Abstracts

Plenary talks

Simon Arridge, Center for Medical Image Computing, University College London, UK

Title: Quantitative Photoacoustic Using the transport equation

Abstract: Quantitative photoacoustic tomography involves the reconstruction of a photoacoustic image from surface measurements of photoacoustic wave pulses followed by the recovery of the optical properties of the imaged region. The latter is, in general, a nonlinear, ill-posed inverse problem, for which model-based inversion techniques have been proposed. Here, the full radiative transfer equation is used to model the light propagation, and the acoustic propagation and image reconstruction solved using a pseudo-spectal time-domain method. Direct inversion schemes are impractical when dealing with real, three-dimensional images. In this talk an adjoint field method is used to efficiently calculate the gradient in a gradient-based optimisation technique for simultaneous recovery of absorption and scattering coefficients. Joint work with B. Cox, T. Saratoon, T. Tarvainen.

Stefan Catheline, Lab. of Therapeutic Applications of Ultrasound, INSERM, Lyon

Title: Elastographie passive, élasto-tribologie, et élastographie par force de Lorentz: trois expériences à l'interface médecine-sismologie-physique.

Abstract: L'élastographie, encore appelée sismologie du corps humain, est une modalité d\u2019imagerie médicale récemment implémentée sur les échographes commerciaux. La fusion de deux thématiques de recherche fondamentales et appliquées que sont l\u2019élastographie et le retournement temporel a profité aux deux parties. En effet, le champ élastique permanent qui existe dans le corps humain à cause d\u2019activités musculaires recèle des informations sur les paramètres mécaniques (élasticité, viscosité) du corps humain. La clé pour extraire ces informations de ce champ physiologique complexe, diffus, réverbéré, est le retournement temporel. Cette technique est connue en sismologie sous le nom de corrélation de bruit sismique. Le second volet de cette présentation montre l'utilité de l'élastographie pour comprendre, dans des expériences de tribologie, comment les frictions faible et forte peuvent donner naissance à la propagation d'onde de cisaillement y compris en régime dit "super shear". Enfin dans la dernière partie, l'utilisation de densité de courant en présence d'un champ magnétique est à l'origine de force de Lorentz capable d'émettre des ondes cisaillement dans la matière molle. Les potentialités de cette nouvelle approche seront discutées.

Michel Dietrich , Institut des Sciences de la Terre, Grenoble

Title: Electroseismic: a natural bridge between seismology and electromagnetism for geological reservoir characterization

Abstract: Transient electrokinetic coupling phenomena created at the microscopic scale by the passage of seismic waves through fluid-saturated porous media generate conversions between seismic and electromagnetic (EM) energy which can be observed at the macroscopic scale. Far from being a mere scientific curiosity, transient seismoelectric or electroseismic phenomena are

especially appealing to oil and gas exploration and to hydrogeology as they open up the (fairly unique) possibility to characterize fluid-bearing geological formations with the resolution of seismic methods. Indeed, electrokinetic effects are likely to reconcile the sensitivity of electromagnetic exploration methods to fluids with the high resolving power of seismic prospecting techniques for structural imaging, thus naturally bridging the gap between these two important geophysical investigation means. Accounting for the electromagnetic dimension of the seismic wave propagation, or conversely, accounting for the seismic dimension of electromagnetic wave propagation gives new insights into the microstructure and physico-chemistry of fluid-filled porous or fractured media.

Mathias Fink , Institut Langevin, CNRS-ESPCI ParisTech, Paris

Title: Multiwave Imaging

Abstract: Interactions between different kinds of waves can yield images that beat the single-wave diffraction limit. Multiwave Imaging consists of combining two different waves-- one to provide contrast, another to provide spatial resolution - in order to build a new kind of image. Contrary to single-wave imaging that is always limited by the contrast and resolution properties of the wave that generated it, multiwave imaging provides a unique image of the most interesting contrast with the most interesting resolution. Multiwave imaging opens new avenues in medical imaging and a large interest for this approach is now emerging in geophysics and non-destructive testing. We will describe the different potential interactions between waves that can give rise to multiwave imaging and we will emphasize the various multiwave approaches developed in the domain of medical and biological imaging. Common to all these approaches, ultrasonic waves are almost always used as one of the wave to provide spatial resolution, while optical, electromagnetic or sonic shear waves provide the contrast. Recently the multiwave approach have been extended by introducing optical wavefront shaping to get images that combine the best spatial resolution of optical waves to the optical contrast. We will discuss these new approaches.

Vitaly Gusev, Laboratoire d'Acoustique de l'Université du Maine, Le Mans

Title: Depth-profiling of the acoustic, optic and acousto-optic spatial inhomogeneities by techniques of laser-based nanoacoustics

Abstract: In picosecond laser ultrasonics or laser-based nanoacoustics ultra-short laser pulses are used both for the generation and detection of the acoustic pulses with a typical length from 100 nm down to several nanometres. These acoustic pulses could be applied for the depth profiling, i.e., spatially resolved imaging, of the inhomogeneous materials. Monitoring the reflection of these wide-frequency-band acoustic pulses, incident on the interface between a solid and a liquid, it is possible to determine the near-interface structuring of liquid caused by its interaction with the solid with a nm spatial resolution. Picosecond acoustic interferometry or time-resolved Brillouin scattering technique, which monitors temporal evolution a single frequency component of these wide-frequency-band acoustic pulses, provides opportunity for the depth-profiling of the optically transparent spatially inhomogeneous materials, for revealing individual micro-crystallites in optically isotropic polycrystalline materials and for monitoring the nonlinear transformation of the finite amplitude acoustic pulses of GHz frequency range. The spatial resolution of the method can be controlled either by the spatial scale of the linear laser-generated picosecond acoustic pulse propagating inside the tested material or the spatial width of the weak shock front in the nonlinear acoustic pulse. These scales are much shorter than optical wavelength.
[1] C. Mechri, P. Ruello, J. M. Breteau, M. R. Baklanov, P. Verdonck, V. Gusev, Appl. Phys. Lett. 95, 091907 (2009). [2] V. Gusev, A. M. Lomonosov, P. Ruello, A. Ayouch, G. Vaudel, J. Appl. Phys. 110, 124908 (2011). [3] A. M. Lomonosov, A. Ayouch, P. Ruello, G. Vaudel, M. R. Baklanov, P.

Verdonck, L. Zhao, and V. E. Gusev, ACS Nano 6, 1410 (2012). [4] C. Klieber, V. E. Gusev, T. Pezeril, K. A. Nelson, http://arxiv.org/abs/1403.3222 [5] V. E. Gusev, http://archive.org/details/TheoryNLBrillouinScattering

---

Otmar Scherzer, Université de Vienne, Autriche

Title: Quantitive Estimation of Imaging Parameters in Photoacoustics using Focusing or Assuming Piecewise Constant Imaging Parameters

Abstract: In this talk we will discuss mathematical possibilities of estimating imaging parameters quantitatively via photoacoustic imaging. We derive backprojection formulas for focused illumination and detection. Moreover,we consider parallel estimation of the wave speed function and the absorption density, the later is the standard imaging parameter of photoacoustics. The second part of the talk is concerned with quantitative imaging of piecewise constant parameters in photoacoustic imaging. As we show, the numerical realization can be based on edge detection algorithms. The talk is based on joint work with Peter Elbau, Wolf Naetar (Vienna) and Andreas Kirsch (Karlsruhe).

John Schotland, Michigan University, USA

Title: Acousto-optic imaging and related inverse problems

Abstract: A method to reconstruct the optical properties of a highly-scattering medium from acousto-optic measurements is proposed. The method is based on the solution to an inverse problem for the radiative transport equation with internal data. I will also discuss a related inverse source problem with applications to molecular imaging.

Laurent Seppecher, Ecole Normale Supérieure, Paris

Title: Mathematical modeling of hybrid biomedical imaging by mechanic perturbation

Abstract: We see how an ill posed problem posed by biomedical imaging can by accurately solve using additionnal mechanical perturbations. From the coupled physics problem, we deduce an internal data from which it is possible to start a recovering procedure for the physical parameter that we want to image. Finding this internal data is based on Radon type geometric integral operator inversion. The reconstruction step involve a non linear coupled system of elliptic PDEs. To deal with hybrid problems, we need a smoothness a priori hypothesis of the unknown parameter. This hypothesis assures that the collected measurements are meaningful. Here, we see that these methods still work if the unknown parameter only belongs to a certain class of bounded variation functions.

Gunther Uhlmann, University of Washington, USA

Title: Recovering the index of refraction from travel times

Abstract: We will consider the problem of recovering the index of refraction or sound speed of a medium by measuring the travel times of sound waves going through the medium. We will report on recent results the case of partial or incomplete data.

Contributed talks

Maïtine Bergounioux (MAPMO, Orléans)

Title: OPTIMAL CONTROL APPROACH   FOR PHOTOACOUSTIC TOMOGRAPHY
joint work with T. Haberkorn, X. Bonnefond (MAPMO) and Y. Privat (JL2)

Abstract:
We deal with a classical photoacoustic tomography model. The inverse problem consists in determining absorption and diffusion coefficients in a system coupling a hyperbolic equation (acoustic pressure wave) with a parabolic equation (diffusion of the fluence rate), from boundary measurements of the photoacoustic pressure.

We propose here an optimal control approach, introducing a penalized functional with a regularizing term in order to deal ill-posedness. The coefficients we want to recover stand for the control variable. We provide a mathematical analysis of this problem, showing that this approach makessense and write necessary first order optimality conditions. We present preliminary numerical results.

Giovanni Alberti (University of Oxford, UK)

Title : Using multiple frequencies to enforce local constraints in PDE and applications to hybrid imaging problems

Abstract:

In this talk I will describe a multiple frequency approach to the boundary control of Helmholtz and Maxwell equations. We give boundary conditions and a finite number of frequencies such that the corresponding solutions satisfy certain non-zero constraints inside the domain. The suitable boundary conditions and frequencies are explicitly constructed and do not depend on the coefficients, in contrast to the illuminations given as traces of complex geometric optics solutions. This theory finds applications in several hybrid imaging modalities. Some examples will be discussed.

Bernd Kulessa (College of Science, Swansea University, Wales, UK)

Title: Multi-mode seismoelectric phenomena generated using vibroseis and explosive sources in a clay-rich environment

Karl E. Butler[1], Bernd Kulessa[2], and Andre Pugin[3]

[1]Department of Earth Sciences, University of New Brunswick, Fredericton, NB, Canada

[2]College of Science, Swansea University, Wales, UK (B.Kulessa@swansea.ac.uk)

3Geological Survey of Canada \u2013 NRC, Ottawa, Ontario, Canada

Abstract:

Seismoelectric methods have most commonly been promoted for the delineation of high permeability aquifers and reservoirs. In contrast, we conducted a seismoelectric field trial near Ottawa, Canada, underlain by 20 m of water-saturated Champlain Sea clays and silts overlying bedrock. Seismoelectric interfacial targets (characterised by the conversion of seismic to independently propagating electromagnetic energy) included the silt-bedrock contact, as well as porosity and textural changes within the overburden revealed by existing geotechnical logs. Seismic and seismoelectric shot records, employing 36 vertical geophones and 26 grounded electrical dipoles, were acquired using a Minivib vibroseis source in vertical mode with a 20\u2013350 Hz sweep, and a shotgun source deployed in auger holes. Harmonic subtraction, remote reference dipoles, and stacking of shot records were used to combat electrical noise levels associated with unstable powerline harmonics and apparent AM radio demodulation. Evidence of a possible interfacial seismoelectric conversion from bedrock, distinguished from co-seismic effects (electromagnetic energy contained within the propagating seismic waves) by its lack of move-out, can be observed in shot records. However, most significantly in this case seismic and seismoelectric shot records bear a striking resemblance to each other \u2013 both showing arrivals of direct and refracted P-waves in addition to P, S, and converted wave reflections. However, these co-seismic effects in the seismoelectric records preceded their corresponding seismic arrivals by several milliseconds, and had much broader bandwidths. They are inferred to have been generated beneath each dipole receiver by the arrival of reflected and refracted body waves at a shallow boundary, and suggest that the use of electrical dipoles in place of geophones may be warranted in appropriate situations. The observed co-seismic effects depart from existing end-member models and pose a new challenge for the development of coupled seismic-electromagnetic theory and forward and inverse modelling.

Thomas Chaigne (ESPCI, Paris)

Title: Contrôler de façon non invasive la lumière dans les mi
lieuxdiffusants grâce à la matrice de transmission photoacoustique

Thomas Chaigne, Ori Katz, Jérôme Gateau, Claude Boccara, Mathias Fink, Emmanuel Bossy, Sylvain Gigan
Institut Langevin, ESPCI Paristech, CNRS UMR 7587, INSERM U979, 1 rue Jussieu, 75005 PARIS

Laboratoire Kastler-Brossel, CNRS UMR 8552, 24 rue Lhomond, 75005 PARIS

Abstract:

Focaliser la lumière à l\u2019échelle micrométrique s\u2019avère déterminant dans le domaine biomédical ou
industriel, comme par exemple en microscopie optique ou en chirurgie assistée par laser. Dans les tissus biologiques, néanmoins, les inhomogénéités du milieu diffusent la lumière, ce qui limite les possibilités de focalisation aux couches superficielles, c\u2019est-à-dire pour des profondeurs de quelques centaines de microns [1]. Des techniques de façonnage de front d'onde ont été développées ces dernières années afin de restaurer la focalisation de faisceaux lumineux après leur propagation à

travers un milieu diffusant [2,3]. Concernant leur application en imagerie, le principal défi est de parvenir à focaliser la lumière à l'intérieur même d'un milieu diffusant. Des approches itératives basées sur l'utilisation de particules fluorescentes [4] ou la conjugaison de phase optique de fronts d'onde marqués acoustiquement [5] ont été récemment étudiées, mais ces techniques requièrent une séquence de mesure entière pour chaque position du point de focalisation.
Nous proposons d'utiliser un signal photoacoustique pour contrôler localement, simultanément et de manière non invasive la distribution de l'intensité lumineuse sur un grand nombre d'absorbeurs placés à l'intérieur d\u2019un échantillon [6,7]. Nous étudions les possibilités offertes par la mesure d\u2019une matrice de transmission dite photoacoustique, qui relie les modes optiques en entrée du milieu et la réponse acoustique des absorbeurs. Nous démontrons qu'il est possible de focaliser à travers un
échantillon de blanc de poulet de 0.5mm d'épaisseur en utilisant cette matrice, et nous étudions l'implémentation de cette technique sur des systèmes d'imagerie photoacoustique unidimensionnel ou bidimensionnel (en utilisant un transducteur acoustique mono-élément ou une barrette échographique standard). Nous montrons également que cette matrice de transmission contient d'autres informations que celles nécessaires à la focalisation, qui nous renseignent sur les propriétés de diffusion du milieu. Plus précisément, nous montrons qu' il est possible de remonter à partir de cette matrice à l'effet mémoire tel qu'il se manifeste à l'intérieur de l'échantillon. Nous montrons ensuite que la décomposition en valeurs singulières de cette matrice nous permet d'identifier les particules absorbantes sans information a priori sur leur nombres ou leur position. Enfin, dans le cas d\u2019un système d\u2019imagerie bidimensionnel, la matrice de transmission permet également de révéler certains absorbeurs, invisibles sur une image photoacoustique standard à cause de l\u2019ouverture finie de la barrette échographique.Cette méthode basée sur un contrôle photoacoustique de l\u2019intensité lumineuse permet pour la première fois d\u2019appliquer les techniques de façonnage de front d\u2019onde de manière non invasive, ce qui permettrait à terme d\u2019imager et de focaliser la lumière en profondeur.

REFERENCES :
[1] Ntziachristos, V. Nat Meth 7, 603-614 (2010).
[2] Mosk, A.P., Lagendijk, A., Lerosey, G. & Fink, M. Nat Photon 6, 283-292 (2012).
[3] Popoff, S.M. et al. Phys Rev Lett 104, 100601 (2010).
[4] Vellekoop, I.M. et al. Optics Express, vol.16, is. 1 (2008).
[5] Xu, X., Liu, H., & Wang, L. V. Nature photonics, 5, 154-157 (2011).
[6] Kong, F. et al. Opt. Lett. 36, 2053-2055 (2011).
[7] Chaigne et al., Nature Photonics 8, 58\u201364 (2014).

Laure Giovangigli (Ecole Normale Supérieure, Paris)

Title:Admittivity of biological tissues and its frequency dependence

Abstract: We introduce a mathematical framework for cell membrane imaging. It aims at exhibiting the fundamental mechanisms underlying the fact that effective biological tissue electrical properties and their frequency dependence reflect the tissue composition and physiology. The objectives are twofold: (i) to understand how the dependence of the effective electrical admittivity measures the complexity of the cellular organization of the tissue; (ii) to develop electrical tissue property imaging approaches in order to improve differentiation of tissue pathologies.
We prove that admittance spectroscopy provides information about the microscopic structure of the medium and physiological and pathological conditions of the tissue. Moreover, we propose an optimal control scheme for reconstructing admittivity distributions from multi-frequency micro-electrical impedance tomography and prove its local convergence and stability.

Jean-Baptiste Laudereau (ESPCI, Paris)

Title: Acousto-optic imaging at 793 nm thanks to self-adaptive holography in photorefractive media

Jean-Baptiste Laudereau1, Kevin Contreras1, Alexander A. Grabar2, Mickael Tanter1, Jean-Luc Gennisson1 and François Ramaz1
1 Institut Langevin Ondes et Images, ESPCI ParisTech, PSL Research University, CNRS UMR 7587, INSERM
U979, UPMC, 1 rue Jussieu 75005 Paris
2 Institute of Solid State Physics and Chemistry, Uzhgorod State University, 294 000, Uzhgorod, Ukraine

Abstract:
Biological tissues are very strong light-scattering media. Consequently, it is impossible to recover deep optical contrast unless invasive techniques are used. Acousto-optic imaging is a multi-wave imaging technique that couples ultrasound (US) and light in order to image the local light irradiance far beyond
the transport mean free-path with a millimeter or less resolution. When propagating through an illuminated area, US will shift photons frequency of the US frequency. The number of shifted photons, so-called tagged-photons, is proportional to several parameters, among which is the local light irradiance, so that filtering those photons may allow recovering deep optical contrast. Given that this frequency shift is very low (few MHz compared to the light frequency), one generally focuses on interferometric detection techniques. As spatial coherence of tagged-photons wavefront is poor due to the speckle pattern of scattered light, interferences with a plane wave reference will lead to speckle grains adding incoherently on a large single area detector (poor SNR). We developed a detection scheme based on photorefractive crystals that performs self-adaptive holography in order to adapt the signal and reference wavefronts thus improving SNR. Since it works around 800 nm, in the middle of the biological therapeutic window, we coupled this setup to a commercial US scanner in order to develop a multi-modal imaging platform.

Jean Provost (ESPCI, Paris)

Title: Ultrafast Acoustoelectric Imaging

Jean Provost, Wojciech Kwiecinski, Mathias Fink, Mickael Tanter, Mathieu Pernot

Abstract:
Imaging the electrical activity of the body is central to the diagnosis of and treatment planning for some of our most pressing healthcare challenges, including heart and brain diseases. The acoustoelectric effect has recently been shown to provide contrast directly from current densities by measuring ultrasound-modulated electrical impedance in the heart. While promising, these approaches, based on focused emission at low frequency, result in limited signal-to-noise ratios (SNR), and temporal and spatial resolutions. In this study, we developed Ultrafast Acoustoelectric Imaging (UAI), based on plane wave emissions, which provides high frame rates and uniformly high spatial and temporal resolutions. We developed a novel reconstruction approach for UAT and demonstrated its feasibility in phantom experiments at current density levels similar to the ones occurring naturally in vivo, indicating that UAT could become a unique technique to map current density distributions in tissues and image their propagation at very high frame rates.