Thin Film Measurement Facilities

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N.i.P.S Laboratory
Noise in Physical Systems

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Introduction

The measurement of losses in coating materials is a great challenge. A lot of different techniques and facilities are used around the world to improve our understanding of them.

Our idea is to perform a direct measurement of the thermal noise of thin membranes (~100 nm) using **2 facilities**:

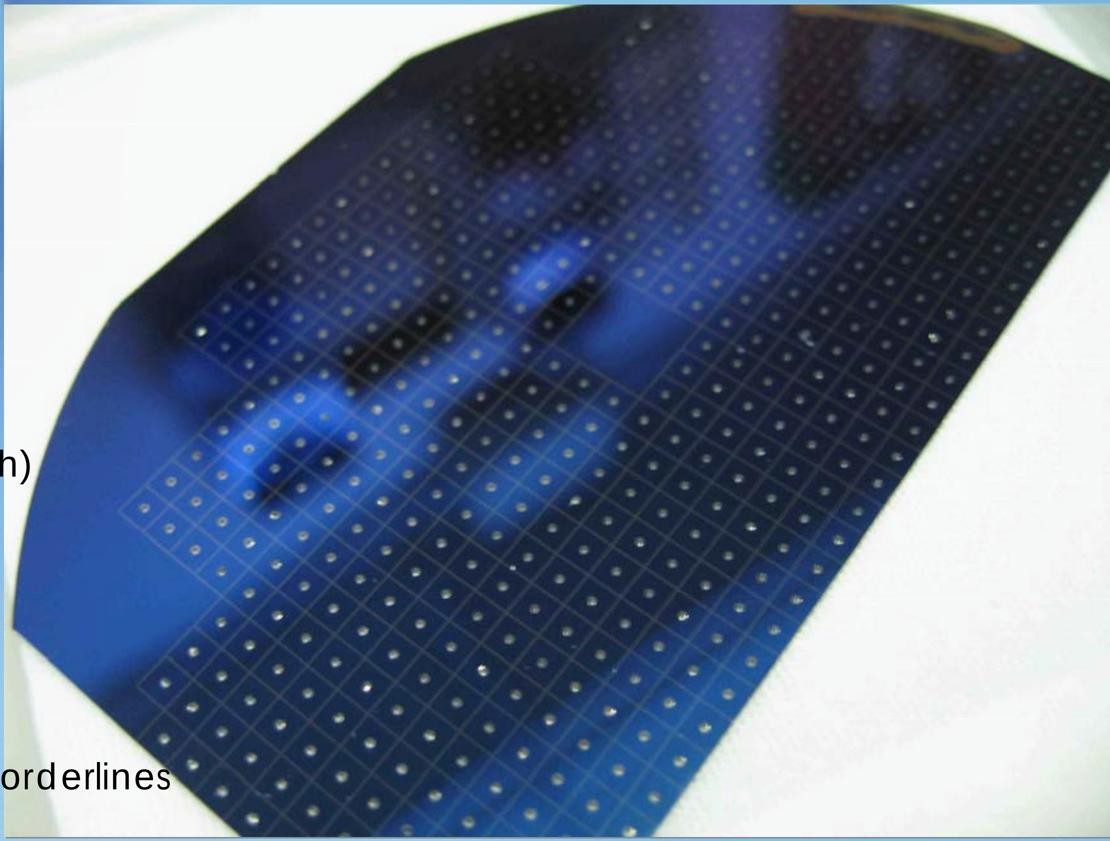
1) **Michelson Morley** interferometer
2) **Non stationary facility**: stabilized Fabry-Perot cavity

We aim at obtaining the following data:

- **Direct measurement** of the coating thermal noise
- Difference between the coating with and without the substrate: **skin-deep stress** and **annealing behavior**
- Dynamics of a system **out of stationary condition (relaxation to equilibrium)**

In this talk I'll present the idea, the status of the facilities, the different material we would use in the future, the data we would find and the problems we have to overcome.

Sample



Si-wafer:

diameter 10 cm (4")
thickness ~ 500 µm

Al2O3 film (both sides)/membranes:

thickness 92 - 96 nm (a bit rough)

Holes etched through the Si-wafer:

diameter ~ 500 µm

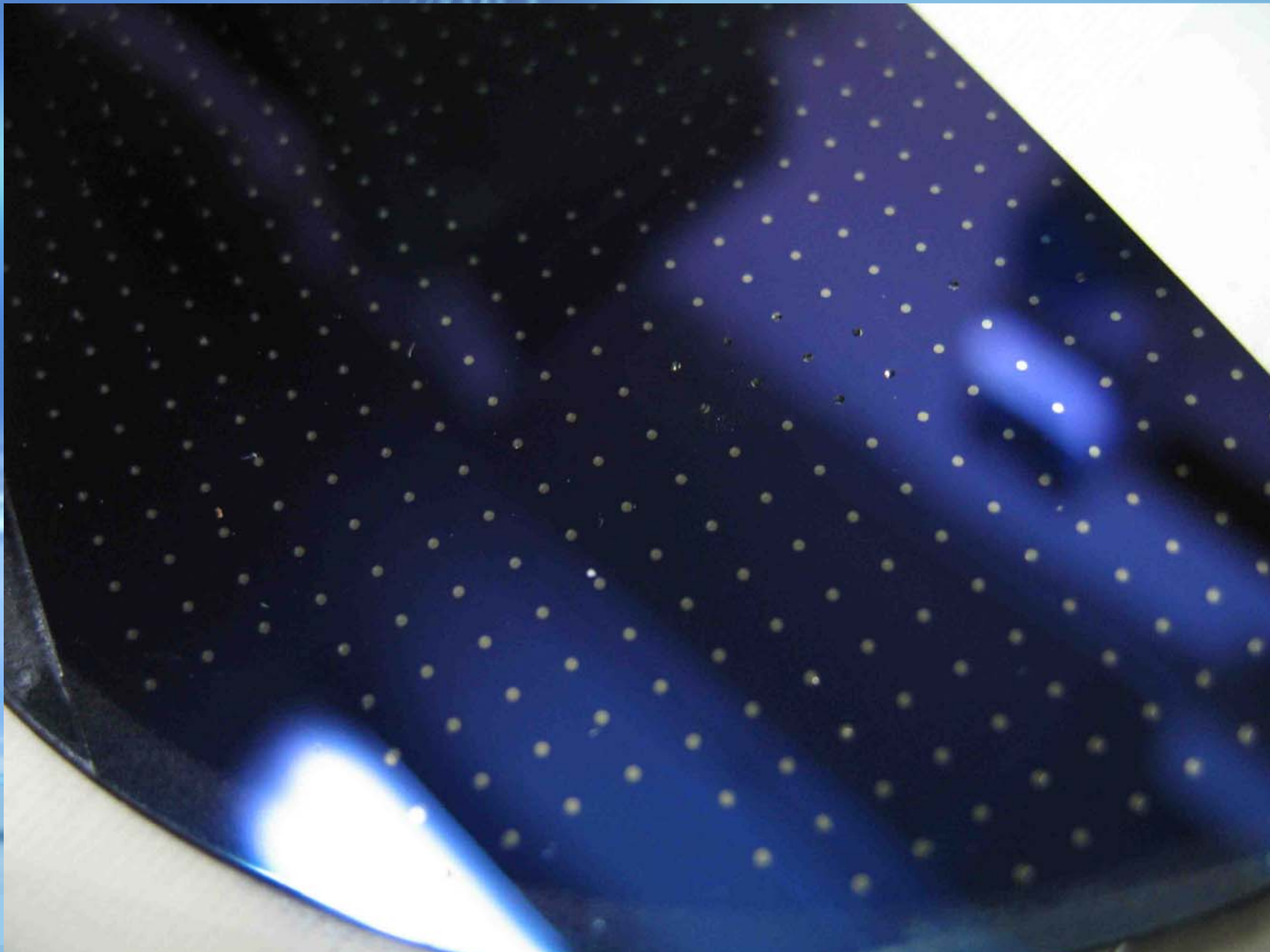
Chip size:

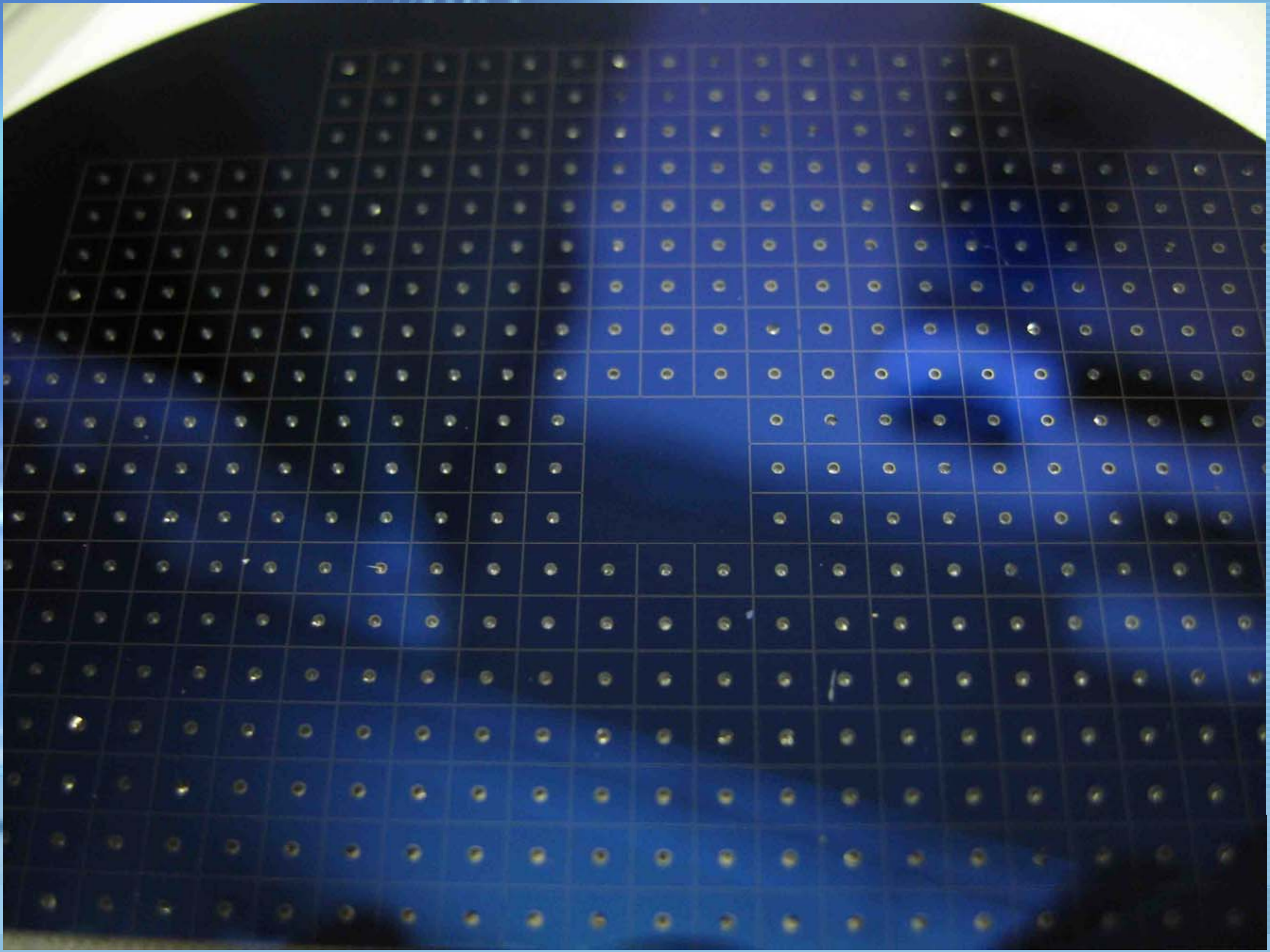
square, ~ 2.5 mm x 2.5 mm;
chips defined by etching the borderlines
half way through the wafer

Supplier:

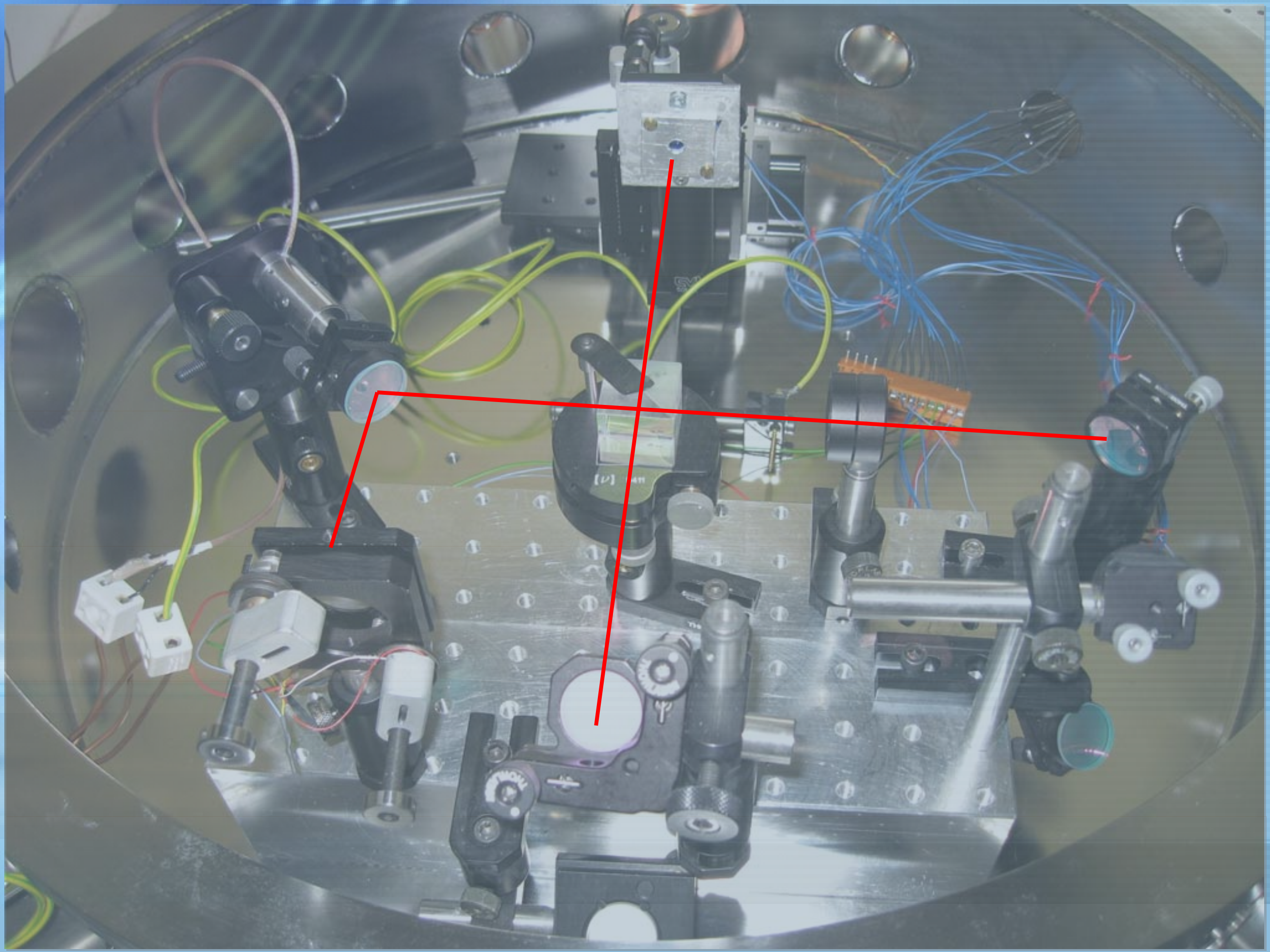
VTT - Technical Research Centre
of Finland on Micro and Nanoelectronics

...with ALO the process is easy - just coating, patterning and etching; no annealing. ALD ALO is rather uniform; it should have less than 1% thickness variation over the wafer and rather small surface roughness. As the surface roughness of ALO on substrate is the same as in the membranes, you can easily measure it with AFM if interested. *(email from VTT)*



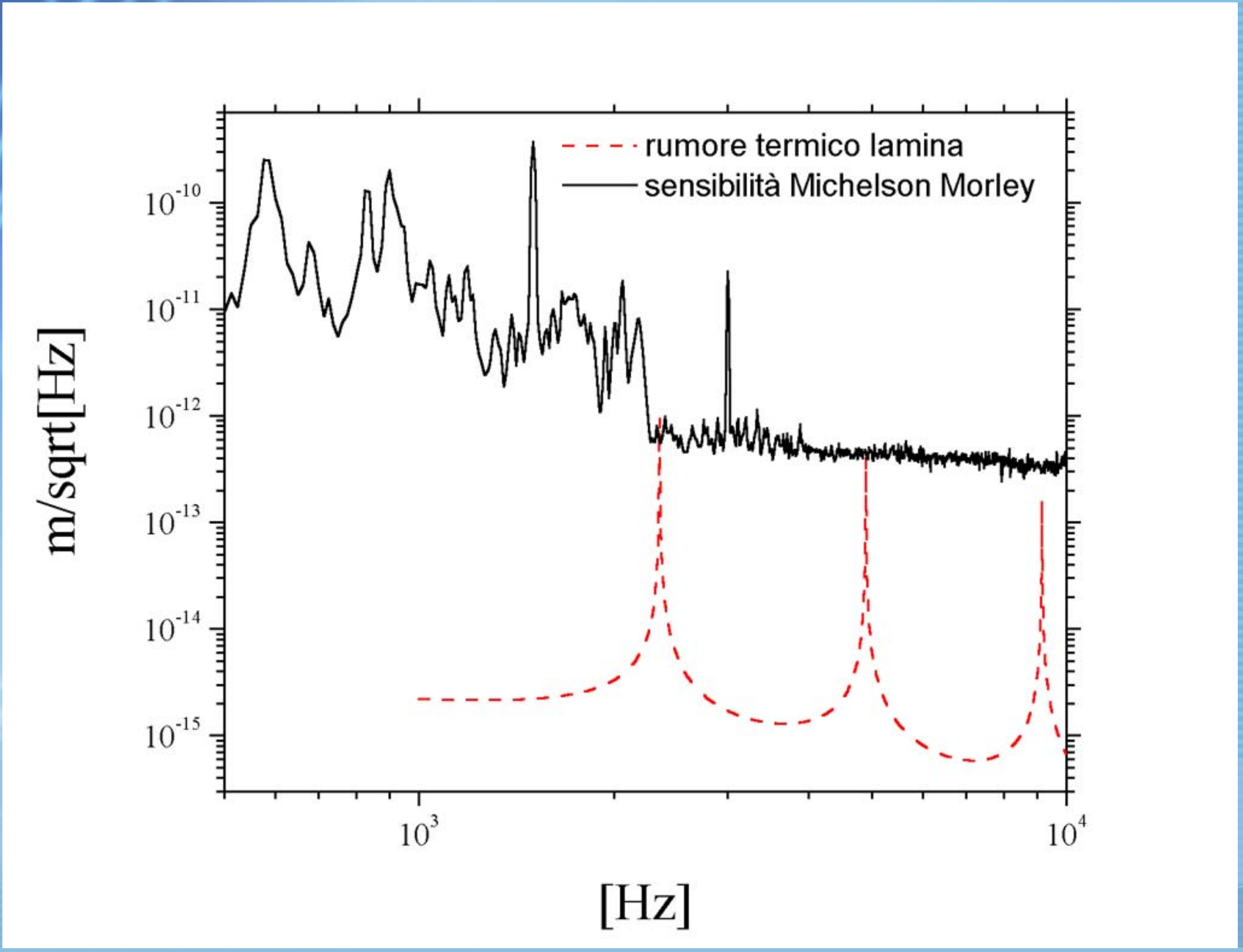


1 – Michelson Thermal Noise Facility

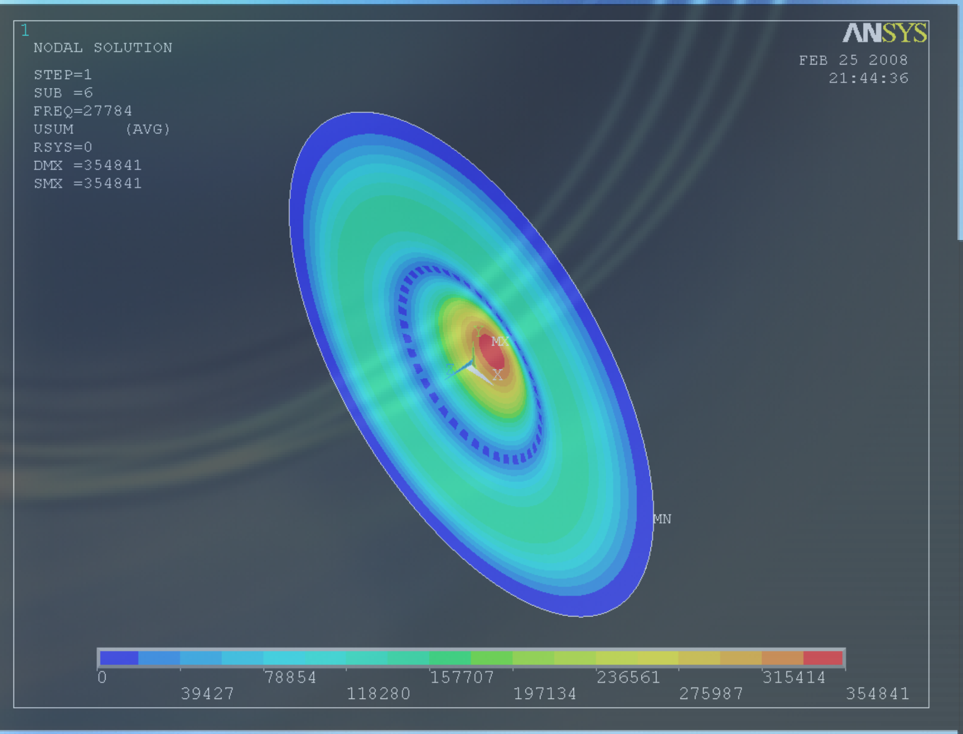


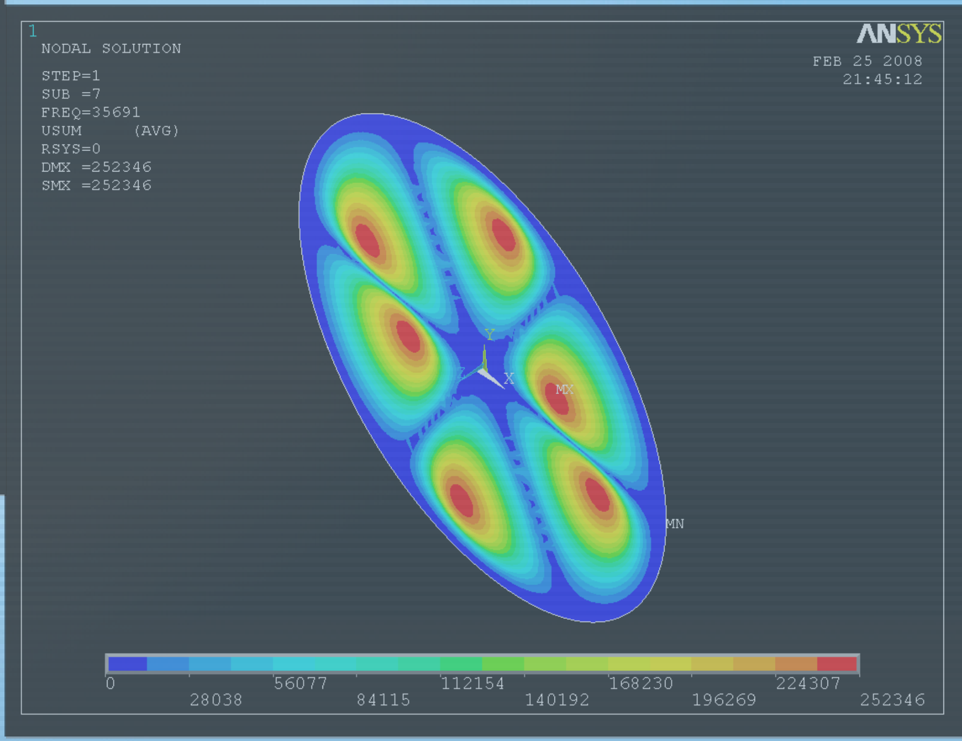
Why a Michelson?

Very simple optical scheme with a good sensitivity: very fast measurements to increase our statistics about a parameter we would study



Estimated RMS for the membranes





FEM Simulation: rms ~ 10^{-10}m
at about 7kHz

Measurements in progress

- **“Direct measurement”** of the thermal noise

- Correlation between the **coating stress and the thermal noise**: the original coating is not annealed. We can divide the Si-wafer in different pieces and anneal them with different process in order to see how the TN changes.

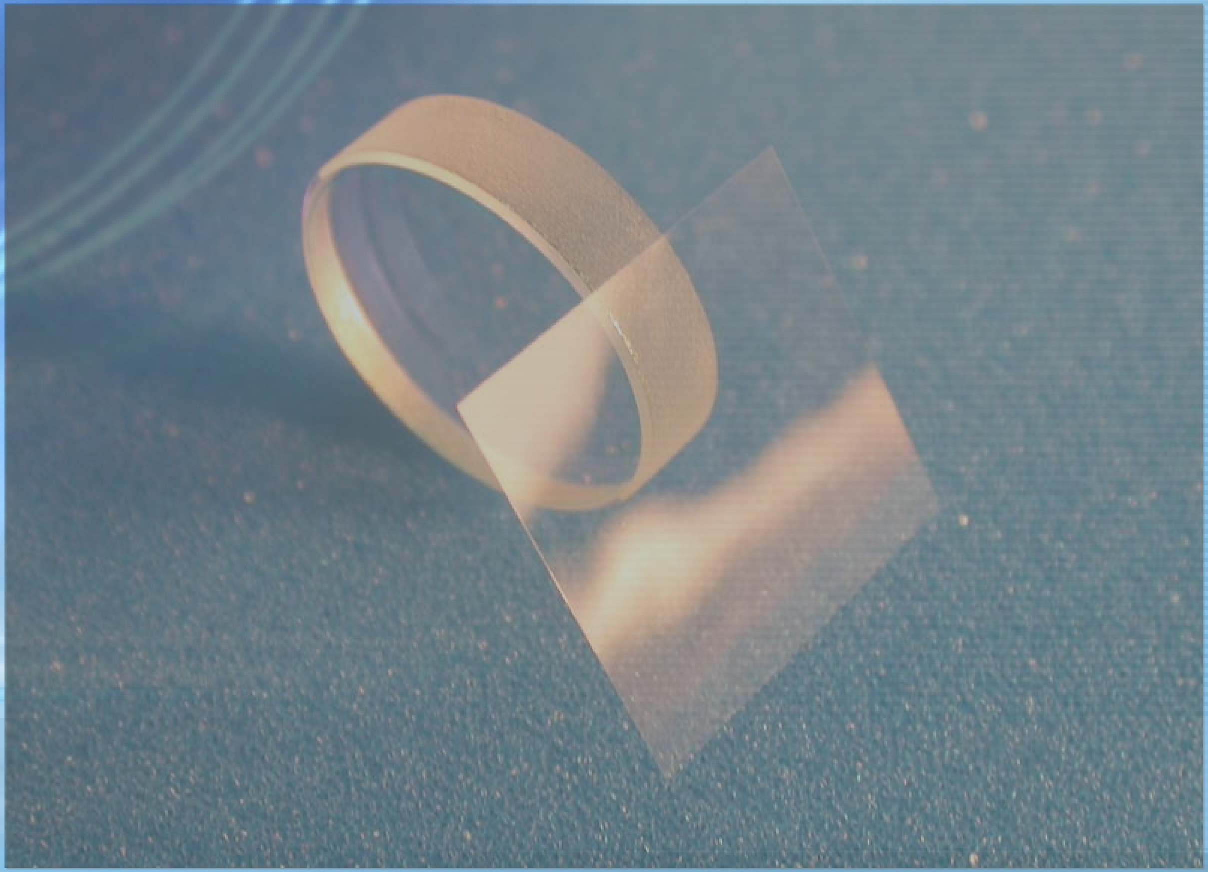
This idea is suitable for whatever process you can imagine

- **Use of different materials**: tantala and silica

For the etching process the use of tantala or the use of silica could be ok. To avoid any dubt the VTT laboratories could check it the next future

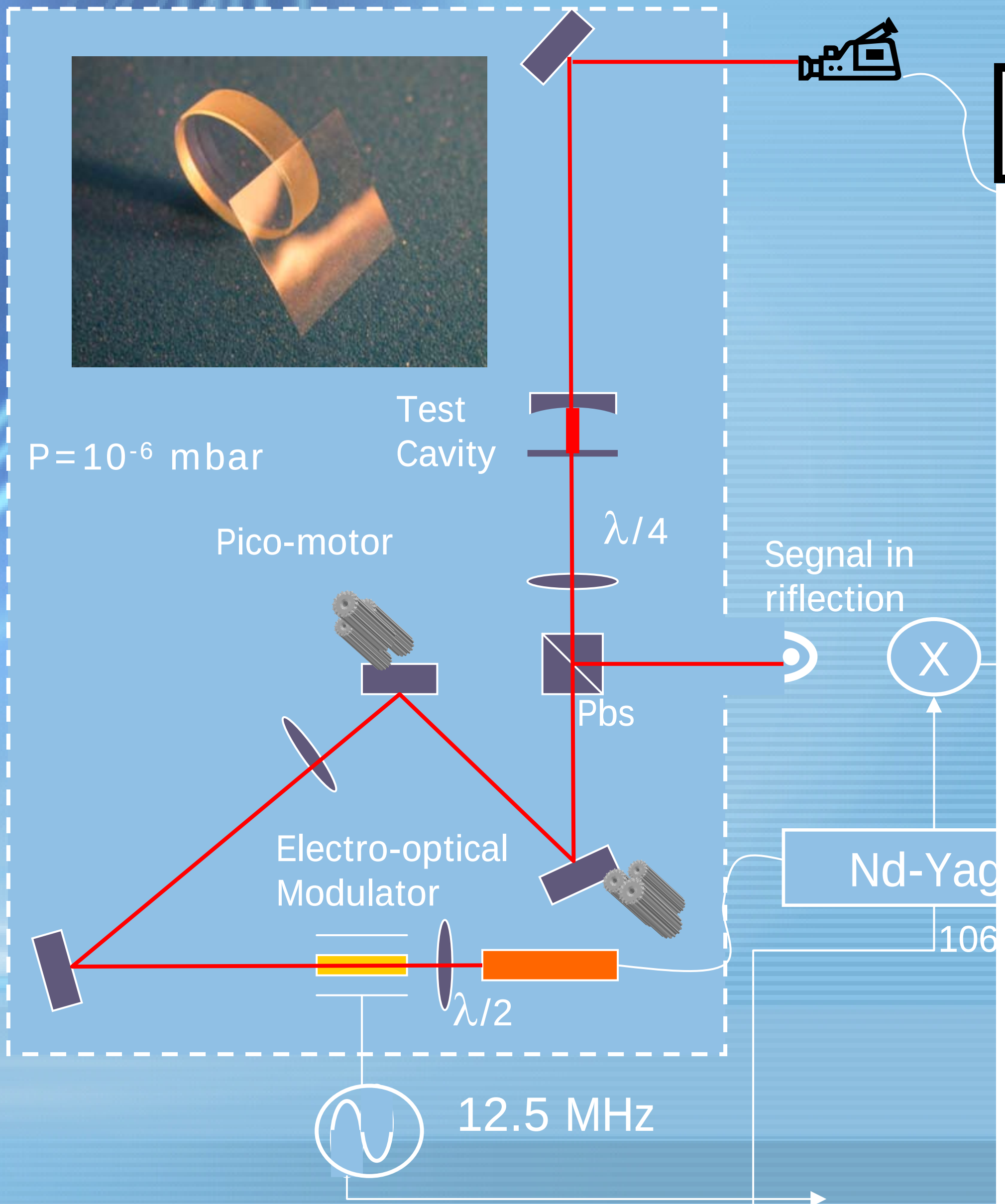
In the past the VTT labs tested the SiN and the a-Si:H

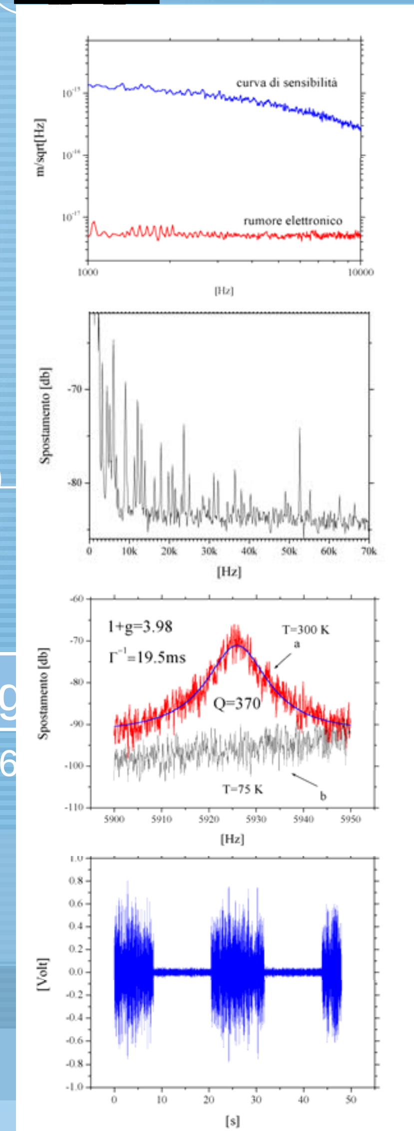
2 – Non stationary Thermal Noise Facility



Non-stationary thermal noise

Schema ottico





Purpose

To understand the dynamics of a perturbed system at thermal equilibrium or rather:

- read directly the thermal noise of a thin slab

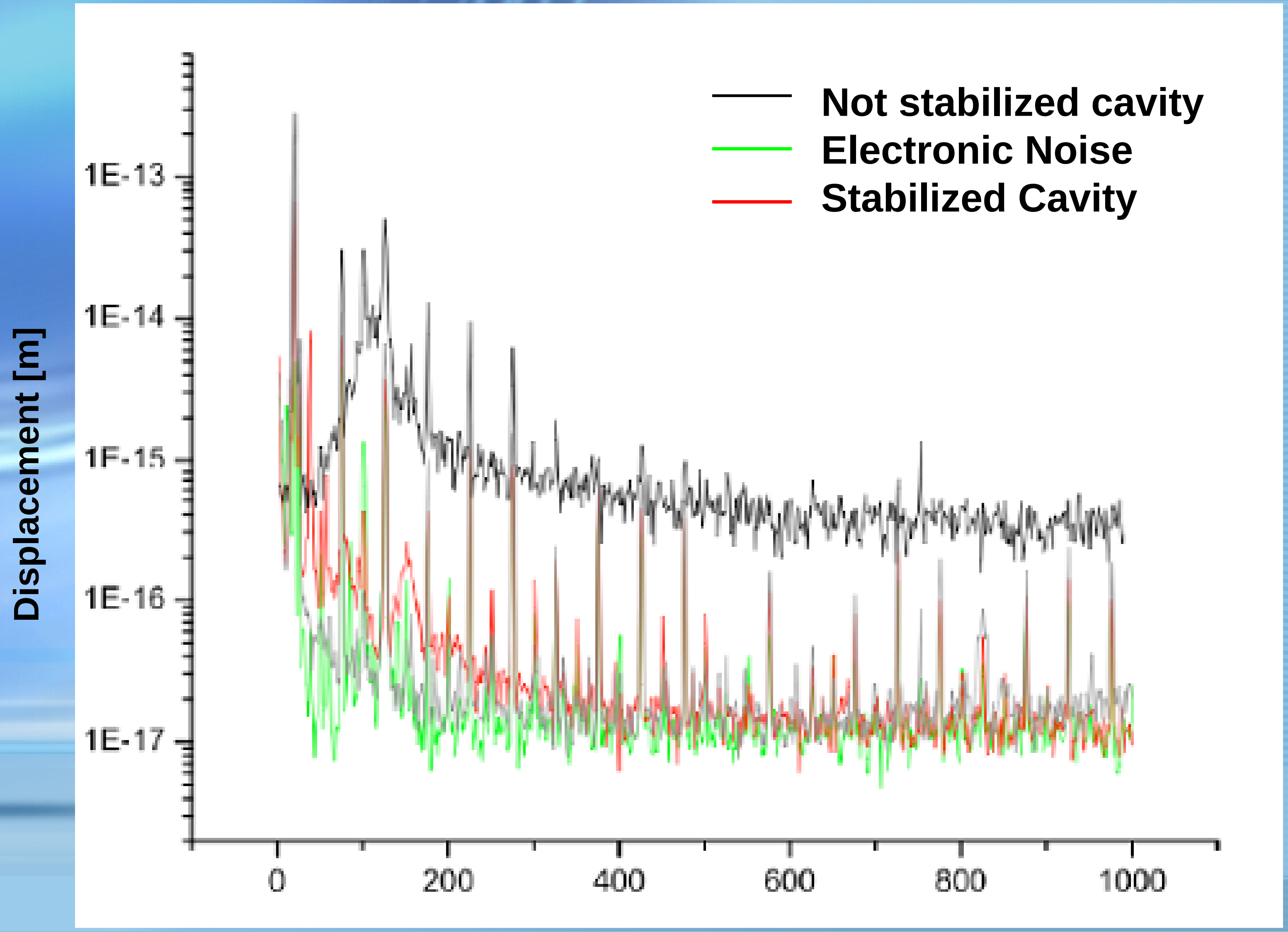
- reduce a TN peak with a sine in counter-phase with the oscillation of the slab

- see how the peak comes back to the equilibrium: it should absorb energy from the other modes reducing the thermal noise

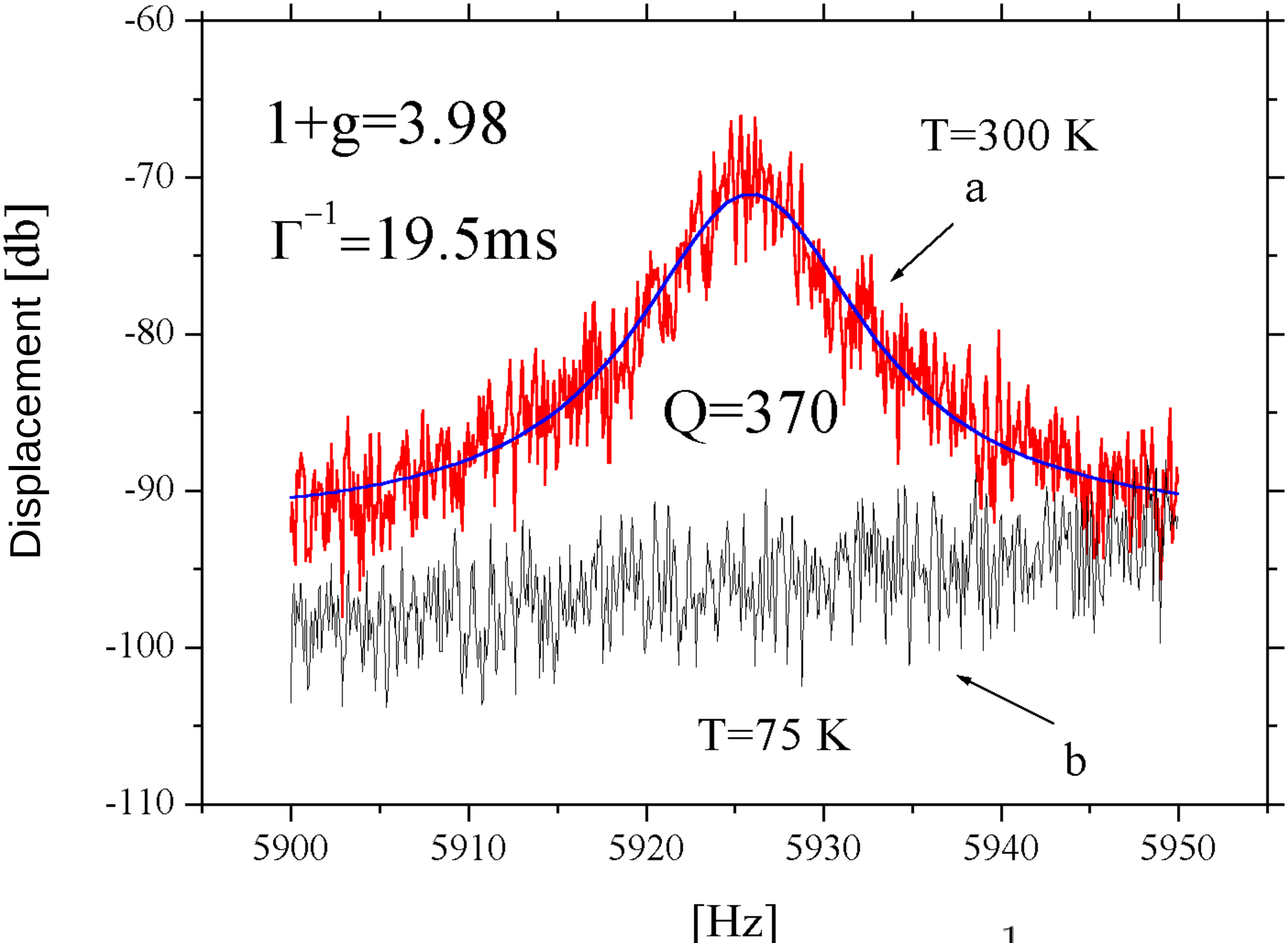
- see if the system changes its dynamics

- to improve the sensibility of an optical system driving the dynamics of the optics

New sensitivity



Frequency [Hz]



$$\frac{1}{2}M\omega_0^2\Delta x^2 = \frac{k_b T}{2(1+g)}$$

Results for the thin silica slab

With the past setup (thin slab and non stabilized cavity) we reduced the peak amplitude (mechanical cooling) in order to see how the system comes back to the thermal equilibrium:

- there is a **crosstalk** between the modes => it's very hard to understand if the perturbed peak is stealing energy from the slab and so if it’s improving the TN on the other region: **new exciter**

- the **rigidity** of the slab seems to change: if we could understand how to change this parameter we could move the peaks in order to reduce the thermal noise in a region of the spectrum with a particular interest

Work in progress:

Conclude our study on the **thin silica slab**: test of the stabilized cavity and the new exciter

Apply all we learned and all we are going to learn on the thin slab to the **membranes** in order to obtain the needed data on the substrate and on the coating to control both of them

Check the **maximum radius** for the hole: it depends on the coating material => different skin-deep stress

Summary

- **Advantage of the membranes**
  - Coating **without substrate**
  - **A lot of samples** (that we can work as we desire) just with a single coating run
  - **No so complex** as the NEMS..you can use the traditional facilities just paying more attention

- **Facilities**
  - Michelson: **very fast** measurements
  - Fabry-Perot cavity: Long and hard measurements to study the non stationary **dynamics of the substrates and of the coating**

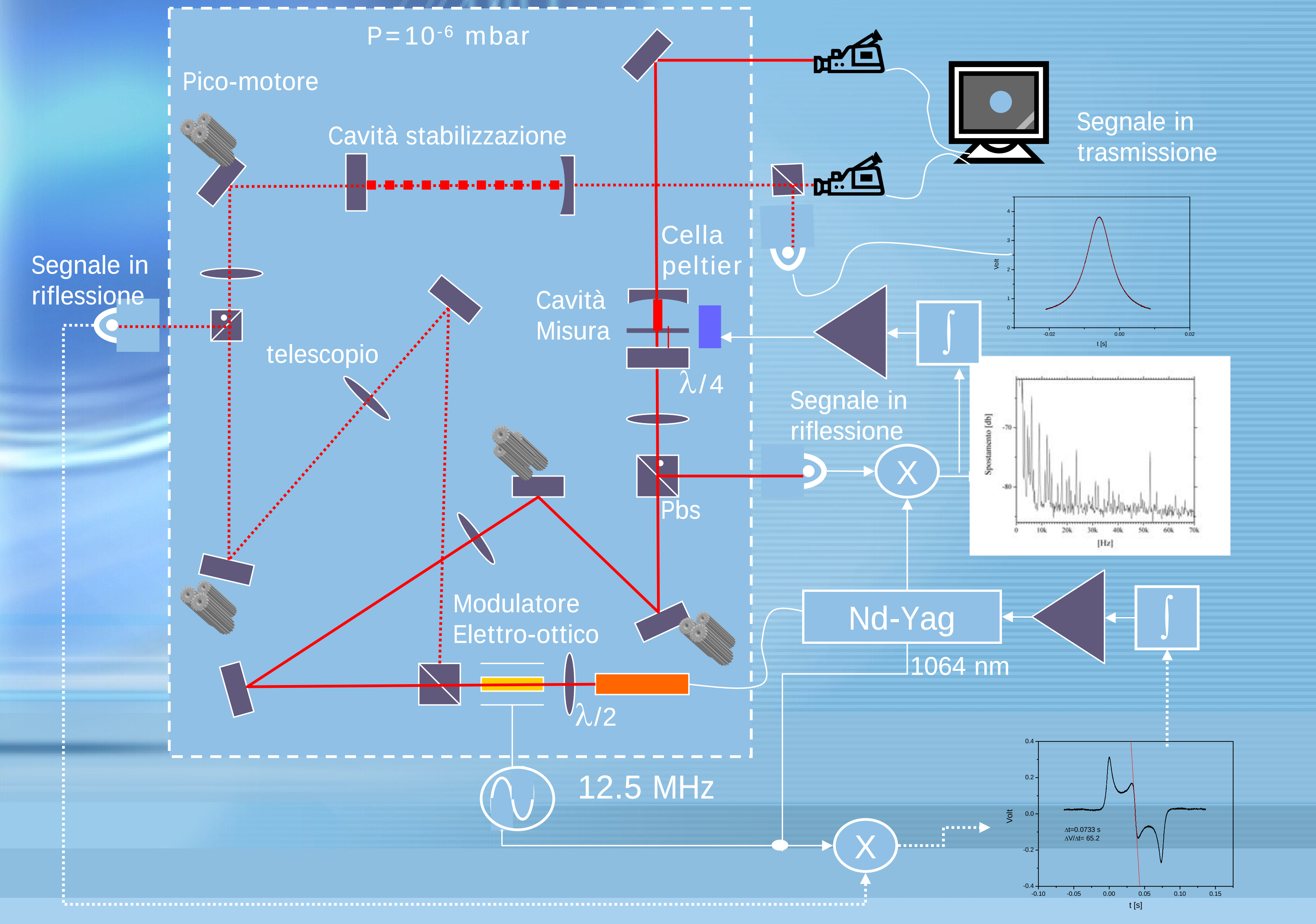
Facilities Status

- Michelson: optics, vacuum, electronics are ok…we are waiting for the **new laser** (I broke the old one the last weekend)

- Fabry-Perot cavity: we test the stabilized cavity but we have some **manpower problem**

The End

Non-Stationary Thermal Noise: stabilized cavity



Abstract..

The measurement of losses in coating materials is a great challenge. A lot of different techniques and facilities are used around the world to improve our understanding of them. Our idea is to use a very focused Michelson interferometer to read directly the thermal noise of a thin membrane. The thickness of these membranes is 100 nm (very similar to the thickness of a single layer in a standard coating: 130-182 nm), the diameter is about 0.5mm while the material is sapphire. The membrane is obtained by etching a coated silicon substrate. In this way we have a little free coating without any substrate or rather a little membrane. Performing a FEM simulation we evaluated the rms, about 10-10 m - a value comparable with the sensitivity of a good Michelson interferometer.

We plan to obtain the following data:
1) Direct measurement of the coating thermal noise
2) Difference between the coating with and without the substrate: skin-deep stress and annealing behavior

In this talk I'll present the idea, the status of the facility, the different material we would use in the future, the data we would find and the problems we have to overcome.