Spectroscopy
Solutions for Materials Analysis

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Optics and Lasers

From NIR to LIBS, laser-based techniques have continued to experience tremendous growth, while advances in the associated field of optics have more than kept pace. Joining us for this discussion are Andy Whitehouse, Applied Photophysics; Ken Kaufman, Hamamatsu; Matthieu Baudelet, University of Central Florida; and Rob Morris, Ocean Optics.

What laser-based application areas do you see growing the fastest and why?

Whitehouse: I can only speak for my particular area of laser-based applications, namely laser-induced breakdown spectroscopy (LIBS). I have just returned from an international conference on LIBS (LIBS 2010, Memphis, Tennessee) and so am reasonably up to speed on recent advances. What is clear to me is that over the last year or so the application base for LIBS has expanded considerably. The more traditional application areas for LIBS such as rapid, noncontact compositional analysis of alloys and metal-bearing materials (e.g., minerals, technical plastics, etc.) is very active although acceptance and commercial exploitation of the technology by industry has been slow, influenced perhaps by the worldwide economic downturn. New potential applications for LIBS, however, are now starting to emerge, some of which are well beyond what one would normally consider to be appropriate for what is essentially an elemental analysis technique. What is helping to make some of these new applications possible is the use of broad-band spectrometers linked with advanced chemometric software which is able to analyse the complete LIBS spectrum (typically 200–900 nm) yielding information on the chemical form of the material and not just its elemental composition. This has allowed LIBS researchers to analyze and classify a much broader range of materials including polymers, explosives, and even bacterial pathogens. Much of this new work is at a very early stage although a number of exciting new applications were presented at LIBS 2010 earlier this month.

Kaufman: For us there are two major changes. The first is the recent introduction of red enhanced CCDs which have large increases in the QE out to 1 µm. The QE at one micron is 40 % without requiring deep cooling.

The other is the improvements in QCL lasers that make it easy to measure isotope ratios in gases such as carbon dioxide and methane. Thus, QCL will have a big impact in understanding the sources of green house gases. QCL lasers are currently impacting mid-IR Laser-based sensing application such as environmental analysis, combustion, breath analysis, and emission gas measurement. Recently liquid phase matter analysis has been demonstrated such as sugar in blood. QCL-based sensing applications are promising. Broadband mid-IR tunable laser source is one of the biggest demand from the market.

Baudelet: Stand-off sensing is still growing and very fast. This is mainly thanks to better laser sources that can be adapted to existing stand-off systems as well as a better detection technology (low noise, low jitter). Cheap laser sources and detection systems are now available for multiple applications that can be bought at home and I think that areas we could call "domoscopy" live a great time and will have a brighter future.

Morris: Although no one application immediately comes to mind, we've certainly observed how significant lasers are to developments in medical diagnostics and treatments. Lasers aren't new to medical applications, but it seems as if the scope of their use in medicine has expanded.

What has been the most important development in the field of optics in the past year?

Baudelet: Globally in optics, I really saw a jump in the use of nondiffracting beams (Airy, Bessel, vortices). Their influence for laser material processing, imaging, and laser propagation are of great influence for spectroscopy.

LIBS has generally been associated with homeland security. In what other areas can this technique be used?

Whitehouse: Although in recent years LIBS has been of considerable interest to homeland security and related areas, it is not true that the majority of LIBS development is in this area. Perhaps of most interest to the security agencies is the ability of LIBS to perform stand-off detection and classification of threat materials, where LIBS has been demonstrated to perform well at distances in excess of 100 m (330 ft). The application areas where LIBS has historically been most active, some of which have been mentioned above, are metals and alloys industries, minerals and mining industries, pharmaceuticals industries, nuclear power and waste processing industries, glass industries, and materials recycling industries, to name a few. Security applications of LIBS only really started to gain momentum in 2005, although a large amount of work has been conducted in this area since that time as evidenced by the significant number of scientific papers that have been, and continue to be, published on this application area.

Baudelet: LIBS can be used in a large panel of areas other than homeland security. The fast interrogation of the samples (sampling/excitation/spectrum in a single shot) is of interest for production chain monitoring. The application of LIBS to the monitoring of hazardous zones (hot cells, nuclear waste tanks, ...) has been proved. I think that a large field where LIBS can have a footprint is forensic science. The simplicity of operation and the rich information you can get from LIBS are factors considered in forensics that brought LIBS in this field and show a growing development of the technique.

Morris: LIBS measurement techniques can be applied to a wealth of potential applications — everything from art restoration and environmental analysis to forensics research and hazardous materials investigation. Because LIBS is an elemental analysis technique, it's particularly useful for characterization of metals, ceramics, and gemstones. The steel industry, for example, has interest in using LIBS to classify metals used in recycling. Mining is another area where the market has expressed interest in LIBS.

What new technological advances do you hope to see in the optics field in the future?

Baudelet: I hope that analytical spectroscopy can be made even more compact and sensitive. Compact spectrometers (without sacrificing the resolution) as well as fast and compact optical detection (with low noise and low jitter) are major pillars for the distribution of the spectroscopy either for education and applications.

Morris: I'll suggest something that is relatively simple: optical modeling tools that are simpler to use and more accessible to most design engineers. I'm not an engineer, but my sense is that the modeling software of today — so integral to product development — is so sophisticated that perhaps it's become less accessible. Or perhaps just the opposite is true: the software is now so accessible that it appeals more to the late adopters, who have a higher learning curve. But what the heck do I know? I went into marketing so I wouldn't have to think of such things.

What does the future hold for laser technology? Where do you see the next advance happening?

Whitehouse: Again, I only feel qualified to answer this question from the LIBS perspective. Although there have been considerable advances in laser technology in recent years (fiber lasers, DPSS lasers, femtosecond lasers, etc.), the majority of "real-world" applications of LIBS still use flashlamp-pumped Nd:YAG lasers which have changed very little in design during the last decade or more. One reason for this is that LIBS generally requires relatively high laser pulse energies (typically 100s mJ) and pulse repetition rates of typically less than 100 Hz (more often 10–20 Hz) for which the most affordable laser is the flashlamp-pumped Nd:YAG. Furthermore, the majority of DPSS lasers, which are considerably more compact and energy efficient than their flashlamp-pumped counterparts, have relatively low pulse energy but can provide very high repetition rates — features which are not well-suited to the majority of LIBS applications. DPSS lasers are also considerably more expensive than flashlamp-pumped lasers, but are still used in some specialist applications of LIBS where a high pulse repetition rate is a necessity. In my opinion, considerable advances in portable LIBS devices would quickly follow the advent of a low-cost, compact Q-switched laser capable of operating in a "burst fire" mode (say 10 Hz burst of 100 mJ pulses for up to 30 s followed by an "off" period of 1 or even 2 min, thereby allowing a more compact cooling system to be utilized).

Baudelet: The future of laser technology is bright. I think that two needs are being answered. The high energy fiber lasers provide compact, robust, and rugged sources for applications in the field. Their development towards larger tunability and broader spectral range is a technology we need. The reach of ultrashort pulses (few optical cycles) with high intensity is of interest for ultrashort spectroscopy and material characterization. And their development towards compactness is a near future advance from which we have to take advantage.

Morris: It's amazing how lasers have evolved over the years. Our spectrometer customers are using lasers for an incredibly diverse array of applications, as the technology has become more application-specific, less expensive, and simpler to use. Although not new, exactly, ultra-fast lasers — and the applications they enable — certainly seem to garner significant interest.

What do you think?

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If you are interested in participating in any upcoming Technology Forums please contact Group Technical Editor Steve Brown [sbrown@advanstar.com] or Associate Editor Meg Evans [mevans@advanstar.com] for more information. Next month's forum will be a discussion about Fluorescence.

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