

# ImagEM<sup>®</sup>

Electron Multiplying CCD Camera C9100-13, -14

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



Great  
Stability

High  
Sensitivity

Low  
Noise

**NEW**  
High  
Resolution

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  $-90^{\circ}\text{C}$  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

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

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



NEW



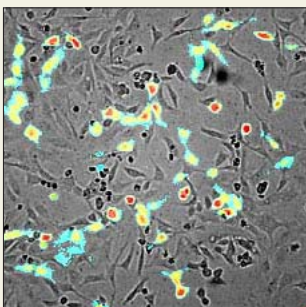
- High frame rate format with 512 x 512 pixels
- 16  $\mu\text{m}$  pixels suited for high dynamic range imaging
- High resolution format with 1024 x 1024 pixels
- 13  $\mu\text{m}$  pixels suited for high N.A. imaging
- Back thinned FT CCD with greater than 90% QE for short exposure times
- Precise 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.

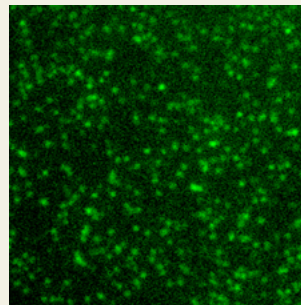


This image is displayed by overlapping luminescence image (pseudo color) and actual image.

- 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”

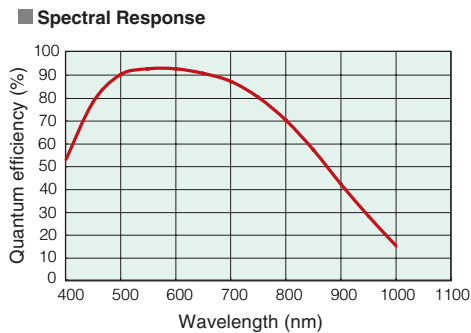


## Benefits of ImagEM Cameras

### 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.



#### ● 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.

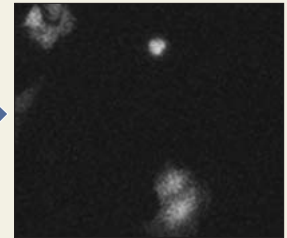
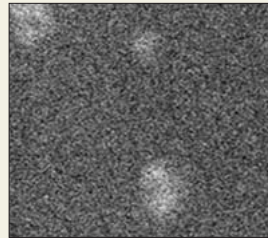
#### ■ Comparison of sensitivity with conventional camera

(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 °C and C9100-14 is -70 °C (Water cooling, water temperature +20 °C). Superior cooling performance provides minimum dark noise.

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

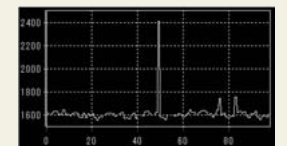
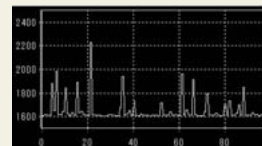
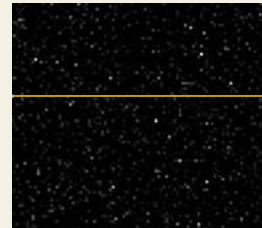
CIC is internally optimized for either fast readout or long term integration by the camera.

#### ■ 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

### 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.

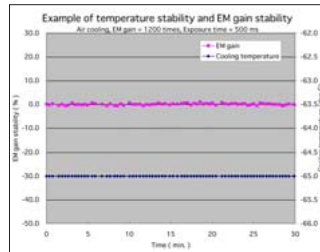
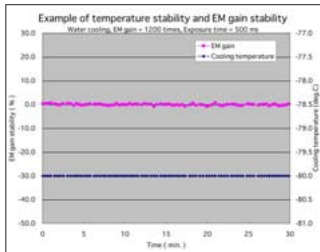
#### ■ Examples of temperature stability and EM gain stability (C9100-13)

##### ● Water cooled

- Temperature stability :  $\pm 0.01$  °C
- EM gain stability :  $\pm 1$  %
  - Cooling temperature :  $-80$  °C
  - Water temperature :  $+20$  °C
  - (Operated with circulating water cooler)

##### ● Forced-air cooled

- Temperature stability :  $\pm 0.03$  °C
- EM gain stability :  $\pm 1$  %
  - Cooling temperature :  $-65$  °C
  - Room temperature : Stable at  $+20$  °C

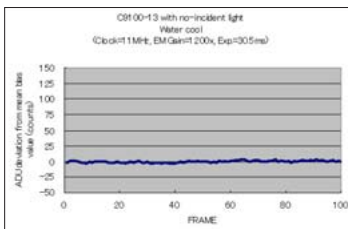


#### ● Stability of mean bias value (Digitizer Offset)

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

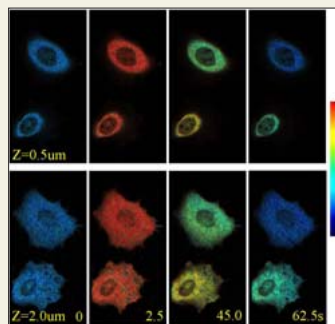
### ● Dual readout mode

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.

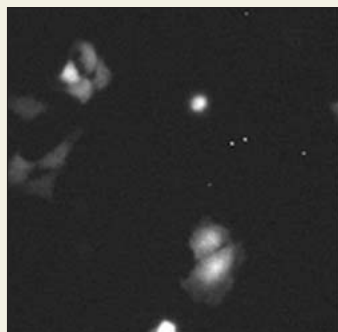


- Objective lens: 100x
- EM gain: 300x
- Exposure time: 100 ms
- Confocal unit: CSU by Yokogawa Electric Co.
- CFP/YFP FRET: 2 wavelength imaging, W-view optics A8509
- Z scan: 19 slices/2.5 s Piezoelectric Z stage

■ 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

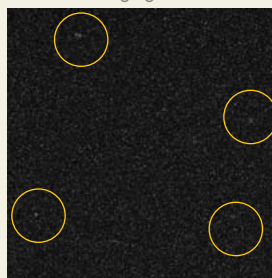
### ● Photon imaging mode (Patent pending)

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.

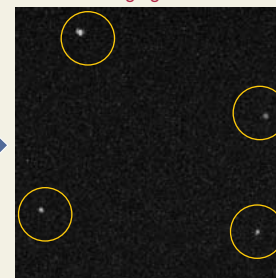
### ■ Sample of photon imaging mode (C9100-13)

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 trigger signal outputs are available.

## SPECIFICATIONS

|   |                       | ImagEM Enhanced   | ImagEM 1K   |
|---|-----------------------|---|---|
|   |                       | C9100-13  | C9100-14  |
| Type number                             |                       |   |   |
| 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<br>417 frames/s (Binning option)  | 9.5 frames/s to 231 frames/s<br>242 frames/s (Binning option)   |
| Readout noise<br>(r.m.s.) (typ.)        | EM-CCD<br>readout     | EM gain<br>4x (C9100-13)  | 25 electrons (at 11 MHz)  |
|   |                       | 10x (C9100-14)  | 20 electrons (at 2.75 MHz)  |
|   |                       | EM gain<br>1200x  | 8 electrons (at 0.69 MHz)   |
|   | NORMAL CCD<br>readout | 1 electron max. (at 11 MHz)   |   |
|   |                       | 1 electron max. (at 2.75 MHz)   |   |
|   |                       | 1 electron max. (at 0.69 MHz)   |   |
|   |                       | 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 /<br>temperature ⑤       | Forced-air cooled     | -65 °C stabilized (0 °C to +30 °C)<br>-75 °C (Room temperature : Stable at +20 °C)                            | -55 °C stabilized (0 °C to +30 °C)<br>-65 °C (Room temperature : Stable at +20 °C)                            |
|   | Water cooled ⑥        | -80 °C stabilized (Water temperature : +20 °C)<br>-90 °C (Water temperature : lower than +10 °C)              | -70 °C stabilized (Water temperature : +20 °C)<br>-80 °C (Water temperature : lower than +10 °C)              |
| Temperature<br>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.)<br>(Water temperature : +20 °C [Operated with circulating water cooler] ) (-80 °C stabilized) | ±0.01 °C (typ.)<br>(Water temperature : +20 °C [Operated with circulating water cooler] ) (-70 °C stabilized) |
| Dark current ⑦<br>(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 ⑪                        |                       | Exposure timing output, Programmable timing output (Delay and pulse length are variable)                      |   |
| Image processing features (real-time)   |                       | Background subtraction, Shading correction,<br>Recursive filter, Frame averaging, Spot noise reducer ⑫        |   |
| 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 ⑩ |
| 16 x 16 ⑩ | 248                                  | 313  | 360 | 389 | 405 | 413   |

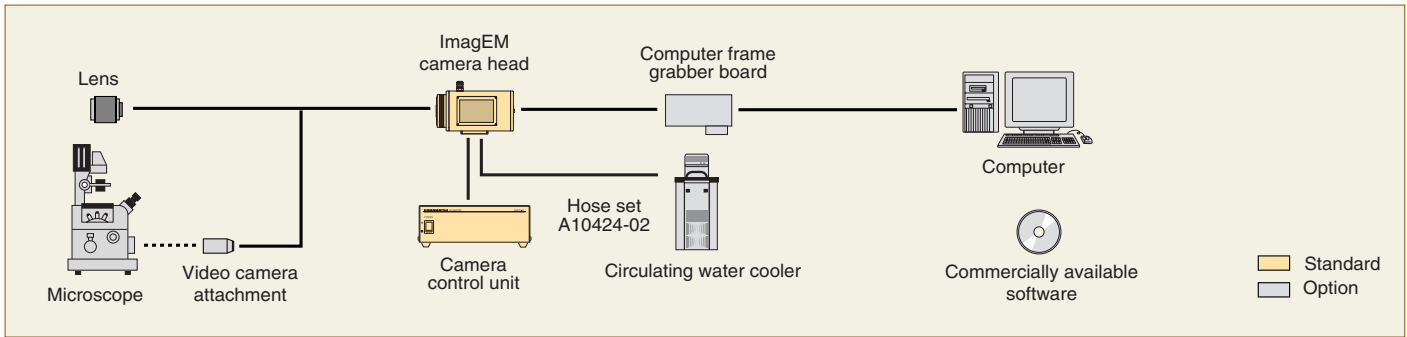
| C9100-14  |                                      |      |      |      |      |     |     |
|-----------|--------------------------------------|------|------|------|------|-----|-----|
| Binning   | Effective vertical width (Sub-array) |      |      |      |      |     |     |
|           | 1024                                 | 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 ⑩ | 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 capacity 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 x 8 and 16 x 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.

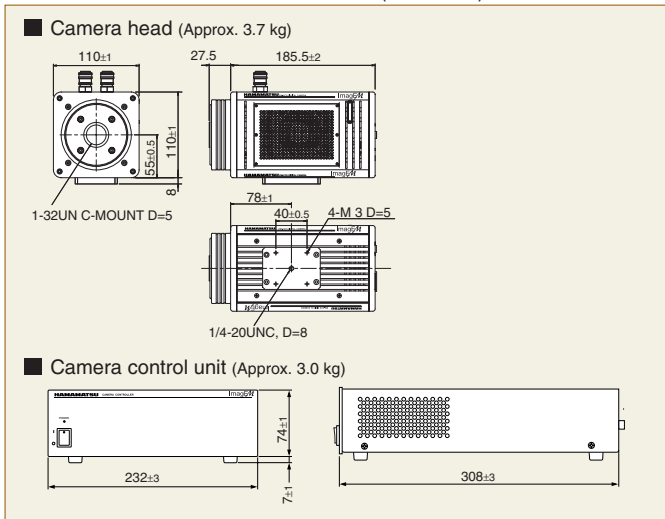
ImagEM



## SYSTEM CONFIGURATION



## DIMENSIONAL OUTLINES (Unit : mm)



## OPTIONS

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



Learn more about ImagEM

[imagemccd.com](http://imagemccd.com)

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