



Nano Electro Mechanical Systems and interactions at nanoscale

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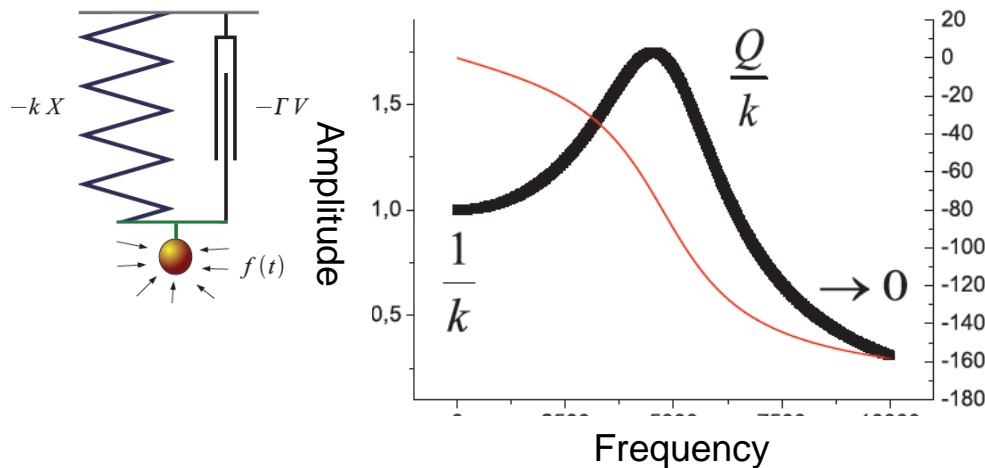
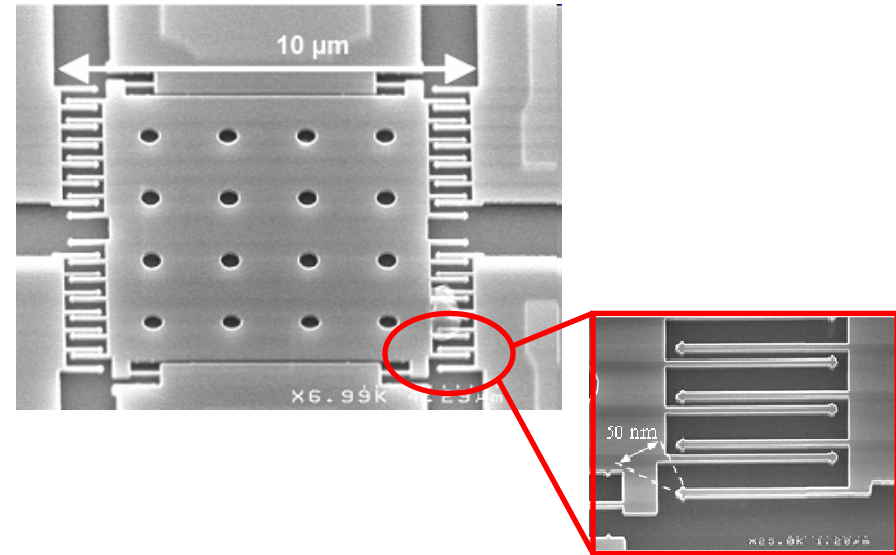
Hubert Grange, CEA-LETI/MINATEC Grenoble



Nano Electro Mechanical Systems (NEMS)

NEMS are devices integrating electrical and mechanical functionalities at the nanoscale.

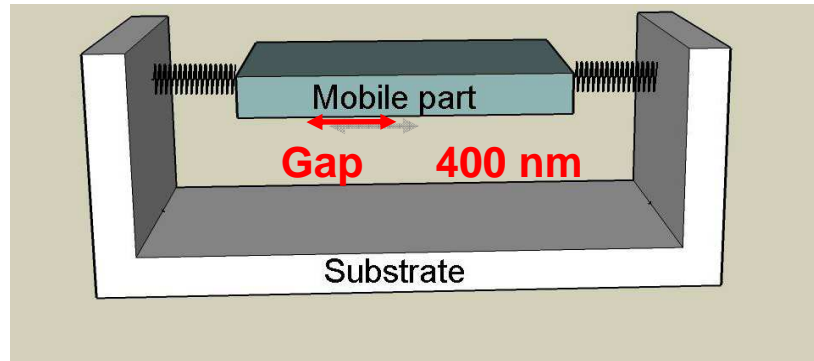
NEMS are among the best candidates for measurement of interactions at nanoscale



NEMS resonators can be assimilated to harmonic oscillators

Phase

$$\chi(\omega) \equiv \frac{1}{m(\omega_0^2 - \omega^2) + i\gamma\omega}$$



NEMS standard scheme:

- Mobile part suspended over a fixed substrate;
- Gap from tens nanometers to several microns;
- Plane-Plane geometry.

Interactions between mobile and fixed parts can dominate the NEMS dynamics

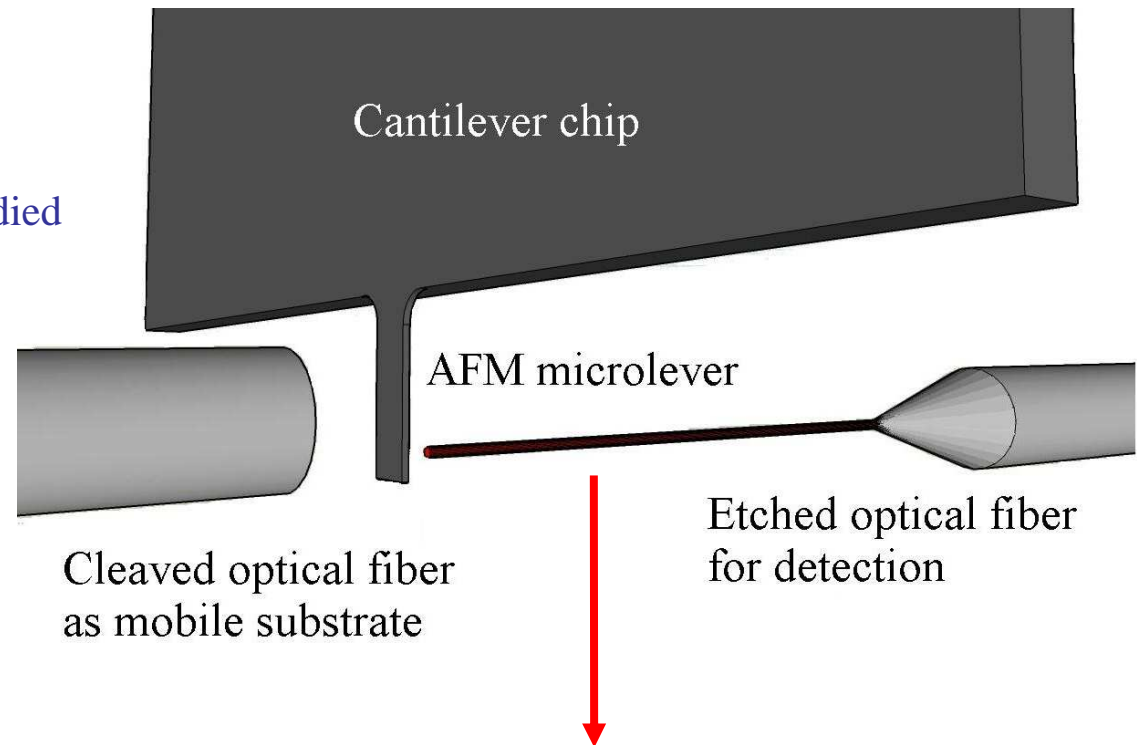
- Chemical forces;
- Van der Waals and Casimir forces
- Electrostatic (residual) forces;
- Optical forces;
- Hydrodynamic forces;
- Near field thermal radiation.

Hydrodynamic forces at short distances

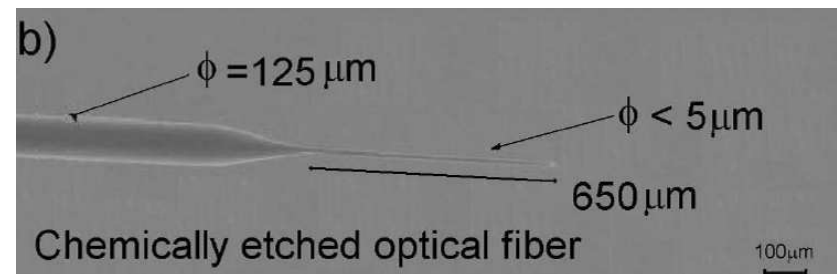
The oscillating behavior of a lever is studied when an “infinite” wall is gradually approached.

This system mimics a MEMS oscillating closed to a substrate

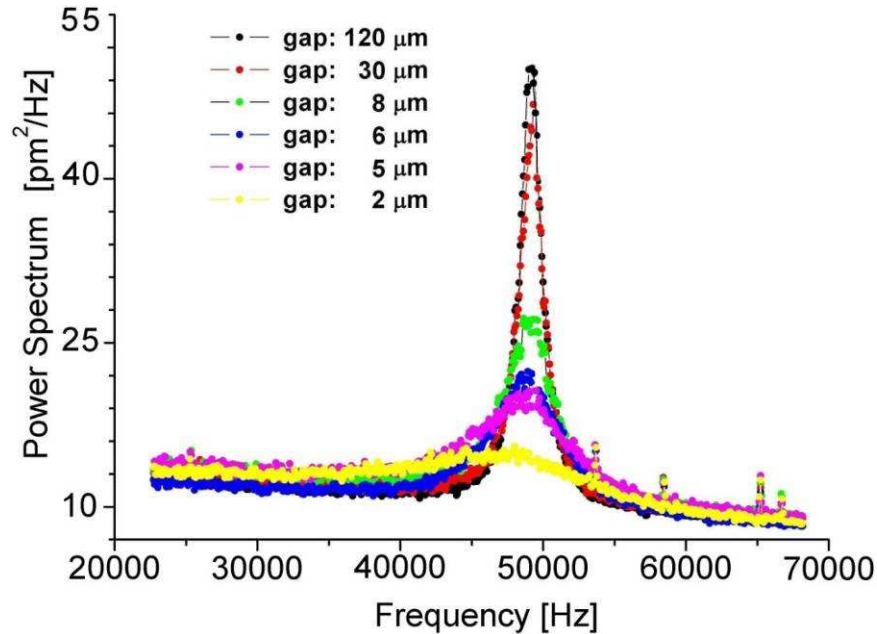
Si cantilever:
 $L = 107 \mu\text{m}$
 $w = 30 \mu\text{m}$
 $t = 0.18 \mu\text{m}$
 $\omega_0/2\pi \approx 50 \text{ kHz}$



No additional damping



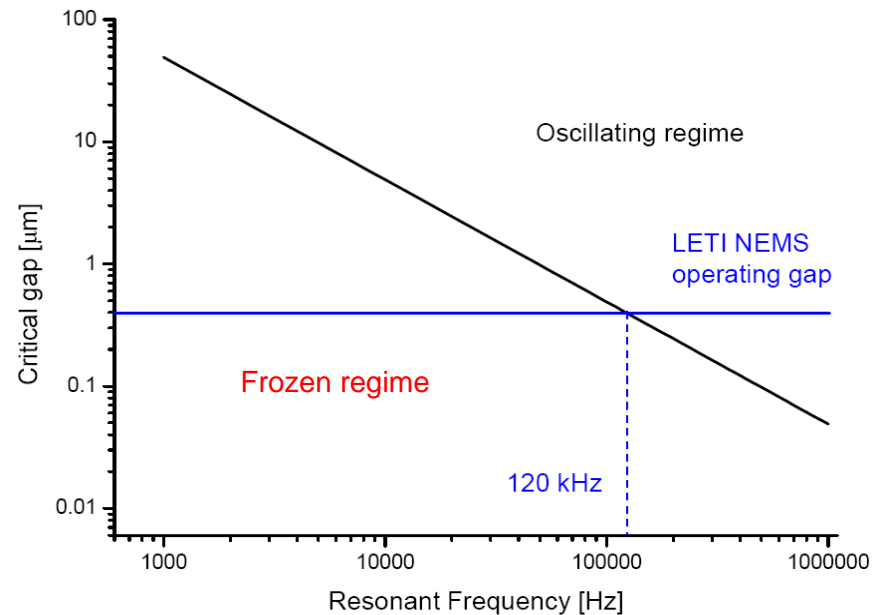
Hydrodynamic forces at short distances



The lever is thermally actuated.
 With decreasing gap in micrometer range we observe a broadening and softening of fundamental resonance.

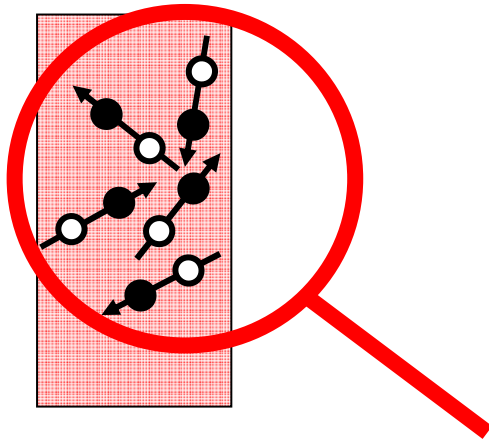
If the gap is small enough air confinement can eventually freeze the mechanical oscillator

$$Gap_{crit} = \frac{\sqrt{2}\eta}{m} \frac{A}{\omega_0} \quad \square \quad \omega' = 0$$

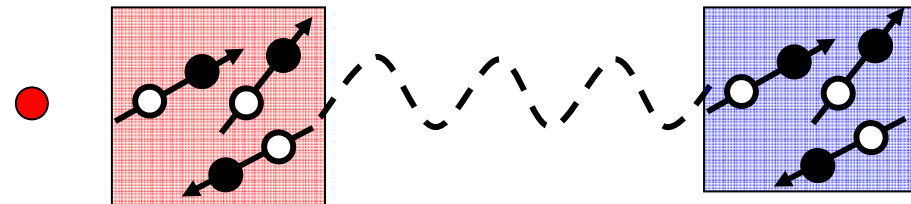


Near-field radiative heat transfer

Fluctuating dipole
induced by thermal effect

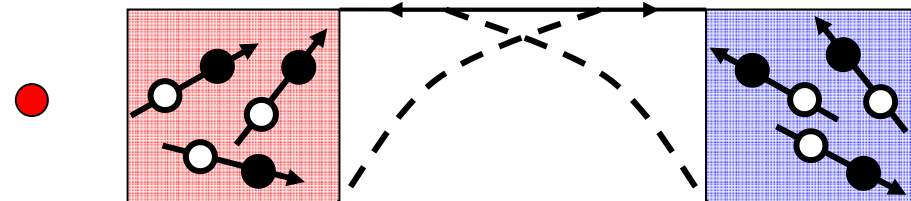


FAR-FIELD: propagative waves



Independent by distance

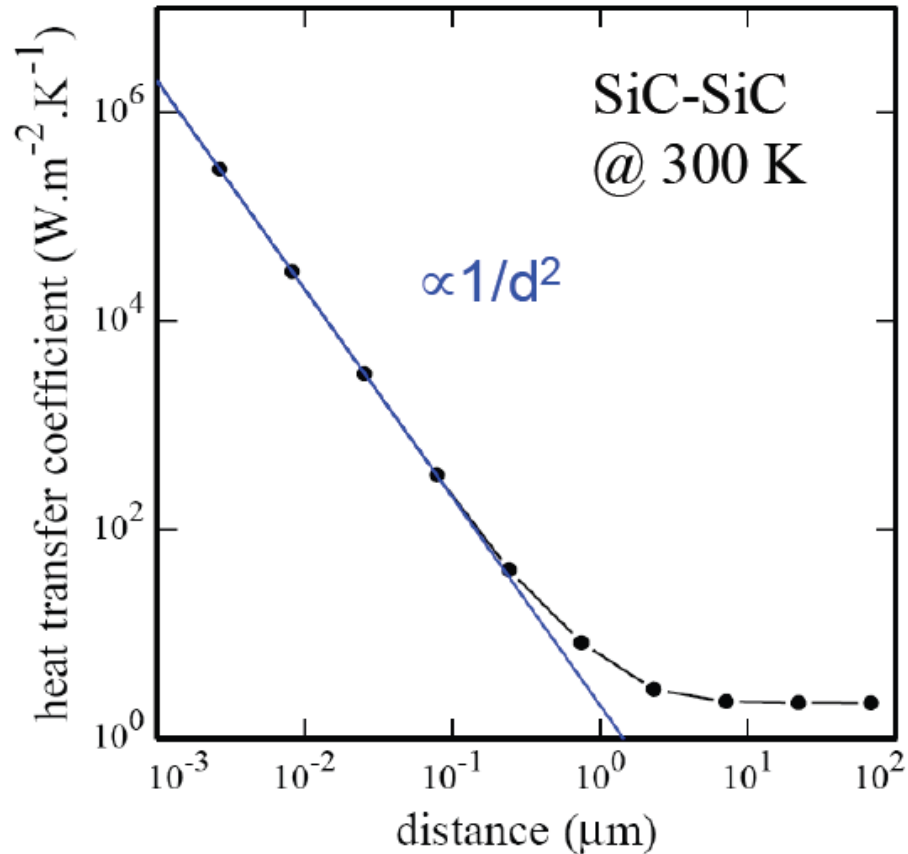
NEAR-FIELD: evanescent waves



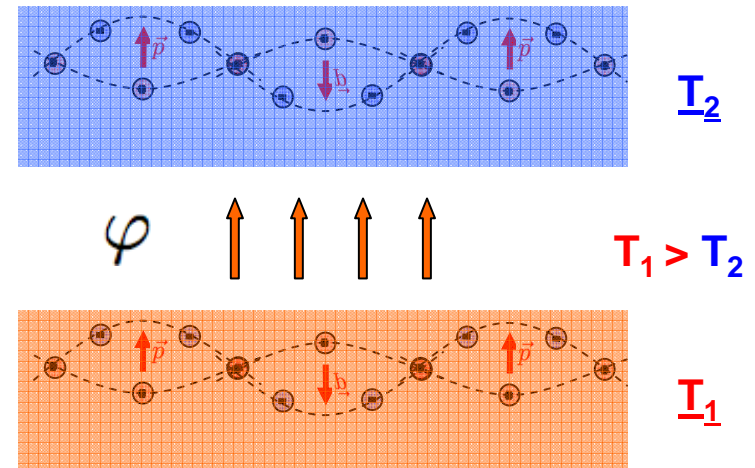
Strongly dependent by distance

Dielectric materials: surface Phonon-Polariton enhancement effect

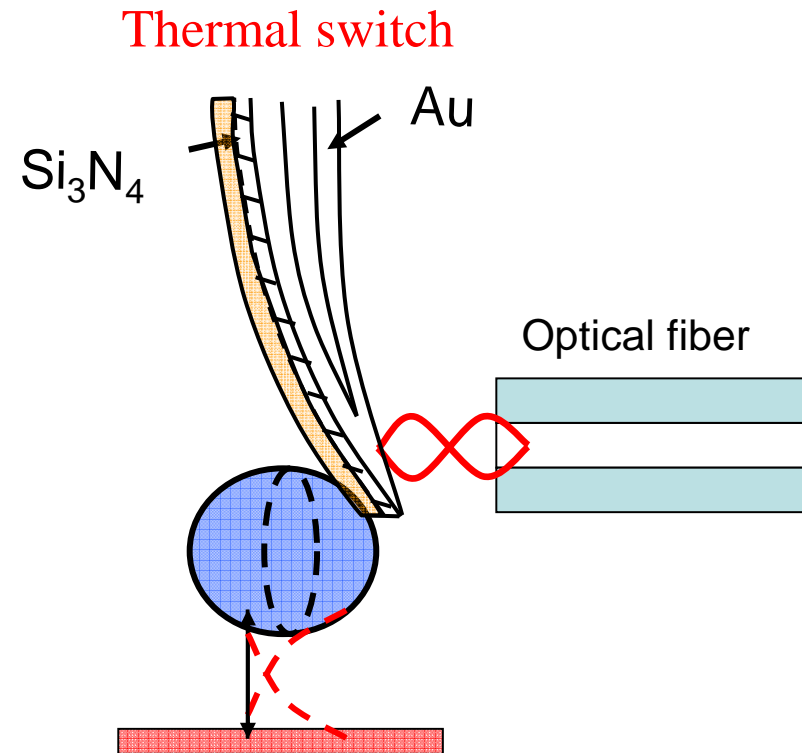
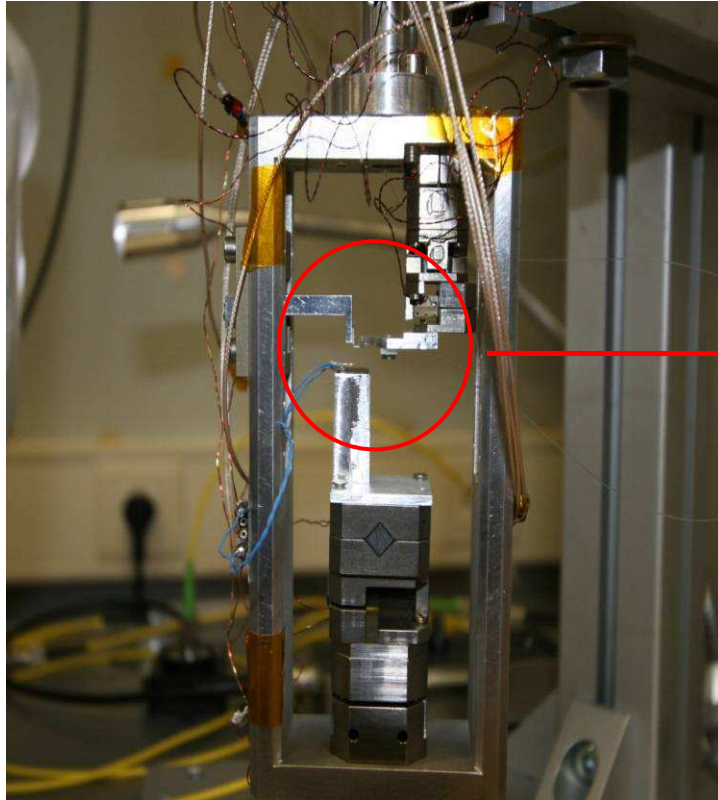
Theoretical model



Plane-Plane geometry

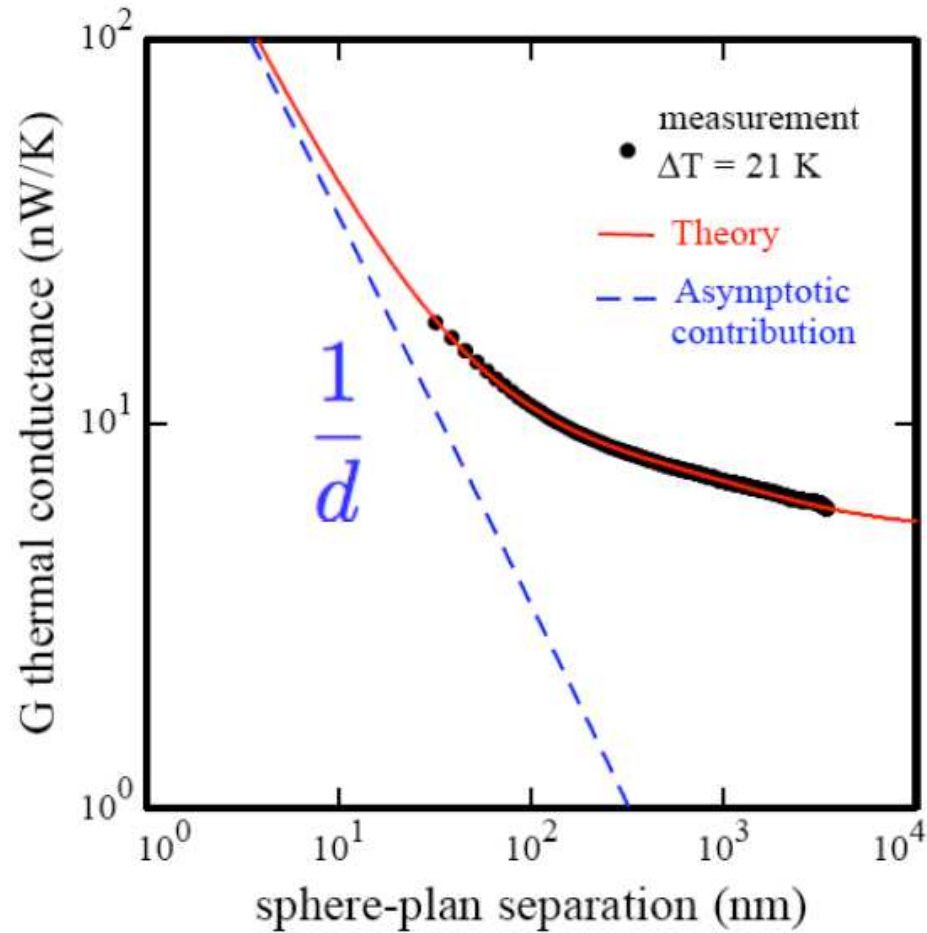


Experimental set-up



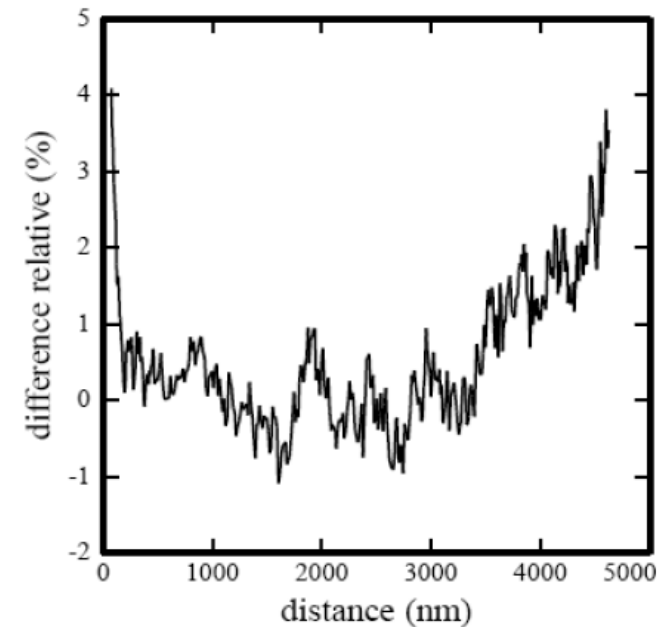
- Power exchanged = lever deflection : thermal switch effect on the lever
- High vacuum $P \sim 10^{-6}$ mbar : conduction negligible
- $\Delta T = 10-20$ K.

Comparison Experiments-theory



Glass sphere – glass plane

Sphere diameter 40 μm





Aknowledgements

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