

Colloquium Final Report

N. 610 – Emerging topics in acoustic and mechanical metamaterials

Dates and location: **25/04/2022 - 27/04/2022, Castellón de la Plana, Spain**

Chairperson **Daniel Torrent**

Co-Chairperson **Anastasiia Krushynska**

Conference fees

- Regular registration (speaker) **180.0 €**
- Reduced registration (attendee) **90.0 €**

What other funding was obtained? **We have received financial support from the EU-funded EIC Pathfinder project “DYNAMO” (2022-20267) led by D. Torrent.**

What were the participants offered? **The registration fees included:**

- **the electronic book of abstracts;**
- **a colloquium dinner at the Miramar hotel, April 26th 2022;**
- **2 daily coffee breaks and three lunches;**
- **a half-day excursion to visit the mountains and the seaside nearby Benicassim.**

Number of members of Euromech (reduced registration fee) **50**

Number of non-members of Euromech (full registration fee) **0**

Applicants (members)

- Diana Andres
- Alejandro Aragón
- Raffaele Ardito
- Bernard Bonello
- Federico Bosia
- Olga Boyko
- Yi Chen
- Yi Chen
- Johan Christensen
- Andrea Colombi
- Richard Craster
- Steven Cumber
- Pedro David García
- Bahram DJAFARI-ROUHANI
- Fernando Fraternali
- Pavel Galich

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- Michael Haberman
- Aida HEJAZI
- Mahmoud Hussein
- Shahram Janbaz
- Noé Jiménez
- Abdelkrim KHELIF
- Anastasiia Krushynska
- Vincent Laude
- Marc Martí Sabaté
- Agustín Mihi
- Mohammad J. Mirzaali
- Pawel Packo
- Antonio Palermo
- YAN PENNEC
- Rubén Picó
- Xingbo Pu
- Maria Rosendo López
- Marc Serra Garcia
- Clivia M. Sotomayor
- Clivia M. Sotomayor
- Tim Starkey
- Vincent TOURNAT
- Judit Vela
- Ke Wang
- Zhihui Wen
- Oliver Wright
- Oliver Wright
- Oliver Wright
- Zhaohang Zhang

Scientific Report

Phononic-based materials have recently received increasing interest from researchers due to their advanced functionalities and unprecedented mechanical and acoustic abilities, which often cannot be found in conventional materials. Constantly increasing demand for real-life engineering applications of these novel materials requires the development of reliable computational techniques for estimating the material performance in real-world environments, by considering finite structural sizes and non-trivial loading conditions, as well as the development of novel phononic configurations addressing practical requirements at target frequencies. This EUROMECH colloquium provided a platform to discuss and explore the possibilities enabled by various computational and experimental techniques for different research areas, including physics, material and mechanical engineering, aerospace, acoustics and underwater acoustics, non-destructive material evaluation, etc.

The goal of this was to gather together the leading experts in the field of phononic crystals and acoustic metamaterials in order to review the state-of-the-art in the physics and mechanics of architected materials of broad size ranges, including the nano-, micro-, and macro-scales, and to activate cross-pollination of the research ideas in lively discussions.

Altogether there were 41 participants and 34 presentations. The list of participants is given above, the full programme is available on the website (<https://610.euromech.org/program/scientific-program/>) and in a separate document. Most importantly, there was ample time for informal stimulating discussions among the participants during the coffee breaks, lunches and social activities.

All the talks were formally separated into seven thematic sessions:

1. Phononics and nano-phononics
2. Elastic and acoustic metamaterials
3. DYNAMO (the session dedicated to the EU EIC Pathfinder project co-funding this event)
4. Nonlinear, time-dependent, and tunable metamaterials
5. Acoustic metamaterials and metasurfaces
6. Applications of phononics, acoustic and mechanical metamaterials
7. Theoretical aspects of designing metamaterials and phononic crystals.

Each thematic session included five 20-minutes presentations, except the 7th session that contained four talks. In addition, there was a poster session aimed at presenting the research activities of the attending PhD students and post-docs.

Specific topics addressed in the talks and discussed included:

? Phononics and nano-phononics

The talks in this session were focused in phononics at the nano or micro scales, showing that the main applications are focused towards the control of the propagation of elastic waves by thin structures (metasurfaces) and that optomechanics is still a topic with many challenges to be solved. Open resonant structures, where the lifetime of the modes is finite, were also discussed, showing that more advanced tools are still required for their study in nanophononics since, unlike in photonics, there is a lack of knowledge of this topic in the literature.

? Elastic and acoustic metamaterials

The domain of acoustic and elastic metamaterials continues being a topic of great interest in the scientific community. As the fabrication methods evolve, more advanced structures can be envisioned by theorists in the area, and new concepts continue emerging. In this specific session, different metamaterial concepts and structures were presented: metamaterials for the attenuation of sound in tracks, isolators for seismic waves, analysis of soft metamaterials and their stability and the presence of roton-like dispersion relation in elastic metamaterials, showing as well that the analogues between quantum materials and metamaterials continues being a topic of intense interest.

? DYNAMO (the session dedicated to the EU EIC Pathfinder project co-funding this event)

The special session devoted to Dynamo was used to present the research activities of the different partners of the project, since this just started in March and no results of the project itself were publishable yet. Then, Sebastien Guenneau presented a new concept for the active cloaking of thermal waves, Pawel Packo showed a formulation of multiple scattering theory for non-linear resonators attached to an elastic beam, with a large number of interesting effects which could be easily exported to elastic plates in the near future. Agustin Mihi did a presentation of the fabrication methods that he has been developing for photonic crystals and how these will be now applied to phononics. Bernard Bonellow

showed his last results in the localization of elastic waves by random scatterers in the range of the GHz, and Vincent Tournat, the only speaker of the session not belonging to the project, talked again about nonlinear waves in metamaterials. It was obvious during the session that “nonlinear metamaterials” is also an emerging topic in acoustics and that new tools are still required for their adequate study.

? Nonlinear, time-dependent, and tunable metamaterials

One of the main problems of metamaterials is that their extraordinary properties are specially seen in a resonant regime, where dissipation is also important, which hinders most of the applications of these structures. Additionally, the realization of tunable metamaterials is still challenging, since some applications require real-time reconfigurability.

Among other mechanisms, nonlinear and time-dependent materials are known to present some kind of gain and reconfigurability, so that they are excellent candidates to overcome these drawbacks. In this session several works were presented regarding the possibilities of non-linear and time-mulated materials, showing that, although their realization is still challenging, great advances are made from the theoretical and practical point of view.

? Acoustic metamaterials and metasurfaces

In this session the authors presented more exotic properties and applications of acoustic metamaterials and metasurfaces, like particle trapping with metamaterials, non-Hermitian whispering gallery modes, multiple scattering between Helmholtz resonators to enhance their tunability, diffraction of waves by doubly-periodic gratings and Willis coupling induced by thermal interactions. We conclude that the number of exotic effects related with metamaterials continues growing and more applications are expected to emerge within the next few years.

? Applications of phononics, acoustic and mechanical metamaterials

Although still in the proof-of-concept stage, metamaterials have already started to show promising applications in different areas. Energy harvesting is always an interesting topic, and the great capability of metamaterials to concentrate (dissipate) energy makes them potential candidates for energy conversion.

Acoustic holograms based on metasurfaces can be used for therapeutic applications. Tunable metamaterials, which as was discussed before is always a challenging technical problem, can be made by means of magnetic elements. Finally, it was also discussed that more efficient dissipative metamaterials can be made by means of bio-inspired structures.

? Theoretical aspects of designing metamaterials and phononic crystals.

The final session of the conference was devoted to the progress in the design of metamaterials from the theoretical point of view. Specifically, it was proposed to move from a common intuition-based design approach for phononic crystals to alternative computational tools that rely on optimization procedures allowing to efficiently explore the multi-dimensional geometry-property spectrum. Another talk discussed a methodology for correctly defining a unit cell and IBZ path for band gap analysis in periodic structures. Next, the potential of octet-based lattice and shell-based plates in effectively inhibiting wave propagation or focusing wave energy was presented to lay the ground for the development of novel wave control structures. Finally, the application of mechanical metamaterials to the problem of speech recognition was presented and raised lively discussions in the audience.

Number of participants from each country

COUNTRY	PARTICIPANTS
Netherlands	6
France	8
Italy	5
Spain	16
Poland	1
Germany	3
United Kingdom	2
Japan	3
Switzerland	2
United States	3
Israel	1
TOTAL	50

Please send this report in electronic form to the Secretary General of EUROMECH, within one month after your Colloquium.