

Educating Students on Metamaterials

- The Story of the EUProMeta

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<http://school.metamorphose-vi.org/>

pictures in this presentation are taken from
leading experts in the field of metamaterials

Introduction

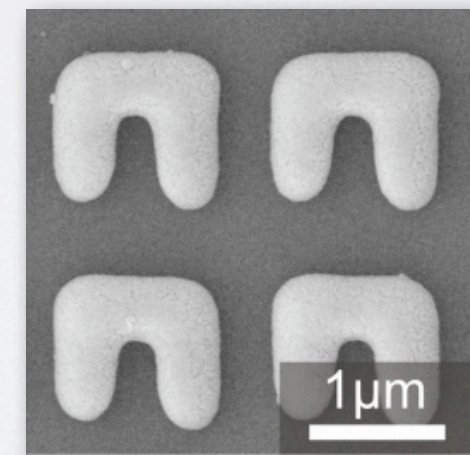
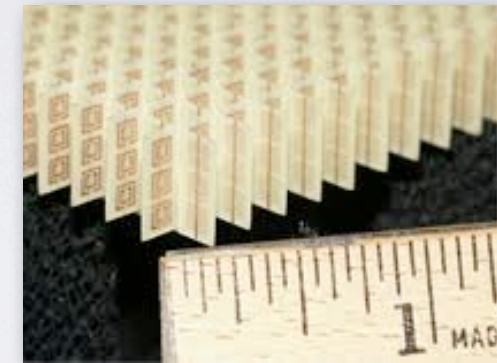
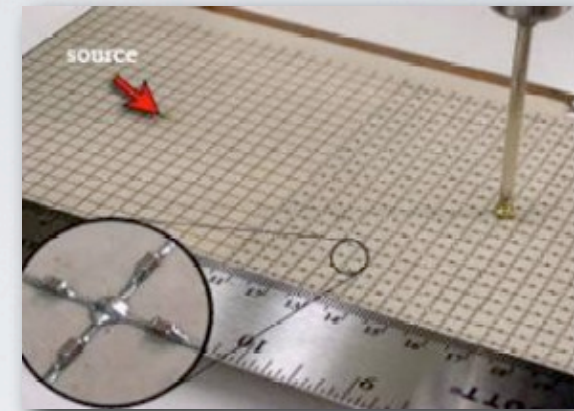


- education on metamaterials
- > 25 partner institutions
- acceptance of school credits by consortium members
- 2-3 distributed schools per year
- >20 schools so far
- 20-40 participants
- part of the VI Metamorphose

promoting metamaterials, stipulating fascination, fostering collaborations

The challenge to educate students on metamaterials

- different scientific and engineering communities are involved



The challenge to educate students on metamaterials

- different scientific and engineering communities are involved
- theory, numerics, fabrication, and characterization

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

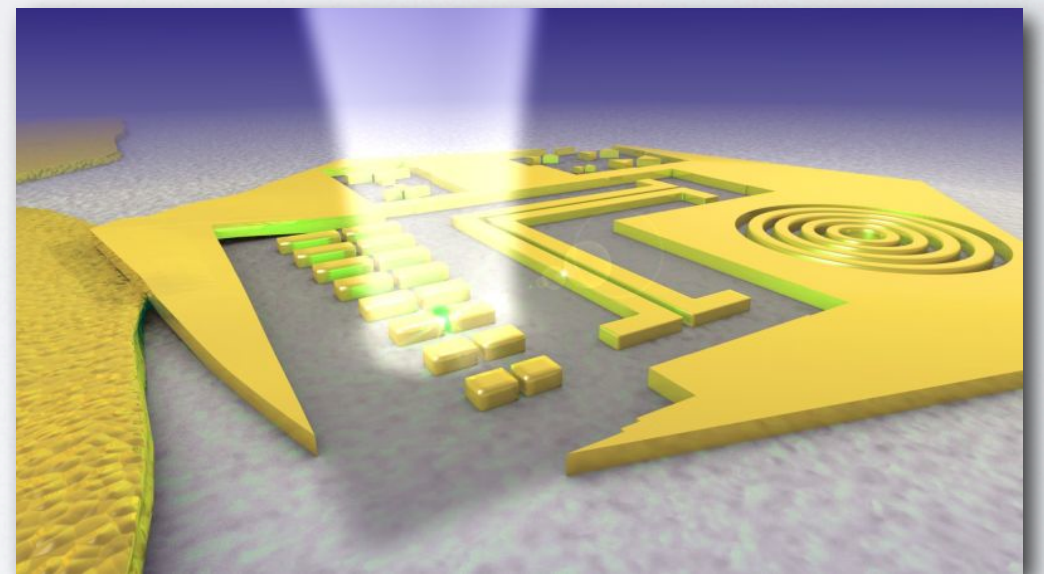
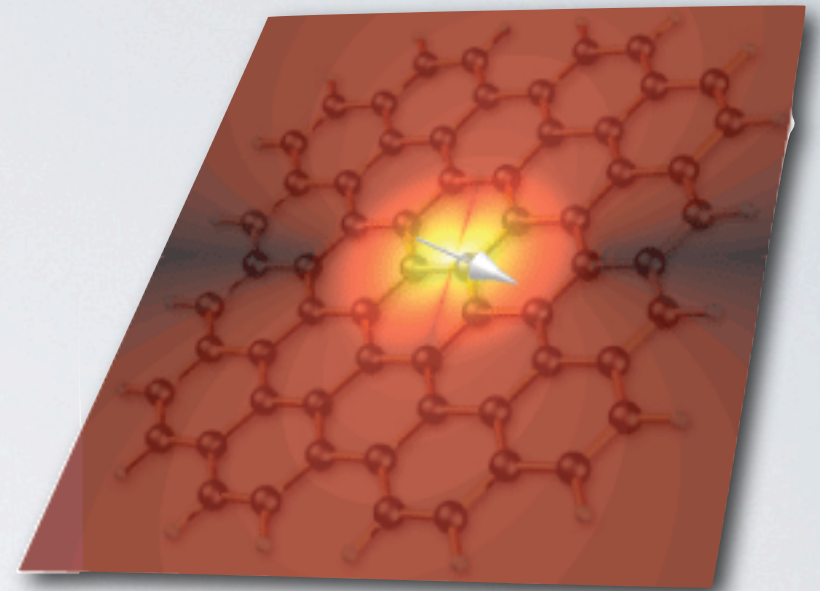
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$



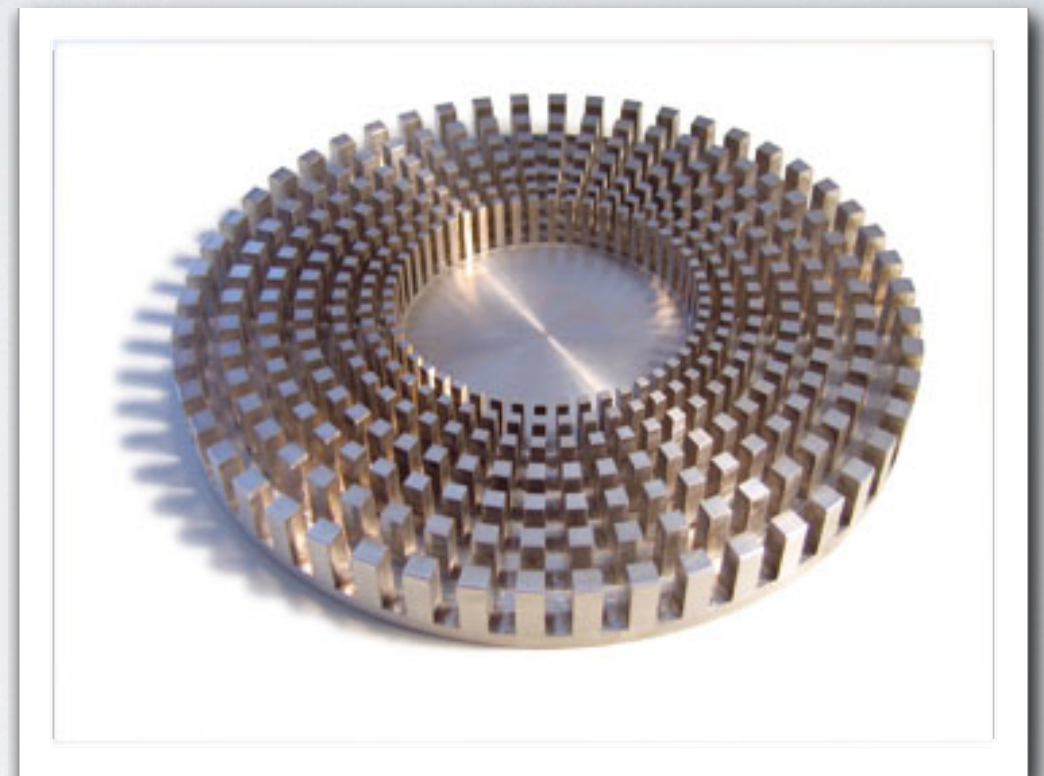
The challenge to educate students on metamaterials

- different scientific and engineering communities are involved
- theory, numerics, fabrication, and characterization
- fast developing but also competitive field



The challenge to educate students on metamaterials

- different scientific and engineering communities are involved
- theory, numerics, fabrication, and characterization
- fast developing but also competitive field
- many systems eventually employ metamaterial concepts and not just electromagnetics



Where does it came from

EUROPEAN COMMISSION: SIXTH FRAMEWORK PROGRAM

Network of Excellence *Metamorphose*:

METAMaterials **OR**ganized for radio, millimeter wave, and **PHO**tonic **S**uperlattice **E**ngineering

Start of the project: June 1 2004

Duration: 4 years

23 institutions

13 countries

Budget: 4.4 M€

May 2007 → **Metamorphose Virtual Institute**

August 2012 → **International Individual memberships**

<http://www.metamorphose-vi.org/>

Metamorphose Coordinator:

Prof. Sergei Tretyakov

Aalto University



Profile of the mother organization

- integrate, manage, coordinate and monitor *research projects*
- *spread excellence* by organizing conferences and training activities
- *promote information* on artificial electromagnetic materials
- facilitate *transfer of the new technology* in this field to industry
- *offer advice and services* related to artificial electromagnetic materials and metamaterials to industries, producers, distributors, and potential users



Profile of the father WP

WP3.1 of the Metamorphose NoE

EU PhD Programme and the distributed PhD school on metamaterials

led by F. Capolino (now at University of California, Irvine)

- creator of the whole program
- convincing the partners of what to do
- developing ideas for the first proposal
- draft of MOU and getting it signed after 2 years
- achieving the recognition of school credits
- developing the mention of excellence awards



making the school operational

Structure of the EUPROMETA

EU Doctoral Programmes Coordinator

Carsten Rockstuhl - Friedrich Schiller University Jena, Germany

Past EU Doctoral Programmes Coordinator (2004-2009)

Filippo Capolino - now at the University of California, Irvine, CA, USA

Steering Committee

- Filippo Capolino - University of California (Irvine), USA
- Filiberto Bilotti - University of Roma Tre, Italy
- Nigel Johnson - University of Glasgow, UK
- Ferran Martin - Universidad Autonoma de Barcelona, Spain
- Dorota Pawlak - Institute of Electronic Materials Technology, Poland
- Alex Schuchinsky - Queen's University of Belfast, UK
- Ari Sihvola - Aalto University, Finland
- Tomasz Szoplik - Warsaw University, Poland
- Sergei Tretyakov - Aalto University, Finland
- Irina Vendik - St. Petersburg Electrotechnical University, Russia
- Said Zouhdi - University of Paris Sud, France

usually one or two individuals that act as host organizers for the school

Structure of the entire program

towards the

Mention of Excellence in Metamaterials

- obtain at least **5 credits from different school** events,
 - publish at least **one journal publication** in the field of metamaterials **jointly** authored **with researchers from another institution**
 - publish at least **one more journal publication in the field of metamaterials**
 - have at least **three conference publications** in the field of metamaterials,
 - submit a **Ph.D. thesis** in the field of metamaterials
 - **spend at least 3 months** conducting metamaterials research in the laboratories of another research institution
-

Core school

- fundamental and general subject that are of broader interest
 - regularly scheduled adjusted to the cycle of a PhD student
 - usually last for one week
 - lectures / exercises / seminars / lab tours
 - written examination or final assignment
 - 4-6 experts (2 locals, ~ up to 4 external persons)
 - course material online
 - partially video recording for further distribution
 - social events such as town visits, excursion
 - school dinner
 - poster presentation to foster interaction among students
 - 1.5 ECTS
-

Core program of the school

Focus	Frequency	Courses
Introduction	every 2nd year	Electromagnetics of complex materials
		Basics of plasmonics
		Computational methods
Fabrication	every 3rd year	Nano-fabrication
		Direct Laser writing
		Nanoimprint
		Self-assembled metamaterials
Characterization	every 3rd year	Homogenization and material parameter extraction
		Experimental practicum on characterization
		Ellipsometry
		Near-field characterization methods
Effects	every 3rd year	Active metamaterials
		Transformation optics and cloaking
		Chirality
		Nonlinear effects in metamaterials
Optical Metamaterials	every 3rd year	Optical applications
		Optics in multilayer structures
		Optical metamaterials
Microwave Metamaterials	every 3rd year	Antenna applications
		Transmission-line metamaterials and applications
		Microwave metamaterials

More specialized schools

- focused on specific topics
- usually last for two days, exceptionally up to three days
- often collocated with the Metamaterials conference
- final assignment
- up to 8 experts (mostly externals)
- e.g. nonlinear or tunable metamaterials, computational methods
- comparable social events
- up to 1 ECTS

Recent past and future schools

14th/15th October 2011 → Barcelona

**Engineering applications
of metamaterials**

7th/11th May 2012 → Louvain-la-Neuve

**Introduction to
metamaterials**

21th/22th October 2012 → St. Petersburg

**Tunable and
reconfigurable
metamaterials**

events in 2013 → Bordeaux

**Self-organized
metamaterials**



Glasgow

**Fabrication of
metamaterials**

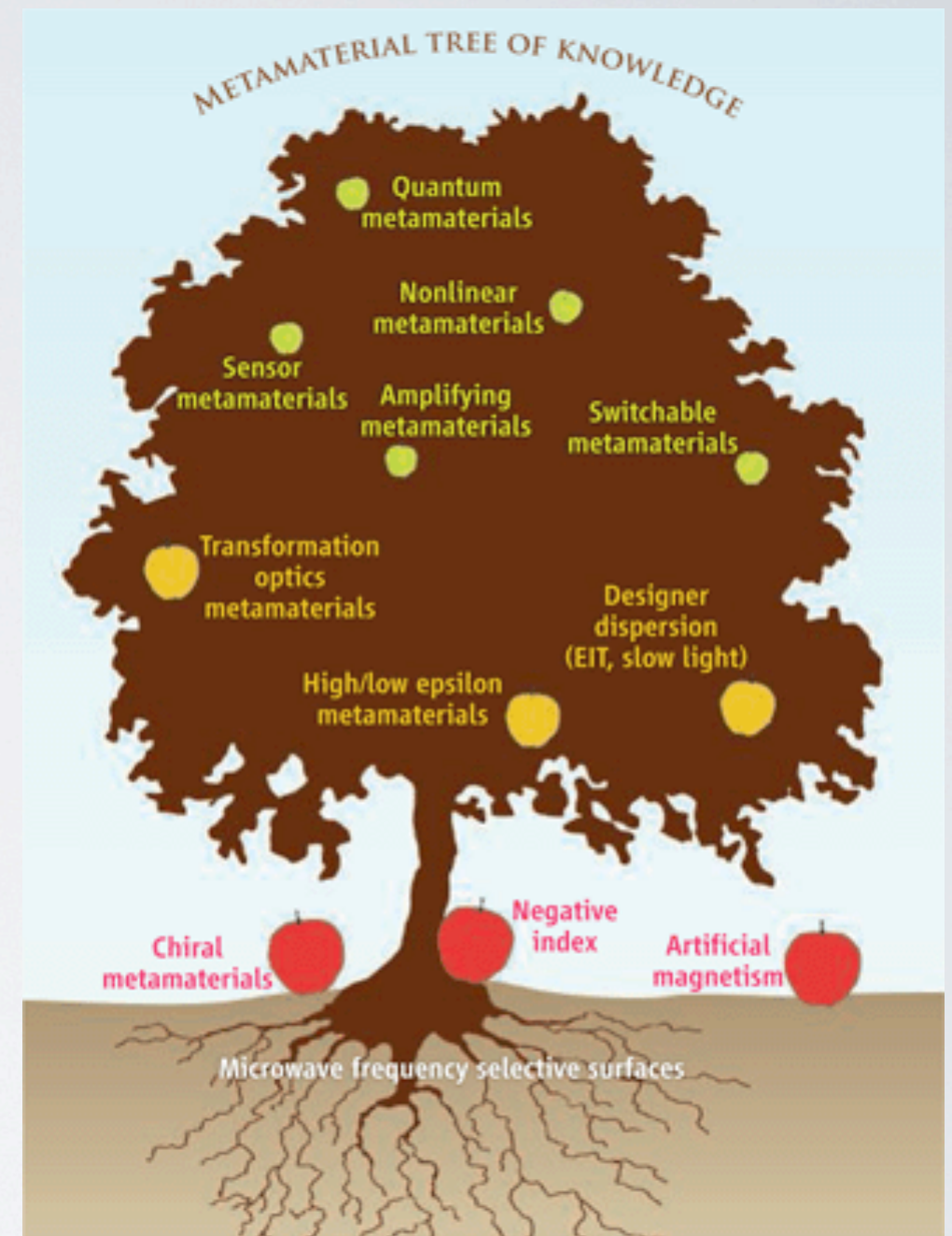
shared events with schools in other disciplines in the past (*School in Antennas*)
and anticipated joint schools in the future also outside Europe

Financial aspects

- registration fees for members / non-members / professionals
- up to three travel grants from countries with less scientific funds
- associated is a registration waiver
- decision by a steering committee of the individual school
- travel support if really necessary to experts
- fees in the order of 400€-600€ for a weekly school
- fees in the order of 100€-200€ for a two-day school

Problems and challenges

- financially unstable situation
- each school has to be self-supported usually by registration fees
- finding people who are willing to organize a school
- keep abreast with an extremely fast evolving research field
- reflecting novel streams in the curriculum of the school is crucial to maintain being attractive
- competing with other comparable events



Summary and conclusions

- sound program in place to educate on metamaterials
- research projects are stipulated by gathering PhD students
- reaching different communication is beneficial for everybody
- relations to schools discussing adjacent subjects are looked for an partially established



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