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Technical Note

Echelle spectrometers provide high resolution over a broad wavelength range

Introduction

Echelle spectrometers resolve the conflict between high resolution and broad wavelength range. Unlike Czerny-Turner and Littrow spectrometers, these comparably compact instruments are able to offer both properties. The optical design of echelle spectrometers allows utilization of the entire image detection array without binning.

LTB Lasertechnik Berlin leverages decades of spectroscopy experience and expertise to develop different types of echelle spectrometers for various applications, including:

- Laser-induced breakdown spectroscopy (LIBS)
- Raman spectroscopy
- Isotopic measurements
- Laser-induced fluorescence (LIF)
- Spectral investigation of lasers

The patented design of LTB's echelle spectrometers, which utilizes minimal transmission optics, offers a spectral range from the deep ultraviolet (150 nm) to the near infrared (1700 nm). Refer to Figure 1.

The combination of Princeton Instruments CCD/ICCD cameras and the LTB echelle spectrometer series results in a high-performance, cost-efficient, and user-friendly analytical instrument with many notable advantages.

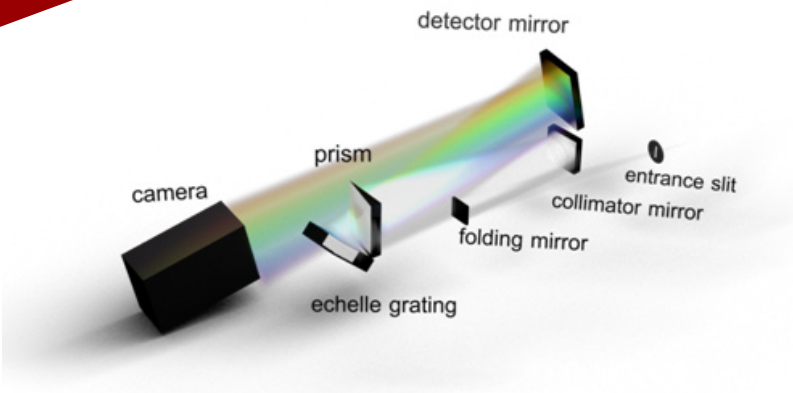

Figure 1. Echelle spectrometers from LTB utilize minimal transmission optics and offer broad spectral coverage.

Technical considerations

In contrast to Czerny-Turner spectrometers, echelle spectrometers use two dispersive elements, usually a prism and a grating. Therefore, the spectrum is divided not only in the x-direction but also in the y-direction. The primary advantage of this assembly is that the entire image detection array is used, not just a small row.

Czerny-Turner spectrometers cannot provide high resolution and broad wavelength range simultaneously, an especially inconvenient limitation when it comes to process analyzing methods like LIBS. Echelle spectrometers, however, afford users the opportunity to perform a "one-shot" analysis with spectral coverage from 190 to 1700 nm. (See Table 1, as well as Figure 2.) In addition, echelle spectrometers do not have any moving parts, such as a grating turret or an adjustable entrance slit; consequently, calibration is reliable and stable.

	Czerny-Turner		Echelle (ARYELLE Series from LTB)	
Focal length (mm)	300	750	200	400
Resolution (pm)	210*	90*	55**	19***
Simultaneous wavelength range (nm)	144*	61*	580** e.g., 220 – 800	400*** e.g., 300 – 700
* Entrance slit: 10 µm; CCD pixel size: 13.5 µm; CCD array size: 27.6 mm; Grating: 600 l/mm; @ 500 nm ** Entrance slit: 40 µm; CCD pixel size: 13.5 µm; CCD array size: 13.3 mm; @ 500 nm *** Entrance slit: 40 µm; CCD pixel size: 13.5 µm; CCD array size: 27.6 mm; @ 500 nm				

Table 1. Technical comparison of select spectrometers.

Unlike other echelle spectrometers, LTB echelle spectrometers achieve equal light throughput (akin to Czerny-Turner spectrometers with lower f-numbers) due to a patented optical design that uses minimal transmission optics.

Table 2 lists several LTB echelle spectrometer / Princeton Instruments camera combinations and their primary applications. (Two pairings are shown in Figure 3.) All spectrometer and camera functions are fully controlled via software that includes quantitative algorithms as well as script language for complex automated measurement tasks.

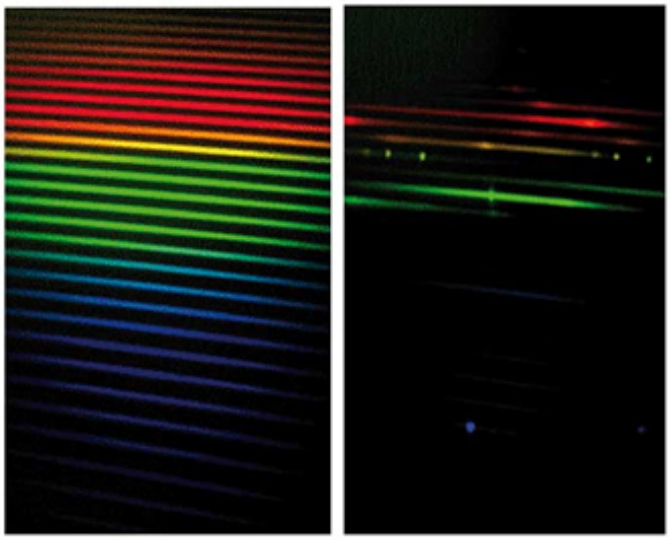

Figure 2. Echellogram of a tungsten lamp (left) and a fluorescent lamp (right), 400 – 800 nm.

	Princeton Instruments PIXIS (CCD camera)	Princeton Instruments PI-MAX 3 (ICCD camera)
LTB ARYELLE 150, 200	Portable LIBS systems, compact Raman systems	Time-critical LIBS
LTB ARYELLE 400, Butterfly	LIBS, Raman, LIF, Raman-LIBS combination	High-temporal-resolution and high-spectral-resolution LIBS
LTB DEMON	Spectral investigation of diode lasers	Isotopic shift measurements
LTB ELIAS	Spectral investigation of excimer lasers	

Table 2. Key applications of various LTB echelle spectrometer / Princeton Instruments camera combinations.

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Figure 3. LTB ARYELLE 400 paired with Princeton Instruments PIXIS (left); LTB ARYELLE 200 paired with Princeton Instruments PI-MAX® 3 (right).

LIBS-Raman

LTB has united two measurement methods, LIBS and Raman spectroscopy, in one instrument. The fast elemental analysis achievable via LIBS has now been combined with the detailed chemical and structural information obtainable via Raman spectroscopy.

LIBS is an analytical method that uses laser ablation and the subsequent atomic emission from the plasma to perform elemental analysis. It allows online multi-elemental analysis of all types of materials (solids, liquids, gases) without any restrictions, especially with regard to light elements.

In addition to the extremely fast elemental analysis enabled by the use of LIBS, this instrument's utilization of Raman spectroscopy provides detailed information about the molecular and structural composition of a sample. The Raman effect is a form of photon scattering attributable to the vibrational and rotational states of a molecule after a sample has been excited with monochromatic light.

The following specifications are for a LIBS-Raman setup (shown in Figure 4) that is based on the LTB ARYELLE Butterfly design.

LIBS:	Resolution:	λ/Δλ 15000 (16 pm @ 250 nm) (3 pixels)
	Wavelength range:	190 nm – 500 nm
	Entrance slit:	50 µm
Raman:	Resolution:	0.5 cm^{-1}
	Wavelength range:	4000 cm^{-1}
	Laser:	532 nm, 633 nm, 785 nm
	Entrance slit:	200 µm

Figure 4. LIBS-Raman setup utilizing an echelle spectrometer from LTB and a CCD camera from Princeton Instruments.

Combining LIBS with Raman spectroscopy provides many advantages:

LIBS

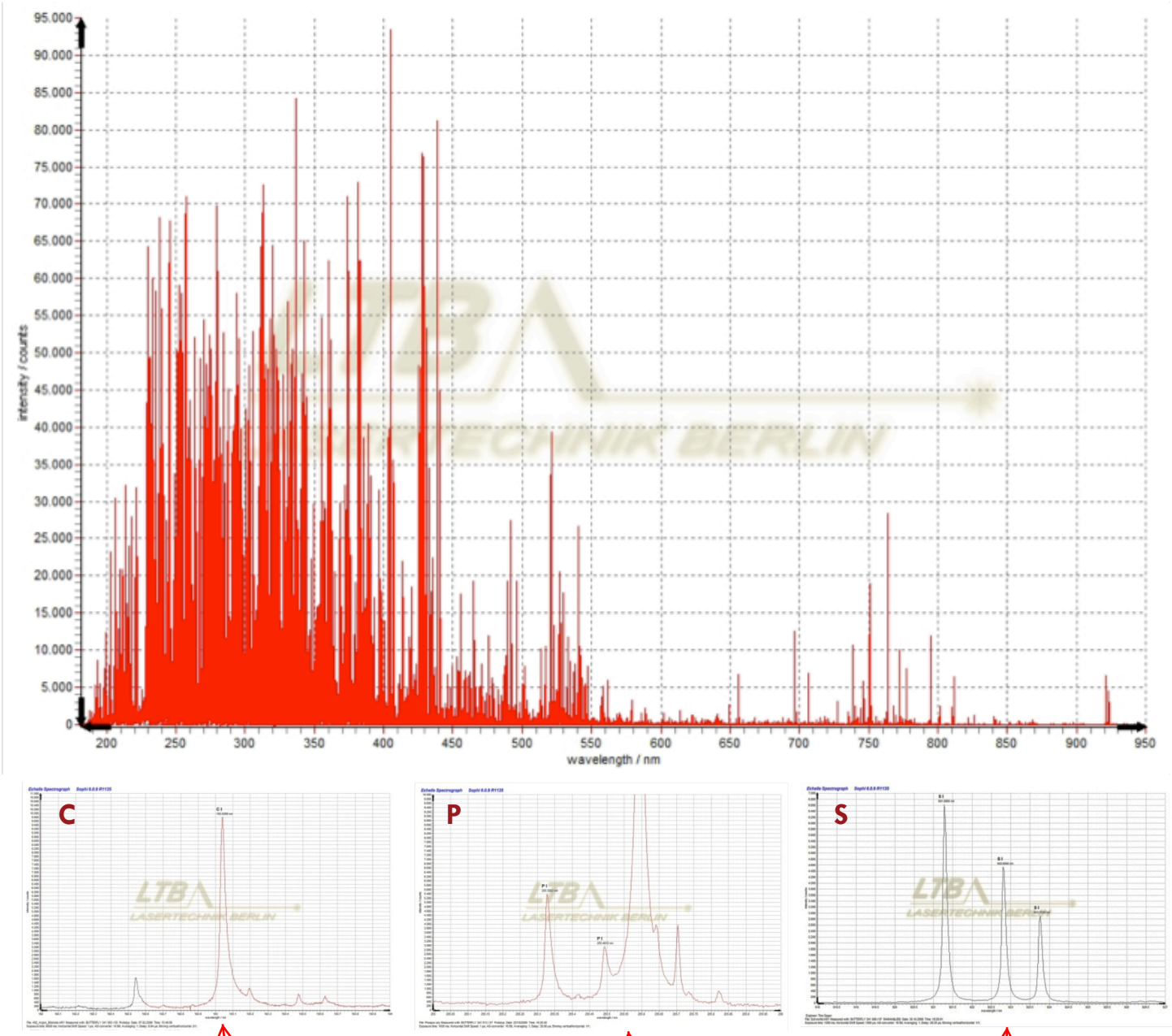
- Fast multi-elemental analysis of solids, liquids, gases
- Analysis of spectral emission
- No sample preparation necessary
- Qualitative and quantitative determination of sample

Raman

- Molecular and structural information (fingerprint method)
- Completely nondestructive
- Analysis via scattering of monochromatic light
- Subtle-band investigation enabled by high-resolution capability

Resultant LIBS-Raman data is displayed in Figure 5. Application fields include mineralogy, pharmaceuticals, exploration, environment, homeland security, and many others.

Figure 5. LIBS-Raman offers a highly useful combination of chemical and elemental analysis.



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