Spectral Reflectometer SP2100

SD1024G   Spectrometer   FL2100 Flashlamp

Verity INSTRUMENTS, INC.

Spectral Reflectometer SP2100

Features and Benefits

- Designed for in-situ and in-line measurement of films in etch and CVD applications, and for metal or transition breakthrough in CMP
- Real-time measurement
- SD1024G Spectrometer provides:
  - Excellent UV sensitivity
  - Wide dynamic range
  - Excellent S/N ratio
  - Multi-fiber input capability (depending on application)
- Pulsed light source provides:
  - In-situ measurement by subtraction of plasma
  - Freeze-frame images in case of moving wafer
  - High brightness for excellent S/N ratio
- SpectraView™ software provides:
  - Robust endpoint, etch depth and film thickness
  - algorithms
  - Open algorithms and sequences for flexibility
  - Tool integration via Ethernet, RS232, and DI/O
- Usable range:
  - Standard: 225-800nm
  - Optional: <225-800nm
- Fringe-count, reflectivity and model-based algorithms
- RoHS compliant

Description

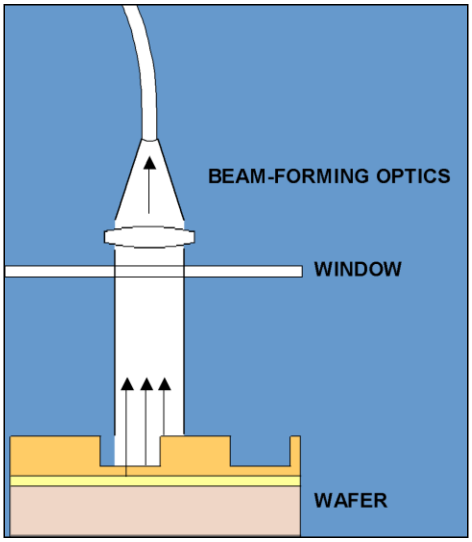
Verity's SP2100 Spectral Reflectometer is designed for a wide variety of film thickness and depth measurement applications, including those required in etch, CVD and CMP processes. Verity's Spectral Reflectometers are successfully controlling hundreds of semiconductor process tools worldwide.

The key components of the SP2100 are the SD1024G spectrometer, FL2100 Xenon flashlamp, and SpectraView™ applications software. The heart of the SP2100 is the SD1024G Spectrometer, which uses a scientific grade CCD detector for excellent dynamic range, UV detection capability, and low noise. The SD1024G also has capability for multi-fiber input operation, and controls the flashlamp.

The FL2100 flashlamp is a bright, broadband source useful for the applications described herein. The FL2100's output has a strong UV content thus enabling the measurement of relatively thin film layers that would not otherwise be possible using a reflectometer. Since a flashlamp is used, the motion of moving wafers does not result in the blurring of data, which enables more accurate measurement.

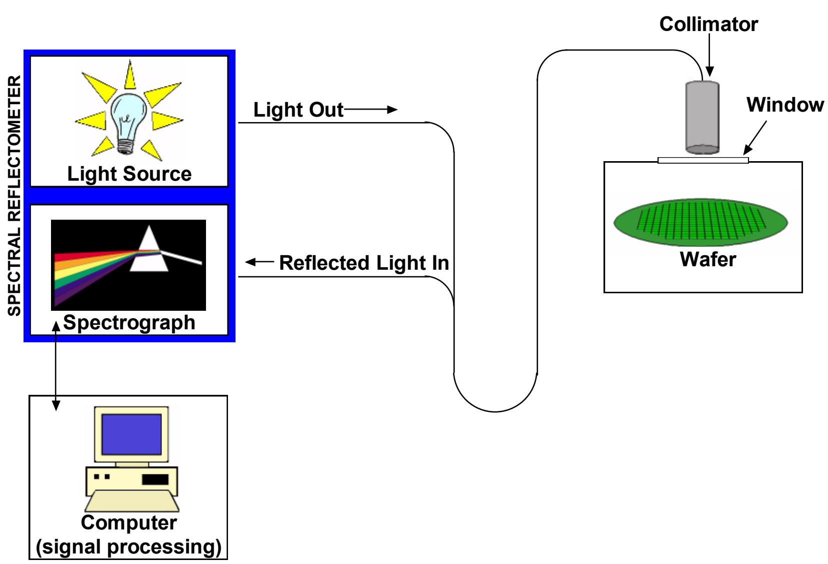
The SpectraView™ PC host application provides robust film thickness determination through a variety of "open" algorithms. SpectraView™ enables integration with tool-to-application-PC communication based on RS232, Ethernet or DI/O.

System Overview



Theory of Operation

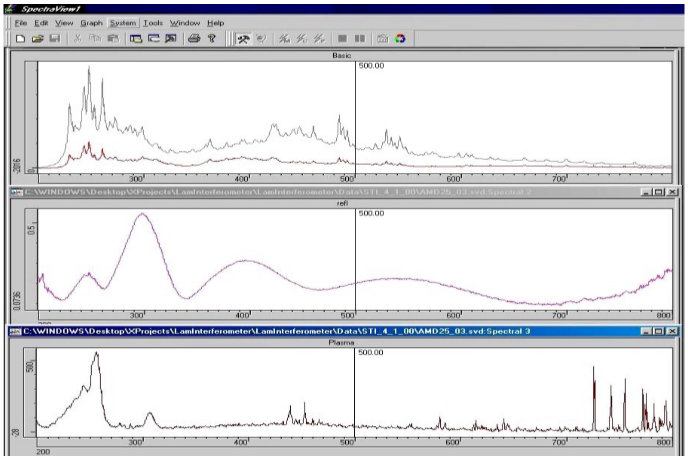
Spectral reflectometry is a proven technology for the measurement of thin films. Polychromatic light incident on the wafer is reflected from the wafer surface and various layer interfaces. At a given wavelength, the reflected light will exhibit interference phenomena that may be analyzed to determine various properties of the thin film(s) on the wafer surface.



System Schematic

The FL2100 Xenon flashlamp provides broadband, high-intensity illumination that is delivered by fiber optics and a collimator to the wafer's surface. The light reflected from the wafer is collected by the collimator and transmitted via fiber-optic cable to the SD1024G spectrometer. Optical data is then transferred from the spectrometer to the computer (running Verity's SpectraView™ application) for processing.

Algorithm Overview



General

Most of Verity's algorithms are "open" algorithms, allowing key parameters to be fine-tuned by the user to obtain maximum performance.

In the case of plasma applications, basic data (from graph above) includes:

- Top graph, red line: raw reflectance spectrum
- Top graph, grey line: reference spectrum for normalization
- Middle graph: normalized wafer reflectivity (raw reflectance spectrum divided by the reference spectrum)
- Bottom graph: plasma spectrum

The SP2100 is licensed under patent numbers 6,160,621 and RE39,145 for in-situ plasma etch and plasma deposition applications.

Fringe Counter Based Algorithms

The most common algorithm used with the SP2100 is the fringe counter. The fringe counter is used for relatively simple CVD film stacks or etch applications to determine thickness or depth. The basic concept is that the thickness or depth change is equal to the number of fringes multiplied by $\lambda/2n_{\lambda}$, where "n" is the optical index of refraction at a specific wavelength, "λ".

A number of enhancements have been made to the fringe counter to accommodate changes in etch rate, reduction in signal from deep recesses, etc.

Reflectivity Based Algorithms

Verity's copper and tungsten CMP algorithms use reflectance-based calculations to determine the existence of remaining copper or tungsten. In CVD systems, other reflectance based algorithms are used for determining the thicknesses of films deposited over complex sub-stack layers.

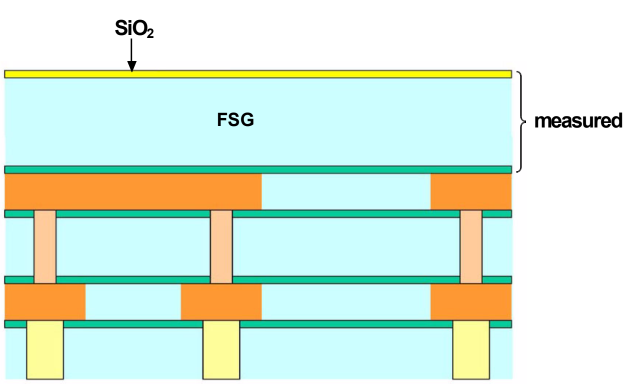
Model Based Algorithms

Model based algorithms are used for applications where the film stack can be readily defined by a system of material layers. An example is the shallow trench isolation (STI) etch process in which both the trench and photoresist are etched at the same time and may be independently modeled and monitored.

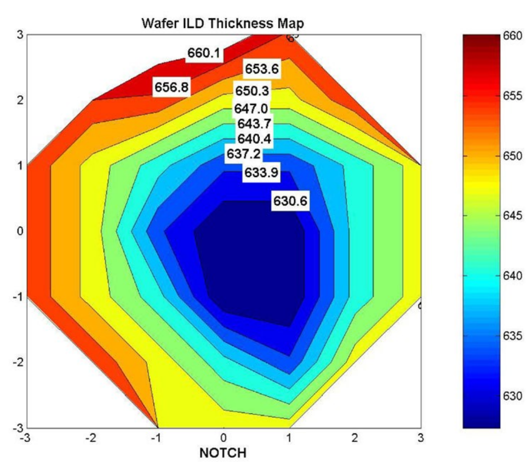
Model-based algorithms are easily adapted to accommodate new applications.

Applications – CVD

ILD Film Stack



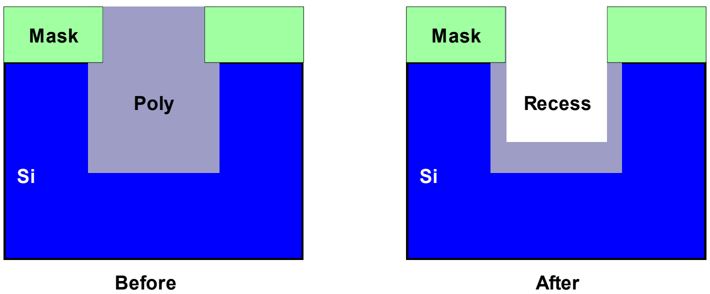
In this ILD application, the goal is to measure the total top layer film thickness (SiO_2 + FSG).



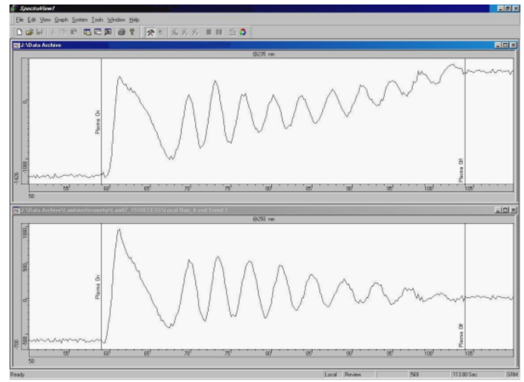
A classic bull's-eye pattern is developed using wafer positioning and model-based data. Thickness varies from approximately 6300 Å in the center to 6600 Å at the edge. This plot was developed using data from the SP2100 and plotted using an off-line utility.

Applications - Etching

Recess Etch

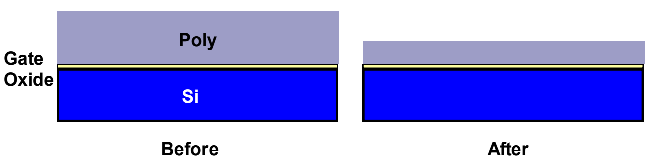


In a recess application, the goal is to determine and control the depth of the recess.

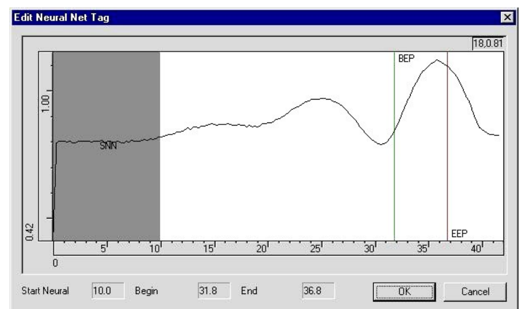


Interference traces at 235nm (top graph) and 250nm (bottom graph) during a recess etch step indicate that the shorter 235nm wavelength significantly improves fringe visibility at the end of the run. SpectraView™ measured the depth, including mask at 1293nm, compared to an SEM measurement of 1336nm.

Gate Etch

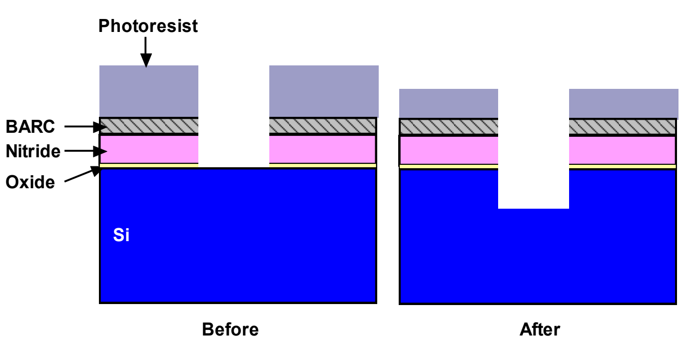


In a gate etch applications the goal is to control the final poly thickness. The etch rate and initial poly thicknesses are variable.

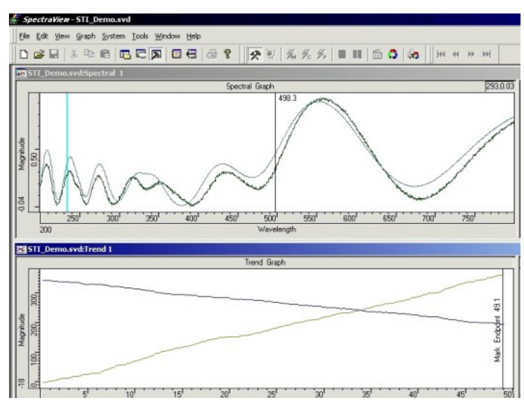


In gate applications, the interference fringe does not develop until the poly is no longer opaque. Once the fringe appears, endpoint is determined using pattern recognition on a trend line developed from one wavelength.

STI Etch



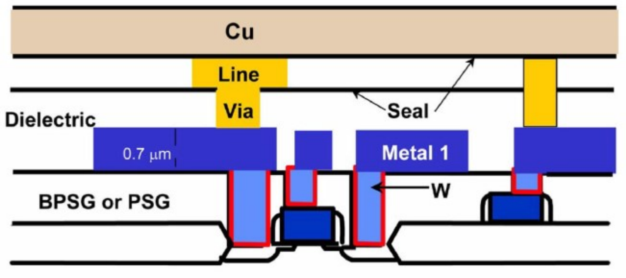
In STI Etch applications, the goal is to control the depth of the trench in the silicon. This application is more complex than gate and recess applications as the photoresist mask is etched at the same time the silicon is being etched.



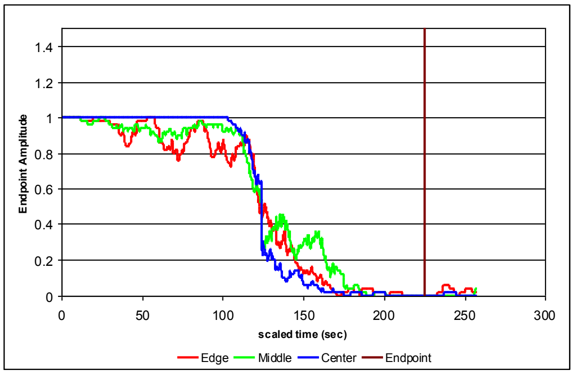
The top graph shows the fitted spectrum (light blue) and the actual spectrum (green). In the bottom time-series graph, a trend of the photoresist thickness (blue) and depth of trench (orange) are shown. Regression is done in real-time.

Applications - CMP

Copper CMP



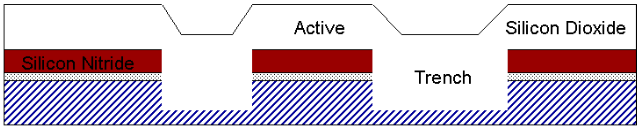
In copper CMP applications, the goal is to stop when all copper is first removed.



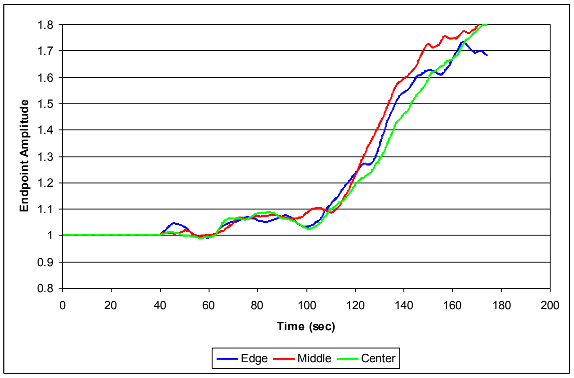
Using a multi-fiber input SP2100, the copper algorithm tracks the remaining copper at edge, middle and center of the wafer. These traces show data from a three-zone polish process.

At 150 seconds, the green trend line indicates remaining copper in the mid-radius areas of the wafer, whereas the blue and red lines indicate predominantly cleared areas of the wafer.

STI CMP



In STI CMP applications, the goal is to stop the polish when all of the oxide covering the nitride mask in the active area is removed

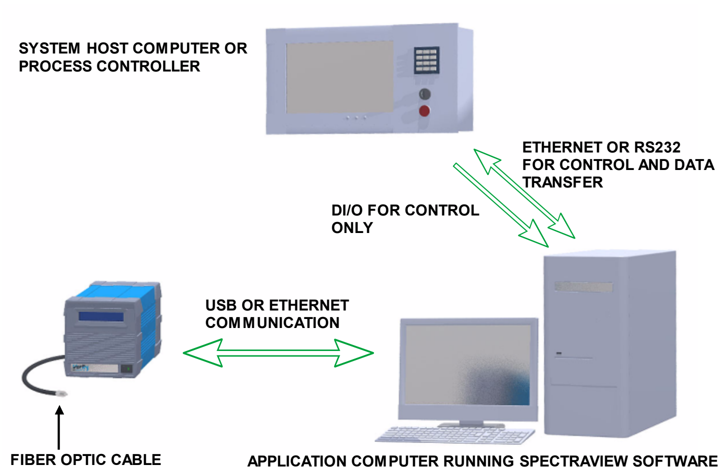


The STI algorithm tracks the transition from oxide to nitride. These three traces show uniform oxide removal from a three-zone polish process.

Due to strong pattern density clearing effects in STI structures, the actual "endpoint" is a continuum. As the different density features clear, the endpoint signal changes. These endpoint trend lines are used to stop polishing when the 50% active areas clear and then an overpolish is performed.

System Schematic

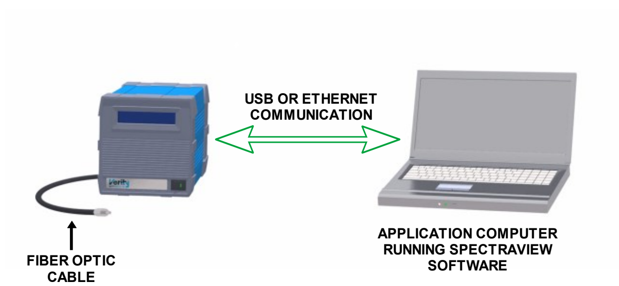
Partially Integrated Within a System



In a partially integrated configuration, an application computer is used to provide the user interface and data storage. Communication from the spectrometer to the application computer includes Ethernet or USB.

Control between the application computer and the system host computer can be via DI/O and/or RS232, or DI/O and/or Ethernet. In some cases, it may be desirable to use DI/O for control communication and RS232 or Ethernet to provide a data stream of trend points to the system host computer.

Non-Integrated Configuration



When used for troubleshooting or plasma diagnostic applications, the spectrometer is frequently not integrated with the process tool. Communication to the application computer includes Ethernet or USB.

Spectrometer Specifications

Model Number	**SD1024G**
Type	High Performance
Performance/Optics	
Range[1]	200–800nm
Resolution[2]	<2.0nm, 1.33 nm typical
CCD	1024 x 128 pixels – for multi-fiber input option TE cooled – for low noise Backthinned – for enhanced UV sensitivity Deep well – for wide dynamic range
Saturation (counts)[3]	40,000[4] to 65,536
Mechanical	
Dimensions - inches (mm)	5.4” (137 mm) W x 10.2” (259 mm) L x 5.6” (142 mm) H
Weight	6.5 lbs (3 kg)
Integration	
Fiber Optic Connection	Custom Design
Power	20-28VDC, 45W max. User accessible 2.5A fuse
Standards	
Compliance	EN 55022 EN 55024 IEC 61010-1 SEMI S8-0308 SEMI S2-0310 Semi S10-0307 RoHS
Environmental	
Operating Temperature Range	32 (0°C) — 104 (40°C)[4]
Storage Temperature Range	-4 (-20°C) – 140 (60°C)
Max. Humidity (Operation and Storage)	85% Non condensing

[1] Range — the SP2100 with a standard F.O cable and standard flashlamp is useable from about 225nm to 800nm. Consult factory for shorter wavelength options.
[2] Resolution — full width at half of maximum peak height, the maximum average of several measurements taken across the spectrum.
[3] 40,000 is the minimum saturation for generic SD1024Gs; non generic SD1024G's have different saturation values. 65,000 is the minimum saturation value for all SD1024GHs
[4] Airflow should not be restricted.

Application Computer Software

Application Software	SpectraView™
Operating System	SpectraView 4.xx to 6.0.xx: Windows 2000® SP4 or Windows XP® SP2 or SP3 SpectraView 6.1.xx to 6.5.00: Windows XP SP2 or SP3 or Windows 7 Pro 32BIT With SP1 SpectraView 6.5.01+: Windows 7 Pro 32BIT With SP1 or Windows 7 Pro 64 Bit with SP1
Communications from Applications PC to Spectrometer	TCP/IP over USB (RNDIS Driver) or Ethernet (Ethernet is recommended)
Communications from Tool to Applications PC	ASCII or Proprietary Serial (RS232) and/or DI/O, Proprietary TCP/IP and/or DI/O

Recommended Application Computer Requirements (SpectraView Only)

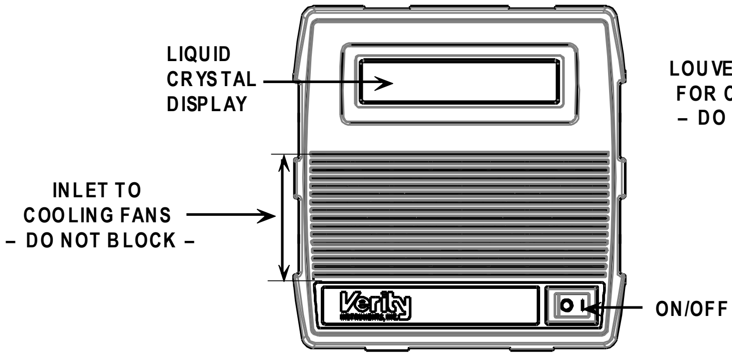
Attribute	Specification
Platform	Intel X86 architecture
Processor	Pentium 4 class CPU, 2.0+ GHz (minimum, some advanced algorithms or multi-instance needs may require more processing power)
Memory	512MB or greater, 300Mhz DDR RAM (minimum, some advanced algorithms or multi-instance needs may require more memory)
Hard Drive	Current PC industry standard minimum storage available (80+ GB) is adequate for all data storage needs
Graphics	XGA (1024x768, 256Colors)
COM Port(s) to SD1024 **COM Port (s) to Tool** **Com Port to LAN** **Optional**	USB or 10/100 or 10/100/1000 Ethernet (Ethernet preferred) RS232, Digital I/O, or 10/100 or 10/100/1000 Ethernet Additional 100/1000 Ethernet recommended (for data uploading) PCI card slot(s) for DIO and/or analog output card installation

Flashlamp Specifications

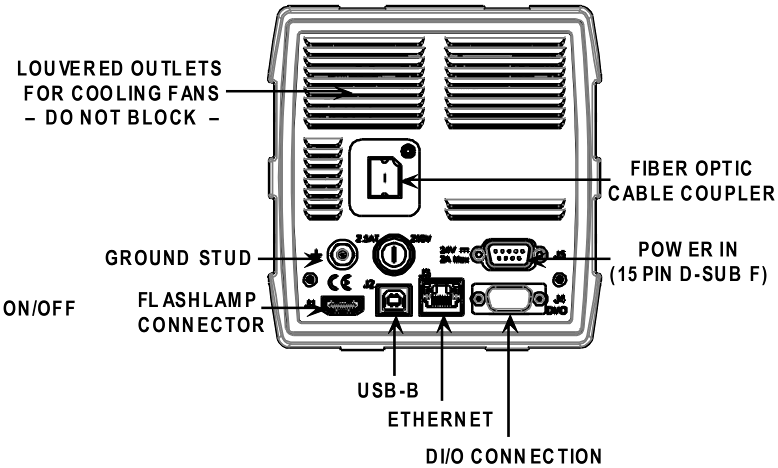
Model Number	FL2100
General	
Lamp	Xenon flashlamp
Data Acquisition	Synchronized to spectrometer
Wavelength Range	Supports Supports UV- NIR wavelengths (200-1700)
Pulse Duration	1-2 x 10^{-6} seconds
Mechanical	
Size (L x W x H) inches (mm)	10.32” (262.1 mm) 5.42” (137.6 mm) 4.00” (101.6 mm)
Weight	4.4 lbs (2 Kg)
Mounting Orientation	Base should face downwards
Electrical	
Power	20-28VDC, 45W maximum (optional 72W high power version)
Connections	J1: Control Interface from Spectrometer J2: Secondary Control Interface (not normally used) J3: 20-28 VDC Power at 2A (3A with high power option) maximum Fuse, 2.5A (4A with high power option) Ground Stud Lamp Housing with Cable Coupler
Standards	
Compliance	EN 55022 EN 55024 IEC 61010-1 SEMI S8-0308 SEMI S2-0310 SEMI S10-0307 RoHS
Environmental	
Operating Temperature Range	32 (0°C) — 104 (40°C)
Recommended Storage Temperature Range	68 (20°C) — 140 (60°C)
Max. Humidity (Operation and Storage)	85% Non condensing

SD1024G Series Spectrometer Dimensions

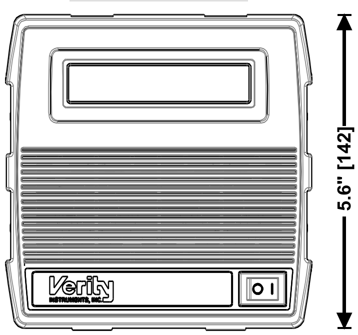
FRONT VIEW



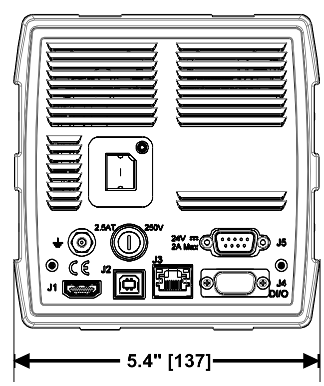
REAR VIEW



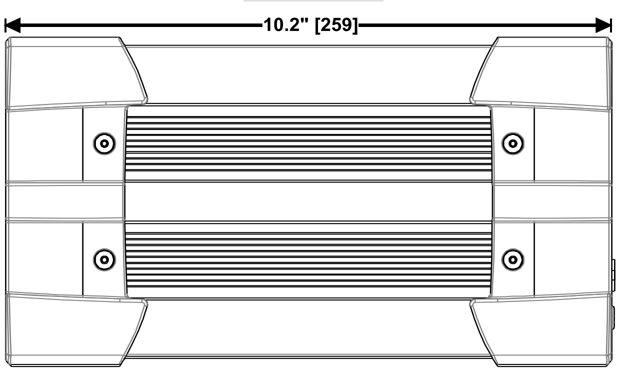
FRONT VIEW



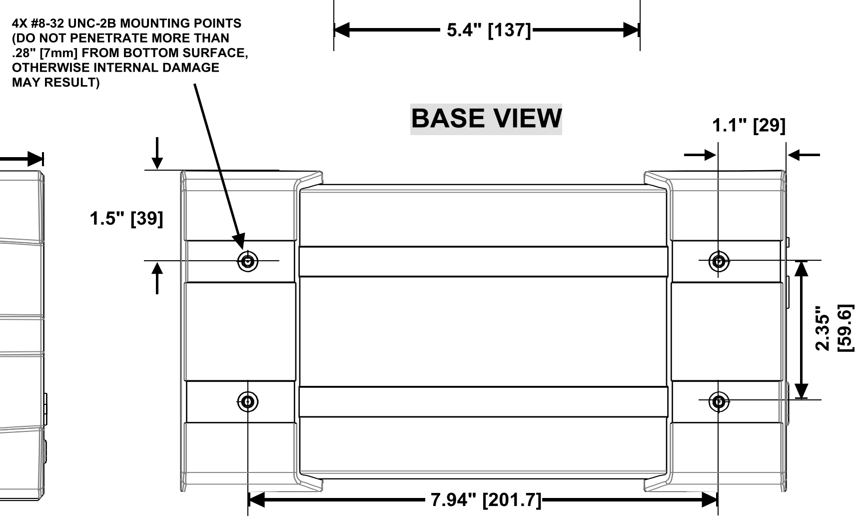
REAR VIEW



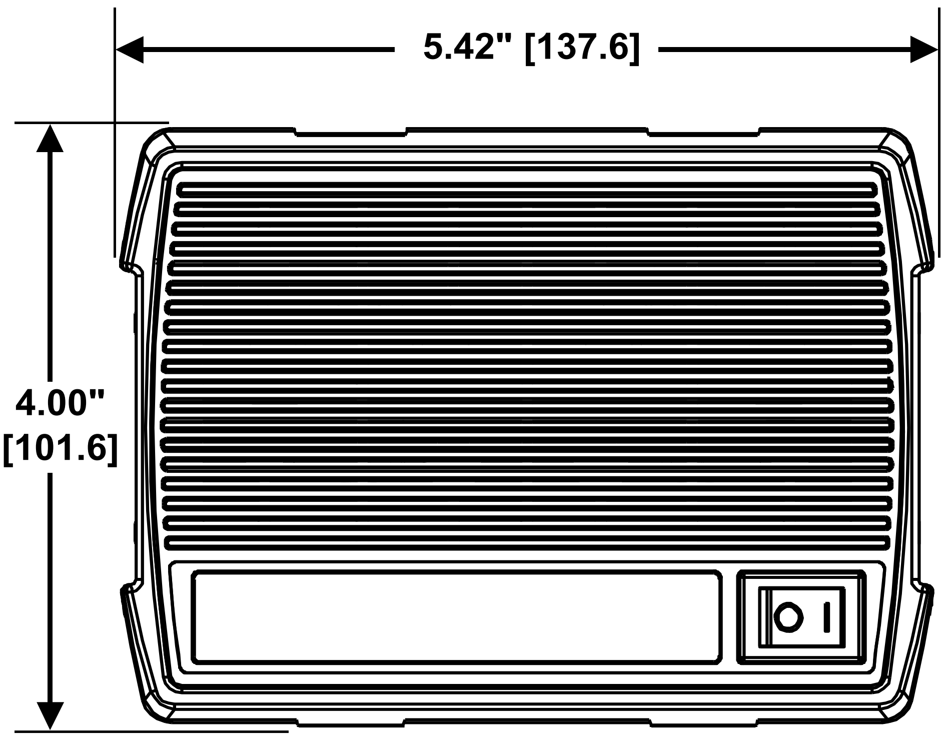
SIDE VIEW

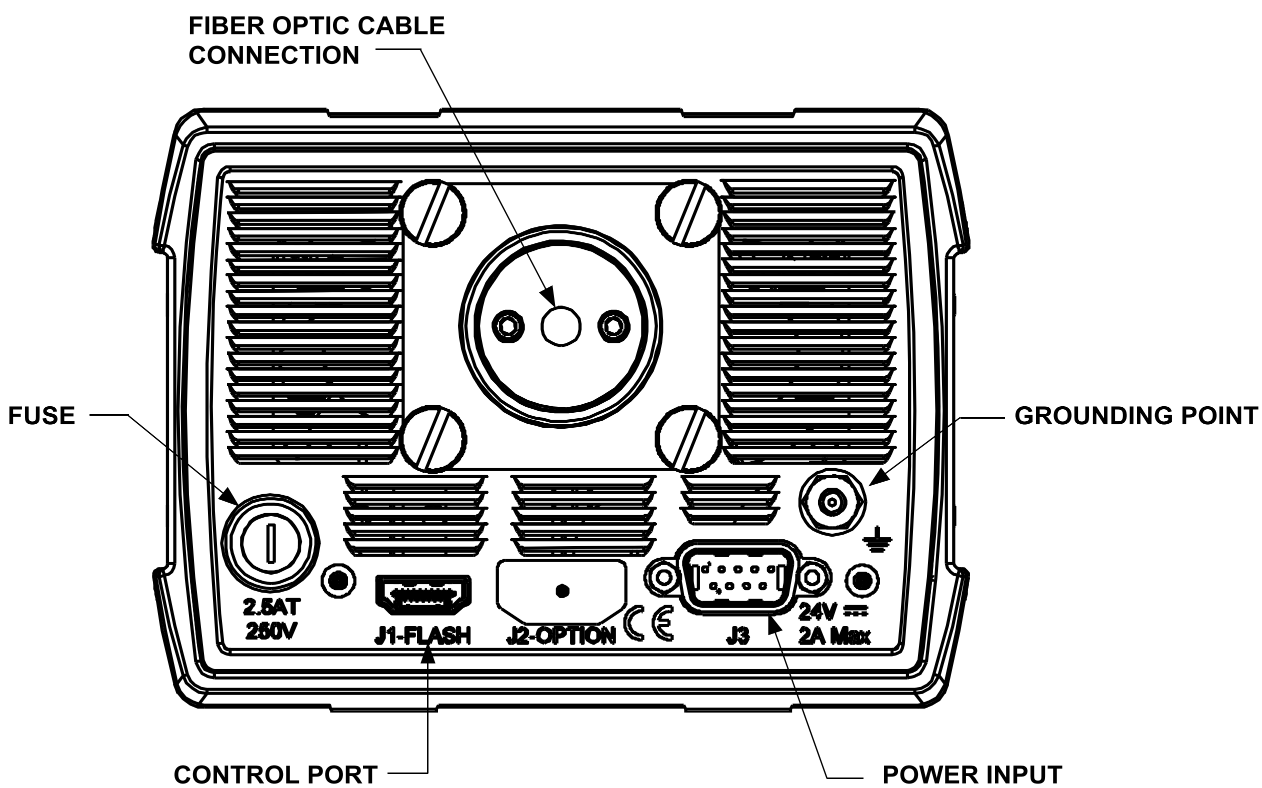


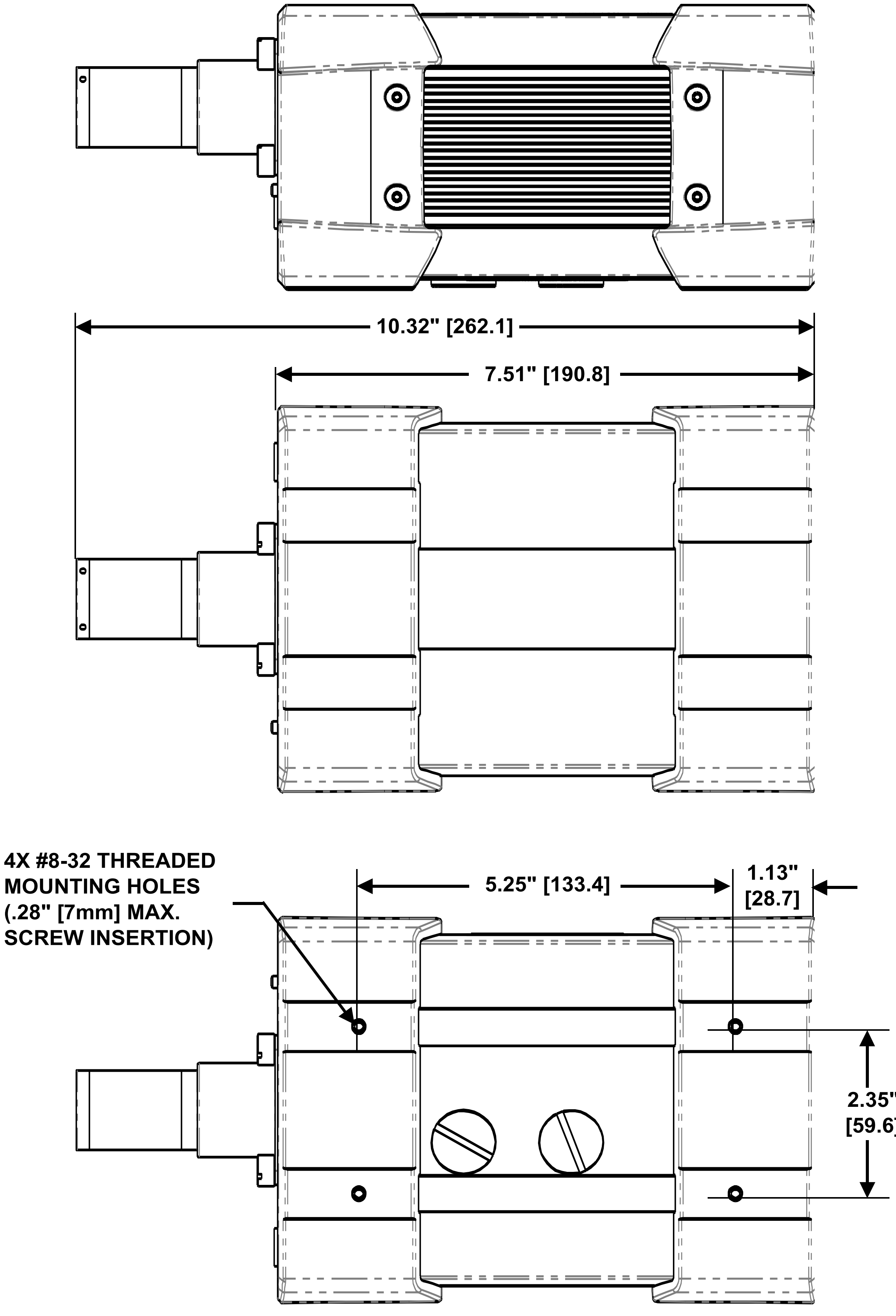
BASE VIEW



FL2100 Flashlamp Dimensions






10.32" [262.1]
7.51" [190.8]
4X #8-32 THREADED
MOUNTING HOLES
(.28" [7mm] MAX.
SCREW INSERTION)
5.25" [133.4]
1.13"
[28.7]
2.35"
[59.6]

Ordering Information – SP2100

Description	Model	Part Number
Low-power flashlamp, AC input	SP2100	Consult Factory
High-power flashlamp, AC input	SP2100	Consult Factory

Fiber Optic Cables

Description	Model Number	Part Number
200 cm stainless steel jacket	N/A	1005474-079
300 cm stainless steel jacket	N/A	1005474-119
400 cm stainless steel jacket	N/A	1005474-158
500 cm stainless steel jacket	N/A	1005474-199

Hardware for Partially Integrated Application

Digital I/O Card for Use in Application Computer

Description	Model Number	Part Number
Digital I/O Card (PCI type, 16 inputs/16 outputs)	DAS-7230	1005418

Communication Options

For Single Spectrometer to Computer	Length	Part Number
Ethernet Cable - from spectrometer to switch - from switch to applications PC	1' (0.3m) 7' (2m) 14' (4m)	1004442-012 1004442-084 1004442-168
Ethernet Switch, including: 8 ports 10/100 Auto-sensing 12VDC Adapter to 120VAC & USA plug	Not applicable	1005879

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