1st KV 3G Workshop

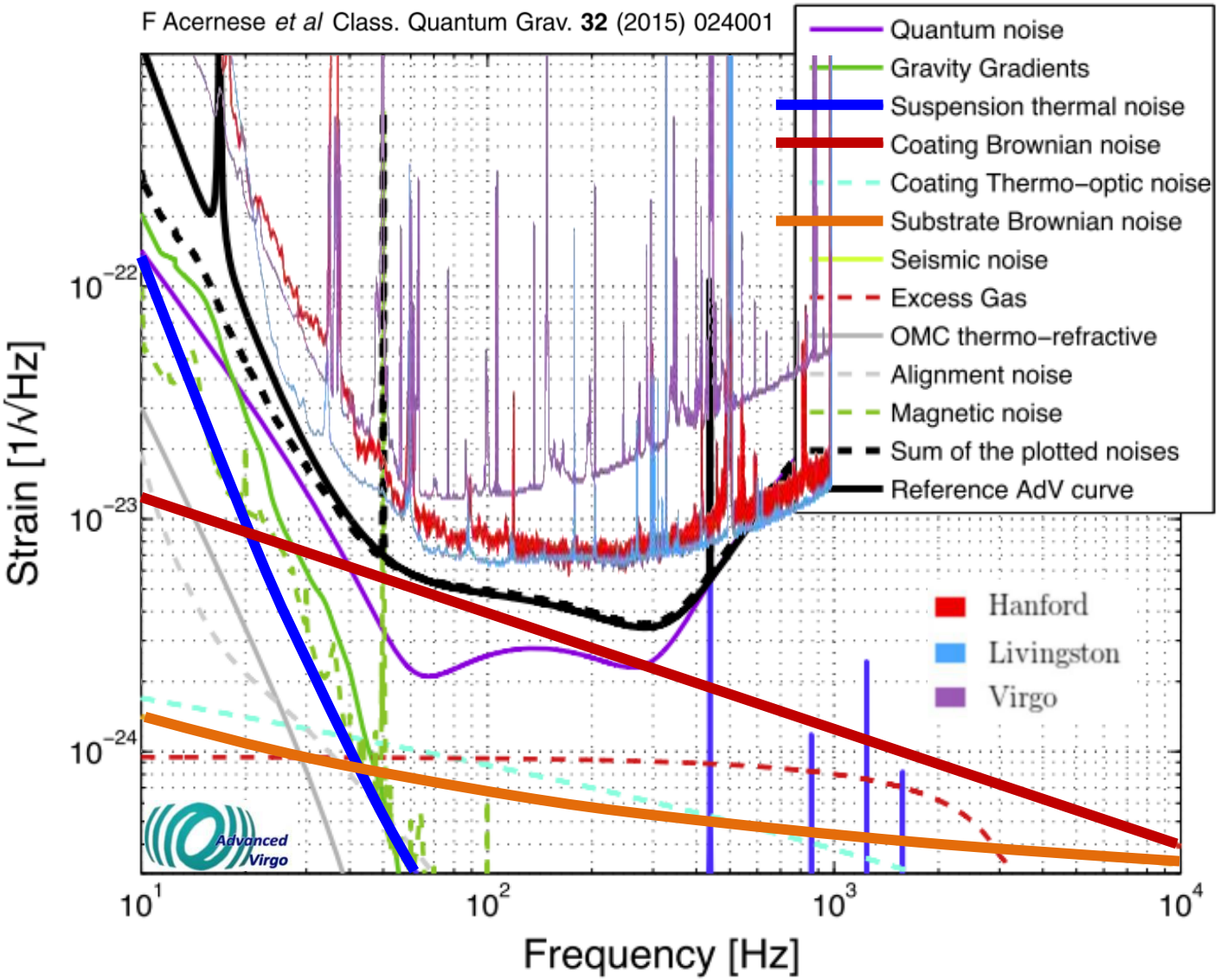
Amorphous materials investigation in optical coatings: the VCR&D perspective for the 3G detectors

Gianpietro Cagnoli

gianpietro.cagnoli@univ-lyon1.fr

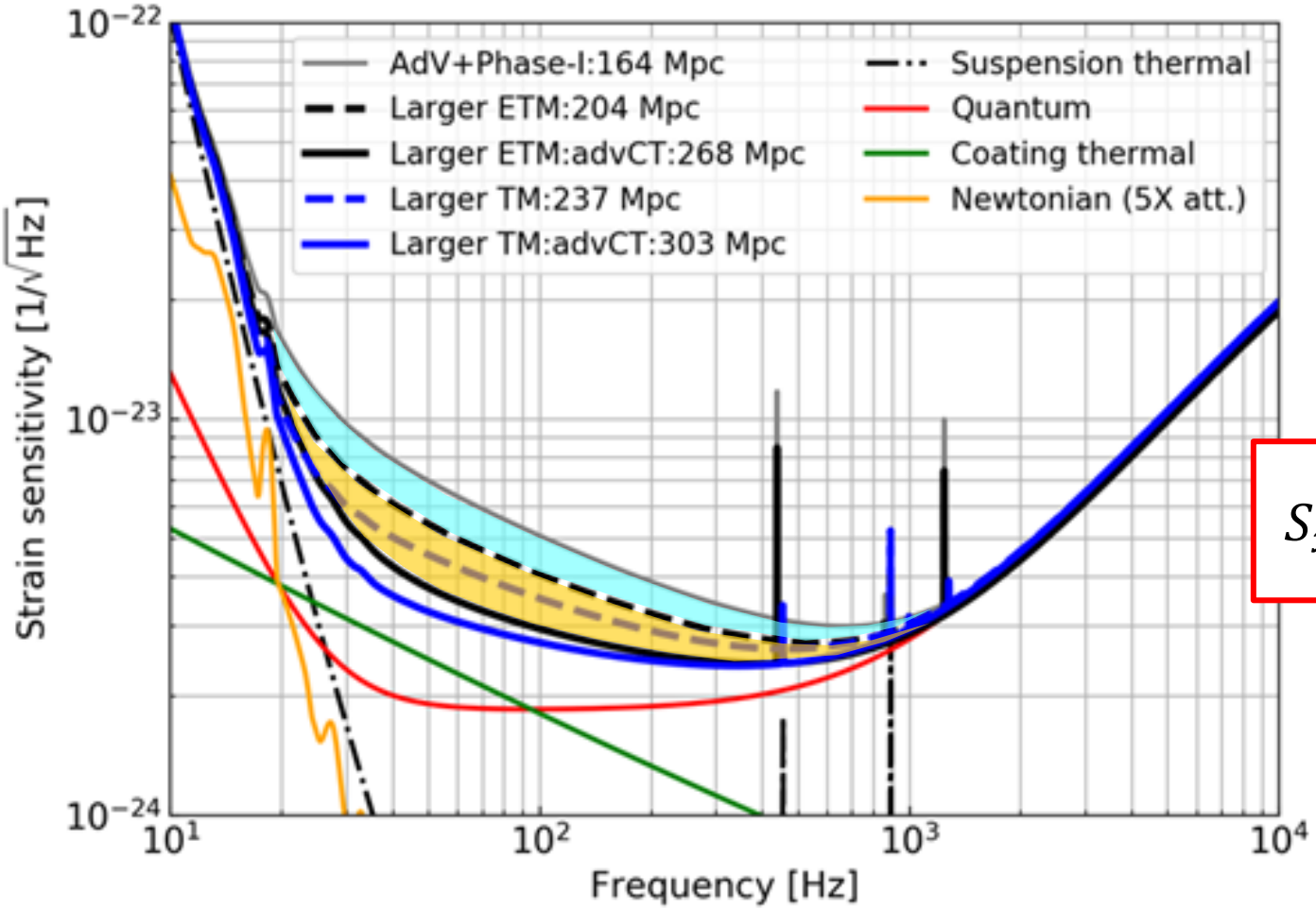
Better glasses on mirrors
and
replacement of steel wires with
silica fibres
made possible the detection of GW

The situation today



Can amorphous materials take the challenge of future detectors ?

The expected AdV+ sensitivity



PSD of coating thermal noise

$$S_x(\omega) \propto \frac{T}{\omega} \frac{\varphi \cdot d}{D^2_{laser}}$$

$$n(\lambda) + i\,k(\lambda)$$

Extinction coefficient

Figure 3.3: *Virgo sensitivity after the modification of the arm cavities optical design. The solid curves correspond to a factor of 3 reduction of coating losses with respect to the state-of-the-art (dashed curves). The results for the two possible configurations in which the beam size is increased either on ETMs or in all test masses are presented.*

The two main actions supporting the coating development in Virgo

- **Materials (VCR&D)**

  Pragmatic

  Selection and Optimization

  - Materials
  - Deposition parameters
  - Metrology

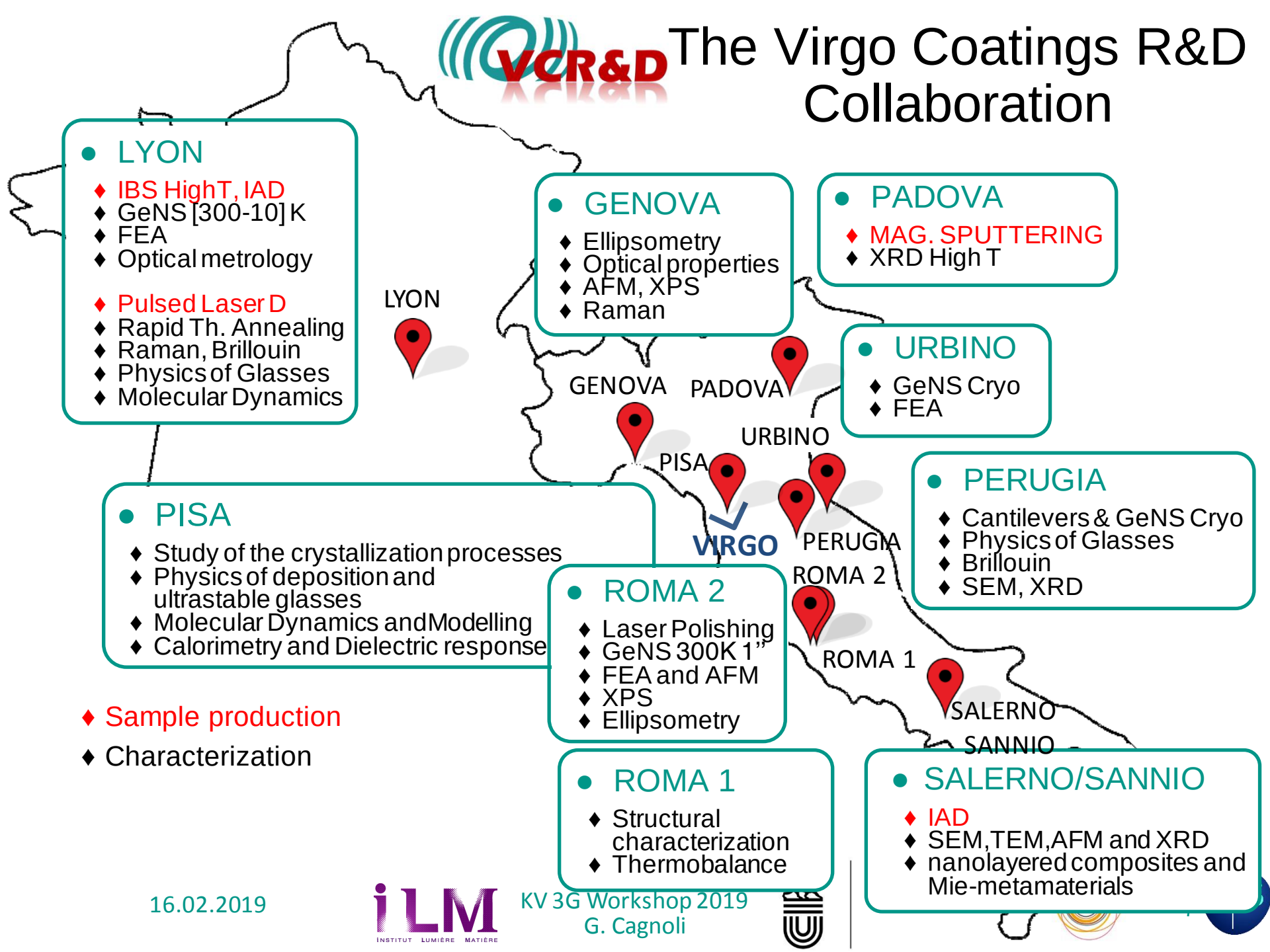
  Fundamental Physics

  - Density of TLS and structure
  - TLS distribution and structure
  - Crystallization dynamics
  - Ultra-stable glasses
  - Geometric frustration of relaxations

- **Coaters and metrology (LMA)**

  - To deal with the problem of extending the uniformity and metrology on large test masses

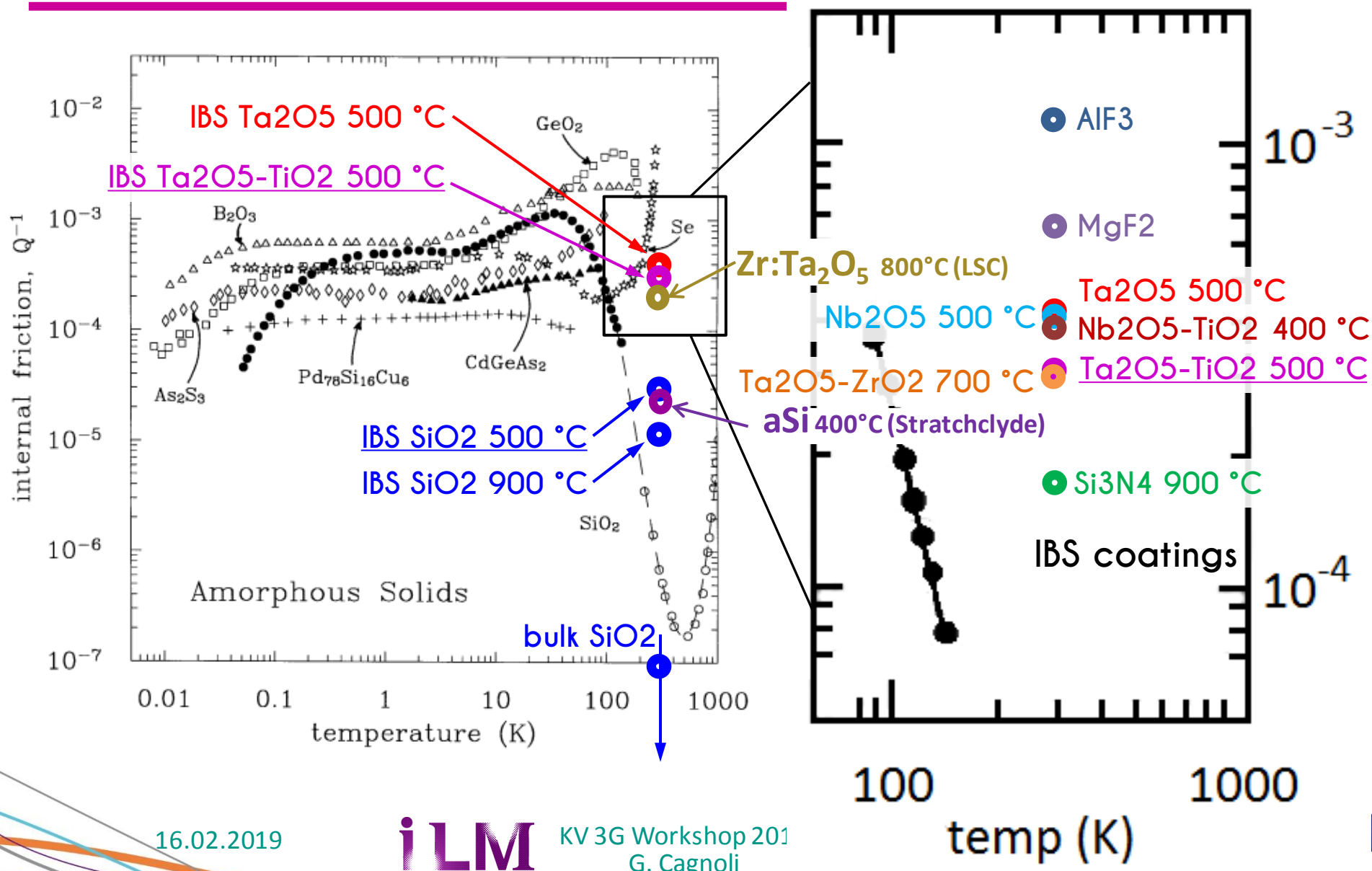
The Virgo Coatings R&D Collaboration



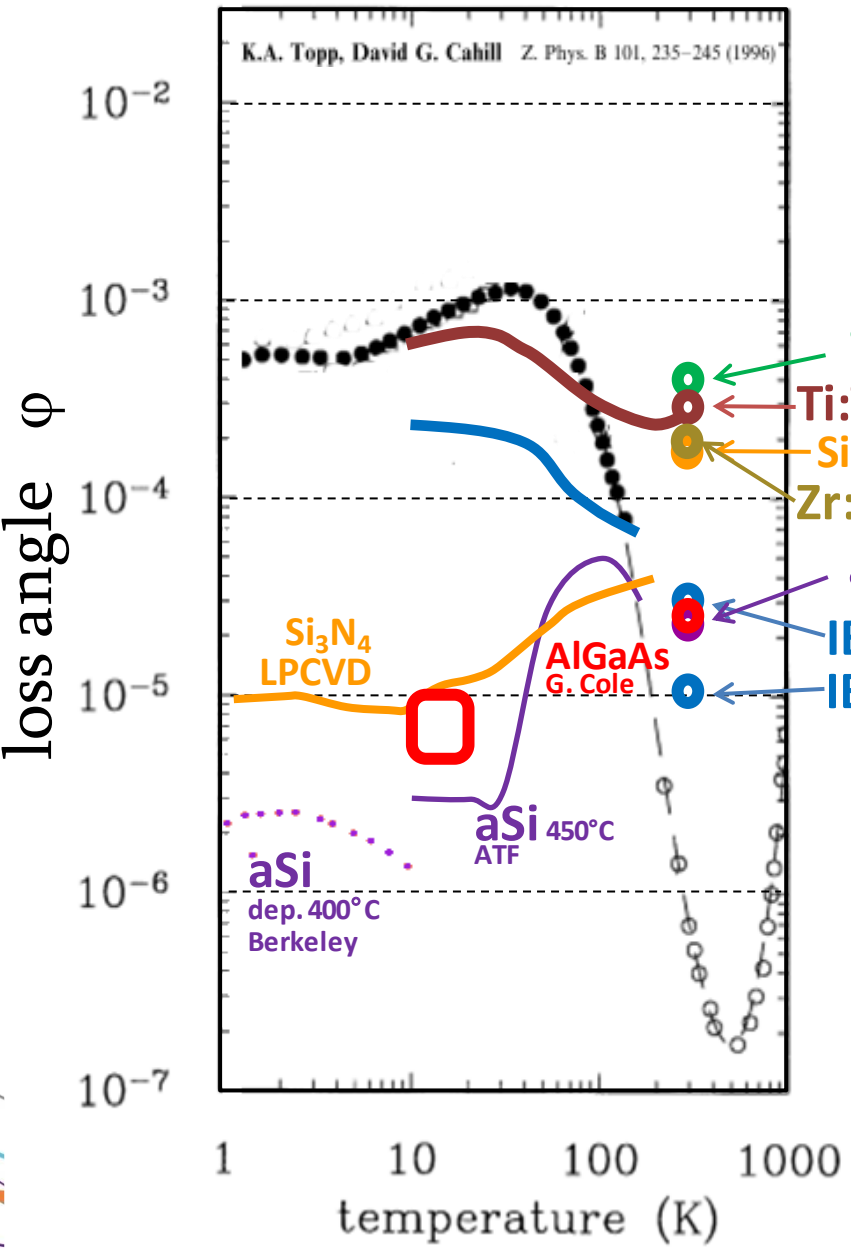
- **LYON**
  - IBS HighT, IAD
  - GeNS [300-10] K
  - FEA
  - Optical metrology
  - Pulsed Laser D
  - Rapid Th. Annealing
  - Raman, Brillouin
  - Physics of Glasses
  - Molecular Dynamics
- **GENOVA**
  - Ellipsometry
  - Optical properties
  - AFM, XPS
  - Raman
- **PADOVA**
  - MAG. SPUTTERING
  - XRD High T
- **URBINO**
  - GeNS Cryo
  - FEA
- **PERUGIA**
  - Cantilevers & GeNS Cryo
  - Physics of Glasses
  - Brillouin
  - SEM, XRD
- **PISA**
  - Study of the crystallization processes
  - Physics of deposition and ultrastable glasses
  - Molecular Dynamics and Modelling
  - Calorimetry and Dielectric response
- **ROMA 2**
  - Laser Polishing
  - GeNS 300K 1”
  - FEA and AFM
  - XPS
  - Ellipsometry
- **ROMA 1**
  - Structural characterization
  - Thermobalance
- **SALERNO/SANNIO**
  - IAD
  - SEM,TEM,AFM and XRD
  - nanolayered composites and Mie-metamaterials

- Sample production
- Characterization

Materials tested at room temperature



Losses of other materials at low T



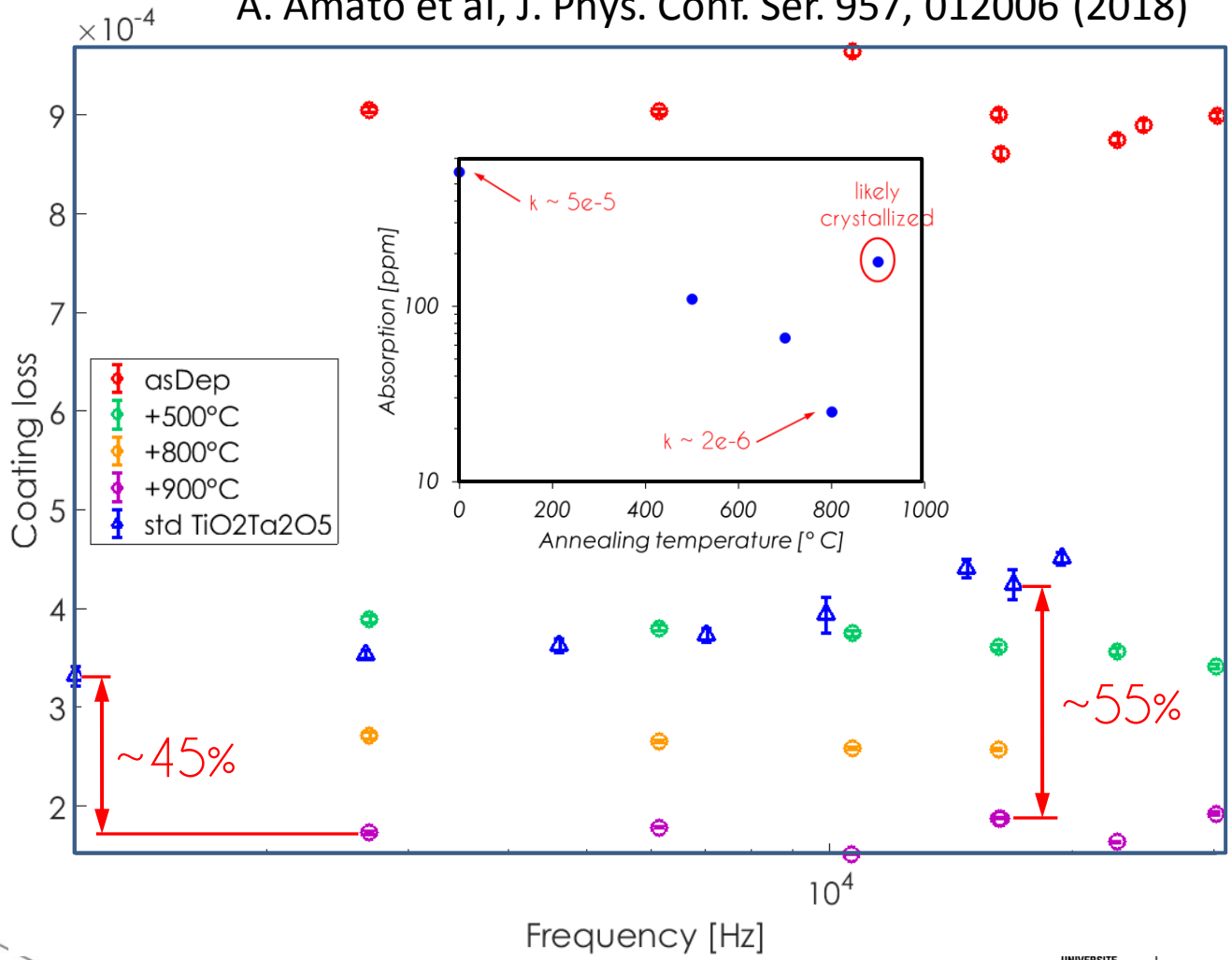
- Losses at lowT increas because there are more TLS with low barrier than with high barrier
- Ultrastable glasses
  - In some glasses the high temperature deposition makes the TLS density very low
- Shaping the TLS distribution
  - Annealing
  - Nanolayering

Research lines of VCR&D

Post deposition annealing	Study on silica To show the evolution of the TLS distribution ILM, LMA, Naval Research Lab (USA)
High temperature deposition	LMA is completing the installation of the sample holder on the DIBS
Deposition parameter optimization	On hold because it seems that annealing erases all the production history
Nano-layering	Presented above Sannio/Salerno, Genova, Roma2
High index silica glasses	Samples has been asked to Schott ILM
High coordination number glasses	ZnS deposited by SILO Roma2, ILM, Pisa, Padova
Nitrides	LMA has restarted the production LMA, ILM
Crystallization	Definition of the material under investigation Pisa, ILM
Origin of absorption	Detection of the absorption mechanisms in amorphs Genova, ILM

IBS SiNx from LMA

A. Amato et al, J. Phys. Conf. Ser. 957, 012006 (2018)



- First tests done by S. Chao on LPCVD Si3N4 LIGO-G1700304
- It seems IBS can be used to produce the material
- Further optimizations will be presented soon
  - Reduction of absorption
  - Low temperature measurements

Geometrical conditioning of TLS distribution

LING-CHI KUO, HUANG-WEI PAN, CHI-LI CHANG, AND SHIUH CHAO*

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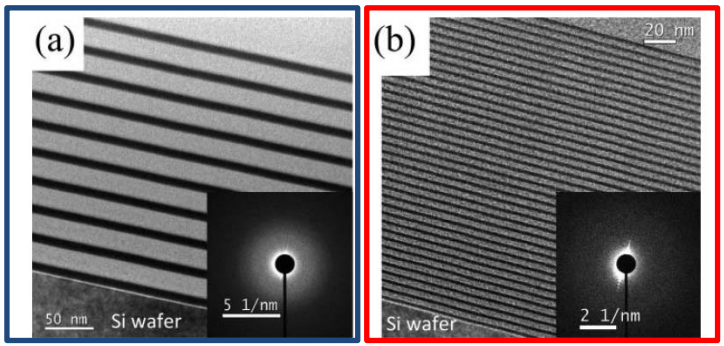
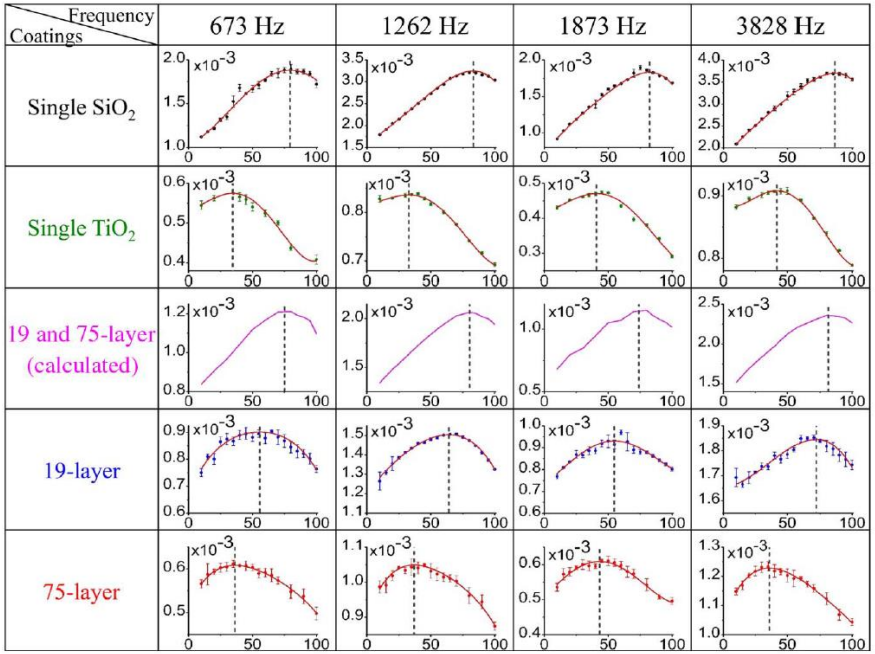
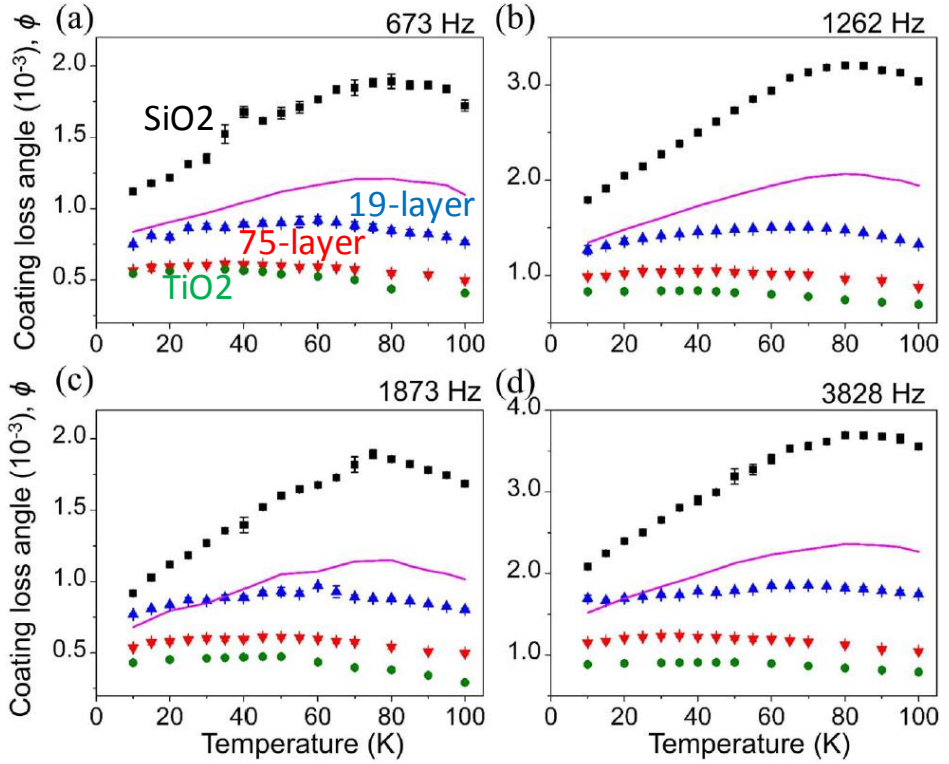


SiO2/TiO2 (a) 19-layers (b) 75-layers





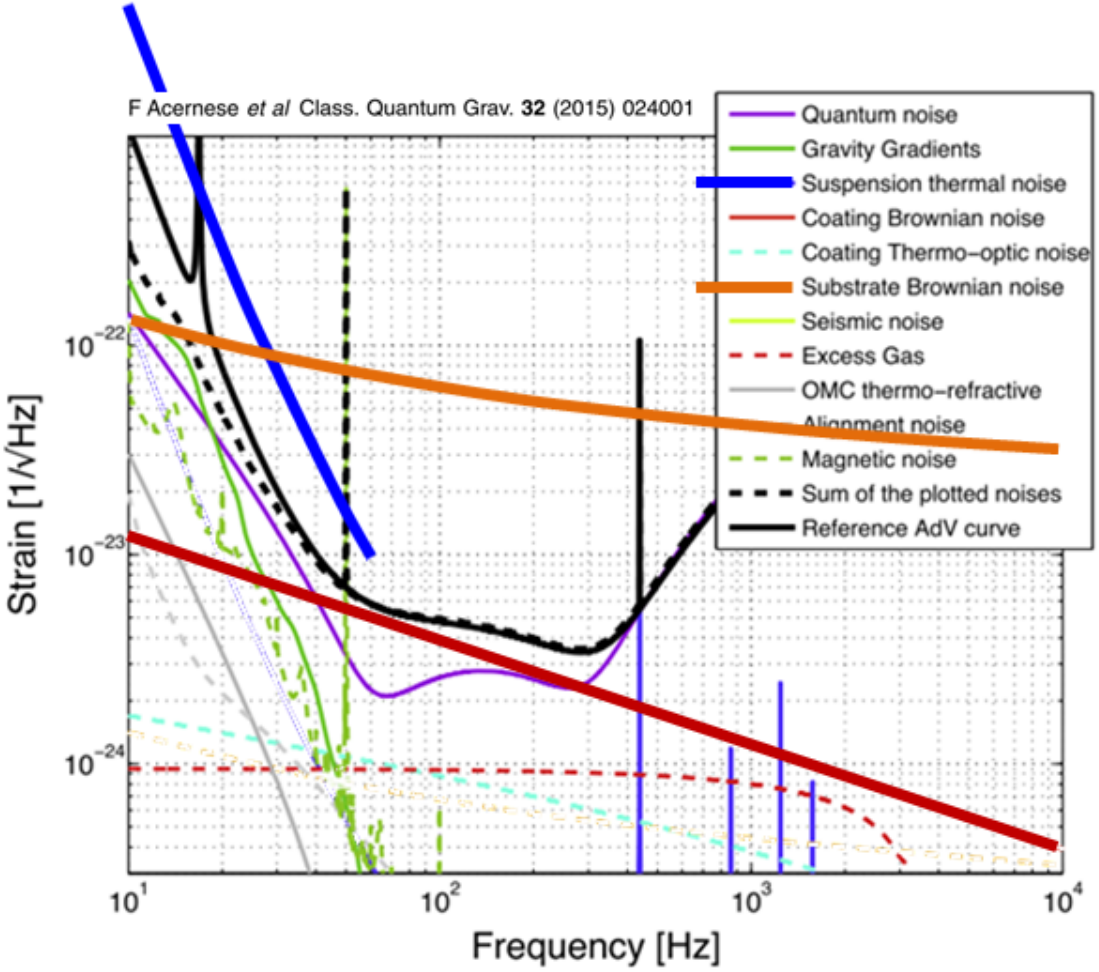
Cryogenic loss angle peak position versus temperature (K)

A possibility for a KAGRA upgrade?

- Si3N4 as high index material
- SiO2/Al2O3 nanolayers for the low index film

Further tests are waited

Substrates and suspensions at cryogenic temperatures (20k)

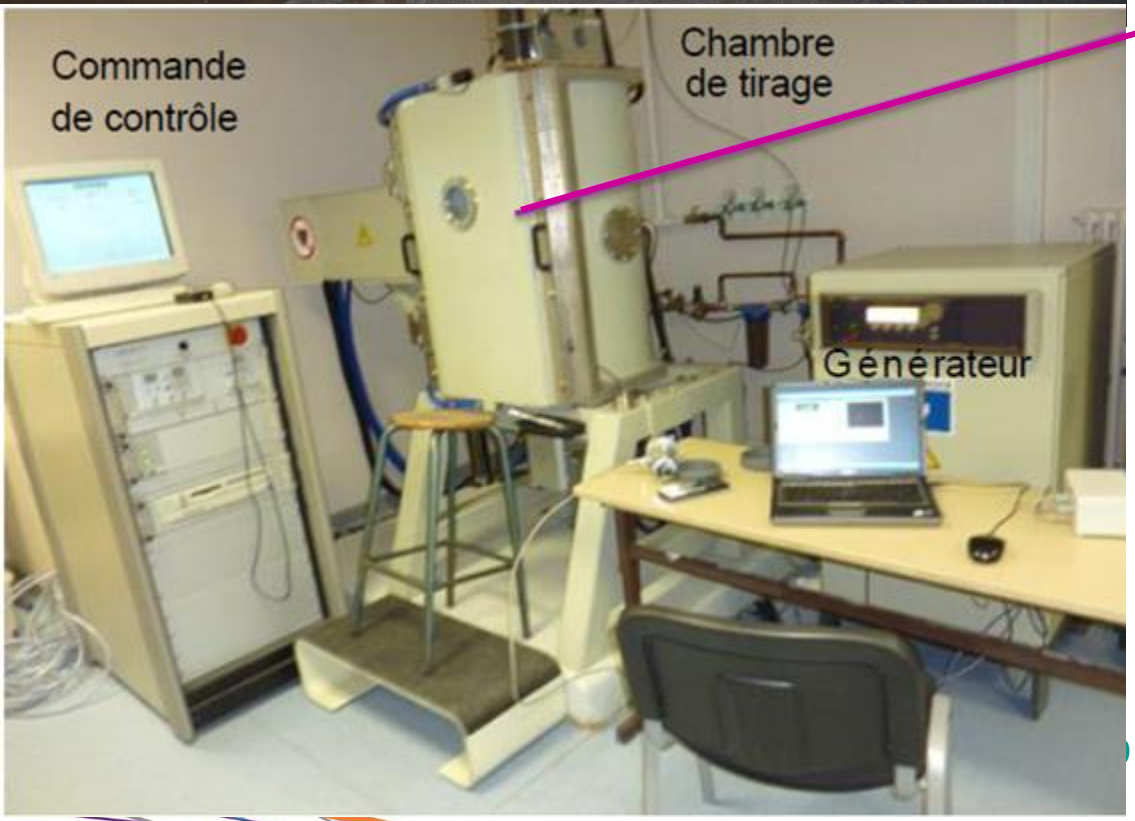


- Silica cannot be used
- Sapphire is a good replacement
  - Transparent at 1064 nm
  - Very high elastic constants
  - Density almost twice that of silica
- Issues to solve
  - Lower the absorption from the 50 ppm of today value
  - Remove the bubbles inclusion during the crystal formation
  - Demonstrate the polishing at the sub-nm level

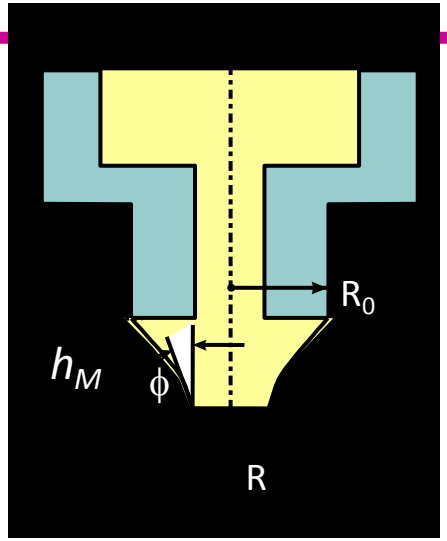
The project OSAG

- Gravitational Astronomy Sapphire Optics
- Project **submitted** to a University funding scheme (IDEXLYON): 1.2 M€
- Partners: g-MAG at iLM and LMA at iPNL
- Objectives
  - Ø450 mm, 200 mm thickness
  - 10 ppm/cm absorption
  - 50% success rate of bubble-free ingots production

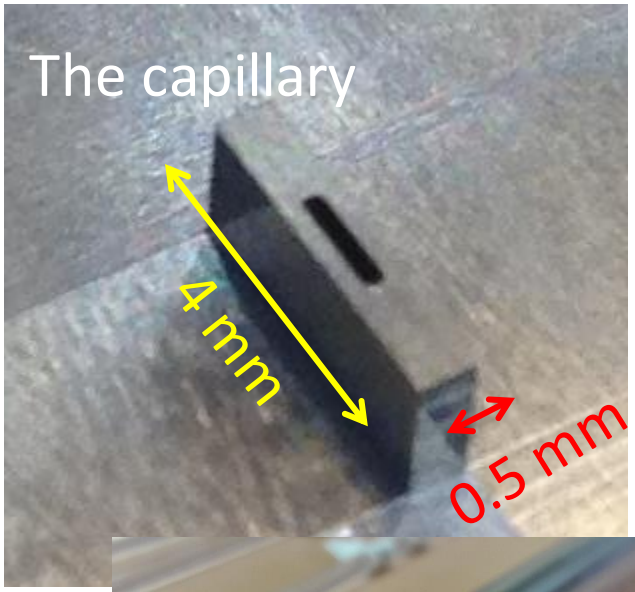
The expertize in Lyon: ingots growth

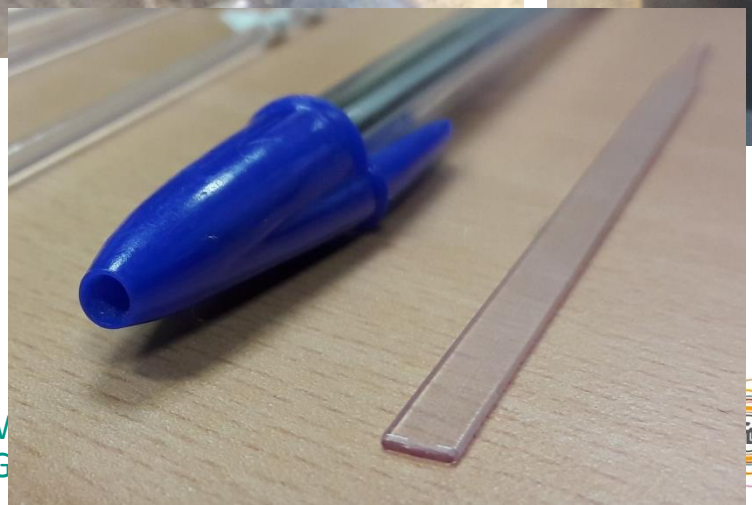


The expertize in Lyon: fibre growth

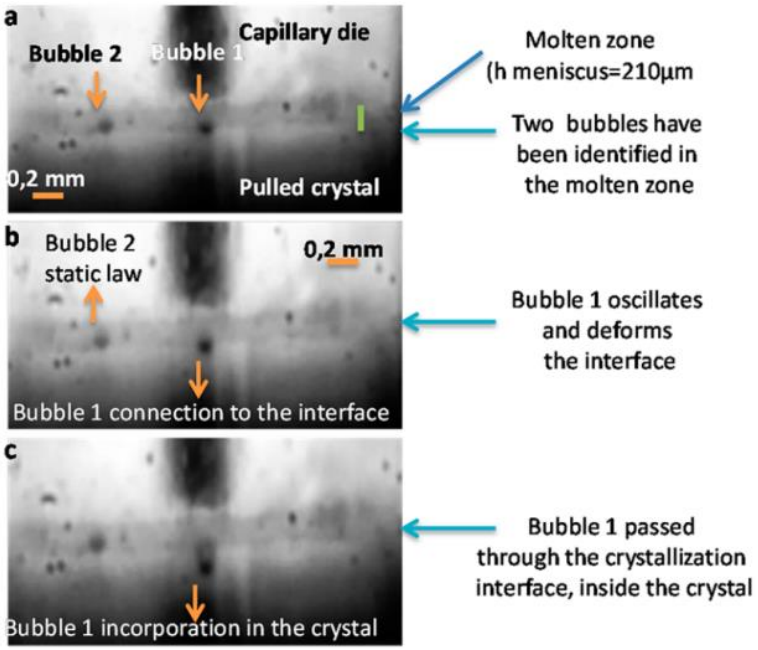


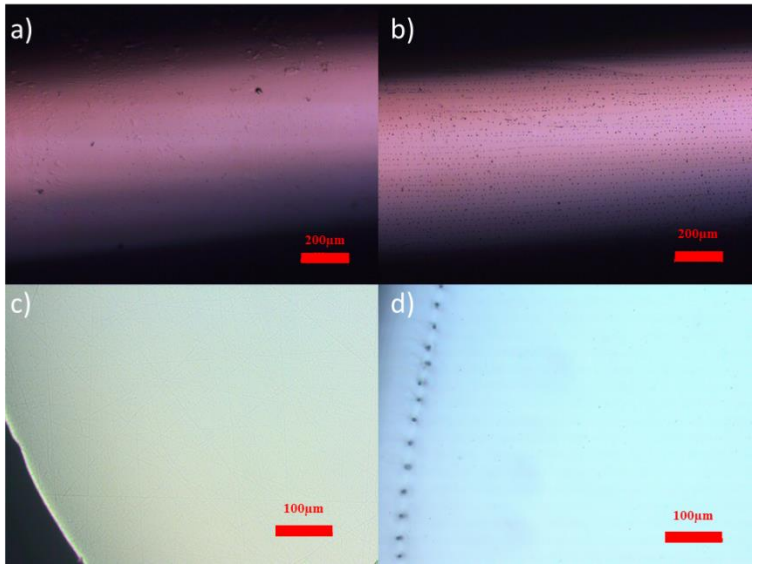
- Crucible made of iridium
  - Dimensions suitable for KAGRA

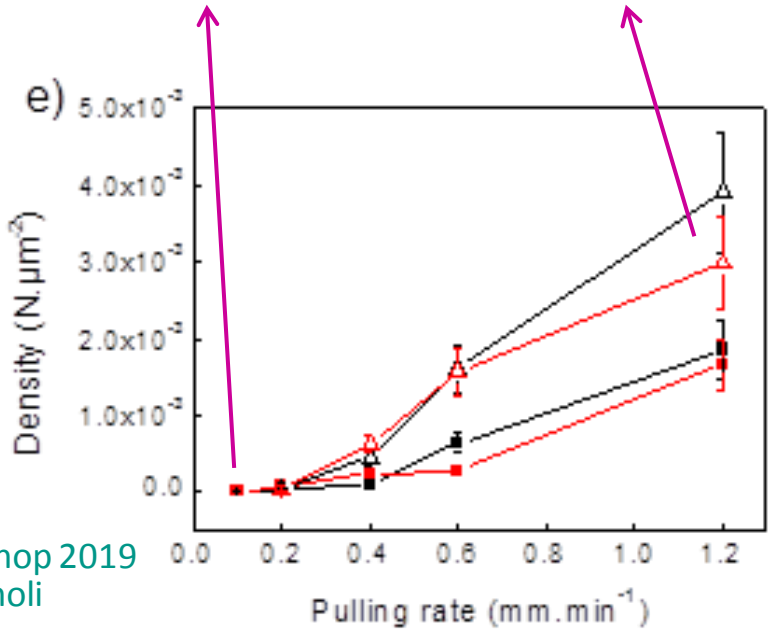




The expertize in Lyon: bubble inclusions







- Article about to be submitted
  - Authors: R. Bouaita, G. Goget Allombert, A. Ghezal Elhadj, A. Nehari, O. Benamara, M. Benchiheub, G. Cagnoli, Y. Kazuhiro, K. Lebbou

- There are some evidences supporting that amorphous materials can be used for coatings at room as well as at cryogenic temperature

- Sapphire is a valuable material for cryogenic detectors as long as crystal growth projects are supported

Thank you