Optical Bench Design



Avaspec-ULS Optical Bench Design: Symmetrical Czerny-Turner

1. Detector
2. SMA Connector
3. Grating
4. Slit, mode stripper
5. 2nd mode stripper
6. Collimating mirror
7. Focusing mirror
8. CPC light traps
9. CPC light traps
10. DCL-UV/VIS
11. OSC-filter

The heart of most AvaSpec fiber-optic spectrometers is an optical bench with 37.5, 50, 75 or 100 mm focal length, developed in a symmetrical Czerny-Turner design. Light enters the optical bench through a standard SMA-905 connector and is collimated by a spherical mirror. A plain grating diffracts the collimated light; a second spherical mirror focuses the resulting diffracted light. An image of the spectrum is projected onto a 1-dimensional linear detector array.

Avantes AvaSpec-HS2048XL high-sensitivity spectrometers have a revolutionary optical bench design with multiple toroid mirrors which ensure that the full numerical aperture of the fiber entrance will be projected on the backthinned CCD array.

All of our optical benches have a number of components installed inside, allowing a wide variety of different configurations, depending on the intended application. The choice of these components such as the diffraction grating, entrance slit, order-sorting filter, and detector have a strong influence on system specifications such as sensitivity, resolution, bandwidth and stray-light. Each of these specification will be discussed in detail in the following paragraphs.



How to configure a spectrometer for your application

The modular AvaSpec line of instruments provides you with a number of configuration options to optimize the optical and spectroscopic performance of your instrument for your application.

This section provides you some guidance on how to choose the right grating, slit, detector and other configuration options, to be installed in your AvaSpec.

Wavelength Range

In the determination of the optimal configuration of a spectrometer system the wavelength range is key parameter that defines the appropriate grating choice.
If you are looking for a wide (broadband) wavelength range, we recommend the use of a 300 lines/mm grating. For lesser range (approximately 500 nm) but higher resolution, you might consider a 600 lines/mm. Higher lines/mm gratings (1200, 1800, 2400, 3600) provide higher resolution for applications that require this (see Grating selection table in the spectrometer product section). Broadband gratings provide the greatest flexibility but may not provide the best performance for specific applications. Contact an Avantes Sales Engineer or representative for a recommended grating configuration.

Detector Choice

The choice of your wavelength range along with the demands of your measurement speed and accuracy often suggests the appropriate detector for your application.

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Avantes offers a variety of different detector types, each with different sensitivity curves (see Figure 3a and 3b on page 20).
The AvaSpec instrument line is divided into multiple groups based on general requirements. The AvaSpec-Starline is comprised of general purpose UV/VIS instruments with low-cost CCD or CMOS detectors. The AvaSpec Sensline is comprised of higher performance back-thinned CCDs and thermo-electrically cooled CCD UV/VIS instruments. These instruments are particularly better in the UV and NIR range, compared to standard CCD and CMOS detectors. The AvaSpec NIRLine is comprised of instruments with InGaAs arrays for longer wavelength measurements, ranging from 900-2500 nm. For applications where the size of the instrument is a critical factor, Avantes offers the CompactLine with spectrometers that have a small form factor.

For high-speed applications, the 2048 pixel CMOS detectors in the AvaSpec-ULS2048CL from the StarLine are normally the best options. For low-light level applications such as fluorescence and Raman, the SensLine instruments may be the most appropriate. The AvaSpec NIRLine features 6 different InGaAs detectors for various applications.

The modularity and inter-compatibility of the AvaSpec line also make it possible to combine two or more detectors in a single instrument enclosure to provide optimal performance over a broad wavelength range. For example, an AvaSpec StarLine (UV/VIS) spectrometer can be combined with a NIRLine spectrometer to enable measurements from 200-2500 nm in a single instrument.

Optical Resolution & Slit size

If high optical resolution is required, you may want to consider a grating with higher lines/mm (1200, 1800, 2400, 3600), thus limiting the range of the instrument to a more narrow range. Additionally, it is advisable to consider a detector with 2048 or 4096 pixels and a small slit (10 or 5 µm). For the best resolution with all other criteria of lesser importance, the AvaSpec-4096CL with a 5 micron slit is optimal.

Slit size is a key factor in determining both resolution and throughput of the optical bench. It is important to balance your need for resolution with the need for sensitivity and throughput of the optical bench. If resolution is optimized without considering the need for throughput, you may not have adequate light to get a stable measurement. As previously mentioned, for optimal resolution our smallest slit (5 microns) is recommended. If your application does not require the highest possible resolution and is not one that has an excess of light (laser measurement for example), we recommend that you consider as larger slit to maximize throughput into the optical bench.
The AvaSpec-RS with replaceable slit makes your spectrometer a versatile instrument for both high-resolution and high-sensitivity measurements.

Sensitivity

When considering sensitivity, it is very important to distinguish between photometric sensitivity (How much light do I need for a detectable signal?) and chemometric sensitivity (What absorbance difference level can still be detected?)

a. Photometric Sensitivity

For the best photometric sensitivity a combination of a high-throughput optical bench and a high quantum-efficiency (QE) detector is recommended. The instruments in the AvaSpec SensLine are specifically optimized for photometric sensitivity.

For example fluorescence applications require high photometric sensitivity. Avantes AvaSpec-HS2048XL is the highest performance instrument we offer for this application. For Raman applications, where the combination of resolution and sensitivity is required, we commonly recommend our AvaSpec-HERO with TEC cooling. To further enhance photometric sensitivity, we recommend the use of a detector collection lens (DCL-UV/VIS or DCL-UV/VIS-200), which is a cylindrical lens with focuses light from larger core fiber-optics and bundles down onto the smaller detector pixels.
For additional photometric sensitivity, a larger slit and a 300 line/mm grating to minimize light dispersion are available. Some more demanding applications also require thermo-electric cooling of the CCD detector (see product section AvaSpec-ULS2048LTEC and AvaSpec-HERO) to minimize noise and increase dynamic range at long integration times (up to 60 seconds).

For our detector types the photometric sensitivity is given in Table 4 (page 19) and Table 5 (page 21), the spectral sensitivity for each detector is depicted in Figures 3a and 3b.

b. Chemometric Sensitivity

To detect drastical different absorbance values, close to each other with maximum sensitivity, you need high Signal to Noise (S/N) performance. The detectors with best S/N performance are again in

the AvaSpec SensLine series spectrometers



with the AvaSpec-HERO at the top of the line. The S/N performance can also be enhanced by averaging multiple spectra. The square root of the number of averages translates to the improvement in signal to noise.

Timing and Speed

The data capture process is inherently faster with linear detector arrays and no moving parts as compared with a monochromator design, however, there are optimal detectors for each application. For high-speed applications such as measurements involving pulsed lasers and light sources, we recommend the AvaSpec-ULS2048CL-EVO spectrometers.
These instruments support high-speed data acquisition with the capability of starting an acquisition as fast as within 1.3 microseconds of receiving an external trigger. Since data transfer time is critical for these applications, Avantes' unique Store-to-RAM mode enables on board storage of up to 5000 spectra to the instrument RAM buffer.

The above parameters are the most important in choosing the right spectrometer configuration. Please contact our application engineers to optimize and fine-tune the system to your needs. Table 1 on the next page provides a quick reference guide for spectrometer selection for many common applications. The system recommendations in this table are for simple configurations of mostly single channel spectrometers.
For more elaborate explanations of specific explanations, see the applications section at the back of the catalog.

Table 1 Quick Reference Guide for Spectrometer Configuration

Application	AvaSpec-type	Grating	WL range (nm)	Coating	Slit (µm)	FWHM Resolution (nm)	DCL	OSF	OSC
Biomedical	VARIUS-2048CL	NB	500-1000	-	50	1.2	-	475	-
Chemometry	VARIUS-2048CL	UA	200-1100	-	50	2.3	-	-	OSC-UA
Color	VARIUS-2048CL	BB	360-780	-	200	4.5	X/-	-	-
Fluorescence	ULS2048x64TEC ULS2048XL	VA, VB, UB	350-1100, 300-800	-	200	9.2 4.6	X	305	OSC
	HS2048XL	HS-500-0.33	200-1160	-	200	10.0	-	-	OSC
Fruit-sugar	VARIUS-2048CL	IA	800-1100	-	50	6.4	X	600	-
Gemology	VARIUS-2048	VA	350-1100	-	25	1.2	X	-	OSC
High-resolution	VARIUS-2048CL	VD	600-700	-	10	0.12	-	550	-
	VARIUS-4096CL	VD	600-700	-	10	0.05	-	550	-
High UV/NIR-Sensitivity	HS2048XL	HS-500-0.33	200-1160	-	200	10.0	-	-	OSC
Irradiance	VARIUS-2048CL	UA	200-1100	DUV	50	2.3	X/-	-	OSC-UA
Laserdiode	VARIUS-4096CL	NC	700-800	-	10	0.18	-	600	-
LED	VARIUS-2048CL	VA	350-1100	-	25	1.2	X/-	-	OSC
LIBS	VARIUS-4096CL	D,E,F	200-900	DUV	10	0.09	-	-	-
Raman	ULS2048LTEC ULS2048x64TEC	NC	780-930	-	25	0.3	X	600	-
Solar	ULS2048XL	VA	300-1100		50	2.5		305	OSC
Thin Films	ULS2048CL	UA	200-1100	DUV	100	4.6	X	-	OSC-UA
UV/VIS/NIR	ULS2048CL	UA	200-1100	DUV	25	1.2	X/-	-	OSC-UA
	ULS2048XL	UA	200-1100	-	25	1.5	-	-	OSC-UA
NIR	NIR512-1.7TEC	NIR200-1.5	1000-1750	-	25	6.0	-	1000	-
	NIR256-2.5TEC	NIR100-2.5	1000-2500	-	50	15.0	-	1000	OSC-NIR

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The grating can only be changed by Avantes.
Therefore, choose your grating wisely.
Our application specialists are available to support you with your choice.
In general, a higher resolution means a lower bandwidth.
By combining multiple spectrometers
in our AvaSpec-Dual or rack-mountable versions,
you can create one virtual spectrometer with high-resolution
and high bandwidth.

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