TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	July 12	**July 13**	**July 14**	**July 15**	**July 16**
9.00 - 9.45	Registration	Pham	Yu	Zhang	Zhang
9.45 - 10.30	Guenneau	Pham	Yu	Zhang	Zhang
11.00 - 11.45	Maurel	Maurel	Zhang	Yu	Yu
11.45 - 12.30	Maurel	Maurel	Zhang	Yu	Yu
14.00 - 14.45	Guenneau	Guenneau	Ammari	Ammari	
14.45 - 15.30	Guenneau	Guenneau	Ammari	Ammari	
16.00 - 16.45	Pham	Ammari	Pham	Maurel	
16.45 - 17.30	Pham	Ammari	Pham	Maurel	

ADMISSION AND ACCOMMODATION

The registration fees are:
- Participation in presence, 600.00 Euro + VAT*
This fee includes a complimentary bag, four fixed menu buffet lunches (on Friday upon request), hot beverages, downloadable lecture notes.
- Participation online, 250.00 Euro + VAT*
This fee includes downloadable lecture notes.

Applicants must apply at least one month before the beginning of the course. Application forms should be sent on-line through the following web site: http://www.cism.it. A message of confirmation will be sent to accepted participants. Applicants requiring assistance with the registration should contact the secretariat at the following email address: cism@cism.it.

Applicants may cancel their course registration and receive a full refund by notifying CISM Secretariat in writing (by email to cism@cism.it) no later than two weeks prior to the start of the course.

Cancellation requests received during the two weeks prior to the start of the course will be charged a 50.00 Euro handling fee. Incorrect payments are also subject to a 50.00 Euro handling fee.

A limited number of participants from universities and research centres who are not supported by their own institutions can be offered lodging and/or board, if available, in a reasonably priced hotel or student guest house.

Requests should be sent to CISM Secretariat by **May 12, 2021** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

Information about travel and accommodation is available on the web site www.cism.it, or can be mailed upon request.

* where applicable (bank charges are not included)
Italian VAT is 22%.

For further information please contact:
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ACADEMIC YEAR 2021
The Erwin Stein Session
Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

METAMATERIAL IN ACOUSTICS, ELASTODYNAMICS AND ELECTROMAGNETISM

HYBRID FORMAT

Advanced School
coordinated by

Habib Ammari
ETH-Zurich, Switzerland

Agnès Maurel
Institut Langevin, Paris, France

Udine *July 12 - 16* 2021

METAMATERIAL IN ACOUSTICS, ELASTODYNAMICS AND ELECTROMAGNETISM

A revolution is currently taking place in physics and engineering through the manufacture of metamaterials and metasurfaces with the aim of achieving full control of waves. This was made possible by conceiving and designing new materials whose macroscopic behavior results from a specific structure, often periodic, at the microscopic scale. Typical examples are the band-gap materials and the double negativity metamaterials which are based on the local resonance (of the Mie, Minnaert or Helmholtz's type) of a subwavelength building block repeated periodically. These materials have found numerous practical applications among which cloaking, lensing, super-resolution, quantitative imaging in the near field, shielding, perfect absorption.

In acoustics, a well known example is inspired by the pots used in the ancient greek theaters and later on in churches and mosques to control the acoustic of the places; these pots are Helmholt'z resonators and they are thought nowadays as the key to soundproof wall design.

More recent examples are related to the shielding of regions from wave tanks to recent advances in the design of metamaterial based devices. This is the case of the so-called anti-seismic wedge formed by a forest of trees able to convert the destructive surface waves into mainly harmless downward propagating bulk waves. Another striking example is the design of gigantic «wave breakers» to surround and protect a region from swell and stormy waves. The efficiency of such belts becomes a vital prerequisite to viable and sustainable floating cities which are sought in the foreseeable future.

The purpose of this course is to provide an introduction to well known techniques and to introduce more advanced, state-of-the-art techniques, able to tackle the challenges of the metamaterials by providing a mathematical framework able to explain the observed extraordinary properties of meta-structures and useful to help optimize these properties. These include transformation optics/ transformation elastodynamics, classical and modern homo-genization methodologies, asymptotic and spectral analysis, variational methods, layer potential techniques, as well as modern multi-mathematics. Particular attention will be paid to present practical applications that illustrate the workings and effectiveness of the introduced techniques and discussions on the breakthroughs and the remaining open questions on topical issues in acoustics, electromagnetism, elasticity and in the context of water waves. Bearing these objectives in mind, academic experimental studies as well as commercial devices will be presented during the course.

Overall this is a joint effort from a diverse group of lecturers working on different aspects of metamaterial modelling, to report the current state-of-the-art in the field and form a collaborative network and shared knowledge platform in an area where there is still considerable room for research.

The course is addressed to a broad public: graduate students, doctoral students, young researchers and practicing engineers. Since a major part of the course will be devoted to theoretical and numerical modelling, a sound mathematical basis is expected and basic knowledge of wave theory is recommended.

The topics explore the applications in Engineering and Physics, showing the interconnections with acoustics, electromagnetism, elasticity, water waves that are normally treated as independent topics.

Both theoreticians and experimentalists from the academic and industrial sectors are expected to gain useful knowledge from attending the course.

PRELIMINARY SUGGESTED READINGS

A. Maurel, K. Pham & J.-J. Marigo, Homogenization of Thin 3D Periodic Structures in the Time Domain–Effective Boundary and Jump Conditions. Fundamentals and Applications of Acoustic Metamaterials: From Seismic to Radio Frequency, ISTE, 1, 73-105, 2019.

R.V. Craster, S. Guenneau, Acoustic metamaterials: Negative refraction, imaging, lensing and cloaking, Springer, 2012.

J.-J. Marigo & A. Maurel, An Interface Model for Homogenization of Acoustic Metafilms, chap. 14 of World Scientific Handbook of Metamaterials and Plasmonics, pp. 599-645, 2017.

H. Ammari, B. Fitzpatrick, H. Kang, M. Ruiz, S. Yu, and H. Zhang, Mathematical and Computational Methods in Photonics and Phononics, Mathematical Surveys and Monographs, Volume 235, American Mathematical Society, Providence, 509 page, 2018.

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from the CISM web site. Instructions will be sent to accepted participants. S. Guenneau, A. Maurel and K. Pham have already confirmed their presence in Udine at CISM.

INVITED LECTURERS

Habib Ammari - ETH, Zürich, Szwitzerland
6 lectures on:
Subwavelength resonances; Hybridization of subwavelength reso-nances; Metasurfaces; Double-negative metamaterials; Subwave-length bandgaps; Topological metamaterials.

Sébastien Guenneau - Imperial College, London, UK
5 lectures on:
Locally resonant structures in electromagnetism and elastodynamics. Electromagnetic metamaterials; Transformation optics for invisibility cloaks and twisted waveguides; Plasmonics and structured surfac-es. Acoustic metamaterials; Localised modes in arrays of split ring resonators; Phononic band gap guidance in arrays of elastic fibers; Transformation elastodynamics for flexural waves.

Agnès Maurel - Institut Langevin, Paris, France
6 lectures on:
Introduction to the classical homogenization of massive periodic structures; effective materials. Higher order homogenization of finite extend structures, derivation of unusual transmission/boundary con-ditions; the case of laminar structure; Segev's anomalies in electro-magnetism. Homogenization for water waves, sea-bed structuration and floating structure with subwavelength structuration. Homogeniza-tion of seismic metamaterials; shielding effect.

Kim Pham - IMSIA, ENSTA ParisTech, France
6 lectures on:
Homogenization of non-resonant meta-surfaces/meta-films: the case of a thin array of penetrable inclusions and of roughnesses: effectives models, variational bounds and applications. Homogeniza-tion of resonant meta-film with highly-contrasted material/geometric properties. Resonances of the Mie type, of the Helmholtz type and of the Minnaert type.

Sanghyeon Yu - Korea University, Seoul, South Korea
6 lectures on:
Muller's method; Green's functions, and layer potential techniques; Spectrum of Neumann-Poincaré operator and plasmonic reso-nances; Elastic metamaterials; Computations of subwavelength bandgaps; Near cloaking and anomalous resonances; Quantitative imaging in near-field optics.

Hai Zhang - HKUST, Hong Kong
6 lectures on:
Super-resolution in high-contrast media; Super-resolution by using a system of subwavelength resonators; Super-resolution using plasmonic spectroscopic data; Scattering and field enhancement of a perfect conducting narrow slit; Scattering by a periodic array of subwavelength slits: the homogenization regime; Scattering by a periodic array of subwavelength slits: the diffraction regime.