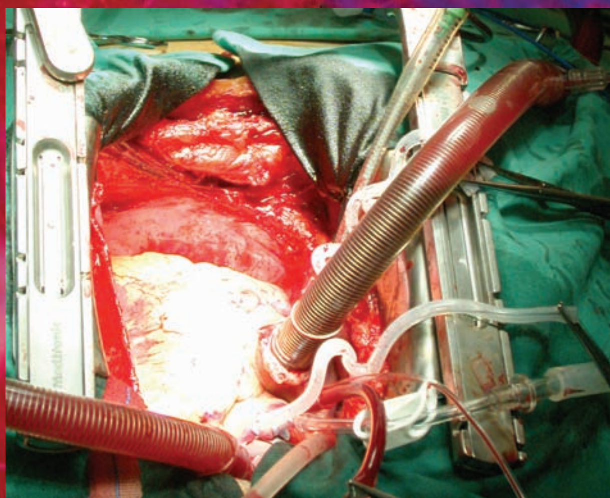
Applications/Sensors



Introduction - a wide range of application references

Avantes line of spectrometers enables the use in a very wide variety of sensing and sensor applications, such as:

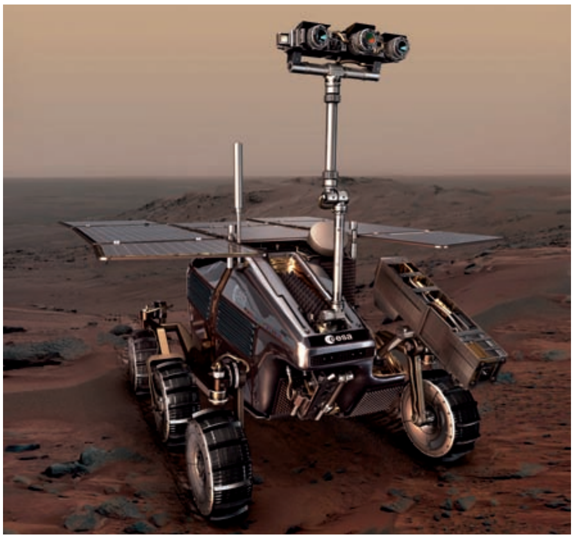
- Agriculture - Measure oxygen content of soil, determination of chlorophyll by fluorescence measurements, determination of Nitrate fertilizer concentration in crops
- Astronomy - Measuring the spectrum of stars, planets and comets
- Automobile Industry - Measure on-line low concentration of water contamination in oil, measure coating on car glass windows
- Biology - To measure chlorophyll concentration and UV absorption, measuring color change and sexual behavior of fish under influence of sunlight, determine bird feather color and ornamental appearance, investigating photonic crystal structures for UV protection mechanism of the high altitude flower Edelweiss, measure the mechanical properties of small bio-molecules, to develop an artificial bio-inspired multilayer system which reproduces the visual effects provided by the insects cuticle.
- Biotechnology - Measuring survival of microorganism's population after high UV pulsed light emission
- Chemistry - Determination of Phosphates in burning processes, endpoint detection in crystallization processes, measuring oxygen concentration of gasses, determine the oxidation state of vanadium in catalyst reactions, measure high-density multimode integrated polymer optics, determine effect of Organic Impurities on the Hydrocarbon Formation
- Coating Industry - Measure layer thickness of optical transparent coatings, in-line measurement of the color of glass windows
- Colorimetry - Color determination of plastics, textile, food, paints, birds, fish, lizards
- Construction - Measuring gas content of isolated double glass windows by high-energy spark light emission.
- Cosmetics - Measuring color of lipstick, nail polish and hair dye.
- Dairy industry - measuring color of milk products and yogurts, measuring consistency of cheese during fabrication process
- Dental - Measuring the color of teeth and spectral analyses of residuals in gums. Carious identification in teeth with plasma spectroscopy
- Dermatology - Measuring UV Absorption of the skin in correlation with UV protection of digested carotenoids. Determination of penetration of chemicals through the skin into the blood stream.
- Environmental - Water quality measurement (chlorine/nitrate) with deep UV absorption, measuring pH of seawater, detect forest fires on 15 km distance, quantitative model of the performance of laser pointer style gas leak detectors, UV radiation monitoring
- Film Industry - Controlling the color of thermo graphic films and lightning
- Food - Measure water content of tomatoes, potatoes, measure sweetness of carrots and tomatoes, measure origin of olive oil. Determination of soluble solids in apples, kiwifruit and ripeness of peach, using NIR spectroscopy. Determination of odor and flavor of white wine. Detecting color change in ripening process of bananas. Measuring color change of meat during cooking process
- Gas Chromatography - UV absorption and gas detection
- Gemology - Value determination of diamonds (synthetic/natural) by measuring absorption peaks, measure color of diamonds and other gemstones. Determination of authenticity of gemstones, using Raman spectroscopy
- LCD industry - Measure transmission, retardance, twist angle, thickness and other optical properties of thin films
- LIBS Laser Induced Breakdown Spectroscopy for analysis of solids and gasses, beryllium contamination in saphires
- Light Industry - Measure Laser diodes and LED's characteristics, measure irradiance values of light bulbs and UV-light sources, used for water purification
- Meteorology - UV radiation monitoring
- Medical - Measure hemoglobin, cytochromes and beta-carotene non-invasively, measure CO_2 and HbO_2 in the heart to monitor myocardial ischemia during bypass operations. Measure oxygen consumption of tumors. Fluorescence measurements for cancer and cardiovascular diseases diagnosis
- Military - Identify color of smoke screens, transmission and illumination measurement on night vision devices
- Nanotechnology – detection of Plasmon line shapes, measure non-reciprocal refection of sub-wavelength hole-array
- Narcotics - Identification of drugs with Raman spectroscopy
- Nuclear Industry - To determine fluorescence in an active nuclear reactor
- Optical Filters - Quality control to by determining absorption and transmission properties of interference filters
- Painting Industry - On-line measurement of color during color mixing process
- Paper Industry - Measure color/whiteness of paper, moisture determination of paper pulp.
- Particle Size analyses of cancer cells
- Pharmaceutical - Determination of bacteria concentration in fermentors, endpoint detection in crystallization processes.
- Photovoltaic Industry – Layer thickness and spectral absorbance measurement during fabrication process
- Plasma Etching - Layer thickness measurement
- Printing Industry - Color determination of ink, spectral measurement of high-power UV light sources for drying printing ink.
- Pyrometry - measuring temperature of turbine blades in electrical power plants
- Radiometry - measuring energy spectrum of light sources and the sun
- Raman Spectroscopy - Analyses of compounds in organic chemistry
- Semiconductor Industry - Layer thickness measurement and mapping of wafers
- Solar spectrum measurements – measure the airmass and reference spectra for Photovoltaic performance evaluation
- Space Research – Measure UV radiation on Martian surface
- Sun Glasses Industry - Measuring UVA, UVB, and UVC absorbance of sunglasses.
- Textile Industry - Measuring colors

For some of the applications a typical setup and more detailed information are given in the following paragraphs.

Avantes spectrometers used all over the world... and in space

Just a few examples to illustrate the wide variety of applications in which AvaSpec spectrometers are used.

High Resolution UV-VIS Spectrometer for the Surface of Mars

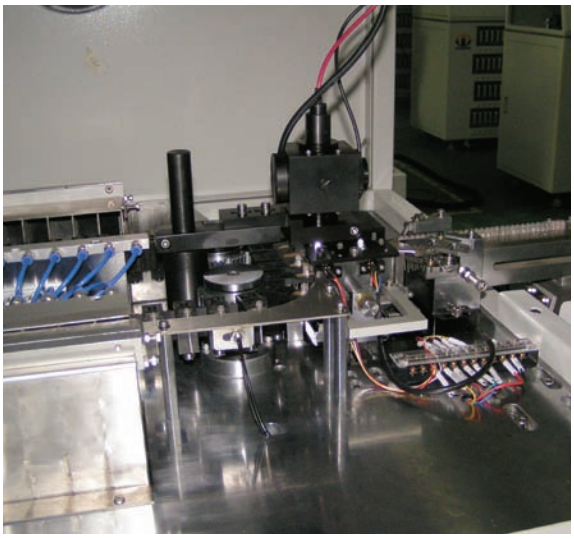


The UV environment on Mars remains an unmeasured quantity, requiring in situ instrumentation on planetary landers. UV radiation plays a major role in a range of situations, such as the photochemistry of upper atmospheres, creation of surface oxidation environments and damage to biological organisms.
A special lightweight version of the AvaSpec miniature spectrometer (~100 g) which is in the process of development for future surface missions to Mars, aimed at measuring the UV-VIS spectrum encountered at the Martian surface. Responsivity of the AvaSpec covers the wavelength range 200-800 nm, with a resolution of 1.5 nm. At present, great uncertainty lies in the derivation of optical properties of suspended dust in the Martian atmosphere at UV wavelengths, and these parameters are required for accurate modeling of the transfer of UV to the surface in astro-biological investigations. This instrument will provide surface spectra ranging from the UV to visible, thus allowing the derivation of optical properties across a wide region of wavelength. The expected launch date will be in 2013 as part of the ExoMars mission to Mars.

Forest Fire Finders include AvaSpec and telescope

The Forest Fire Finder is an innovative forest fire detector and tracking system, developed in Portugal and is placed on top of a tower. The system makes human observation unnecessary since it is autonomous and automatic.
It was developed with the aim of creating a system to help minimize the impact of forest fires through their early detection and tracking. In the Forest Fire Finder an Avaspec-2048-USB2 spectrometer is installed, next to a video camera, a weather station, a telescope, a processing/controlling unit and a communications unit. The telescope and the video camera are constantly scanning the horizon (in a 320° angle). A fiber connected to the Telescope brings light to the spectrometer, and can collect spectra up to 15km of distance. Spectra collected from the spectrometer are processed and analyzed. A video camera takes pictures in an established time interval and it is capable to send real time video as well. The camera is aligned with the telescope, ensuring that what is “seen” is what is analyzed. Whenever the system detects a forest fire, an alarm report is sent from the managing system control to the operations center via SMS, IP, GSM, etc. The alarm report contains several informations including fire location, detection time, weather conditions (wind direction and velocity, temperature and humidity) and a image of the fire.

Compact ultrafast spectrometers inside LED sorting machines



The lighting industry is rapidly progressing into the new dimensions of opportunity provided by solid-state lighting. Especially Light Emitting Diodes (LED’s) and Organic LED’s (OLED’s) will replace traditional lightning and fluorescent lights in the coming decade.

In order to have a uniform lightning it is important that the LED’s that are used are matching in color.

These so-called color parameters of LED’s can be determined by a radiometric calibrated fiber coupled spectrometer, such as the AvaSpec-2048-USB2. Important aspect of this application is the speed and accuracy with which the LED’s can be classified. The AvaSpec-2048-USB2 spectrometers can run at a 1.1 ms integration time and a 2ms/scan data transfer time, allowing the LED sorting machine to run at maximum speed.

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AvaSpec for bird research on the Falkland Islands

The AvaSpec 2048, fitted with a 2048 pixel CCD array, was chosen by seabird behavioural scientist for bird research on New Island on the Falklands. The AvaSpec, enabled a portable setup which was needed to take directly to the seabird colonies, working from a small 12V battery and laptop computer. The data-sampling allowed fast read-out and storage of the data.

An indicator to determine the maturity level of birds, in this instance 'Thin-Billed Prions', is their feather color and ornamental appearance. Because of their ability to see UV and produce signals in this range (plumage color, bill displays), spectrometry needs to be used to objectively assess skin and feather colors.

Besides of the spectrometer use to measure colors as indicators for individual quality, the scientists are also interested to determine 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.

AvaSpec in medical device to determine risk for cardiovascular diseases

The AGE Reader is a medical device to estimate cardiovascular risk. The AGE Reader non-invasively assesses the accumulation of advanced glycation end-products (AGE's) in the patient, using autofluorescence of the skin with ultraviolet light. In the AGE Reader is an Avaspec spectrometer used to do this. AGE's have a pivotal 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 non-invasive measurement immediately offers valuable additional information, comfortably and safely for your patient and you. The AGE Reader has been validated in several large-scale, clinical trials over the past 6 years involving 1000s of adults.

AvaSpec used to monitor fertilizer concentration

Site specific Nitrogen fertilization is one of the main objectives in precision agriculture. The Nitrogen sensor consists of a dual channel AvaSpec spectrometer, fiber-optics and processing electronics mounted in a blue cap on top of a tractor. The sensor can determine the crop Nitrogen status, by measuring the light reflecting properties.

The crops show typical light reflectance properties, that are indirectly influenced by the nitrogen nutrition status of the crop. In the visible spectral range (380-740nm) the reflection is an indicator of the leaf chlorophyll content, in the NIR range (700-1000nm) reflectance is mainly affected by crop biomass.

A special viewing geometry and integrated irradiance correction guarantees accurate measurements, the system logs crop and GPS data on a chip card.

AvaSpec in Mineral Automated Yield Analyzer (MAYA) for the Online analysis in the Fertilizer Industry

The Mineral Automated Yield Analyzer System (MAYA 6060) is designed for real-time analysis of minerals, ores, chemicals and raw material. When placed above the conveyor belt to scan material passing below, the MAYA system provides a rapid, reliable and straightforward solution for mineral analysis. With its advanced technology, the MAYA system is compact, self-contained, easy to install or relocate and user friendly. Unlike other elemental analyzers, the MAYA system does not generate ionizing radiation (X-Ray, gamma, neutron, etc.) and is the safest available method for full elemental on-line analysis. This level of safety provides an enhanced and more secure working environment.

The MAYA system is based on Laser Induced Breakdown Spectroscopy (LIBS), a state-of-the-art optical technique for measuring the elemental composition of materials. Spectral analysis of emissions created by a pulsed laser beam yields a fingerprint of the elemental composition of the sample.

The method of analysis is as follows:

- A laser beam is intensely focused on the surface of the material under analysis.
- The temperature at that point reaches 20,000°C-40,000°C. The surface material becomes plasma and emits light whose wavelength ("color") 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 (~spectra) to a given chemical element's spectrum.
- The laser typical operating frequency generates approx. 300-500 "good" spectra, which enables to receive a full analysis result every 3 - 5 minutes.

AvaSpec in MultiSpec Analyzer of Chemotherapy Bags

Over the past few years Microdom has focussed its R&D activity on spectroscopic analysers designed for the control of chemotherapy infusion bags prior to dispensation to cancer patients.

The bags of cytotoxic solutions have to be compounded at "point of care" (hospital or cancer institute pharmacy) for two main reasons:

- The formulation is customized for each patient: type of molecule, molecule concentration, type of vector (glucose, NaCl).
- The stability of the active molecules once in solution is reduced.

3 main parameters are essential to qualify the produced cytotoxic bags:

- Molecule identification
- Solvent identification
- Molecule concentration.

In order to meet these requirements Microdom has developed an innovative concept based on the coupling of 2 spectrometers (patented design): a UV/Vis spectrometer from Avantes (200-700 nm) and a FTIR spectrometer. An auto-sampler from Gilson is used to inject the samples into the measure cells of the analyser. The UV/Vis spectrometer is fundamental for the quantification step since most molecules absorb at the low end of the UV range. The FTIR spectrometer on the other hand is essential for the identification step and the quantification of highly absorbent solutions (the dilution step is thus avoided).

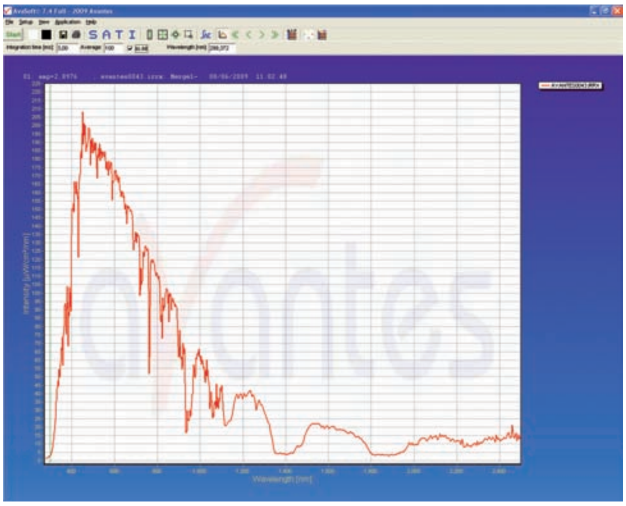
The system has been successfully marketed in France for the past 2 years. The international deployment is now starting.

Solar spectrum Irradiance measurement

Typical solar spectrum Irradiance measurement applications include scientific meteorological/climate observations, material testing research, solar collector/Photo Voltaic panel efficiency and solar renewable resource assessment.

Sunlight is defined as the total spectrum of the electromagnetic radiation emitted by the Sun. On Earth, sunlight is filtered through the atmosphere, and the solar radiation is visible as daylight when the Sun is above the horizon. When the direct radiation is not blocked by clouds, it is experienced as sunshine, a combination of bright light and heat. Sunlight may be recorded using a pyranometer, pyrheliometer or the AvaSolar system as described below.

Typical Solar irradiance spectrum measured by a dual channel broad band AvaSpec-UV/VIS/NIR.



In the AvaSolar setup configuration we have a total of 4 channels, 2 x an identical setup for 200-2500nm. One spectrometer setup measures the direct sun radiation through a CC-UV/VIS/NIR-5.0 special cone cosine corrector with 5 degrees opening angle (see section Fiber Optics - Cosine correctors page 104). This 5 degree Cosine corrector is normally connected to a sun-tracker system.

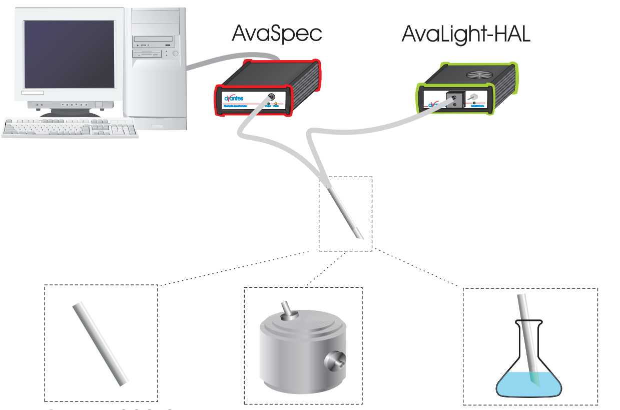
The other spectrometer setup measured with a standard CC-VIS/NIR cosine corrector and measures the total radiation.

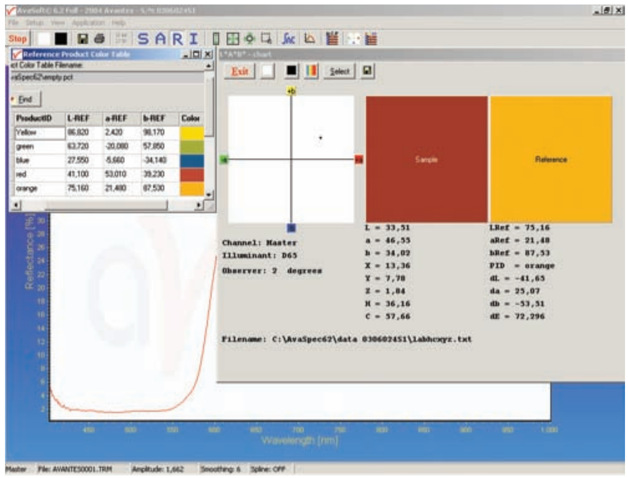
Components used in the Solar Spectrum Irradiance setup are depicted in the following table:

Spectrometer	2 x Broadband spectrometer in Rackmount 200-2500nm, consisting of: AvaSpec-2048-USB2-RM Grating UA (200-1100nm), 50µm slit, DCL-UV, OSC-UA AvaSpec-NIR256-2.5-RM (1000-2500nm), 50µm slit, OSC-NIR
Software	AvaSoft-Full + AvaSoft-IRRAD
Fiber optics	2 x FCB-UV/IR600-2, 1 UV/VIS, 1 VIS/NIR, 2m, SMA
Accessories	CC-VIS/NIR + CC-UV/VIS/NIR-5.0, 2 x IRRAD-CAL-UV/VIS, 2 x IRRAD-CAL-NIR or AvaLight-D-CAL and AvaLight-HAL-CAL + HL-recal-NIR

Color measurements

Generally, color measurements of objects and thick fluids can be done in different setups, e.g. using reflection probes or an integrating sphere. A spectrometer is needed with a range from 380 to 780 nm and a spectral resolution of 5 nm FWHM. Further a white continuous light source is needed as well as a white reflective tile. For the different applications, such as color of textile, paper, fruit, wine, bird feathers etc. different probes can be used. A typical setup for color measurements in reflection is given below.





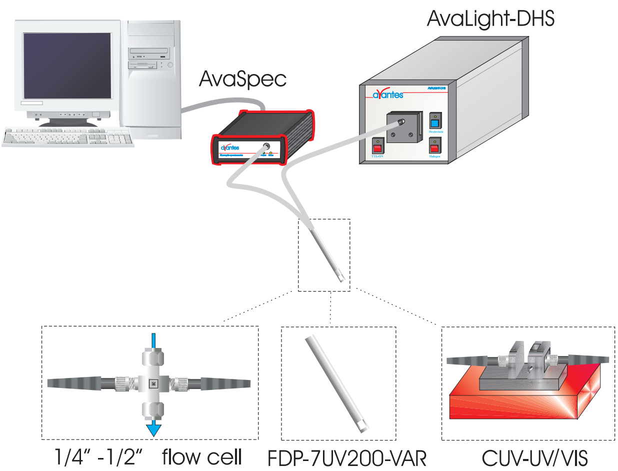
Components used in the color measurement setup are depicted in the following table:

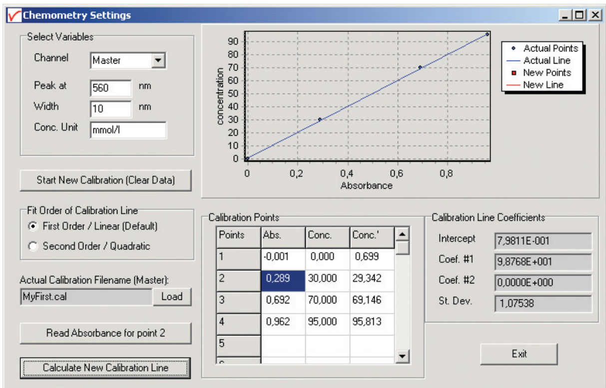
	Color Reflection with fiber optic probe	**Color Reflection with integrating sphere**	**Color Reflection in thick fluids**
Spectrometer	AvaSpec-128 -USB2, Grating VA (360-780nm), 100µm slit AvaSpec-256 -USB2, Grating VA (360-780nm), 50µm slit AvaSpec-2048 -USB2, Grating BB (360-780nm), 200µm slit, DCL-UV*		
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 6x200µm illumination fibers, 1 200 µm read fiber, UV/VIS, 2m, SMA	1 pc. FC-UV600-2 illumination fiber 600µm UV/VIS, 2m, SMA 1 pc. FC-UV600-2 detection fiber 600µm UV/VIS, 2m, SMA	FCR-7UV200-2-45 Reflection probe with 45 degree window with 6x200µm illumination fibers, 1 200 µm read fiber, UV/VIS, 2m, 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

Absorbance measurements in fluids can be done in different setups and wavelength ranges, like with fiber optic dip probes or flow cells for in-line absorbance or a cuvette holder for absorption measurement in a sample. For UV/VIS measurements a spectrometer can be configured with a range from 200 to 1100 nm and a spectral resolution of 1.4 nm FWHM. Further a combined deuterium-halogen light source is needed. For the different applications different probes can be used. A typical setup for absorption measurement is shown below.





Components used in the absorption measurement setup are depicted in the following table:

	In-line Absorption with flow cell	In-line Absorption with Dip probe	Absorption with cuvette holder
Spectrometer	AvaSpec-2048-USB2, grating UA (200-1100nm), DUV, slit-25, DCL-UV, OSC-UA AvaSpec-2048x14, grating UA (200-1100nm), 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 200µm UV/VIS, solarization resistant, 2m, SMA	FDP-7UV200-2-VAR Transmission dip probe with variable path length, with 6x200µm illumination fibers, 1 read fiber, UV/VIS, 2m, SMA	2 pcs. FC-UV200-2-SR fiber cable 200µm UV/VIS, solarization resistant, 2m, SMA
Accessories	1/4"or 1/2"flow cell	-	CUV-UV/VIS cuvette holder

Irradiance measurements

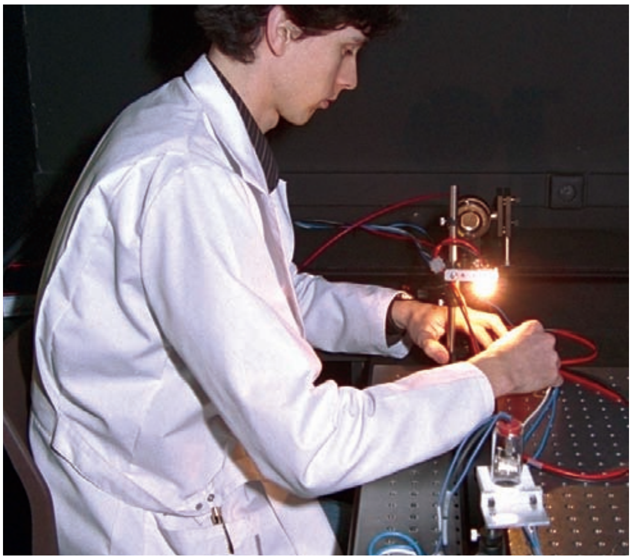
Spectral Irradiance measurements can be done in different setups and wavelength ranges, like with fiber optic cosine corrector or integrating sphere. Irradiance measurements can be done in the UV, VIS as well as in the NIR range.

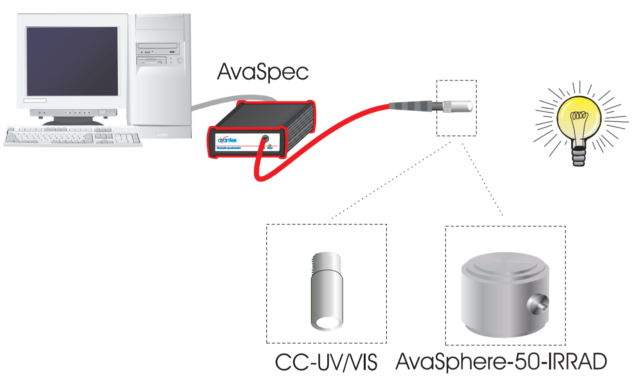
For absolute irradiance measurements a spectrometer can be configured and radiometrically calibrated in the Avantes calibration laboratory with a range from 200 to 400 nm or from 350-1100 nm for a combined UV/VIS range of 200-1100nm, or for the 1100-2500nm range. This calibration is done on a fixed setup, i.e. fiber optics and diffusor can not be changed afterwards.

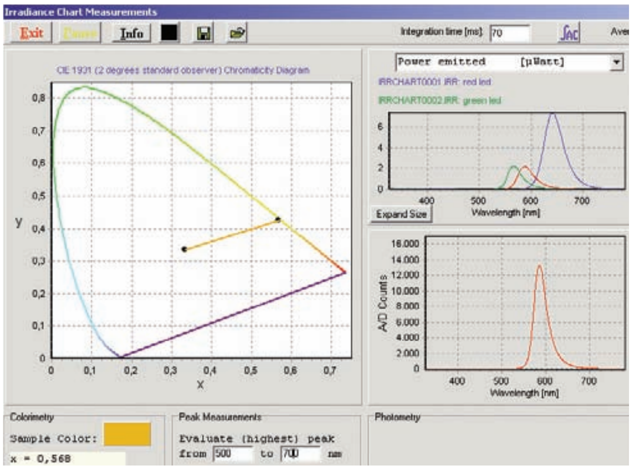
In order to be more flexible in the setup a calibration can be performed on location with a calibrated VIS/NIR light source (AvaLight-HAL-CAL) or calibrated UV/VIS light source (AvaLight-DH-CAL).

Our comprehensive AvaSoft-IRRAD software allows you to perform and load irradiance calibrations.

A typical setup for irradiance measurement is given below.







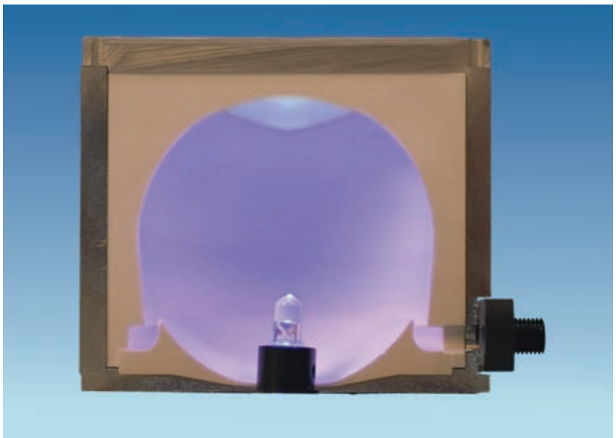
Components used in the irradiance measurement setup are depicted in the following table:

	UV Irradiance	VIS Irradiance	NIR Irradiance
Spectrometer	AvaSpec- 2048-USB2		AvaSpec-NIR256-2.5
	Grating UC (200-400nm), DUV, 50 µm slit	Grating VA (360-1100nm), 50µm slit, OSC	Grating NIR100-2.5 (1100-2500nm), 50µm slit, OSF1000
	Grating UA (200-1100nm), DUV, 50µm slit, OSC-UA		
Software	AvaSoft-full and AvaSoft-IRRAD		
Calibration	IRRAD-CAL-UV (200-400 nm)	IRRAD-CAL-VIS (360-1100nm)	IRRAD-CAL-NIR (1100-2500nm)
	IRRAD-CAL-UV/VIS (200-1100nm)		
Light source (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 pcs. FC-UV200-2 fiber 200µm UV/VIS, 2m, SMA		FC-IR200-2 fiber 200µm VIS/NIR, 2m, SMA
Accessories	CC-UV/VIS or CC-VIS/NIR cosine corrector or AvaSphere-IRRAD integrating sphere		CC- VIS/NIR

LED measurements

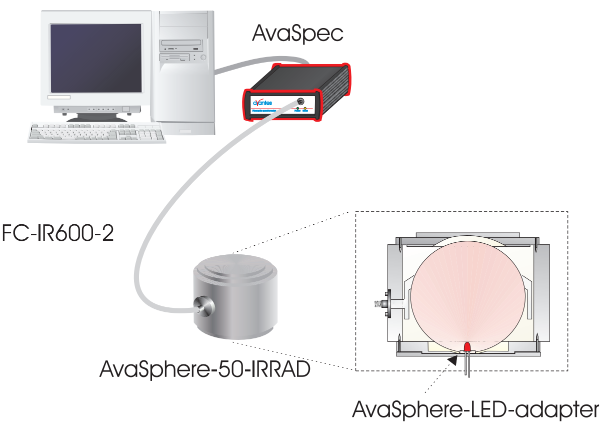
Since it is possible to manufacture Light Emitting Diodes in a wide variety of colors and brightness, it is also necessary to accurately measure their optical characteristics.
There are two ways of measuring LED's, photometry and radiometry. Photometry only relates to visible radiation, like the human eye response. Radiometry is not limited to the human eye response. In both photometry and radiometry, the LED can be characterized in emitted power or in the intensity. The 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 flux per unit solid angle directed toward the observer, usually along the axis of the LED and is given in candela's.

Because of their size, LED's are very difficult to mask and standards are not currently available defining how such measurements should be performed. Careful consideration in the design and use of LED test and measurement equipment is essential to achieve valid measurement results that fit the application.
The simplest and quickest way to measure the total luminous flux from an LED is to use an integrating sphere, coupled to an Avantes spectrometer. The integrating sphere is a simple



device for measuring optical radiation. The interior surface of the integrating sphere is perfectly diffusing and has spatially uniform reflectance. The radiant exchange from diffuse surface to diffuse surface integrates the light, resulting in equal radiance at any point on the sphere wall.

The system can be calibrated with a halogen light source AvaLight-HAL-CAL-ISP. With AvaSoft-IRRAD spectrometer software it is possible to calculate the parameters from the measured spectral distribution and to perform an absolute irradiance measurement. Also the intensity of the measured light can be calculated, displayed and saved as spectral irradiance in $\mu Wcm^{-2}nm^{-1}$. Further, the following output parameters are displayed in a separate window: radiometric quantities $\mu W/cm^2$, $\mu Joule/cm^2$, µWatt or µJoule, photometric quantities Lux or Lumen, color coordinates X, Y, Z, x, y, z, u, v and color temperature. In addition raw data in Scope mode is displayed as well as the X-Y Chromaticity diagram, including parameters, specially useful for LED measurements, such as: Dominant Wavelength, Purity, Central Wavelength, Peak Wavelength, Centroïd, etc.
A typical setup for LED measurements is given on the left.



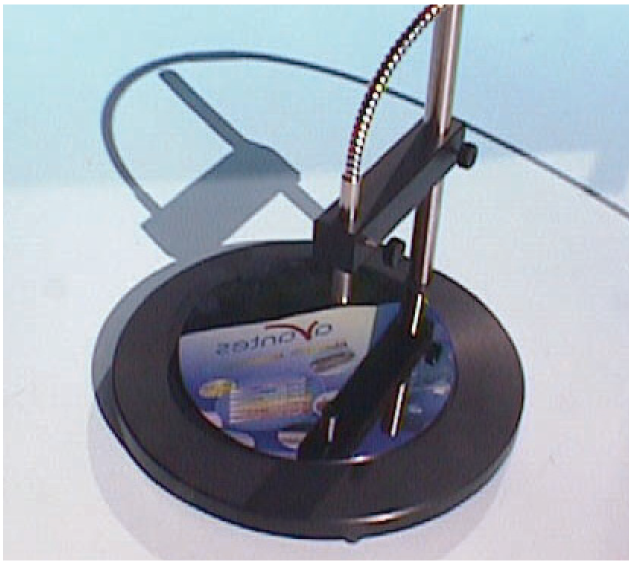
Components used in the LED measurement setup are depicted in the following table:

Spectrometer	AvaSpec- 2048-USB2 Grating VA (350-1100nm), 25µm slit , DCL-UV, OSC	
Software	AvaSoft-full and AvaSoft-IRRAD	
Calibration	AvaLight-HAL-CAL-ISP Calibrated halogen light source	IRRAD-CAL-VIS (360-1100nm) irradiance calibration
Fiber optics	1 pcs. FC-UV600-2 fiber 600µm UV/VIS, 2m, SMA	
Accessories	AvaSphere-50-IRRAD integrating sphere AvaSphere-LED-ADR adapter to hold 3,5,8 mm LED's	

Thin Film measurements

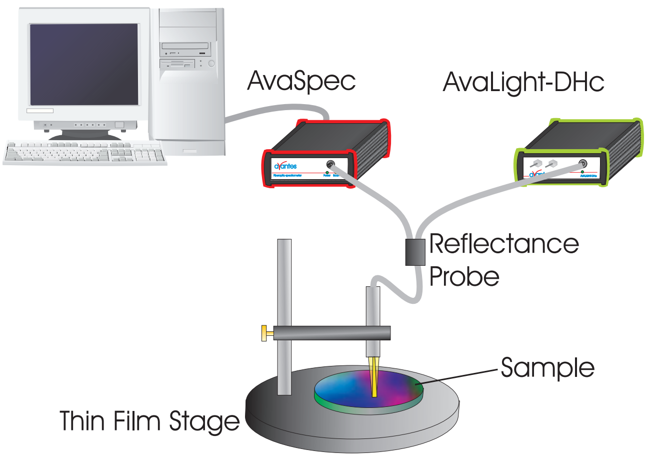
The Thin Film measurement system is based on white light interference measurement to determine optical thickness. This white light interference pattern is translated through mathematical functions into optical thickness calculation. For single layer systems the physical thickness can then be calculated when the n and k values of the materials are known.
The AvaSoft-ThinFilm software has an extensive built-in database of n and k values for most common used materials and coatings.
The AvaSoft-ThinFilm software has an extensive built-in database of n and k values for most common used materials and coatings. For multiple layers the TFProbe multilayer measurement software package is available.
Thin Film measurement is frequently used in the wafer industry, where plasma etching and deposition processes need to be monitored. Other applications are in fields where optical transparent coatings on metals and glass substrates need to be measured.

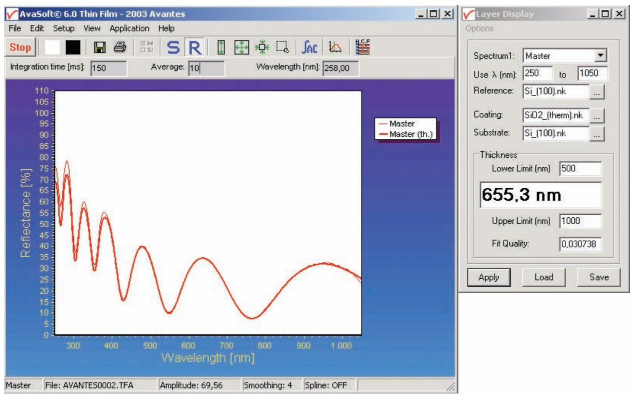
The AvaSoft-Thin film application software enables on-line monitoring of layer thickness and has the possibility to be combined with other AvaSoft applications, such as XLS export to Excel and Process control.



The Thinfilm-standard with 2 calibrated different thickness layers of SiO_2 and a reference layer is available to test the feasibility of the instrument.

A typical setup for Thin Film measurements is depicted on the left.





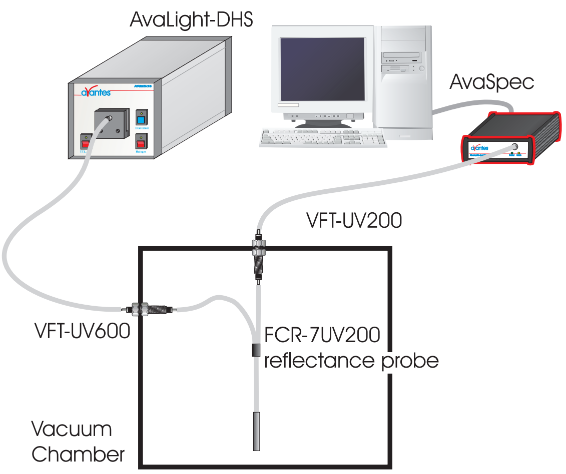
Components used in the Thin Film measurement setup are depicted in the following table:

Spectrometer	AvaSpec- 2048-USB2 Grating UA (200-1100nm), DCL-UV/VIS,100 µm slit, DUV coating, OSC-UA
Layer thickness	10 nm- 50 µm, 1nm resolution
Software	AvaSoft-Thinfilm or TFProbe
Lightsource	AvaLight-DHc Compact deuterium-halogen light source
Fiber optics	FCR-7UV200-2-ME reflection probe UV/VIS, 2m, SMA
Accessories	THINFILM-STAGE to hold reflection probe Thinfilm-standard Tile with 2 calibrated different thickness layers of SiO_2 and a reference layer

Monitoring Coating Processes in Vacuum Chambers

Important parameters that need to be monitored during coating processes, such as layer thickness, composition, surface finish, light transmission, reflectance, polarization ability, and others, can be done by spectroscopy and spectroscopic interferometry. Fiber optics provide a versatile tool to take light in and out of the remote vacuum and clean room chambers and at the same time organize the select measurement geometry for the coating analysis. The illumination of and detection from the coating layering 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. The fiber optics can be arranged to monitor several parameters simultaneously or to measure at different spatial positions or masking conditions simultaneously.

For on-line production several fiber optic sensors with suitable geometries can be placed across the web to monitor the production run. In some cases the ionic source; for example a plasma source, can be monitored for spectral emission to confirm its conditional efficiency during the operating process.



Most applications require a dedicated composition for the monitoring system. You can contact us for confidential advice on what items are best for your application. Here is just one system example.
In this case a reflection sensor is monitoring an on-line coating process on a web. Light is passed into the vacuum area via a vacuum feed through and then passes to the reflectance sensor. The reflected light returns via another feed through, to a measurement spectrometer channel. The reflectance sensor itself can be disconnected locally using the SMA interconnects. A second channel can be added for reference measurement to compensate for fluctuations in the light source.
A typical setup for vacuum measurements is given on the left.

Components used in the vacuum measurement setup are depicted in the following table:

Spectrometer	AvaSpec- 2048-USB2 Grating UA (200-1100nm), 50µm slit, DUV coating, DCL-UV/VIS, OSC-UA
Software	AvaSoft-Full and XLS or PROC add-on
Lightsource	AvaLight-DHS-BAL Balanced deuterium-halogen light source
Fiber optics	FCR-7UV200-2-ME reflection probe UV/VIS, 2m, SMA FC-UV600-2 and FC-UV200-2
Vacuum Feedthrough	FC-VFT-UV200 and FC-VFT-UV600

Applications/Sensors

Horticulture measurements

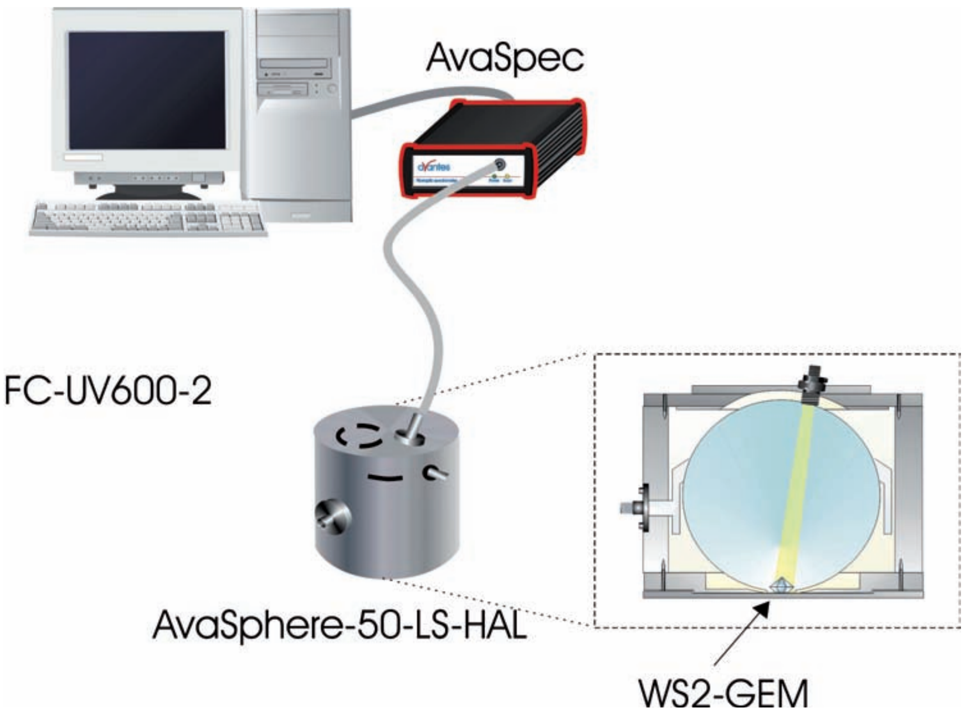
The HortiSpec was developed to measure the light intensity and spectral distribution in the visible and NIR range inside greenhouses.
Plant growth and the photo synthesis depends very much on light intensity and spectral distribution of the light intensity. The light intensity can be measured with the irradiance calibrated HortiSpec in Photons or other parameter, specific for the Horticulture. The HortiSpec can be connected wireless via Bluetooth to a distant computer. The computer can then be used to control the movement of screen filters in the greenhouse or to control special lamps.

Technical Data

Spectrometer	AvaSpec- 2048-SPU2-BT, CCD linear array 2048 pixels. Grating VA, wavelength range (360-1100nm) 200μm slit, Detector Collection Lens, Order Sorting Coating
Data Communication	Via Bluetooth®, maximum distance 150 meter or USB2 high speed
Aperture	Diffusor, diameter 3.9 mm
Software	Hortispec Irradiance software Measurement units: photon flux in μmol/s.m^2 Parameters : Lux, PAR, Blue, Yellow/Green, Red, Far red
Battery Pack	Exchangeable 12 VDC, 1500 mA hr 10 NiMH cells Spectrometer measurement time ca. 4 hours Output: 4-pole IP65 connector
Batterypack-charger	1A

Gemology measurement setup

Color is one of the value determining factors in diamond, in research natural and treated diamonds can be measured in the spectral range of 400-750 nm. Interesting wavelengths can be found in the absorption spectrum at 415 nm and 478 nm (Type Ia diamond natural diamond), where artificial diamonds show no absorption peaks. For treated diamonds artificial coloring can be measured at a wavelength of 592 or 741 nm. The value difference between a natural and treated diamond may be as high as a factor 10. Of course other gem stones may be measured as well, like ruby, alexandrite, sapphire, etc.
A typical setup for gem stone measurements is given below.



Components used in the gemology setup are depicted in the following table:

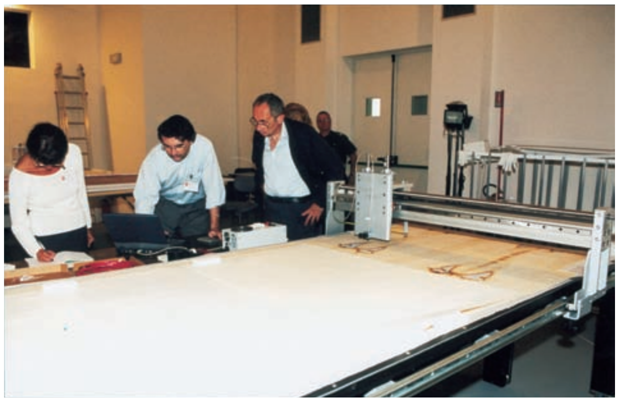
Spectrometer	AvaSpec- 2048 –USB2 Grating VA (360-1100nm), 25µm slit, DCL-UV, OSC
Software	AvaSoft-Full
Fiber optics	FC-UV600-2, UV/VIS, 2m, SMA
Accesories	AvaSphere-50-LS-HAL Integrating sphere with halogen light source WS-2-GEM White reference tile with 10 mm radius hole, specially for gemstone measurement AvaSphere-50-HOLD WS-2-GEM Tile holder for AvaSphere-50 for gemology applications

Fluorescence measurements

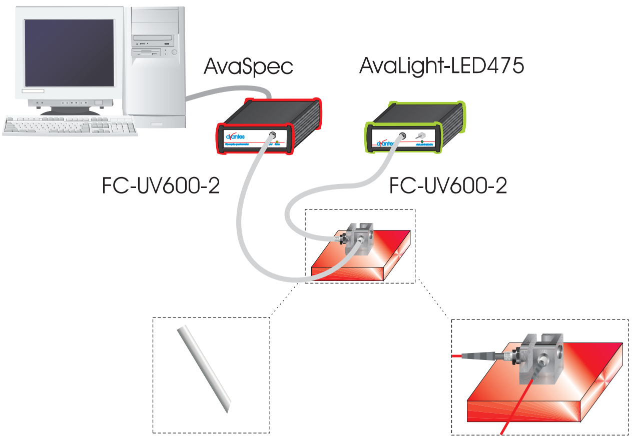
Fluorescence measurements are required in many biology (chlorophyll and carotenoid), biomedical (fluorescence diagnosis of malignancies) and environmental applications.
Fluorescence measurements typically need a high sensitivity setup (AvaSpec-2048TEC recommended for integration times > 5 seconds). For most fluorescence applications the amount of fluorescence energy emitted is only 3% of the amount of excitation light energy. The fluorescence light is of a lower energy (higher wavelength) than the excitation energy and is usually scattered light (emits energy in all directions).
Most important consideration for the setup is to prevent excitation light to enter the spectrometer.
This can be done with different methods, where one does not exclude the other:

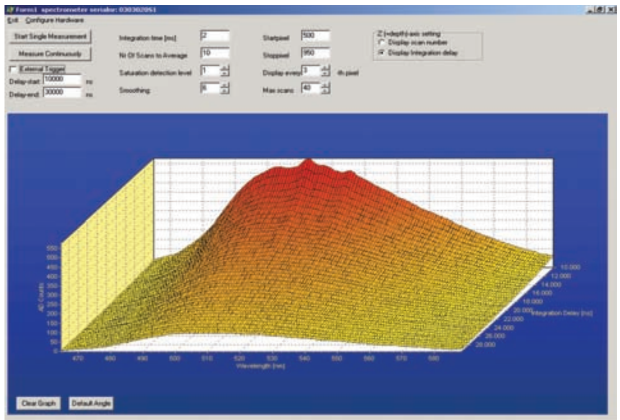
1. Use an AvaLight-LED light source for excitation (small bandwidth), emitting no energy at fluorescence wavelength.
2. Use an (interference) band pass or low pass filter in combination with an AvaLight-HAL light source for high output, small bandwidth excitation
3. Make sure that the optical path for excitation light and fluorescence are 90 degrees perpendicular. This way the excitation light will not enter the receiving fiber (use of the CUV-UV/VIS-FL or the CUV-DHc/XE/LED)
4. Use the fluorescence decay time to separate excitation energy from the integration time start pulse. For this a pulsed light source is required (pulsed laser or AvaLight-XE Xenon flash).

A typical setup for fluorescence measurements is given on the left.



Fluorescence measurements on the Holy Shroud in Turin



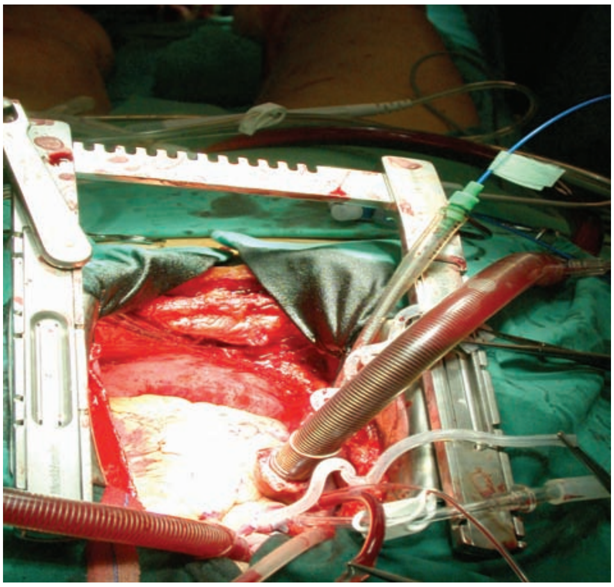


Components used in the Fluorescence setup are depicted in the following table:

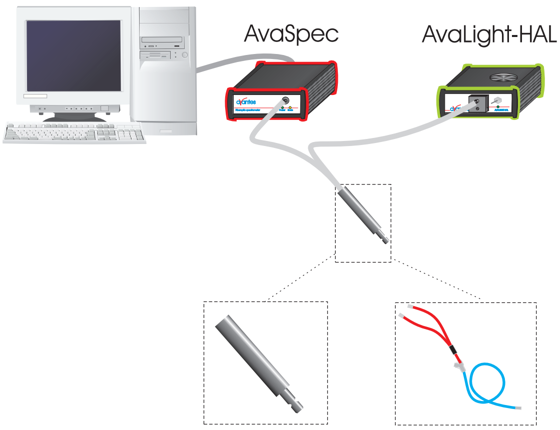
Spectrometer	AvaSpec- 2048 -USB2(optional –TEC) Grating VA (360-1100nm), 200µm slit, DCL-UV/VIS, OSC
Software	AvaSoft-Full
Light source	AvaLight-LED470 or AvaLight-HAL with CUV-HAL and interference filter
Fiber optics	FCR-UV200/600-2-IND with FCR-FLTIP-IND or 2 FC-UV600-2 fiber optic cable UV/VIS, 600 µm, 2m, SMA
Accessories	CUV-DHc/XE/LED or CUV-HAL or CUV-FL-UV/VIS

Biomedical applications

Over the last decade Avantes has helped many application engineers to develop both non-invasive and invasive spectroscopic methods for blood parameter measurements. Important medical indicators are oxygen, hemoglobin, cytochrome and water concentration measurements in tissue and in the veins. Non-invasive measurements are based on an AvaSpec-2048 single channel fiber optic spectrometer, an AvaLight-HAL tungsten halogen light source and a reflection probe.
Invasive measurements can be done with a special reflection probe, built into a hart catheter, as can be seen in the picture.
Implementation of the system has been successful in medical applications in which continuous measurement of oxygen saturation, concentration of total, oxygenated and deoxygenated hemoglobin needs to be done.
The AvaSpec has been implemented successfully in the following fields:



- 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 ulzeration.
- Cardio surgery - Oxygen consumption of the heart muscle during/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 newborn during birth.
- Plastic surgery / Transplantation medicine - Monitoring of transplanted and re-implanted tissues, bones or organs
- Accident surgery - Determination of surface of burned or frozen skin.



A typical setup for biomedical measurements is given on the left.

Components used in the biomedical setup are depicted in the following table:

Spectrometer	AvaSpec- 2048-USB2 Grating NB (500-1000nm), OSF-475, 50µm 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