Advanced materials

The materials of the future will have to be low cost and low energy consuming, while opening up very broad horizons thanks to their properties and the and the resulting applications.

SOLEIL's Upgrade will be part of the knowledge production chain: laboratories, synthesis platforms, characterization platforms, coupled with artificial intelligence and high-performance computing, which will accelerate the design of materials with innovative functionalities.

MORE COMPACT AND ENERGY-EFFICIENT COMPUTERS

Today, total data storage capacity is between 10 and 50 zettabytes (1021), and this value could double every two years.

For higher data storage density and lower power consumption, new nano-sized magnetic objects, such as single molecular magnets or skyrmions (see back page), could enable the design of high-density information storage media.

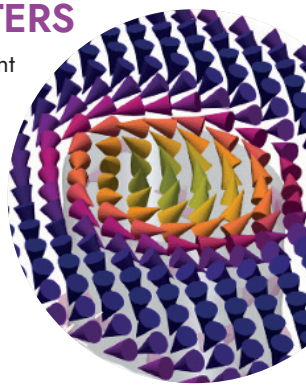
SOLEIL UPGRADE

Extreme brightness + increase in coherent photon flux =

→ Precise understanding of the formation mechanism of quantum materials.

→ Eventually: use of these materials in future technologies: microelectronics responding to new societal challenges, quantum computers...

More information on back page



AFTER MICROELECTRONICS, NANOELECTRONICS?

On the surface of graphene, a so-called 2D material because of its extreme thinness (single layer of carbon atoms), electrons move 150 times faster than in silicon.

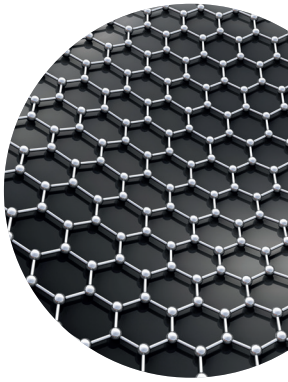
Is it possible to envisage electronics 150 times faster, based on graphene? The problem is that graphene is not a semiconductor, a property that is essential for electronic components. But modifications of graphene, as well as other 2D materials with analogies to graphene, are being studied to meet this challenge.

SOLEIL UPGRADE

Extreme brightness + increased coherent photon flux =

→ Identifying and optimizing materials for a new generation of ultrafast, nano-sized transistors.

→ Opening the way to nanoelectronics.



MADE-TO-MEASURE MATERIALS

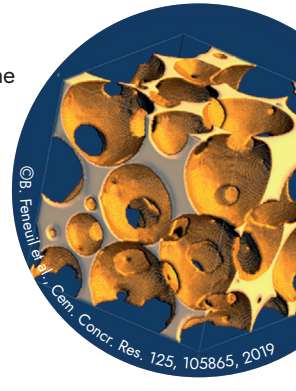
Modifying or adapting the properties of new materials on demand; guiding their synthesis to obtain the desired properties; accelerating and reducing their development costs thanks to artificial intelligence methods will make it possible to design products that meet our needs in many fields: computing, energy conversion, intelligent textiles, construction, transportation, the automotive industry, aeronautics, security, etc.

SOLEIL UPGRADE

Increase in the flux of coherent photons and the focusing of photon beams + Optimized high throughput measurements using automation & artificial intelligence methods =

→ Monitoring the evolution of materials in real operating conditions and over time.

→ Reverse design of materials (materials selected or designed based on expected properties).

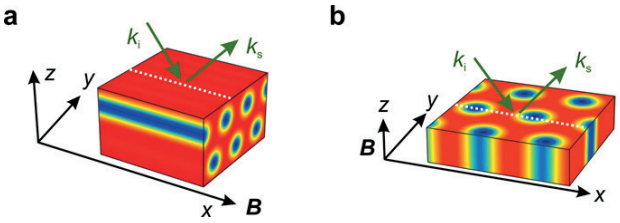


THE COMPUTERS OF THE FUTURE WILL BE FASTER, MORE COMPACT AND LESS ENERGY CONSUMING THANKS TO QUANTUM MATERIALS

Birch et al Nature communications, 11: 1726 (2020)
Zhang et al., Nano Letters 20(2): 1428-1432 (2020)

Artificial intelligence and Big Data require increasing data storage capacity, and computers, data centers and networks swallow up nearly 10% of global power consumption, growing at 5-7% per year. The quest for better information carriers is therefore crucial to slowing this surge. To do this, we try to form bits by manipulating as few atoms as possible.

Skyrmions, first observed in 2009, are vortices of magnetization, and can be formed from the electrons of only a dozen atoms. It takes 100,000 times less electric current density to manipulate them than the magnetized atomic bundles of standard memories. They are also stable to external perturbations (temperature or magnetic field fluctuations), and have a small footprint allowing high storage densities. Skyrmions could therefore be used to build faster, more compact and more economical computers.



a) New state of skyrmions on the surface
b) Conventional state in volume

Current responses from SOLEIL:

A new type of skyrmions has been discovered by elastic X-ray scattering at SOLEIL: surface skyrmions!

They have been observed directly by X-ray microscopy and holography techniques, first in volume (skyrmion tubes) by Birch et al. and then on the surface by Zhang et al. They have a thickness of less than 120nm and thus a very small footprint, an asset for applications in magnetic memories and data storage.

The advantage of X-ray imaging in the study of these systems subjected to a magnetic field is that it allows the determination of the structure of magnetic textures without ambiguity, unlike electron microscopy which is disturbed by the presence of this magnetic field. The spatial resolution of the X-ray holography measurements at SOLEIL is currently less than 20nm.

The possibility to use at SOLEIL several X-ray instruments and techniques, with unique capabilities (brightness, spatial resolution and adjustable X-ray energies) has played an essential role in the success of this project.

UPGRADE OF SOLEIL

Access to several complementary experimental techniques using soft X-rays

\+

Increase of brightness and coherence

=

Unique combination in Europe

The SOLEIL Upgrade will allow a factor >100 increase in brightness and coherence, which will improve by 100 000 the flux efficiency of soft X-ray imaging techniques.

It will then be possible to reach a spatial resolution at the nm scale, and to consider operando imaging of these potential bits of our future computers.

Synchrotron SOLEIL
L'Orme des Merisiers - Départementale 128 - 91190 Saint-Aubin - FRANCE
www.synchrotron-soleil.fr