

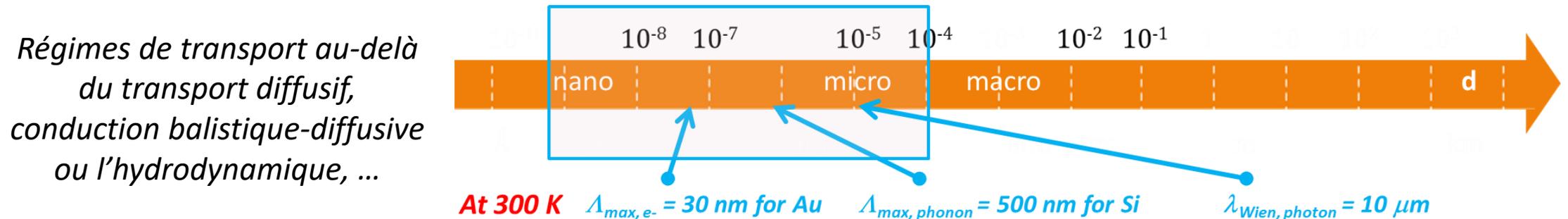
Fiche identité du profil recherche Section 28 du CNU

- Profil section 28 du CNU
- Equipe : Thermodynamique et Biophysique des Petits Systèmes
- Laboratoire: Institut NEEL, 450 personnes, couvre tous les aspects de la physique de la matière condensée au sens large
- Date de début : 01/09/2026
- Thème de recherche: Nanophononique et transfert thermique dans les systèmes 1D, 2D ou nanostructurés.
- Instrument : Axe H.11 : Capteurs, imageurs et instrumentation

Contexte scientifique du profil recherche

Propriétés de transport de phonons et de chaleur à l'échelle du nanomètre (nano-objets, matériaux nanostructurés, matériaux bio-inspirés etc...),

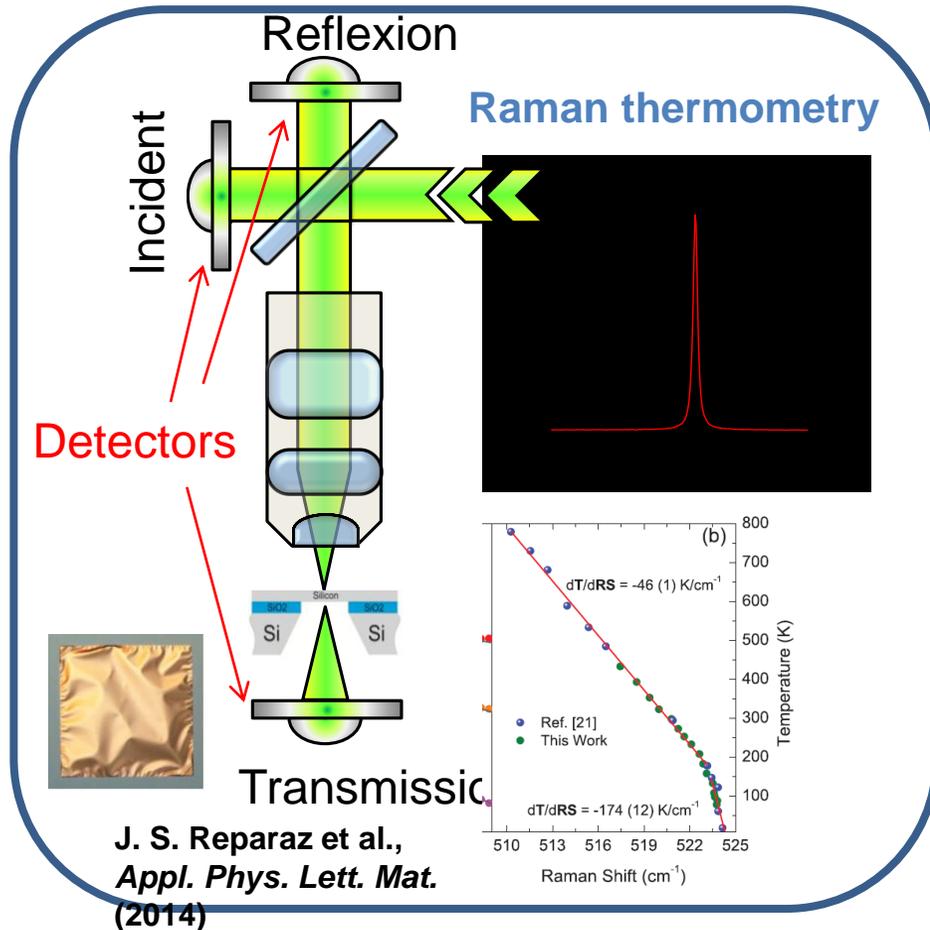
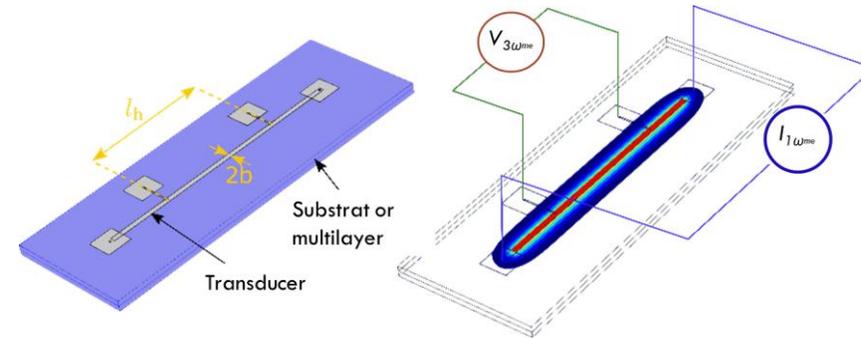
- Régimes de conduction thermique différents de ceux à l'échelle macroscopique: régime non-Fourier, limite Casimir-Ziman et régime de Landauer.



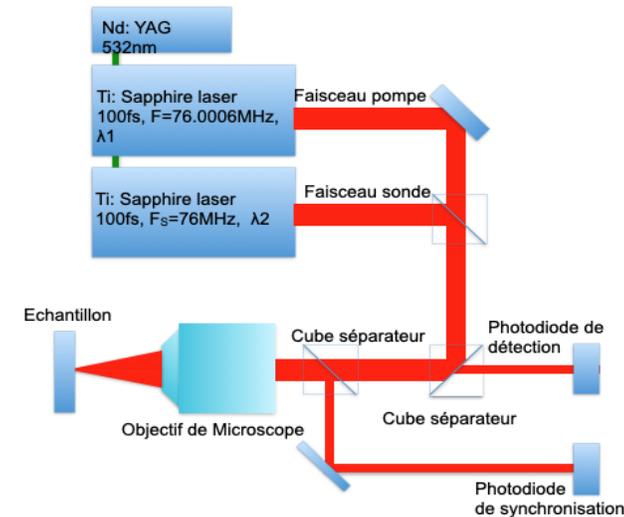
- Etudes théoriques intensives non entièrement étayées par des expériences
- Besoin de nouvelles méthodes de mesure avec
 - ❑ une sensibilité thermique élevée,
 - ❑ une résolution spatiale nanométrique,
 - ❑ permettant d'étudier et d'évaluer les mécanismes physiques sous-jacents sur une large gamme de températures allant de la température cryogénique (azote liquide) à la RT.

All the main different methods for thermal measurements at the nanoscale

In-contact methods
(electrothermal methods)
Contact less methods (optical methods)



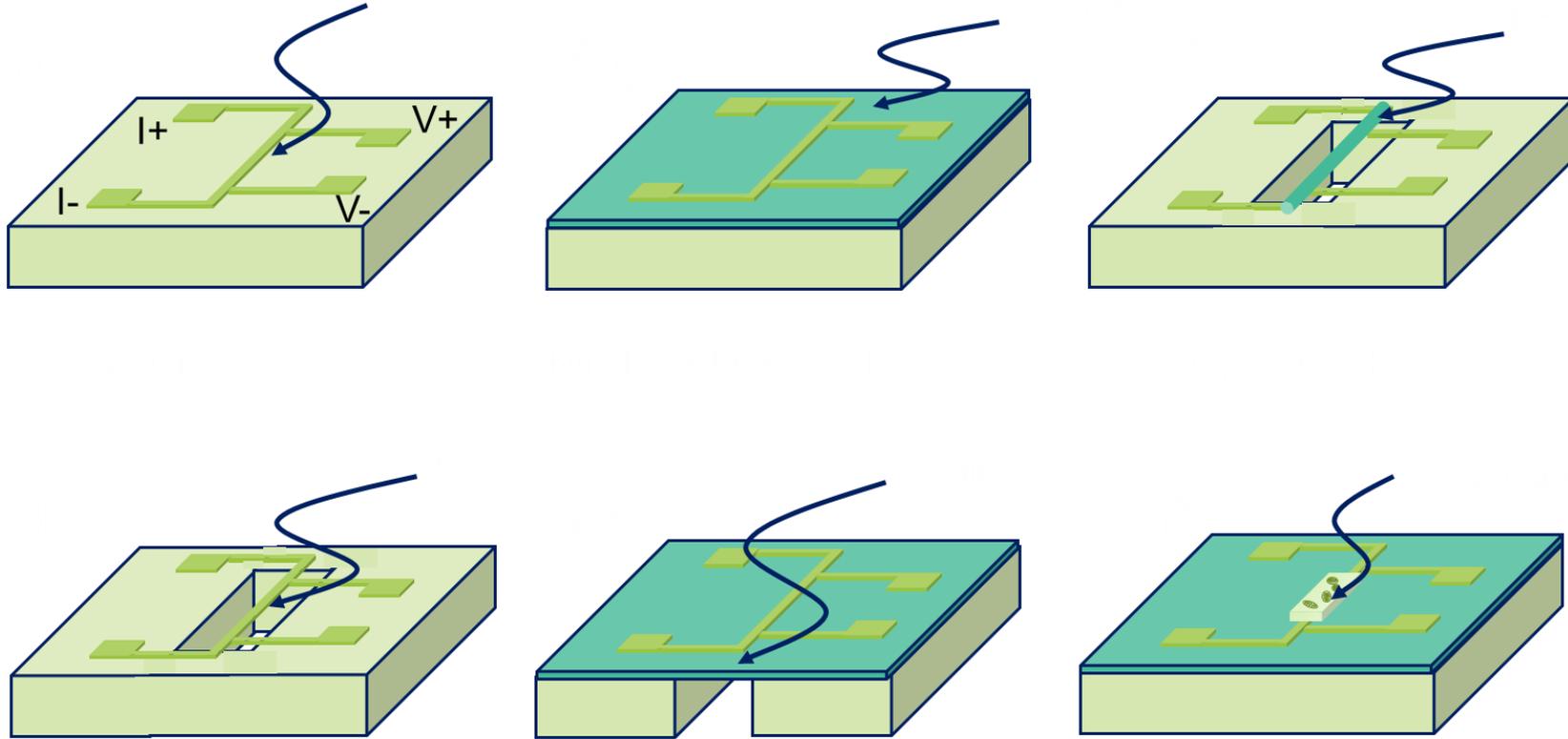
Laser reflexion method (FDTR or TDTR)



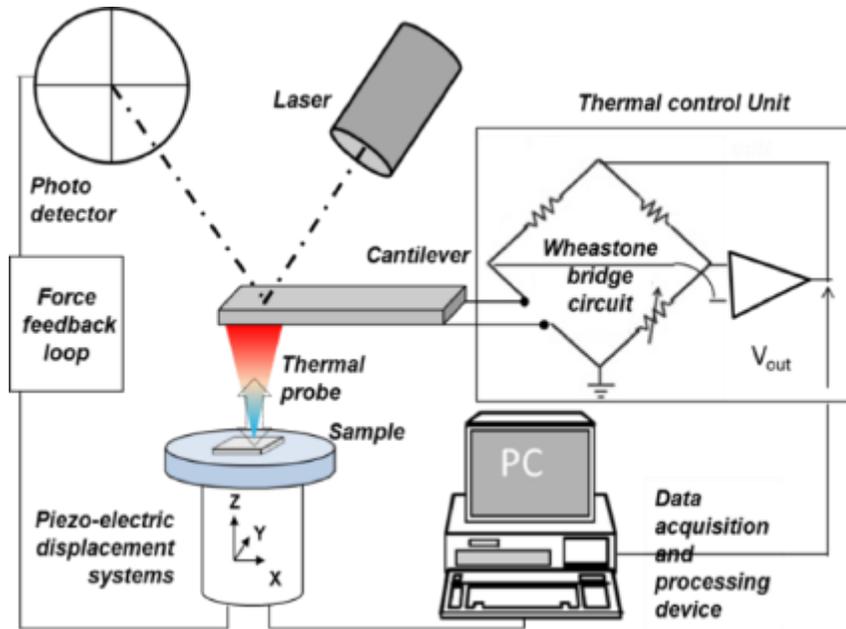
Highly time resolved

See Friday, lecture by Stefan Dilhaire !!

All kinds of geometry for 3ω : in-plane out-of-plane, linear, membrane, etc...



Scanning Thermal Microscopy\General Principle of SThM



Schematic of SThM

Principle

Scanning a sharp temperature sensing probe across the surface of the sample

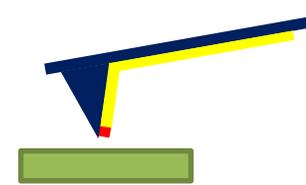
Spatial resolution

Tip sharpness, tip-sample heat transfer mechanism

AFM probe



SThM probe: AFM + thermal sensor



Different operation modes:

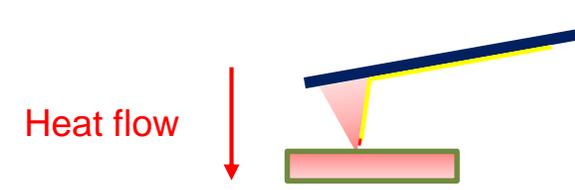
Passive mode: Temperature mapping (heat flows from hot sample to probe)

Active mode: Thermal conductivity (heat flows from probe to sample)

Hot SThM probe



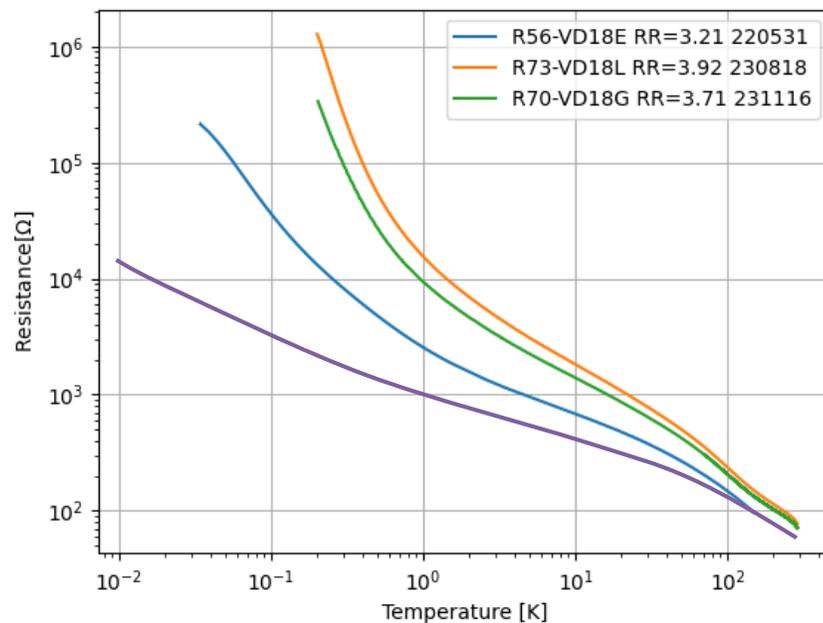
Cooling of SThM probe



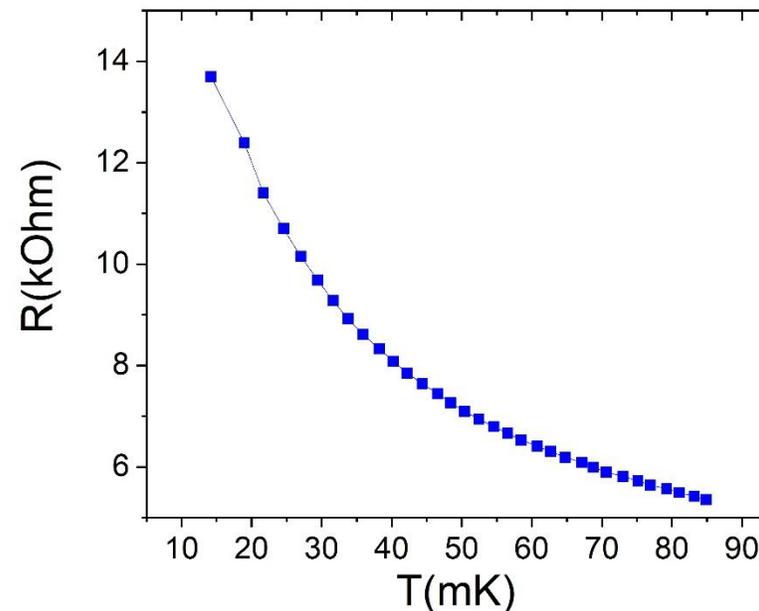
Temperature dependent physical property changes

NbN Resistive thermometry using Anderson insulator

- Metal (Pt, Au, Ni) Temp=40K-1500K
- Semiconductor (Ge, Si) 0K-50K
- Mott-Anderson insulator (Metal to insulator transition materials: NbN, NbSi, AuGe) 0K-400K and more.
- Specific electronic transport linked to disorder (VRH).

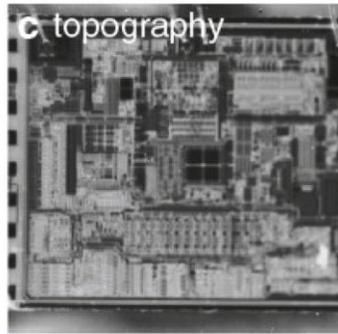
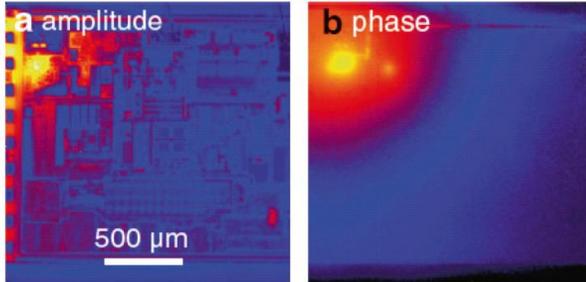


Experiment on NbN with Lancaster



8 State of the art and motivations \ Thermal transports at nanoscale

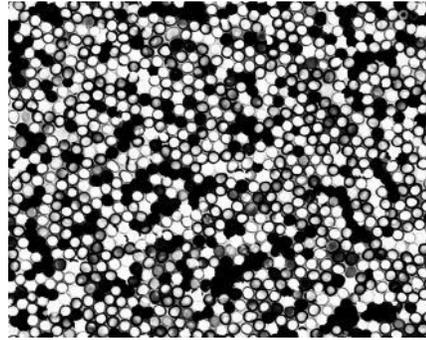
Heat management,
detection of hot spot



Integrated circuit: Excess
heat due to Joule effect

Requirement: High thermal
conductivity materials

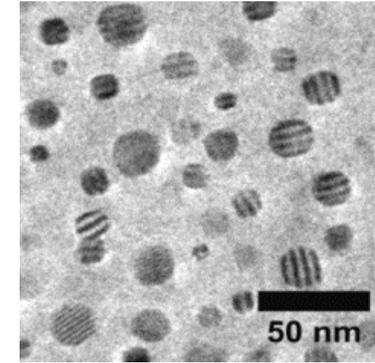
Nanowires



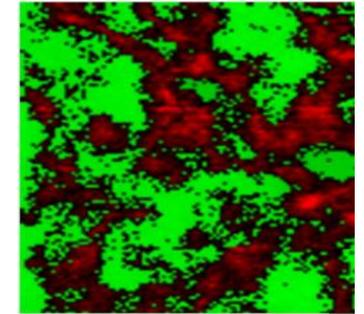
SEM image (Top view): Si Nanowires

Thermoelectric device: Low
thermal conductivity materials

Nanomaterials

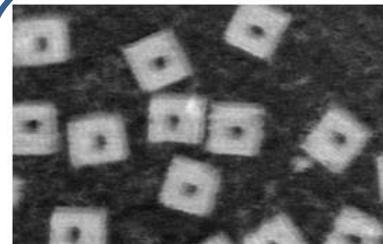


GeMn nano inclusions in Ge

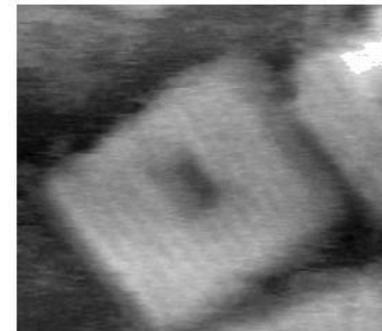


GeTe(C)

$$ZT = \frac{S^2 \sigma T}{k_{\text{tot}}}$$



14 nm x 27 nm x 61 nm



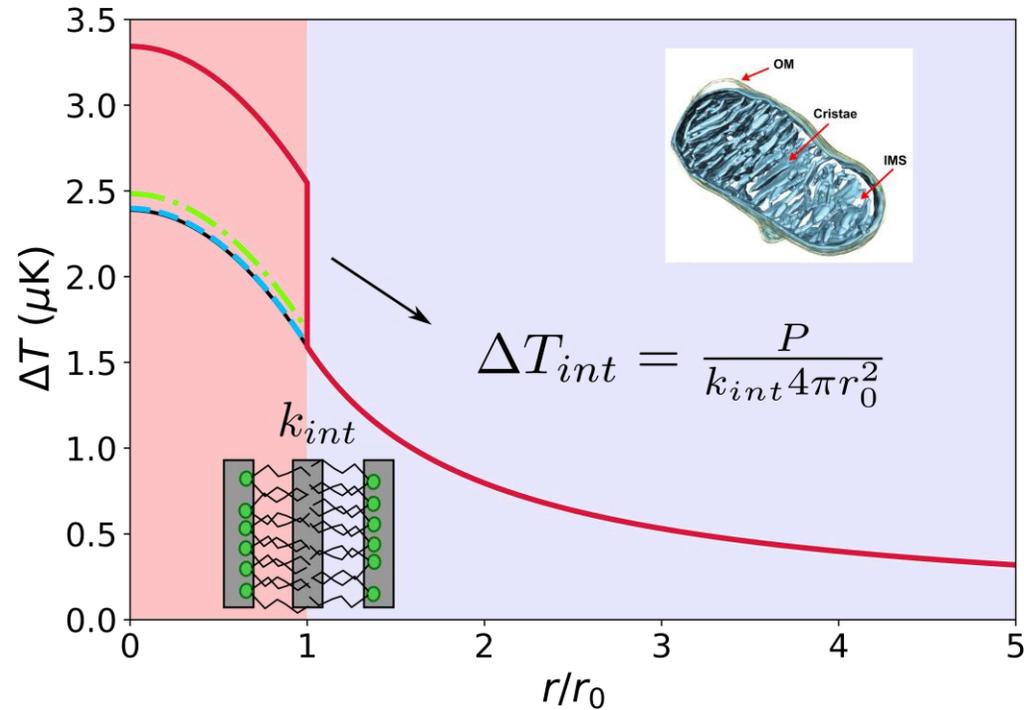
Heat transport in biological system: DNA origami

**Study temperature
fields at nanoscale**

Scanning Thermal Microscopy
(SThM)

Spatial resolution:
sub- 50 nm

Bio-inspired materials



Temperature gradients measured by biologists cannot be explained by physics

1. Instrumentation :

- probes
- sensitivity
- coupling to environment

2. Fundamental :

- sub-micrometer scale temperature
- transport in disordered materials
- interfaces

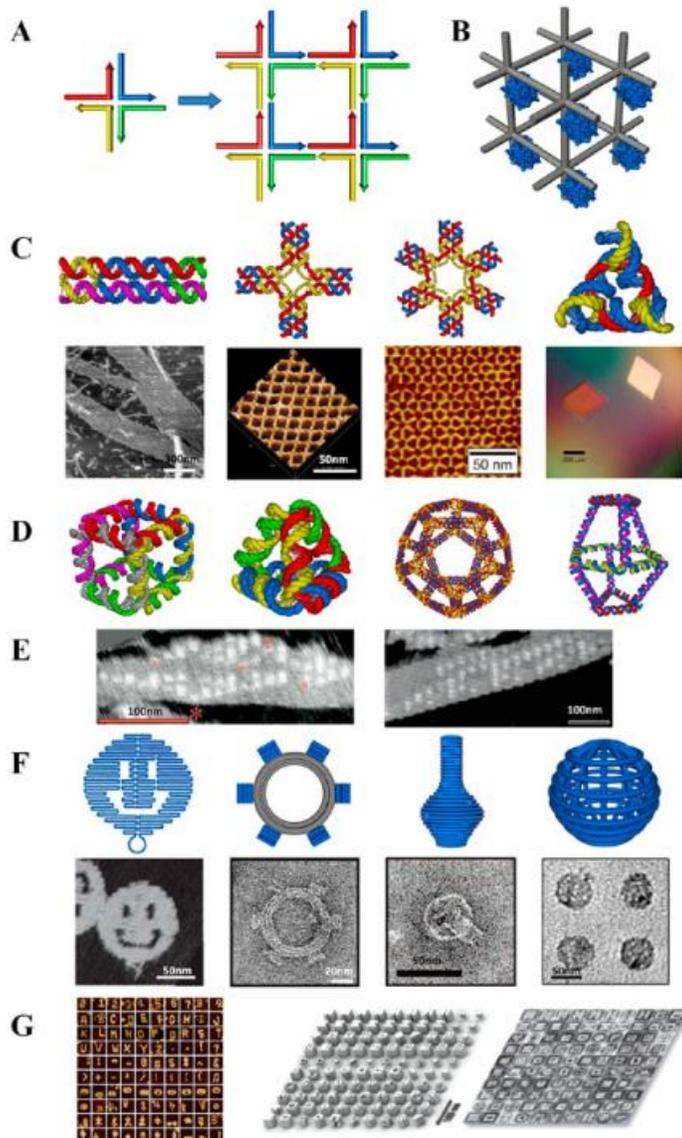
➡ Heat and energy transfer in biomaterials from the molecule to the tissue.

- Model system: DNA Origami

➡ Heat dissipation in living systems (out of equilibrium) :

- Synthetic model systems (chemical networks, molecular pumps,), self organization
- Organelles, bacteria, cells, tissues

DNA origami



Fondations Nadrian Seeman

Seeman, Nadrian C. « Nucleic Acid Junctions and Lattices ». *Journal of Theoretical Biology* 99, n° 2 (1982): 237-47. [https://doi.org/10.1016/0022-5193\(82\)90002-9](https://doi.org/10.1016/0022-5193(82)90002-9).

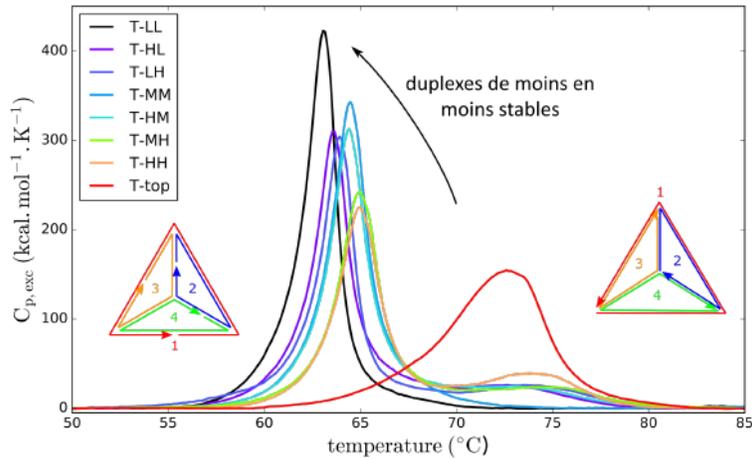
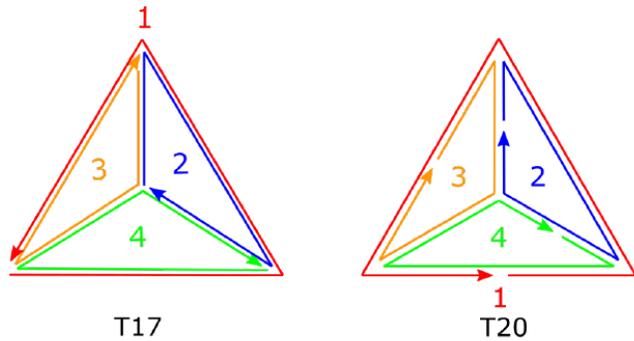
Origami

Rothemund, Paul W K. « Folding DNA to create nanoscale shapes and patterns ». *Nature* 440, n° 7082 (2006): 297-302. <https://doi.org/10.1038/nature04586>.

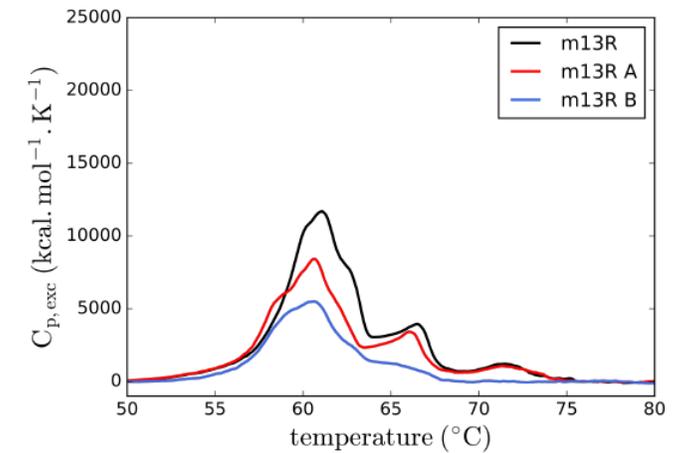
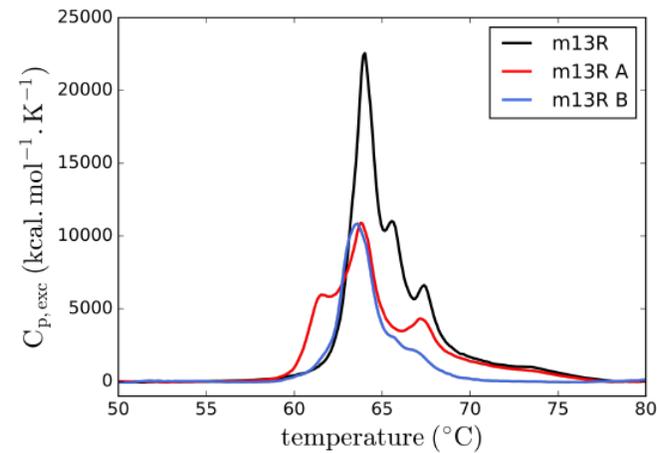
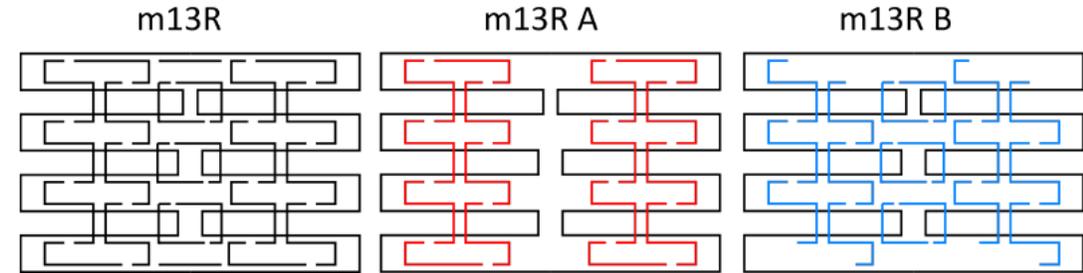
DNA Structural Nanotechnologies

Zhang, Fei, Jeanette Nangreave, Yan Liu, et Hao Yan. « Structural DNA Nanotechnology: State of the Art and Future Perspective ». *Journal of the American Chemical Society* 136, n° 32 (2014): 11198-211. <https://doi.org/10.1021/ja505101a>.

Sequence engineering

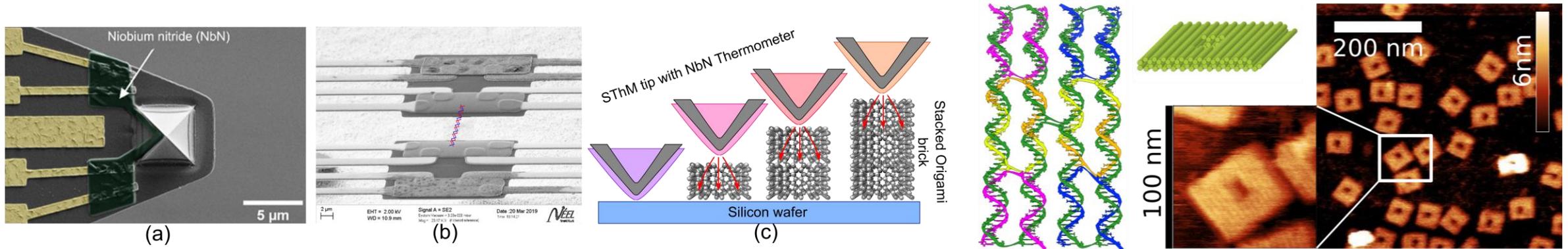


Free energy landscape engineering



Use these tools to study out of equilibrium processes by incorporating enzymes or complex materials (gels)

- ➔ Heat and energy transfer in biomaterials from the molecule to the tissue.
- Model system: DNA Origami



- Use hierarchical assembly and programmability of DNA origami to self assemble and control molecular scaffold at the level of 100 nm
- Parametrize heat transport as a function of shape and topology
- Deduce intrinsic thermal conductivity

Wagenbauer, Klaus F, Christian Sigl, et Hendrik Dietz. « Gigadalton-scale shape-programmable DNA assemblies ». *Nature Publishing Group* 552, n° 7683 (2017): 78-83.

<https://doi.org/10.1038/nature24651>.

HCERES Report 2025 (TPS : Team 144)

Recent PhD Thesis

- <https://theses.hal.science/tel-05290313v1> : Thermal rectification of phonon heat flux at very low temperatures in nanostructured asymmetric systems
- <https://theses.hal.science/tel-05107772v1> : Analyse thermodynamique et rhéologique pour la conception rationnelle des gels d'ADN
- <https://theses.hal.science/tel-03879142v1> : Development of highly sensitive SThM probes for nanoscale thermal measurements
- <https://theses.hal.science/tel-01831617v1> : Thermodynamique de l'assemblage de nano-structures et d'origami d'ADN

Relevant papers

- F. Mazzelli, J. Paterson, F. Leroy, and O. Bourgeois, *A combined $2\omega/3\omega$ method for the measurement of the in-plane thermal conductivity of thin films in multilayer stacks: application to a Silicon-On-Insulator wafer*, J. Appl. Phys. **137**, [015106 \(2025\)](https://doi.org/10.1063/5.0203890)
- Swami, R., G. Julié, S. Le-Denmat, et al. « Experimental Setup for Thermal Measurements at the Nanoscale Using a SThM Probe with Niobium Nitride Thermometer ». *Review of Scientific Instruments* 95, n° 5 (2024): 054904. <https://doi.org/10.1063/5.0203890>.
- J. Paterson, S. Mitra, Y.Q. Liu, M. Boukhari, D. Singhal, D. Lacroix, E. Hadji, A. Barski, D. Tainoff, and O. Bourgeois, *Thermal conductivity reduction due to phonon geometrical scattering in nano-engineered epitaxial germanium*, Appl. Phys. Lett. **124**, [181902 \(2024\)](https://doi.org/10.1063/5.0204222) DOI10.1063/5.0204222
- C.A. Polanco, A. van Rookeghem, B. Brisuda, L. Saminadayar, O. Bourgeois, and N. Mingo, *The phonon quantum of thermal conductance: are simulations and measurements estimating the same quantity?* Sci. Adv. **9**, eadi7439 (2023). DOI: 10.1126/sciadv.adi7439
- Macherel, David, Francis Haraux, Hervé Guillou, et Olivier Bourgeois. « The Conundrum of Hot Mitochondria ». *Biochimica et Biophysica Acta (BBA) - Bioenergetics* 1862, n° 2 (2021): 148348. <https://doi.org/10.1016/j.bbabi.2020.148348>.

Historical works:

- T.D. Nguyen, J. Richard, J. Doumourro, Y. de Wilde, and O. Bourgeois *Thermal exchange of glass micro-fibers measured by 3ω technique*, J. Heat Transfer **142**, [101701 \(2020\)](https://doi.org/10.1063/5.0203890).
- 2018 A. Tavakoli, K. Lulla, T. Crozes, E. Collin, and O. Bourgeois, *Heat conduction in a ballistic 1D phonon waveguide indicates breakdown of the thermal conductance quantization*, Nature Commun. **9**, 4287 (2018).
- 2017-A. Tavakoli, C. Blanc, H. Ftouni, A.D. Fefferman, K.J. Lulla, E. Collin, and O. Bourgeois, *Universality of thermal transport in amorphous nanowires at low temperature*, Phys. Rev. B **95**, [165411 \(2017\)](https://doi.org/10.1063/5.0203890)
- 2015 Hossein Ftouni, Christophe Blanc, Dimitri Tainoff, Andrew D. Fefferman, Kunal J. Lulla, Jacques Richard, Eddy Collin, and Olivier Bourgeois, *Thermal conductivity of silicon nitride membranes is not sensitive to stress*, Phys. Rev. B **92**, [125439 \(2015\)](https://doi.org/10.1063/5.0203890).
- 2009 J.-S. Heron, T. Fournier, N. Mingo and O. Bourgeois, *Mesosopic surface effects on the phonon transport in silicon nanowire*, Nano Letters **9**, 1861 (2009).

[Link](#) toward the official information (check for updates).

<https://emploi.univ-grenoble-alpes.fr/metiers/enseignants-enseignants-chercheurs-titulaires/concours-enseignants-chercheurs/concours-enseignants-chercheurs-935820.kjsp?RH=1135797159731976>