AVANTES
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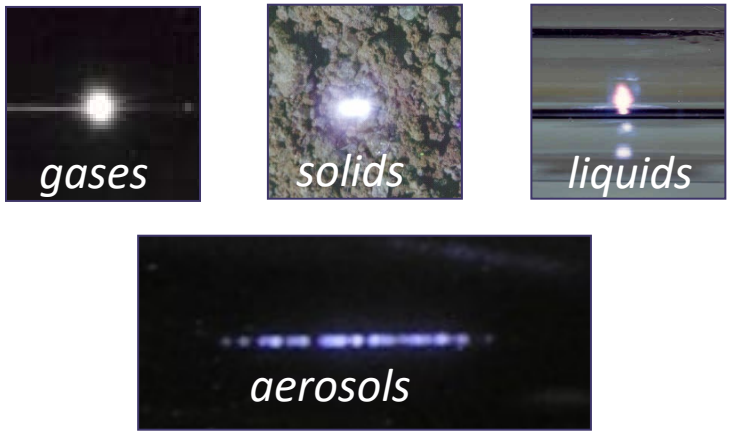
LIBS Configurations

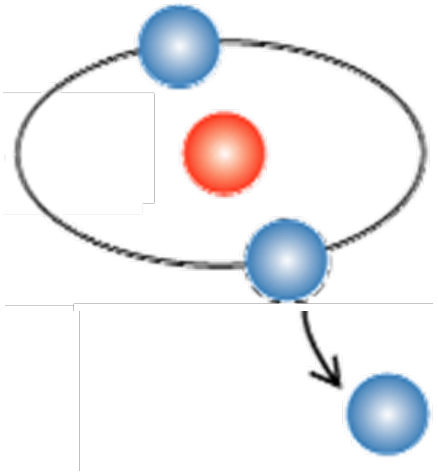
Avantes USA

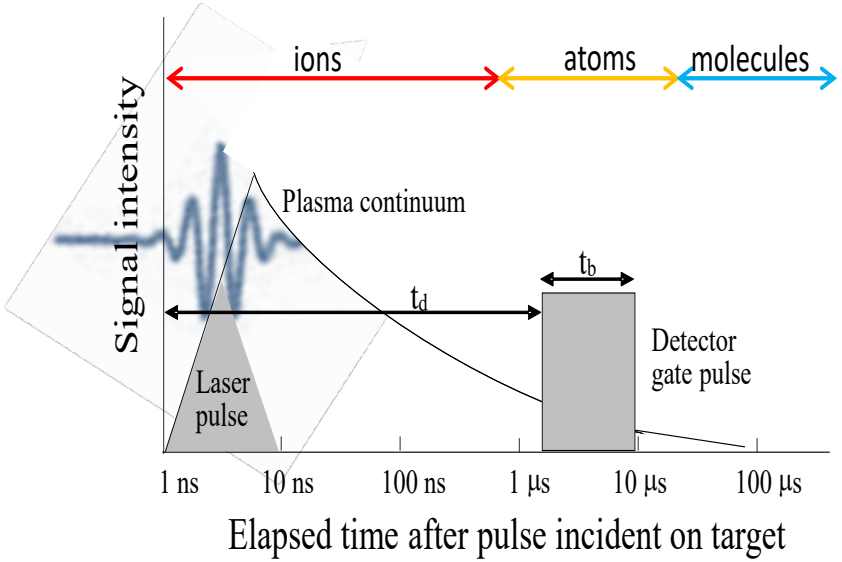
Laser Induced Breakdown Spectroscopy

LIBS is an Atomic Emission Spectroscopy technique, that uses a focused high energy laser to ionize a sample resulting in atomic emissions



Typical threshold ~10^{11}W/cm^2 for gasses and ~10^{10}W/cm^2 for liquids, solids, and aerosols.



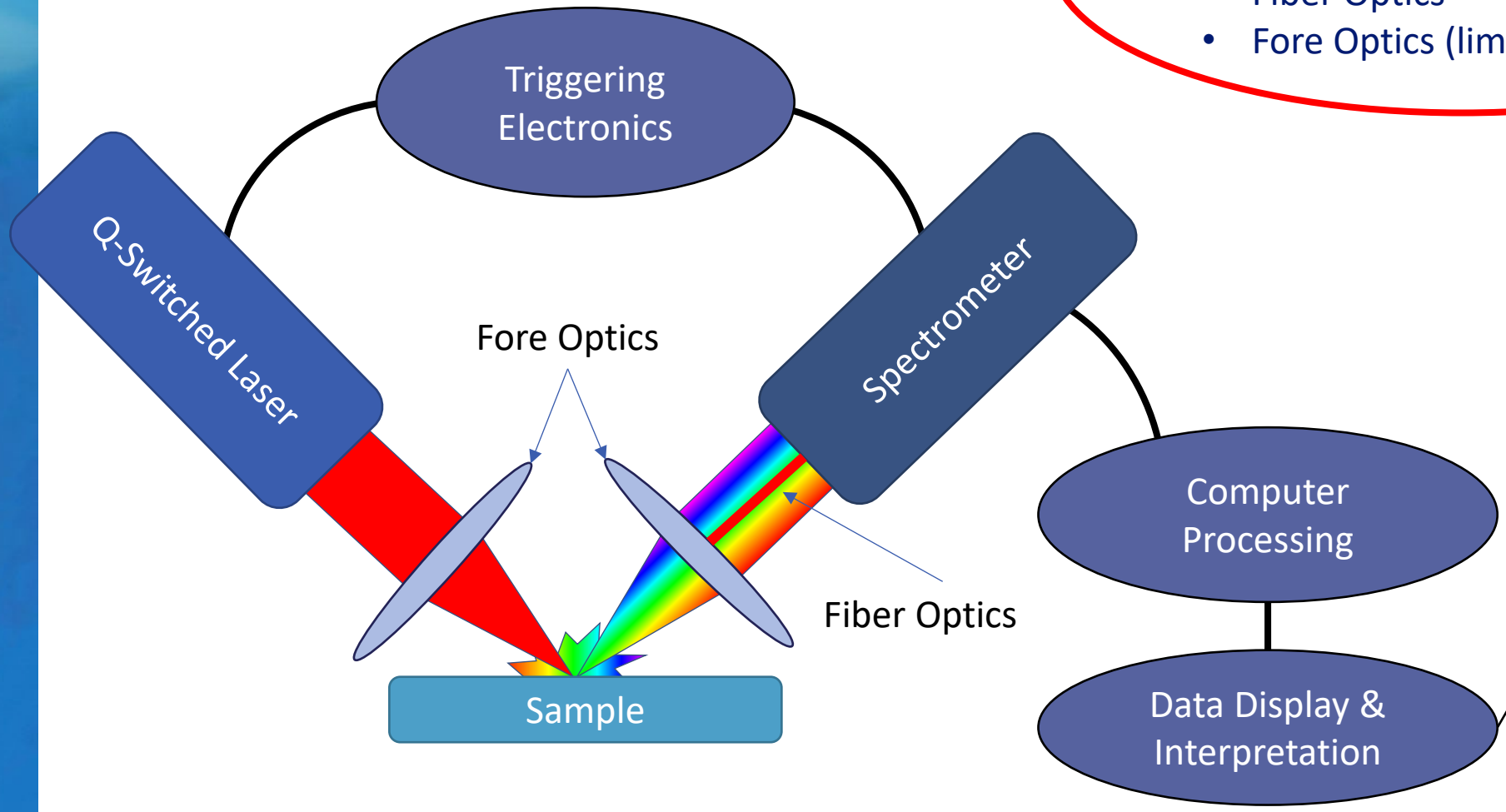


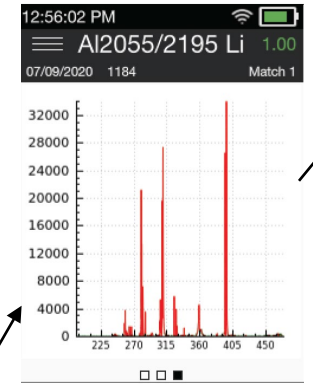
Advantages of LIBS

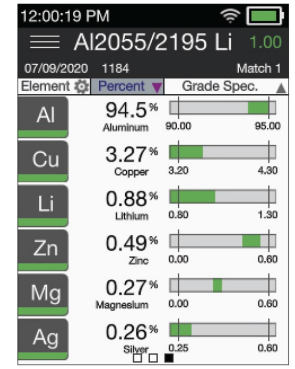
- ✓ No need for sample preparation
  - ✓ Only AES technique that doesn't require prep
- ✓ Minimal Sample Consumption – "micro-destructive"
  - ✓ μg level sample ablation per shot
  - ✓ ~100 μm laser spot (typical)
- ✓ Rapid measurements (real-time)
  - ✓ ~1 ms per spectrum
- ✓ Non-contact technique
  - ✓ Analysis of samples behind a window
- ✓ Detection of smaller atoms including C
  - ✓ XRF is typically limited to Si and up.

Components of a LIBS System

Avantes Capabilities
- Spectrometers
- Fiber Optics
- Fore Optics (limited offerings)







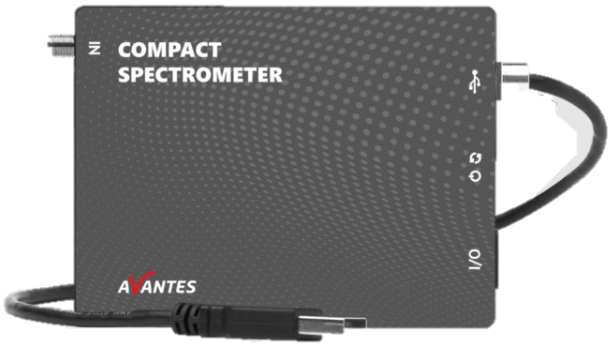
Why Avantes Spectrometers for LIBS?

- ✓ Size & Robustness
  - Relatively small form factor still capable of supporting high resolution (as low as 0.05 nm)
  - Fixed slits and optics provide for exceptional wavelength and thermal stability
- ✓ Timing and Triggering
  - On board field programmable gate array to control timing of spectrometer providing for 800 ns external trigger delay with 21 ns jitter
  - Synchronization of spectrometer channels
- ✓ Multi-channel capability
  - By arraying multiple spectrometer together Avantes can cover the full analytical window (190-1000 nm) for LIBS in very high resolution (around 0.1 nm FWHM)
- ✓ Cost
  - Avantes instruments are relatively low cost as compared with competitive technologies such as Eschelle grating instruments
- ✓ Inter-instrument repeatability
  - Avantes Avamation technology provides for semi-automated manufacturing allow for superior inter-instrument repeatability and the ability to scale to volume without adding human resources
- ✓ Experience
  - Avantes has worked with hundreds of LIBS applications over our 30 year history

LIBS Spectrometer Model Recommendations

ULS

Varius



Starline

- 2048 and 4096-pixel CMOS detectors
- Rackmount and Multi-Channel Housing (ULS only)
- Slight speed advantage with data transfer
- Digital IO: HD-26 connector, 2 Analog in, 2 Analog out, 13 Digital bidirectional, trigger, sync., strobe, laser
- USB3 and Ethernet communication
- Form Factor ULS: 177 x 127 x 44.5mm, 1155 grams
- Form Factor Varius: 183 x 130 X 45.2 mm, 1068 grams
- Replaceable slit optional add-on

Nexos

- 2048 and 4096-pixel CMOS detectors
- Improved Optical Bench and Detector Collection Lens, slight stray light advantage.
- Digital IO:5 bidirectional programmable I/O; 1 Analog out, 1 Analog in, 1x5V
- USB2 and SPI communication options
- Form Factor: 105 x 80 x 20mm, 277.5 grams
- Replaceable slit standard
- Can 3D print a multi-channel housing

Gratings and Resolution

Usable range (nm)	Spectral range (nm)	Lines/mm	Blaze (nm)	Order code
200-1100**	900	300	300	UA
200-1100**	900	300	300/1000	UNA-DB
200-850	515	600	300	UB
200-750	247-218*	1200	250	UC
200-650	163-143*	1800	UV	UD
200-580	113-69*	2400	UV	UE
200-400	69-45*	3600	UV	UF
250-850	515	600	400	BB
300-1100**	800	300	500	VA
360-1000	495	600	500	VB
300-800	247-218*	1200	500	VC
350-750	142-89*	1800	500	VD
350-640	74-49*	2400	VIS	VE
500-1050	495	600	750	NB
500-1050	218-148*	1200	750	NC
600-1100	346-297	830	800	SI
600-1100**	500	300	1000	IA
600-1100	495	600	1000	IB

Slit size (µm)	10	25	50	100	200	500
	2K resolution					
300 lines/mm grating	1.0	1.4	2.25	4.8	9.2	21.3
600 lines/mm grating	0.40-0.53*	0.7	1.2	2.4	4.6	10.8
830 lines/mm grating	0.32	0.48	0.93	1.7	3.4	8.5
1200 lines/mm grating	0.20-0.28*	0.27-0.38*	0.52-0.66*	1.1	2.3	5.4
1800 lines/mm grating	0.10-0.18*	0.20-0.29*	0.34-0.42*	0.8	1.6	3.6
2400 lines/mm grating	0.09-0.13*	0.13-0.17*	0.26-0.34*	0.44-0.64*	1.1	2.7
3600 lines/mm grating	0.06-0.08*	0.10	0.19	0.4	0.8	1.8
	4K resolution					
300 lines/mm grating	0.50-0.70	1.4	2.25	4.8	9.2	21.3
600 lines/mm grating	0.30-0.36*	0.7	1.2	2.4	4.6	10.8
830 lines/mm grating	0.25	0.48	0.93	1.7	3.4	8.5
1200 lines/mm grating	0.14-0.18*	0.27-0.38*	0.52-0.66*	1.1	2.3	5.4
1800 lines/mm grating	0.09-0.11*	0.20-0.29*	0.34-0.42*	0.8	1.6	3.6
2400 lines/mm grating	0.07-0.09*	0.13-0.17*	0.26-0.34*	0.44-0.64*	1.1	2.7
3600 lines/mm grating	0.05-0.06*	0.10	0.19	0.4	0.8	1.8

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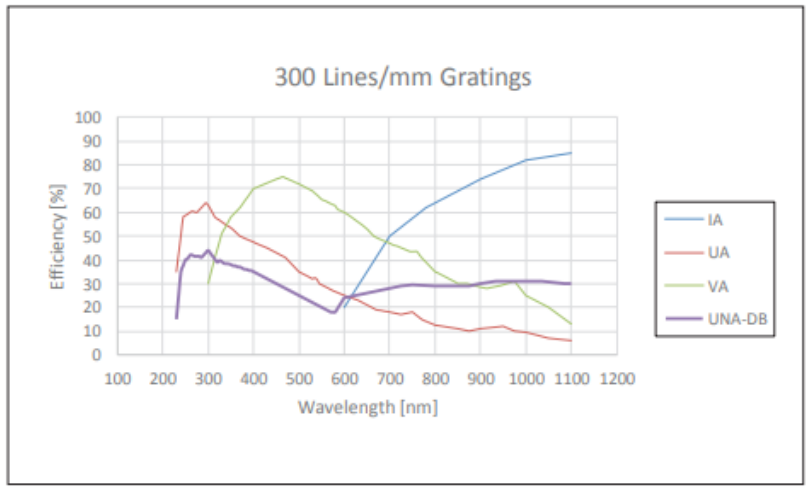
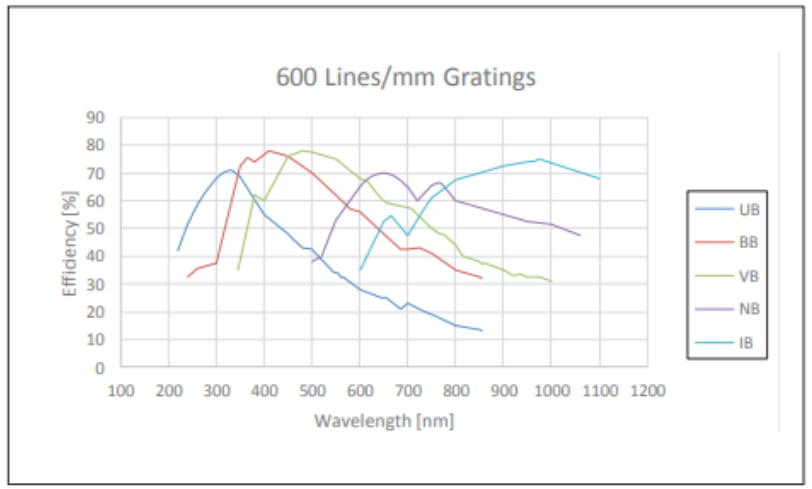
Grating Quantum Efficiency Curves

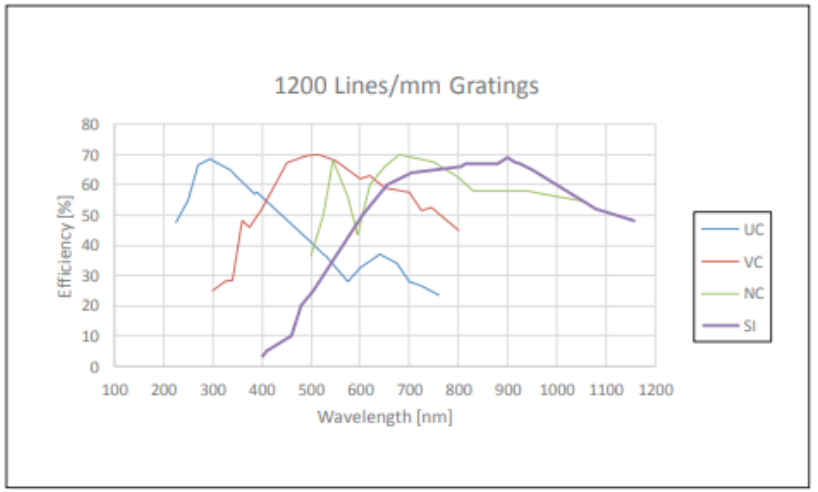
300 lines/mm Gratings



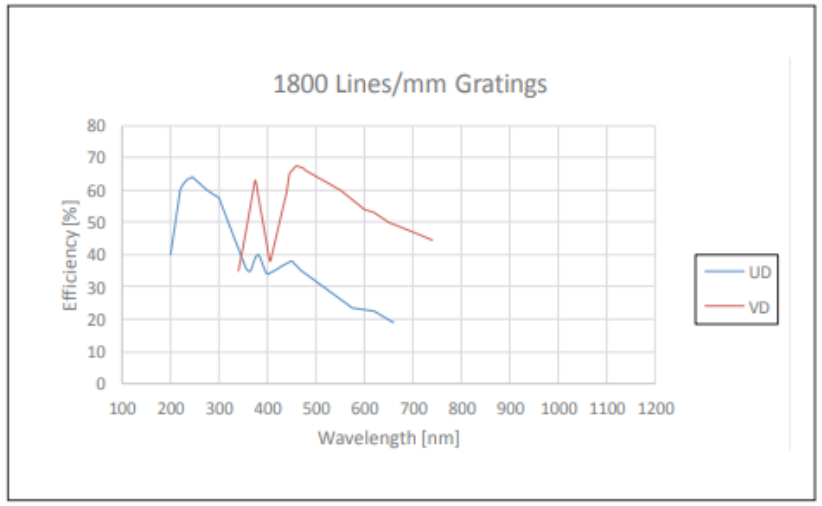
600 lines/mm Gratings



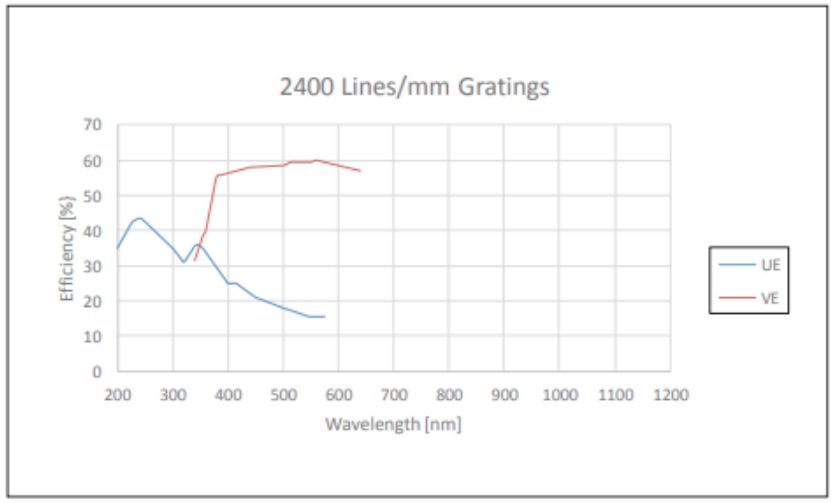
1200 lines/mm Gratings



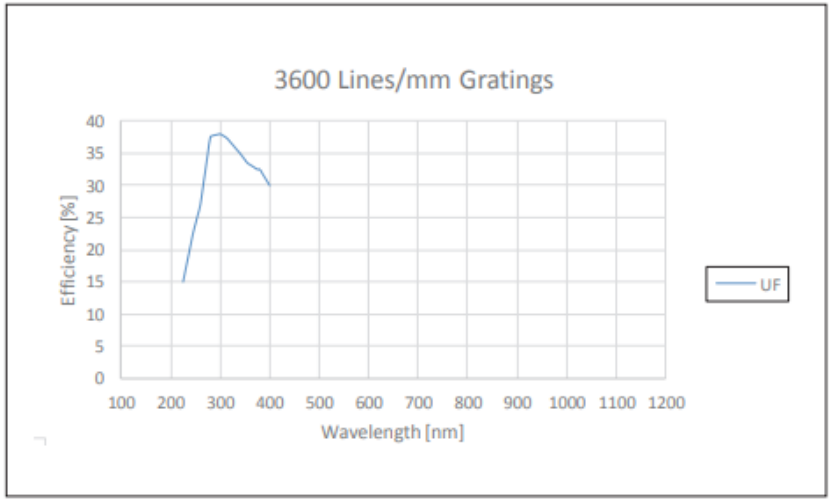
1800 lines/mm Gratings



2400 lines/mm Gratings



3600 lines/mm Grating



Single Channel LIBS Configuration Examples

Broadband Example			
Grating	**Spectral Range**	**Resolution w/ 10µm slit**	**Resolution w/ 25µm slit**
300 line/mm UA or VA (aka: Gratings MN0300-0.3, MN0300-0.5)	190-1100 nm or 300-1100 nm	2048: 1.0 nm 4096: 0.50-0.70 nm	2048: 1.4 nm 4096: 1.20-1.30 nm

UV/VIS Example *Using 'off-menu' L2 Grating			
Grating	**Spectral Range**	**Resolution w/ 10µm slit**	**Resolution w/ 25µm slit**
500 line/mm L2 (aka: Grating MN0500-0.33)	190-840 nm	2048: 0.50-0.55 nm 4096: 0.36-0.41 nm	2048: 0.8 nm 4096: 0.8 nm

UV Only			
Grating	**Spectral Range**	**Resolution w/ 10µm slit**	**Resolution w/ 25µm slit**
1200 line/mm UC (aka: MN1200-0.25)	190-440 nm	2048: 0.20-28 nm 4096: 0.14-0.18 nm	2048: 0.30 nm 4096: 0.30 nm

Dual-Channel LIBS Configuration Examples

Broadband Full Range 200-1100nm				
Channel #	**Grating**	**Spectral Range**	**Resolution w/ 10µm slit**	**Resolution w/ 25µm slit**
Channel 1	600 line/mm UB grating	190-600 nm	2048: 0.40-0.53 nm 4096: 0.30-0.36 nm	2048: 0.7 nm 4096: 0.7 nm
Channel 2	600 line/mm NB grating	600-1100 nm	2048: 0.40-0.53 nm 4096: 0.30-0.36 nm	2048: 0.7 nm 4096: 0.7 nm

Considering QE curves, best to pick up at 600 with NB grating. Could forgo 200-250nm and use more efficient BB grating.

Targeted Range Example 320-909nm				
Channel #	**Grating**	**Spectral Range**	**Resolution w/ 10µm slit**	**Resolution w/ 25µm slit**
Channel 1	1200 line/mm VC grating	320-567 nm	2048: 0.20-0.28 nm 4096: 0.14-0.18 nm	2048: 0.30 nm 4096: 0.30 nm
Channel 2	830 line/mm SI grating	565-909 nm	2048: 0.32 nm 4096: 0.25 nm	2048: 0.48 nm 4096: 0.48 nm

Four-Channel LIBS Configuration Example

4-Channel Desktop Housing Example				
Channel #	**Grating**	**Spectral Range**	**Resolution w/ 10µm slit**	**Resolution w/ 25µm slit**
Channel 1	1200 line/mm UC grating (aka: Grating MN1200-0.25)	200-466 nm	2048: 0.2-0.28 nm 4096: 0.14-0.18 nm	2048: 0.30 nm 4096: 0.30 nm
Channel 2	1200 line/mm VC grating (aka: Grating MN1200-0.50)	460-694 nm	2048: 0.2-0.28 nm 4096: 0.14-0.18 nm	2048: 0.30 nm 4096: 0.30 nm
Channel 3	1200 line/mm NC grating (aka: Grating MN1200-0.75)	690-890 nm	2048: 0.2-0.28 nm 4096: 0.14-0.18 nm	2048: 0.30 nm 4096: 0.30 nm
Channel 4	1200 line/mm NC grating (aka: Grating MN1200-0.75)	885-1050 nm	2048: 0.2-0.28 nm 4096: 0.14-0.18 nm	2048: 0.30 nm 4096: 0.30 nm

Six-Channel LIBS Configuration Example

6-Channel Desktop Housing Example				
Channel #	**Grating**	**Spectral Range**	**Resolution w/ 10µm slit**	**Resolution w/ 25µm slit**
Channel 1	2400 line/mm UE grating (aka: Grating MN2400-0.25)	190-310 nm	2048: 0.09-0.13 nm 4096: 0.07-0.09 nm	2048: 0.13 – 0.17 nm 4096: 0.13-0.17 nm
Channel 2	2400 line/mm VE grating (aka: Grating MN2400-0.50)	305-410 nm	2048: 0.09-0.13 nm 4096: 0.07-0.09 nm	2048: 0.13 – 0.17 nm 4096: 0.13-0.17 nm
Channel 3	2400 line/mm VE grating (aka: Grating MN2400-0.50)	405-493 nm	2048: 0.09-0.13 nm 4096: 0.07-0.09 nm	2048: 0.13 – 0.17 nm 4096: 0.13- 0.17 nm
Channel 4	1800 line/mm VD grating (aka: Grating MN1800-0.50)	489-615 nm	2048: 0.1-0.18 nm 4096: 0.09-0.11 nm	2048: 0.20-0.29 nm 4096: 0.20-0.29 nm
Channel 5	1200 line/mm NC grating	610-818 nm	2048: 0.2-0.28 nm 4096: 0.14-0.18 nm	2048: 0.27-0.38 nm 4096: 0.27-0.38 nm
Channel 6	1200 line/mm NC grating	815-990 nm	2048: 0.2-0.28 nm 4096: 0.14-0.18 nm	2048: 0.27-0.38 nm 4096: 0.27-0.38 nm

Eight-Channel LIBS Configuration Example

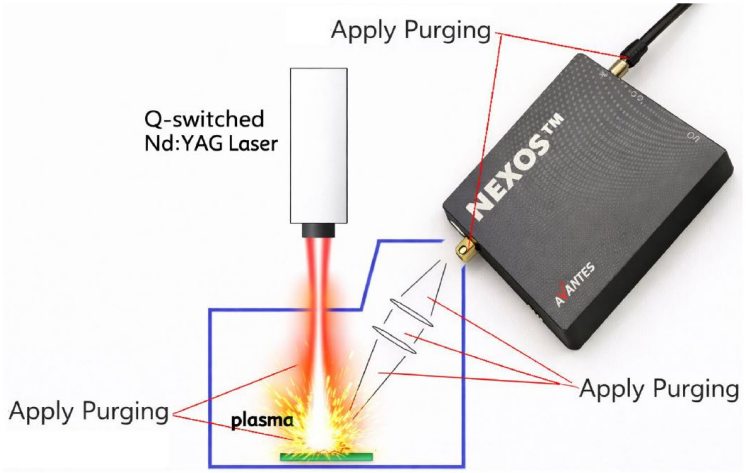
8-Channel Desktop Housing Example				
Channel #	**Grating**	**Spectral Range**	**Resolution w/ 10µm slit**	**Resolution w/ 25µm slit**
Channel 1	2400 line/mm UE grating	200-319nm	2048: 0.09-0.13 nm 4096: 0.07-0.09 nm	2048: 0.13-0.17 nm 4096: 0.13-0.15 nm
Channel 2	2400 line/mm UE grating	315-418nm	2048: 0.09-0.13 nm 4096: 0.07-0.09 nm	2048: 0.13-0.17 nm 4096: 0.13-0.15 nm
Channel 3	2400 line/mm VE grating	415-501nm	2048: 0.09-0.13 nm 4096: 0.07-0.09 nm	2048: 0.13-0.17 nm 4096: 0.13-0.15 nm
Channel 4	2400 line/mm VE grating	496-566nm	2048: 0.09-0.13 nm 4096: 0.07-0.09 nm	2048: 0.13-0.17 nm 4096: 0.13-0.15 nm
Channel 5	2400 line/mm VE grating	562-617nm	2048: 0.09-0.13 nm 4096: 0.07-0.09 nm	2048: 0.13-0.17 nm 4096: 0.13-0.15 nm
Channel 6	1800 line/mm VD grating	615-718nm	2048: 0.10-0.18 nm 4096: 0.09-0.11 nm	2048: 0.20-0.29 nm 4096: 0.18 nm
Channel 7	1200 line/mm NC grating	715-906nm	2048: 0.20-0.28 nm 4096: 0.14-0.18 nm	2048: 0.30 nm 4096: 0.30 nm
Channel 8	1200 line/mm NC grating	900-1050nm	2048: 0.20-0.28 nm 4096: 0.14-0.18 nm	2048: 0.30 nm 4096: 0.30 nm

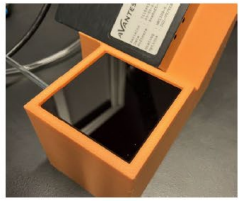
Deep UV Spectrometers

Detection of some elements such as sulfur, carbon, nitrogen require measurements into the deep UV below the 185 nm oxygen absorption limit. While a vacuum purge is not possible with most portable application purging with an inert gas such as argon is feasible for such applications. Avantes offers purge port options on specific models (ULS) as a standard and as special upgrade option for other models (Nexos).

With the purge option installed the use of fibers is not possible so free space illumination of the slit is required and this may require the additional of focusing optics.

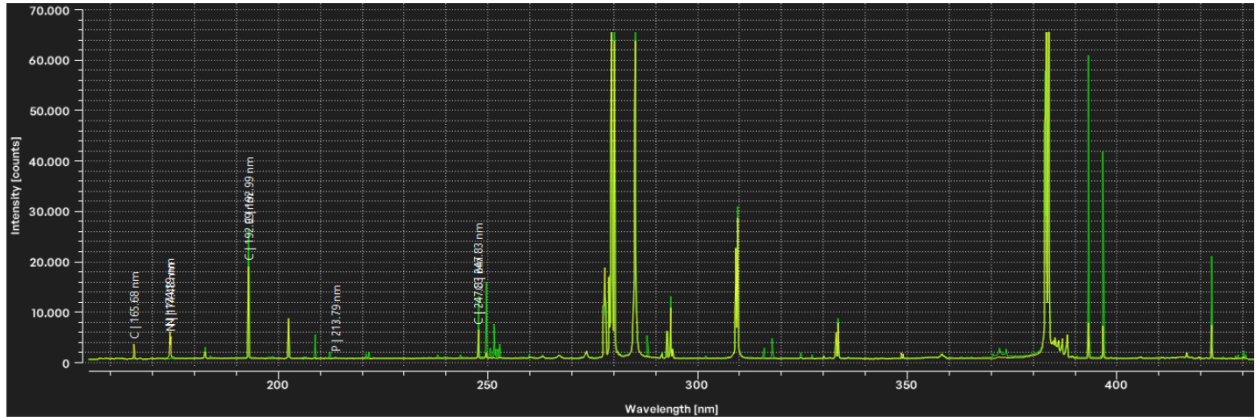
PURGED SPECTROMETERS





PURGED MEASUREMENT (NITROGEN)

Similar measurements without Purge (Green Spectrum) and with Purge (Yellow spectrum):



Multi-Channel Housing Options for Starline and ULS Models only

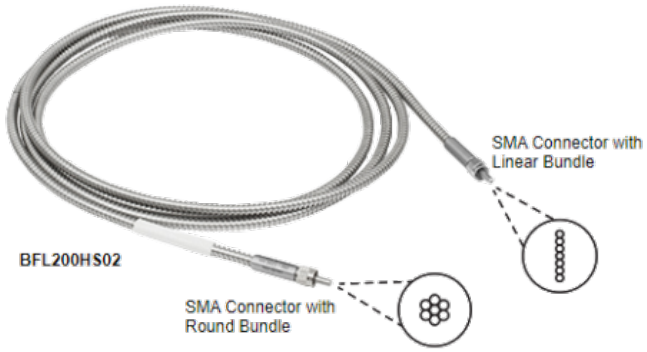
Dual-Channel Housing for ULS spectrometers

Four-Channel Desktop Housing for ULS spectrometers

10-Channel Rackmount for ULS spectrometers

Fibers Optics and Collection Optics

- Multi-Furcated Fibers – Single fiber leg per spectrometer channel to common end bundle for collimating lens
- Round to linear fiber configurations
- Multiple Jacketing Options. Stainless steel –BX jacketing or PVC coated steel monocoil recommended.
- Various Collimating Lens Options.



Additional Considerations

- Choosing a 4096-pixel detector over a 2048-pixel detector yields better resolution only with a 10µm slit and slightly with a 25µm slit. This does provide twice as many data points as well. It comes at the cost of half the photon density per pixel given the same integration. Most LIBS applications use our 2048 pixel detectors
- The tighter the groove density on the grating, the shorter the range and higher resolution. But the grating is also taking a smaller sampling of light and spreading it out over the detector. This yields less signal per integration compared to more broad gratings. It is possible to be overambitious chasing resolution and not have enough light to avoid long integration times which will negatively impact signal to noise
- Relative irradiance calibration can be applied to each spectrometer channel for a normalization of detector response across one or more spectrometer channels. Avantes offers some lamps for this purpose (Avalight-DH-CAL).
- Generally fibers must remain attached to the slit post-calibration to maintain calibration integrity.

THANK YOU!

Go ahead and buy.