PEPR LUMA: Advancing French Research in Light-Matter Interactions

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Under the "France 2030" investment plan[1], the French government has supported several emerging national research initiatives since 2022 through Priority Research and Equipments Programmes[2] (PEPR, French abbreviation). Launched in 2023 for seven years, the PEPR LUMA 'Harnessing Light-Matter Interactions' (Fig.1),[3] fosters high-level interdisciplinary research in this strategic field. With a national scope, it seeks to coordinate French research efforts on high-impact scientific and socio-economic topics, reinforce national research infrastructures to an international standard, and enhance the visibility of this strategic domain in France.

Figure 1. Banner of the PEPR LUMA website

The PEPR LUMA aims to study, understand, develop, and exploit light as a unique tool to explore and control physicochemical and biological systems at the interfaces between chemistry, physics, engineering, life sciences, health, and environmental sciences. In order to create the conditions for synergy and cross-fertilization to drive new science, the program focuses on three truly interdisciplinary scientific challenges that bring together the above-mentioned disciplines and communities:

- **Smart Photoscience.** This challenge focuses on controlling molecular photoreactivity through 'ultrafast' or 'ultrasmall' instrumentation, enabling the study of complex chemical, physical, and biological dynamics for advanced photoactivation processes. It will provide a promising and attractive playground for scientists and engineers in these disciplines, from both the fundamental and the applicative areas.
- **Photons for Green.** This second interdisciplinary scientific challenge focuses on high-performance green devices for energy and industry. By leveraging the conversion of light energy into chemical energy, LUMA aims to drive new technologies for efficient, clean, and sustainable production.
- **Light for Protection.** The third interdisciplinary scientific challenge focuses on the use of light for health, environment, and natural or cultural heritage. Through the development of advanced light sources and multifunctional photoactive materials, the related research will focus on photoaging effects, photo-cleaning materials, diagnostic tools and photo-medicine.

To kick off this ambitious initiative, PEPR LUMA held its inaugural event on June 6-7, 2024, in Bordeaux (France).[4] The event featured opening remarks by Antoine Petit (CEO, CNRS), François Jacq (CEO, CEA), Dean Lewis (President, University of Bordeaux), and Frédéric Ravel (Scientific Director for Energy and Chemistry, French Ministry of Research). On this occasion, exceptional scientific presentations were given by Maguy Jaber, Professor at Sorbonne University, and Pierre Agostini, Nobel Laureate in Physics in 2023 (replay in French available on the PEPR LUMA YouTube channel).[5] This event reinforced LUMA's core principles, sparked discussions on national research infrastructures and interdisciplinarity, and

introduced upcoming calls for proposals. The two-day event featured engaging lectures, round tables, and poster sessions, fostering collaborations in a dynamic scientific environment. No less than 150 people attended the event on-site, with additional participants online (more than 120).

Figure 2. Pictures of the PEPR LUMA inaugural event, which took place in Bordeaux (France) on June 6-7, 2024.

The research objectives of the PEPR LUMA organize along four thematic axes (Fig. 3):

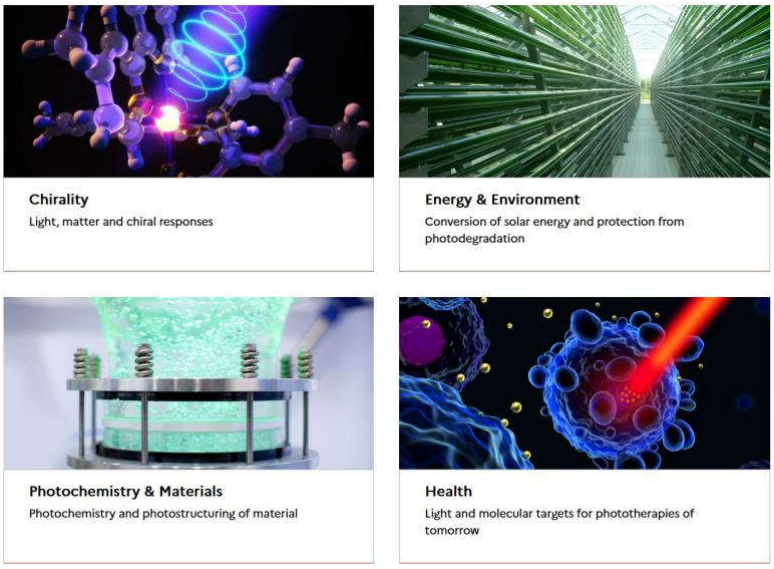


Figure 3. Representation of the four thematic research axes of the PEPR LUMA.

- **Chirality.** It aims to stimulate research on advanced chiroptical spectroscopies to detect subtle changes in biological tissues, chiroptical effects enhanced by chiral nanostructures, spin selectivity induced by chirality, and the generation of exotic chiral light. Through multidisciplinary approaches, researchers will design innovative chiral structures and environmentally friendly materials by controlling the local orientation of light. This axis aims to control the local orientation of light in space and time, which is necessary for the emergence of new ultrafast spectroscopic approaches that will ultimately be used to create unexplored states of matter.
- **Photochemistry & Materials.** Advances in laser sources offer a wide range of wavelengths and temporal dynamics, revolutionizing chemical synthesis and materials production. It is essential to harness and control

the advanced chemical and structural transformations mediated by light, to develop high-level expertise in photochemistry, optics, and materials science. This axis intends to push back the limits of the efficiency of photoreactivity, the spatial resolution of photoproduced structures, and the bottom-up control of optical and mechanical properties of materials, for example, based on nanometer scale photostructuring.

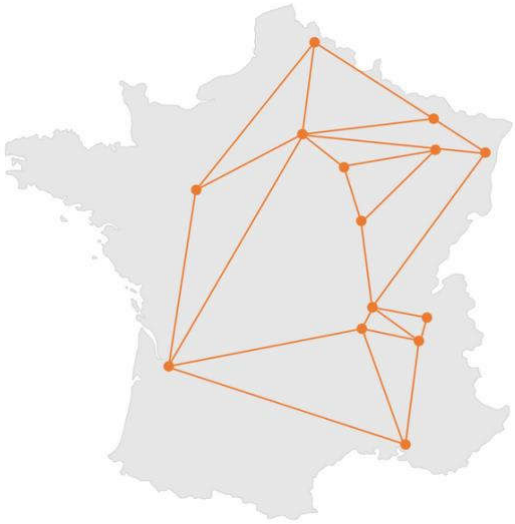
- **Energy & Environment.** Natural photosynthetic systems efficiently convert light energy into chemical energy thanks to a high degree of control over the four key processes involved in photochemistry: it includes initial photon harvesting, light-induced charge separation, efficient capture of relevant abundant substrates, including atmospheric CO_2, and the use of photogenerated charges to drive multi-electronic transformations of these substrates, sometimes in a cascade of catalytic steps. LUMA aims to replicate this organization in artificial photosynthetic hybrid systems, integrating biological, synthetic, and inorganic materials.
- **Health.** Light can detect and heal, but phototherapies presently remain niche treatments. Innovative tools and protocols with optimal spatial and temporal control are needed to improve their efficiency and reduce side effects. The key idea in this area is to effectively combine the design of photo-medicines and the control of ultrafast light beams to achieve real therapeutic breakthroughs. This research axis will require the synthesis of functionalized objects with specific light-induced properties (such as photodynamic therapy effects), the use of suitable light/radiation sources capable of triggering the expected photoinduced processes, and the optimization of effective treatments at the clinical level.

To address these major scientific, technological, and societal challenges, while stimulating the emergence of new scientific knowledge through sharing and exchange within the LUMA community, several large-scale targeted or open actions are being implemented:

- Targeted experiments around instrumental platforms to enable the creation of a national network of top-level platforms (LUMA Infrastructures Hub).
- Targeted thematic research projects, called "Moonshot Projects", with high scientific impact, selected through a call for expressions of interest and covering the four thematic areas of LUMA.
- Calls for projects to complement and further develop thematic research activities, modeling-simulation activities, or joint research activities related to novel instrumentation.
- Scientific animation, communication, and international actions and meetings, to promote discussions, cross-fertilization of methods and practices, specific training of students and scientists, scientific outreach, as well as the initiation of international relations and the promotion of new European networks.

The LUMA Infrastructures Hub consists of platforms distributed throughout France (Fig. 4), accessible to all scientists working on light-matter interactions, to support and promote their research activities. First, LUMA funding has been used to purchase additional equipment to expand the capacity of the platforms. Second, the PEPR LUMA supports collaborative projects of users of the instrumental platforms by covering all costs of user access, following an ongoing assessment of proposals submitted through a dedicated online portal (involving a rigorous evaluation of proposals by external reviewers) to achieve their research goals. International teams can also use the LUMA Infrastructures Hub on a fee-paying basis. However, the associated costs cannot be covered by LUMA. Officially active since February 2024, the Infrastructures Hub includes two networks with 26 platforms (Fig. 4):

- the ULTRAFAST infrastructure, led by Pascal D'Oliveira in Paris-Saclay, brings together 12 laser platforms for ultrafast photoscience and nano-machining;[6]
- the OPERANDO/PROTOTYPING infrastructure, led by Jean-Pierre Simorre in Grenoble, comprises 14 operando and prototyping platforms.[7]



INFRASTRUCTURE
ULTRAFAST

CELIA • Bordeaux
I2BC • Gif-Sur-Yvette
ILM • Lyon
IPCMS • Strasbourg
LIDYL • Saclay
LP3 • Marseille
LabHC • Saint-Etienne
ICB • Dijon
IMMM • Le Mans
L2N • Troyes
LASIRE • Villeneuve d'Ascq
LOB • Palaiseau

INFRASTRUCTURE
OPERANDO/PROTOTYPAGE

IRCELYON • Lyon
SOLEIL • Saint-Aubin
INES • Le-Bourget-du-Lac
LCBM • Grenoble
LAMS • Paris
LASIRE • Villeneuve d'Ascq
SyMMES • Grenoble
ICP • Orsay
IBS • Grenoble
CRAN • Vandoeuvre-lès-Nancy
CRM2 • Vandoeuvre-lès-Nancy
BIP • Marseille
ISM • Talence
LCP-A2MC • Metz

Figure 4. The Infrastructures Hub of the PEPR LUMA is a network of research facilities distributed in France and related to light-matter interactions, with free access to French academic users through a proposal portal.

The four 'Moonshot Projects' involve 7 to 17 research teams from institutions such as the CNRS and CEA, each addressing a core LUMA research axis. They have been selected through a specific process: a brainstorming workshop in September 2023, a call for expressions of interest in November 2023, and an evaluation operated by the ANR (French National Agency) involving a panel of international experts until February 2024. The research activities have started in September 2024 for 4.5 years:

- **TORNADO Project** (led by Valérie Blanchet, Bordeaux & David Hagenmüller, Strasbourg): "Multiscale, multidimensional approach to chiral light-matter interactions for enhanced chiroptical responses".[8]
- **SUNRISE Project** (led by Dario Bassani, Bordeaux & Nathalie Destouches, Saint-Etienne): "Surpassing normal resolution and intrinsic shortcomings of excited states".[9]
- **SYNFLUX-LUMICALS Project** (led by Philipp Gotico, Paris-Saclay & Murielle Chavarot-Kerlidou, Grenoble): "Synchronization of the photon, charge, and molecule flows molecules for optimized conversion of sunlight into fuels and chemicals".[10]
- **PDT-PDAC Project** (led by Céline Frochot, Nancy & Vincent Sol, Limoges): "Photodynamic therapy to meet the challenge of treating pancreatic cancer".[11]

A multi-level governance structure ensures efficient decision-making, management, and oversight. The PEPR LUMA governance includes two Program Directors from the CNRS (represented by Rémi Métivier, CNRS Research Director) and the CEA (represented by Céline Fiorini Debuisschert, CEA Research Director), supported by two Program Managers from the CNRS (Laureen Moreaud) and the CEA (Sarah Garçon). They form the Management Committee, which is complemented by the Steering Committee (composed of representatives from the CNRS, the CEA, and six partner universities), the Executive Committee (composed of the coordinators of the Infrastructures Hub and the Moonshot Projects), and the Scientific Advisory Board (composed of internationally recognized scientists external to the program).

In conclusion, the PEPR LUMA brings together a novel and solid network of research consortia and infrastructures in France related to light-matter interactions, structuring the national scientific landscape. LUMA offers exciting opportunities for collaboration with European research programs and paves the way for major international projects in photochemistry, photophysics and photobiology. All initiatives are welcome, do not hesitate to contact us!

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