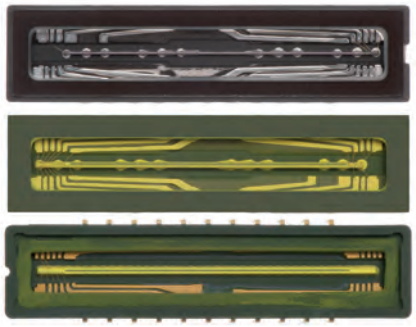
Detector arrays

The AvaSpec line of spectrometers can be equipped with several types of detector arrays. Presently we offer silicon-based CCDs, back-thinned CCDs, and CMOS Arrays for the 200-1100 nm range. A complete overview of each is given in the next section " Sensitivity " in Table 4. For the NIR range (1000-2500 nm) InGaAs arrays are implemented.

All detectors are tested in incoming goods inspection, before they are used in our instruments. Avantes offers full traceability on following detector specifications:

- Dark noise
- Signal to noise
- Photo Response Non-Uniformity
- Hot pixels

StarLine and CompactLine CMOS Detectors (2048CL/4096CL)



Both CCD (charge-coupled device) and CMOS (complementary metal-oxide semiconductor) detectors start at the same point -- they convert light into electrons, only with different technologies. In the last years CMOS sensors has improved up to a point where they reach near parity with CCD devices.

Looking to the future the CMOS detectors seem to definitely take over the standard CCD technology in general purpose spectrometers. In general the CMOS detectors have a good UV response (without the need of using UV enhancement coatings and a higher response in the NIR region.

The overall sensitivity tends to be somewhat lower than with the CCD technology.

SensLine Back-thinned CCD Detectors (2048XL/2048x64/1024x58)

For applications requiring high quantum efficiency in the UV (200-350 nm) and NIR (900-1160 nm) range, combined with good S/N and a wide dynamic-range, back-thinned CCD detectors are the right choice.

Avantes offers cooled and uncooled versions. In case of a 2D-detection the vertical pixels are binned, giving effectivly one high pixel to increase sensitivity.

+ Advantage of the back-thinned CCD detector is the good UV and NIR sensitivity, combined with good S/N and dynamic range.

- Disadvantage is the relatively higher cost.

NIRLine InGaAs linear image sensors (AvaSpec-NIR256/512)

The InGaAs linear image sensors deliver high-sensitivity in the NIR wavelength range. The detector consists of a charge-amplifier array with CMOS transistors, a shift-register and timing generator. For InGaAs detectors the dynamic range is limited by the dark noise. For ranges up to 1.75 µm no cooling is required and these detectors are available in both 256 and 512 pixels. Detectors for the extended range -2.5 µm all have 2- stage TE-cooling to reduce dark noise and are available in 256 and 512 pixel versions.

6 versions of detectors are available:

- 256/512 pixel non-cooled InGaAs detector for the 900-1750 nm range
- 256/512 pixel cooled InGaAs detector for the 900-1750 nm range
- 256/512 pixel 2-stage cooled Extended InGaAs detector for the 1000-2500 nm range

Sensitivity

The sensitivity of a detector pixel at a certain wavelength is defined as the detector electrical output per unit of radiation energy (photons) incident to that pixel. With a given A/D converter this can be expressed as the number of counts per mJ of incident radiation.

The relation between light energy entering the optical bench and the amount hitting a single detector pixel depends on the optical bench configuration. The efficiency curve of the grating used, the size of the input fiber or slit, the mirror performance and the use of a Detector Collection Lens are the main parameters. With a given set-up it is possible to do measurements over about 6-7 decades of irradiance levels. Some standard detector specifications can be found in Table 4 detector specifications. Optionally, a cylindrical detector collection lens (DCL) can be mounted directly on the detector array.

The DCL-UV/VIS-200 can be used for our spectrometers with larger pixel heights to have a better vertical distribution of light focusing on the detector and is primarily for fiber diameters larger than 200 µm and round- to-linear assemblies.
Our SensLine has the most sensitive detectors out of all of our instrument lines, as it includes back-thinned and thermoelectrically cooled detectors.

In Table 4 the UV/VIS detectors are depicted with their specifications, please find below some additional information on how those specifications are determined.

Pixel Well Depth (electrons)

This value is specified by the detector supplier and defines how many electrons can fit in a pixel well before it is saturated, this value determines the best reachable Signal to Noise (=√(Pixel well depth)).

Sensitivity in Photons/count @ 600 nm

The number of Photons of 600 nm that are needed to generate one count of signal on a 16-bit AD converter, the lower this number is, the better is the sensitivity of the detector.

The calculation of the number of Photons/count is (Pixel Well depth in electrons)/16-bit AD/Quantum Efficiency @ 600 nm.

Sensitivity in counts/µW per ms integration time

Sensitivity here is for the detector types currently used in the UV/VIS AvaSpec spectrometers as output in counts per ms integration time for a 16-bit AD converter. To compare the different detector arrays we have them all built up with an optical bench with UA 300 lines/mm grating covering 200-1100 nm, DCL if applicable, and 50 µm slit.

The measurement setup for 350-1100 nm has a 600 µm fiber connected to an AvaSpere-50-LS-HAL, equivalent to an optical power of 1.14 µW.

For the UV/VIS measurement at 220-1100 nm we connected the 600 µm fiber to an AvaLight-DHS through a CC-VIS/NIR diffuser, equivalent to 2.7 µW power.

Peak Wavelength and QE @ peak

The peak wavelength is provided by the detector supplier as well as the Quantum Efficiency, defined as the number of electrons generated by one photon.

Signal/Noise

Signal/Noise is measured for every detector at Avantes' Quality Control Inspection and defined as the illuminated maximum Signal/Noise in Root Mean Square for the shortest integration time. The RMS is calculated over 100 scans.

Dark Noise

Dark noise is measured for every detector at Avantes' Quality Control Inspection and defined as the non-illuminated noise in

Root Mean Square for the shortest integration time. The RMS is calculated over 100 scans.

Dynamic Range

The dynamic range is defined as the (maximum signal level- baseline dark level)/dark noise RMS.

Photo Response Non-Uniformity

Photo Response Non-Uniformity is defined as the max difference between output of pixels when uniformly illuminated, divided by average signal of those pixels.
PRNU is measured for every detector at Avantes' Quality Control Inspection.

Frequency

The frequency is the clock frequency at which the data pixels are clocked out through the AD-converter.

Table 4 Detector Specifications (based on a 16-bit AD converter)

	StarLine			SensLine			
Detector	HAM-2048CL	HAM-4096CL	SONY-2048L	HAM-2048XL	HAM-2048x64TEC	HAM-2048x64	HAM-1024x58
Type	CMOS linear array	CMOS linear array	CCD linear array	Back-thinned CCD array	Cooled Back-thinned CCD array	Back-thinned CCD array	Cooled Back-thinned CCD array
# Pixels, pitch	2048, 14 µm	4096, 7 µm	2048, 14 µm	2048, 14 µm	2048, 14 µm	2048, 14 µm	1024 x 58, 24 µm
Pixel width x height (µm)	14 x 200	7 x 200	14 x 200	14 x 500	14 x 14 (total height 0.9 mm)	14 x 14 (total height 0.9 mm)	24 x 24 (total height 1.4 mm)
Pixel well depth (electrons)	80,000	80,000	90,000	200,000	300,000	200,000	1,000,000
Sensitivity Photons/ count @600 nm	2	2	2	4	6	4	16
Sensitivity in counts/µW per ms integration time	375,000 (AvaSpec-ULS2048CL)	218,000 (AvaSpec-ULS4096CL)	470,000 (AvaSpec-ULS2048L)	460,000 (AvaSpec-ULS2048XL)	300,000 (AvaSpec-ULS2048x64 TEC)	650,000 (AvaSpec-ULS2048x64)	445,000 (AvaSpec-HERO)
Peak wavelength	700 nm	700 nm	450 nm	650 nm	600 nm	600 nm	650 nm
QE (%) @ peak	80%	80%	40%	78%	78%	78%	92%
Signal/Noise	300:1	335:1	300:1	525:1	550:1	450:1	1200:1
Dark noise (counts RMS)	16	16	20	5	5	11.5	2
Dynamic Range	4000	4000	3300	13,700	19,000	1600	40,000
PRNU*	± 5%	± 5%	± 5%	± 3%	± 3%	± 3%	± 3%
Wavelength range (nm)	200-1100	200-1100	200-1100	200-1160	200-1160	200-1160	200-1160
Frequency	6 MHz	6 MHz	2 MHz	1 MHz	500 kHz	1.33 MHz	250 kHz

* Photo-Responsive Non-Uniformity

Figure 3a Sensitivity Curve StarLine

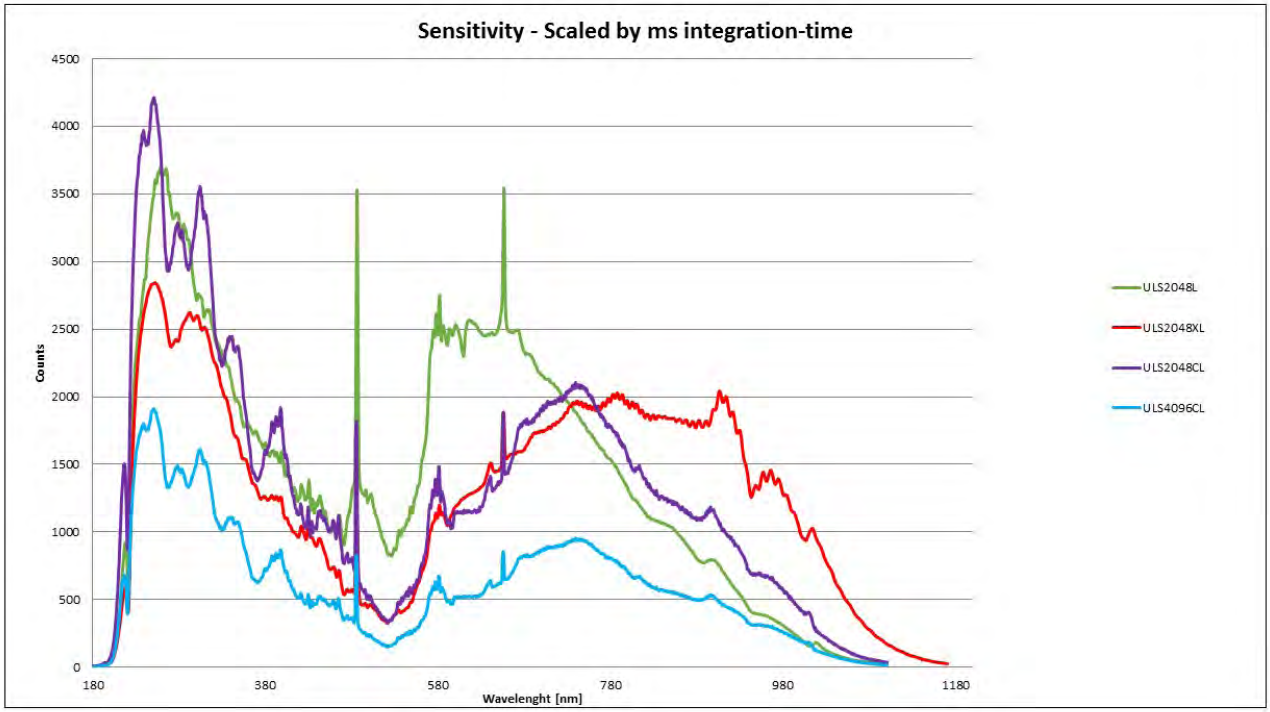


Figure 3b Sensitivity Curve SensLine