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UNIVERSITÀ
DEGLI STUDI
DI PADOVA

**PhD course of National Interest in Technologies for
Fundamental Research in Physics and Astrophysics**

Annual report

Name and surname: Lorenzo Sclafani

Cycle and a.a.: 39° cycle, a.a. 2024/25

Supervisor: Antonio Carcaterra

- Research activity carried out during the year**

Given the challenges associated with operating at ultra-low temperatures, this project aims to address a crucial gap in the understanding of damping and its behaviour under extreme conditions. By characterizing damping in cryogenic environments, it seeks to improve the precision and stability of high-sensitivity experiments in fundamental physics. The objective is to develop a damping model that highlights the strong relationship between dissipation and variables such as temperature and pressure, and to validate it experimentally. The experimental validation is being carried out using a single-stage pulse tube cryostat available at the DIMA department of La Sapienza, by measuring the vibrational response of a centimeter-scale cantilever across a broad temperature range (from room temperature down to 70 K) and at varying pressures. For these measurements, fiber optic sensors with Fiber Bragg Grating (FBG) technology have been identified as the most suitable choice due to their minimal intrusiveness and excellent performance under cryogenic conditions. During the first months of the year, efforts have focused on establishing a benchmark to ensure the reliability of our measurements. After reviewing internationally recognized procedures for damping measurements, the ASTM E756-05 (2023) standard was found to be highly compatible with our setup. Following this standard, an initial experimental campaign at room temperature on a larger scale was carried out, allowing us to validate both the methodology and the sensor choice in a controlled environment before introducing temperature variations. In this phase, both accelerometers and FBG sensors were used to cross-validate the latter in view of future cryogenic experiments, alongside the implementation of different damping identification algorithms. To better understand dissipation as the degradation of ordered macroscopic energy into disordered microscopic energy, a model based on a loss-free oscillator connected to a piston has been introduced. Although the system is theoretically loss-free, the results exhibit the emergence of macroscopic dissipative effects in parallel with an increase in the kinetic energy of the mass, showing hysteretic cycles typical of solids. The calculations yield a stress-strain constitutive relationship term proportional to the strain rate and sensitive to temperature, in addition to the classical linear dependence on strain through the Young's modulus. Incorporating this updated constitutive relationship makes the beam response exponentially more complex, leading to issues of non-convergence between numerical and analytical results, which will be addressed in the short term.

The cryogenic experimental setup itself has proven to be quite challenging due to the small dimensions of the chamber. Significant heat dissipation effects were observed along the beam, creating a temperature gradient of approximately 30 °C, which cannot be neglected and must either be reduced or explicitly included in the model. Due to this and other technical issues, the initial measurements were limited to the effect of pressure. Mounting the setup has been particularly demanding given the brittleness of the fibers and the need to preserve the pressure seal. The experiment was conducted both at atmospheric pressure, where accelerometers were also used to characterize the cryostat response and transfer function, and under medium vacuum conditions. The beam was excited by applying an impact force on the external shell of the cryostat. The FBG sensors exhibited a significantly higher noise level compared to the accelerometers, which required high-energy excitations to obtain a measurable response. Filtering techniques to reduce noise in post-processing are currently under consideration.



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- **List of attended courses and passed exams**

- Random Excitation and response of structures (September 2025)

- **List of attended conferences, workshops and schools, with mention of the presented talks**

- Programmed:

- IMAC –XLIV Conference, United States, January 2026

Oral presentation of:

- *Damping Identification using FBG sensors in controlled thermal pressure conditions*
- *Temperature-driven Unsupervised Damage Identification using Cepstral Features*

- **List of published papers/proceedings**

- In writing:

- IMAC 2026 Proceedings: *Damping Identification using FBG sensors in controlled thermal pressure conditions* – L. Sclafani, S. Milana, A. Culla and A. Carcaterra
- IMAC 2026 Proceedings: *Temperature-driven Unsupervised Damage Identification using Cepstral Features* – L. Sclafani, L. Stagi, S. Milana and E. M. Tronci

- Published:

- Sclafani, L., Stagi, L., Tronci, E.M., Betti, R. and Milana, S., 2025. Real-time unsupervised structural damage detection using cepstral features and principal component analysis. *Structural Health Monitoring*, p.14759217251355946.

- **Thesis title (even temporary)**

Measurements of vibrations in cryogenic conditions

Date, 11/09/2025

Signature

Seen, the supervisor