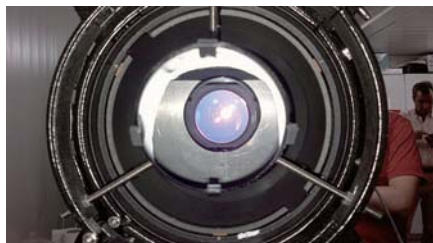


APPLICATION NOTE: LIBS

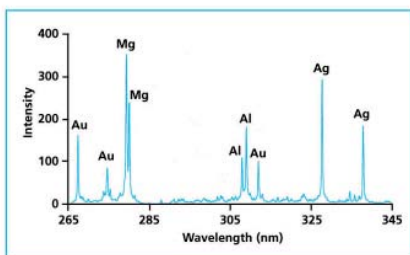


Telescopic optics used in "stand-off LIBS" for an explosives detection several meters away from a sample

Laser Induced Breakdown Spectroscopy or LIBS is a form of atomic emission spectroscopy which is typically performed using a pulsed laser to create a surface ablation on a sample which is then analyzed spectroscopically for its elemental and molecular composition. Focusing optics within a LIBS system typically enables a relatively low power pulsed laser (10-100 mJ) to ablate a very small sample of the material being measured such that a luminous plasma is created which can then be analyzed with high speed spectrometers for subsequent qualitative and quantitative analysis.

The advent of fiber optic spectrometers has benefited the science of LIBS by providing affordable, ruggedized, field portable spectrometers which can often replace higher cost instruments with lesser portability and flexibility. The flexibility of fiber optic technology enables the measurement of LIBS plasma in harsh environments without exposing the instrumentation to these conditions. Avantes has significant experience designing custom

fiber optics to meet our customer's demands. Avantes has remained on the innovation forefront of the integration of fiber optic spectrometers into LIBS solutions for research and industrial applications. Avantes remains committed to supporting researchers and engineers in the deployment of LIBS technology into new areas which will further its viability as an analytical technology for wider adoption.



Example LIBS spectra with line identification

LIBS advantages

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 used may depend on the feature(s) being sought. Most often, the chamber will include the ability 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-ULS3648TEC (thermoelectrically cooled) spectrometer. An AvaRaman-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 the US Federal Trade Commission requires 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 speed photoluminescence system as it leaves a trace peak at 694 nm.



AvaSpec-ULS2048 single channel USB spectrometer

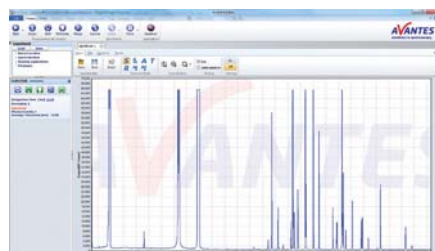
AvaSpec-ULS2048 - The LIBS spectrometer

The centerpiece of Avantes' solutions for LIBS spectroscopy is our AvaSpec-ULS2048-USB2 instrument. This 2048 pixel instrument has several key attributes which make it an excellent fit for this application. The first attribute is our symmetrical Czerny-Turner optical bench design which provides 30-50% better resolution than comparably configured cross Czerny-Turner designs. The second attribute is in the area

of timing control. The CCD detector in the AvaSpec-ULS2048 is the Sony ILX554B, running at 2MHz. Avantes uses a 24MHz FPGA to generate control signals that provides for a maximum jitter of 21 ns compared with >250 ns for competitive instruments. The third attribute is fast buffer clearing. Delay between spectral acquisitions can mean the difference between seeing and missing spectral features of inter- >



AvaSpec Multi-Channel spectrometer



AvaSoft advanced spectroscopy software

Application Note: LIBS

est, especially in the LIBS application. The AvaSpec-ULS2048-USB2 has a 1.3 μ sec clear buffer time (time needed to reset the detector and clear the buffer). This clear buffer time minimizes the delay time between signal acquisitions to 1.3 μ sec. A fourth attribute of the AvaSpec-ULS2048-USB2 spectrometer is its flexibility with integration time delays. The de-lay time for the AvaSpec-ULS2048-USB2 is programmable and can be set in steps of 21ns and each channel can have individually set integration times. The AvaSpec-ULS2048-USB2 is available individually as an enclosed instrument, as part of a rackmount enclosure in an array of high resolution instruments or as an OEM component that can be easily integrated into a customer's system. Avantes' unique instrument platform enables true synchronous operation of our spectrometer in a multi-channel array, a common requirement for LIBS applications. Avantes' AVS-Rackmount

(pictured to the left) enclosure can house up to 10 spectrometers in a single enclosure for LIBS array configuration. Instruments with different detector types such as back-thinned CCDs (AvaSpec-ULS2048XL-USB2) can be commingled with our AvaSpec-ULS2048-USB2 or any other instrument type as Avantes instrument platform is totally inter-operable. Avantes OEM modules are available for system integrators or industrial customers who already have a laser and prefer to handle their own integration of the spectrometers into a LIBS system. Avantes OEM instruments consist of our Avabench-75 optical bench and the independent AS-5216 and ASM-5216 electronics boards. OEMs can opt to use only our optical bench or the combined optical bench and electronics board. The picture to the right is a six channel OEM instrument stack configuration for LIBS.

Instrument control software

Avantes proprietary AvaSoft software is a Windows-based 32 and 64 bit compatible software package which includes a LIBS control module. The spectrometer and software facilitate direct connection of a Q-switched laser to an AvaSpec so that the laser can trigger the spectrometer or the spectrometer can trigger the laser. Programmable delays range from 1.3 microseconds up to 60 seconds can be entered in the LIBS configuration window. AvaSoft also facilitates the connection of multiple spectrometers and the merging of spectra into a single graph and data file. For spectral line identification Avantes offers the Plasus Specline software which is available in 3 versions (Specline-A, Specline-AM and Specline-

AMS). OEM and integrator customers typically use Avantes AS5216 dynamic linking library to control the spectrometer. Avantes AS5216 DLL software development kit is 32 and 64 bit compatible and comes with sample programs in Matlab, Linux, LabView, C#, C++, Visual Basic and Borland Delphi. Avantes instruments and fiber optics support a multitude of LIBS applications. In addition to our standard offerings, we also develop custom engineered systems for specific applications. Contact an Avantes Sales Engineer at infousa@avantes.com in North America and info@avantes.com in the rest of the world.

Application	LIBS configurations
Spectrometers	AvaSpec-2048-USB2 (Starline) - front illuminated CCD—2048 pixels AvaSpec-ULS2048XL-USB2 (Sensline) - back-thinned CCD—2048 pixels
Gratings Range & Resolution	Grating UE (2400 lines/mm) , DUV, 190-309 nm, 0.09 nm (FWHM) Grating UE (2400 lines/mm), DUV, 307-410 nm, 0.07 nm (FWHM) Grating VE (2400 lines/mm), OSF-385, 408-494 nm, 0.06 nm (FWHM) Grating VD (1800 lines/mm), OSF-475, 493-616 nm, 0.09 nm (FWHM) Grating VD (1800 lines/mm), OSF-550, 615-715 nm, 0.07 nm (FWHM) Grating VC (1200 lines/mm), OSF-600, 714-902 nm, 0.14 nm (FWHM)
Fiber Optics	Multi-furcated fibers optic splitters—see Avantes catalog
Accessories	IC-DB26-EXTRIG-BNC-2—external triggering cable