Journées Des Doctorants de l'Institut Fresnel

1er et 2 juin 2017

Carry-le-rouet

Jeudi 1er juin 2017

dès 9h10	**Accueil Café devant la salle "Bord de Mer"**		
9h40	**Introduction**		
9h50	ALWAKIL Ahmed	**CONCEPT**	*Transformation Thermodynamics : Towards Thermal Camouflage*
10H00	CANONGE Rafael	**MOSAIC**	*Imagerie 3D quantitative utilisant la microscopie non linéaire sans marquage dans la peau humaine*
10h10	DIONI Luca	**CLARTE**	*Development of a Multi-purpose Fast Neutron Spectrometric Capability in the MASURCA Experimental FacilitY*
10h20	ELSAWY Mahmoud	**ATHENA**	*Modeling of complex nonlinear plasmonic waveguides*
10h30	FAGET Xavier	**HIPE**	*Application expérimentale de méthodes inverses avancées pour l'imagerie des propriétés EM d'un matériau magnéto-diélectrique*
10h40	GARCIA VERGARA Mauricio	**ATHENA**	*Electromagnetic pulses in ultra-dispersive media : a numerical and theoretical approach*
10h50	LABOUESSE Simon	**SEMO COMIX**	*La microscopie super-résolue, les yeux fermés et pour pas cher*
11h00	**Caroline PERON** *The institutional repository of Aix-Marseille University & Managing your references*		
11h45	**Distribution des T-shirt et des bulletins de vote**		
12h15	**Pause Déjeuner** ***A partir de 13h00 Remise échelonnée des clés à la réception***		
15h00	BEAUDIER Alexandre	**ILM**	*Laser-induced modifications in fused silica up to damage initiation caused by multiple UV nanosecond pulses*
15h10	NEGASH Awoke	**SEMO**	*Super-resolution fluorescence microscopy using speckle illuminations based on blind-SIM reconstruction strategies*
15h20	NEVES Luisa	**HIPE**	*Development and assessment of a biological tissue-equivalent phantom for electromagnetic properties assessment in the microwave domain*
15h30	RAVEL Sylvain	**GSM**	*Extraction de données d'essais issues d'essais en vol, sous l'angle des BigData*
15h40	REGMI Raju	**MOSAIC**	*Optical nanoantenna for live cell research*
	De 15h50 à 17h30 - Session Posters 1ère Années **16 personnes** (cf. liste) ***Pause-café pendant la session 16h-16h30***		
	Temps Libre - Cocktail à 19h00 devant la mer		
20h00	**Diner**		
21h00 - 00h30	**Bar et Concert devant la salle "Bord de Mer"**		

Vendredi 2 juin 2017

	Le Petit-déjeuner est servi de 7h30 à 9h15 – *Rendu des clés impérativement avant 9h30*		
9h30	**Laurent LAMAIGNIERE** **CEA**		
10h20	ROBERT Hadrien	**MOSAIC**	*Thermal imaging by using Gold Nanoparticules and wafefront sensing for the study of thermal biology at the single cell level*
10h30	SALEH Hassan	**HIPE**	*Application of Microwave-analogy to the study of scattering by trees, atmospheric particles and micro-organisms*
10h40	VIGNAUX Maël	**RCMO**	*Optimized procedure for controlling the deposition of multilayer structures in situ*
10h50	ZIDI Abir	**GSM**	
11h00	**Pause Café**		
11h15	Ateliers Rencontre PhD - Permanents		
12h00	**Pause Déjeuner**		
14h00	**Prof. Arjun G. YODH, LRSM, University of Pennsylvania, USA** *Biomedical Optics*		
14h45	**2ème Années "Ma thèse en 180 secondes"**		
Liste Participants 2A	**AILLOUD Quentin**	CONCEPT	*Optical Depolarizing Systems*
	AUDIER Xavier	MOSAIC	*Fast stimulated Raman scattering with optical delay line*
	BEN AYOUB Mohamed	HIPE	*Development of devices for measuring dielectric constants in wet materials to a better traceability of the measurement of humidity in solid*
	GEBRAYEL EL REAIDY Georges	ILM	*Laser induced contamination on space optics*
	GIL Marion	DIMABIO	*Analyse de la diffusion lumineuse de pathologies cornéenne pour la quantification d'efficacité médicamenteuse*
	LASSALLE Emmanuel	CLARTE	*On the spontaneous emission of quantum emitters*
	MARTIN Benoit	GSM	*Détection et reconnaissance de cibles d'intérêt dans les images pour la mesure d'audience*
	MYTSKANIUK Vasyl	MOSAIC	*Development of a Non-Linear Endoscope for Multimodal Imaging*
	NADJI Séverin	RCMO	*Real time monitoring of thin-film deposition during the manufacturing of complex optical interference filters: towards a realization without calibration deposition*
	POULIN Cyndie	ILM CONCEPT	*Study of materials, components and systems in terahertz domain by analogy with optical methods*
	RIMOLI Caio	MOSAIC	*Nanoscale Structural Organization of Cytoskeletal Assemblies probed by Polarized Microscopies*
	VEINHARD Matthieu	ILM	*Endommagement surfacique de la silice avec des faisceaux laser de type LMJ*
	De 15h45 à 17h00 - Session Posters 2ème Années ***Pause-café pendant la session 16h à 16h30***		
17h00	Remise des Prix et clôture des JDD vers 17h15-17h30		

Liste Participants 1A	Session Poster des 1ère Années		
	ABDELRAHMAN Mohamed	**EPSILON**	*Frequency and spatially dispersive media: modeling of metamaterials and high frequency homogenization*
	BOURZGUI Sophia	**DIMABIO**	*Développement d'un nouveau procédé de polissage mécano-chimique d'oxyde de silicium pour les caissons d'isolations de dispositifs microélectroniques*
	CATALANO Ricardo	**CONCEPT**	*Minimising the risk associated with nanomaterials used in sunscreen at all product lifecycle stages-Nanoscreen*
	GAO Guochao	**DIMABIO**	*Analogy between electromagnetic and elastic waves to probe rough interfaces in case of seismic imaging*
	GORSHKOVA Oksana	**MOSAIC**	*Nanodynamic Imaging of Leukemic Cell Adhesion*
	HATIFI Mohamed	**CLARTE**	*Non-linearity and Quantum Mechanics: Limits of the No-Signaling Condition*
	HOFER Matthias	**MOSAIC**	*Light manipulation for polarized nonlinear imaging in scattering media*
	LE CARDINAL DE KERNIER Isaure	**MOSAIC**	*Microscopie sans lentille et fluorescence*
	LETERTRE Thibault	**HIPE**	*Etude des comportements électromagnétiques des matériaux en fonction de la température pour modéliser l'impact des échauffements générés par les frottements de l'air sur un aéronef lors d'un vol à vitesse élevée*
	MOISSET Charles	**ILM**	*Nano photoinscription 3D de composants photoniques par inscription laser et processus optiques non-linéaires*
	NGUYEN Hai	**MOSAIC**	
	OLLE Alexandre	**ILM**	*Study of laser damage growth under short pulse durations*
	PAN Xiaoxi	**GSM**	*Classification of medical data using graphs and bio-inspired algorithms*
	SCOTTE Camille	**MOSAIC**	*Compressed spontaneous Raman microspectroscopy*
	UNGER Kevin	**SEMO**	*Electromagnetic imaging techniques in complex media with random illuminations*
	VIDAL Thibault	**ILM**	*Laser-UO2 Interaction: Towards a laboratory-scale RIA simulation*

Frequency and spatially dispersive media: modeling of metamaterials and high frequency homogenization

ABDELRAHMAN Mohamed – EPSILON
Directeurs de thèse : Boris Gralak et Sébastien Guenneau

Propagation of electromagnetic waves in dispersive homogeneous media has been originally investigated by Brillouin and Sommerfeld. The technical difficulty of this problem lies in the presence of a branch-cut in the plane of the complex frequencies. We have recently shown that it is possible to eliminate the branch-cut for frequency-dispersive media of finite dimensions; thus, a closed-form expression for the temporal response of arbitrarily dispersive media has been established. This Ph.D. thesis mainly addresses two areas of research. The first area is an extension of the proposed model of dispersive media to include spatial dispersive media. Simple metamaterials structures will be analyzed in temporal regime. The notions of propagation velocity and energy will be discussed, especially in the presence of absorption. In a second research area, a new modeling of metamaterials will be approached that aims to provide a homogeneous effective parameters, which allows a straightforward analysis. In particular, the properties of causality and passivity of the effective parameters, and the high-frequency homogenization, established in 1D, will be studied in 2D and 3D. It is expected to open possibilities to design arbitrarily artificial spatio-temporal dispersive media. These concepts will be used to design a new generation of metamaterials.

Spatially structured infrared multilayer components

BOURGADE Antoine – RCMO
Directeur de thèse : Julien Lumeau

For the past couple of decades, there has been huge progress within the fabrication method and the complexity of optical thin film filters. Coatings can now be accurate at nanometric scales even for stacks up to hundreds of layers. However, more and more uniform and performant filters are now needed, requiring better and better control of the processes during the deposition. Spectral performances of a filter are related to the optical thickness of each layer and performances are fixed at filter achievement. To overcome this limitation, the use of materials which index of refractive index or thickness (and therefore the transmitted or reflected phase) can be locally changed after deposition appears as an attractive solution.

The PhD project concerns the development and manufacturing of optical thin films based on photosensitive materials and the integration of these layers into complex multilayer stacks. As a material, we based our research on chalcogenide glasses such as As_2S_3 also known as AMTIR-6. These glasses are known for their broad transparency in the near and far infrared (AMTIR stands for Amorphous Material Transmitting Infrared Radiations) and have the unique characteristic of being photosensitive, i.e. some of its opto-geometrical properties can be modified after exposure to

actinic radiation. Very large refractive index change up to 0.1 and large thickness change as large as 8.3 % of the total thickness have been demonstrated in e-beam evaporated As_2S_3 layers.
Using these photosensitive properties of the chalcogenide glass-based layers, volume micro and nano structures in thin films and multilayer stacks will be created and will allow the development of new features and infrared components. For example, it will be possible to achieve volumetric phase plates for beam shaping, holographic transmission and reflection volume Bragg gratings, filters with integrated resonant gratings or structured multilayer filters.

Développement d'un nouveau procédé de polissage mécano-chimique d'oxyde de silicium pour les caissons d'isolations de dispositifs microélectroniques

BOURZGUI Sophia – DIMABIO

Directeurs de thèse : Gaëlle Georges

Le polissage mécano-chimique (CMP) intervenant au niveau des zones actives représente une étape critique dans le processus de fabrication des puces électroniques. Cette étape consiste à polir l'oxyde de silicium jusqu'aux zones actives en respectant un cahier des charges stricte. En outre, il est essentiel d'avoir une bonne maîtrise de la planarisation, i.e. un polissage uniforme sur l'ensemble du wafer, un « dishing » faible, autrement dit, ne pas creuser l'oxyde au centre de la tranchée d'isolation et finalement, un respect des spécifications en termes d'épaisseur des matériaux polis. Dans ce contexte, il est important d'améliorer le procédé de fabrication, notamment en mettant en place des outils de contrôle du temps de processus de fabrication en fonction des paramètres d'entrée (épaisseur du matériau à polir, densité des motifs sur le wafer). Le sujet de recherche présenté est l'étude du signal optique de détection d'arrêt du temps de polissage du matériau dioxyde de silicium. En effet, certains produits du site de fabrication de puce électroniques de la compagnie STMicroelectronics de Rousset sont actuellement polis par temps fixe, en fonction des paramètres d'épaisseur de dioxyde de silicium et de profondeur de tranchée d'oxyde. Néanmoins, ce système par temps fixe ne couvre pas l'ensemble de la variabilité du procédé de fabrication des étapes en amont du polissage (dépôt d'oxyde, profondeur de la tranchée d'oxyde). En effet, les interféromètres installés aujourd'hui servant de détection optique in situ pour stopper le polissage, ne peuvent être utilisés sur certains produits. L'objectif de cette recherche est de trouver les causes et les paramètres contributeurs de perturbation du signal de détection et de proposer des perspectives d'amélioration.

Minimising the risk associated with nanomaterials used in sunscreen at all product lifecycle stages-Nanoscreen

CATALANO Ricardo – CONCEPT / Interfast

Directeurs de thèse : Jérôme Labille et Myriam Zerrad

Among nanotechnology-based products, sunscreens are of emerging concern. Nanometric titanium dioxide (TiO2) UV-blockers are advantageous in terms of sun protection and aesthetics. However from a regulatory perspective, their fate and impact are still under consideration, due to their potential influence on both consumers and the environment. At present, many gaps remain in the scientific knowledge regarding the efficacy and safety of nanomaterials used in sunscreen. The present project aims to develop the eco-design of sunscreen by minimizing the risk at different stages of the product lifecycle, starting from its manufacture. This will be achieved by optimizing the properties of the UV blockers prior to their integration into the cosmetic formulation. The consequences of these characteristics on the overall risk of the final sunscreen product will be better evidenced throughout its lifecycle.

On the scale of nano-TiO2 filter, different coatings exist. The objective is to test and select different UV filters, in terms of both efficiency for filtering UV, of photo-passivation and of weatherability of the coating with respect to its environmental fate. During the aging of the product, the coating undergoes alteration likely or not to promote the dispersion of the nanoparticles in the environment. In addition, design a UV filter that does not fall within the category of nanomaterials, but preserves the sunscreen is also a track considered.

Analogy between electromagnetic and elastic waves to probe rough interfaces in case of seismic imaging

GAO Guochao – DIMABIO

Directeurs de thèse : Carole Deumié, Paul Cristini
et Nathalie Favretto-Cristini

Compared with electromagnetic wave and seismic wave, I conclude four important different points between them:

(1) The scales (in term of wavelength or frequency): The wavelength of electromagnetic wave we study is visible light, ranging from 400nm to 800um, while seismic wave is about from ten meters more or less to hundreds of meters.

(2) Types of wave used: The electromagnetic wave we use is the harmonic plane wave, while seismic wave we use is mainly spherical generated from a point-source. But I think a certain number of point-sources arranged on a straight line could generate a plane wave.

(3) The states of polarization: Any polarized electromagnetic wave can always be donated as TE and TM waves. This means these two waves often exist simultaneously, unless one of them becomes zero. However, seismic wave is elastic wave, which either includes P and SV waves or only includes SH wave. This means the SH wave is independent of the P and SV waves.

(4) The type of data received: In electromagnetic wave, the waves we receive in fact are proportional to the square of the electric wave, while in seismic wave, the wave we get is the amplitude of all kinds of wave (P wave , SV wave or SH wave).

Nanodynamic Imaging of Leukemic Cell Adhesion

GORSHKOVA Oksana – MOSAIC / CRCM

Directeurs de thèse: Serge Monneret, Michel Aurrand
et Arnault Serge (CRCM)

Cell junctions play a key role in the integrity of biological tissues, via Cell Adhesion Molecules (CAMs). In particular, in the bone marrow, interactions between hematopoietic and stromal cells allow for the mutual transmission of signals involved in the development and homeostasis of both cell types (Arcangeli, 2012). Interactions between Junctional Adhesion Molecules C (JAM-C) expressing hematopoietic stem cells and JAM-B-expressing stromal cells are deeply revised in leukemia context, provoking resistance to chemotherapy and relapses. Moreover, integrin-mediated adhesion to collagen, a major component of the extracellular matrix (ECM), is profoundly implicated in tumor evolution.

In this project, we propose to combine single molecule fluorescence imaging (Sergé, 2008) in the visible wavelength range for JAM tracking, with both phase and intensity collagen imaging

(Aknoun, 2014) in the infrared spectral range. This ultra-resolved imaging will document the role of CAMs in the dynamic establishment of cell/cell and cell/ECM adhesion in real time. We intend to improve these imaging techniques with high-speed low-noise EMCCD cameras (able to run up to 3500 frames/s with sub-electron readout noise), provided by our partners (First Light Imaging) in frames of the project.

Non-linearity and Quantum Mechanics: Limits of the No-Signaling Condition

HATIFI Mohamed – CLARTE

Directeur de thèse : Thomas Durt

The linearity of the Schroedinger equation has the status of a postulate : it is usually postulated to be valid, always and everywhere. Linearity is also congenitally linked to the vectorial space nature of the quantum state space (Hilbert space) as well as to the superposition principle.

The superposition principle is in turn at the origin of serious and fundamental problems (e.g. the Schroedinger cat paradox and the so-called measurement problem), and there were in the past several attempts to investigate non-linear generalisations of Schroedinger equation.

We are interested in studying deterministic non-linear modificationsn of the Schroedinger equation `a la Diosi-Penrose. This theory predicts that whenever coherent superpositions of macroscopically distinct localisations occur in nature, they will compete due to the non-local nature of the self-gravitational energy. We expect that, similar to optical rogue waves, the non-linearity will act as a noise amplifier, which, combined with non-local energy transfer, results in the stochastic appearance of spontaneous localizations (quantum jumps).

Light manipulation for polarized nonlinear imaging in scattering media

HOFER Matthias – MOSAIC

Directeur de thèse : Brasselet, Sophie

Nonlinear signal generation requires high electromagnetic fields. In nonlinear microscopy these are created by focusing ultra-short light pulses in the sample. Fundamentally light scattering prevents focusing light in deep layers for instance in biological tissue. Recently, concepts from adaptive optics have paved the way to refocus light behind scattering media by wavefront shaping. Similar concepts can be exploited to reconstruct a focus within scattering medium rather than behind. It will be crucial to use information that is provided by speckle in a combination with an internal feedback mechanism that can be a nonlinear signal (TPF, FWM) to restore a focus within a biological tissue. The behavior of ps- and fs-pulses in scattering media have to be studied in the spectral and time domain as well as in terms of polarization. Polarization can possibly be used as a selection tool for scattered diffusive paths and in combination with wavefront shaping to optimize and maintain focused light deep in tissue. Thus, the thesis aims at exploring new ways to perform nonlinear microscopy deep in biological tissue.

LE CARDINAL DE KERNIER Isaure

Etude des comportements électromagnétiques des matériaux en fonction de la température pour modéliser l'impact des échauffements générés par les frottements de l'air sur un aéronef lors d'un vol à vitesse élevée.

LETERTRE Thibaut – HIPE
Directeur de thèse : Pierre Sabouroux

En aéronautique, la variation en fonction de la température des caractéristiques électromagnétiques dans le domaine spectral des fréquences radar, de certains matériaux peut générer des problèmes important comme une modification du fonctionnement des antennes radar, ou encore une modification de la signature radar de l'aéronef, ce qui peut engendrer une dégradation importante des niveaux de furtivité nominaux d'avions d'arme. En effet, les matériaux utilisés dans la conception d'aéronefs discrets vis-à-vis des ondes électromagnétiques sont souvent soumis à des échauffements liés d'une part, aux frottements avec l'air dans le cadre de vols à hautes vitesses (par exemple pour les bords d'attaques des ailes) et d'autre part à des échauffement liés à la proximité de sources de chaleurs directes comme des tuyères de moteurs à réactions ou sorties d'échappements.

Les objectifs principaux de ce projet sont de concevoir un système large bande de caractérisations électromagnétiques de matériaux en fonction de la température et de proposer des modèles électromagnétiques relatifs à certains matériaux en incluant le paramètre d'intérêt, à savoir la température. Au-delà de ce travail de recherches de cette thèse, les résultats seront transposables à d'autres cas soit à températures modérées comme des températures biologique pour suivre des processus d'évolutions des permittivités de certains tissus en fonction d'une variation de température locale soit à températures plus élevées comme pour le suivi RFiD de dispositifs soumis à des températures élevées.

Nano photoinscription 3D de composants photoniques par inscription laser et processus optiques non-linéaires

MOISSET Charles – ILM
Directeurs de thèse : Jean-Yves Natoli et Konstantinos Iliopoulos

La résolution en inscription laser est gouvernée par la limite de diffraction. Cette limite correspond au plus petit spot laser accessible avec une longueur d'onde et un système de focalisation donnés. Pour améliorer cette résolution, l'absorption à deux ou plusieurs photons peut être utilisée. Cette méthode permet également l'inscription en 3 dimensions.

Dans l'idée d'encore diminuer la zone d'interaction, deux phénomènes privilégiés peuvent être envisagés. Le premier est l'absorption saturable. La dépendance en intensité de la transmission permet alors de supprimer le bord du faisceau, où, dans le cas d'un faisceau gaussien, l'intensité y est plus faible. De plus le phénomène d'auto-collimation est un phénomène non-linéaire où le matériau agit comme une lentille convergente. Dans ce cas l'indice de réfraction augmente avec l'intensité, soit d'avantage au centre du faisceau que sur le bord de celui-ci. Ce phénomène entrainant alors un effet de convergence du faisceau laser.

Pour utiliser les phénomènes cités précédemment, une structure en multicouche est proposée. D'abord un masque composé d'une couche mince d'un chalcogénure. Ceux-ci sont connus pour leurs importants effets non-linéaires. L'inscription sera effectuée dans une deuxième couche située sous le masque. Actuellement nos recherches se focalisent sur l'étude du Sb_2Te_3 possédant une forte absorption non-linéaire. Plus spécifiquement, nous essayons d'augmenter cette réponse. Nos études montrent que celle-ci est fortement dépendante de l'état de cristallisation du matériau. La prochaine étape sera de réaliser une première inscription super-résolue via un masque de chalcogénure judicieusement choisi afin de modifier les propriétés linéaires ou non-linéaires de la couche d'inscription.

N'GUYEN Hai

Study of laser damage growth under short pulse durations

OLLÉ Alexandre – ILM / CEA

Directeurs de thèse : Laurent Gallais et Laurent Lamaignère (CEA CESTA)

Laser damage has always been the main hindrance to the energetic rise of high-power laser facilities such as the LMJ (Laser Méga Joule) and PETAL (PETawatt Aquitaine Laser). Where this phenomenon is well known for its probabilistic aspect in the nanosecond regime (LMJ), recent studies (Martin SOZET) have shown that laser damage is not totally deterministic in the picosecond and sub-picosecond regimes (PETAL). Indeed, due to pre-existing defaults inside the commonly used mirrors and gratings, a statistical behavior has been highlighted on these optical components for fluences 70% smaller than their respective 1-on-1 LIDT (Laser Induced Damage Threshold determined after a 1-on-1 test).

Not only is it important to be aware that laser damage can also occur below the LIDT for short pulse durations, it is also of a major importance to be able to predict the growth of all type of damages. This would help to estimate with a good accuracy the lifetime of optical components and so to optimize their use.

Thus, the core of this thesis will be the study of laser damage growth on mirrors and gratings within the range of 500 fs to 5 ps in terms of pulse durations (range of PETAL). The studies will be conducted on DERIC (LMO), the damaging laser bench whose characteristics are closed to the ones from PETAL. Moreover, rather than using a Gaussian shaped laser beam, a laser profile called Top-Hat and providing a uniform density of energy on its surface will be used for a better interpretation of the laser damage growth.

Classification of medical data using graphs and bio-inspired algorithms

PAN Xiaoxi – GSM

Directeur de thèse : Mouloud Adel

Medical data represents nowadays a huge amount of information which needs to be processed to extract valuable information for doctors to help them to understand, detect, and diagnose. It is important to develop new methods to represent this information which consists in signal and images processing and understanding.

Alzheimer's Disease (AD) are becoming the dominant neurodegenerative brain diseases in elderly people worldwide. Computer-aided diagnosis (CAD) based on medical imaging is a useful method for doctors, and can bring a quantitative evaluation to better detect and evaluate brain diseases such as AD. Therefore, our objective is developing a method that can be used to distinguish AD and its early stage, Mild Cognitive Impairment (MCI) from Health Control (HC). Firstly, a graph is constructed for each subject using statistical metrics, such as mean value and standard deviation. Then some graph-based features are extracted, such as degree, global efficiency, local efficiency. After that, a dimension reduction method can be used to select features. Finally, feed these features to a classifier, for example, Support Vector Machine(SVM), to classify subjects into three groups, AD, Mild Cognitive Impairment (MCI) and Health Control (HC). In the future, deep presentation based on graph is also considered.

Compressed spontaneous Raman microspectroscopy

SCOTTE Camille – MOSAIC

Directeur de thèse : Hervé Rigneault

Spontaneous Raman scattering is a simple and effective technique which enables to characterize chemical systems composition with high molecular selectivity. One common application consists in estimating the proportion of mixed chemical species whose Raman spectra are known. In its most general implementation, the Raman scattered light from the mixture is spectrally dispersed on a detector array (e.g. CCD) and compared to the pure species spectra. However, as the Raman cross section is weak, this methodology requires typically long acquisition times to overcome noise associated with detection hardware. Then, the aim of our work is to make Spontaneous Raman more efficient, that is to say faster and potentially cheaper.

In our work, we replace to the detector array with a single channel detector coupled with a programmable spectral filter (DMD). We show that selecting well-chosen wavelengths combinations allows to efficiently estimate chemical species proportions with a simple pseudo-inversion. The filters implemented on the DMD are generated to minimize the estimation variance. We validate the latter on a solution of two mixed chemical species and in microspectroscopy. We obtain discriminating images with down to 7 photons/pixel on average. Last, we image microcalcifications powders for possible applications in oncology.

Electromagnetic imaging techniques in complex media with random illuminations

UNGER Kevin – SEMO

Directeurs de thèse : Patrick Chaumet et Kamal Belkebir

The aim of imaging techniques is to remotely retrieve intrinsic properties of an unknown target (shape, position and constitutive material). The target under test is illuminated by an incident wave and the scattered field is measured on a surface outside the target. The accurate modelization of the experiment and the use of iterative nonlinear algorithms enable to estimate the properties of the target. When the surrounding environment of the target is simple, the interaction of the light with the target can be described straightforwardly. In practice this is not the case for the target's environment is not fully controlled (aberrations in an optical set-up) and can even be totally unknown (subsoil problems). In such cases, the incident field which illuminates the target cannot be modelized properly. It is hence necessary to use an illumination which is robust to the complex media. Speckle illuminations, with well-characterized statistical properties, might be an appropriate way to tackle the imaging problem as long as they are robust with respect to the scattering media.

The purpose of my PhD is to develop algorithms for the inverse electromagnetic scattering problem which take advantage of the statistical properties of speckle illuminations.

Laser-UO2 Interaction: Towards a laboratory-scale RIA simulation

VIDAL Thibault – ILM

Directeur de thèse : Laurent Gallais

The thesis subject proposed here falls within a general framework of study, on the one hand, of the phenomena of laser / matter interaction, and on the other hand, the behavior of irradiated nuclear fuels in hypothetical accident situations. It is a question, in fact, of using the characteristics of laser heating to study the behavior of current or future fuels under thermal loads representative of accidents of the RIA (Reactivity Initiated Accident) type. Up to now, these studies are performed thanks to dedicated integral experiments. More specifically, the project to develop an experimental laboratory-scale device capable of subjecting UO2 and / or MOX nuclear ceramics (fuels currently used in French nuclear power plant generating reactors) to very high temperatures (typically up to 2600-2800°C) according to ultra-fast ramps, with gradients controlled thermics, while analyzing their behavior during these annealing tests in terms of fission gases and fission products, in particular. The target system must be able to easily reach those extreme conditions that are currently not conceivable on laboratory facilities such as MERARG (a study means for annealing and analysis of gaseous releases).

RESUMES DES 2ème ANNEES
MT180' + Posters

Optical Depolarizing Systems

AILLOUD Quentin – CONCEPT
Directeurs de thèse : Myriam Zerrad et Claude Amra

Optical coatings are well known to be highly polarizing, in the sense that they may produce an output polarization (reflected or transmitted) strongly different from the input (incident) polarization. Such property was extensively used to produce polarizing devices these last decades; oblique incidence is generally required since thin films are commonly isotropic, though anisotropic films produced at oblique deposition were also considered. For all these devices, polarization is modified or selected, but light remains totally polarized, which means that the temporal and local degree of polarization remains unity. To go further, optical coatings do not reduce the DOP of fully polarized incident light. This result constitutes a limitation for specific systems (space applications) that are polarization sensitive and hence cannot be calibrated with enough accuracy. Several authors have proposed solutions to solve this point, but a demand for significant progress is still expected. We propose an alternative solution to overcome this difficulty. We considered another type of depolarization, the spatial depolarization, which consists in mixing a high number of polarization states within the receiver aperture or bandwidth. To reach an efficient depolarizing device, variation of polarization must be very fast versus position, wavelength, or incidence, which led us to involve specific multilayers.

Fast stimulated Raman scattering with optical delay line

AUDIER Xavier – MOSAIC
Directeur de thèse : Hervé Rigneault

Stimulated Raman Scattering (SRS) is a non-linear spectroscopy scheme used to probe vibrational energy levels of molecules. Two pulsed lasers at ω_1 and ω_2 are focused on the sample. The sample is excited at the beating pulsation $\Omega = \omega_1 - \omega_2$ which typically falls into the vibrational levels of molecules $(1000 \rightarrow 3000\, cm^{-1})$. For instance, for $800nm$ and $1044nm$ lasers, the excited vibrational levels are those around $\Omega = (2\pi c)\, 2900\, cm^{-1}$. This is characteristic of CH2 and CH3 bonds, abundant in lipids and proteins. If these species are present in the focal spot, the transmission properties of our lasers are affected. By detecting this change in transmission over the field of view of a scanning microscope we can therefore realize an image with chemical sensitivity in a fully label-free way. The speed at which these spectral images can be acquired is usually limited by the time taken to switch from one vibrational frequency to the other. Combining Stimulated Raman Scattering in a spectral focusing configuration with an acousto-optic programmable dispersive filter working as a delay line, we achieve acquisition of spectrally resolved images at a frame rate of several images per second. This is orders of magnitudes faster than the traditional speed. This improvement allows for the recording of biologically relevant mechanisms, opening new applications for this technique.

Development of devices for measuring dielectric constants in wet materials to a better traceability of the measurement of humidity in solid

BEN AYOUB Mohamed Wajdi – HIPE
Directeur de thèse : Pierre Sabouroux

Several methods exist to measure moisture content in wet materials. Some of them are direct methods and some others are indirect methods. The first is used to extract the moisture directly from the solid substance but the second uses an intermediate which can be for example the dielectric complex permittivity $\varepsilon^* = \varepsilon' - j\varepsilon''$.

The object of this project is to study a new approach to measure moisture in solids following an indirect non-destructive method. It uses an approach via the electromagnetic measurement of the dielectric permittivity. This last depends on several factors: moisture, temperature and frequency. In our study we will work mainly with the third factor because the water in any solid can be characterized by its relaxation frequency. This frequency depends primarily on the degree of binding between amounts of free water and bounded water that interacts chemically or physically with the solid.

This type of measurement has existed since the 70s. Indeed, most existing systems operate at a fixed arbitrary frequency which can cause a measurement of the loss of sensitivity when it is removed from the relaxation frequency of water contained in the material. To find the best frequency with which we have a better sensitivity, two measurement cells are developed in CETIAT, the first one is a capacitive cell can be used in the range of frequencies between 1 MHz and 100 MHz and the second cell is a coaxial cell adapted to the characterization in the spectrum [50 MHz – 3.4 GHz]. To validate the measurement technique and also to further widen the measurement bandwidth we use EpsiMu® tool was developed at the Institut Fresnel.

The first step of the project is to validate the measurement techniques with a known permittivity material (liquids and solids) and then searching the frequency or the band of frequencies which allows us to find a better transfer function between the complex permittivity and humidity in solids and therefore we use this approach to generalize this relation permittivity - humidity to many types of solid materials.

Laser induced contamination on space optics

GEBRAYEL EL REAIDY Georges – ILM
Directeurs de thèse : Frank Wagner et Jean-Yves Natoli

Laser-induced contamination (LIC) of optical surfaces is a major obstacle for space-bound laser applications. Such hurdle is due to the formation of highly absorbing nanometric layers triggered by the interaction between high-power laser radiation and outgassed species from organic compounds.

A test campaign was performed in cooperation with the French Space Agency (CNES) in context to Mars2020-mission, this prototype test is primarily intended to validate the flight laser/telescope designs and contamination control procedures in the framework of SuperCam. A novel test bench was developed at Fresnel institute in order to perform tests under simulated space conditions, identify potential contamination sources, assess their possible optical degradation due to radiation-induced contaminant deposition in orbit and finally build a data warehouse to provide helpful insight for designers of space instruments.

Analyse de la diffusion lumineuse de pathologies cornéenne pour la quantification d'efficacité médicamenteuse

GIL Marion – DIMABIO

Directrices de thèse : Carole Deumié, Laure Siozade Lamoine et Gaëlle Georges

Avec un coefficient de transmission de plus de 90% dans le visible, la fonction principale de la cornée est de laisser passer la lumière à l'intérieur de l'œil. Cette propriété unique d'un tissu dans le corps humain est liée à une absence de vascularisation et à une organisation très particulière du volume cornéen. Certaines pathologies, comme l'œdème cornéen, peuvent induire une perte de cette propriété. Cette diffusion croissante est attribuée au gonflement de la cornée liée à un disfonctionnement fonctionnel.

L'objectif de ce travail de thèse est de proposer des outils de diagnostic précoce des pathologies cornéennes, plus particulièrement de l'œdème.

Nous cherchons à développer une nouvelle méthode de diagnostic des modifications de l'état du tissu cornéen par une technique optique qui pourra être implanté à long terme in vivo et avec une sensibilité supérieure à celle des instruments existants (lampe à fente, pentacam, OCT…).

Ce projet nécessite de combiner une approche expérimentale utilisant les techniques disponibles au laboratoire (diffusomètre angulairement résolu et un système de tomographie par cohérence optique plein champ) et une approche théorique visant à comprendre comment les modifications structurelles à différentes échelles de tissus de la cornée influent sur les propriétés optiques mesurables par les techniques visées.

Métrologie optique des pathologies cornéennes

HO WANG YIN Gaëlle – DIMABIO

Directeurs de thèse : Louis Hoffart et Carole Deumié

La cornée est un tissu transparent et avasculaire, organisée en cinq couches lui conférant des propriétés optiques particulières. Toute altération de sa structure à l'échelle nanométrique est responsable d'une modification de ses propriétés de diffusion. Le but de ce travail est de proposer des outils de diagnostic précoce des pathologies cornéennes avec une sensibilité supérieure à celle des instruments existants, en mettant à profit la méthodologie précédemment développée (étude de la diffusion tissulaire et tomographie à cohérence optique haute résolution).

Les mesures réalisées sur des tissus cornéens pathologiques, issus de pièces opératoires après greffe de cornée et de la banque de tissus de l'EFS de Marseille, seront confrontés à des modélisations réalisées en parallèle par une doctorante de formation physicienne Marion Gil dans le but d'approfondir les résultats clés obtenus sur une première série de pièces opératoires et greffons cornéens et d'ouvrir la voie de la détection précoce. Les premiers résultats obtenus ont montré que les instruments de mesure actuellement disponibles dans le service d'ophtalmologie de la Timone (OCT-SD du commerce, Pentacam®), ne permettaient pas d'imager correctement les pièces opératoires en cas d'altération structurelle trop importante, la face postérieure n'étant pas visible. Le Pentacam® permettant de mesurer la diffusion dans les 20 premiers degrés, ne pouvait mesurer précisément une cornée trop opaque. L'OCT haute résolution du laboratoire, nous a permis d'imager au micromètre près les pièces opératoires, tout en gardant à l'esprit qu'il s'agissait de coupes optiques et non histologiques. La diffusion angulaire a montré qu'il y avait une relation linéaire entre l'épaisseur et la diffusion et que toute altération structurelle de la cornée se traduisait par une augmentation de la diffusion. L'analyse de la diffusion angulaire plus particulièrement aux angles compris entre 20° et 70°, les 20 premiers degrés correspondant à des effets de surface, pourrait permettre de déterminer des signatures optiques spécifiques à chaque pathologie.

Ainsi, nos premiers résultats semblent prometteurs et une mesure angulaire de la lumière, couplée à une imagerie OCT haute résolution, paraît être un bon moyen de caractériser et de suivre les pathologies cornéennes. A terme, nous espérons créer un outil de diagnostic innovant dont la sensibilité permettra d'identifier de manière précoce des modifications des tissus cornéens liés à des pathologies (œdème, kératocône), d'évaluer l'efficacité de traitements médicamenteux ou encore de détecter très précocement un rejet de greffe.

On the spontaneous emission of quantum emitters

LASSALLE Emmanuel – CLARTÉ

Directeurs de thèse : Thomas Durt et Brian Stout

It is well-known since the pionneer work of Purcell (1946) that the atomic properties such as the lifetime of an atom in its excited state, or its radiative frequency, are not intrinsic properties of the atomic system, but instead characterize its coupling to the electromagnetic (EM) environment. We investigate numerically the radiative frequency-shift (also called Lamb shift) induced by plasmonic nanoparticles on a nearby quantum emitter in the case of weak interaction (in the so-called weak-coupling regime). Due to the coupling to the plasmon modes of the nanoparticle, the frequency-shift presents a Fano-like resonance when the resonance frequency of the quantum emitter coincides with a resonant mode of the nanoparticle. Interestingly, for "good" plasmonic resonators like silver, a positive frequency-shift is predicted, which should lead to a repulsive van der Waals potential as long as the atom remains in its excited state. We also show that this induced frequency-shift could be detected experimentally in a gold dimer configuration. Moreover, we make use of the quasi-normal modes of the plasmonic nanosphere to derive analytic formulas for the decay rate and frequency-shift of a quantum emitter, clearly revealing the coupling to these modes. In a future work, we want to adapt this formalism in order to investigate the strong-coupling regime of light-matter interaction which is of current interest.

Détection et reconnaissance de cibles d'intérêt dans les images pour la mesure d'audience

MARTIN Benoit – GSM

Directeur de thèse : Salah Bourennane

Co-encadrants: Julien Marot et Frédéric Guerault (IntuiSense SAS)

La mesure d'audience est la récolte de données permettant de profiler une clientèle. Les données récoltées peuvent être, par exemple, le nombre de client, leur genre (homme/femme), leur âge ou encore leur temps de présence dans le lieu étudié. Un tel outil est pertinent, tant pour des études à but marketing que pour des études à but anthropologique.

Cette thèse, sous financement CIFRE, entre la société IntuiSense et l'Institut Fresnel a pour objectif le développement d'un outil de mesure d'audience embarqué sur des machines de Vending (type distributeurs de café) récoltant des données à l'aide d'une caméra.

Un tel outil doit être capable de détecter les personnes présentes dans son champ de vision, de les caractériser et de les suivre au cours de leurs potentiels mouvements tout respectant un fonctionnement en temps réel et en utilisant un minimum de ressources processeur.

Development of a Non-Linear Endoscope for Multimodal Imaging

MYTSKANIUK Vasyl – MOSAIC

Directeur de thèse : Hervé Rigneault

A 2mm diameter non-linear endoscopic probe has been developed in frames of this work. Despite being miniaturized this multimodal endo-tool is able to successfully perform coherent anti-Stokes Raman scattering (CARS), two-photon excitation fluorescence (TPEF), second harmonic generation (SHG) imaging in bio tissues. The distal part of our endoscope consists of a piezo-tube which performs a circular scanning on the sample. An image of 300x300 microns field of view can be acquired in less than 1 second. Due to its label-free chemically selective (CARS) imaging modalities along with its small size and high spatial resolution (800nm), this imaging device has a great potential for different types of medical diagnostics. The most suitable application area could be an early stage diagnosis of the digestive system cancers.

The apparatus will be validated on mice in-vivo. Then, all its constituents will be revised in order to find an optimal cost-quality correspondence. An expensive bulky pulsed laser will be substituted with a cheaper fiber laser for example. We aim at making our device portable, and more importantly, useful and affordable for hospitals and clinics.

Real time monitoring of thin-film deposition during the manufacturing of complex optical interference filters: towards a realization without calibration deposition

NADJI Séverin Landry – RCMO

Directeurs de thèse : Michel Lequime et Thomas Begou

Optical Interference filtering is based on the use of a stack of thin layers with optimized thicknesses and different optical refractive index. The realization of complex filtering functions requires a perfect mastering of the deposition process and an accurate real time control of the optical thickness of the deposited layer. The deposition process used during my thesis implements ion beam sputtering with ion beam assistance, usually designated by the acronym DIBS (*Dual Ion Beam Sputtering*).

There are various techniques of monitoring of the deposited layers based on physical or optical methods, the principle consisting in the last case to follow in real time the evolution of the spectral performances of the stack during its formation. My thesis work aims to implement a **multi-criteria optical monitoring** in the DIBS machine in order to carry out complex optical components without calibration, i.e. without recourse to a first deposition run to validate all the parameters of the process system.

A first application of the real-time **broadband monitoring** involved in this multi-criteria optical monitoring was to implement a new method to determine the spectral dependence of the optical constants ($n(\lambda)$ and $\kappa(\lambda)$) of a tantala (TA_2O_5) layer without using a dispersion model. This method can also be used for low index layer by using high index substrate instead of silica (SiO_2). Furthermore, we demonstrate theoretically that the method can be applied on high and low refractive index material bilayers, and how to extract the optical constants of both materials by sequentially processing the time variation of the transmission at each wavelength. The availability of this method paves the way towards the study of the impact of the substrate on the refractive index of the layer of transparent dielectric oxides.

Present works are devoted to the development of the **third optical system** based on the use of **real time phase measurements**.

Study of materials, Components and Systems in Terahertz domain by analogy with optical methods

POULIN Cyndie – ILM / CONCEPT
Directeurs de thèse : Hassan Akhouayri, Myriam Zerrad,
Meriam Triki (Terahertz Waves Technologies)

The aim of my thesis consists on developing models to describe interactions between THz waves and matter to get a good understanding of the physical phenomena which may be involved. This work is performed by comparisons between modeling and experimentation achieved by terahertz imaging. These developed models are used as a support for a better comprehension of THz images. In the future, they will be used as predictive tools for material characterization in the terahertz domain.

Terahertz waves are located between far infrared and microwaves in the electromagnetic spectrum ranging from 0,01mm to 3mm. They provide features of optics and microwaves depending on the operating wavelength. Several applications can be investigated in the surface and volume like detection of defects, delaminations, humidity, etc.…

As a first step in my work, I simulate the optical response of homogeneous and planar polymers samples. Recently, I obtained a good agreement with experimental results. Therefore, our team is encouraged to enlarge this study to heterogeneous samples which exist in the current industrial environment. Furthermore, we will consider more complex phenomena like diffusion and diffraction.

Structural Organization of Cytoskeletal Assemblies probed by Polarized Microscopies

RIMOLI Caio – MOSAIC
Directeurs de thèse : Sophie Brasselet et Manos Mavrakis

A better understanding of how cells move and change their shape would help us not only elucidate how these physiological processes occur, but also what is different in disease, for example during metastasis of cancer cells. Animal cell shape and movement are generated by cytoskeletal fibers, in particular actin filaments. However, many key questions on how cells control actin filament assembly and organization remain unclear due to the lack of suitable techniques to probe actin organization in a noninvasive manner and in real time. Polarized fluorescence techniques are promising tools for probing molecular organization in vivo, but one of their main limitations is the contribution of the intrinsic floppiness of the fluorophore attached to the molecule of interest.

Nevertheless, using polar-dSTORM, a polarized fluorescence super-resolution microscopy, our group was able for the first time to disentangle structural disorganization of the target molecule (F-actin) from the fluorophore floppiness, thus enabling nanoscale structural imaging. Within this context, our work aims at unveiling how cells organize and assemble actin filaments using different fluorescence polarization approaches at ensemble and at single-molecule levels. Using such polarimetric imaging approaches, we will quantify the floppiness of different fluorophores in order to determine actin organization more precisely. In addition, multicolor imaging is necessary for investigating interactions among different cytoskeletal proteins. To this end, we are also adapting polarization-resolved nanoscopes for real-time multicolor structural imaging.

Our first investigation of actin organization is focused on actin Stress Fibers (SFs), which organization is reasonably well characterized by conventional microscopes. We hypothesize that contractile SFs have actin filaments that are more aligned than non-contractile SFs, either for maximizing myosin-II mediated contractility or due to myosin-II itself reorganizing actin. Our preliminary polar-confocal and polar-spinning disk results in fixed human bone cancer (U-2 OS) cells support our hypothesis, but further simulations, functional studies (perturbations of contractility), and polar-dSTORM measurements must be done for a rigorous quantitative analysis. In parallel to these investigations, we are developing an even more powerful type of polarized super-resolution imaging technique, termed 4polar-dSTORM, which does not require any a priori knowledge and assumption of the filament organization.

Within this context, our preliminary results using 4polar-dSTORM are consistent with previous polar-dSTORM data in the sense that the wobbling of our standard fluorescent label has much higher angular distribution than the filament disorder. This result suggests that these label's fluctuations contribute to a large extent to the ensemble disorder (Ψ) measurements, thus they can lead to an overestimation of the disorder of our structures in ensemble measurements (the structures can be more ordered than we think based only on Ψ). Gradual improvements in the optical setup, data analysis and sample preparation are on the way in order to probe actin organization in a noninvasive manner and in real time.

Growth of laser-induced damage on the exit surface of fused silica optics with large aperture beam

VEINHARD Matthieu – ILM / CEA

Directeurs de thèse : Jean-Yves Natoli et Laurent Lamaignère (CEA)

Laser induced damage growth is the main phenomenon that prevents high energy laser facilities to work at their peak power output. The growth behaviour of laser initiated damage sites have herein been studied with a large aperture beam (7mm), in both lateral and longitudinal directions, for pulse durations of 5 and 1.5 ns. It appears that the previously reported exponential behaviour (for pulse durations above 2 ns) and linear behaviour (for pulse durations below 2 ns) are correct for damage sizes within micrometric scales. However, once the damage reaches millimetric scales, it has been observed that the growth saturates for a few shots until the development of radial cracks. The use of fractal analysis on the images of the damage longitudinal structure has shown that these shifts in growth behaviour seems to be correlated with changes in the damage morphology. This analysis has also shown that the damage morphology seems to be laser pulse duration-dependant.

RESUMES DES 3ème ANNEES

Transformation Thermodynamics : Towards Thermal Camouflage

ALWAKIL Ahmed – CONCEPT

Directeurs de thèse : Claude Amra et Myriam Zerrad

This PhD thesis is concerned with the control of thermal energy propagation in the space using transformation optics (TO) theory. The main application of this theoretical work is thermal camouflage where two different objects with different parameters, shapes and temperatures have the same thermal radiation signature such that they cannot be differentiated by a detector. In this thesis, we applied TO to heat conduction in solids and thermal radiation in an unified manner. In the first year of this thesis, TO has been applied to heat transfer in solids, where Fourier's law of heat conduction had been assumed. In the second year, we extended TO to thermal radiation physics described by fluctuation electrodynamics theory which states that given a lossy linear medium in thermodynamic equilibrium with temperature T, the thermal radiation from such medium is associated with fluctuating thermal electric and magnetic currents embedded in the thermal emitter, which are the electromagnetic source of the thermal radiation. We showed that fluctuation electrodynamics is invariant under TO transformations, then we integrated this proposed approach with heat conduction by solving for the temperature field solution of the heat equation. Numerical calculations done confirm the proposed theory.

Laser-induced modifications in fused silica up to damage initiation caused by multiple UV nanosecond pulses

BEAUDIER Alexandre – ILM

Directeurs de thèse : Jean-Yves Natoli et Frank Wagner

Fatigue effects in fused silica have been largely studied in the past years, as this phenomenon is directly linked to the lifetime of high power photonic materials. Indeed, in the UV regime, we observe a decrease of the LIDT (Laser-Induced Damage Threshold) when the number of laser shots increases and this has been attributed to laser-induced material modifications. Under 266 nm laser irradiation, with nanosecond pulses of constant fluence, we observed that the photoluminescence is modified until damage occurs. High-OH fused silicas like Suprasil®, "UV fused silica" or Herasil® show NBOHC (Non-Bridging Oxygen Hole Center) luminescence at 664 nm (1.87 eV) whereas low-OH fused silica like Infrasil shows ODC (Oxygen-Deficient Center) luminescence at 404 nm (3.07 eV). We found that the laser-induced density of NBOHCs increased until bulk damage occurred while the ODC's density decreased. We propose a new representation of the experimental S-on-1 breakdown data which allows predicting the occurrence of material breakdown consuming fewer sample surface and saving time compared to the classic representation Nd (Number of shots before damage) versus F (Fluence). The link between laser-induced fluorescence and the modifications leading to breakdown is however modified if a break is used during the irradiation. We also study the evolution of linear index modifications thanks to in situ phase imaging techniques and transmission or absorption evolution versus laser shots until damage.

Imagerie 3D quantitative utilisant la microscopie non linéaire sans marquage dans la peau humaine

CANONGE Rafaël – MOSAIC

Directeur de thèse : Hervé Rigneault

Les récentes avancées de la recherche sur la peau ont permis une compréhension détaillée des mécanismes d'absorption qui ont lieu lors de l'application de produits pharmaceutiques ou cosmétiques. Jusqu'à aujourd'hui, la plupart des techniques utilisées pour la pénétration percutanée et l'absorption ont échoué à fournir des cartes quantitatives en trois dimensions des composants moléculaires actifs. Le système utilisé dans le cadre de ma thèse permet d'imager et de reconstituer la concentration moléculaire en fonction de la profondeur dans la peau artificielle ou humaine en utilisant la microscopie non lineaire sans marquage. Des techniques comme la fluorescence à deux photons, la génération de seconde harmonique, et CARS/SRS (effet Raman stimulé) sont utilisées sur une seule plateforme pour fournir des images colorées multimodales avec une sélectivité chimique.

L'utilisation de composants deutérés constitue un pan essentiel de l'étude des produits cosmétiques et pharmaceutiques, car combinée avec la spectroscopie et microscopie cars, elle permet une distinction des molécules marquées dans les différentes strates de la peau.

Une autre utilisation de cette plateforme est l'imagerie des muqueuses du système digestif humain. Cette étude s'inscrit dans le cadre d'une colaboration avec l'institut Pauli Calmette de lutte contre le cancer. Les différentes techniques utilisées permettent de reconstituer la structure et discerner les différents éléments présents dans le but d'obtenir une caractérisation de zones touchées par le cancer.

Enhancing light-matter interactions with high-index dielectric scatterers

COLOM Rémi – CLARTE

Directeurs de thèse : Nicolas Bonod, Brian Stout et Boris Kulhmey

Photonic resonances in subwavelength dielectric or metallic scatterers have generated a keen interest on account of their ability to induce strong light-matter interactions near subwavelength particles. Optimizing the resonant interaction between light and such particles appears to be of fundamental importance to improve the light scattering efficiency and to increase the near-field enhancements.

By means of the Mie theory which permits to analytically calculate the optical response of spherical scatterers, we determined the higher limits of absorption and scattering by subwavelength-sized particles. We have also determined the conditions (permittivity and size) required to achieve these limits.

A second part of our work is devoted to the derivation of simplified models describing the interaction of sub-wavelength-size scatterers. Such models have been extensively used to study localized surface plasmon resonances (LSPR) hosted by small metallic particles. They have provided a better understanding of plasmonic resonances. However, they fail to predict the photonic resonances hosted by dielectric particles. Our work aims at generalizing the analytical models to predict the resonances occurring either in high-index dielectric or metallic subwavelength-sized scatterers.

Development of a Multi-purpose Fast Neutron Spectrometric Capability in the MASURCA Experimental Facility

DIONI Luca – CLARTE
Directeurs de thèse : Brian Stout, Marco Sumini (UNIBO)
et Robert Jacqmin (CEA)

In this work, we investigate the possible use of the CEA Cadarache MASURCA experimental fast reactor to generate a fairly high-intensity continuous beam of fast neutrons, having energies distributed in the 1 keV to 5 MeV range. Such an extracted beam of fast neutrons, tailorable in intensity, size and energy, would be rather unique; it would be of interest to neutron-based research and could open a range of new applications at MASURCA.

Different types of high-performance neutron and gamma spectrometers have been considered for characterizing the beam at the channel exit and the neutron flux near and inside the core. Among the methods for intermediate-to-fast neutron energy spectrometry in mixed fields, a combination of different techniques - which comprehends proportional counters, organic scintillators and proton recoil telescopes - has been selected for the purpose.

Tests with the new solution-grown stilbene (crystal organic scintillator) have been performed at mono-energetic neutron fields, at neutron beams produced in a 10 MW research reactor (LVR-15) and in different positions in a zero power research reactor (LR-0).

Development of Prototype Electrical Impedance Tomograph for measurements of void fraction in two-phase flows

DUPRE Antoine – GSM / CEA Cadarache
Directeur de thèse : Salah Bourennane

In the context of better understanding of two-phase flows occurring in heat exchangers, void fractions measurements at high pressure and temperature are needed. Special instrumentation needs to be developed to solve this challenge. Electrical impedance tomography is such a technique, originally used in medicine to detect anomalies from measurements taken across the chest of the patient.

Given a set of independent measurements of electrical potentials and currents at the boundary of a study domain and a numerical model, an inverse problem is able to recover the map of the electrical conductivity across the domain. The mathematical problem being ill-posed, it is essential to find an efficient algorithm and obtain accurate measurement data. Typically, electrical measurements are obtained very fast, but noise reduction schemes may involve averaging at the cost of time resolution.

A prototype sensor has been developed at the laboratory of hydromechanics of core and circuits (LHC) at CEA Cadarache. It features 16 electrodes and 800 frames per seconds. Preliminary validation of the measurements obtained has been performed and the task is ongoing. Upgrades to reduce the noise are planned. In parallel, collaboration has been launched with Telemark University College Norway in order to use the raw impedance measurements for flow regime identification. This algorithm will provide the starting point (i.e. the a priori information) for performant image processing.

Modeling of complex nonlinear plasmonic waveguides

ELSAWY Mahmoud – ATHENA
Directeur de thèse : Gilles Renversez

Nonlinear plasmonic slot waveguides (NPSWs) in which a nonlinear material is surrounded by two metal regions have received a great attention, at least since 2007, due to the strong light confinement in the nonlinear dielectric core ensured by the surrounding metal regions and due to its peculiar nonlinear effects. Several applications have already been proposed for NPSWs. Nevertheless, the experimental observation of plasmon-soliton waves in these NPSWs is still lacking due to the high power needed to observe the interesting nonlinear effects and due to the usual trade-off between the confinement of the light and the high losses in these NPSWs.

In our first work, we have provided a complete study of a NPSW improved by the inclusion of supplementary dielectric buffer layers between the nonlinear core of isotropic focusing Kerr type and the metal regions. For the transverse magnetic (TM) polarization, the added buffer layers have two main consequences. First, they reduce the overall losses and allow us to obtain low loss solutions at high powers. Second, they modify the types of solutions that propagate in the NPSWs for both linear and nonlinear cases. In our second work, we have developed two distinct models to investigate the TM stationary solutions propagating in a one-dimensional anisotropic nonlinear plasmonic structure made from a nonlinear anisotropic metamaterial core of Kerr-type embedded between two semi-infinite metal claddings. The first model is semi-analytical, this method allows us to derive analytically the field profiles and the nonlinear dispersion relations in terms of the Jacobi elliptical functions. The second model is fully numerical, it is based on the finite element method (FEM) which is valid beyond the weak nonlinearity regime and generalizes the well-known single-component fixed power algorithm that is usually used to the two-component case needed in our study. Using our two methods, we have demonstrated that for a highly anisotropic diagonal elliptical core, the bifurcation threshold of the asymmetric mode is reduced from the GW/m level for the isotropic case to 50 MW/m level indicating a strong enhancement of the spatial nonlinear effects. Moreover, the nonlinear phase shift is extremely enhanced at low power due to the huge enhancement of the refractive index at low power. In addition, we have shown that for the hyperbolic case, an effective defocusing effect can be obtained from initial focusing Kerr nonlinearity due to the peculiar anisotropy. Loss issues are reduced through the use of a realistic gain medium in the nonlinear metamaterial core. Currently, we are working on extending our one-dimensional FEM to the two-dimensional case, in which we try to develop a full vectorial nonlinear FEM solver in the frame of the fixed power algorithm in order to quantify the nonlinear characteristics of realistic two-dimensional nonlinear plasmonic structures that can be fabricated and characterized experimentally.

Application expérimentale de méthodes inverses avancées pour l'imagerie des propriétés EM d'un matériau magnéto-diélectrique

FAGET Xavier – HIPE / CEA
Directeurs de thèse : Amélie Litman et Nicolas Mallejac (CEA Le Ripault)

Lors de la réalisation d'un matériau magnéto-diélectrique, des défauts entraînant une fluctuation des propriétés radioélectriques peuvent apparaître. Selon les applications, ces fluctuations peuvent s'avérer plus ou moins gênantes et il est un enjeu important de pouvoir les détecter. En plus de valider une chaîne de fabrication, cela permet de garantir l'homogénéité des matériaux produits. Afin de répondre à cette problématique, une première étape, démontrant la faisabilité de l'imagerie micro-onde de matériaux magnéto-diélectriques inhomogènes à géométrie complexe est nécessaire.

Dans cette présentation, on fera un résumé des travaux réalisés lors des trois dernières années. Cela comprend le développement d'un banc de mesure, l'établissement de protocoles pour mesurer les échantillons, la modélisation de l'expérience et le traitement du problème inverse. Les résultats, ainsi que leurs interprétations seront ensuite discutés.

Electromagnetic pulses in ultra-dispersive media : a numerical and theoretical approach

GARCIA VERGARA Mauricio – ATHENA

Directeurs de thèse : Guillaume Demésy et Frédéric Zolla

For the first year of our research, we have been working both on theoretical treatment and numerical simulation of an electromagnetic wave packet that propagates in an extremely frequency dispersive single slab embedded in a vacuum. The methodology used is based on temporal Fourier transformation, PDE's, and complex analysis techniques. We pay a special attention to causality by including a self consistent constitutive relation such as a Drude-like model.

During the second year we accomplished the following tasks: 1) The theoretical treatment and numerical simulation of propagation of plasmons through metallic nano-particles such as gratings made of gold or silver. 2) The numerical implementation on Python code of the Tetrachotomy Method, that allow us to obtain the transmission coefficients poles which are localized on the complex plane.

For the third year we have described a very general procedure to obtain a causal fit of the permittivity of materials from experimental data with very few parameters. Unlike other closed forms proposed in the literature, the particularity of this approach lies in its independence towards the material or frequency range at stake. Many illustrative numerical examples have been obtained and the accuracy of the fitting is compared to other expressions in the literature (see Fig \ref{fig:Comparison}). Moreover we are extending our research to the study of transient regime of radiated field by 3D dispersive/leaky open structures, combining our results in QNME and Finite Elements Method.

La microscopie super-résolue, les yeux fermés et pour pas cher

LABOUESSE Simon – SEMO / COMIX

Directeurs de thèse : Anne Sentenac et Marc Allain

La technique de microscopie à éclairements structurés (SIM) permet théoriquement de doubler la résolution d'un microscope optique standard. Le microscope SIM requière cependant un control particulièrement fin des illuminations, ce qui le rend couteux et difficile à calibrer. Ma thèse étudie du point de vue théorique et algorithmique une approche aveugle qui produit des images à partir d'éclairements aléatoires (Blind-SIM). Cette stratégie permet l'imagerie super résolue tout en réduisant fortement le coût de l'instrument. Une expérience illustrant la capacité de super résolution et la rapidité d'une technique Blind-SIM sera présentée et suivie de résultats sur données réelles.

Super-resolution fluorescence microscopy using speckle illuminations based on blind-SIM reconstruction strategies

NEGASH Awoke – SEMO

Directeurs de thèse : Hugues Giovannini

Using multiple non-uniform illuminations, classical harmonic structures or random speckle patterns, permit to retrieve the sample information beyond the frequency support of the optical transfer function of the microscope. Yet, a reconstruction procedure must be used to restore the high-resolution sample image from the low-resolution data obtained under multiple illuminations. For algorithms that require a prior knowledge of the illumination pattern such as classical SIM, precise control of the illuminations is achieved at the expense of instrumental constraints. In random speckle illuminations the control of the illuminations is not even physically possible.

Therefore, it is desirable to have a reconstruction mechanism that require a little prior knowledge on the illuminations. We present the blind-reconstruction mechanisms that retrieve transverse and axial resolutions without requiring the information of individual non-uniform illumination patterns. The approach only assumes that the temporal average of the illumination intensity patterns over the sample is homogeneous. The resolution gain of the non-uniform illuminations based on these novel reconstruction strategies is illustrated using synthetically-generated, standard-calibrated and biological samples.

Development and assessment of a biological tissue-equivalent phantom for electromagnetic properties assessment in the microwave domain

NEVES Luisa – HIPE

Directeur de thèse : Pierre Sabouroux

Although it has been a largely studied field in the past few years, experimental models of the human head and body (phantoms) for dosimetry and high field MRI are nowadays still very simple, and are mostly used for the evaluation of SAR (Specific Absorption Rate) in telecommunications. Considering the contrast in the dielectric properties of the different brain regions (white matter, grey matter, cerebellum, etc.), it has become pertinent to accurately describe the human brain/head in terms of permittivity and conductivity, in a more detailed manner than that that has been performed and described so far in the literature, only evaluating two or three different regions. With these conditions, it is difficult to precisely evaluate the distribution of SAR throughout the whole head, especially while performing high field MRIs (arriving to 7 T nowadays) – the higher the field, the higher will be the dose received by the patient.

It is with this insight in mind that, with this project, we intend to develop an accurate and realistic head phantom for dielectric properties and SAR assessment. With the help of the multi-material permittivity and permeability measurement kit EpsiMu®, some representative brain tissue-like solutions of the interest zones have been produced and characterized, with the dielectric contrast and conductivity values as found in the literature. Future work will involve the molding and assembly of the different brain-simulant samples in a realistic skull and undergoing of an MRI scan.

Optical nanoantenna for live cell research

REGMI Raju – MOSAIC

Directeurs de thèse : Jérome Wenger

Sub-diffraction photonics based on plasmonics/dielectrics offer opportunities to follow single molecule events as they can confine electric fields in nanoscale hotspots with spatial dimensions comparable to single molecules (~5 nm). In this talk, I will summarize our nanoantenna based efforts with immediate application in biophysics and live cell research (e.g. single-molecule fluorescence detection and investigating diffusion dynamics of membrane lipids with unprecedented resolution).

Single molecule coherent control on light harvesting complexes : Role of coherence in energy transport at the femtosecond timescale

VIKAS Remesh – MOSAIC

Directeurs de thèse : Niek F. van Hulst et Hervé Rigneault

Light harvesting complexes (LH2s) are pigment protein complexes found in purple bacteria (Rhodopseudomonas acidophila), designed for energy reception and transfer during the initial stages of photosynthesis. This highly efficient energy transfer is believed to be assisted by the interplay of coherent coupling between chromophores and finer interactions between chromophore and surroundings. Existence of a coherent superposition in a noisy environment in room temperature is truly surprising. A better understanding of the process will help in designing clean and efficient solar harvesting devices. Here in this project between ICFO- Barcelona and Institute Fresnel- Marseille, I try to explore more on this energy transfer process at the single molecule level.

Single molecule studies are superlative, in terms of the spectroscopic information accessible, which normally average out in conventional ensemble studies. Fluorescence based single molecule spectroscopy is by far the most feasible measurement scheme, in terms of the signal to noise ratio achievable. However, for molecular systems like LH2s which have very low quantum yield (10%), and limited photostability (on the order of few minutes), it is important to device a better method to perform long measurements. Nanoantennas offer promising alternative for this, by increasing the radiative rate for emitters (eg. Single molecules) thanks to the highly concentrated electric field in the hotspots. This provides us with longer photostability and enhanced fluorescence signal, enabling long time measurements on these systems.

We apply a simple coherent control scheme in a pump- probe approach, via phase only shaping of broadband laser spectrum to monitor change in fluorescence to study the energy transfer process at the single molecule level. Alternatively, we also expect to derive information on the possible vibrational modes assisting this energy transfer process, by pump-probe experiments looking at surface enhanced Raman scattering signal.

Thermal imaging by using Gold Nanoparticules and wafefront sensing for the study of thermal biology at the single cell level

ROBERT Hadrien – MOSAIC

Directeurs de thèse : Benoit Watelier, Serge Monneret et Guillaume Baffou

Nowadays, thermal studies in cell biology remain complicated to implement. Usually, scientists heat the entire sample, or even the whole microscope, to study the temperature dependence of the metabolism of living cells. The approach has limitation: all the cells are heated at once at the same temperature, and the heating exhibits a large thermal inertia.

We developed an approach to locally heat using gold nanoparticules at the micrometric scale, and control the temperature using an optical wavefront sensor [1]. Furthermore, our setup is able to simultaneously acquire quantitative phase and confocal fluorescence images which allows us to combine morphological and functional informations.

I will illustrate the capabilities of this technique by presenting two recent works.

RPE1 (Retinal pigment epithelial) cells were transfected by a HSF1 (heat stress factor 1) plasmid labeled with a GFP fluorophore. The HSF1 proteins have the property to agglomerate in the nucleus if we heat them at 43°C for a few minutes. We managed to heat single cells and observe the agglomerate formation (see Fig 1).

Microtubules are long hollow filaments that are part of the cytoskeleton. They have many functions like maintaining the cell shape or proteins transport. It has been shown that microtubules can depolymerize at 4°C and polymerize again at 37°C. I will show in my presentation that we can locally modify the polymerization of microtubules within single cells.

Controlling emission with metamaterials

RUSTOMJI Kaizad – CLARTE

Directeurs de thèse : Stefan Enoch, Redha Abdeddaim et Boris Kuhlmey

Metamaterials have attracted a lot of attention because of their potential to engineer the electromagnetic response of materials. Its exotic applications like negative refractive index and electromagnetic cloaking have interested scientists and the public alike. In our work we analyze hyperbolic metamaterials to modify the rate of spontaneous emission, characterized by the Purcell factor. Hyperbolic metamaterials are a class of materials, with an indefinite anisotropic permittivity tensor that lead to hyperbolic dispersion relations. These metamaterials, due to hyperbolic dispersion have a large local density of states and can be used to achieve broadband enhancement of the Purcell factor.

It was shown recently that the impedance of an antenna is linked to the local density of states and can be used to measure the Purcell factor. We have used this approach to study the Purcell factor for a hyperbolic metamaterial structure in the frequency range 5-15 GHz. We find that depending upon the polarization the Purcell factor can be enhanced or suppressed in the metamaterial. This method has the added benefit that by replacing the electric dipole by a magnetic dipole we can independently evaluate the electric and magnetic Purcell factors.

We compare our method with an alternate approach to obtain the local density of states, from band structure calculations of the periodic unit cell of the metamaterial. We shall be extending our approach from microwave to terahertz frequencies. The research will contribute towards a coherent understanding of local density of states in hyperbolic metamaterials.

Application of Microwave-analogy to the study of scattering by trees, atmospheric particles and micro-organisms

SALEH Hassan – HIPE

Directeurs de thèse : Jean-Michel Geffrin et Hervé Tortel

The electromagnetic scattering of light by particles and complex-organisms is a key stone in research fields related to biology, photobioreactors, astronomy and many others. However, when targets become of very small dimensions, such as nanoparticles and molecules aggregates, the scattering measurement becomes difficult to manage in the optical region due to the scale limitations. The microwave analogy is a useful approach, based on the scale invariance rule, which allows to do the scattering measurements in the microwave domain instead on the optical domain where the experimental environment is better controlled. By conservation of the wavelength over target dimension ratio and the initial refractive index, a double scale translation of both wavelength and target dimensions can be applied. Nanometer objects can therefore be represented by mm ones and the reproducibility of the initial wave-material interaction could be achieved.

The HIPE team of Institut Fresnel works on this subject since several years using the anechoic chamber of the Centre Commun de Ressources en Microondes (CCRM). From a practical point of view, the implementation of the microwave analogy principles could be improved by the fabrication of objects carrying specific dimensional and electromagnetic characteristics, as well as by performing spherical measurement of the scattered field surrounding the object. The aim of this thesis is to enhance these points by adopting the appropriate techniques to create objects of controlled shapes and electromagnetic properties using special technologies (3D printing, composite materials) as well as developing the capacity of the actual measurement setup in the anechoic chamber of the (CCRM) to be able to perform measurements in all the directions surrounding the target. The scattering measurement of three main targets is concerned along this thesis: objects equivalent to trees in forests, soot aggregates that exist in the atmosphere, and photosynthetic microalgae existing specially in the oceans.

Optimized procedure for controlling the deposition of multilayer structures in situ

VIGNAUX Maël – RCMO

Directeurs de thèse : Fabien Lemarchand et Julien Lumeau

Interferential thin films are key elements in a large area of optics because they make it possible to obtain complex optical functions.

With the recent evolution of deposition systems as well as automated processes, it is now possible to design and manufacture increasingly sophisticated filters, up to several hundred layers. However, the spectral characteristics of an optical filter measured at completion may differ from the targeted characteristics due to the errors made in the monitoring of the thickness of each layer, in spite of efficient deposition and control techniques. We propose here to simulate, a priori, the expected differences in function of characteristic error that can be made to estimate even before deposition a predicted success rate at completion of the filter.

It will then be possible to determine the optimum strategy for controlling the thickness, layer by layer, of a multilayer stack without the need of deposition trials. A first study is carried out on the manufacture of an optical fabry-perot filter made of an optical cavity surrounded on each side by 10 layer. We demonstrate with the algorithms implemented that the use of a mixture of two different optical control techniques greatly improves the spectral response of the filter once it has been realized.

Ultra short pulse characterization, a new in-situ approach using disordered nonlinear ferroelectric crystals

WANG Bingxia –ILM
Directeurs de thèse : Hassan Akhouayri,
José Trull et Crina Cojocaru (UPC Barcelona)

Strontium Barium Niobate (SBN) crystals at room temperature show a random size distribution of ferroelectric anti-parallel oriented domains. This property leads to broadband transverse second harmonic generation (owing to disorder induced quasi-phase matching). As an application, we successfully implement single-shot auto-correlation measurements of the initial chirp and duration of laser pulses in the femtosecond regime which is based on the determination of the transverse width of the auto-correlation trace along the propagation direction. This transverse auto-correlation technique permits a real-time analysis of the pulse evolution and facilitates fast in-situ correction of pulse chirp acquired in the propagation through an optical system. Furthermore, we implemented this broadband transverse second harmonic generation for single-shot cross-correlation measurements of laser pulses with an unknown temporal duration and shape. We optimize the error of the pulse measurement by controlling the incident angle and laser beam width. As novelty, we show that this cross-correlation technique can be used for the temporal characterization of pulses over a very wide range of durations, from 30 femtoseconds up to 1ps, and wavelengths. With these transverse techniques we can measure the pulse evolution along the propagation distance and break the demand of a thin nonlinear crystal and angular alignment or temperature control using mono-domain nonlinear crystals.

Abir ZIDI – GSM
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