AGENCE NATIONALE DE LA RECHERCHE ANR	Scientific Report	INVESTISSEMENTS D'AVENIR

LABEX

CEMPI

1. Progress of the project

Introduction. The ``Laboratoire d'Excellence" CEMPI (Centre Européen pour les Mathématiques, la Physique et leurs interactions), a project of the Laboratoire de Mathématiques Paul Painlevé and the Laboratoire de Physique des Lasers, Atomes et Molécules (PhLAM), was created in the context of the "Programme d'Investissements d'Avenir" in February 2012 and started operations effectively in September of that year. The text of the project, as it was proposed in 2012, can be found at the following internet address:

http://math.univ-lille1.fr/~cempi/files/CEMPI_b_public.pdf.

The goal of the partnership Painlevé-PhLAM through the CEMPI project, and in close collaboration with the Equipex FLUX, is to stimulate fundamental and applied research, as well as training and technological development within a wide spectrum of knowledge stretching from pure and applied mathematics to experimental and applied physics. Emphasis is put on fostering interactions between mathematics and physics, as well as with other sciences such as biology or computer science, and also with technological innovation in fiber optics. Among the three mathematics-physics interaction themes that make up the first focus area of CEMPI, essentially one concerns research carried out at PhLAM, namely complexity in atomic physics and optics, and the two other touch physics studied elsewhere, although new opportunities are appearing in quantum information theory. The other main area of interaction between Painlevé and PhLAM is the "Physics and Mathematics for Biology" focus area. The CEMPI furthermore develops its activities through partnerships with internationally renowned teams in first rate foreign institutes such as the Universities of Bristol and Aberdeen (United Kingdom), Leuven, Louvain-La-Neuve and Photonics@be IAP (Belgium), the Max-Planck Institute in Bonn (Germany), the Fields Institute in Toronto (Canada) and SISSA (Italy).

In the following sections, we will describe the activities and results of the CEMPI between September 2012 and December 2014, in its three fields of action: research, training, technology transfer and economic impact. For many of these activities, details can be found in the different pages of the CEMPI website at http://math.univ-lille1.fr/~cempi. We will also provide information on the CEMPI governance and budget.

As will become apparent in the following pages, after almost three years of operation, CEMPI has gone forward with all programs and actions foreseen in the original project. It is now consolidating those efforts and looking into the future for their further development or adjusting. In addition, by bringing together the strengths of the two main physics and mathematics laboratories of the Université Lille 1, CEMPI has helped to re-structure the scientific landscape on its principal campus, in Villeneuve d'Ascq. Starting in 2012 with two laboratories whose members knew little each other and were unfamiliar with each other's research, the CEMPI teams have succeeded in creating an effective scientific collaboration whose measurable results are increasingly visible, as explained below.

Further points to which particular attention will be paid in the coming years are the following.
- We will continue our efforts to increase the visibility of our training programme (Master-PhD-Postdoc), which have proven fruitful. They will be enhanced and consolidated notably to attract more top-level master's students and to constitute in this manner a CEMPI Graduate School.
- Increased emphasis will be placed on the promotion of CEMPI and its activities. We aim for CEMPI to be recognized as a label of excellence and a partner of choice in the academic, institutional and technological worlds. To promote this view, a CEMPI day that brings together players of these worlds will be regularly organized on the model of the inaugural conference (2013) and the CEMPI Scientific Day (2015).
- Besides those described in the original project, we have identified several research themes of the CEMPI physicists that would benefit from increased interaction with the colleagues of the Probability and Statistics team of the Painlevé Laboratory. The latter was only marginally associated to the initial project, but steps have been undertaken to strengthen its links with CEMPI. In particular, its team leader, Prof. D. Dereudre, has joined the CEMPI executive board at the end of 2013, to replace Prof. C. Besse, who left the Université Lille 1. Preliminary discussions have convinced us that promising interactions between probabilists and physicists can take place both in the study of complex atomic and optical systems (focus area 1, theme 1) and of biological systems (focus area 2). Examples of open questions include characterization of extreme deviations in optical turbulence and extreme optical wave generation, or the interplay of determinism and noise in biological networks.
- Painlevé researchers of themes 2 (algebraic geometry) and 3 (analysis) of focus area 1 of the project, inspired by the multiplicity of problems related to singularities that arise both in geometry and analysis, recently initiated a common project around this theme. The interactions between singularities and complex analysis, q-differential equations, algebraic geometry, differential geometry, algebraic topology, number theory and mathematical physics will be studied through in particular the subject of singularities of holomorphic foliations and singularities of q-differential equations arising in transcendence theory. In parallel the research activity on quantum information theory, which involves members of the PhLAM and of the analysis team of the Painlevé Laboratory will be further developed.
- The knowledge exchange with theoretical computer scientists, successfully begun with the workshop and series of mini-courses in 2012, has continued. It further materialized in the project for a volume in the CEMPI Subseries in LNM containing contributions of both computer scientists and geometers on the topics that are at the interface of the two subjects; it will culminate with a 6 month programme covering the theme, to be held at the Isaac Newton Institute in Cambridge in January-June 2017, an occasion to consolidate the advances in the area and to chart new directions of research.
- CEMPI will accentuate its research into geometric group theory, deformation theory of geometric structures on manifolds and the dynamical properties of actions of groups, which concerns both theme 1 of focus area 1 and theme 2 of focus area 3. The new members of CEMPI's team working on these subjects will make possible further advances in this area of research that touches upon a wide range of mathematical and physical applications.
- In the framework of the new Contrat de plan État-Région (CPER, 2015-2020), CEMPI and FLUX have proposed the Photonics4Society project that has been validated by the Region Nord-Pas de Calais, for 5M€ and that will be additionally funded by the European Regional Development Fund. More details are given in Section 2.D.

Since it seems in the nature of time to accelerate, 2019 will soon be here, and signal the end of the CEMPI contract as such. Perceiving, as we do, the many positive effects of the dynamics set up by

CEMPI, we have started to prospect ways in which to make them perdure. More details on those efforts can be found in Section 2.D.

1.1 Governance

The eleven member executive committee and the scientific coordinator of CEMPI, assisted by a coordination assistant, run the everyday business of CEMPI. The assistant was made available by the Université Lille 1 in January 2013 when she joined the secretarial staff of the Laboratoire P. Painlevé.

After three years of operation, we feel the administrative procedures necessary for the organisation of the scientific events hosted by CEMPI and for the hiring of non-permanent staff have been streamlined and function well. Constant attention is nevertheless paid to their further perfection, following up on suggestions by the executive committee or by members of the partner laboratories and keeping in mind our guiding principles: flexibility, efficiency, reactivity, simplicity. The administrative environ-ment in which we function is of great complexity due to the simultaneous intervention of numerous different local, national, and international organisms. The staff of the CEMPI partner laboratories deploys treasures of inventiveness to shield its researchers from these complications.

The coordination assistant assists the scientific coordinator in all administrative matters concerning the hiring of non-permanent personnel (contracts, visas, housing, office, pay...), in all budgetary matters, and assists the scientists with the organisation of the thematic semesters and other scientific activities. She also maintains the website, assisted by a member of the project.

The CEMPI executive committee meets every two to three months to review the project's progress, to plan future activities and to take decisions on the hiring of master's and Ph.D. students, postdocs and invited professors. The scientific coordinator prepares the meetings by providing a detailed agenda, taking into account suggestions by committee members. He writes complete minutes after the meeting, to ensures there is trace of the decisions taken and of the remaining problems to be addressed.

The LABEX are a new feature of the French academic landscape. As such, its traditional actors raised concerns that they would be a source of administrative complications or worse, of conflicts with the existing structures, in particular with their partner laboratories. At CEMPI, every effort has been made to avoid such problems, and none have arisen. Both laboratories, and all scientific directions, are well represented in the executive committee. As an example, as mentioned already above, when C. Besse left the Université Lille 1, he was replaced by D. Dereudre, from the probability and statistics team of Painlevé. In this manner, each team of the Laboratoire Paul Painlevé is now represented in the executive.

To inform the members of both partner laboratories of the functioning and goals of the CEMPI project, the scientific coordinator organised several meetings in the first year of operation. In each of the following years, a meeting was held to discuss the progress of the project and possible changes in operating procedures, and to inform the new members of the project. This practice will be continued.

Every year in spring, an informal meeting has been set up of the scientific coordinator and the scientific correspondent of the PhLam with the president and vice-president for research of the Université Lille 1, in order to discuss the progress of the project and to outline its future course.

Finally, regular contact is maintained with the members of the Advisory Board, who participated in several of the scientific activities of the CEMPI. Meetings of the Advisory Board with the Executive Committee and Steering Committee were organized during the CEMPI Inaugural Conference (September 2012) and during the CEMPI scientific Day (February 2015).

1.2 Research

The main research ambition of CEMPI, as formulated in the original project, is to stimulate research at the interface of mathematics and physics, in particular to generate collaborations between the two partner laboratories, and, beyond that, to favour interdisciplinary research between mathematics, physics, biology, computer science, on a number of selected topics. The opportunities offered by the creation of CEMPI have been seized enthusiastically and we feel we are realizing this program successfully; in particular, the collaboration between the two communities is starting to prove fruitful, as detailed below. Our efforts have also been rewarded through the recognition afforded by the awarding of one ERC grant and one IUF grant within the project boundaries, and of a CNRS Bronze Medal to one of our young researchers.

It is very satisfying that where the CEMPI project involves both the Painlevé and PhLAM laboratories (Focus Area 1, Theme 1, "Complex atomic and optical systems" and Focus Area 2, "Physics and Maths for Biology"), joint discussion and research has materialized in different ways. As discussed later, common seminars have been organized in these two themes and helped to identify possible interactions. More concretely, a joint PhD student in theoretical cold atom physics and a joint post-doctoral researcher in theoretical nonlinear optics have been hired, with promising preliminary results. Another young Italian post-doctoral researcher, hired in the PhLAM Photonics team for working on theoretical nonlinear optics, became involved in a physics-mathematics collaboration about the propagation of light pulses in optical fibers whose diameter varies periodically, with open problems both on the physical and mathematical sides. Two months ago, he was awarded an "ANR @raction" grant ("Accueil de chercheurs étrangers de haut niveau") for his project on the nonlinear dynamics of abnormal wave events (NoAWE). Mid-march 2015, he was ranked first in the First Class Junior Researcher (CR1) annual hiring procedure of the "Atomic and Optical Physics" division at CNRS (section 04), demonstrating both the attractivity and leveraging effect of CEMPI.

To complete this very succinct overview of CEMPI research we end this section by listing some of the most striking results obtained in the first three years of operation, in each of the six CEMPI themes. More details are provided in Section 2.A.

FOCUS AREA 1: THE INTERFACE OF MATHEMATICS AND PHYSICS

(1) NONLINEAR COLLECTIVE DYNAMICS IN COMPLEX ATOMIC AND OPTICAL MANY-BODY SYSTEMS: DETERMINISTIC AND STOCHASTIC ASPECTS

Stability in the energy space for chains of solitons for the Landau-Lifshitz equation

The Landau-Lifshitz equation is a nonlinear evolution equation describing the dynamics of magnetization (spin) in ferromagnets. In the one-dimensional case, the existence of explicit multisoliton solutions is an important example of chains of solitons in anisotropic materials. We have proved in [1] the stability of "well-ordered" chains in the sense that if the system is close to such a chain of solitons at an initial time, then the evolution of the system remains close to a chain of solitons for all positive time. The Landau-Lifshitz equation is also related to other physical systems such as vortex filaments, moving spaces curves and has intimate connections with nonlinear Schrödinger and sine-Gordon equations. Moreover, micromagnetic simulations justify the use of the Landau-Lifshitz equation to provide guidelines for the structural design of magnetic materials and recording devices.

[1] A. de Laire, P. Gravejat, J. Differential Equations, 258(1): 1-80, 2015.

Unveiling the spatial structures formed by relativistic electron bunches and their dynamical evolution.

Systems of particles with long-range interaction, such as electrons in plasmas or free-electron lasers, are notoriously difficult to study in the framework of statistical mechanics. They can be described by Vlasov-type equations, whose analysis leads to open mathematical problems. Such systems are known for displaying dynamical instabilities, leading to the spontaneous formation of spatial structures in the particle distribution. However experimental observations of the structures remained up to now generally indirect, thus hampering detailed comparisons of Vlasov models with experimental data. In 2013-2014, we demonstrated the possibility to record directly the resulting spatio-temporal structures, in real time in relativistic electron bunches. A main challenge was to obtain the necessary detection speed. At UVSOR [1], direct recordings were possible using a novel ultrafast superconducting YBCO detector developed by the IMS group of the Karlsruhe Institute of Technology. Then at SOLEIL, we demonstrated the possibility to record spatial structures with sub-picosecond resolution, using the so-called "time-stretch" strategy [2]. These results open the way to direct tests of statistical physics models that were impossible before.

[1] E. Roussel, C. Evain, C. Szwaj, S. Bielawski, et al, Phys. Rev. Lett. 113, 094801 (2014).
[2] E. Roussel, C. Evain, M. Le Parquier C. Szwaj, S. Bielawski, et al, to appear in Scientific Reports ; arxiv:1410.7048 (2014).

(2) ALGEBRAIC GEOMETRY, MODULAR FORMS WITH APPLICATIONS TO PHYSICS

R. Cluckers (with J.Gordon and I. Halupczok) obtained new transfer principles in the context of motivic integrals, answered positively the question on local integrability for Harish-Chandra characters. V. Gritsenko (with K. Hulek) found a new type application of modular forms in algebraic geometry: a criterion for uniruledness of modular varieties of orthogonal type. This result opens a new perspective in the study of hyperkähler varieties and their moduli.

[1] R. Cluckers, J. Gordon, I. Halupczok, Integrability of oscillatory
functions on local fields: transfer principles, Duke Math. J., Vol. 163, (2014), 1549-1600.
[2] V. Gritsenko, K. Hulek, Uniruledness of orthogonal modular varieties,
J. Algebraic Geometry, Vol. 23, (2014), 711-725.

(3) OPERATOR ALGEBRAS, HARMONIC ANALYSIS, QUANTUM GROUPS WITH APPLICATIONS TO PHYSICS.

J. Crann and M. Neufang have constructed a new class of counterexamples to the Asymptotic Quantum Birkhoff Conjecture, formulated by Smolin-Verstraete-Winter in 2005. This central problem in quantum information theory was first solved in 2011 by Haagerup-Musat (and, independently, by Ostrev-Oza-Shor). Parts of the results are published in J. Physics A: Math. Theor. (2013). Several exciting questions stem from the Pontryagin type duality relation between our channels.

[1] J. Cran, M. Neufang, Quantum channels arising from abstract harmonic analysis, J. Phys. A, (46) 4, 045308 (2013).

FOCUS AREA 2: THE INTERFACE OF PHYSICS AND BIOLOGY

To maintain life, cells orchestrate molecular events in response to external or internal stimuli. To generate these events, biological functions such as the cell division cycle rely on a network of genes and proteins interacting through feedback loops. These networks are dynamical systems which harness typical nonlinear behaviors such as bistability or oscillation. However, since they involve small numbers of molecules, they are subjected to strong fluctuations. Important questions are then how cell networks can be made immune to their intrinsic stochasticity, or whether noise can play a functional role. In a recent work [1], we have shown that intrinsic fluctuations may enhance the regularity of oscillations in protein expression of a self-repressing gene. To provide evidence of this counter-intuitive behavior, we derived a moment expansion of the master equation of the stochastic process. This approach allowed to show how nonlinearities feed fluctuations back to the deterministic part of the dynamics, which implies that these fluctuations can also carry biological information.

[1] J. Wang, M. Lefranc, and Q. Thommen, “Stochastic oscillations induced by intrinsic fluctuations in a self-repressing gene”, Biophysical Journal 107, 2403 (2014).

FOCUS AREA 3: THE INTERFACE OF MATHEMATICS AND THEORETICAL COMPUTER SCIENCE.

(1) ALGEBRAIC TOPOLOGY, HIGHER CATEGORIES, OPERADS, WITH APPLICATIONS TO THEORETICAL COMPUTER SCIENCE. Chataur-Saralegi-Tanré have discovered an analogue for the Goreski-MacPherson intersection cohomology of pseudo-manifolds of the Sullivan model for the rational homotopy of spaces. One of the significant outcome of their work is the solution of a conjecture of Goreski and MacPherson about the definition of Wu classes in intersection cohomology.

[1] David Chataur, Martintxo Saralegi-Aranguren, Daniel Tanré, "Intersection Cohomology. Simplicial Blow-up and Rational Homotopy", preprint arXiv:1205.7057 (2012), x+108 pages, http://arxiv.org/abs/1205.7057

(2) GRAPHS AND GROUPS, WITH APPLICATIONS TO THEORETICAL COMPUTER SCIENCE.

C. Drutu, in a joint work with P. Nowak, studied spectral gap properties in a very general form, consequently formulated new versions of property (tau), new types of expansion and proved that the warped cone construction of J. Roe can replace, in many instances, a family of expanders.

[1] Cornelia Drutu and Piotr Nowak, “Kazhdan projections, random walks and ergodic theorems,” arXiv:1501.03473v2

1.3 Training

The training of interdisciplinary scientists from the Masters to the postdoctoral level is an essential part of CEMPI’s activities. As detailed on the CEMPI website, four master’s programs are associated to CEMPI. To strengthen these programs through the recruiting of excellent students, CEMPI offers every year a number of master’s fellowships. In addition, CEMPI also proposes several PhD and postdoctoral fellowships every year.

The openings for these positions are announced in the late fall, via the web and through posters sent to over 120 institutions in France and abroad. In addition, the scientists from both laboratories publicize the openings in their own networks in France and abroad. In 2014 an announcement was also made in the Journal of the AMS. The number of applicants for the various positions is satisfactory, and has been rising. We hope this trend will continue.

As a result of these efforts, since September 2012, 24 Master’s students (out of a total of 140) and 9 Ph.D. Students (out of a total of 50), joined the CEMPI training programs with total or partial CEMPI funding. Five postdocs funded by CEMPI (out of a total of 15) have joined the program since September 2012. The following table summarizes the current situation.

Fellowships	2012 Number of students hired	2013 Number of students hired	2014 Number of students hired	Percentage of funding currently committed
Master’s	8	5	13	20%
PhD	3	3	3	50%
Postdoc	0	2	3	75%

We have created a flexible system of master's fellowships, which has two complementary goals: attract excellent students from other French and foreign universities and keep our top students in our own programs. Initially, the program was intended to fund only second year master students, but changes in the structure of the master's programs as a result of recent reforms in higher education, as well increased competition from other universities also offering fellowships, made it clear it is in our interest to also open our fellowships to first year master students. To provide a legal framework for the master's fellowships, we created in collaboration with the Labex CAPPA and the Université Lille 1 the ``Bourse Scientifique Lille 1''. We have instated two levels of funding, to take into account in particular the extra costs students from foreign countries have to bear in coming to Lille to study and live. In addition, in the last three years, the Région Nord-Pas de Calais has awarded 15 000 euros annually in merit-based fellowships to the mathematics master's programs. These factors explains why the total amount of CEMPI funding currently committed is considerably lower than what could be expected in view of the total number of students funded so far (26). Of the 11 different students that joined our master's programs with CEMPI financing, in 2012 or in 2013, 9 continued in a Ph.D. program; seven inside CEMPI, and two outside.
Except in one case, CEMPI finances only half of the total cost of the three-year PhD fellowships. So, the 9 students hired so far will use 15 years of CEMPI funding only. Either the Université Lille 1, or the Région Nord-Pas de Calais has provided the remaining part of those fellowships. We expect to keep hiring PhD students with complete or partial CEMPI funding at approximately the same rate in 2015, 2016 and 2017. It is clear from what precedes that the impact of CEMPI has gone beyond the funding it provides. There is a clear leverage with several granting institutions that are generally keen to co-finance doctoral theses with us.

We expect to hire, over the coarse of the full project, 15 postdoctoral researchers with CEMPI funding, rather than the originally planned 12. The extra funding will come from reallocating part of our original ``invited scholar'' funding, which is proving less costly than initially projected.

1.4 Valorisation/Result exploitation

The tight collaboration between the Labex Cempi and the Equipex flux has lead to 4 patents:
-Y. Quiquempois, G. Bouwmans, A. Bétourné, L. Bigot et M. Douay, « Hybrid photonic crystal fiber », PCT/EP2012/060851 (W 2012168400 A1) publication : 2012-12-13
-E. Hugonnot, L. Lago, Y. Quiquempois, G. Bouwmans, L. Bigot, C. Valentin et A. Mussot, « Dispositif de conversion du profil spatial transverse d'intensité d'un faisceau lumineux, utilisant de préférence une fibre optique microstructuré " N°: EP28233A1 (WO201313877 A1), pubilcation 2013-09-12
-E. Hugonnot, L. Lago, Y. Quiquempois, G. Bouwmans, L. Bigot, C. Valentin et A. Mussot, "Fibre optique microstructurée à grand coeur et à mode fondamental aplati, et procédé de fabrication de celle ci, application à la microfabrication par laser " N° EP2758816 A1 (WO2013041533) , publication 2014-08-30
-E Hugonnot, A Mussot, Bigourd, and A Kudlinski « Method and device for the optical parametric amplification of pulses with frequency drift" US201433994 A1 publication: 2014-11-13

Knowledge and know-how were shared through various collaborations. ***Nationally:*** Université de Limoges, Marseille, Saint-Etienne, Besançon, Dijon, Montpellier, laboratoire LPN, l'Institut d'Optique GraduateSchool, **Internationally**:Imperial College (Londres), Institut of Quantum Electronics (Pékin), Université de Calgary (Canada), Institut ICFO (Barcelone), Institute of Inorganic Chemistry (Vienne), Ecole Polytechnique Fédérale de Lausanne (Suisse), École Polytechnique de Montréal (Canada), Carleton University (Canada), Pontifical Catholic University of Rio de Janeiro (Brésil), Sydney

(Australie), Hong kong (Chine). **Industrials**: Prysmian Group, Genes diffusion, CEA-DAM, CEA-LIST, ONERA, Alcatel-Lucent, LSO médical, Eolite, Horiba Scientific, Multitel, Mader, Indelec….

Similarly, the creation of the CEMPI Subseries of Lecture Notes in Mathematics/Physics is an important element in the publicizing of CEMPI research. The first volume of the series will appear in the coming months. Others are in the planning stage.

1.5 Outreach and visibility. Promotion of CEMPI.

Beyond the actions mentioned in the previous section, the activities we undertook jointly with our privileged international partners also contribute to our visibility and notoriety. For lack of space, we only mention a few examples, such as: joint PhD supervision with KU Leuven and SISSA Trieste ; joint conferences organised with KU Leuven, SISSA Trieste, Max Planck Bonn, Photonics@be and the Fields Institute in Toronto. Meetings were also organized with the "Nanobiophotonics" consortium of the University of Gent, in the perspective of establishing a long-term partnership, and there are discussions of applying for a joint Marie-Curie doctoral school, and which have already resulted in the participation of some CEMPI researchers in a ERC consolidator project coordinated at Ghent University.

Various actions have been undertaken to publicize CEMPI, its activities, hiring possibilities and research results. Some have been already mentioned above. In September 2012 the one-week CEMPI Inaugural Conference included six workshops on the CEMPI themes, as well as lectures by prestigious scientists, such as Fields Medalist A. Connes (http://www.dailymotion.com/video/xuiyfo_the-music-of-shapes_tech) and the recipient of the Wolf Price, A. Aspect (https://www.youtube.com/watch?v=vqEg4VnoCmc). In November 2012, another important event was the symposium in honor of Pierre Glorieux, with speakers such as again A. Aspect and the 2012 Nobel laureate S. Haroche. More generally, the annual thematic semesters of CEMPI, and the international conferences organized by CEMPI researchers contribute greatly to its notoriety. As an example, the 2014 EGAS conference took place in Lille at the initiative of the PhLAM, and counted among its participants Nobel laureates S. Haroche and D. Wineland.

Additionally, CEMPI sponsored a number of scientific events taking place outside of the campus, in the organization of which CEMPI members were involved, and devoted to themes at the heart of CEMPI. One such example is the Rencontre du Non-Linéaire, the main french-speaking annual conference of nonlinear dynamics.

2/ Impact of Labex label and associated funding obtained

A) Description des réalisations scientifiques/Scientific achievement description

CEMPI research is structured in three ``focus areas'', further divided in a total of six ``themes'', a full description of which can be found on the CEMPI website and in its project, referred to above. In this section, we synthetically present the progress made in each of the themes since September 2012. It will become apparent that the core ideas underlying the original CEMPI project have taken on concrete form in the three first years of CEMPI operation. In particular:

- Collaborative research has been developed between the two partner laboratories, and more generally in novel subjects at the confluence of mathematics and physics.

- Research activity in physical and mathematical biology and more generally at the interface between physics and the life sciences and medicine has been expanded, in particular through a joint PhD supervision with the Labex EGID (European Genomics Institute for Diabetes). In the framework of the Photonics4Society CPER project, CEMPI teams have build a consortium also including teams from IEMN in Lille (along the 5 top nanotechnology centers in France), bringing together their complementary expertises. This consortium has developed a partnership with the Nanobiophotonics consortium in Ghent, leading to a participation in an ERC consolidator project coordinated in Ghent.

FOCUS AREA 1. THE INTERFACE BETWEEN MATHEMATICS AND PHYSICS This focus area encompasses three themes. The first is concerned with key problems of a mathematical, physical and technological nature coming from the study of complex behaviour in cold atoms physics and non-linear optics, in particular fibre optics. The two other themes deal with fields of mathematics such as algebraic geometry, modular forms, operator algebras, harmonic analysis and quantum groups that have promising interactions with several branches of theoretical physics.

Focus area 1, Theme 1: Nonlinear dynamics in complex atomic and optical systems This theme is mainly concerned with nonlinear complex behavior in cold atoms andoptical systems, including optical fibers. It constitutes the main CEMPI theme where mathematicians (from Painlevé) and physicists (from PhLAM) have built bridges for fruitful and sustainable collaboration. Indeed, almost all physical systems under consideration have in common a non-linear description mainly based on the generalized nonlinear Schrödinger (NLS) equation. In the following we describe a few highlights were there is a tight interaction or collaboration between mathematicians and physicists, and thus which benefitted most from the existence of the CEMPI project, or will benefit from it in the near future.

The following constitute the four main advances obtained in 2012-2013. First, we have made a study of the effect of nonlinearity on the Anderson transition ("metal-isolator transition") and on localization due to disorder, with views on their application to the experimental observation of such phenomena with cold and ultra-cold atoms. Second, we have opened a new activity concerning the early stage of the formation of rogue waves (waves of abnormal amplitude) in highly dissipative systems (a fiber cavity). We have proposed (in collaboration with our Belgian CEMPI partners from Photonics@Be), a complete analytical, numerical, and experimental characterization of nonlinear symmetry breaking induced by broken reflection symmetry in an optical fiber system. Third, we have evidenced original optical properties of optical fibers such as the generation of new frequencies for four-wave mixing in fibers having a controlled modulation of their diameter along their axis. An analytical model of the parametric gain in the presence of this modulation is developed. Such a study could lead to the design of suitable fibers for frequency conversion, the generation of ultrafast pulses or control shift soliton trains. Finally, a new second order numerical scheme which is asymptotics preserving was proposed for the linear and nonlinear Schrödinger equation, based on a phase/amplitude representation that yields a system similar to the hydro-dynamical formulation, whose novelty consists in including an asymptotically vanishing viscosity.

In 2013-2014 the CEMPI research activity lead to the following main results. In the context of optical nonlinear statistics, two experiments were performed and revealed new phenomena. First, considering an initial field with a Gaussian statistics, we realized a nonlinear optical fiber experiment showing that the probability density of the field fluctuations goes under the normal distribution in a normal dispersion regime (defocusing). Furthermore, this experiment also revealed an unexpectedly intermittent phenomenon already observed in the context of turbulence. The originality of the result lies in the fact that the dynamics underlying the intermittency phenomenon can be of integrable nature. Second, the experiment was extended to anomalous regime where we have evidenced the integrable turbulence phenomena and the formation of rogue waves. This study opens the way for a tight analogy between turbulence in optics and in hydrodynamics.

As highlighted in Section 1, spatial structures forming in relativistic electron bunches have been directly observed.

For cold atoms systems the work in this period concentrated on the theoretical and numerical basis underlying the K-BEC project, funded by the ANR and by CEMPI. This project will lead to the development of an experimental setup for Bose-Einstein condensation of potassium atoms, allowing the study of the Anderson transition in the presence of interactions. We already mentioned above the theoretical study based on the self-consistent theory that allowed us to show that the localized phase of the transition is replaced, in the presence of interactions, by a sub-diffusive phase. We also used the Bogoliubov technique to study the stability of a condensate subjected to quasi-periodic pulses of a standing wave. This allowed us to show that the condensate survives to these pulses for times comparable to experimental time scales. A PhD student, co-directed by J.C. Garreau (PhLAM) and S. De Bièvre (Painlevé) has started his doctoral work on these topics in September 2014.

In the second half of 2014, the Photonics group and the ANEDP team of Painlevé have initiated a collaboration on Modulational Instability (MI) in dispersion oscillating fibers. Stefano Trillo (University of Ferrara) joined this collaboration when he visited CEMPI as Invited Professor during the month of October 2014. The first problem addressed was the study of the "linear" stage of MI in a microstructured fiber with a very rapidly varying dispersion, mimicking a train of Dirac delta peaks. The study concentrates on the normal group velocity dispersion regime, where standard MI cannot take place. The interest in the study of such fibers is further enhanced by the similarity of the system to a nonlinear version of the Quantum Kicked Rotor, a representative model for the study of quantum chaos, and intensely studied in the cold atoms group of the PhLAM. It is the triple interaction between the ANEDP team of Painlevé and the two teams of PhLAM inside the CEMPI discussion groups that led to the identification of the problem. The team of Painlevé performed a stability analysis the results of which were confirmed experimentally in a fiber realized and characterized at the drawing tower of IRCICA. A publication on this work is currently in preparation and will be submitted to Physical Review A shortly. The second task in this program – now under way - is the study and experimental realization of the nonlinear development of MI in dispersion oscillating fibers.

The PDE specialists of CEMPI have made progress on problems in quantum chaos and in the nonlinear dynamics of various nonlinear PDE's of mathematical physics such as the Navier-Stokes, Euler and Ginsburg-Landau equations. A representative sample of their results follows. G. Rivière (Painlevé) has described some asymptotic properties of stationary solutions of the damped wave equation on a compact manifold, and deduced geometric criteria to have a subexponential decay of the energy. The strategy consists in translating the question into a semiclassical problem for nonselfadjoint Schrödinger operators to which techniques recently developed for the study of quantum chaos can be applied. André de Laire (Painlevé) has, with his collaborators, considered solitons for the Landau-Lifshitz equation, a model describing the dynamics for the spin in ferromagnetic materials. He has studied properties such as regularity and asymptotic behavior at infinity of solitons. In the one-dimensional case, he has proved the orbital stability in the energy space for chains of solitons. S. De Bièvre, S. Rota Nodari (CEMPI postdoc 2013-2015) and F. Genoud (CEMPI visitor, September 2013) have explained the geometry underlying the so-called energy-momentum method for proving orbital stability in infinite dimensional Hamiltonian systems. Applications include the orbital stability of solitons of the NLS and Manakov equations. This work is to appear as a chapter (120p) in the first volume of the CEMPI Lecture Notes in Mathematics.

Focus area 1, Theme 2: Algebraic geometry, modular forms, with applications to physics. In 2012-2014, new results were obtained in algebraic and analytic number theory, in Galois theory, in algebraic geometry and in the theory of automorphic forms. We highlight some of the most important ones below. R. Cluckers and J. Nicaise (with F. Loeser) reduced a conjecture of Chai on the additivity of the base change conductor for semiabelian varieties over a discretely valued field to a Fubini property for the dimensions of certain motivic integrals. Cluckers, jointly with Gordon and Halupczok,

obtained several new transfer principles in the context of motivic integrals. They applied these principles to answer positively the question raised in the seventies about the (large) positive characteristic case of local integrability for Harish-Chandra characters. P. Dèbes showed that for a large class of finite groups, the number of Galois extensions over rationals with discriminant smaller than y grows like a power of y, for some specific exponent. This result is a step toward the Malle conjecture on the number of Galois extensions of given group and bounded discriminant. M. Dimitrov obtained strong results on the automorphic symbols, the p-adic L-functions and the p-adically completed cohomology of a Hilbert modular variety and he constructed p-adic L-func-tions for Hida families of Hilbert automorphic forms in universal deformation rings of Galois representations. New reflective modular forms on orthogonal groups appearing in quantum gravity, were constructed by V. Gritsenko and F. Cléry. Gritsenko (with K. Hulek) found a new geometric application of strongly reflective modular forms: a criterion for uniruledness of modular varieties of orthogonal type. Together with C. Poor and D. Yuen, he proved also an unexpected theorem on the holomorphic theta-blocks which gives a very powerful algorithm for construction holomorphic Borcherds products. D. Markushevich, jointly with U. Bruzzo and A. Tikhomirov, constructed an algebro-geometric partial Donaldson-Uhlenbeck compactification of the moduli space of framed sheaves over an algebraic surface. The same authors proved the irreducibility of the moduli space of tame sympelctic instantons of higher rank over the projective 3-space. Jointly with M. Jardim and Tikhomirov, he constructed new boundary divisors in the Gieseker compactification of the rank 2 instantons on the projective 3-space. O. Ramaré obtained results on quantitative equivalences of asymptotics for some summatory functions and an explicit density estimates for Dirichlet L-series. Techniques range from a new stream of identities, Mellin transforms of powers of the fractional part, a new way to handle coprimality conditions to large sieve bounds for Dirichlet polynomials. Results on the quantum limits of scattering states for the modular surface were obtained by N. Raulf with Y. Petridis and M. Risager. They also studied quantum unique ergodicity for Eisenstein series of half-integral weight.
Applications to theoretical computer science. The studies of effective algebraic geometry are exploited in theoretical computer science and in discrete mathematics. D. Grigoriev worked on tropical linear systems and proposed an algorithm that detects their solvability and an isomorphism in polynomial time in the size of the system and in the coefficients. His works on algorithms in tropical algebra find numerous applications to computer science, cryptography and further, to model reduction of dynamical systems produced by biochemical reactions. In particular, applications to solving systems of algebraic equations in Newton-Puiseux series, or more recent applications of tropical linear systems to train schedule composing.

Focus area 1, Theme 3: Operator algebras, operator spaces and quantum groups with applications to physics. The research advances of CEMPI in 2012-14 related to Focus Area 1, Theme 3 range from operator algebras and operator spaces (M. Neufang) to operator theory (C. Badea, E. Fricain, M. Mbekhta), classical and abstract harmonic analysis (E. Fricain, S. Grivaux, M. Neufang, H. Queffélec), as well as dynamical systems and ergodic theory (S. Grivaux, M. Neufang), with various applications to physics.

Scientific events in connection with this Theme include the Workshop *Operator algebras, harmonic analysis and quantum groups*, held in September 2012 as part of the CEMPI Inaugural Conference. Over and above the scientific exchange with visitors through an international conference, the Working Group *Operator algebras and quantum physics* has been formed, and has held a series of working seminars which bring together mathematicians studying operator algebras and harmonic analysis from Painlevé with physicists from PhLAM who are experts in quantum mechanics. Moreover, CEMPI researchers related to this area have been heavily involved in scientific activities with the Fields Institute, a CEMPI partner, such as the six-month Fields Thematic Program in *Abstract harmonic* *analysis, Banach and operator algebras*, held January-June, 2014 at the Institute. The Painlevé-CEMPI-PhLAM thematic semester 2015, now under way, is centered on this and related areas.

As an example of an area where several of the above fields interact in a mutually fruitful fashion, we cite the current rapid development of Fourier analysis on locally compact quantum groups. Particular themes of study are algebras of completely bounded multipliers, random walks on quantum groups, and non-commutative Poisson boundaries. This leads to intriguing synergies with Theme 2 of CEMPI's Focus Area 3, *Graphs and groups* (C. Drutu): indeed, "geometric quantum group theory" is presently being developed, which includes the investigation of quantum group versions of concepts such as the Haagerup property and the approximation property (as introduced and studied in this setting by Hu-Neufang-Ruan).

CEMPI researchers have also discovered fascinating connections between non-commutative harmonic analysis and quantum information theory. In particular, M. Neufang and his Ph.D. student J. Crann have used tools from operator algebra and operator space theory to generate two 'dual' classes of quantum channels associated with any locally compact quantum group. This has in particular allowed them to provide a new class of counter-examples to the Asymptotic Quantum Birkhoff Conjecture, first disproved by Haagerup-Musat (and, independently, Ostrev-Oza-Shor) in 2011.

The team in operator theory and functional analysis working in Lille obtained several important results on linear dynamical systems. In particular, S. Grivaux and E. Matheron showed that any frequently hypercyclic operator T acting on a reflexive Banach space admits an invariant probability measure with full support, which may be required to vanish on the set of all periodic vectors for the operator T. A further nice result is obtained by C. Badea and M. Crouzeix on the numerical radius. If T is an operator acting on a Hilbert space H, a well-known result of Stampfli says that if T is invertible and the numerical radius of T and its inverse are less than 1, then T is unitary. C. Badea and M. Crouzeix proved an interesting generalization: if the numerical radius of T and its inverse are less than 1+epsilon, for some epsilon>0, then the distance of T to the unitary operators is (up to a constant) less than epsilon^{1/4}. Note that the constant ¼ is optimal.

In the context of canonical models in quantum scattering theory, L. de Branges and J. Rovnyak introduced in 1966 a new class of reproducing kernel Hilbert spaces, called now the de Branges—Rovnyak spaces. E. Fricain, in collaboration with J. Mashreghi, has recently written a book on these spaces, which will be published by the London Mathematical Society.

FOCUS AREA 2. THE INTERFACE OF PHYSICS AND BIOLOGY The "Physics and Mathematics for Biology" axis aims at developing quantitative and integrative approaches to understand the dynamics of molecular interactions underlying biological functions. We use tools and methods from physics (essentially optics, atomic and molecular physics, and nonlinear dynamics) and mathematics (essentially probability and statistics) to decipher the design principles operating in regulation networks governing cell decisions and cell fate as well as in signaling pathways conveying and processing biological information, and especially mechanisms using dynamical processes. To this aim, we combine imaging techniques in real time in living cells with mathematical modeling of the time evolution of cellular state (gene activity, protein concentration,...). Mathematical modeling is either data-driven to uncover the molecular network at play in a specific biological system and analyze its dynamics, or considers minimal models designed to capture general biological principles. We have developed long-standing collaborations with biologists but also carry out investigations on cells cultured in PhLAM. Mathematical modeling is essential to understand the dynamics of biological regulation networks since mere intuition cannot predict the combined effect of multiple entangled feedback loops, and thus brings truly new approaches to the life sciences.

Since the start of the CEMPI project in 2012, substantial effort has been devoted to the study of two biological functions: the circadian clock, which keeps time in living systems, and the response to stress (oxidative, thermal or both), which controls cell fate in adverse conditions. We had obtained previously important results on these two subjects, accompanied by press releases from CNRS. Specifically, we had shown on the one hand that the microscopic green alga Ostreococcus tauri exploits generic properties of nonlinear oscillators to shield its biological clock from fluctuations in daylight intensity, and the other hand that cell death can be induced by illuminating them with laser radiation at 1270 nm, without requiring a photosensitizer, plausibly by triggering responses to oxidative stress.

Since then, a model of Ostreococcus clock incorporating putative green-sensing and blue-sensing photoreceptors has been built. This model may help to understand how the algal clock can function both in the open sea and in coastal waters, with different light qualities, in changing environmental conditions. A new collaboration has been initiated in 2012 with a leading research center on diabetes and cardio-vascular diseases at Institut Pasteur de Lille (LABEX EGID). It aims at understanding how the mammalian circadian clock and metabolism influence each other, and how disruption of one or the other perturbs the other one. A first mathematical model describing how feeding/fasting entrains the liver clock has been built, with excellent agreement with the data. As for the stress project, a set of innovative physical, optical and chemical tools have been built both to induce oxidative and thermal stresses in living cells with high spatio-temporal resolution, and to allow a precise quantification of the cellular response. This includes tracking the kinetics of reactive oxygen species and of molecular actors related to cellular redox state, as well as gene induction under thermal stress. An important question is to understand how the metabolic state of the cell influences its susceptibility to oxidative stress, with an important synergy with the clock and metabolism project. This synergy will be reinforced in 2015 by the arrival at PhLAM of a biophotonics team, who has developed novel approaches to extract more precise and reliable information from Fluorescence Lifetime Imaging Microscopy (FLIM) and Förster Resonance Energy Transfer (FRET) images, used to quantify protein-protein interactions in living cells.

Together with this biophotonics team, mathematicians from the Painlevé laboratory have developed sophisticated methods based on the transportation distance between two statistical distribution to analyze FLIM and FRET experiments, illustrating the benefits of the interaction between mathematics and physics. The same mathematicians are also using their expertise in probability theory to study random walks performed by proteins inside the cellular environment, in connection with questions such as anomalous diffusion. This overlaps considerably with studies of gene activation carried out at PhLAM and suggest another new interaction between the two laboratories. Other colleagues from the Painlevé laboratory have developed approaches to characterize graphs, representing for example protein-protein interaction networks, to identify clusters of highly connected actors, or to quantify network similarity.

On the theoretical physics side, mathematical models have been used to clarify fundamental aspects of the cellular dynamics. Models of stem cell differentiation have been developed and their theoretical and computational analysis has shed light on sophisticated mechanisms of decision making. In particular, a theoretical study of the coordination of neural progenitor self-renewal and differentation through oscillating dynamics has been published in the well-established biology journal Development. Theoretical models of the cellular response to thermal stress have been compared with experimental measurements. We have also shown how fluctuations may induce relatively regular oscillations in a self-repressing gene using a moment-closure approximation of the chemical master equation that allowed us to incorporate fluctuations in the dynamics.

We are currently establishing collaborations with colleagues developing therapeutic approaches for diabetes and cancer, including the already existing connections. This strategy is pursued inside a larger consortium associating, besides the CEMPI members, local experts in microfluidics, nanochemistry, acoustics and molecular biophysics from the Institute of Electronics and Nanotechnology of our university, bringing together a wide set of complementary expertises at the interface between physics, mathematics and biology (http://nonlineaire.univ-lille1.fr/AIVBS/). This initiative occurs at an opportune time, since it brings together teams from Lille 1 (Science and Technology) and Lille 2 (Law and Medicine) in a context where the three universities in Lille have decided to merge before 2018. As an example of our ability to merge efficiently competences for observing, modelling and manipulating biological systems, several groups from this consortium are involved in an ERC consolidator grant obtained recently by Kevin Braeckmans, member of the Nano-Bio Photonics consortium at Ghent University.

FOCUS AREA 3. THE INTERFACE OF MATHEMATICS AND THEORETICAL COMPUTER SCIENCE This focus area explores various problems at the meeting point between theoretical computer science and pure mathematics, in particular algebraic topology and the geometry of graphs and groups.

Focus area 3, Theme 1: Algebraic topology, with applications to theoretical computer science. The research carried out in algebraic topology in the CEMPI project, in 2012-2014, has mostly concerned the mathematical facets of the proposal : the theory of operads, of rational homotopy theory, and the applications of algebraic topology to the study of manifolds. The team has been strengthened by the arrival of two new permanent faculty members who have enlarged our expertise in several domains of algebraic topology, namely : quantum topology ; the interplay between algebraic topology, K-theory and C*-algebras (this topic is also related to the subject of Theme 3, Focus Area 1).

A first significant advance, which we would like to emphasize in this report, is the homotopy counterpart of the intersection cohomology theory discovered by Chataur-Saralegi-Tanré. In summary, they use a simplicial blow-up to define a filtered cochain complex that gives the intersection cohomology for every perversity. They observe afterwards that they get a poset when they take all perversities together. They associate a minimal model and Steenrod squares to this poset. They prove, as a first main outcome of their theory, that these Steenrod squares can be used to work out a conjecture of Goresky and Pardon about the definition of Wu classes in intersection cohomology.

Another significant advance is a generalization, in the equivariant framework, of the classical Lefschetz-Hopf fixed point formula (Dell'Ambrogio, joint work with H. Emerson, at U. of Victoria, and R. Meyer at U. of Göttingen). To be specific, we assume that $f: X \to X$ is a smooth equivariant map on a smooth compact G-manifold X (where G is a compact Lie group). The formula obtained gives an identity between two G-homotopical invariants of f : on the one hand, an analytical index, given by local and geometric information ; on the other hand, a homological invariant, which is expressed in terms of equivariant topological K-theory. The proof is carried out in the framework of Kasparov's KK-theory, and the obtained formula is actually valid for « geometrical correspondences », which are defined as elements of Kasparov G-equivariant groups $KK^G(C(X),C(X))$.

The advances made in operad theory include : a homotopy invariance result for bialgebras over PROPs that provides a wide extension of the classical homotopy theory of algebras to structures governed by bialgebras (Lie bialgebras, Hopf algebras, …) ; and some work is in preparation on the intrinsic formality of E_n-operads. In quantum topology, our main advances concern the effective definition of homotopical field theories (a homotopical version of the classical topological field theories introduced by Virelizier and Turaev in their work on quantum invariants of manifolds).

Focus area 3, Theme 2: Graphs and groups, with applications to theoretical computer science. This theme is mainly concerned with the recent trend in mathematical research, of constructing ``discrete'' versions of existing theories coming from analysis and differential geometry, of applying

them to (large scale) studies of graphs and groups, to algorithm design etc. Within it, the study of actions of groups (discrete or unimodular) on manifolds or more general compact spaces are particularly significant. Among the advances made in these directions are the following.
-M. Bourdon, jointly with B. Kleiner, proved the Cannon Conjecture for Coxeter groups, and obtained a wealth of relevant information on the boundaries of Gromov hyperbolic groups.
-L. Flaminio obtained, in a joint work with G. Forni, a polynomial control on the speed of equi-distribution of generic orbits of nilflows on certain nilmanifolds.
-F. Gueritaud and collaborators described decompositions into ideal polyhedra of certain cusped, finite-volume hyperbolic 3-manifolds. They provided explicit positive angle structures, and lower bound estimates, for veering triangulations (a notion introduced by I. Agol).
-F. Kassel studied deformations of compact Clifford-Klein forms and proved that they have entire ``neighborhoods" of Clifford-Klein forms, in rank one. In joint work with T. Kobayashi, she studied the nature and behavior under small deformations of the spectrum, and of the eigenfunctions, for Clifford-Klein forms of reductive symmetric spaces, and for anti-de Sitter manifolds.
-F. Kassel, F. Gueritaud and collaborators generalized two-dimensional results and constructions of Thurston and extended his asymmetric metric on Teichm\"uller space to a geometrically finite setting and to higher dimensions. They also proved that every non-abelian, non-Fuchsian representation of a surface group into PSL(2,R) is the holonomy of a folded hyperbolic structure on the surface; they also compared non-Fuchsian representations and Fuchsian representations in terms of hyperbolic translation lengths. They proved that certain proper, isometric actions of non-solvable discrete groups on the 3-dimensional Minkowski space can only be realized by a deformation of the quotient surface that everywhere contracts distances at a uniform rate.
-I. Liousse, in collaboration with N. Guelman, studied the dynamics of actions of discrete solvable Baumslag-Solitar groups on surfaces. They also proved finiteness of torsion groups acting on orientable compact surfaces other than the torus.
-In a joint paper with T. Delzant, L. Potyagailo compared the volume of a hyperbolic three-dimensional manifold and the complexity of its fundamental group. In particular, he obtained a generalization of the Cooper inequality.
-The systematic investigation of analytical properties of direct limits of hyperbolic groups was continued by C. Drutu and collaborators, focusing on the much larger class of graphical small cancelation groups. In collaboration with P. Nowak, C Drutu also provided a new definition of property (T), adapted both for the classical and for the Banach space version. In particular, this yields the most consistent Banach definition of property (tau) and of expander graphs. The book written by C. Drutu in collaboration with M. Kapovich, which covers most of the topics within this theme, is about to appear in the series Colloquium Publications, of the American Mathematical Society Publishing House.

THEMATIC SEMESTERS. As foreseen in the original project, the CEMPI organises every year a thematic semester centered on one of the CEMPI research focus areas or themes. These Painlevé-CEMPI-PhLAM semesters play an important role in the realization of the CEMPI project and in the development of its visibility. They take place principally between January and July, but some activities may also extend into the fall. A typical semester is composed of two to four major international conferences, and a number of smaller workshops or meetings, as well as short, intensive post-graduate courses. The activities of the semesters are funded for about 40% by CEMPI, with the rest of the financing coming from other sources: the recurrent funding of the partner laboratories, the ANR projects of the organizers, FEDER funding, etc. In addition, the hiring of CEMPI postdocs and invited scholars is each year coordinated with the theme of that year’s semester. The semesters are publicized through the usual channels. About 150 posters are sent to institutions in France and abroad, and publicity is made through our partnership with the Fields Institute, described below. The themes addressed in the successive semesters that have already taken place or are in the planning stage are the following[1]

2013 Focus area 1. Theme 1. Complex optical and atomic systems.
2014 Focus area 1. Theme 2. Algebraic geometry, modular forms, with applications to physics.
2015 Focus area 1. Theme 3. Operator algebras and spaces, with applications to physics.
2016 Focus area 2. The interface of physics and biology.

Note that the 2016 semester will, like the one of 2013, involve teams of both the PhLAM and Painlevé laboratories, and in particular the probabilists from the latter.

OTHER SCIENTIFIC EVENTS

-The CEMPI researchers have organised or co-organised a considerable number of conferences outside the framework of the semesters , in Lille and elsewhere[2]

-In addition, to foster interactions between the two partner laboratories, which is an important goal pursued by the CEMPI project, three discussion groups were set up in the initial phase of the project. We refer to the CEMPI webpage for their program. During the first meetings of these groups, members of both laboratories explained their research work and interests to both communities. In further meetings, invited speakers gave seminars accessible to the same large audience. It is our distinct impression that this procedure has been very beneficial to all. As a first example, the common research described below between the Photonics group of the PhLAM and the ANEDP team of Painlevé emerged directly out of the discussions in the meetings of the discussion group ``Nonlinear dynamics in complex systems.''

-Furthermore, physicists and mathematicians involved in the "Physics and Mathematics for Biology" axis of CEMPI, have organized a common working group together with colleagues from the local Institute of Electronics and Nanotechnology, building together a consortium named "Interdisciplinary Approaches of Living Systems for Biology and Health". The consortium meets each week, with club journals and internal seminars alternating every other week, in addition to seminars by external speakers, twice a month (http://nonlineaire.univ-lille1.fr/AIVBS/). This allows the consortium members to better know each other and also to share their knowledge of biological facts.

-The first lecture in the CEMPI Distinguished Lecture Series took place in October 2014. The format we retained for this series is the following. We plan to invite, once or twice a year, a colleague to join CEMPI for a one-week stay, during which he/she participates in one of the conferences organized by CEMPI, and gives in addition a colloquium style lecture accessible to a larger audience.

B) Human resources

The Labex CEMPI enjoys the support of the Université Lille 1 also through its hiring policy. An administrative assistant (A. Henry) was hired by the University on a permanent position to help the coordinator. At the Laboratoire Paul Painlevé, one full professor (A. Virelizier, Topological quantum field theory, September 2013) and one assistant professor (A. Delaire, nonlinear PDE, September 2013) were hired on CEMPI themes. At PhLAM, one assistant professor (F. Anquez, biophotonics) was hired in 2013 and one assistant professor (A. Mussot, nonlinear photonics) was promoted to full professor the same year. M. Conforti, a post-doctoral physicist involved in a Painlevé-PhLAM collaboration, was

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[1] The programs of the 2013, 2014, and 2015 semesters are available on the CEMPI website.

[2] The complete list can be consulted on the CEMPI webpage.

ranked first in the first and most selective stage ("jury d'admissibilité") of the contest for a permanent researcher position at CNRS. He is thus very likely to become a CNRS fellow in September 2015. The fact that his expertise could benefit several teams involved in the CEMPI project and his ability to exchange with mathematicians appears to have been an important point of his application.

C) Financial resources, leverage effect

We present here first a brief synthetic overview of the CEMPI budget itself. CEMPI has been awarded a total budget of 5M euros for the duration of the contract, which runs for 7 years and 10 months (2012-2019). This amounts to 600 000 euros per year on average, to which 200 000 euros in overhead must be added.

Annual distribution of the budget :
Among the 2 partner laboratories: 400keuros Painlevé, 200keuros PhLAM.
Among the 3 principal budget lines:

Salaries :	65%	390 keuros	(invited scholars ; Postdoc, PhD and master fellowships
Equipment :	20%	120 keuros	
Operating costs :	15%	90 kEuros	

After roughly three years of effective operation (since September 2012), CEMPI has used the following sums :

Salaries:	785 keuros
Equipment:	430 keuros
Operating costs:	225 keuros
TOTAL:	1 440 keuros

One observes an efficient start in the use of the funding, largely respecting the balance between the different budget lines in the original project. There is only a small apparent delay in the use of the total budget in comparison to what could be expected based on an average annual budget of 600 keuros, which would correspond to 1 500 keuros over two and a half years. This is a transient effect explained by the following observation concerning the salary part of the budget. It proved impossible to recruit postdoctoral researchers and invited scholars in 2012, because of the extremely short time between the arrival of the first funding in May 2012 and the start of the academic year 2012-2013. We expect this delay in spending to be entirely absorbed by the end of 2016. As an example, the contract foresees a total of 12 years of postdoctoral fellowships. CEMPI has recruited 2 postdocs in September 2013 and 3 in September 2014. We expect to recruit again at least three 4 in September 2015 on the CEMPI budget. This will mean that, halfway through the CEMPI contract, after four years of operation, in summer 2016, we will have used 75% of CEMPI's postdoctoral positions.

It is expected of the ``Laboratoires d'Excellence'' in general and therefore of CEMPI in particular that they show a capacity for attracting additional budgets to complete the funding obtained from the ANR. The following is a list of the main such funds obtained by CEMPI in 2012-2014.

-FEDER (European funds: 2013-2015) CEMPI: 500keuros
-R. Cluckers (Painlevé) obtained an ERC Consolidator Grant (MOTMELSUM: 2014-2019): 1 Meuros
-V. Gritsenko was appointed senior member of the Institut Universitaire de France (october 2013-october 2018). 75keuros.
-M. Conforti, who joined CEMPI as a postdoc in the photonics team of the PhLAM, in Januari 2014, obtained a three year fellowship from the ANR for his NoAwe project. 460 K€
-About 6M euros of additional funding has so far been obtained in tight coordination by the Labex

CEMPI and the Equipex FLUX for the period 2014-2018, from a variety of industrial and public sources, among which the ANR, to develop their research and technology transfer projects.
-A further 400keuros in ANR funding was obtained for CEMPI-related research at Painlevé.
-The Université Lille 1 supported CEMPI through its Bonus Qualité Programme, and via PhD funding.

Substantial funding will also be obtained in the context of the CPER projet Photonics4Society, already mentioned and further described below.

D) Labex Impact on its ecosystem policy

In 2008, the University Lille 1 had been reorganized around thematic sectors such as Environment, Biology and Biotechnologies, Material Science, and disciplinary sectors such as Mathematics and Physics sectors, essentially including the Painlevé and PhLAM laboratories, respectively. The latter were thus relatively isolated. Since the start of the CEMPI project, "Mathematics, Physics and their interactions" has been identified and presented by the University as a research area of excellence, considerably strengthening the two laboratories. Naturally, this theme will also a research priority within the framework of the future Université de Lille that is to be created in 2018 at the latest by merging the three universities in Lille (Science and Technology, Law and Health, Human and Social Sciences). Accordingly, CEMPI has actively participated in the elaboration of the IDEX (Initiative d'Excellence) project (2016-2025) that the three united universities of Lille, together with the CNRS, INRIA and INSERM, have recently deposited in the context of the PIA.

CEMPI has worked together with LABEX CaPPA (Chemical and Physical Properties of the Atmosphere), which is the other LABEX coordinated within Lille 1, to establish a system of grants of excellence aimed at students coming to Lille to follow Master studies. The applicants to both LABEX masters are validated together by the board of the University.

Together with CEMPI, the EQUIPEX FLUX was funded in 2012 to develop optical fibers carrying very high light intensity, harnessing the oustanding optical fiber fabrication facility in Lille. Since then, the two projects have worked in close coordination to strenghten mutually. There is more emphasis on basic research and human potential on the CEMPI side, and on equipment and technology on the FLUX side, however the two projects make together a continuum. This continuum forms the basis on which the "Photonics4Society" CPER (Contrat de Plan Etat Région) project was built. It was announced in March that this CPER project will receive 5M€ from the government and the Region, with total budget of 12 M€ including funding from the European Regional Development Fund. This success, which relied importantly on the labeling of CEMPI and FLUX, further reinforces the impact of CEMPI on the regional and national ecosystems.

The "Photonics4Society" project puts emphasis not only on optical fiber technology but also on using biophotonics and microscopy for the life sciences and to develop a high-level infrastructure in this area, in close collaboration with research themes of the "Physics and Mathematics for Biology" CEMPI focus area. The latter currently develops a strategy of building long-term partnerships with biologists, medical doctors and pharmacologists and also with colleagues bringing complementary expertises from the physical and engineering sciences. In this context, a long-term collaboration has been initiated two years ago with LABEX EGID (European Genomics Institute for Diabetes), with a joint PhD between Institut Pasteur de Lille and PhLAM. Also the "Photonics4Societey" CPER project teams CEMPI members with colleagues from IEMN, one of the 5 large nanotechnology centers in France, who are experts in microfluidics and nanochemistry.

CEMPI has co-financed a study on the impact of mathematics on the GNP of France (EISEM), which was ordered by the network LABEX AMIES. The results of the study will be made available publicly in the coming months. It is expected that the study will help publicize the importance and impact of mathematics in the direction of local, national and international funding agencies.

Finally, the increased interactions between mathematicians and physicists have been beneficial in several other ways, such as working together to promote their common views on the requirements of the curriculums in the first years at the University.

3/ SOCIO-ECONOMIC IMPACT

3.1 Partnerhips with social and economic actors

A major effort is made to increase the economic impact and transfer of knowledge / skills within companies and manufacturers. During the 2013-2014 year, workshops were organized to demonstrate all the potentiality of the Labex Cempi / Equipex FLUX. The topics are deliberately focused on industrial concerns. These workshops are conducted by invitation to reduce the dissemination of information on competing manufacturers. Here are 3 examples of workshops in 2014: High power fibre laser, Specialty optical fibres: from the realization to the innovative applications, Discovery and awareness of the FTTH.

Efforts were made also for the creation of common laboratories; it is a good step forwards the knowledge transfers and increases of the partner ships with the industrial actors. Two common laboratories were involved in the Labex Cempi/Equipex Flux.

Common Laboratory with Prysmian: In recent years, the company Draka - Prysmian Group (world leader in optical cables) has gradually transferred part of its R & D activity in the Nord - Pas de Calais in one of its production plant in Billy Berclau. The two parties considered that many of their research activities were complementary and it would be beneficial synergies on few specific axes by merging the technical know-how or the facilities of both parties. This led to the creation and implementation of a joint laboratory as part of a technical program for the design, modeling, fabrication and characterization of a new generation of optical fibers. Among the first research areas covered, for example, the use of micro-structured fibers for the production of supercontinuum was successful. Here, the expertise of Draka - Prysmian Group in the realization of highly nonlinear photonic fibers with low losses was combined with the expertise of the group's non-linear photonic sources to achieve the broad bands of very high densities and spectral power. Today, joint research activities focus on the study of loss mechanisms in optical fibers, the impact of OH radicals in hydrogenated atmospheres, slightly multimode or multi-core fibres and inclusions of nanoparticles to modify characteristics of optical amplifiers. A dozen people involved in this joint laboratory in balanced contributions between University / CNRS and Prysmian.

Common laboratory with CEA CESTA: The research laboratory under agreement with CEA DAM Bordeaux (CEA CESTA see: http://www-dam.cea.fr/organisation-competences/cesta.html) has been set up this year. It follows many prior works perform in collaboration with CEA: project under joint partnership in ANR (ANR JCJC FOPAFE) and several contracts to develop power fiber lasers and / or short pulses generators. This work is in the framework of the Megajoule laser project. In our collaboration, the objective is to set up more and more all-fiber- components, more stable and less bulky than solid solutions currently in place. Recent acquisitions in the context of Equipex FLUX allowed to progress significantly on high technology deployed in the central FiberTech of the PhLAM laboratory. The CEA CESTA expertise is in the field of power lasers / short pulse lasers. The complementarity between the skills and expertise is remarkable and has already resulted in several patents and numerous publications. In the future, the objective is to develop efficient power laser systems covering a wide spectrum of applications where the market is booming. Several projects are in discussions with industry especially with the CILAS.

These efforts have strengthened links with industry through research actions supported by contracts (contracts with industry, ANR , FUI, Europeans) as shown in the following list:
Draka/Prysmian, Nord Pas de Calais : Optical fibres for communications
LSO médical, Nord Pas de Calais, Catheters
Mader, Nord Pas de Calais : Diffusion in optical fibres
Indelec, Nord Pas de Calais : lightning and optics (avec le CERLA)
Genes diffusion, Nord Pas de Calais : Biophotonic
Horiba Jobin Yvon, Nord Pas de Calais : Raman endoscopes and filters
MC2, Nord Pas de Calais : TeraHertz Photonic
***Start up** in preparation, Nord Pas de Calais : Linoptics*
CEA CESTA, Région aquitaine: Specialty fibres and lasers
CEA List/ CEA Tech, Ile de France : Bragg Tower
ONERA, Midi Pyrénées: Brillouin effect and specialty optical fibres
Leukos, Limousin: Fibres for supercontinuum
Novae, Limousin: fiber lasers,
Thales, Ile de France: Systèmes de communication : TiFi
Alcatel, Lucent Ile de France: communication slightly multimodes
Cailabs, Pays de la loire: Mux et Demux
Galderma, Provence : endoscopes
Beam, Alsace lorraine: 3D processing and fibres,
CILAS, Région aquitaine: High power lasers and specialty profils
Eolite, Région aquitaine: Specialty optical fibres and lasers
Amplitude systèmes, Région aquitaine: Raman systems;

Finally, the overall sum of contracts and projects with industry reached in 2844 keuros.

3.2 Relationship with the SATT (Societé d'Accelération de Transfert Technologique)

Four patents were taken in the framework of the Labex CEMPI and the Equipex FLUX. One European industrial has shown interested in buying one of the patents. Discussions on the possible sale are in progress with the SATT Nord (Christine Useille, Directrice Nord Pas de Calais, and Alexis Pouille STIC SPI).

3.3 Commercial relations with European public-private partnership research institutes, within the Framework Programmes

The development of commercial relations is not one of the central objectives of the LABEX CEMPI.

3.4 Promotion measures for knowledge dissemination ; schedule, durability of the measures (excluding publications in scientific journals)

CEMPI negociated with Springer the creation of a CEMPI Subseries of LNM/LNP. The contract was signed in 2014. The first volume is to appear in the coming months. The goal is to publish monographs or course notes on various topics of CEMPI research. Several other volumes are in the planning stage.

Free comments

Although we respected the total length of the document, which was not to exceed 22 pages, we did not respect the page limit of only 3 pages in section 1. Indeed, this is the only section where information could be given on the important training aspect of the CEMPI project, and we felt also it was more convenient to link the description of the CEMPI trajectory to a first discussion of the CEMPI added value, which according to the instructions, was supposed to be described in Section 2.