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Editorial

The photoacoustic era

Photoacoustics – Editorial

My mentor Britton Chance once said that the optical method is the most robust and best surviving method of biophysics [1]. I would like to extend this notion. The more one is surrounded with science the more optical approaches one witnesses. From clinical diagnosis using histology, spectroscopy or color endoscopy to optical microscopy and fluorescence assays, the optical method is probably the most widespread biomedical sensing tool. Several other scientific areas, from physics and astronomy to chemistry, nanotechnology and environmental sensing widely employ measurements in the optical range, from ultraviolet to the infrared.

For centuries however, photon scattering has shaped the nature of optical observations, in particular within biological and medical interrogations. Tissues have been cut to 10 micron thin slices in order to be visualized. Glass window chambers have been mounted on animals to gain in vivo insights of biological processes within depths of a few tens of microns. And while light-absorbing solutions in cuvettes are accurately measured by photo-spectroscopy, their in vivo quantification is evasive due to the effects of scattering. Several radiological methods have been alternatively employed for biological imaging, including X-ray imaging, Magnetic Resonance Imaging, ultrasound or nuclear imaging. Yet the attractiveness and versatility of optical contrast continues to drive a widespread use of optical methods and the continuous emergence of novel techniques. From super-resolution to advances in fluorescence and bioluminescence imaging, photonic methods do not cease to excite with their breadth of technological and application possibilities and their ability to reveal information on cellular and subcellular tissue and disease characteristics.

Optical detection has driven the implementation of optical sensing and imaging, using cameras or photon detectors such as photomultiplier tubes or avalanche photodiodes. However, parallel developments have enabled the detection of optical contrast with photo-acoustics. The photoacoustic effect describes the generation of pressure waves in response to the absorption of light with transient intensity, first described in 1880 by Alexander Graham Bell [2]. At the time Bell was investigating wireless audio communication by modulating the intensity of reflected sun-light, which, focused on a selenium cell, altered the cell's electrical resistance within a telephone receiver circuit. While experimenting with his new invention, the Photophone, he discovered that rapidly chopping the transmission beam produced audible sound directly from the selenium cell. Following this lead he realized that different materials produced different acoustic signals, whose amplitude and acoustic spectra depended on the optical spectrum employed for illumination and the optical absorptivity of the material. With the subsequent invention of the Spectrophone Bell attempted to exploit his observations to facilitate photoacoustic identification of materials. However, interest rapidly faded due to lack of quantitative measurements and sensitivity. Thereafter the technology lay dormant for almost 60 years, until in 1938 the advent of the microphone enabled M. L. Veingerov to employ the photoacoustic effect for gas analysis. Nonetheless, it took the development of the laser in the early 1970s to truly propel the photoacoustic effect into the limelight of research. Rosencwaig was the first to show photoacoustic spectroscopy and imaging in biological materials [3,4] and to establish, together with Gersho, a theory of the photoacoustic effect in solids [5]. Consequently, early investigations ranged from theoretical and technical considerations to practical applications [6–11]. Surprisingly, progress in photoacoustics in decades that followed remained slow and of restricted scope compared to optical advances – perhaps, because optical technology was easier to implement. Or because through the centuries of optical interrogations, biology and medicine has become resistant to thinking beyond a few hundred microns of tissue depth, happily resonating between tissue slices and Petri dishes.

This is now changing. Many important diseases implicate multiple organs, may be systemic in nature and require multi-scale observations of host interactions in vivo through entire tissues and organs. It has now become critical to relate isolated biological observation to function of entire systems and organisms. Advanced imaging methods enabling the simultaneous measurements of multiple physiological and molecular parameters are becoming important translational tools. In parallel, detection in similarly challenging media, including environmental metrology or the food industry can permit deeper insights when studying optically turbid media.

In this translational environment photoacoustic detection has enormous biosensing implications. Photoacoustic detection of optical contrast obeys the physics of ultrasonic wave propagation, which means that measurements are insensitive to photon scattering. This is an exciting feature for optical detection in opaque media including tissues. Insensitivity to scattering implies breaking through the limits of optical microscopy or optical spectroscopy of tissues, enabling unprecedented resolution and quantification. Using multiple wavelength measurements further enables the concurrent measurement of multiple chromophores,

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whereby fast detection and data processing can lead to real-time sensing and imaging techniques.

This is a time of change for the optical method. And it is time for a journal that captures all the exiting developments in this highly promising field. The aim of the *Photoacoustics* journal is to publish original research and review contributions within the fast growing field of photoacoustics (optoacoustics) and thermoacoustics, which exploits optically and electromagnetically excited acoustical and thermal phenomena for visualization and characterization of a variety of materials and biological tissues, including living organisms. While some of the spectroscopic and photothermal applications have reached a mature state, many other research directions are experiencing explosive growth, in particular biomedical photoacoustics, which is currently considered the fastest growing bio-imaging modality. The wealth of investigated topics clearly indicates that this field has developed a broad range of tools for fundamental and applied research. The enormous recent progress is greatly supported by the advances in laser technologies, ultrasound detection approaches, development of data inversion theory and fast reconstruction algorithms. This progress is also driven by a large number of unmet biological and medical needs that can be addressed by the unique contrast mechanisms available to photoacoustic (optoacoustic) methods. These include pre-clinical research and clinical imaging of vasculature, tissue and disease physiology, drug efficacy and treatment monitoring, optical anatomical and molecular imaging employing fluorochromes, dyes and nanoparticles. Correspondingly applications span the entire range of biological and medical imaging including cancer, cardiovascular diseases, neuroimaging, ophthalmology or imaging in immunology, diabetes and obesity, cell trafficking application and a multitude of other biological functions. The multi-disciplinarily nature of photoacoustics and thermoacoustics is also evinced by the growing contribution from chemistry and nanotechnology where a multitude of novel contrast agents have been developed, from nanoparticles and organic dyes, to targeted agents and genetically encoded markers.

The topics of interest include, but are not limited to, the following.

1. Photoacoustic/optoacoustic imaging, tomography
2. Photoacoustic/optoacoustic mesoscopy and microscopy
3. Novel detectors
4. Novel laser and light sources and delivery technologies
5. Spectroscopy and analysis of compounds
6. Signal processing and image reconstruction methods
7. Thermoacoustics and microwave-induced imaging
8. Ultrasound-modulated optical phenomena
9. Multi-modality systems involving light and sound
10. Contrast agents, nanoparticles, nanotechnology
11. Interactions with cells and tissues
12. Pre-clinical imaging
13. Molecular imaging
14. Clinical translation and applications

The terms "photoacoustic" and "optoacoustic" are used synonymously. The "photoacoustic" phenomenon has been used as the basis for the title of the journal and correspondingly is employed to describe technologies and applications within this area. However, in analogy to the term "optical" for devices and applications using "photons", the term "optoacoustic" is equally employed even if the "photoacoustic" effect is used. "Optoacoustic" in this case implies the use of optics for light delivery i.e. optical fibers and lenses and rather describes the implementation aspects of the technology. The "photoacoustics" journal will equally accept the terms optoacoustic and photoacoustic for describing systems, methods and agents.

Photoacoustic techniques are expected to shape the future of the optical method and bring significant new performance in sensing and imaging sciences. *Photoacoustics* should not only contribute as a medium to report on exciting progress in the field but also bring a sense of identity to a currently diverse scientific community stemming from fields including optical physics, ultrasound, optical imaging, nanotechnology, chemistry, biology, plant and environmental research and medicine. *Photoacoustics* aims therefore to serve also as means to develop a society of scientists with interests in the development and application of the technology. With an editorial board consisting of top investigators in the field and a structure that allows the establishment of thematic sections to enable growth into multiple associated areas, this field this new journal is geared to serve our emerging community and contribute to our growth. So let's publish and flourish!

References

[1] Chance B. Optical method. Annual Review of Biophysics and Biophysical Chemistry 1991;20.

[2] Bell AG. On the production and reproduction of sound by light: the photophone. Proceedings of the American Association for the Advancement of Science 1880;29:115–36.

[3] Rosencwaig A. Photoacoustic spectroscopy of biological materials. Science 1973;181:657–8.

[4] Busse G, Rosencwaig A. Subsurface imaging with photoacoustics. Applied Physics Letters 1980;36:815–6.

[5] Rosencwaig A, Gersho A. Theory of the photoacoustic effect with solids. Journal of Applied Physics 1976;47:64–9.

[6] Afromowitz MA, Yeh P, Shu x, Yee S. Photoacoustic measurements of spatially varying optical absorption in solids: a theoretical treatment. Journal of Applied Physics 1977;48:209–11.

[7] Bennett HS, Forman RA. Frequency dependence of photoacoustic spectroscopy: surface and bulk absorption coefficients. Journal of Applied Physics 1977;48:1432–6.

[8] Farrow MM, Burnham RK, Auzanneau M, Olsen SL, Purdie N, Eyring EM. Piezoelectric detection of photoacoustic signals. Applied Optics 1978;17:1093–8.

[9] Campbell SD, Yee SS, Afromowitz MA. Applications of photoacoustic spectroscopy to problems in dermatology research. IEEE Transactions on Biomedical Engineering 1979;26:220–7.

[10] Luukkala M, Penttinen A. Photoacoustic microscope. Electronics Letters 1979;15:325–6.

[11] Mandelis A, Royce BSH. Time domain photoacoustic spectroscopy of solids. Journal of Applied Physics 1979;50:4330–8.

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