FEMTO-ST institute

- ~ 750 staff members, in 7 departments: Time&Frequency, Appl. Mecha, Energy, Optics, Comp. Sci., Autom. Control, *Micro Nano Sciences & Systems (*MN2S)
- 3 lecturers + 1 CNRS + 1 PhD in GDR NAME from *Phononics & Microscopies* team of the (MN2S) department
- CNRS section 8, CNU 28 and 63 for those in the GDR.
- Themes in the GDR : SThM + Time Domain ThermoReflectance + flexoelectricity

AXE
Mesures de propriétés
Mesures de performances de dispositif
Simulations/Théorie

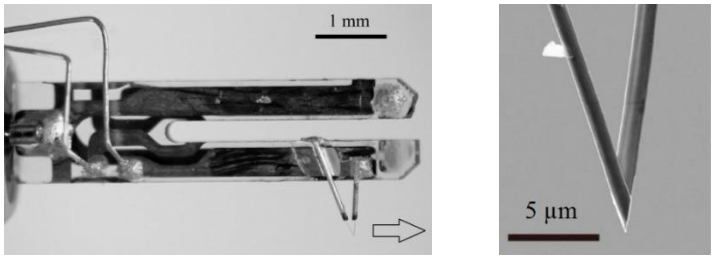
NAME
GDR Nanomaterials for Energy Applications
ELABORATION
MEASUREMENTS & METROLOGY
SIMULATIONS & THEORY
APPLICATIONS

femto-st SCIENCES & TECHNOLOGIES

UBFC

cnrs

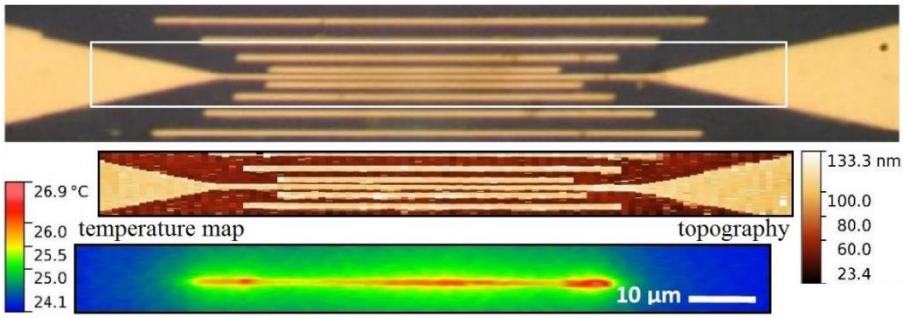
Scanning Thermal Microscopy (SThM)



Thermocouple probe on Quartz Tuning Fork
(Pt/Pt-Rh ∅ 1,3µm wires)
Tip radius: ≈ 50 nm after FIB reshaping
Contact strength: 100 nN

Passive mode: temperature mapping

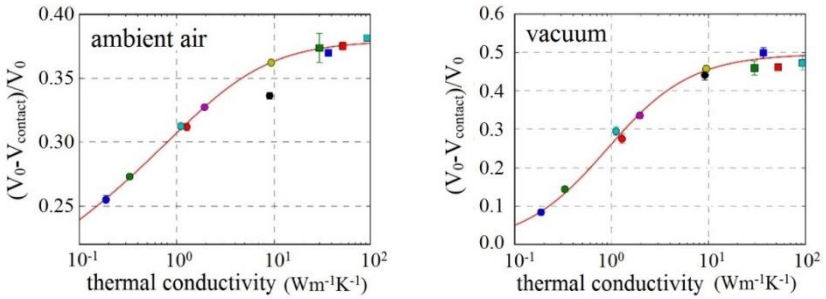
Hot platinum strip 600 nm width, heated by Joule effect



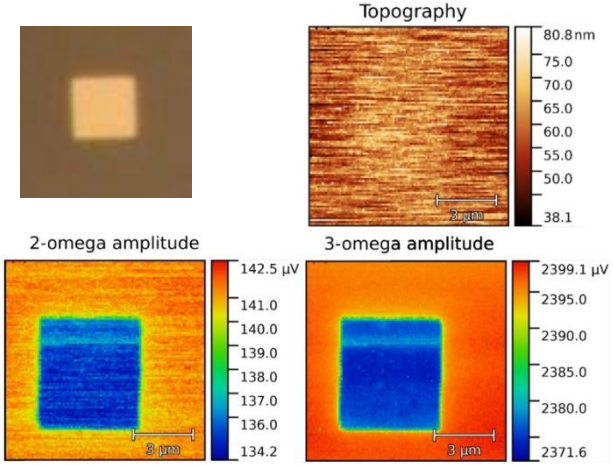
Temperature resolution: 0,1 K / Spatial resolution: 100 nm
Measurement range: ambient to 1000 K

Active mode: thermal conductivity mapping

Calibration curves on bulk materials



Topography free sample of gold thin film 5µm x 5µm / 20 nm thick, buried in a 400 nm SiN_x film.

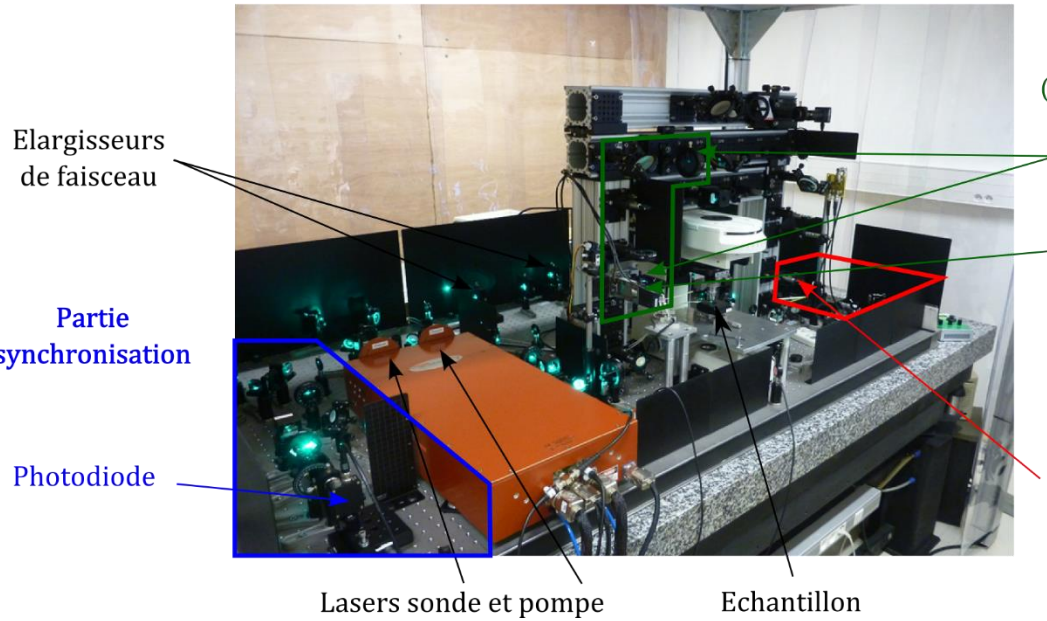


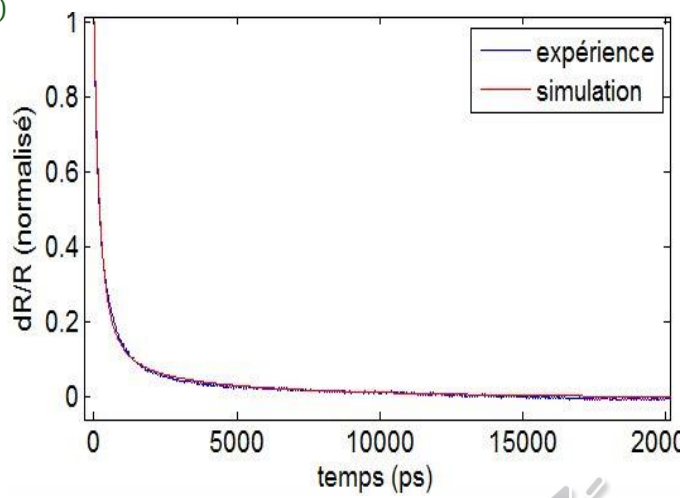
Optimal thermal conductivity measurement range: 0-20 W m^{-1} K^{-1};
Spatial resolution: 150 nm

T. P. Nguyen, L. Thiery , S. Euphrasie , S. Gomès , B. Hay, and P. Vairac, Calibration of thermocouple-based scanning thermal microscope in active mode (2ω method), Rev. Sci. Instrum. 90, 114901 (2019); https://doi.org/10.1063/1.5119044.
T. P. Nguyen, L. Thiery, S. Euphrasie, E. Lemaire, S. Khan, D. Briand, L. Aigouy, S. Gomes and P. Vairac, J Heat Transfer 141(7) 071601 (2019); HT-18-1667; doi: 10.1115/1.4043381.

Time Domain Thermoreflectance (TDTR)

- Femtosecond pump probe set-up with ASOPS (Asynchronous Optical Sampling) technique, designed by S. Dilhaire *et al.* (LOMA, Bordeaux)
- 2 Yb fs laser (1030 nm or 515 nm) with a controlled shift in repetition rate (~48 MHz)
- Typical spot radius ~1 µm to several µm
- Typical pump power density a few mW/µm²
- Time resolution ~1 ps
- Thermal conductivities & interface resistances extraction by fitting model to exp. curves
- For now, mostly used for picosecond acoustic and not TDTR

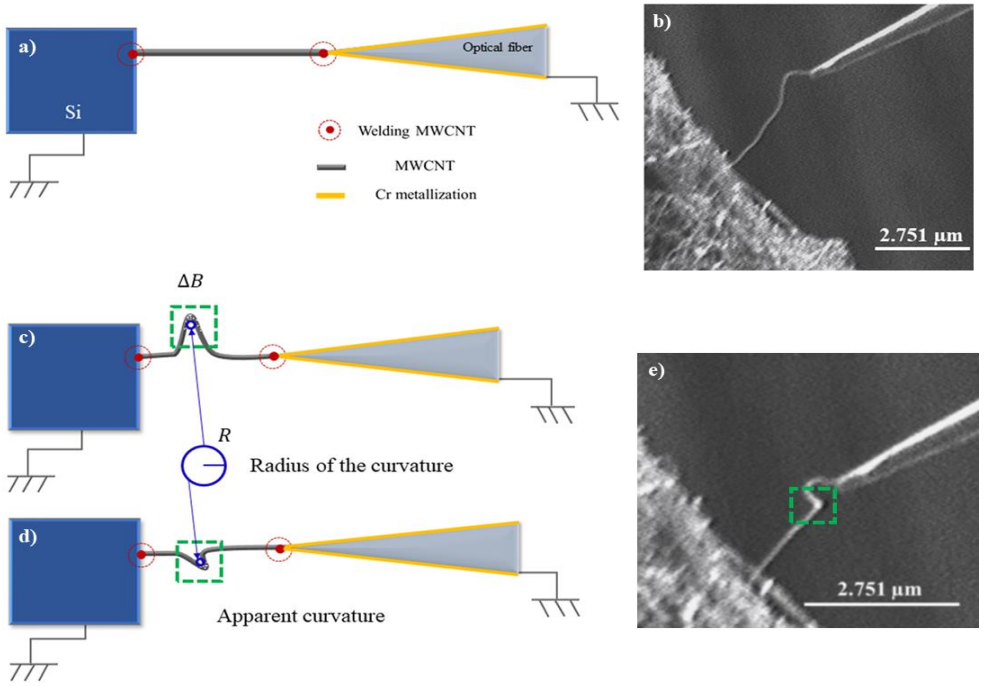




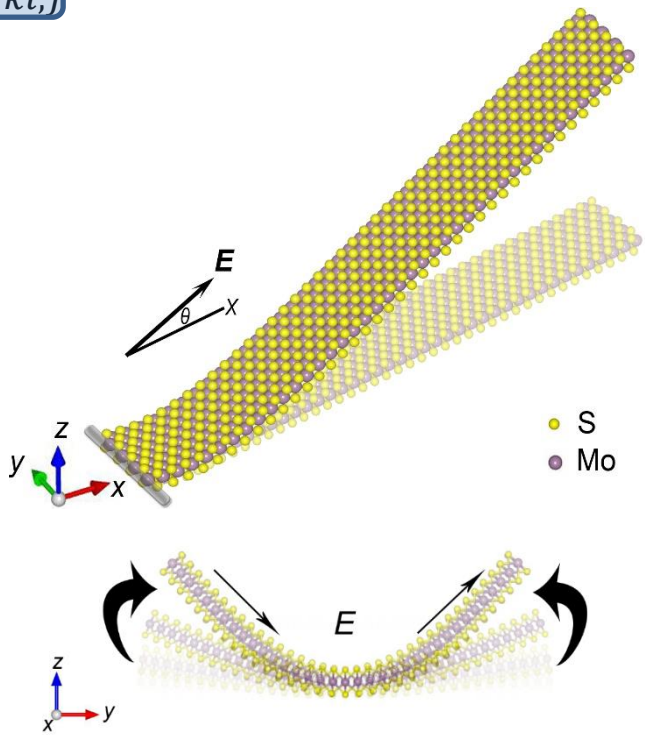
GDR Nanomaterials for Energy Applications

Flexoelectricity

$$P_i = \varepsilon_0 \chi_{ij} E_j + e_{ijk} u_{jk} + \mu_{klij} u_{kl,j}$$



R. El Beainou et al. (submitted)



Y. Yang et al. (to be submitted)

- Simulation Method: Molecular Dynamics with Gaussian-regularized QP model[1-2] + link with continuum physics [3] (locally developed codes / LAMMPS)
- Applications targeted: thermal energy harvesting or flexible strain gradient sensors ; predict flexoelectricity tensor of heterostructures of 2D materials
- Numbers: PZT-mwCNT nanogenerator was found to produce a peak output voltage of 8.6 V and an output current of 47 nA when a force of 20 N was applied (Han et al., Sci. Rep., **6**, 29562 (2016).
  $\mu^*_{eff}(MoS_2) \approx 0{,}065$ nC/m (Brennan et al., APL, **116**, 053101 (2020)
  $|\mu| \sim \chi\, e/a$. 4µC/m measured for $Pb(Mg_{1/3}Nb_{2/3})O_3$ (Ma, Cross, APL, **78**, 1920 (2001)). $d_{33}^{eff}(BST) > 2\ \mu C/N$

1. *Z. Wang, M. Devel, Phys. Rev. B, **76**, 195434-1 à -5 (2007)*
2. *Y. Yang, M. Devel, Z. Wang, J. Chem. Phys., **149**, 124102-1 to 124102-7 (2018),*
3. *G. Lecoutre, N. Daher, M. Devel, L. Hirsinger, Acta Mech., **228**, 1681-1710 (2017)*