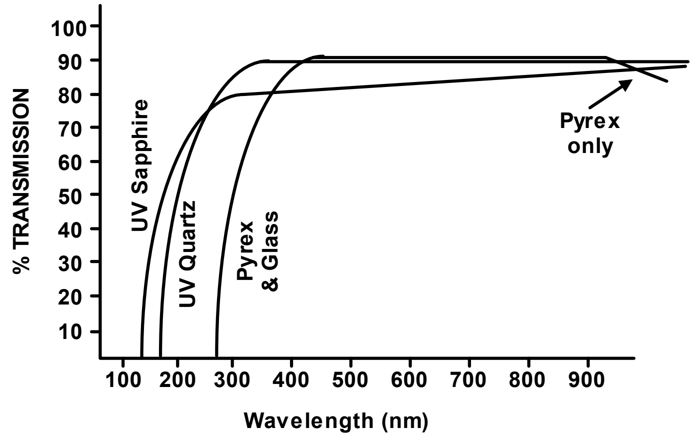
Applications Information

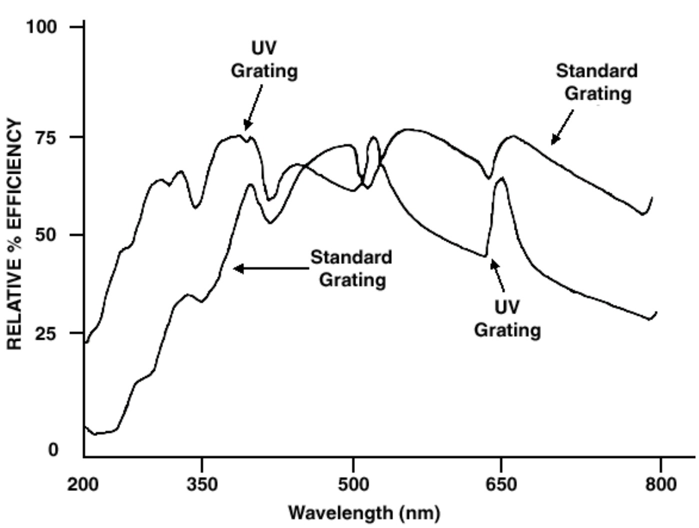
Window Materials



In applications where plasma is viewed through a window, the proper selection of window material is essential to viewing the desired spectra. Use the chart at the left to select the proper window material, viewports, lenses, etc. As a rule, costs increase as ultraviolet (UV) transmittance improves.

Resistance to etching is an additional consideration in window material selection. Of the options presented here, UV sapphire offers the greatest resistance to etching. Of course, window material selection is not an issue when using a viewing technique that employs a vacuum feedthrough.

Grating Options



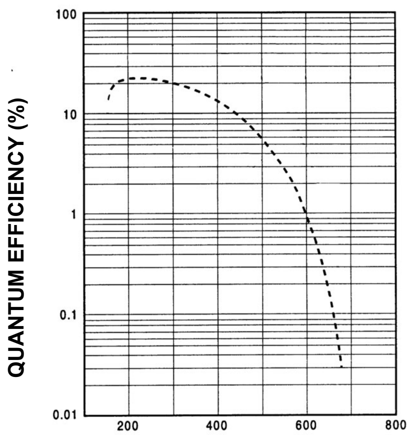
The EP Series monochromators are available with a UV or standard grating. The diagram on the left shows the relative efficiency of these gratings. Note that the blaze wavelength occurs on the low side of the grating ≥30% efficiency range.

Grating Type	Standard	UV
Typical Range	VIS/NIR	UV/VIS
Blaze Wavelength	450nm	350nm
≥ 30% Efficiency Range	310–920	220–750

Detector Spectral Response

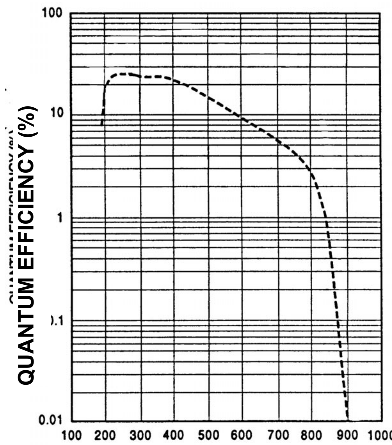
EP200 Series/SD100

UV Enhanced PMT



WAVELENGTH (nm)
Range: 185–650nm
Max. Voltage: 1000VDC

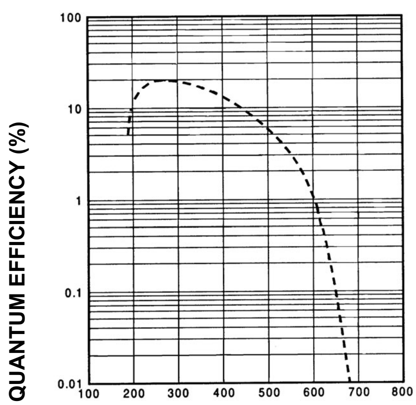
Standard PMT



WAVELENGTH (nm)
Range: 185–900nm
Max. Voltage: 1000VDC

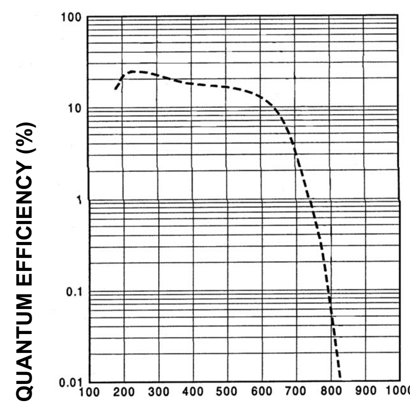
PM Series – PM100/140/220/225

UV/VIS PMT



WAVELENGTH (nm)
Range: 185–650nm
Max. Voltage: 1000VDC

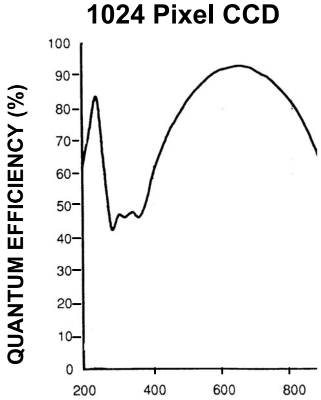
UV/VIS/NIR PMT



WAVELENGTH (nm)
Range: 185–830nm
Max. Voltage: 1000VDC

SD1024D

1024 Pixel CCD

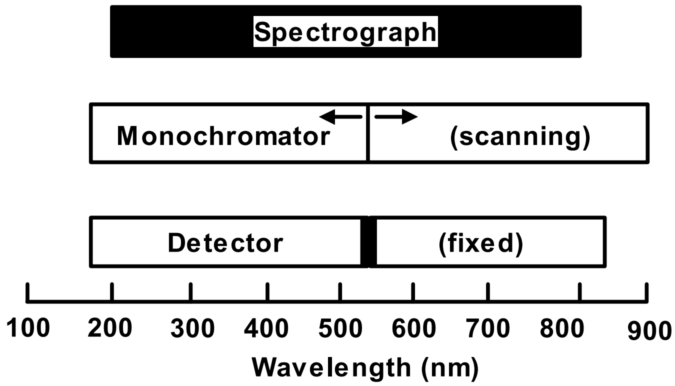


WAVELENGTH (nm)
Range: 200–800nm

The CCD used in the SD1024D spectrograph provides scientific grade performance. Since it is backthinned, it has excellent UV performance and is TE cooled for increased stability. Additional sensitivity is derived through software that permits the selective addition of discrete wavelengths.

Note: the quantum efficiency of the general-purpose CCD in the SD1024DL and SD2048DL is not represented.

Instrument Ranges



The wavelength(s) of interest are a major consideration when selecting the proper instrument. Spectrographs, using CCD technology, permit continuous measurement of all wavelengths in the instrument's operating range.

Monochromators measure a single wavelength by means of slits, gratings, mirrors and photomultiplier tubes (PMTs). To change a monochromator's wavelength setting, a stepper motor or micrometer is used to adjust grating position.

Interference filter-based detectors are the simplest, least expensive optical emission analysis instrument. The drawback of the interference filter detector is its wider bandpass, typically 10nm, and the inability to easily change the wavelength analyzed.

Automatic Gain Control

All Verity photomultiplier-based instruments include a provision for automatic PMT high voltage control. The setting of the PMT's high voltage control determines its sensitivity or gain. When used with Verity's system controllers, or integrally with the SD100, the automatic gain control (AGC) feature implements a gain correction algorithm to automatically adjust PMT high voltage.

The AGC is completed once the output of the PMT detector reaches a preset target value, typically about 7V on a 0–10V scale. When it is found that the signal level is not significantly changing, an automatic gain correction is made at a fixed time interval near the beginning of each process step. In this manner, both the short- and long-term effects of signal degradation can be corrected, providing each endpoint trace starts at the same preset value.

Correction for Clouding Optics

Clouding of the optical interface can be minimized through the use of a bakeable capillary cartridge assembly as part of a vacuum feedthrough system. See page 79 in the Optics section for additional information on the capillary cartridge assembly.

Direct Viewing

Monochromator with Direct Viewing Quartz Lens Coupler

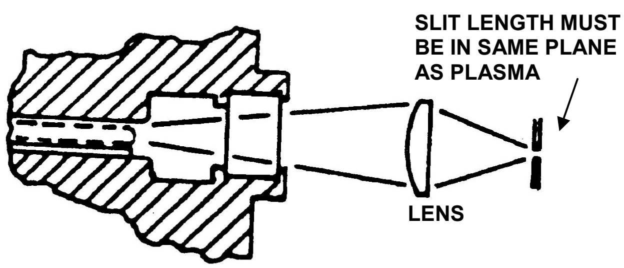
Direct viewing refers to the use of an instrument without a fiber optic cable.

General Information

Use direct viewing in applications when an optical window provides line-of-sight access to the plasma and when there is room to mount the instrument in close proximity to the window. For this technique, it is essential for the window to possess proper transmission characteristics.

When using the EP200 Series monochromator or the PM100 detector in this viewing mode, please note that harmful UV light could be transmitted through some window types (e.g., quartz and sapphire). A light shield or UV blocker, such as acrylic, should be adapted around the detector bus coupler to prevent UV light leakage outside the detector system.

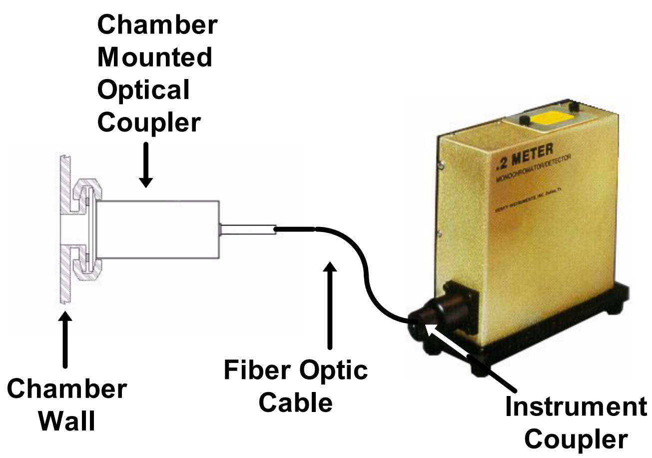
Direct viewing is standard with PM100, PM140, PM220 and PM225 detectors, and optional with EP200 Series monochromators. Note, however, that the PM140 and PM225 are optically sealed using a KF40 flange, thus eliminating concerns of UV leaks at the instrument/chamber interface.



Monochromator Slit Orientation

When using direct viewing techniques, it is important that the monochromator slit is oriented in the same plane as the plasma. This orientation will provide the strongest signal for endpoint species. Note that the monochromator's slit length is vertically oriented when the monochromator is placed on the front or back side (the narrow sides, not the largest sides).

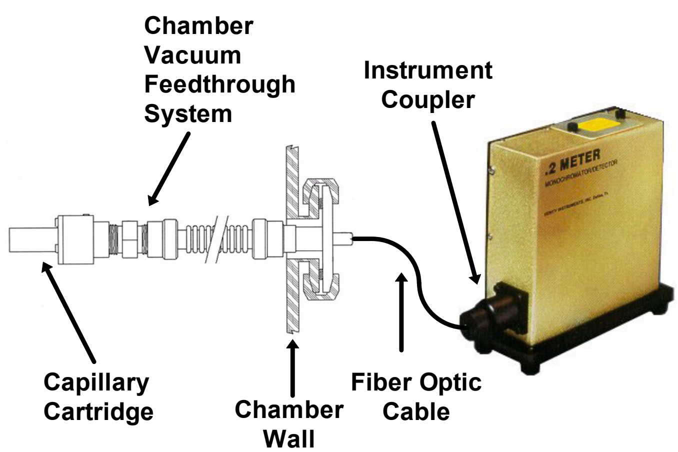
Indirect Viewing



Indirect viewing refers to the use of an optical instrument with a fiber optic cable.

Without a Vacuum Feedthrough System

Use indirect viewing without a vacuum feedthrough when an optical window is available with direct viewing access to the plasma, but without room to mount the instrument adjacent to the window. With this technique, it is important that the window have proper transmission characteristics. Additional hardware required for indirect viewing adds to the cost of the system.



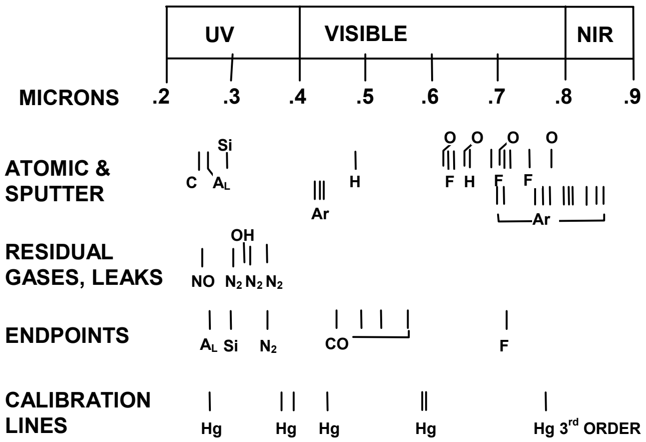
With a Vacuum Feedthrough System

Use indirect viewing with a vacuum feedthrough system in applications where the window or viewport may become coated with process material, or if a feedthrough provides better viewing of the plasma.

This system includes a vacuum feedthrough, flexible tube and an optical head. The optical head includes an optional capillary cartridge, which is an array of small bore stainless steel tubes with a high aspect ratio (length to diameter) that help prevent contamination from reaching the lens. See page 79, Chamber-Mounted Vacuum Feedthroughs for additional information.

Emission Species

Spectra of Common Species



Representative Emission Lines Used in Endpoint Detection of Plasma Etching

Use the table below when considering wavelengths to monitor. This table is an abbreviated list of the wavelength information presented on pages 11 and 12, and has been developed from Verity research and Herman[1].

Monitored species	Wavelength (nm)
Al	308.2, 309.3, 396.1
AlCl	261.4
As	235.0
C_2	516.5
CF_2	251.9
Cl	741.4
CN	289.8, 304.2, 387.0
CO	292.5, 302.8, 313.8, 325.3, 482.5, 483.5, 519.8
F	703.7, 712.8
Ga	417.2
H	486.1, 656.5
In	325.6
N	674.0
N_2	315.9, 337.1
NO	247.9, 288.5, 289.3, 303.5, 304.3, 319.8, 320.7, 337.7, 338.6
O	777.2, 844.7
OH	281.1, 306.4, 308.9
S	469.5
Si	288.2
SiCl	287.1
SiF	440.1, 777.0

[1] From Herman, Irving, P. (1996), “Optics Diagnostics for Thin Film Processing,” Academic Press, p. 177. Ref. From Singer (1988), Selwyn (1993) and other sources cited in the text.

Common Spectral Lines in Etching Applications

200nm	201.2 – Au 202.1 – Au 205.5 – Cr 206.8 – Ge 221.6 – Ni 228.8 – Cd 229.9 – SiO 232.0 – Ni 234.4 – SiO 235.0 – As 237.0 – NO 238.9 – CO	240.0 – CF 241.4 – SiO 242.8 – Au 247.4 – CF 247.9 – NO 248.3 – Fe 248.7 – SiO 248.8 – CF_2 249.8 – B 251.9 – CF_2 253.6 – P 253.7 – Hg	254.4 – Cl_2 255.1 – W 255.3 – P 255.8 – CF 256.1 – Cl_2 257.8 – He 258.0 – CCl 259.5 – CF_2 259.6 – NO 261.4 – AlCl 262.8 – Pt 262.9 – CF_2	264.8 – AlCl 264.7 – Ta 265.1 – Ge 265.9 – Pt 266.5 – BCl 266.9 – SiO 267.6 – Au 268.0 – NO 268.3 – AlCl 269.4 – SiO 269.8 – CO 270.2 – Pt	271.1 – CF_2 271.5 – Ta 272.2 – BCl 272.2 – NO 272.4 – W 274.8 – Au 275.0 – CF_2 277.8 – CCl 278.8 – CCl 280.0 – CF_2 280.2 – Pb 280.7 – SiCl	281.0 – SiCl 281.1 – OH 281.4 – N_2 282.0 – N_2 282.4 – SiCl 283.3 – CO 283.3 – Pb 283.7 – C 286.0 – BCl 286.0 – NO 287.1 – SiCl 288.0 – CO_2	288.2 – Si 288.5 – NO 289.3 – NO 289.8 – CN 290.0 – CO_2 292.1 – CF_2 292.5 – CO 293.0 – Pt 295.3 – N_2 296.2 – N_2 297.7 – N_2
300nm	301.2 – Ni 301.2 – Ta 302.1 – OH 302.8 – CO 303.5 – NO 304.2 – CN 304.3 – NO 306.4 – OH 306.5 – Pt 306.7 – OH 307.0 – CCl 307.8 – OH 308.2 – Al 308.9 – OH 309.3 – Al 310.4 – N_2	311.7 – N_2 312.3 – Au 313.2 – Mo 313.4 – CO 313.6 – N_2 313.8 – CO 315.9 – N_2 317.0 – Mo 319.3 – Mo 319.8 – NO 320.7 – NO 321.4 – CF_2 324.7 – Cu 325.3 – CO 325.6 – In 326.8 – N_2	327.4 – Cu 328.1 – Ag 328.5 – N_2 330.6 – CO 330.9 – N_2 331.1 – Ta 333.9 – N_2 334.6 – SiF 335.0 – Gd 335.0 – N_2 335.0 – Ti 336.0 – NH 336.3 – SiF 337.0 – CO_2 337.1 – N_2 337.7 – NO	338.3 – Ag 338.6 – NO 339.2– Zr 340.5 – Pd 341.5 – Ni 343.8 – Zr 346.2 – Ni 346.6 – Cd 349.3 – CO 349.6 – Zr 350.0 – N_2 352.5 – Ni 353.7 – N_2 357.2 – NO 357.7 – N_2 357.9 – Cr	358.1 – Fe 358.4 – NO 358.6 – CN 359.0 – CN 359.3 – Cr 360.1 – Zr 360.5 – Cr 361.0 – Pd 361.1 – Cd 363.5 – Pd 363.5 – Ti 364.2 – N_2 365.0 – Hg 365.3 – Ti 367.2 – N_2 368.3 – Pb	371.1 – N_2 372.0 – Fe 373.7 – Fe 375.5 – N_2 376.8 – Gd 379.8 – Mo 380.5 – N_2 382.0 – He 385.8 – N_2 386.2 – CN 386.4 – Mo 387.0 – CN 387.1 – CN 388.3 – CN 388.9 – He 389.5 – N_2	389.0 – Zr 390.2 – SiCl 390.3 – Mo 391.2 – O 394.3 – N_2 394.4 – Al 395.5 – SiF_2 396.0 – Al 396.5 – He 397.3 – O 399.8 – N_2 399.9 – Ti
400nm	400.0 – Ti 400.9 – W 402.6 – He 404.7 – Hg 405.1 – SiN 405.8 – Pb 405.9 – N_2 407.2 – W 407.4 – W 407.6 – O	407.7 – TiF 408.1 – Zr 408.7 – SiN 409.5 – N_2 410.2 – In 411.6 – SiN 412.7 – SiN 414.2 – N_2 417.2 – Ga 418.1 – CN	418.3 – TiCl 419.0 – O 419.3 – TiCl 419.7 – CN 420.0 – N_2 420.4 – SiN 421.6 – CN 423.9 – SiN 424.1 – AlH 425.4 – Cr	425.9 – AlH 426.7 – C 427.0 – N_2 427.5 – Cr 429.5 – W 431.4 – CH 434.0 – H 434.5 – N_2 434.8 – Ar 435.8 – Hg	436.8 – SiF 438.8 – He 440.1 – SiF 440.7 – SiN 444.3 – SiN 447.1 – He 451.1 – In 451.1 – CO 460.0 – CO 460.2 – P	464.9 – O 468.8 – Zr 469.0 – Zr 469.5 – S 471.3 – He 473.7 – C_2 474.2 – Ge 476.5 – Ar 479.4 – Cl 482.5 – CO	483.5 – CO 486.1 – H 488.0 – Ar 489.7 – Cl 492.2 – He
500nm	501.6 – He 504.1 – Si 504.8 – He 505.5 – Si	508.6 – Cd 516.5 – C_2 519.8 – CO 520.8 – Cr	520.9 – Ag 521.8 – Cl 542.3 – Cl 546.6 – Ag	546.0 – Hg 561.0 – CO 575.5 – N_2 580.4 – N_2	585.8 – Cn 585.4 – N_2 587.6 – He 589.3 – Ge	590.6 – N_2 595.9 – N_2	
600nm	601.4 – N_2 607.0 – N_2 608.0 – CO 615.6 – O 615.7 – O 615.8 – O	623.9 – F 632.3 – N_2 634.7 – Si 634.8 – F 637.1 – Si 639.5 – N_2	639.7 – Ga 641.3 – Ga 641.4 – F 643.8 – Cd 645.6 – O 646.0 – P	646.9 – N_2 647.8 – CN 654.5 – N_2 656.3 – H 656.5 – H 662.0 – CO	662.4 – N_2 667.8 – He 670.5 – N_2 674.0 – N 677.4 – F 678.9 – N_2	683.4 – F 685.4 – F 685.6 – F 687.0 – F 690.2 – F 691.0 – F	696.5 – Ar 696.6 – F
700nm	703.7 – F 706.5 – He 706.7 – Ar 712.8 – F 716.5 – N_2	720.2 – F 725.4 – O 725.6 – Cl 727.3 – N_2 728.1 – He	732.6 – C 733.2 – F 738.4 – Ar 738.7 – N_2 739.9 – F	741.4 – Cl 742.6 – F 750.4 – Ar 750.4 – N_2 751.5 – Ar	751.5 – F 755.2 – F 757.3 – F 760.7 – F 762.6 – N_2	763.5 – Ar 772.4 – Ar 775.3 – N_2 775.5 – F 777.0 – SiF	777.2 – O 780.0 – F 787.3 – CN 789.6 – N_2 794.8 – Ar
800nm	844.7 – O						

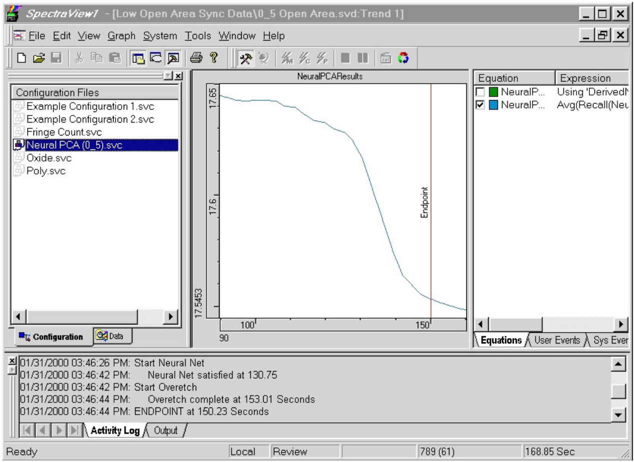
[1]This table is based on Verity research; Herman, Irving P. (1996), "Optics Diagnostics for Thin Film Processing," Academic Press, p. 177 (from Singer (1988), Selwyn (1993), and other sources cited in the text "CRC Handbook of Chemistry and Physics," CRC Press, Inc. (1978); and Pearse, R.W.B. and Gaydon, A. G. (1976), "Identification of Molecular Spectra", Chapman and Hall.

Common Spectral Lines in Etching Applications

A	Ag	328.1, 338.3, 520.9, 546.6
	Al	308.2, 309.3, 394.4, 396.1
	AlCl	261.4, 264.8, 268.3
	AlH	424.1, 425.9
	Ar	434.8, 476.5, 488.0, 696.5, 706.7, 738.4, 750.4, 751.5, 763.5, 772.4, 794.8
	As	235.0
	Au	201.2, 202.1, 242.8, 267.6, 274.8, 312.3
B	B	249.8
	BCl	266.5, 272.2, 286.0
C	C	283.7, 426.7, 732.6
	C_2	473.7, 516.5
	CCl	258.0, 277.8, 278.8, 307.0, 460.0
	Cd	228.8, 346.6, 361.1, 508.6, 643.8
	CF	240.0, 247.4, 255.8
	CF_2	248.8, 251.9, 259.5, 262.9, 271.1, 275.0, 280.0, 292.1, 321.4
	CH	431.4
	Cl	479.4, 489.7, 521.8, 542.3, 725.6, 741.4
	Cl_2	254.4, 256.1
	CN	289.8, 304.2, 358.6, 359.0, 386.2, 387.0, 387.1, 388.3, 418.1, 419.7, 421.6, 585.8, 647.8, 787.3
	CO	238.9, 269.8, 283.3, 292.5, 302.8, 313.4, 313.8, 325.3, 330.6, 349.3, 451.1, 482.5, 483.5, 519.8, 561.0, 608.0, 662.0
	CO_2+	337.0
	Cr	205.5, 357.9, 359.3, 360.5, 425.4, 427.5, 520.8
	Cu	324.7, 327.4
F	F	623.9, 634.8, 641.4, 677.4, 683.4, 685.4, 685.6, 687.0, 690.2, 691.0, 696.6, 703.7, 712.8, 720.2, 733.2, 739.9, 742.6, 755.2, 757.3, 760.7, 775.5, 780.0
	Fe	248.3, 358.1, 372.0, 373.7
G	Ga	417.2, 639.7, 641.3
	Gd	335.0, 376.8
	Ge	206.8, 265.1, 474.2, 589.3
H	H	434.0, 486.1, 656.3, 656.5
	He	257.8, 382.0, 388.9, 396.5, 402.6, 438.8, 447.1, 471.3, 492.2, 501.6, 504.8, 587.6, 667.8, 706.5, 728.1
	Hg	253.7, 365.0, 404.7, 435.8, 546.1
I	In	325.6, 410.2, 451.1
M	Mo	313.2, 317.0, 319.3, 379.8, 386.4, 390.3
N	N	674.0
	N_2	281.4, 282.0, 295.3, 296.2, 297.7, 310.4, 311.7, 313.6, 315.9, 326.8, 328.5, 330.9, 333.9, 335.0, 337.1, 350.0, 353.7, 357.7, 364.2, 367.2, 371.1, 375.5, 380.5, 385.8, 389.5, 394.3, 399.8, 405.9, 409.5, 414.2, 420.0, 427.0, 434.5, 575.5, 580.4, 585.4, 590.6, 595.9, 601.4, 607.0, 632.3, 639.5, 646.9, 654.5, 662.4, 670.5, 678.9, 716.5, 727.3, 738.7, 750.4, 762.6, 775.3, 789.6
	NH	336.0
	Ni	221.6, 232.0, 301.2, 341.5, 346.2, 352.5
	NO	237.0, 247.9, 259.6, 268.0, 272.2, 286.0, 288.5, 289.3, 303.5, 304.3, 319.8, 320.7, 337.7, 338.6, 357.2, 358.4
O	O	391.2, 397.3, 407.6, 419.0, 464.9, 615.6, 615.7, 615.8, 645.6, 725.4, 777.2, 844.7
	OH	281.1, 302.1, 306.4, 306.7, 307.8, 308.9
P	P	253.6, 255.3, 460.2, 646.0
	Pb	280.2, 283.3, 368.3, 405.8
	Pd	340.5, 361.0, 363.5
	Pt	262.8, 265.9, 270.2, 293.0, 306.5
S	S	469.5
	Si	288.2, 504.1, 505.5, 634.7, 637.1
	SiCl	280.7, 281.0, 282.4, 287.1
	SiF	334.6, 336.3, 436.8, 440.1, 777.0
	SiF_2	390.2, 395.5
	SiN	405.1, 408.7, 411.6, 412.7, 420.4, 423.9, 440.7, 444.3
	SiO	229.9, 234.4, 241.4, 248.7, 266.9, 269.4
T	Ta	264.7, 271.5, 301.2, 331.1
	Ti	335.0, 363.5, 365.3, 399.9
	TiCl	418.3, 419.3
	TiF	407.7
W	W	255.1, 272.4, 400.9, 407.4, 429.5
Z	Zn	339.2, 343.8, 349.6, 360.1, 389.0, 407.3, 408.1, 468.8

Algorithms for Endpoint Detection

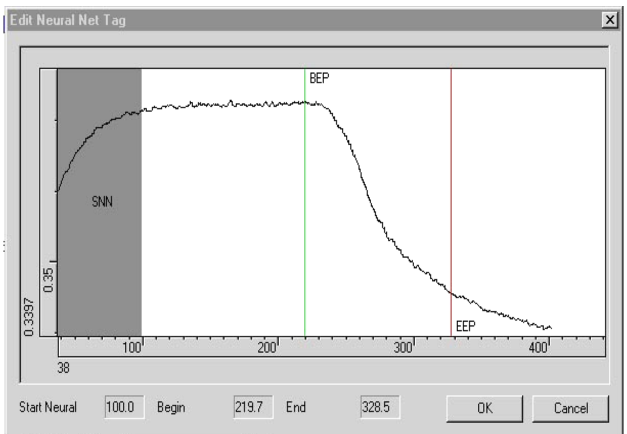
Verity Instruments provides a powerful suite of endpoint algorithms, including the multivariate Neural PCA algorithm, which can be processed with Verity's proprietary Neural Network pattern recognition software.



Neural PCA Multi-Wavelength Algorithm

Verity's endpoint-detection computations can employ robust algorithms such as the patent pending Neural PCA for multivariate, full-spectrum analysis.

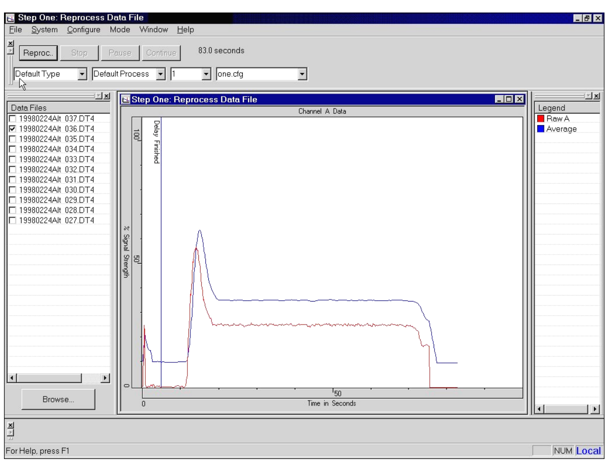
Data represented at left apply to a 0.5% exposed area contact etch using Verity's Neural PCA algorithm. Within the SpectraView™ endpoint software application, the Neural PCA endpoint trace can be processed using Neural Network or threshold-based methods.



Neural Network Algorithm

The Neural Network algorithm is used to analyze endpoint traces. The Neural Network uses proprietary techniques to recognize characteristic endpoint shapes in the trend line. This is performed in real time and the pattern recognition algorithm adapts to expected amplitude and duration changes in the endpoint trace during successive runs.

Unlike other types of neural networks, Verity's algorithm can be set up with only a few training runs. If a false positive or negative is found, it can easily be added to the training set for improved robustness. Process engineers using Verity's Neural Net software are freed from the burden associated with developing and testing threshold-based algorithms. In addition, data can be analyzed "on-the-fly" or replayed, reviewed, or reprocessed with SpectraView™.



Threshold-Based Algorithm

Using threshold-based algorithms, endpoint recognition is based upon the output rising above or below a preset level for a predetermined length of time. However, for demanding applications, the Neural Network algorithm is commonly selected over the threshold-based algorithm.

Suggested Further Reading

Applied Optics and Optical Engineering, Volume V, Optical Instruments, Part II. 1969. Academic Press, New York and London. (For Design, Construction and Testing of Optical Devices)

“CRC Handbook of Chemistry and Physics – A Ready-Reference Book of Chemical and Physical Data.” 1978. *CRC Press*. (Scientific Reference of Atomic Spectra)

Herman, Irving P. 1996. “Optic Diagnostics For Thin Film Processing”, *Academic Press*, ch. 6. (Optical Emission Spectroscopy as Applied to Thin Film Processing)

Pearse, R.W.B. and Gaydon, A.G. 1976. “The Identification of Molecular Spectra”, *Chapman and Hall*. (Scientific Reference of Molecular Spectra)

Selwyn, Gary S. 1993. “Optical Techniques for Plasma Processing”, *American Vacuum Society*. (A “How to” Book to Enable Better Understanding of Optical Techniques)