Applications

INTRODUCTION

On the following pages we have listed some examples of the wide variety of solutions Avantes spectrometers are used for. From plasma-wall-interaction to detection of explosives and from the Falkland Islands to Portugal.

AVANTES
solutions in spectroscopy

Furthermore a number of example setups have been listed. LED, Irradiance, Thin Film and Color measurements are just some of the many possibilities. But the Avantes Spectrometers can be used in many more applications. Contact an application engineer to discuss your situation and the perfect spectroscopy solution for your needs.

Some of the markets our spectrometers are used in:
- Agriculture
- Astronomy
- Automobile industry
- Biology
- Biotechnology
- Chemistry
- Coating industry
- Colorimetry
- Construction
- Cosmetics
- Diary industry
- Dental
- Dermatology
- Environmental
- Film industry
- Food
- Gas chromatography
- Gemology
- LCD industry
- Light industry
- Meteorology
- Medical
- Military
- Nanotechnology
- Narcotics
- Nuclear industry
- Optical filters
- Painting industry
- Paper industry
- Particle size analysis
- Pharmaceutical
- Photovoltaic industry
- Plasma etching
- Printing industry
- Pyrometry
- Radiometry
- Semiconductor industry
- Solar spectrum measurements
- Space research
- Sun glasses industry
- Textile industry

Avantes spectrometers: versatility worldwide

Finding fires with AvaSpec

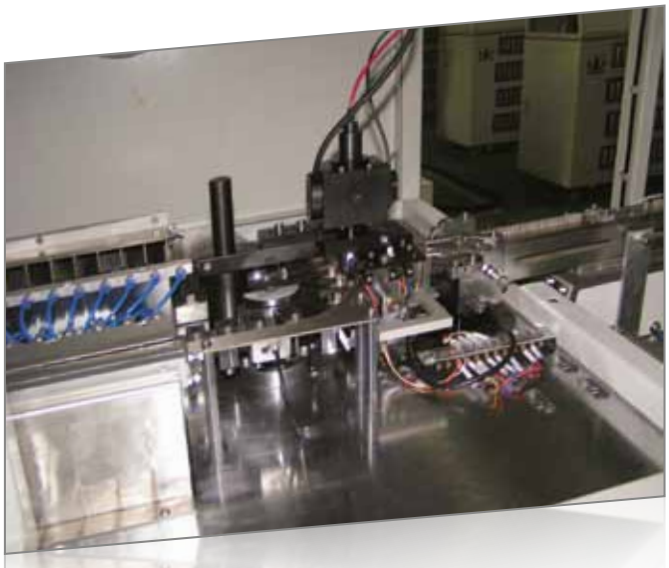
Developed in Portugal, the Forest Fire Finder is an advanced fire detection and tracking system. The system consists of an individual or a series of towers which feature telescopic optics to measure spectra over forested areas. The system features an AvaSpec-ULS2048-USB2 spectrometer, a video camera, weather station, telescope, processing/controlling unit and communications unit. The telescope and the video camera scan the horizon non-stop, at an angle of 320 degrees. The telescope is connected to the spectrometer by means of a fiber and can collect spectra up to 15km away. These spectra are then processed and analyzed. The video camera takes pictures at pre-set intervals and can also be used to send real-time video. It is aligned with the telescope, to ensure what is measured.

Should the system detect a forest fire, automatically alerts are sent out through SMS, IP, GSM, etc. The alert contains needed information, such as fire location, detection time, weather conditions and an image of the detected fire. The weather conditions include wind speed and direct, temperature and humidity.

Fast sorting of LEDs

Traditional incandescent light bulbs are already banned in some countries and many more will soon adopt similar laws. This means there will be huge demand for alternative light sources, such as LED (Light Emitting Diodes) and Organic LEDs (OLED) in the coming decade. During production, it is vital that these (O)LEDs have uniform color and spectral output.

The color parameters of an LED can be measured by a radiometrically calibrated fiber coupled spectrometer and the AvaSpec-series spectrometers are ideal for this task. Critical to this type of inline measurements are the speed and accuracy of measurements: Avantes offers a 1.1 ms integration time and 2 ms/scan data transfer time, enabling for and LED sorting machines to run at full speed.



Bird research on the Falkland Islands

The Thin-billed Prion, or Pachyptila Belcheri, is a species of sea-birds that is mostly found in the southern oceans. To determine their maturity level, their feather color and ornamental appearance is used. Since these birds can see and produce signals in the UV-range (such as plumage color and bill displays), spectroscopy is used to objectively assess skin and feather colors.

The spectrometer used on New Island, part of the Falkland Islands (or Islas Malvinas) is an AvaSpec-2048 in a portable setup with laptop, 12V battery, a light source and a connected reflection probe. The scientists are interested in color measurements, the origins of signaling with ornaments, hormonal control and trade-offs between signal production and e.g. reproduction, or the maintenance of a strong immune system.

Non-invasively determining risk for cardiovascular diseases made easy

For an easy and immediate cardiovascular risk prediction for major chronic diseases, such as diabetes, cardiovascular disease and renal failure, the AGE-Reader was developed. It assesses the accumulation of advanced glycation end products (AGEs) in patients, non-invasively. This is done by using auto-fluorescence of the skin with ultraviolet light, measured by an AvaSpec series spectrometer. AGEs have an important role in the development of chronic complications of diabetes and other common conditions. The amount of AGE in tissue serves as an important risk predictor of such complications.

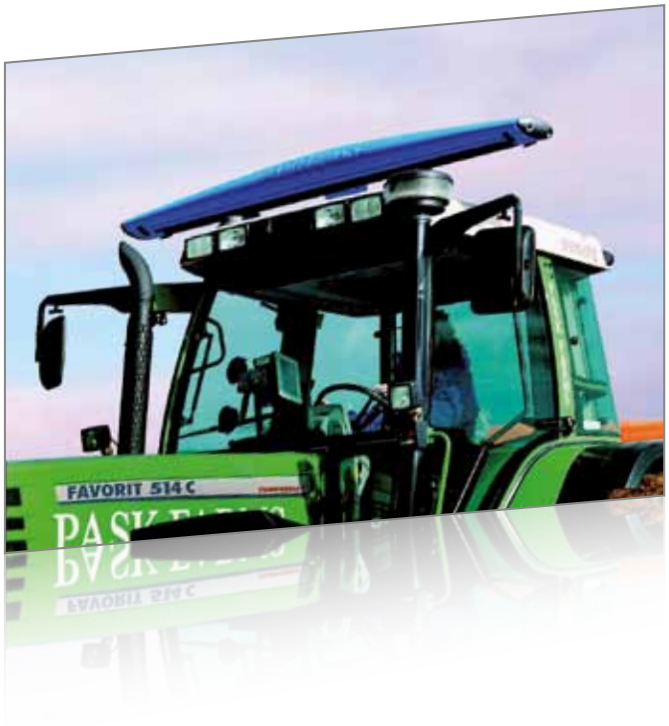
The AGE-Reader has been used to test many thousands of patients over the last decade because it supplies directly usable results, in a comfortable and safe way for both the medical professional and the patient.

Monitoring fertilizer concentration on the go

To measure and apply the appropriate levels of fertilization on crops can be a time consuming activity. This is what the Yara system was designed to facilitate. Featuring a dual channel AvaSpec series spectrometer, fiber-optics and processing electronics mounted in a blue box on top of a tractor, the system makes real-time measurements of the optical appearance of crops and intelligently applies fertilizers accordingly.

Relevant for the fertilization is the level or nitrogen in a crop, which is measured by means of reflection spectroscopy. In the visible range (380-740 nm) the reflection is an indication of the leaf chlorophyll content, in the NIR range (700-1000 nm) reflectance is mainly affected by the crop's biomass.

Included with the Yara system is a terminal for real-time monitoring. A special viewing geometry and integrated irradiance correction guarantees accurate measurements. The system logs crop and GPS data on a on-board data card.



The MAYAs use Avantes spectrometers

The Mineral Automated Yield Analyzer system, or MAYA for short, is designed for real-time analysis of minerals, ores, chemicals and raw materials. Housed in a compact case, it is easy to install and relocate to any desired location. It uses Laser Induced Breakdown Spectroscopy (LIBS) technology to safely analyze mineral material passing below it on a conveyor belt. Unlike other elemental analyzers, the MAYA system does not generate ionizing radiation (X-Ray, gamma, neutron, etc.) and therefore is the safest available method for full elemental on-line analysis.

LIBS is a type of atomic emission spectroscopy which uses a highly energetic laser pulse as the excitation source. The laser is focused to form a plasma of the material to be analyzed. Spectral analysis of the plasma emission created yields a fingerprint of the elemental composition of the sample.

The method of analysis is:

- A laser beam is focused on the surface of the material to be analyzed
- The temperature at the focus point reaches 20,000-40,000°C. The material becomes plasma and emits light whose wavelength distribution is material dependent (fingerprint of the elemental composition of the sample)
- The emitted light is collected and dispersed according to its wavelength component (spectra)
- Sampled material is analyzed by comparing the sampled dispersed light to a given chemical element's spectrum
- The laser's typical operating frequency generates approximately 300-500 spectra, which enables a full analysis result every three to five minutes

High Dynamic-Range Time Intensity Measurement of Intense Femtosecond Laser Pulses

Ultrafast lasers are now broadly used in many research fields such as high intensity laser-matter interaction, femtochemistry, THz generation or time-resolved spectroscopy.

Characterization of femtosecond laser pulses has always been a difficult task, but with a new technique called Self-Referenced Spectral Interferometry, invented and patented by Fastlite (Paris, France), researchers can perform single-shot, calibration-free measurements with a simple and compact setup.

The Wizzler system, which includes an AvaSpec-2048L spectrometer, provides spectral intensity, spectral phase and coherent contrast measurements with an unprecedented dynamic range over 40dB, and is now becoming the reference tool in the field of femtosecond pulse measurements.

The included spectrometer covers a bandwidth ranging from 650 to 1080 nm and matches the full spectral bandwidth covered by the widely used Ti:Sapphire lasers. The hardware trigger allows single-shot acquisition up to 1kHz.

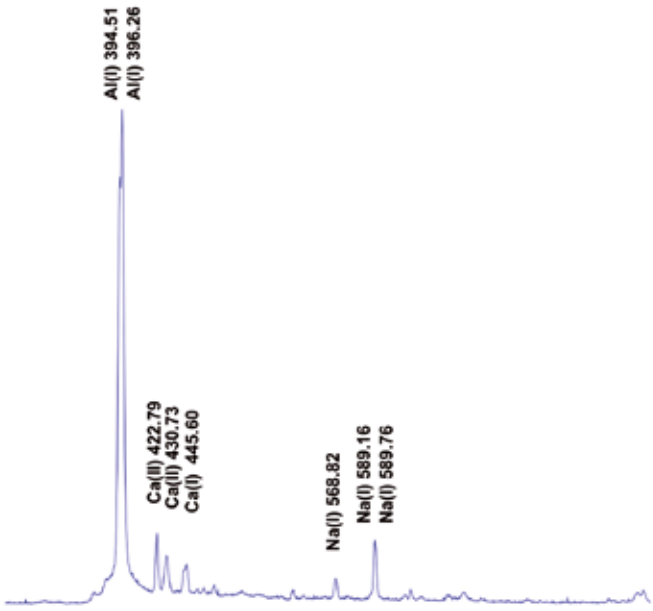
OPTIX Helps Fight Terrorism

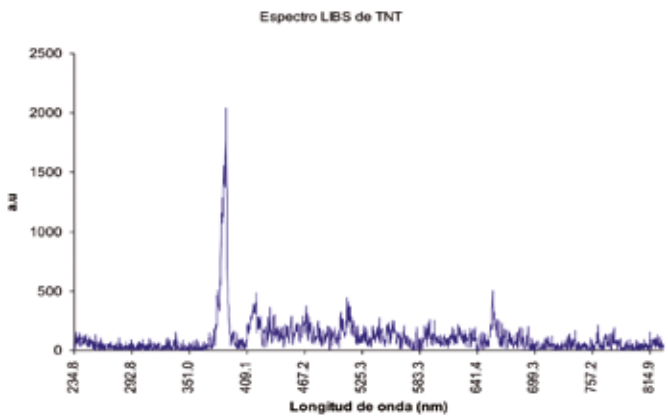
The aim of the EU funded OPTIX project is to contribute to the safety of European citizens by the development of a transportable system that can do standoff detection and identification of explosives in real scenarios at distances of around 20 meters. The goal is to develop a system with a detection time of less than 60 seconds, reliability of over 90 percent (with less than 3 percent false alarms), and over 95 percent correct identification of explosives. To accomplish this, an alternative or simultaneous analysis is done by three complimentary optical technologies (LIBS, RAMAN, IR). The project started in November 2008 and is projected to take 54 months, finalizing in April 2013.

All three techniques have a number of common components that facilitate integration:

- Laser: Raman and LIBS spectrometers can both operate using a frequency-doubled Nd:YAG, although the power density requirements are different, so the analyses cannot be performed simultaneously. The Nd:YAG operating at 532 nm can also provide the pulsed laser fragmentation required for IR whilst IR spectroscopy also requires two Quantum Cascade Lasers (QCL).
- Collection optics: The integration of the three techniques requires collection optics optimized for light in several different regions; 350 to 974 nm for LIBS and Raman, and 5.2 to 5.3 µm and 6.2 to 6.3 µm for the IR QCLs. A telescope will collect the returning light and then the signals are divided into different paths through a series of mirrors and fiber-optic cables to three separate detectors.
- Spectrographs: Although other combined Raman/LIBS systems utilize a single spectrograph and detector, the OPTIX system will contain 3 AvaSpec-ULS2048-USB2 spectrometers for LIBS and a special version of the AvaSpec-HS with a gated, intensified CCD camera for Raman to increase the spectral resolution obtainable, compared to that of a combined spectrograph.
- The OPTIX system will allow alternative or sequential analysis by the three different optical technologies at a stand-off distance of 20 meters. The advantages of using the three complementary technologies include a higher probability of detecting the presence of explosives over a range of potential threats, lower probability in confusing or defeating the system, and increased sensitivity, specificity and robustness.

OPTIX is funded by the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n°[218037].



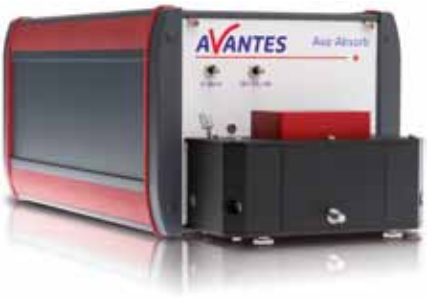


AVANTES solutions in spectroscopy

AvaAbsorb

The AvaAbsorb system was designed for those situations in which you would like to do consecutive sample and reference measurements in a controlled environment. This setup is normally referred to as dual beam spectroscopy. No fiber cables are used and drifting of the light source is automatically corrected in AvaSoft. It has two cuvette holders in the front, which can be covered to prevent any interference of light. The selection between the two paths is easily done through AvaSoft or the front side switch. The path length is variable up to 60 mm, making low concentration measurements possible.

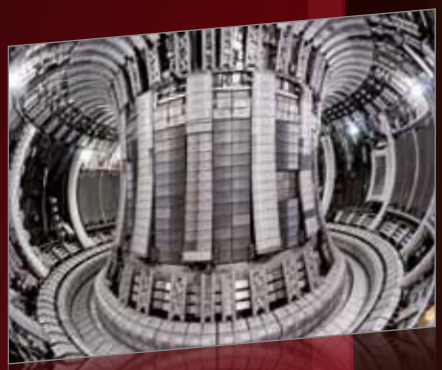
Inside, the AvaAbsorb features the AvaSpec-ULS2048L spectrometer, combined with an AvaLight-DHc compact Deuterium Halogen light source or an AvaLight-HAL series Halogen light source. This means easy measurements in the ultraviolet, visible and near infrared range for the AvaLight-DHc, and in the visible and near infrared range for the AvaLight-HAL. The spectrometer features extra high detector pixels, giving better signal-to-noise ratio and long term stability.



Tehcnical Data

Path length	Up to 60 mm
Light beam diameter	3 mm
Cuvette dimensions	Up to 60 mm long Up to 12 mm wide
Wavelength range	200-1100 nm
Resolution	0.06 – 20 nm, depending on configuration
Stray-light	0.04-0.1%, depending on the grating
Photometric range	Up to 3 AU
Detector	CCD linear array, 2048 pixels
Signal/Noise	300:1
AD converter	16-bit, 2 MHz
Integration time	1.11 ms – 10 minutes
Interface	USB 2.0 high-speed, 480 Mbps RS-232, 115.200 bps
Sample speed with on-board averaging	1.1 ms /scan
Data transfer speed	1.8 ms /scan (USB2) 430 ms/scan (RS-232)
Power supply	110-220 V

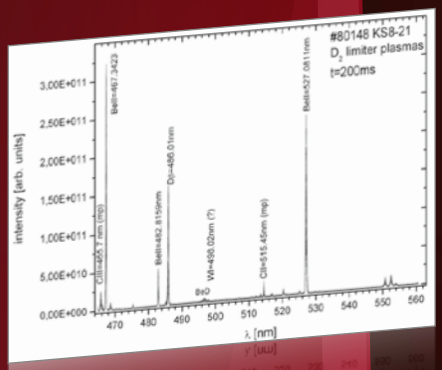
Plasma-Surface Interaction Measured by Avantes



Just a small town in the English countryside, but it hosts a research facility that might change the world as we know it. The Joint European Torus, based in Oxfordshire, researches how to use fusion energy in daily life. Fusion offers the promise of energy that is environmental friendly, safe and available in almost unlimited quantities. Avantes spectrometers are used at the facility to measure changes during these plasma experiments.

Deputy leader Dr. Sebastijan Brezinsek of the JET-EFDA task force E2 is responsible for all spectrometers used at both the English and German facilities. When upgrading the torus, new miniature spectrometers were also needed. Mr. Brezinsek explains their choice:

"we used a European Tender and the Avantes spectrometers offered the best quality for the best price. They are used to measure changes in the internal environment of the torus over time and they run 24 hours per day, for several years to come. This way we can measure the influence of the plasma on the internal environment of the torus. So far the quality of Avantes has proven itself."



To prevent any influence from radiation, fiber cables guide the light to a facility 100 meters away from the torus building. There the 53 Avantes spectrometers work non-stop. For this application Avantes had to develop special systems, or as Klaas Otten, Avantes' technical sales manager, puts it:

"we are used to design custom made spectrometers for different applications. The systems used at JET-EFDA have special casing and low-noise detectors, to prevent any distortion. This system asked for individually triggered spectrometers, with fast data acquisition. Plasma is a fast changing substance and therefore fast repetition rate was one of the key requirements."

Avantes supplies their spectrometers with high-performance measurement software, AvaSoft. For JET-EFDA, the DLL-package was used to control the instruments. According to Mr. Brezinsek:

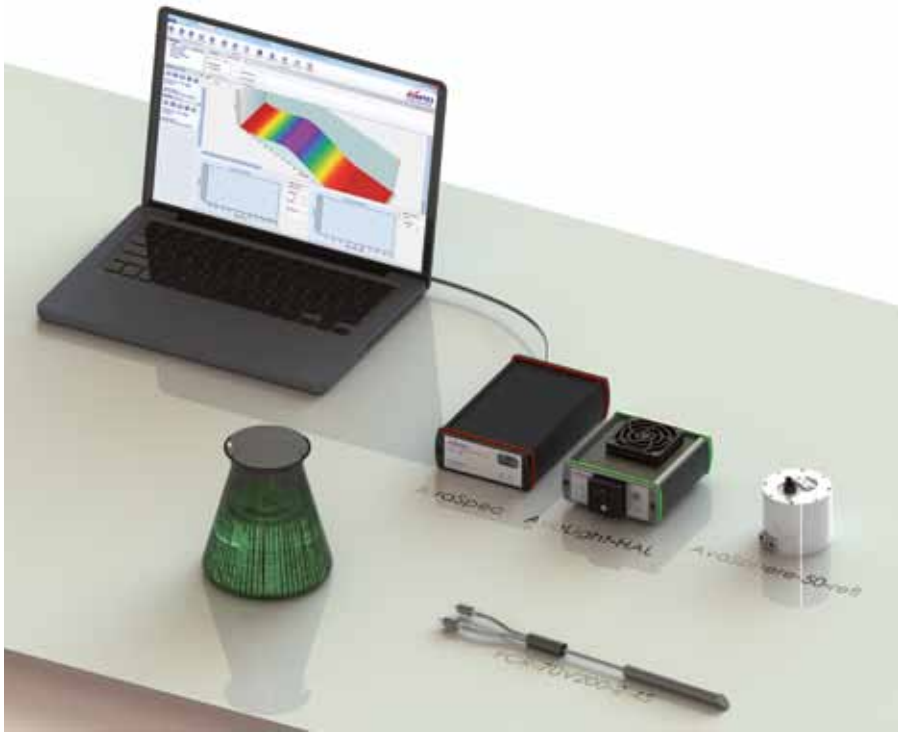
"all our measurement systems connect to one central software solution, therefore we decided to use Avantes' DLL-files. This way we can combine all information into one view, thus enhancing the quality of our work." He concludes: "Thanks to Avantes, we can do our work better, faster and deliver better results. In France we are building a torus that should supply five times the energy we put into the system. This will really be the future of power supply in the world and Avantes helps to make it possible!".

Color measurements

The human eye has a spectral sensitivity that peaks at around 555 nm, which means that the color green gives an impression of higher brightness than other colors. At 490 nm the sensitivity is only 20% compared to the sensitivity at 555 nm. Furthermore, the human eye can only distinguish about 10 million different colors which is actually quite limited relative to the needs of color measurement applications. Spectrometers are designed to measure exact wavelengths, and are therefore ideal for color measurements.

Visible light has a wavelength range of 390-750 nm, so generally color measurement systems are configured to cover the range from 380-780 nm with a spectral resolution of around 5 nm (FWHM).

To facilitate reflective color measurements a reflection probe or integrating sphere is typically required. In either case, a white continuous light source illuminates the surface to be measured and a white reflective standard tile is needed for calibration. Color measurements may be applied to a variety of industrial applications such as color of textile, paper, fruit, wine, and bird feathers. Avantes has developed a variety of custom probes to meet the specific demands of the color measurement application. Color measurements are manifested in the L*a*b* color model which includes parameters for brightness and hue.



Components used in the color measurement setup

	Color Reflection with fiber-optic probe	Color Reflection with integrating sphere	Color Reflection in thick fluids
Spectrometer	AvaSpec-128-USB2, Grating VA (360-780 nm), 100 µm slit AvaSpec-ULS2048-USB2, Grating BB (360-780 nm), 200 µm slit, DCL-UV*		
Software	AvaSoft-Full and AvaSoft-Color		
Light source	AvaLight-HAL with PS-24V-1.25A power supply		
Fiber-optics	FCR-7UV200-2-ME Reflection probe with 6x200 µm illumination fibers, and 200 µm read fiber, UV/VIS, 2 m, SMA	1 pc. FC-UV600-2 illumination fiber 600 µm UV/VIS, 2 m, SMA 1 pc. FC-UV600-2 detection fiber 600 µm UV/VIS, 2 m, SMA	FCR-7UV200-2-45 Reflection probe with 45 degree window with 6x200 µm illumination fibers, and 200 µm read fiber, UV/VIS, 2 m, SMA
Accessories	RPH-1 probe holder WS-2 reference tile	AvaSphere-50-REFL integrating sphere WS-2 reference tile	WS-2 reference tile

** not necessary for reflection probe, only for integrating sphere and high-speed applications*

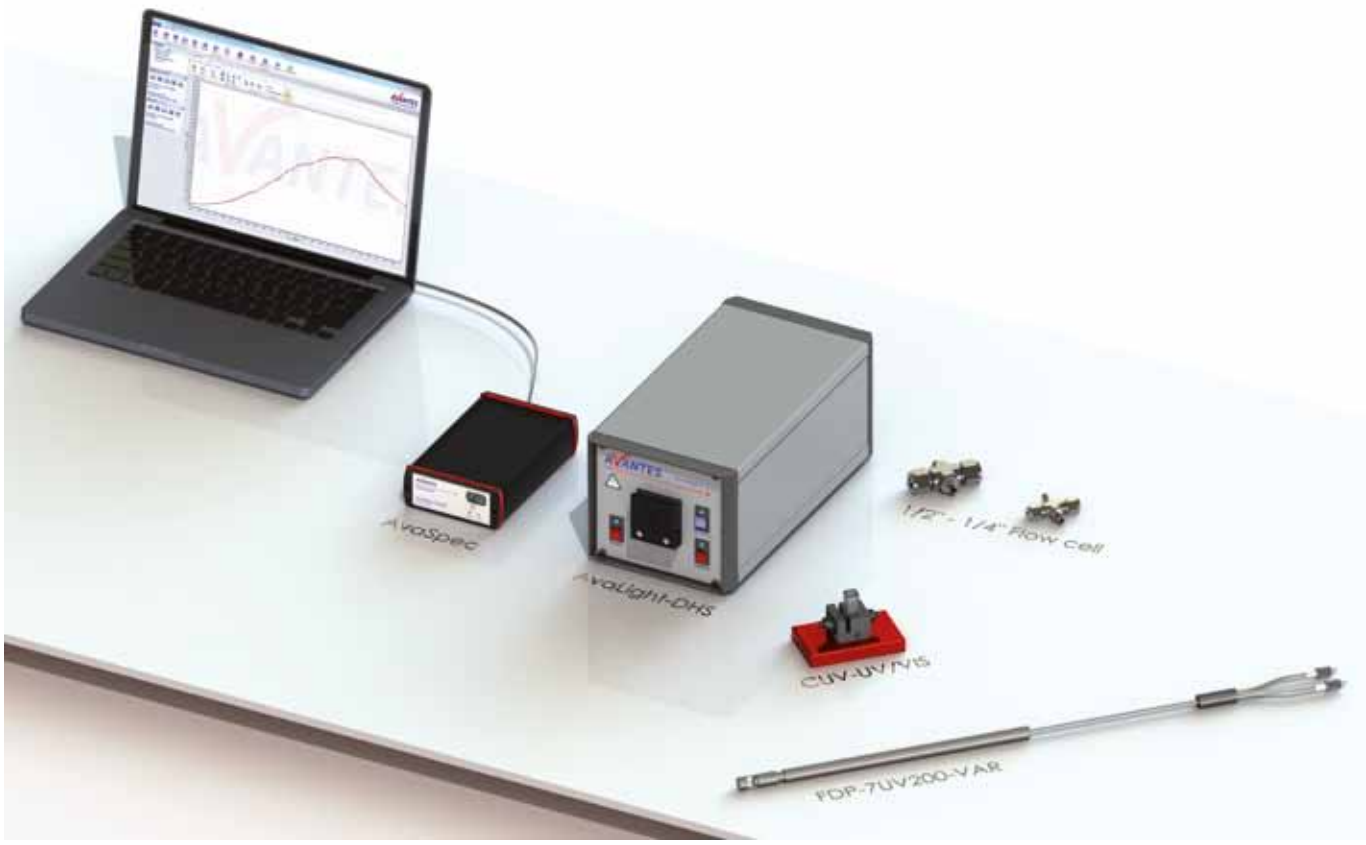
UV/VIS absorbance measurements

The absorbance (also called optical density) of a material is a logarithmic ratio of the radiation falling upon a material, to the radiation transmitted through a material. UV/VIS absorbance measurements encompass a wide variety of chemical and biochemical applications which involve many areas of research and industrial end uses. UV/VIS absorbance can be applied qualitatively and quantitatively in spectroscopic measurement applications ranging from blood parameters to chemical concentrations in process and reaction monitoring. Fiber-optic spectrometers offer a tremendous value proposition for UV/VIS measurements because of their relatively low cost, small size and ability to be introduced in harsh environments through the fiber interface. Combined with a fiber-optic transmission dip probe, inline flow cells or the more traditional cuvette cell, a fiber-optic spectrometer can accurately and repeatably measure over the range from 200-1100 nm.

Small Instruments Come of Age

Scientists who are largely familiar with more traditional bench top spectrophotometers may have the perception that fiber-optic instruments cannot provide the resolution or stray-light rejection required for more demanding applications. In fact, fiber-optic spectrometer technology has come a long way and Avantes' instruments are on the leading edge for this technology. Our instruments are capable of measuring at resolutions as high as 0.05 nm in the UV. In terms of stray-light rejection, Avantes has developed a special optical bench called the ultra-low stray-light (ULS) optical bench to provide optimal performance for our customers. AvaSpec ULS spectrometers have stray-light levels as low as 0.04%.

Typically UV/VIS absorbance systems consist of a spectrometer, stabilized light source and fiber-optics, which are connected to some form of sampling accessory (probe or cuvette cell). Single fiber-optic spectrometers can be configured for broadband measurements (200-1100 nm) or narrow band (any range from 200-1100 nm) depending upon the desired wavelength range and resolution. Avantes UV/VIS instruments are also fully compatible with our AvaSpec NIRLine spectrometers, which enable spectroscopic measurements out to 2500 nm.



Common System Configurations

Avantes modular platform enables users to configure systems in a variety of ways and also allows the flexibility of changing the system configuration later to provide additional functionality. The typical UV/VIS absorbance system consists of an AvaSpec spectrometer, AvaLight fiber-optic light source, fiber cables and a cuvette cell holder. To the left this system configuration is shown with a cuvette cell holder above with a dip probe configuration below.

Our affordable AvaSpec-ULS2048-USB2 and AvaSpec-ULS2048L-USB2 provide excellent resolution (1.0 nm FWHM) over the entire range from 200-1100 nm, or higher resolution for a shorter-range configuration. For higher resolution (0.6 nm FWHM from 200-1100 nm) the AvaSpec-ULS3648-USB2 is recommended. Customers that demand higher signal-to-noise performance and higher sensitivity in the UV or NIR should consider Avantes SensLine instruments. The AvaSpec-ULS2048XL has a high-performance back-thinned CCD detector and the AvaSpec-HS1024X58/122-TEC is Avantes highest sensitivity spectrometer with a thermo-electrically cooled CCD detector and a high numerical aperture optical bench. Any of Avantes' instruments can be combined with our AvaLight-DHS-BAL deuterium halogen source and a CUV-UV/VIS cuvette cell holder. The CUV-DA-DHS is a nice alternative, which enables directly coupling of the cuvette cell holder to the front plate of the light source to minimize the use of fiber-optics.

This same system configuration can be integrated into a single housing (AVS-Desktop) to provide an integrated spectrophotometer module with a common power supply for the light source and spectrometer.

Fiber-optics

One of the key value propositions to fiber-optic instruments is the ease with which measurements can be made inline or in-process using a fiber-optic probe or accessory. Avantes offers a variety of sizes and configurations of fiber-optic transmission dip probes, which include special configurations for measurements in high temperatures (up to 500 °C), high pressure or vacuum. Also available are fiber-optic flow cells for standard and micro-fluidic applications.

Instrument Control Software

Avantes proprietary AvaSoft software is a Windows-based 32- and 64-bit compatible software package which enables full instrument control and includes a basic chemometry add-on module (AvaSoft-Chem). For customers requiring more sophisticated analytical software, which enables model development and multi-variate analysis, Avantes instruments are fully compatible with Panorama-Pro software from LabCognition.

Components used in the absorbance measurement setup

	In-line Absorption with flow cell	In-line Absorption with Dip probe	Absorption with cuvette holder
Spectrometer	AvaSpec-ULS2048-USB2, grating UA (200-1100 nm), DUV, slit-25, DCL-UV , OSC-UA AvaSpec-ULS2048XL-USB2, grating UA (200-1100 nm), slit-25, OSC-UA		
Software	AvaSoft-Full optional AvaSoft-CHEM		
Light source	AvaLight-DH-S-BAL Balanced Deuterium-Halogen light source		
Fiber-optics	2 pcs. FC-UV200-2-SR fiber cable 200 µm UV/VIS, solarization resistant, 2 m, SMA	FDP-7UVIR200-2-VAR Transmission dip probe with variable path length, with 6x200 µm illumination fibers, and 200 µm read fiber, UV/VIS/NIR, 2 m, SMA	2 pcs. FC-UV200-2-SR fiber cable 200 µm UV/VIS, solarization resistant, 2 m, SMA
Accessories	1/4"or 1/2"flow cell	-	CUV-UV/VIS cuvette holder

Three years
limited warranty on all
Avantes spectrometers,
light sources and accessories

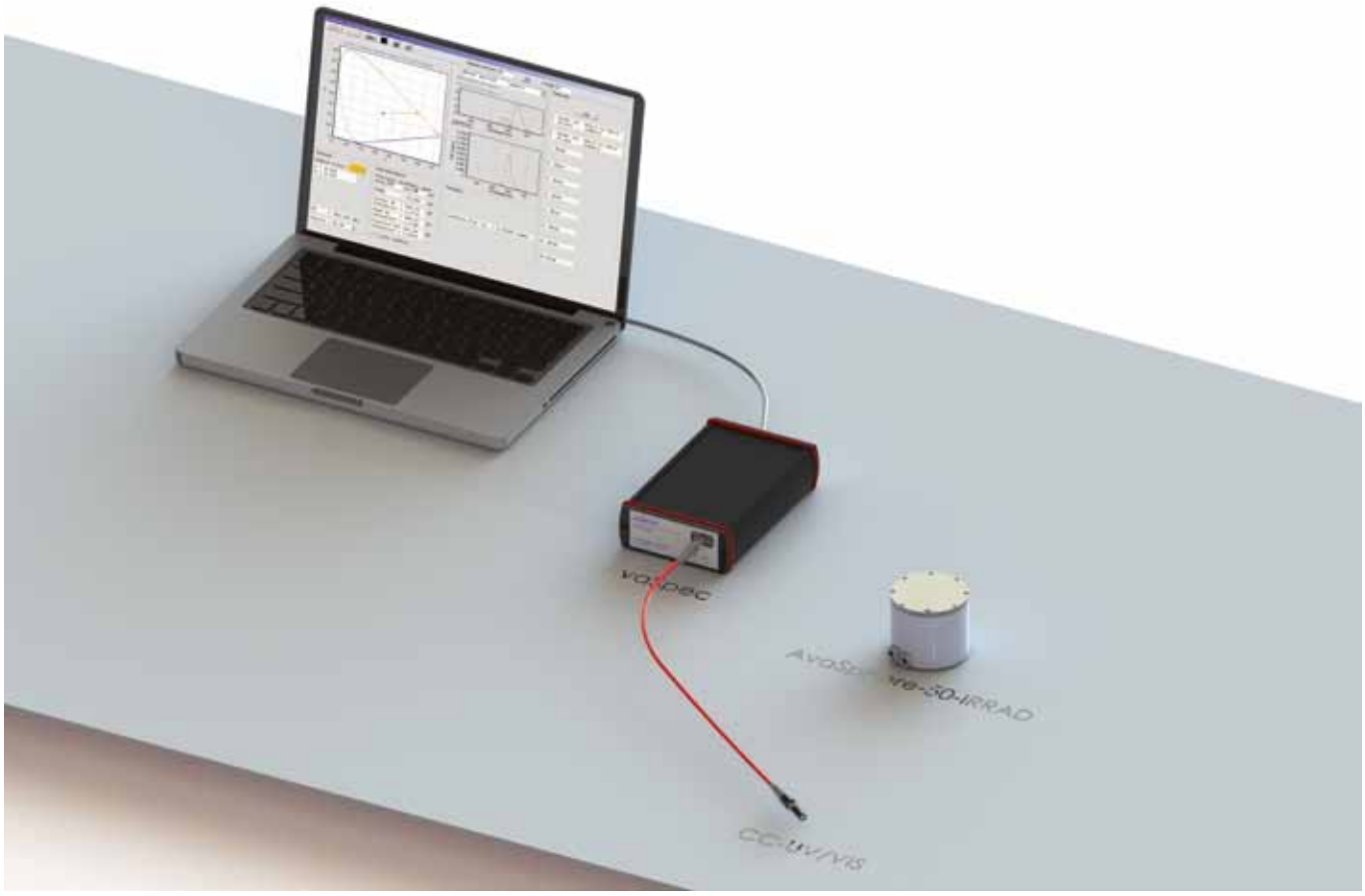
Irradiance measurements

Radiometry deals with the measurement of all optical radiation inclusive of the visible portion of this radiant energy. Irradiance is a parameter of radiometry. It describes the amount of radiant power impinging upon a surface per unit area. Irradiance measurements can be done in the UV, VIS and NIR wavelength ranges.

Avantes works with a variety of irradiance applications ranging from pulsed solar simulator characterization to free space measurements of radiant sources such as street lights. The AvaSpec line of instruments provides exceptional resolution and stray-light rejection to ensure the accuracy of these measurements. Typical system configurations involve one or more spectrometers configured for the appropriate range 200-400 nm for UV irradiance, 360-1100 nm for VIS irradiance and 1100-2500 nm for NIR irradiance. While broadband configurations covering 200-1100 nm are feasible with one spectrometer, optimal performance is achieved with dedicated UV (200-400 nm), VIS/NIR (400-1100 nm) channels. The spectrometer or group of spectrometers is connected via fiber-optic cable to a diffuser with a known surface area and the entire system is calibrated against a NIST traceable source for irradiance. Avantes offers a variety of cosine diffusers and integrating spheres for irradiance applications. The calibrated system is shipped as an integrated system (connected together) and should remain in this configuration in order to ensure the integrity of the calibration. FC/PC connectors are recommended in lieu of the standard SMA, which enable repeatable disconnection and re-insertion of the fiber-optics, so the system may be disconnected for transportation.

Customers that wish to conduct their calibrations may consider one of Avantes' intensity calibration sources. The AvaLight-HAL-CAL is available for VIS/NIR wavelengths (360-2500 nm) and the AvaLight-DH-CAL is available for UV/VIS wavelengths (200-1100 nm).

The Avantes AvaSoft-IRRAD software module enables irradiance parameter measurements such as radiometric quantities - µWatt/cm², µJoule/cm², µWatt or µJoule, photometric quantities Lux or Lumen, color coordinates X, Y, Z, x, y, z, u, v, color rendering index and color temperature, and number of photons µMol/s•m², µMol/m², µMol/s and µMol. AvaSoft-IRRAD software also facilitates the performance of irradiance intensity calibrations.



Configurations used for irradiance measurement setups

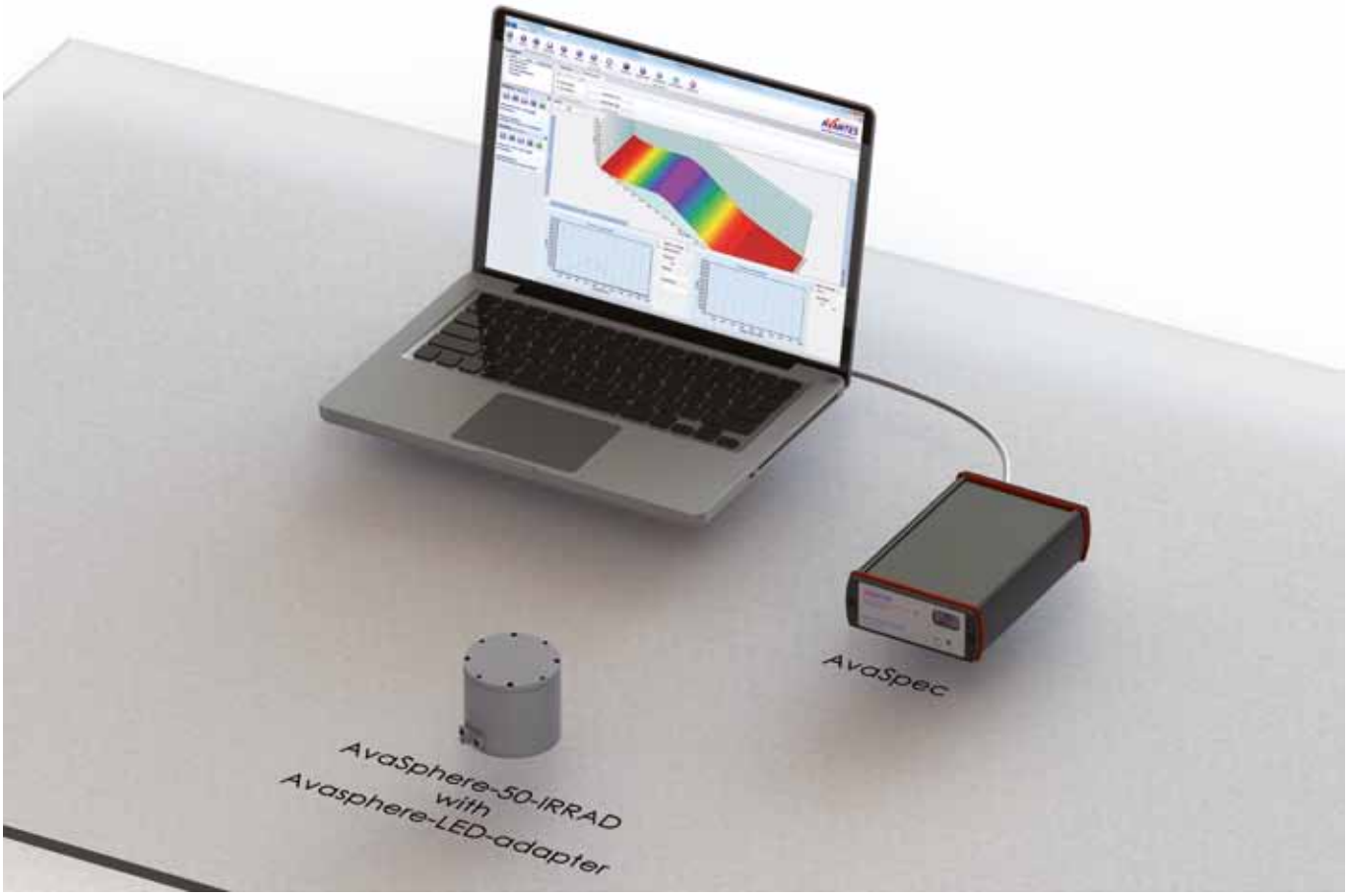
	UV Irradiance	VIS Irradiance	NIR Irradiance
Spectrometer	AvaSpec- ULS2048-USB2-FCPC		AvaSpec-NIR256-2.5TEC-FCPC
	GratingUC(200-400nm),DUV, 50 µm slit, FC/PC connector	GratingVA(360-1100nm),50 µm slit, OSC, FC/PC connector	Grating NIR100-2.5 (1100-2500nm),50µmslit,OSF1000, FC/PC connector
	Grating UA (200-1100 nm), DUV, 50 µm slit, OSC-UA, FC/PC connector		-
Software	AvaSoft-Full and AvaSoft-IRRAD		
Calibration	IRRAD-CAL-UV (200-400 nm)	IRRAD-CAL-VIS (360-1100 nm)	IRRAD-CAL-NIR (1100-2500 nm)
	IRRAD-CAL-UV/VIS (200-1100 nm)		-
Light source for calibration (optional)	AvaLight-DH-CAL Calibrated Deuterium-Halogen light source with CC-UV/VIS	AvaLight-HAL-CAL Calibrated Halogen light source with CC- VIS/NIR	AvaLight-HAL-CAL extra NIR Calibrated Halogen light source with CC-VIS/NIR
Fiber-optics	1 pc. FC-UV200-2-FC-SMA fiber 200 µm UV/VIS, 2 m, 1FC/PC, 1SMA		FC-IR200-2-FC-SMA fiber 200 µm VIS/NIR, 2 m, 1FC/PC, 1SMA
Accessories	CC-UV/VIS or CC- VIS/NIR cosine corrector or AvaSphere-IRRAD integrating sphere		CC- VIS/NIR

LED measurements

The measurement of LEDs presents unique application requirements for which Avantes has the appropriate instrumentation and applications experience to assist our customers in configuring a system. Avantes' many years of working with LED application has prompted us to develop a variety of system configurations that meets most LED metrology requirements. Light Emitting Diodes can be measured in a wide variety of colors and brightness. Accurate measurement of the LEDs therefore is essential. This can be done in two ways: photometry and radiometry.

Photometry relates to visible radiation alone, just as the response of the human eye. Radiometry goes beyond these limitations. In both photometry and radiometry, the LED can be characterized in emitted power or in intensity. Emitted power is all the power (flux) emitted from the LED in lumens or Watts, collected and measured without regards to the direction of the flux. The intensity is the ratio of the flux, leaving the source and propagating in the element of solid angle containing the given direction, and is expressed in candelas.

For basic measurements of photopic parameters and irradiance (excluding flux) a system is typically configured with the AvaSpec-ULS2048-USB2-FCPC spectrometers, a 25 or 50 µm slit and 300 line/mm grating covering the range from 360-1100 nm and provides 1.4 -2.4 nm full width half maximum (FWHM) resolution. A 2 meter fiber-optic cable (FC-UV200-2-FC-SMA) is mated to the instrument and terminated in a cosine function diffuser (CC-UV/VIS/NIR) which has 3.9 mm diameter surface area. The entire system is irradiance calibrated with an NIST source over the specified wavelength range for spectral irradiance (µW/cm²/nm). This calibrated system can be operated using Avantes proprietary AvaSoft-IRRAD software which provides the following parameters: X, Y, Z, x, y, z, u, v, CRI, Color Temperature, Dominant Wavelength, Complementary Dominant Wavelength, FWHM, Centroid, Peak Wavelength & Purity. Additionally raw data in scope mode is displayed, as well as the X-Y chromaticity diagram. Optionally, the system can be configured with longer fiber lengths and the AvaTripod to hold the diffuser in



place during measurement. The system can be controlled via Avantes dynamic linking library (DLL) interface through LabView, C#, C++ and a number of other programming environments.

For flux measurements the entire LED must be inserted into the port of an integrating sphere. Avantes offers a complete line of integrating spheres ranging from 30-200 mm (internal diameter).

For system calibrations, Avantes offers the AvaLight-HAL-CAL calibration sources which are offered in configurations that are compatible with cosine diffusers and small integrating spheres (30, 50, 80 mm).

Avantes also offers two system configurations to enable the CIE Average LED Intensity (ALI) measurements which are specified in the CIE Publication No. 127.

AvaSPEC-IRRAD-ILEDA and AvaSpec-IRRAD-ILEDB correspond to the condition A (316 mm measurement distance) and condition B (100 mm measurement distance) standards, respectively. The system is typically based upon the AvaSpec-ULS2048-USB2-FCPC spectrometers which are configured with a 25 or 50 µm slit and 300 line/mm grating covering the range from 360-1100 nm and provide 1.4-2.4 nm (FWHM) resolution. A fiber-optic cable (FC-UV200-2) is mated to the instrument and terminated in our AvaSphere-IRRAD-30 integrating sphere which couples with the corresponding ILED-TUBE-A or ILED-TUBE-B. The system is irradiance calibrated with a NIST source over the specified wavelength range for spectral irradiance (µW/cm²/nm). The ILED TUBE-A or ILED-TUBE-B is coupled with the Ava-LED-Holder-5 mm (LED holder for 5 mm/ T1 ¾ LEDs) which is coupled with a current stabilized power supply.

Components used in the irradiance measurement setup

Spectrometer	AvaSpec- ULS2048 –USB2-FCPC	
	Grating VA (360-1100 nm), 25 µm slit , DCL-UV, OSC, FC/PC connector	
Software	AvaSoft-Full and AvaSoft-IRRAD	
Calibration	AvaLight-HAL-CAL-ISP Calibrated halogen light source	IRRAD-CAL-VIS (360-1100 nm) irradiance calibration
Fiber-optics	1pc. FC-UV600-2-FC-SMA fiber 600 µm UV/VIS, 2 m, 1 SMA, 1 FC/PC	
Accessories	ILED-A tube for LED T13/4 condition A (316 mm, 0.001sr), incl. AvaSphere ILED-B tube for LED T13/4 condition B (100 mm, 0.01sr), incl. AvaSphere AvaSphere-50-IRRAD integrating sphere AvaSphere-LED-ADR adapter to hold 3, T1 ¾ , 8 mm LED's	

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Thin Film Metrology

Optical thickness of a coating is determined by white light interference and the pattern is translated into optical thickness through mathematical calculations.

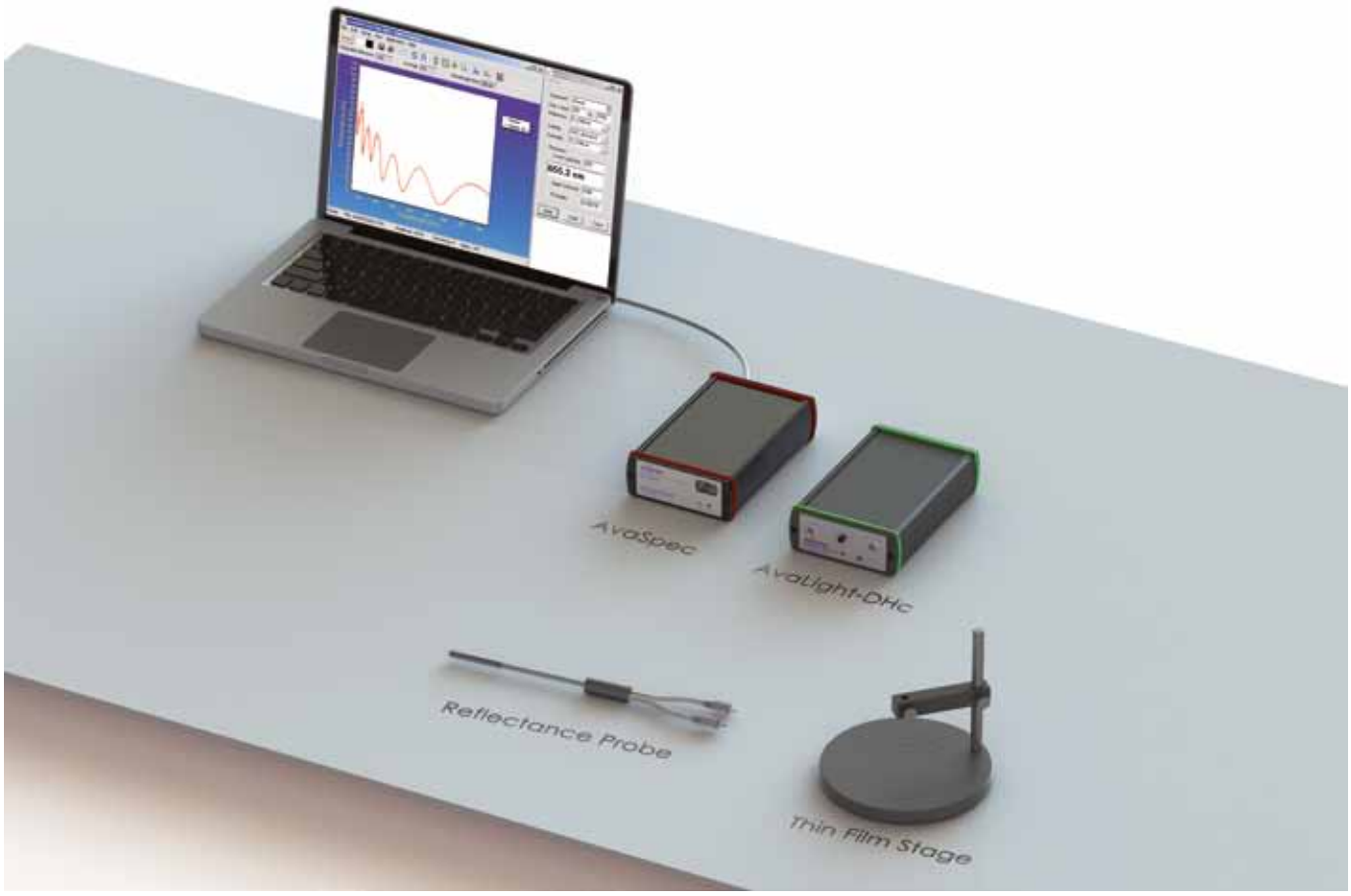
Thin film metrology involves the use of these mathematical calculations to the presence and thickness of coatings which have been deposited on a substrate material using a variety of processes. The techniques available for this measurement range from profilometry to ellipsometry, spectroscopic reflectometry and x-ray analysis. Avantes instruments and fiber-optic sampling tools enable spectroscopic reflectometry measurements to support applications in a variety of industries from semiconductor to solar and optical coating measurements. Avantes thin film solutions provide low cost measurement systems for single and multi-layer thin films on a number of substrates.

Thin Film Quality Control

Thin film deposition processes require regular monitoring and quality control particularly as new recipes are implemented and optimized in a coating facility. Typical applications require regular quality control inspection during the initial phases requiring a high-speed offline measurement system to validate film thickness. Avantes thin film solutions enable high-speed spot measurements which can facilitate thin film presence and thickness validation.

Thin Film Reflectometry

Spectroscopic reflectometry involves illuminating samples with a white light (typically tungsten halogen or deuterium-halogen) at an incident angle which is normal to the sample and then measuring the reflectance and interference from the same geometry. Depending upon the nature of the coating ultra-violet, visible or near infrared wavelength measurements may be necessary to obtain an optimum fitting of the measured curve relative to the theoretical reflectance curve. The theoretical curve is developed from a database of optical constants (n and k). The "n" value is the refractive index and "k" is the extinction coefficient. The sampling process initially involves measuring a reference uncoated substrate followed by the sample measurement using the same conditions. Characteristics about the substrate (thickness and material) are inputs



for the software along with characteristics of the thin film layers (material, thickness). Reflectance spectra are captured and analyzed by software algorithms which compare the measured data to theoretical calculated values derived from the database of optical constants. The software provides a calculated thickness value along with a measure of goodness of fit relative to the theoretical curve.

Single-layer Thin Film Metrology

Avantes' single-layer thin film metrology system consists of our AvaSpec-ULS2048-USB2 fiber-optic spectrometer, AvaLight-DHc/AvaLight-DH-S deuterium-halogen light source or AvaLight-HAL tungsten halogen light source, the FCR-7UV200-2-ME (optional FCR-7UV400-2-ME for higher throughput) fiber-optic reflection probe and our Thin Film Stage. The software that drives the single layer system is Avantes' AvaSoft-Thinfilm which is a 32 or 64-bit application which supports single layer measurements of thin films ranging from 10 nm-50 µm with 1 nm resolution. AvaSoft-ThinFilm supports UV/VIS and NIR wavelength measurements from 200-1100 nm. The system is available with an optional thin film standard which provides samples of uncoated and coated substrates for validation purposes. For most specular surface UV measurements, the AvaLight-DHc compact deuterium halogen source is adequate, but for more diffuse coated surfaces, the higher power AvaLight-DH-S is recommended.

Multi-layer Thin Film Metrology

Avantes' multi-layer thin film metrology system consists of our AvaSpec-ULS2048-USB2 fiber-optic spectrometer, AvaLight-DHc/AvaLight-DH-S deuterium halogen light source or AvaLight-HAL tungsten halogen light source, the FCR-7UV200-2-ME (optional FCR-7UV400-2-ME for higher throughput) fiber-optic reflection probe and our Thin Film Stage. The software which drives the multi-layer system is TFProbe 2.0 which is developed by Angstrom Sun Technologies and is fully compatible with Avantes spectrometers. This sophisticated application supports up to five layer measurements and supports a variety of methods including nk constants, dispersion, and effective media approximation (EMA). TFProbe provides a user-friendly graphical user interface to input layer structure parameters. The system can include an optional thin-film standard which provides sample uncoated and coated substrates for validation purposes. TFProbe supports UV/VIS and NIR wavelengths from 200-1700 nm and enables the connection of multiple spectrometers to support this broadband wavelength measurement capability. For most specular surface UV measurements, the AvaLight-DHc compact deuterium halogen source is adequate, but for more diffuse coated surfaces, the higher power AvaLight-DH-S is recommended.

Components used in the thin film measurement setup

Spectrometer	AvaSpec- ULS2048-USB2
	Grating UA (200-1100 nm), DCL-UV/VIS, 100 µm slit , DUV coating, OSC-UA
Layer thickness	10 nm- 50 µm, 1 nm resolution
Software	AvaSoft-Thinfilm or TFProbe®
Lightsource	AvaLight-DHc Compact deuterium-halogen light source
Fiber-optics	FCR-7UV200-2-ME reflection probe UV/VIS, 2 m, SMA
	Thinfilm stage to hold reflection probe
Accessories	Thinfilm-standard Tile with 2 calibrated different thickness layers of SiO_2 and a reference layer Thinfilm-standard-multilayer Thin Film Reference, Box With Reference sample, a 2-layer sample and a 5-layer sample

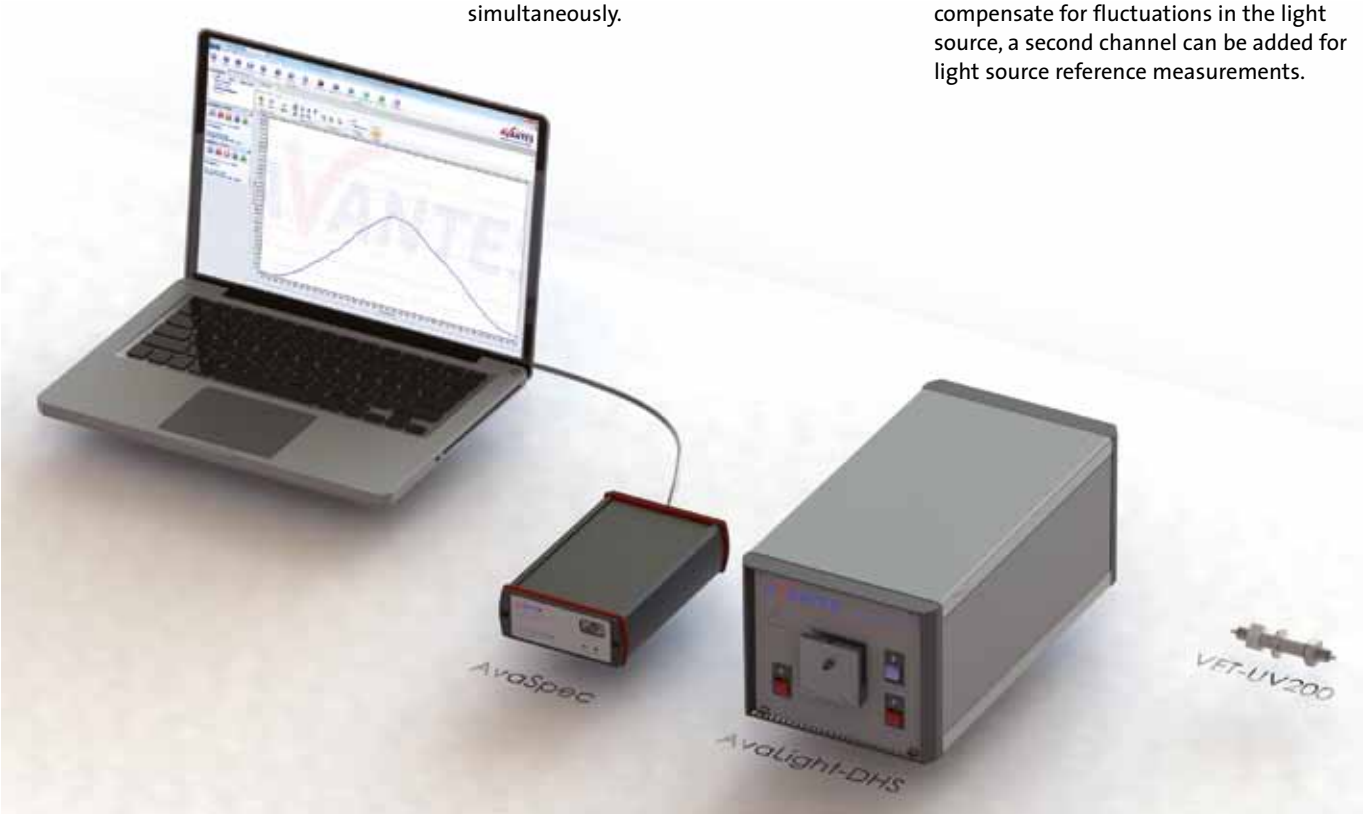
Monitoring Coating Processes in Vacuum Chambers

Layer thickness, composition, surface finish, light transmission, reflectance, polarization ability: these are some of the important parameters that need to be monitored during coating processes. They all are facilitated by spectroscopy and spectroscopic interferometry. Fiber-optics provide a versatile tool to measure in remote vacuum and clean room chambers.

The illumination and detection can be organized at different fiber positions relative to the coating: to allow specular reflection, diffuse reflection, transmission, polarization, interference, fluorescence and even Raman scattering to be measured. Fiber-optics can be arranged to either monitor several positions or to measure at different spatial positions or masking conditions simultaneously.

For on-line production environments, several fiber-optic sensors can be placed to monitor a production run. Ionic sources, such as plasma sources, can be monitored for spectral emission to confirm their conditional efficiency during the operating process.

A typical application for a vacuum chamber system is monitoring an on-line coating process on a web. For this type of system a vacuum feed-through is used to transfer light into the vacuum area and then passes to the reflectance probe. The reflected light is passed through another vacuum feed-through to a spectrometer, AvaSpec-ULS2048-USB2 or SensLine instrument. The reflectance probe can be easily disconnected using the SMA interconnects. To compensate for fluctuations in the light source, a second channel can be added for light source reference measurements.



Components used in the vacuum measurement setup

Spectrometer	AvaSpec-ULS2048-USB2
	Grating UA (200-1100 nm), 50 µm slit , DUV coating, DCL-UV/VIS, OSC-UA
Software	AvaSoft-Full and XLS or PROC add-on
Lightsource	AvaLight-DH-S-BAL Balanced deuterium-halogen light source
Fiber-optics	FCR-7UV200-2-ME reflection probe UV/VIS, 2 m, SMA FC-UV600-2 and FC-UV200-2
Vacuum Feedthrough	FC-VFT-UV200 and FC-VFT-UV600

Botanical/Horticulture/Agriculture measurements

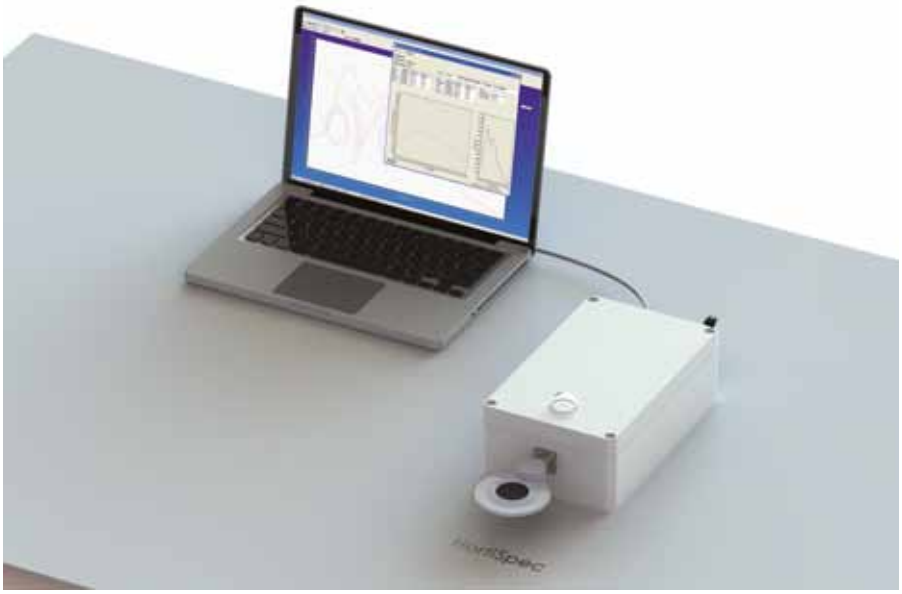
The application of spectroscopy to botany, horticulture and agriculture enables sophisticated spectral analysis of wavelengths of interest to plant scientists. Fiber-optic spectrometers provide the added benefit of real-time in-situ measurements of plants. Avantes' instruments are being used in a variety of plant applications ran–ging from chlorophyll detection in crops to the measurements of sugar (°Bx or brix) in fruit, and radiometric measurements of light levels in greenhouse environments.

Chlorophyll measurements in the visible and near infrared regions can be used to approximate plant health using reflection techniques on plant foliage. The AvaSpec-128-USB2 spectrometer is particularly well suited to this application due to its high-speed and good sensitivity in the region from 600-1100 nm. Integrated systems have been developed to measure chlorophyll in real-time and intelligently apply fertilizers to crops based upon sophisticated chemometric models.

Fruit sorting operations often utilize multi-variate analysis of spectra in the NIR 850-1100 nm to derive sugar (°Bx or brix). Avantes AvaSpec-ULS2048XL-USB2 back-thinned CCD spectrometer is an ideal instrument for this diffuse reflection application, where sensitivity and high-speed are required.

Numerous plant biologists have deployed Avantes AvaSpec-ULS2048L-USB2 and AvaSpec-ULS2048-USB2 spectrometers into the field for in-situ reflection measurements of fruit and flower specimen measurements using the AvaLight-XE pulsed Xenon source for an excitation source and the FCR-7UV400-2-ME fiber-optic reflection probe for sampling. Avantes' convenient battery packs facilitate these types of field measurements where access to electricity is not possible.

Avantes also offers the Hortispec which is a radiometry systems which facilitates the measurement of the light spectrum and energy balance for the benefit of horticulture operations in greenhouses, plastic tunnels, outdoor cultivation and climate cells. It measures in the visible and NIR range and provides parameters for regulating the light conditions (using shading or LED augmentation) and facilitates the development of strategies to control the form and growth rate of plants. The Hortispec is connected to a remote computer where AvaSoft enables easy measurements. The spectrometer has a wavelength range from 200 to 1100 nm and measures photon flux in µMoll/m.sec and provides parameters such as LUX, PAR, Blue, Yellow/green, Red and Far Red.



Technical data

Spectrometer	AvaSpec- ULS2048-SPU2, CCD linear array 2048 pixels.
	Grating VA, wavelength range (360-1100 nm) 200 µm slit, Detector Collection Lens, Order-sorting Coating
Data Communication	USB2 high-speed
Aperture	Diffusor, diameter 3.9 mm
Software	Hortispec Irradiance software
	Measurement units: photon flux in µmol/s.m²
	Parameters : Lux, PAR, Blue, Yellow/Green, Red, Far Red
Battery Pack	Exchangeable 12 VDC, 1500 mAh, 10 NiMH cells
	Spectrometer measurement time ca. 4 hours
	Output: 4-pole IP65 connector
Batterypack charger	1A

Gemology measurements

The measurement needs of the Gemology industry are demanding for a series of reasons. Chief among these can be low signal measurement and the need for rapid measurement systems to handle the volume of gemstones measured. Avantes offers basic measurement tools as well as advanced systems to meet various gemological requirements. Measurements can be accomplished with fairly simple systems using either integrating spheres or reflection probes up to photoluminescence systems requiring lasers and TE-cooled spectrometers.

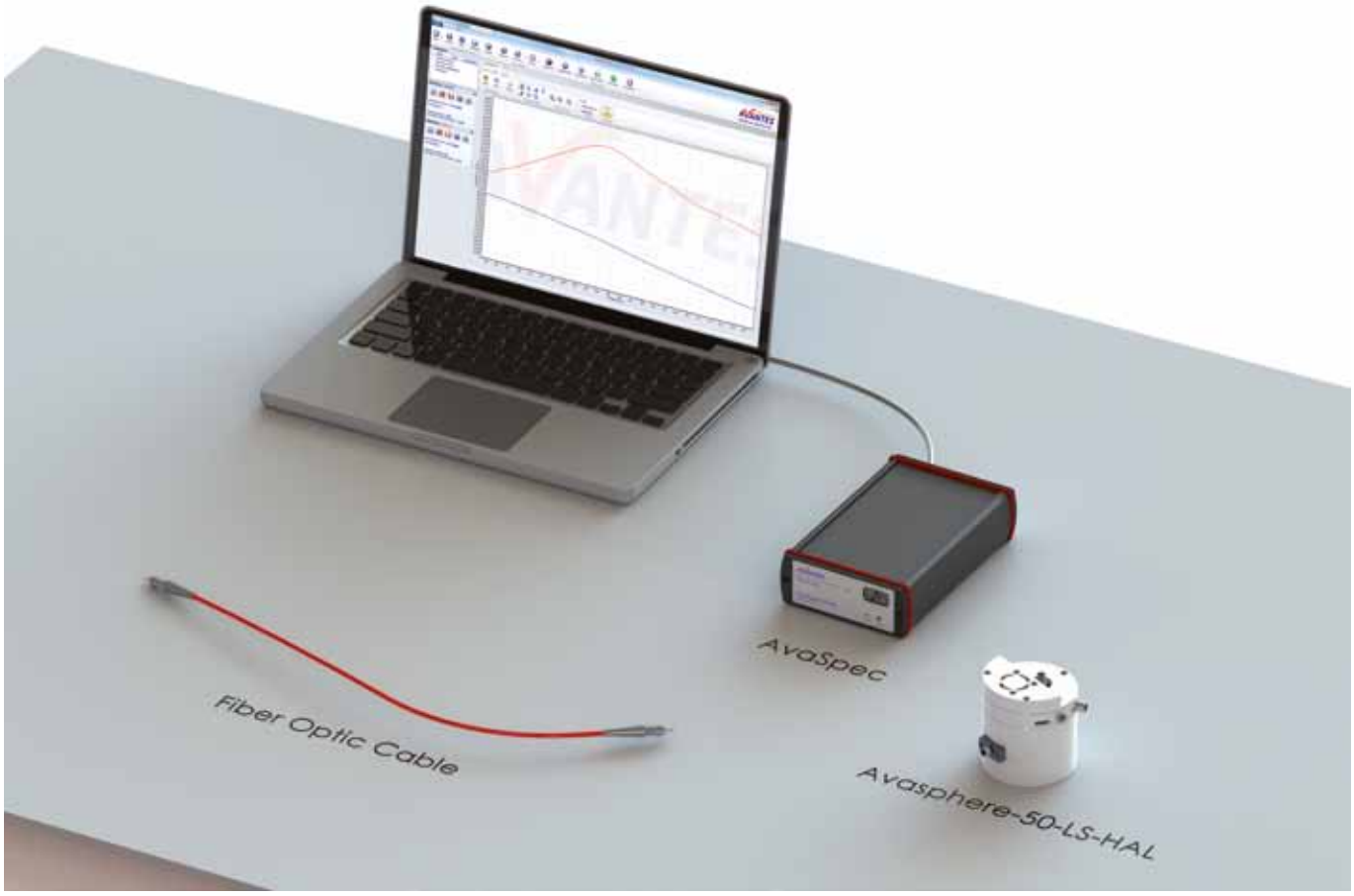
Basic Gemology Measurement

Gemologists often have two basic questions, "What are the characteristics of the stone I'm asked to measure?", and "Are these characteristics natural?" This is because the industry has developed multiple methods to "enhance" stones to improve color and hide imperfections. Methods employed include heat treating, irradiating, resin filling, laser drilling and even simple surface medications such as petroleum product treatments.

A typical basis system consists of an AvaSpec-ULS2048-USB2 spectrometer, a WS-2-GEM, white reference tile for gemology, and either an FCR-7UV200-2-BX fiber-optic reflection probe and AvaLight-HAL halogen light source or an AvaSphere-50-LS-HAL, reflection integrating sphere with Halogen illumination included. Although there are a number of possible applications, the measurement of the main chromium peaks (692.8 nm & 694.2 nm) in rubies or the determination of diamond types Ia or Ib status are frequently performed with this setup. Type Ia or colorless diamonds show strong nitrogen absorption peaks at 415 nm and 478 nm, whereas type Ib, yellow diamonds have wider distribution of nitrogen atoms eliminating these peaks. Other useful peaks are at 592 nm and 741 nm, peaks which indicate artificial coloring has occurred.

Advanced Gemology Measurements

Various entities report the use of photoluminescence systems to detect gemstone



characteristics. This technique most often makes use of a laser excitation source, sample chamber, and detection system. The laser wavelength depends on the feature(s) being sought. Most often, the chamber will include provisions for cryogenic cooling. The detection system can range from simple cameras to photomultiplier tubes. Avantes has provided systems with various lasers as well as the AvaSpec-ULS2048LTEC-USB (thermoelectrically cooled) spectrometer. An AvaRaman-Probe, fiber-optic Raman probe, is required as well to filter the excitation source out of the measured data.

One example of the usefulness of this technique is the detection of high-pressure, high-temperature treatment (HPHT). HPHT is sometimes used to improve diamond color, for instance turning brown diamonds into green or yellow diamonds. Since many regulatory agencies require that all such treatments be disclosed, the chief concern is that stones could be misrepresented as natural or untreated stones. HPHT can be detected with an Avantes low-cost, high-performance photoluminescence system as it leaves a trace peak at 694 nm.

Components used in the gemology setup

BASIC

Spectrometer	AvaSpec- ULS2048 –USB2
	Grating VA (360-1100 nm), 25 µm slit, DCL-UV, OSC
Software	AvaSoft-Full
Fiber-optics	FC-UV600-2, UV/VIS, 2 m, SMA
Accessories	AvaSphere-50-LS-HAL Integrating sphere with halogen light source WS-2-GEM White reference tile with 10 mm radius hole, specially for gemstone measurement AvaSphere-50-HOLD WS-2-GEM Tile holder for AvaSphere-50 for gemology applications

ADVANCED

Spectrometer	AvaSpec-ULS2048LTEC-USB2
	Grating NC (640-830 nm), 50 µm slit, DCL-UV
Software	AvaSoft-Raman
Light Source	HeNe-17 LASER 633 nm red random-polarized laser, 17 mW
Fiber-optics	AvaRaman-PRB-633, LASER-COL-SMA
Accessories	Cryogenic container

Fluorescence measurements

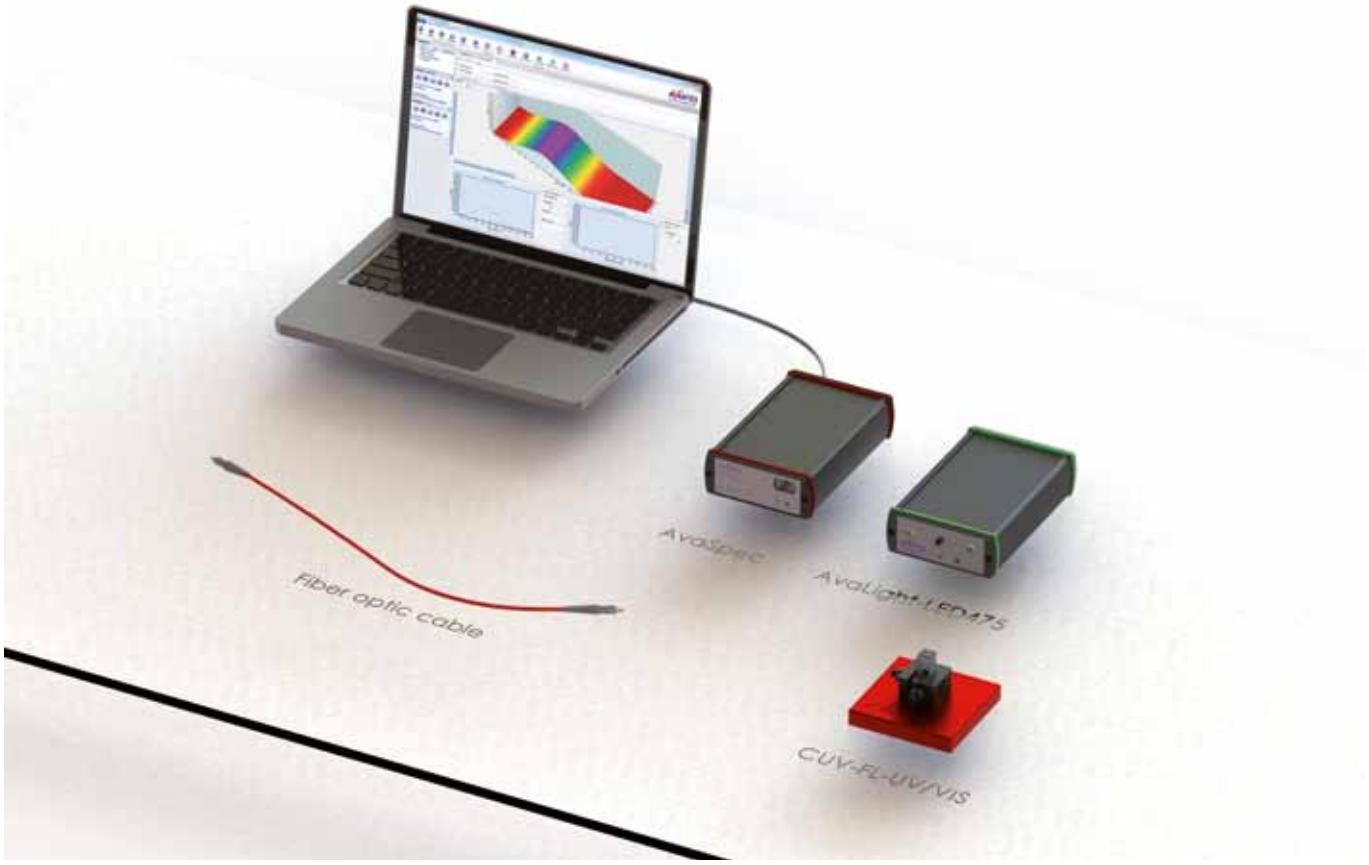
Fluorescence spectroscopy, also known as fluorometry or spectrofluorometry, is a type of electromagnetic spectroscopy, which analyzes fluorescence from a sample. It involves using a beam of light that excites the electrons in molecules of certain compounds and causes them to emit light; typically, but not necessarily, visible light. It is a useful technique in many biological (chlorophyll and carotenoid), biochemical (fluorescence diagnosis of malignancies) and environmental applications. For most fluorescence applications the amount of fluorescence energy emitted is only 3% of the amount of excitation light energy. Fluorescence light has a lower energy (higher wavelength) than the excitation energy and is usually scattered light. This means it emits energy in all directions.

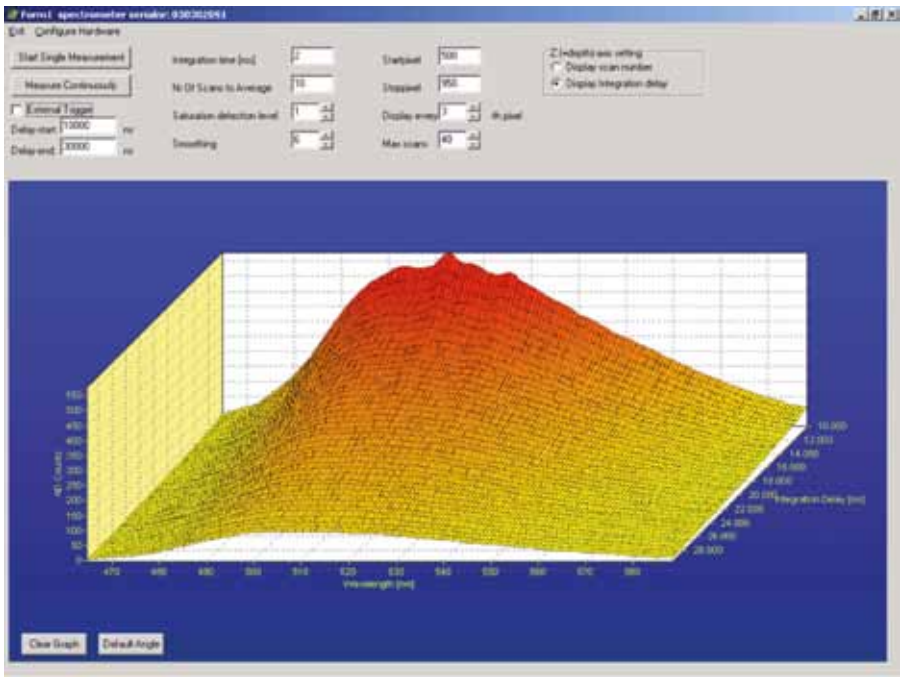
For optimal performance assuming the time acquisition window is not limited, Avantes recommends our AvaSpec-ULS2048LTEC spectrometer for this application, since it can support long integration times often exceeding 5 seconds. When higher-speed acquisition is required, Avantes recommends the AvaSpec-ULS2048XL back-thinned CCD spectrometer. For maximal sensitivity the top model of the SensLine, AvaSpec-HS1024x122-USB2 spectrometer is recommended.

When configuring the measurement setup, preventing excitation light from entering the spectrometer is an important issue.

Possible methods to accomplish this, where one does not exclude the other, include:

- Make use of an AvaLight-LED light source which typically has a narrow bandwidth enabling the limitation of excitation to shorter wavelengths that are not part of the emission spectrum
- Use a broadband light source such as the AvaLight-HAL for high output in combination with an (interference) band-pass or low-pass filter.
- Make sure the optical path for excitation light and fluorescence are perpendicular. This means the excitation light will not enter the receiving fiber (use the CUV-UV/VIS-FL or the CUV-DA)
- Use the fluorescence decay time to separate excitation energy from the integration time start pulse. Use a pulsed light source to accomplish this (pulsed laser or AvaLight-XE Xenon flash)





Components used in the fluorescence setup

Spectrometer	AvaSpec-ULS2048-USB2 (optional–TEC)
	Grating VA (360-1100 nm), 200 µm slit, DCL-UV/VIS, OSC
Software	AvaSoft-Full
Light source	AvaLight-LED470 or AvaLight-HAL with CUV-HAL and interference filter
Fiber-optics	FCR-UV200/600-2-IND with FCR-FLTIP-IND or 2 FC-UV600-2 fiber-optic cable UV/VIS, 600 µm, 2 m, SMA
Accessories	CUV-DA or CUV-HAL or CUV-FL-UV/VIS

Pre-configured spectrometers can be shipped within 24 hours

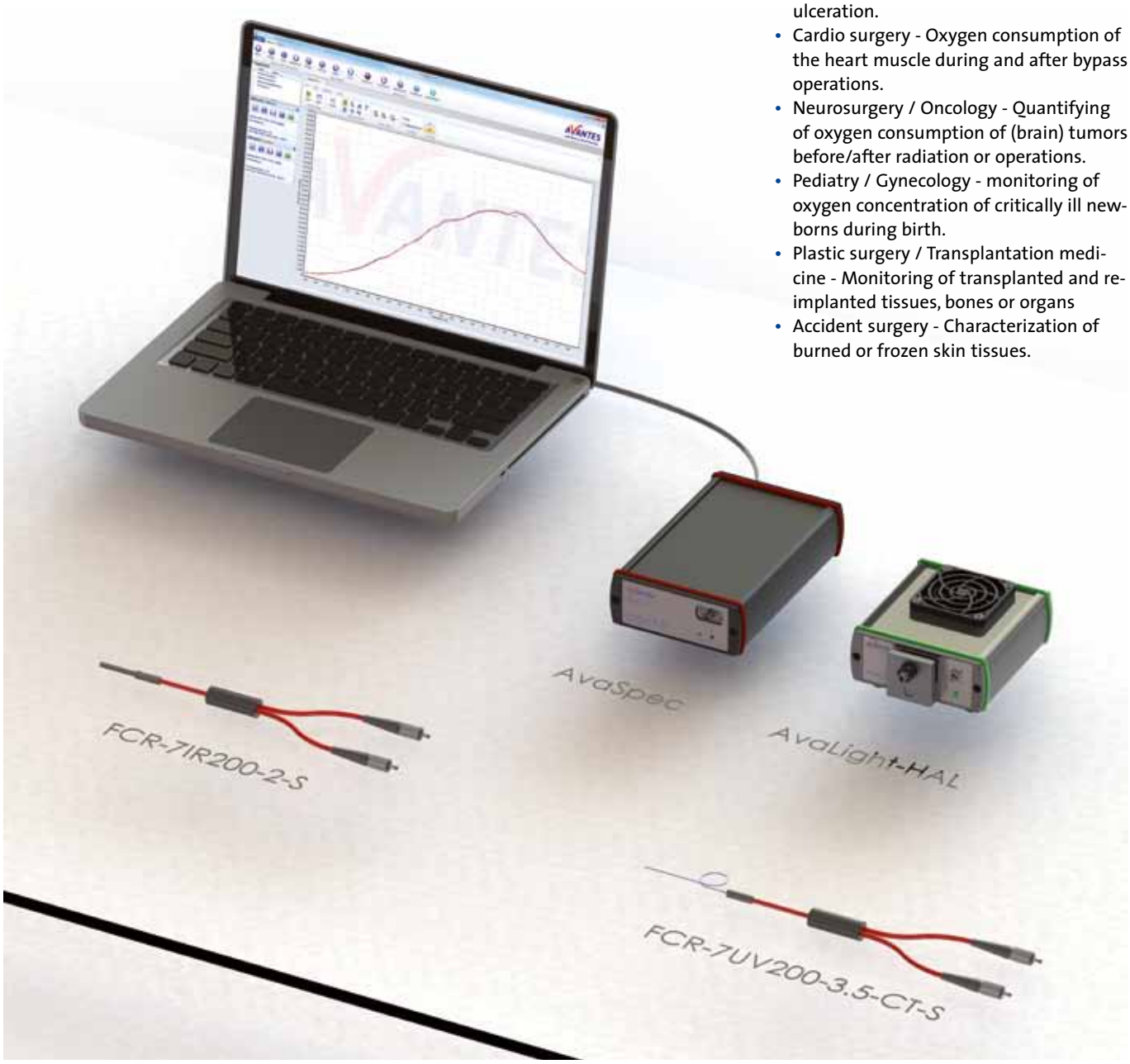
Biomedical applications

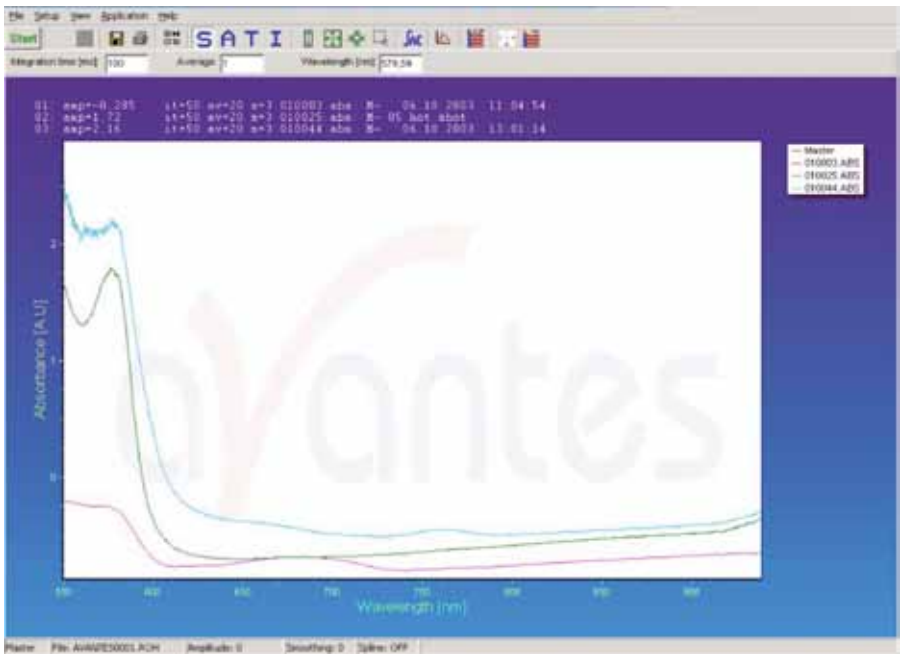
Avantes has extensive experience in the biomedical industry. Over the years, we have supported the development of both non-invasive and invasive spectrometry solutions for tissue and blood parameter measurements.

Some of the important medical indicators which Avantes has worked with include oxygen, hemoglobin, cytochrome and water concentration measurements in tissues and in the venous system. The AvaSpec-ULS2048-USB2 and our SensLine instruments are frequently recommended for these applications. The AvaLight-HAL tungsten halogen light source provides an excellent, high-stability VIS/NIR source for biomedical applications involving reflection measurements. Avantes worked successfully with many customers to enable continuous measurements of oxygen saturation, concentration of total, oxygenated and deoxygenated hemoglobin.

Some examples of implementations of Avantes solutions:

- Angiology / Pharmacology - Monitoring of the oxygen saturation after the application of vaso-active substances. Oxygen changes caused by Reynaud syndrome and microcirculation diseases in tissue.
- Dermatology - Detection of local -regional perfusion diseases, recurrence of melanomas.
- Diabetology - Micro-angiopathy, early detection of Endotheld dysfunction and ulceration.
- Cardio surgery - Oxygen consumption of the heart muscle during and after bypass operations.
- Neurosurgery / Oncology - Quantifying of oxygen consumption of (brain) tumors before/after radiation or operations.
- Pediatry / Gynecology - monitoring of oxygen concentration of critically ill newborns during birth.
- Plastic surgery / Transplantation medicine - Monitoring of transplanted and reimplanted tissues, bones or organs
- Accident surgery - Characterization of burned or frozen skin tissues.





Components used in the biomedical setup

Spectrometer	AvaSpec-ULS2048-USB2
	Grating NB (500-1000 nm), OSF-475, 50 µm slit
Software	AvaSoft-Full (optionally AvaSoft-CHEM)
Light source	AvaLight-HAL
Fiber-optics	FCR-7IR200-2-MS-PK-S special PEEK reflection probe, can be sterilized or FCR-7IR200-3.5-CT-S special catheter reflection probe
Accessories	WS-2 white reference tile

Did you know
Avantes is specialized
in custom made
fiber-optic cables?