Scientific Newsletter

SUMMER 2024

At the front page of IRIG

Towards safer UV disinfection with advanced AlGaN semiconductor solutions

Cheap and user-friendly low-pressure mercury lamps, emitting at 254 nm, have played a crucial role in the widespread adoption of UV disinfection technology. However, these lamps present several drawbacks, including a short lifespan, slow switching, and the risk of toxic leaks. The replacement of these lamps with a semiconductor-based technology offers a safer alternative that aligns better with sustainability objectives. Nonetheless, the current performance of AlGaN LEDs, emitting at 270 nm, remains relatively modest, and it gets even worse at shorter wavelengths. In addition to the efficiency issue, LEDs and mercury lamps emitting at 254-270 nm are strongly carcinogenic and cataractogenic.

Eva Monroy | Pheliqs |
Quantum Photonics, Electronics and Engineering Laboratory

In response to these challenges, there has been a recent surge in research for the development of far UV-C sources emitting around 230 nm. This radiation does not penetrate human skin or eyes, making it a safer choice for disinfection in occupied spaces. In this spectral range, an alternative technology to LEDs is electron beam pumped lamps [**1**], where the electrical power is injected into the semiconductor dice through an electron beam emitted by a cathode.

This technology has the advantage of not requiring p-type doping or contacts, making it a promising choice for UV-C lighting. Devices powered by electron beams and using AlGaN as the active material have achieved notable improvements in both efficiency and output power. The integration of AlGaN quantum dots holds great promise for further enhancing the performance of these lamps, thanks to the dots' intrinsically high internal quantum efficiency.

Researchers at IRIG, in collaboration with the Institut Lumière Matière (University of Lyon), CNRS-Institut Néel and CEA-LETI, have successfully demonstrated AlGaN quantum dot structures that can be fine-tuned to emit within the 230-270 nm range by adjusting the growth parameters by molecular beam epitaxy. These quantum dots consistently achieve an internal quantum efficiency of approximately 50% across the entire spectral range, and they exhibit power conversion efficiencies that outperform AlGaN LEDs in the 230 nm spectral window [**2**].

In summary, our research marks a milestone in the development of efficient and safe far UV-C sources for UV disinfection, and provides valuable insights into the potential use of AlGaN-based electron-pumped emitters for this critical application. Our current efforts are concentrated on narrowing the spectral linewidth [**3**] and improving light extraction efficiency. Furthermore, the scientists are actively working on new cathode designs to extend their lifespan and increase their capacity to deliver high current densities, all with the ultimate goal of enabling the production of safe milliwatt-power lamps for UV disinfection.

Project supported by the ANR agency *via* the FUSSL and ASCESE-3D grants.

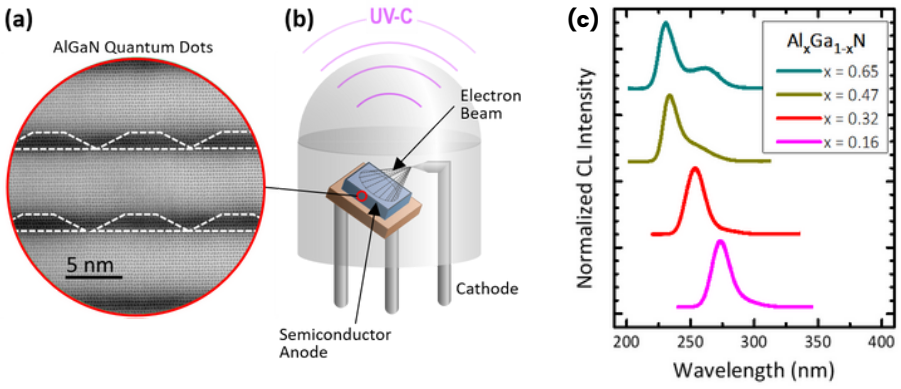


Figure: (a) Bright-field scanning electron microscopy image of two AlGaN quantum dot layers. The quantum dots are closely packed, with a height around 1 nm and a base diameter of 5-7 nm. **(b)** Schematic description of the targeted UV-C lamp, containing the semiconductor dice with AlGaN quantum dots, and the cathode in a vacuum envelop. **(c)** Cathodoluminescence (CL) emission spectra of quantum dot samples with different Al concentration in the dots.

REFERENCES

[1] Cuesta S, Harikumar A and Monroy E.
Electron beam pumped light emitting devices
Journal of Physics D: Applied Physics 2022

[2] Cañas J, Harikumar A, Purcell S T, Rochat N, Grenier A, Jannaud A, Bellet-Amalric E, Donatini and Monroy E.
AlGaN/AlN Stranski-Krastanov quantum dots for highly efficient electron beam pumped emitters: The role of miniaturization and composition to attain far UV-C emission
ACS Photonics 2023

[3] Cañas J, Rochat N, Grenier A, Jannaud A, Saghi Z, Rouvière JL, Bellet-Amalric E, Harikumar A, Bougerol C, Rigutti L and Monroy E.
Effect of extended defects on AlGaN QDs for electron-pumped UV-emitters
ACS Nano 2024

Restricting false discoveries in proteomics and omics biology with rigorous and flexible frameworks

Technological improvements for large-scale molecular characterization of biological samples is a double-edged sword. On the one hand, this reliable and rapid access to thousands of genes, transcripts, proteins or metabolites enable the verification of a considerable number of hypotheses about living organisms. On the other hand, the manifold of hypotheses studied simultaneously increases the risk that one of them is incorrectly validated by chance (a so-called "false discovery"). This increase roots in combinatorics: the probability is low for a random molecule displays measurement fluctuations that match to the expectations induced by the hypothesis studied. However, if several thousand of them are considered simultaneously, the probability that at least one of them behaves accordingly becomes significant.

Thomas Burger | BGE |
Biosciences and Bioengineering for health laboratory

To control for the risk of false discoveries, advanced statistical methods are needed as experimental designs become more and more elaborate. This is particularly the case in **proteomics**, where the complexity of the instrumental set-up (mass spectrometry and liquid chromatography coupling) adds to the small number of samples that it is generally possible to analyze. For years, researchers at IRIG have therefore been working on articulating the experimental constraints and theoretical hypotheses necessary to control for false discoveries, in order to propose data analysis workflows with rigorous quality control properties (*e.g.* www.prostar-proteomics.org). Their recent work has focused on the theory of Knockoffs filters, which has revolutionized the field of **selective inference** by proposing to leverage random draws to better characterize the properties of false discoveries. In particular, they made the link between these filters and the empirical methods for controlling for false discoveries that have historically been used by proteomic researchers, which makes it possible to propose innovative methods [**1, 2**].

ANR fundings

- Multidisciplinary Institute in Artificial Intelligence MIAI @ Grenoble Alpes
- Programme GRAL *via* Chemistry Biology Health Graduate School at University Grenoble Alpes
- ProFI Proteomics French Infrastructure

Proteomics: large-scale characterization (identification and quantification) of proteins present in a biological sample.

Selective inference: a field of high-dimensional statistics, which deals with the generalization of knowledge drawn from experimental data where the data have been previously selected for their specific characteristics.

REFERENCES

[1] Burger T.
Fudging the volcano-plot without dredging the data
Nature Communications 2024
[2] L. Etourneau L and Burger T.
Challenging targets or describing mismatches? A comment on Common Decoy Distribution by Madej et al.
Journal of Proteome Research 2022

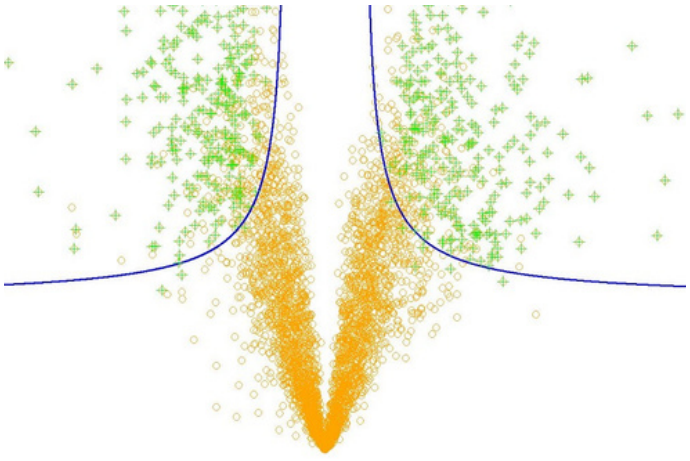


Figure: A typical "volcano-plot", representing the proteins analyzed by orange dots, and which can explain a difference in phenotype (for example healthy or diseased), depending on their significance (on the Y-axis) and the importance of the effect measured (on the X-axis). The most relevant candidate biomarkers are usually located near the top two corners, but some may be located lower in the middle, hereby complicating selection. Knockoff filters make it possible to control for the false discovery rate associated with a selection of proteins (in green) following a more flexible decision boundary, notably hyperbolic (represented here in blue), which allows taking into account both the effect and the significance. © CEA

Characterization of a new plant-specific transcription factor

Living organisms carefully control the activity of their genes. This control is exercised by special proteins, called transcription factors, which bind to specific regions of DNA near the genes they regulate. A few years ago, ALOG proteins were discovered exclusively in plants: they play important roles (in moss, pea, rice or tomato) and are thought to correspond to new transcription factors. It was therefore necessary to conduct research to understand how they work.

François Parcy | LPCV |
Cell & Plant Physiology Laboratory

Researchers at IRIG have studied the ALOGs of the plant model Arabidopsis Thaliana. They were able to identify the DNA motif they recognize and show that it is the same in all land plants. Resolution of the crystallographic structure of the ALOG/DNA complex revealed a new mode of DNA binding (ESRF Grenoble collaboration). In partnership with the University of Milan, scientists have shown that, in Arabidopsis, ALOGs prevent a bract from growing beneath the flowers (a small leaf present in many species).

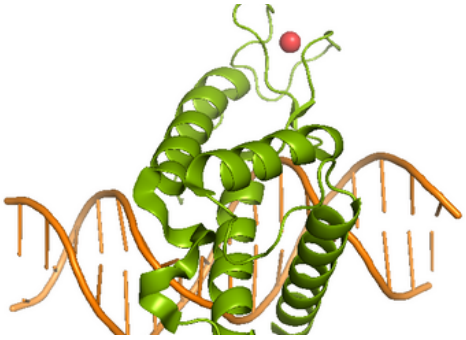


Figure: DNA-binding domain (orange) of the ALOG protein (green). A Zn atom is present (in red). © CEA

The collection of plant transcription factors has been enriched by a new family: the ALOG family [**1,2**]. This biochemical and structural work will serve as the basis for numerous functional studies in rice ears, tomato bunches or air nitrogen fixation in legumes.

These works are supported by Ubiflor ANR project.

REFERENCES

[1] Rieu P, Beretta VM, Caselli F, Thévénon E, Lucas J, Rizk M, Franchini E, Caporali E, Paleni C, Nanao MH, Kater MM, Dumas R, Zubieta C, Parcy F and Gregis V.
The ALOG domain defines a family of plant-specific transcription factors acting during Arabidopsis flower development
Proceedings of the National Academy of Sciences (PNAS) 2024

[2] Blanc-Mathieu R, Dumas R. Turchi L, Lucas J and Parcy F.
Plant-TFClass: a structural classification for plant transcription factors
Trends in Plant Science 2023

THz emission: a tool for studying the spintronic properties of 2D materials

Intense compact THz sources in the microwave to far infrared range are the focus of major research and development. This low-energy, non-ionising radiation has numerous applications in medical imaging, molecule identification and security.

In 2016, a new principle for generating THz waves emerged, based on the ultra-fast conversion of a spin current into a charge current. The resulting THz transmitter, known as "spintronics", is as intense as competing technologies, but has the advantage of being broadband. In scientific terms, it is also a formidable tool for characterizing and quantifying spin-to-charge conversion mechanisms in materials.

Researchers at IRIG [**Collaboration**] have analyzed THz emission according to the nature, symmetry and number of layers in 2D materials.

Matthieu Jamet | Spintec |
Spintronics and Technology of Components laboratory

The structure of 2D materials gives them a number of advantages, including the ability to manufacture ultra-compact devices that are simpler to use than 3D materials (in particular, their ultimate thickness means that they can be shaped very quickly by etching), and requiring less material for more sustainable electronics. Moreover, their high sensitivity to the chemical or electrical environment makes it easy to modulate their electronic properties, such as spin-orbit coupling, the key ingredient of spin-charge interconversion. The fabrication of heterostructures with perfect interfaces by stacking 2D layers with van der Waals type bonds offers an infinite number of combinations of materials to optimize these effects, particularly for THz emission. More generally, the fundamental study of the conversion between spin currents and charge currents in 2D materials is essential before considering their integration into spintronic devices, such as magnetic memories or sensors.

However, there are two obstacles to the development of such THz sources: the manufacture of 2D materials over large surfaces, and the control of the interface between a 2D material and a ferromagnetic electrode.

Laboratory 2D materials are generally small in size because in the form of micrometric flakes mechanically exfoliated from a bulk material. In addition, the interface between the 2D material and the ferromagnetic material that is the source of spin current is never well defined: the growth of this electrode on the 2D material leads to interface chemical reactions and atomic interdiffusion. The researchers succeeded in overcoming these two obstacles to study the spin-charge conversion mechanisms in $PtSe_2$ platinum diselenide.

For the past 10 years, the IRIG team has been developing ultra-high vacuum molecular beam epitaxy (MBE) growth of 2D single crystals of transition metal dichalcogenides (TMD) over large surfaces of several cm^2. The ferromagnetic material was then deposited in the same ultra-high vacuum chamber under growth conditions optimized to obtain perfect interfaces (see inset in **Figure 1**).

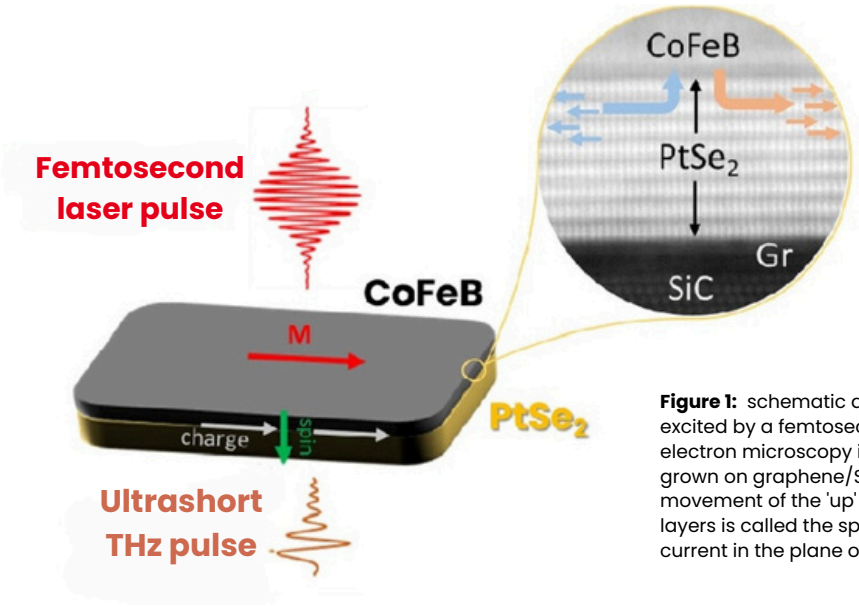


Figure 1: schematic diagram of THz emission from a CoFeB/PtSe$_2$ bilayer excited by a femtosecond laser pulse. Inset: an atomic-scale zoom of the electron microscopy image of the stack of 8 PtSe$_2$ monolayers epitaxially grown on graphene/SiC, showing the quality of the interfaces. The opposite movement of the 'up' (blue) and 'down' (brown) spins perpendicular to the layers is called the spin current. It is associated with the longitudinal charge current in the plane of the layers. © CEA

To identify and quantify the conversion mechanisms, the spintronic characterization technique using THz frequency emission is easy to implement and does not require any other technological process. It is also highly sensitive and non-destructive (**Figure 1**).

The PtSe$_2$ material exhibits an intense THz signal, making it possible to study the emission as a function of the number of monolayers (ML). Remarkably, the curve in Fig. 2 shows a step at 4 ML, which corresponds exactly to the electronic transition from the semiconductor to the semi-metallic state of the material. At low thicknesses (< 4 ML) in the semiconducting regime, the charge transfer between the graphene substrate and the first layer of PtSe$_2$ creates an interface electric field, and also a Rashba-type spintronic effect at the origin of the spin-charge conversion and the THz signal (Fig. 2). In this regime, it would be possible to modulate the THz emission by applying an external electric field. For thicker layers (> 4 ML) the transition to the semi-metallic state adds the phenomenon of conversion called the spin Hall effect which corresponds to a volume effect. (**Figure 2**).

Theoretical studies have validated this interpretation and quantified these effects, combining a simple spin diffusion model and *ab initio* calculations.

In conclusion, 2D materials open up new horizons for spintronics and the emission of THz waves sustainably and in a tunable way.

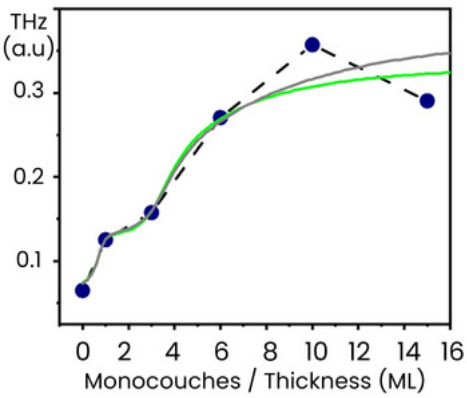


Figure 2: measurements of the intensity of the THz electric field emitted as a function of the thickness (in number of monolayers or ML) of PtSe$_2$ showing two conversion regimes at low thicknesses (< 4ML) and high thicknesses (> 4ML). The blue dots correspond to measurements and the solid lines to theoretical fits.

Collaboration

- IRIG/MEM, IRIG/SyMMES and IRIG/Pheliqs
- Laboratoire de Physique de l'Ecole Normale Supérieure LPENS, Paris
- Laboratoire Albert Fert LAF, Palaiseau
- Centre de Nanosciences et Nanotechnologies C2N, Palaiseau
- Institut Néel, Grenoble

REFERENCE

Abdukayumov K, Mičica M, Ibrahim F, Vojáček L, Vergnaud C, Marty A, VeuillenJ-Y, Mallet P, Gomes de Moraes I, Dosenovic D, Gambarelli S, Maurel V, Wright A, Tignon J, Mangeney J, Ouerghi A, Renard V, Mesple F, Jing Li, Bonell F, Okuno H, Chshiev M, George J-M, Jaffrès H, Dhillon S and Jamet M.
Atomic-Layer Controlled Transition from Inverse Rashba–Edelstein Effect to Inverse Spin Hall Effect in 2D PtSe$_2$ Probed by THz Spintronic Emission
Advanced Materials 2024

Critical deformation of Li-Ion batteries

A manifold of degradation mechanisms causes premature capacity fade of Li-ion batteries. To understand their origin, we need a detailed diagnosis of battery (mal-)function over time. Here we employ correlative neutron and X-ray imaging to observe microstructural changes over time inside high energy density cylindrical cells and focus on unraveling the causes of localized defects where the silicon-graphite anode becomes damaged.

In the study, a team of researchers led by IRIG [**collaboration**] examined Li-ion batteries during their lifetime using state-of-the-art, non-intrusive imaging techniques available at neutron and X-ray sources, respectively the Institut Laue Langevin (ILL). Their sophisticated combination allowed to gain multidimensional information on the components and elements inside working battery cells.

Sandrine Lyonnard | SyMMES | Molecular Systems and nanoMaterials for Energy and Health

The team identified macroscopic deformations in the wound structure of the copper current collector. The deformed areas already existed in fresh battery cells that only went through the initial activation cycle (the first charging-discharging cycle). Further investigations revealed that these defects are due to local accumulations of silicon occurring during electrode manufacturing. Upon activation, the largest agglomerates expand heavily, which leads to deformations in the current collector, wasting capacity before the cell ever went into use.

It was possible to determine how large these accumulations have to be to become a problem: cell structure and functioning is compromised for silicon agglomerations with a size above 50 microns. This is crucial information for both quality control and future developments.

For this study, operating within the InnovaXN and Battery Hub frameworks in Grenoble was a clear advantage. The presence of the industrial partners VARTA and MCL made it possible to work with products and issues that are very close to the market, while having access to all the required know-how, expertise and experimental facilities, including the world leading power and state-of-the-art techniques of the largely complementary ILL and ESRF sources.

While experiments were performed at the ILL and the ESRF, the IRIG had a fundamental role in providing the bridges between know-how, techniques, methods for data acquisition and analysis.

This kind of approach is at the heart of the Battery Hub created in Grenoble by the CEA, the ESRF and the ILL as a European platform for battery diagnosis and investigations using standardised, integrated and multi-technique workflows.

Fundings
European projects ECO2LIB (H2020) and INNOVAXN (ITN Marie Curie) and Battery Hub atGrenoble leadedby CEA

REFERENCE
Lubke E, Helfen L, Cook P, Mirolo M, Vinci V, Korjus O, Fuchsbichler B, Koller S, Brunner R, Drnc J and Lyonnard S.
The origins of critical deformations in cylindrical silicon based Li-ion batteries
Energy & Environmental Science 2024

Collaboration

- Institut Laue-Langevin, European Synchrotron Radiation Facility, IRIG, Grenoble (France),
- VARTA Innovation GmbH (Austria),
- Materials Center Leoben Forschung GmbH (Austria).

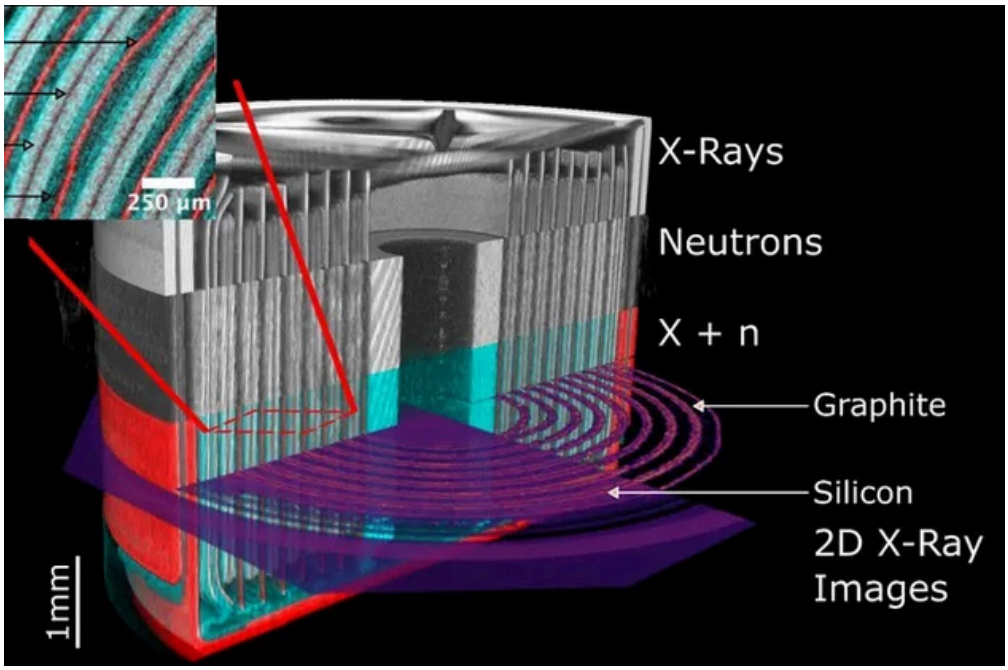


Image: 3D rendering of the cell obtained from the combination and correlation of the different measurements performed with neutrons and x-ray photons
© Erik Lubke – ILL

Cryogenic plant for the MINERVA accelerator

A step towards MYRRHA the world's first large scale accelerator driven system

MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications) the world's first large scale Accelerator Driven System (ADS) that consists of a subcritical nuclear reactor driven by a high power linear accelerator, is a project built by SCK CEN (Belgium nuclear research center) in Belgium. This nuclear complex is scheduled to be commissioned in 2036 at Mol (Belgium).

The phase 1 of this project, entitled MINERVA, consists in design and construct of the first 100 meters accelerator (Linac) section accelerating protons to an energy of 100 MeV. This Linac accelerator requires cryogenic cooling for the radio-frequency superconducting cavities.

Frédéric Michel | DSBT |
Low Temperature Systems
Department

The IRIG team was involved by SCK CEN first to design the cryogenic architecturere and then to carry out preliminary cryogenic studies and to define the requirements to design the 2 Kelvin cooling system for the MINERVA Linac superconducting accelerator cavities. The Linac will be composed of 30 cryomodules, including each 2 superconducting cavities made of bulk niobium and cooled by a saturated superfluid helium bath at 2 Kelvin.

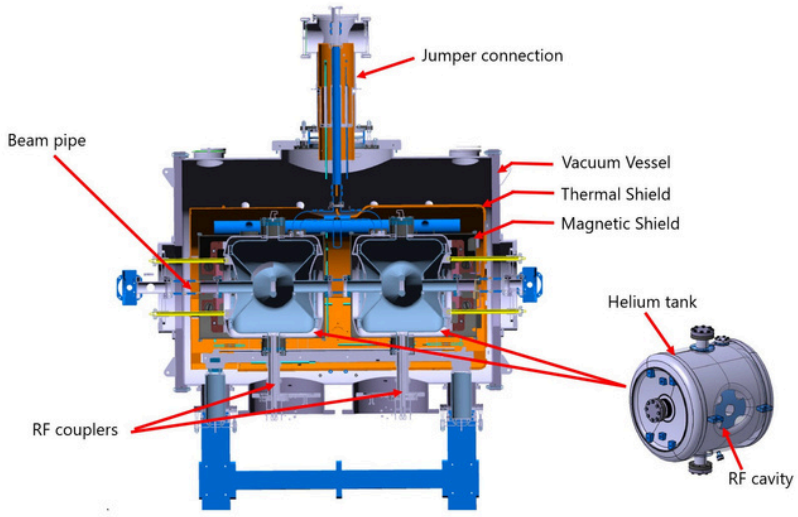
The cryogenic system is a key component of the project. It includes the cryogenic plant, the cryogenic distribution and lines, and the valve boxes connected to the cryomodules containing the cavities.

Following preliminary and conceptual studies initiated in 2021, the IRIG team has written the specifications including more than 500 technical requirements for MINERVA cryogenic plant procurement. The cryogenic plant allows to provide superfluid helium at 2 K for cryomodules cooling, helium flow between 40 K and 60 K for the thermal shields and supercritical helium at 5 K for the cooling of the radio-frequency power couplers.

The power of this cryogenic plant for MINERVA will be around 3500 W equivalent at 4.5 K, consisting of 900 W at 2 K to cool the cavities, and 8600 W to maintain the thermal shields around 50 K. The flow rate of the helium compressors of the cryogenic system is estimated around 320 g/s, requiring about 1.2 MW of electrical power. A heat recovery system will equip the compressor cooling circuit of the MINERVA cryogenic plant (recovering over 90% of the electrical energy injected) and the recover heat will be used for the MINERVA buildings.

Based on the IRIG technical specifications, the tendering phase for the procurement of this cryogenic plant, managed and financed by SCK CEN, is now open. IRIG, acting as expert and technical advisor, will be closely involved in all phases of the cryogenic plant's industrial construction: detailed design, manufacturing, installation and commissioning at the SCK CEN site at Mol, scheduled for 2028. A dedicated new 4-year contract has just been launched in April 2024, following the kick off meeting held on MYRRHA site.

Other contracts for supporting MINERVA cryogenic system are under discussion with SCK CEN. In particular for the development and the implementation of a digital twin of the entire cryogenic system (including cryogenic distribution and cryomodules) in order to prepare commissioning and to optimize the cryogenic operation of the MINERVA accelerator, and training operators too.



Cryomodule (© SCK CEN)

REFERENCES

[1] Michel F, Berkowitz D, Bonthuys G, Poncet J-M, Bonne F and Millet F.
Preliminary studies of the MINERVA cryogenic supply system
CEC-ICMC 2023

[2] Berkowitz D, Bonthuys G, Dekhtiarov V, Dorda U, Marhauser F, Saugnac H, Joly C, Olivier G, Lhomme C-H, Junquera T, Dieudegard F, BENIKE, M-E. A, TIJANI Y, Michel F, Bonne F, Millet F, Poncet J-M and Thermeau J. P.
Status of the MINERVA cryomodules and associated cryogenic system (MYRRHA phase 1)
CEC-ICMC 2023

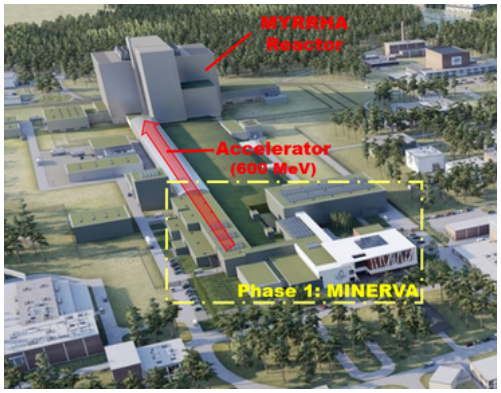


Photo: The MYRRHA Project. © SCK CEN

New anti-cancer treatment targeting a protein kinase

Many pathologies, such as cancer, are linked to the dysregulation of the CK2 protein kinase, which is why medical research aims to inhibit it. However, the CK2 inhibitors developed to date have a lack of specificity potentially targeting several other protein kinases, which can be a source of side-effects.

Claude Cochet | Biosanté |
Biology and Biotechnologies for Health Laboratory

Researchers at IRIG and the Faculty of Pharmacy in Lyon have synthetized and characterized the AB668 molecule which inhibits CK2 activity with a high degree of specificity. This bivalent molecule binds simultaneously to the catalytic site of CK2 and to an adjacent hydrophobic pocket, giving it a unique inhibition mechanism (**Figure A**).

What's more, AB668 has no adverse side-effects because it induces apoptotic death in numerous cell lines derived from aggressive cancers (kidney, breast, melanoma, pancreas, colon), while sparing healthy cells (**Figure B**).

The AB668 molecule could therefore be a promising new anti-cancer agent. The next step will be to test the molecule, after optimization by medicinal chemistry, in pre-clinical models of various cancers.

This research led to the creation of the KAIROS start-up which holds the patent : contact@kairos-discovery.com

REFERENCE
Bancet A, Frem R, Jeanneret F, Mularoni A, Bazelle P, Roelants R, Delcros JG, Guichou JF, Pillet C, Coste I, Renno T, Battail C, Cochet C, Lomberget T, Filhol O and Krimm I.
Cancer selective cell death induction by a bivalent CK2 inhibitor targeting the ATP site and the allosteric αD pocket.
iScience 2024

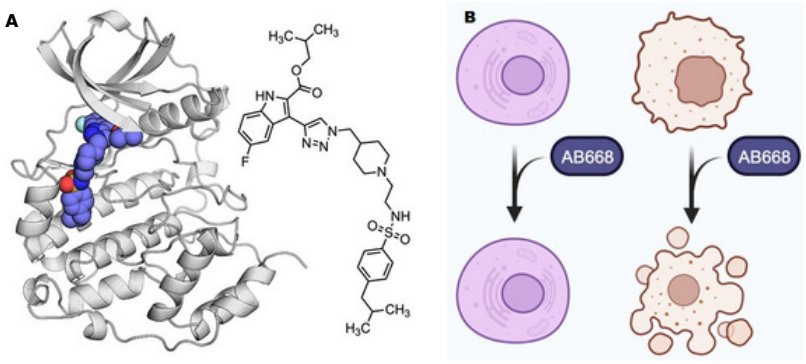


Figure A: an allosteric inhibitor of CK2 with anti-cancer properties. A) AB668 is a bivalent molecule that inhibits CK2 activity by binding simultaneously with high affinity (Kd: 86 nM) to its catalytic site and to an adjacent hydrophobic pocket. © CEA
Figure B: AB668 induces tumour cell death by apoptosis while preserving healthy cells. © CEA

New natural antimicrobials in the fight against antibiotic resistance

The WHO predicts that antibiotic resistance could cause 10 million deaths a year by 2050. Scientists are therefore directing their research towards new natural molecules with structures and modes of action that differ from conventional antibiotics. Antimicrobial peptides or bacteriocins produced by bacteria, represent a very promising alternative. In this way, bacteria from the human gut microbiota represent a vast field of investigation that is still relatively unexplored.

Victor Duarte | LCBM |
Chemistry and Biology of Metals laboratory

Researchers at IRIG in collaboration with the Institut des Sciences Moléculaires de Marseille and the Laboratoire de Microbiologie Génétique et Moléculaire de Toulouse, are studying *Ruminococcus gnavus* E1, a symbiotic bacterium that produces several antimicrobial peptides, including Ruminococcins C. These peptides, expressed as 5 isoforms (RumC1-5) are highly effective against multidrug-resistant pathogens. They have diverse activity spectra, with no synergistic effects between the different isoforms. In addition to their low toxicity, Ruminococcins C also possess other beneficial health properties, such as an anti-inflammatory effect.

Ruminococcins C possess properties that are often lacking in other antimicrobial peptides, including high resistance to physiological conditions, efficacy at very low doses and low toxicity. Ongoing work aims to elucidate the mode of action and to identify the cellular target(s) of these molecules.

Financial support from ANR RUMBA (2016-2020), ANR RUMisBAC (2021-2025), CFR CEA (2016-2019/2020-2023)

REFERENCE
Shamseddine L, Roblin C, Veyrier I, Basset C, De Macedo L, Boyeldieu A, Maresca M, Nicoletti C, Brasseur G, Kieffer-Jaquinod S, Courvoisier-Dezord E, Amouric A, Carpentier P, Campo N, Bergé M, Polard P, Perrier J, Duarte V and Lafond M.
Mechanistic and functional aspects of the Ruminococcin C sactipeptide isoforms
iScience 2023

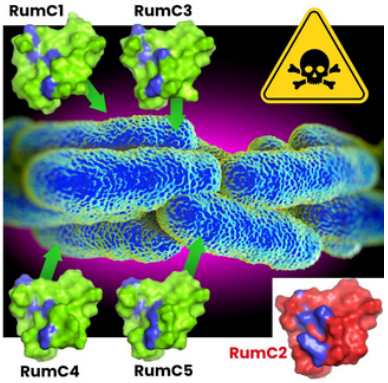


Figure: Antibacterial activity: unlike the other Ruminococcins C, RumC2 is not effective. The nature of the residues shown in blue in the figure may explain these differences in reactivity. © CEA

Molecular insights into the Influenza virus genome organization

Every year, the influenza virus infects between 2 and 6 million people in France. Other influenza viruses, that are very similar to the human influenza virus, cause epizootics that also threaten the human health, as they can cross the species barrier with new viral forms emerging. In particular, the avian influenza epizootic that has been raging in Europe since October 2021 is affecting domestic and wild birds with unprecedented virulence and contagiousness. Given this situation, the WHO has placed the various influenza virus strains under very close surveillance.

In this context, scientists at IRIG are seeking to elucidate the molecular mechanisms that enable the influenza virus to mutate or adapt to other species.

Thibaut Crépin | IBS |
Institut de biologie structurale

The genome of this family of viruses is composed of eight single-stranded RNA molecules. Each RNA fragment is covered with multiple copies of viral nucleoproteins (NP) and the 3′ and 5′ RNA ends interact with an RNA polymerase to form the ribonucleoprotein complex (RNP), (involved in the virus proliferation). Until now, studies of RNPs using cryo-electron microscopy (cryo-EM) had only provided a molecular envelope in which the NP molecules had been positioned imprecisely, and without providing any details of their interaction with the viral RNA.

Thanks to their expertise in the expression and purification of recombinant NP protein, scientists were able to produce significantly more biological material than by starting with viruses, an essential condition for conducting a high-resolution cryo-ME study. Using the Titan Krios electron microscope on ESRF's CM01 line, they succeeded to generate a final model at 5 Å resolution.

This enables them to understand how the nucleoprotein molecules interact with each other within this complex and flexible architecture. This cryo-EM 3D reconstruction at sub-nanometric resolution enables for the first time the visualisation of the RNA placement within RNPs.

RNA appears to be involved in structuring the ribonucleoprotein complexes, it can slide freely on the surface of the proteins, most likely to facilitate access to the RNA polymerase and thus enables replication of the virus.

REFERENCE

Chenavier F, Estrozi L F, Jean-Marie Teulon J-M, Zarkadas E, Freslon L-L, Pellequer J-L, Ruigrok RWH, Schoehn G, Ballandras-Colas A and Crépin T.
Cryo-EM structure of influenza helical nucleocapsid reveals NP-NP and NP-RNA interactions as a model for the genome encapsidation
Science Advances 2023

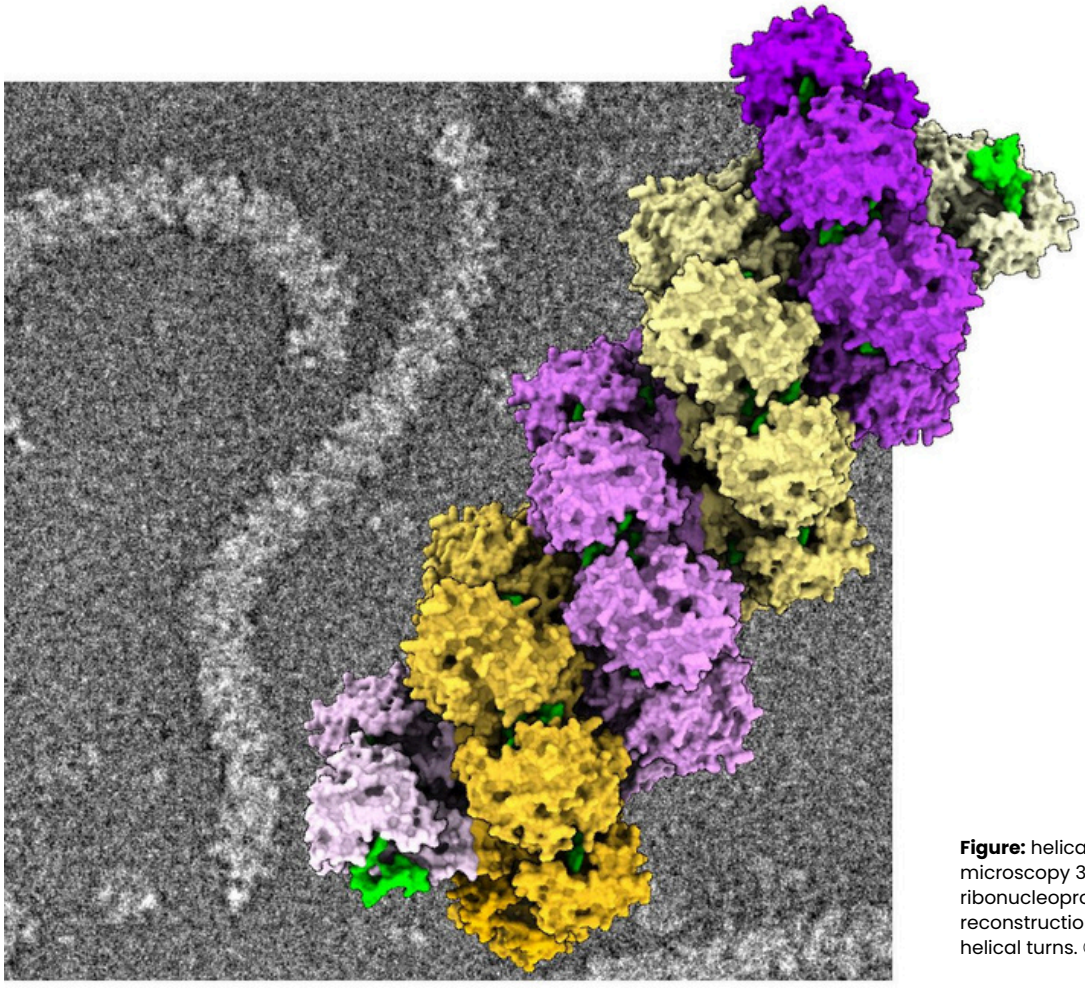


Figure: helically symmetrized cryo-electron microscopy 3D reconstruction of the ribonucleoprotein-like particle at 8.7 Å. The reconstruction displays about two intertwined helical turns. © CEA

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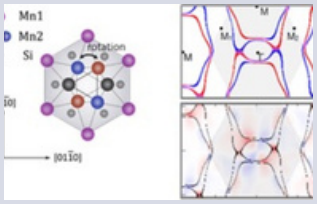

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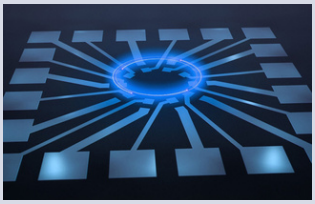

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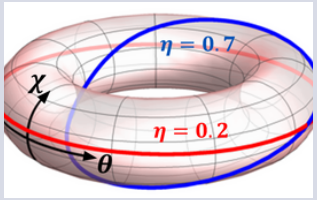

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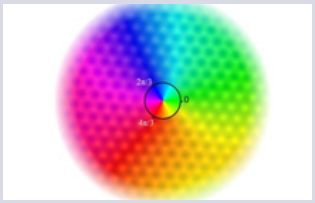

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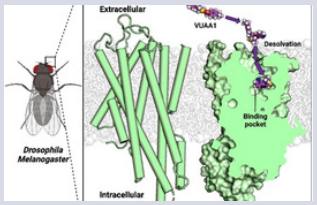

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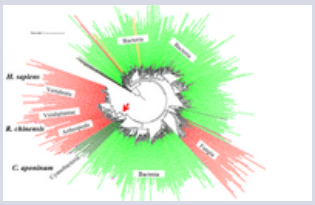

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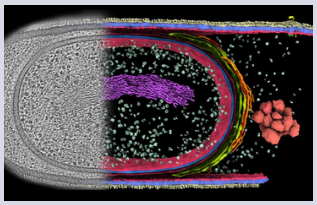

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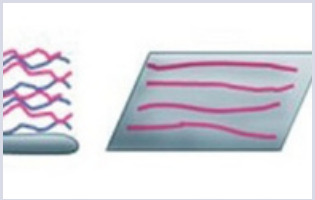

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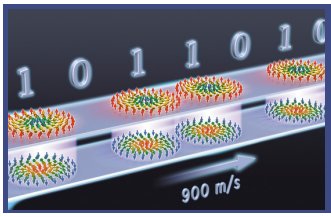

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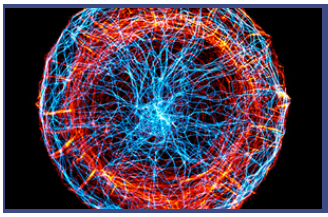

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