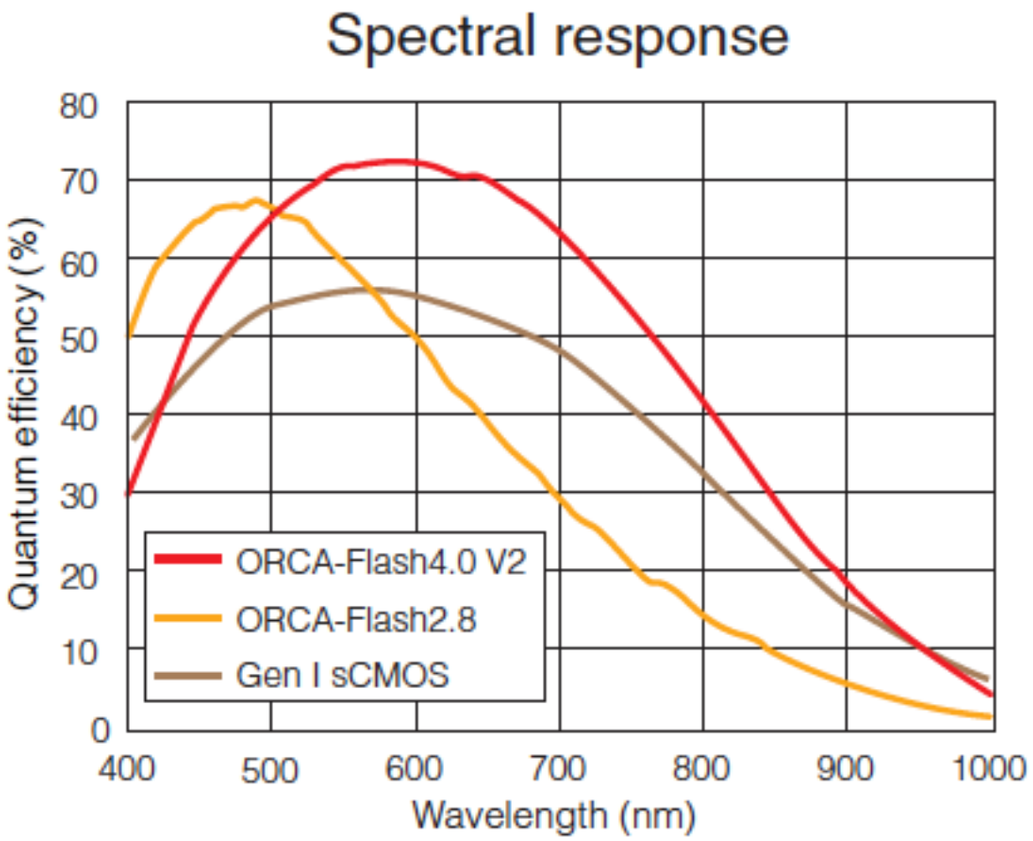
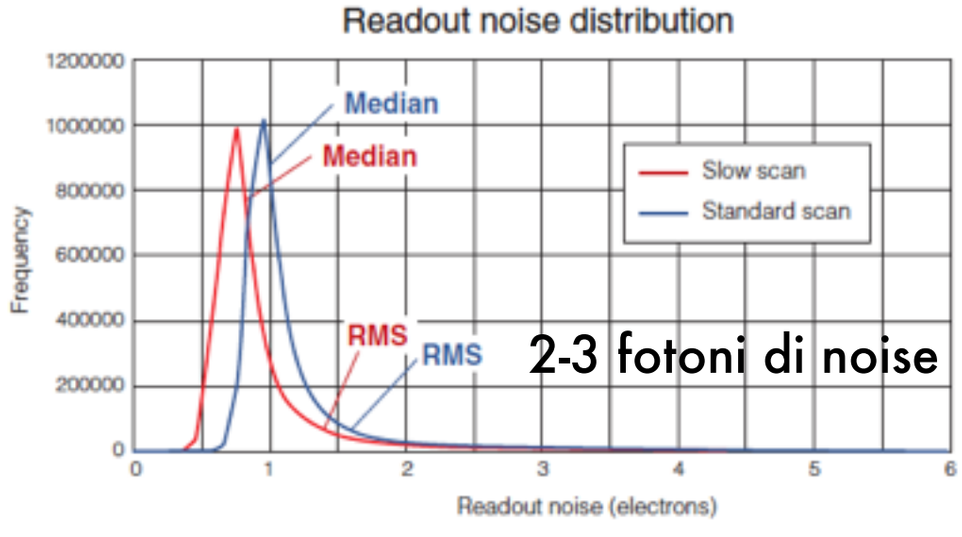
GEM for optical photons

Il sensore: CMOS

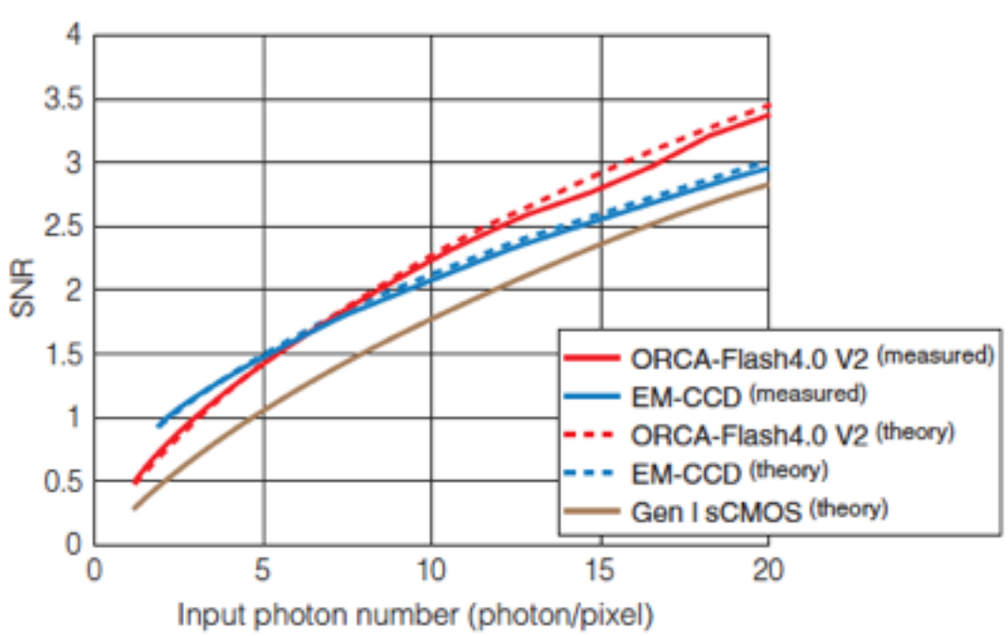
Effective no. of pixels	Readout speed	Readout noise
2048 (H)×2048 (V)	**100 frames/s**	**1.0 electrons**

Il sensore: CMOS





2-3 fotoni di noise



The ORCA-Flash4.0 V2 SNR exceeds that of EM-CCDs at about 6 photons/pixel. The solid lines show measured data at 533 nm. This measurement aligns well with predicted values (dotted line) for EM-CCD and ORCA-Flash4.0 V2. For

Il sensore: CMOS

Product number		C11440-22CU (ORCA-Flash4.0 V2)
Imaging device		Scientific CMOS sensor FL-400
Effective number of pixels		2048(H) × 2048(V)
Cell size		6.5 µm × 6.5 µm
Effective area		13.312 mm × 13.312 mm
Full well capacity (typ.)		30 000 electrons
Readout time	Standard scan (at 100 frames/s)	10 ms
	Slow scan (at 30 frames/s)	33 ms
Readout noise	Standard scan (at 100 frames/s, typ.)	1.6 electrons rms (1.0 electrons median)
	Slow scan (at 30 frames/s, typ.)	1.4 electrons rms (0.8 electrons median)
Dynamic range (typ.)*2		37 000:1
Quantum efficiency		Over 70 % at 600 nm and 50 % at 750 nm

Cooling method	Dark current (typ.)	Sensor temperature (nominal)
Forced air (Ambient at +20 ℃)	0.06 electrons/pixel/s	–10 ℃
Water (+20 ℃)	0.02 electrons/pixel/s	–20 ℃
Water (+15 ℃)	0.006 electrons/pixel/s	–30 ℃

Frame rate	Camera Link	USB 3.0
Full resolution	100 frames/s	30 frames/s
2048 × 1024 (at center position)	200 frames/s	60 frames/s
2048 × 8 (at center position)	25 655 frames/s	7894 frames/s
512 × 8 (at center position)	-	25 655 frames/s

Il sensore: CCD

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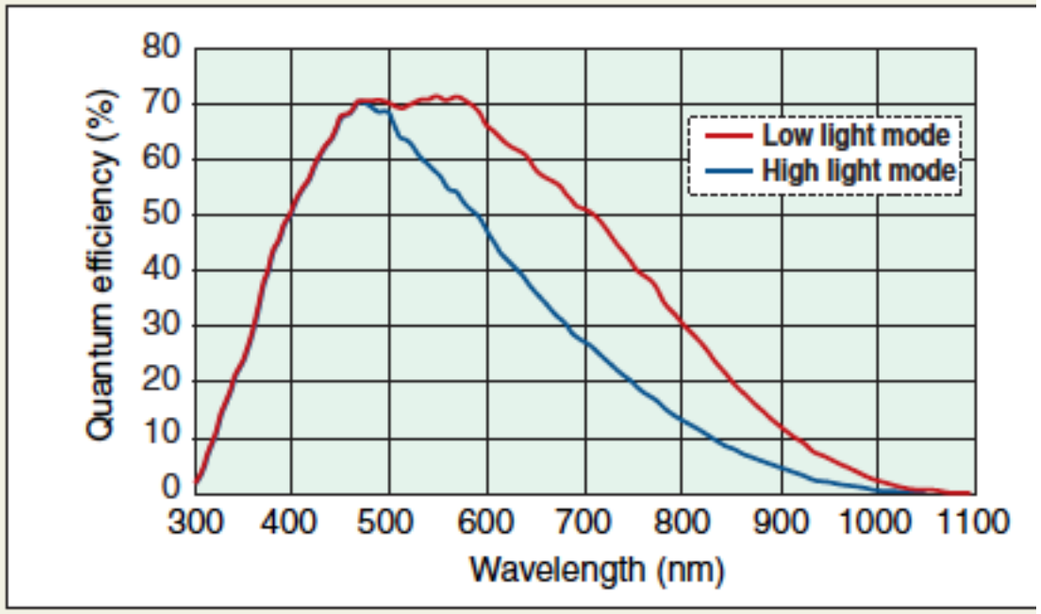
Spectral Response

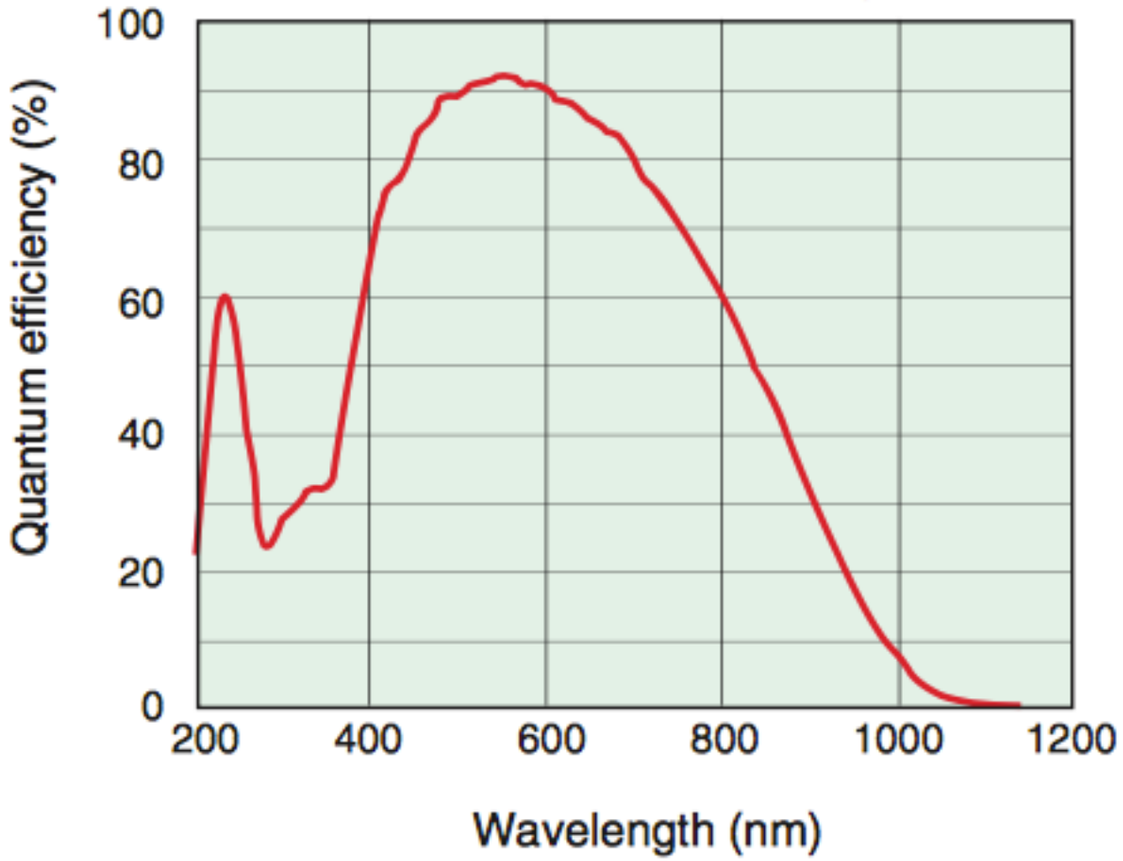


★ This sample is typical of the CCD characteristics, not guaranteed.

Type number			**ORCA-R2** (C10600-10B)
Camera head type			Hermetic vacuum-sealed head
Dual cooling			Air cooling / water cooling
Imaging device			ER-150 progressive scan interline CCD
Effective number of pixels			1344 (H) × 1024 (V)
Cell size			6.45 µm (H) × 6.45 µm (V)
Effective area			8.67 mm (H) × 6.60 mm (V)
Dual scan mode			Normal scan / Fast scan
Pixel clock rate	Normal scan		14.00 MHz/pixel
	Fast scan		28.00 MHz/pixel
Readout noise (rms) typ.	Normal scan		6 electrons
	Fast scan		10 electrons
Full well capacity typ.	High dynamic range mode*	OFF	18 000 electrons
		ON	36 000 electrons
Dynamic range typ.			3 000 : 1 (at Normal scan / 1×1)
Cooling method / temperature	Forced-air cooled		- 35 ˚C
	Water cooled		- 40 ˚C (Water temperature : +20 ˚C)
Dark current			0.0005 electrons/pixel/s (at - 40 ˚C)
Dual A/D converter			12 bit or 16 bit
Exposure time			10 µs to 4200 s
Binning			2 × 2, 4 × 4, 8 × 8
Sub-array			Yes
Dual light mode			Low light mode / High light mode
High dynamic range mode*			Yes
Analog gain feature			Yes (10 times max.)
Analog offset feature			Yes
External trigger mode			Edge trigger, Level trigger, Synchronous readout trigger, Start trigger

Il sensore: CCD

Digital CCD Camera ORCA® II



Il sensore: CCD

Type number			C11090-22B
Camera head type			Hermetic vacuum-sealed air/water-cooled head *1
Imaging device			Back-thinned frame transfer CCD
Effective number of pixels			1024 (H) × 1024 (V)
Cell size			13 µm (H) × 13 µm (V)
Effective area			13.3 mm (H) × 13.3 mm (V)
Pixel clock rate	High-precision readout		312.5 kHz
	High speed readout		5 MHz
Cooling method/ temperature* 2	Forced-air cooled	at temperature control	- 65 ˚C stabilized (0 ˚C to +30 ˚C)
	Water cooled *3	at temperature control	- 75 ˚C (Water temperature : +20 ˚C)
		at maximum cooling typ.	- 90 ˚C (Water temperature: lower than +10 ˚C)
Readout noise* 4 (typ.)			6 electrons rms
Full well capacity (1×1)			80 000 electrons
Dark current (typ.)	Forced-air cooled (- 65 ˚C)		0.0065 electron/pixel/s
	Water cooled (- 75 ˚C)		0.0012 electron/pixel/s
Dynamic range* 5			13 333:1
A/D converter			16 bit
Analog gain	High-precision readout		×1, ×4, ×18
	High speed readout		×1 to × 6
Exposure time* 6	Internal synchronous mode	High-precision readout* 7	3.53 s to 120 min (312.5 kHz)
		High speed readout	307 ms to 120 min (5 MHz)
	External synchronous mode	High-precision readout	400 ms to 120 min
		High speed readout	20 ms to 120 min

Il sensore: EMCCD

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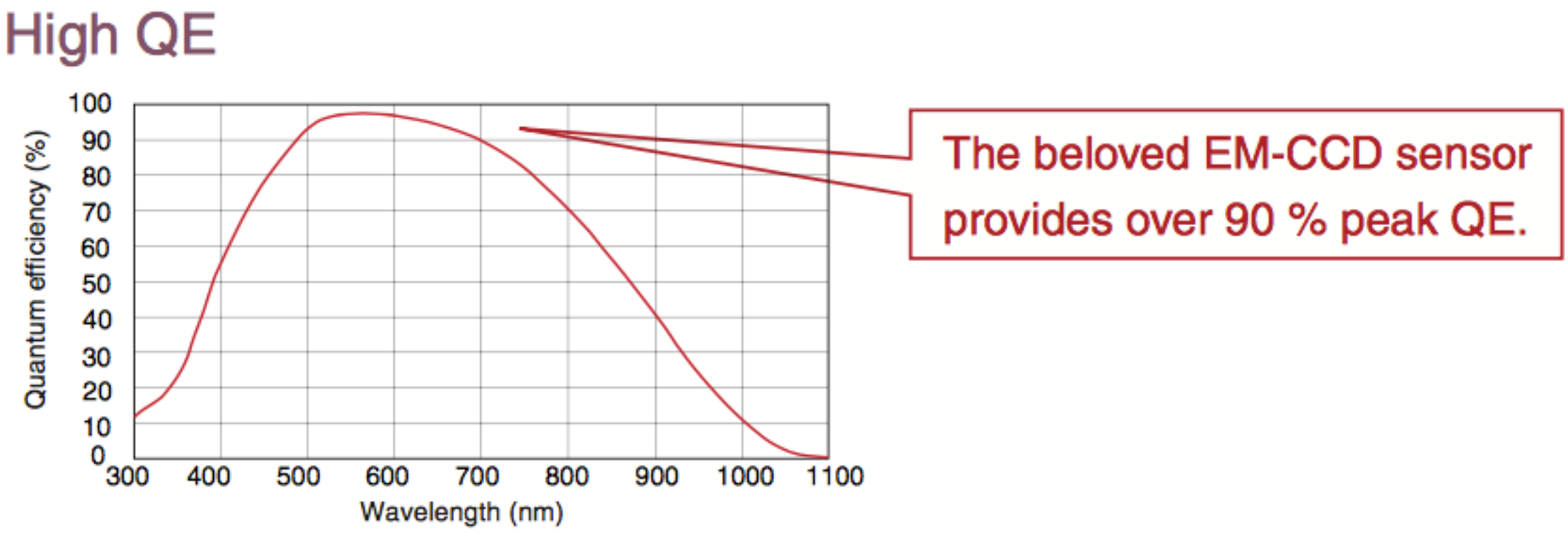

Il sensore: EMCCD

Type number			C9100-23B(ImagEM X2)	C9100-24B(ImagEM X2-1K)
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
Imaging device			Electron Multiplying Back-Thinned Frame Transfer CCD	
Effective number of pixels			512 (H) x 512 (V)	1024 (H) x 1024 (V)
Cell size			16 µm (H) x 16 µm (V)	13 µm (H) x 13 µm (V)
Effective area			8.19 mm (H) x 8.19 mm (V)	13.3 mm (H) x 13.3 mm (V)
Pixel clock rate	EM-CCD readout		22 MHz, 11 MHz, 0.6875 MHz	
	Normal-CCD readout		0.6875 MHz	
EM (electron multiplying) gain (typ.) *2			1x, 4x to 1200x	1x, 10x to 1200x
Ultra-low light detection			Photon Imaging mode (1, 2, 3)	
Fastest readout speed			70.4 frames/s to 1076 frames/s	18.5 frames/s to 314 frames/s*3
Readout noise (rms) (typ.)	EM-CCD readout	EM gain 4x	36 electrons (at 22 MHz)	15 electrons (at 22 MHz)
			25 electrons (at 11 MHz)	10 electrons (at 11 MHz)
			8 electrons (at 0.6875 MHz)	3 electrons (at 0.6875 MHz)
		EM gain 1200x	1 electron max.	
	Normal CCD readout		8 electrons (at 0.6875 MHz)	10 electrons (at 0.6875 MHz)
Full well capacity (typ.)	EM-CCD mode		370 000 electrons	400 000 electrons
	Normal-CCD mode		140 000 electrons	50 000 electrons
Analog gain *4	EM-CCD readout	22 MHz	1x	
		11 MHz/0.6875 MHz	0.5x, 1x	
	Normal CCD readout		1x, 2x, 3x, 4x, 5x	
Cooling method / temperature *5	Forced-air cooled	at temperature control (Room temperature: 0 °C to +30 °C)	-65 °C	-50 °C (at 22 MHz)
				-55 °C (11 MHz, 0.6875 MHz, Normal CCD readout)
		at maximum cooling typ.	-80 °C (Room temperature: Stable at +20 °C)	-65 °C (Room temperature: Stable at +20 °C)
	Water cooled *6	at temperature control (Water temperature: +20 °C)	-80 °C	-65 °C (at 22 MHz)
				-70 °C (11 MHz, 0.6875 MHz, Normal CCD readout)
		at maximaum cooling typ.	-100 °C (Water temperature: lower than +10 °C)	-80 °C (Water temperature: lower than +10 °C)
Temperature stability (typ.)			±0.01 °C	
Dark current (typ.) *7	Forced-air cooled (-65 °C)		0.005 electron/pixel/s	0.01 electron/pixel/s
	Water cooled (-80 °C)		0.0005 electron/pixel/s	0.001 electron/pixel/s
Clock induced charge (typ.)			0.0015 events/pixel/frame	0.01 events/pixel/frame
Exposure time *8	Internal synchronus mode		13.9 ms to 1 s (22 MHz)	52.7 ms to 1 s (22 MHz)
			27.2 ms to 2 h (11 MHz)	103.2 ms to 2 h (11 MHz)
			421.5 ms to 2 h (0.6875 MHz)	1616.9 ms to 2 h (0.6875 MHz)
	External trigger mode		10 µs to 1 s (22 MHz)	
			10 µs to 2 h (11 MHz, 0.6875 MHz, Normal CCD readout)	

Summary

	# pixel	Pixel size [um]	Readout Noise [el]	Dark Current [el/(pix s)]	Min exposure time (us)	ReadOut Speed (frame/s)
ORCA Flash 4.0	2048 x 2048	6.5 x 6.5	1.5	0.06 @ -10^{o} (Aria) 0.006 @ -30^{o} (Acqua 15^{o} C)	10^3	30 - 100
ORCA R2	1344 x 1024	6.5 x 6.5	6 - 10	0.0005 @ -40^{o} (Acqua 20^{o} C)	10	16
ORCA II	1024 x 1024	13 x 13	6	0.0065 @ -65^{o} (Aria) 0.0012 @ -75^{o} (Acqua 20^{o} C)	2 10^4	3.15
EMCCD	1024 x 1024 512 x 512	13 x 13 16 x 16	1 @ 1200 gain	0.01 @ -65^{o} (Aria) 0.001 @ -80^{o} (Acqua 20^{o} C)	10	18.5