Univ. Nikon imaging center

Sample of NORMAL-CCD readout (C9100-13)

Luminescence imaging of HeLa cell expressing Renilla Luciferase.



- Objective lens: UApo/340 20x
- Exposure time: 5 min
- Cooling method: Water cooled (-80 ˚C)
- Binning: 2x2

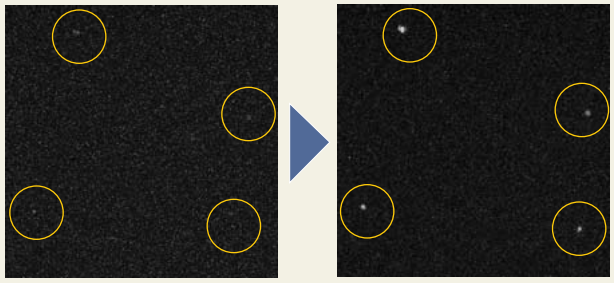
Photon imaging mode (Patent pending)

A unique technology which enhances to support for visualizing or imaging low light signals. It significantly improves signal visibility even at short exposure times and is effective for single molecule fluorescence imaging or rapid observation of luminescence signals.

Sample of photon imaging mode (C9100-13)

Fluorescence beads imaged with reduced excitation light intensity. (Exposure time: 30.5 ms, EM gain: 1200x)

- Photon imaging mode **OFF**
- Photon imaging mode **ON**



Real time image processing features

The following real time processing functions are available.

- **Background subtraction**
  Effective for reducing fluorescence in image backgrounds.
- **Shading correction**
  This feature corrects the shading or uneven illumination in microscope images or other illumination systems.
- **Recursive filter**
  This feature provides random noise elimination in an image by weighted time based averaging.
- **Frame averaging**
  This feature provides noise elimination in an image by simple frame averaging and less “afterimage” effect than the recursive filter.
- **Spot noise reducer**
  This image processing function operates on random spots of intensity by comparing incoming images and eliminating signals that meet the criteria for noise in one image but not in others. This processing eliminates noise elements like cosmic rays.

Various trigger features

Synchronous readout trigger (Patent pending) and programmable terigger signal outputs are available.

SPECIFICATIONS

			ImagEM Enhanced	ImagEM 1K
Type number			C9100-13	C9100-14
Camera head type			Hermetic vacuum-sealed air/water-cooled head ①	
Window			Anti-reflection (AR) coatings on both sides, single window	
AR mask			yes	No ②
Imaging device			Electron Multiplying Back-Thinned Frame Transfer CCD	
Effective no. of pixels			512 (H) × 512 (V)	1024 (H) × 1024 (V)
Cell size			16 µm (H) × 16 µm (V)	13 µm (H) × 13 µm (V)
Effective area			8.19 mm (H) × 8.19 mm (V)	13.3 mm (H) × 13.3 mm (V)
Pixel clock rate	EM-CCD readout		11 MHz, 2.75 MHz, 0.69 MHz	
	NORMAL CCD readout		2.75 MHz, 0.69 MHz	
EM (electron multiplying) gain (typ.) ③			1x or 4x to 1200x	1x or 10x to 1200x
Ultra low light detection			Photon Imaging mode (1, 2, 3)	
Fastest readout speed			31.9 frames/s to 405 frames/s	9.5 frames/s to 231 frames/s
			417 frames/s (Binning option)	242 frames/s (Binning option)
Readout noise (r.m.s.) (typ.)	EM-CCD readout	EM gain 4x (C9100-13) 10x (C9100-14)	25 electrons (at 11 MHz)	10 electrons (at 11 MHz)
			20 electrons (at 2.75 MHz)	8 electrons (at 2.75 MHz)
			8 electrons (at 0.69 MHz)	3 electrons (at 0.69 MHz)
		EM gain 1200x	1 electron max. (at 11 MHz)	
			1 electron max. (at 2.75 MHz)	
			1 electron max. (at 0.69 MHz)	
	NORMAL CCD readout		17 electrons (at 2.75 MHz)	19 electrons (at 2.75 MHz)
			8 electrons (at 0.69 MHz)	10 electrons (at 0.69 MHz)
Full well capacity (typ.) ④			370 000 electrons (Max. 800 000 electrons)	400 000 electrons (Max. 730 000 electrons)
Analog gain			1/2 times to 5 times	
Cooling method / temperature ⑤	Forced-air cooled		-65 ˚C stabilized (0 ˚C to +30 ˚C)	-55 ˚C stabilized (0 ˚C to +30 ˚C)
			-75 ˚C (Room temperature : Stable at +20 ˚C)	-65 ˚C (Room temperature : Stable at +20 ˚C)
	Water cooled ⑥		-80 ˚C stabilized (Water temperature : +20 ˚C)	-70 ˚C stabilized (Water temperature : +20 ˚C)
			-90 ˚C (Water temperature : lower than +10 ˚C)	-80 ˚C (Water temperature : lower than +10 ˚C)
Temperature stability	Forced-air cooled		±0.03 ˚C (typ.) (Room temperature : Stable at +20 ˚C) (-65 ˚C stabilized)	±0.05 ˚C (typ.) (Room temperature : Stable at +20 ˚C) (-55 ˚C stabilized)
	Water cooled		±0.01 ˚C (typ.) (Water temperature : +20 ˚C [Operated with circulating water cooler]) (-80 ˚C stabilized)	±0.01 ˚C (typ.) (Water temperature : +20 ˚C [Operated with circulating water cooler]) (-70 ˚C stabilized)
Dark current ⑦ (typ.)	Forced-air cooled		0.01 electron/pixel/s (-65 ˚C)	0.01 electron/pixel/s (-55 ˚C)
	Water cooled		0.001 electron/pixel/s (-80 ˚C)	0.001 electron/pixel/s (-70 ˚C)
Exposure time ⑧	Internal sync mode		30.5 ms or more	103.3 ms or more
	External trigger mode		10 µs or more	10 µs or more
A/D converter			16 bit	
Output signal / External control			CameraLink	
Sub-array			Every 16 lines (horizontal, vertical) size, position can be set (refer to the table on the right)	
Binning			2×2, 4×4 (8×8, 16×16) ⑨	
External trigger mode ⑩			Edge trigger, Level trigger, Start trigger, Synchronous readout trigger	
Trigger output ⑩			Exposure timing output, Programmable timing output (Delay and pulse length are variable)	
Image processing features (real-time)			Background subtraction, Shading correction, Recursive filter, Frame averaging, Spot noise reducer ⑪	
EM gain protection			EM warning mode, EM protection mode	
EM gain readjustment			Available	
Lens mount			C-mount	
Power requirements			AC 100 V to 240 V, 50 Hz / 60 Hz	
Power consumption			Approx. 140 V·A	
Ambient storage temperature			-10 ˚C to + 50 ˚C	
Ambient operating temperature			0 ˚C to + 40 ˚C	
Performance guaranteed temperature			0 ˚C to + 30 ˚C	
Ambient operating/storage humidity			70 % max. (with no condensation)	

● Fastest Readout Speed (Internal synchronization mode, Unit : frame/s typ.)

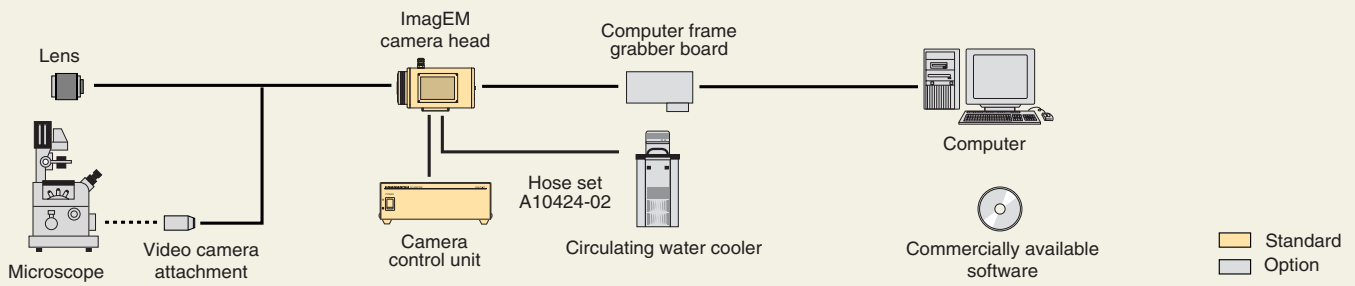
C9100-13						
Binning	Effective vertical width (Sub-array)					
	512	256	128	64	32	16
1 x 1	31.9	59.6	105	170	245	315
2 x 2	60.9	107	172	248	318	370
4 x 4	112	178	254	323	373	405
8 x 8 ⑨	177	252	320	369	401	417 ⑫
16 x 16 ⑨	248	313	360	389	405	413

C9100-14							
Binning	Effective vertical width (Sub-array)						
	1024	512	256	128	64	32	16
1 x 1	9.5	18.4	34.3	60.4	97.7	141	182
2 x 2	18.4	34.2	60.4	97.6	141	182	212
4 x 4	34.2	60.3	97.5	141	181	211	231
8 x 8 ⑨	60.2	97.2	140	180	210	229	240
16 x 16 ⑨	96.6	139	178	207	226	236	242

① The hermetic sealed head maintains a high degree of vacuum 10^{-8} Torr, without re-evacuation.
② AR mask is not placed because the proportion of CCD area to the window is large therefore reflection is quite small.
③ Even with electron multiplying gain maximum, dark signal is kept low level at low light imaging.
④ Linearity is not assured when full well capaicty is over 370 000 electrons (C9100-13) or 400 000 electrons (C9100-14), because of CCD performance.
⑤ The cooling temperature may not reach to this temperature depends on the operation condition.
⑥ Water volume 1.2 liter/min.
⑦ Typical thermal charge value (not guaranteed).
⑧ Image smearing may appear when the exposure time is short.
⑨ 8 × 8 and 16 × 16 binning are available on special order.
Please consult with our sales office.
⑩ C-MOS 3.3 V with reversible polarity.
⑪ Recursive filter, frame averaging, spot noise reducer cannot be used simultaneously.
⑫ Fastest readout speed is at 8x8 binning, sub-array16.

ImagEM

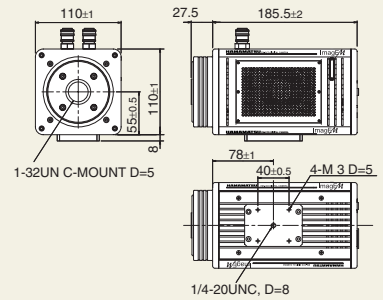
SYSTEM CONFIGURATION



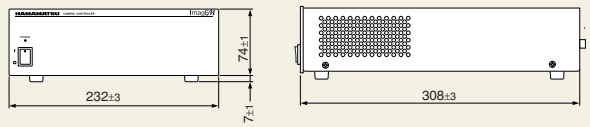
DIMENSIONAL OUTLINES

(Unit : mm)

■ Camera head (Approx. 3.7 kg)



■ Camera control unit (Approx. 3.0 kg)



OPTIONS

- **Commercially available software**
- **Circulating water cooler**
- **Hose set A10424-02**
- **Binning option**

Web

Learn more about ImagEM

imagemccd.com

- Subject to local technical requirements and regulations, availability of products included in this promotional material may vary. Please consult your local sales representative.
- Information furnished by HAMAMATSU is believed to be reliable. However, no responsibility is assumed for possible inaccuracies or omissions. Specifications and external appearance are subject to change without notice.

HAMAMATSU PHOTONICS K.K. www.hamamatsu.com

HAMAMATSU PHOTONICS K.K., Systems Division
812 Joko-cho, Higashi-ku, Hamamatsu City, 431-3196, Japan, Telephone: (81)53-431-0124, Fax: (81)53-435-1574, E-mail: export@sys.hpk.co.jp

U.S.A.: Hamamatsu Corporation: 360 Foothill Road, P. O. Box 6910, Bridgewater. N.J. 08807-0910, U.S.A., Telephone: (1)908-231-0960, Fax: (1)908-231-1218 E-mail: usa@hamamatsu.com
Germany: Hamamatsu Photonics Deutschland GmbH: Arzbergerstr. 10, D-82211 Herrsching am Ammersee, Germany, Telephone: (49)8152-375-0, Fax: (49)8152-2658 E-mail: info@hamamatsu.de
France: Hamamatsu Photonics France S.A.R.L.: 19, Rue du Saule Trapu, Parc du Moulin de Massy, 91882 Massy Cedex, France, Telephone: (33)1 69 53 71 00, Fax: (33)1 69 53 71 10 E-mail: infos@hamamatsu.fr
United Kingdom: Hamamatsu Photonics UK Limited: 2 Howard Court, 10 Tewin Road Welwyn Garden City Hertfordshire AL7 1BW, United Kingdom, Telephone: 44-(0)1707-294888, Fax: 44(0)1707-325777 E-mail: info@hamamatsu.co.uk
North Europe: Hamamatsu Photonics Norden AB: Thorshamnsgatan 35 16440 kista, Sweden, Telephone: (46)8-509-031-00, Fax: (46)8-509-031-01 E-mail: info@hamamatsu.se
Italy: Hamamatsu Photonics Italia: S.R.L.: Strada della Moia, 1/E, 20020 Arese, (Milano), Italy, Telephone: (39)02-935 81 733, Fax: (39)02-935 81 741 E-mail: info@hamamatsu.it
China: HAMAMATSU PHOTONICS (CHINA) Co., Ltd.: 1201 Tower B, Jiaming Center, No.27 Dongsanhuan Beilu, Chaoyang District, Beijing 100020, China, Telephone: (86)10-6586-6006, Fax: (86)10-6586-2866 E-mail: hpc@hamamatsu.com.cn

Cat. No. SCAS0022E09
FEB/2012 HPK
Created in Japan