Curriculum Fisica della Materia
Condensed matter

Responsible:
Paolo Postorino

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Fermi building, IV floor, room 407

Curriculum
(piano di studi)

standard:
Mandatory and eligible courses chosen within the groups A, B, C following the general instructions.

customized:
Mandatory courses but eligible courses can be chosen more freely. The individual plan **must be motivated** and possibly discussed with the responsible of the curriculum.

Corso di laurea in Fisica (LM-17) - Curriculum Fisica della Materia

N.	Insegnamenti	CFU	anno	sem.	SSD	eng	ambito
1	Relativistic Quantum Mechanics	6	1	1	FIS/02	Y	caratt.
2	Condensed Matter Physics	6	1	1	FIS/03	Y	caratt.
3	gruppo C	6	1 / 2	1 / 2			aff.-int.
4	Meccanica statistica e fenomeni critici	6	1	1	FIS/02	N	caratt.
5	Physics Laboratory I (propedeutico a Physics Laboratory II)	6	1	1	FIS/01	Y	caratt.
6	Solid State Physics	6	1	2	FIS/03	Y	caratt.
7	Mathematical Physics	6	1	2	MAT/07	Y	aff.-int.
8	gruppo A	6	1 / 2	1 / 2			aff.-int.
9	Corso a scelta	6	1	2			
10	Physics Laboratory II	12	1	2	FIS/01	Y	caratt.
11	gruppo B	6	1 / 2	1 / 2	FIS/03		caratt.
12	Corso a scelta	6	2	1			
13	Internship	3	2	1		Y	AAF
14	Thesis Project	39	2	2		Y	AAF

Curriculum Fisica della Materia

N.	Insegnamenti	CFU	anno	sem.	SSD	eng	ambito
1	Relativistic Quantum Mechanics	6	1	1	FIS/02	Y	caratt.
2	Condensed Matter Physics	6	1	1	FIS/03	Y	caratt.
3	gruppo C	6	1 / 2	1 / 2			aff.-int.
4	Meccanica statistica e fenomeni critici	6	1	1	FIS/02	N	caratt.
5	Physics Laboratory I (propedeutico a Physics Laboratory II)	6	1	1	FIS/01	Y	caratt.
6	Solid State Physics	6	1	2	FIS/03	Y	caratt.
7	Mathematical Physics	6	1	2	MAT/07	Y	aff.-int.
8	gruppo A	6	1 / 2	1 / 2			aff.-int.
9	Corso a scelta	6	1	2			
10	Physics Laboratory II	12	1	2	FIS/01	Y	caratt.
11	gruppo B	6	1 / 2	1 / 2	FIS/03		caratt.
12	Corso a scelta	6	2	1			
13	Internship	3	2	1		Y	AAF
14	Thesis Project	39	2	2		Y	AAF

Gruppo A (aff.-int.)

1	Fisica dei sistemi a molti corpi	6	1	2	FIS/03	N	
2	Statistical Mechanics of Disordered Systems	6	2	1	FIS/02	Y	

Gruppo B (caratt.)

1	Physics of liquids	6	1	2	FIS/03	Y	
2	Fisica dei sistemi a molti corpi	6	1	2	FIS/03	N	
3	Fisica dei sistemi complessi	6	2	1	FIS/03	N	
4	Surface Physics and Nanostructures	6	2	1	FIS/03	Y	
5	Informazione e computazione quantistica	6	2	1	FIS/03	N	
6	Spectroscopy Methods and Nanophotonics	6	2	1	FIS/03	Y	
7	Superconduttività e superfluidità	6	2	1	FIS/03	N	

Gruppo C (aff.-int.)

1	Biophysics	6	1	2	FIS/03	Y	
2	Fisica dei sistemi a molti corpi	6	1	2	FIS/03	N	
3	Fisica dei sistemi complessi	6	2	1	FIS/03	N	
4	Surface Physics and Nanostructures	6	2	1	FIS/03	Y	
5	Fotonica	6	1	1	FIS/03	N	
6	Informazione e computazione quantistica	6	2	1	FIS/03	N	
7	Computational Statistical Mechanics	6	1	2	FIS/02	Y	
8	Meccanica Statistica del Non Equilibrio	6	1	2	FIS/02	N	
9	Medical applications of physics	6	2	1	FIS/01	Y	
10	Metodi computazionali per la fisica	6	1	1	INF/01	N	
11	Physics of liquids	6	1	2	FIS/03	Y	
12	Spectroscopy Methods and Nanophotonics	6	2	1	FIS/03	Y	
13	Onde non lineari e solitoni	6	1	2	FIS/02	N	
14	Ottica non lineare e quantistica	6	1	2	FIS/01	N	
15	Simulazioni atomistiche	6	1	2	INF/01	N	
16	Superconduttività e superfluidità	6	2	1	FIS/03	N	

Why condensed matter?

- It is the *world* around you.

Why condensed matter?

- It is the *world* around you.

→ Huge number of application fields
→ Most of them are real, substatial you can *touch* them

→ P.W. Anderson (Nobel laureate) : *«more is different»*

Why condensed matter?

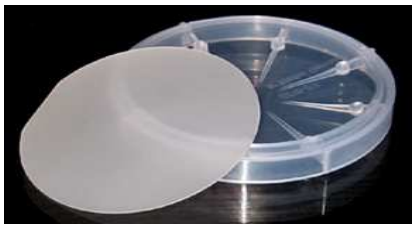
- It is the *world* around you.

→ Huge number of application fields
→ Most of them are real, substatial you can *touch* them

Al_2O_3 aluminum oxide (corundum)

Powder

Pressed



Polycrystalline

single crystal

Doped

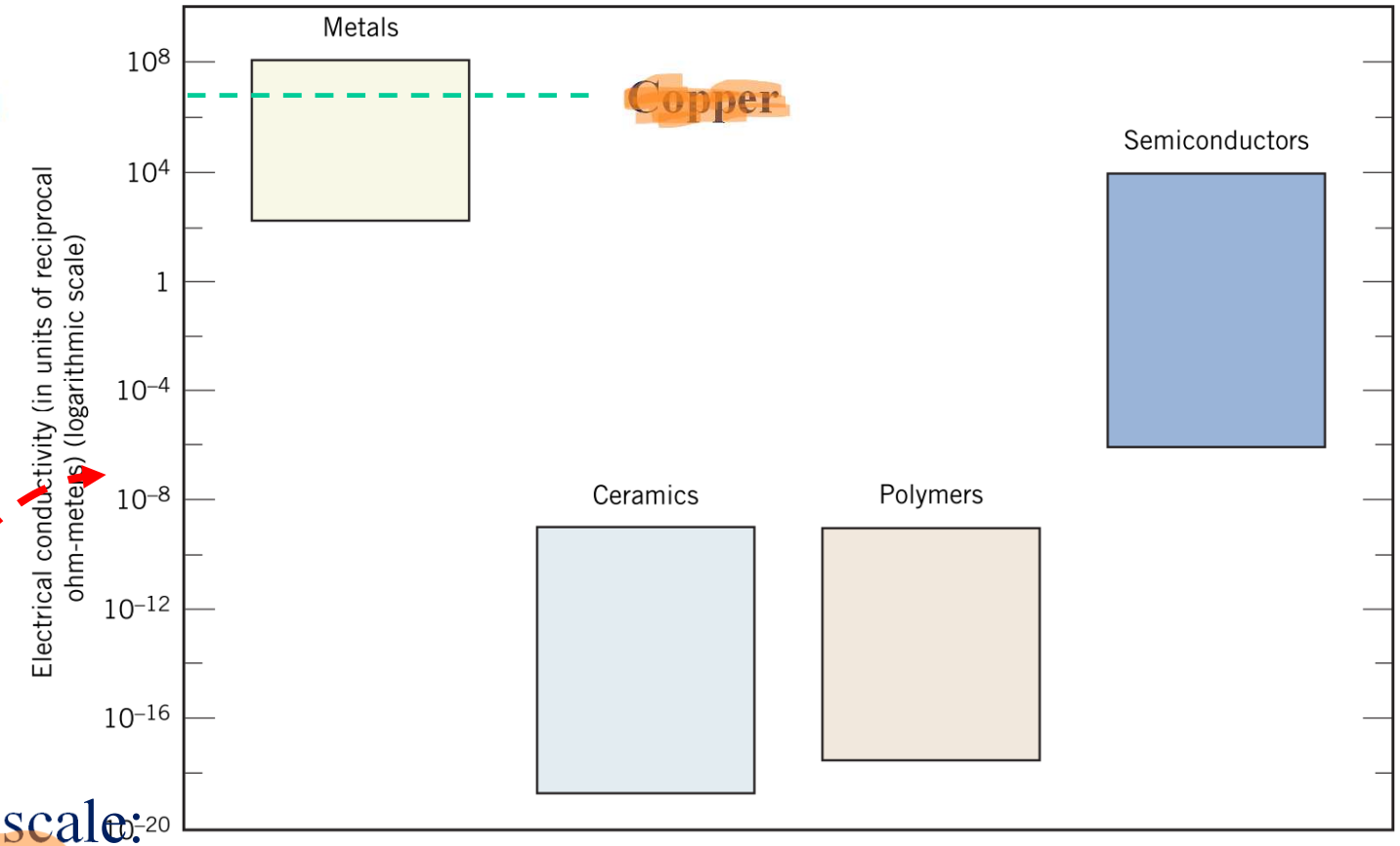
Cr^{3+}

Fe^{3+}

$Fe^{2+} + Ti^{4+}$

General properties of materials

Figure 1.8
Bar chart of room-temperature electrical conductivity ranges for metals, ceramics, polymers, and semiconducting materials.



Notice: Log scale:
More than **28** order of magnitude !

From W.D. Callister, D.G. Retwisch *Fundamentals of materials science and engineering an integrated approach*

Why condensed matter?

- It is the world around you.
- It is useful

- Energy: solar-cell, battery, loss reduction..
- Miniaturization
- Environment: clean water, clean air
- Medical: imaging, cell screening, nano-medicine, theragnosis…

It can be even much more useful

- 60 x10^6 transistors /year/person are produced.
- More than 20% of losses transering electricity
- Maximum solar/eelectricity conversion efficiency 22%

Nanotechnology R. Feynmann (Nobel Laureate):

There is a plenty of space at the bottom.

Why condensed matter?

- It is the world around you
- It is useful
- It is deep

- Condensed matter is a quantum mechanics playground!
  + statistical mechanics + many body interaction + ….
  → **above all creativity!**

Design and **realize** new: experiments, materials, instruments, material architectures (nano-design), analysis…

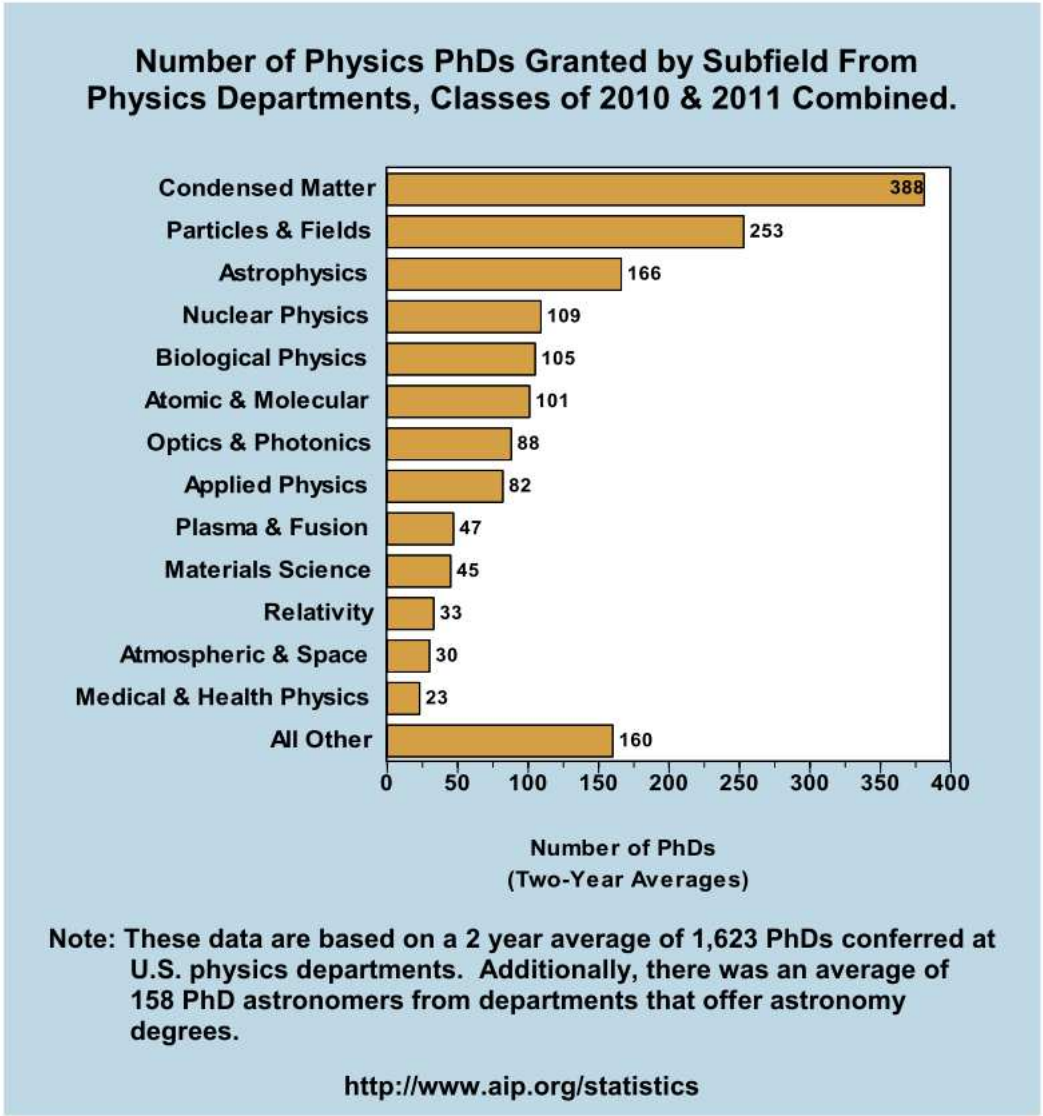
In between *infinity big* and *infinity small*
there is infinity complex

Why condensed matter?

- It is the world
- It is useful
- It is deep
- It is very cross-disciplinary

Biology, chemistry, engineering, humanistic studies (cultural heritage, archeology..), forensic, medical etc. etc.

About 30% of the physicists in the world can be classified as «condensed matter physicists»



AIP Statistical Research Center

AIP – American Institute of Physics

(2014)

Why condensed matter?

- It is the world around you.
- It is useful
- It is deep
- It is very cross-disciplinary
- It shows the way from microscopic → macroscopic

You can: design the material
create the material
ask the questions
get the aswers.

In principle you can do all yourself

https://www.youtube.com/watch?v=3De1rLxvzyU (**So Close and Such a Stranger)**

Superconductivity & strongly correlated systems.

Nanostructured & low dimensional systems

Teaching closely related to the research activity carried out in the Dept.

Liquids & disordered systems

Quantum information, non linear optics

Statistical Mechanics

Materials and methods for cultural heritage …

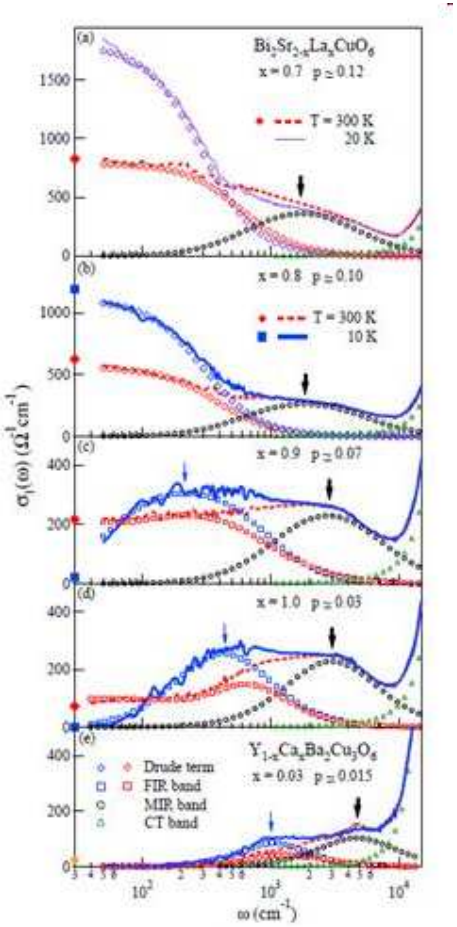
In house laboratory (Spectroscopy: optical, electron, linear, non-linear, time resolved…)

Computational and *ab-initio* methods.

Research activities and methods in condensed matter

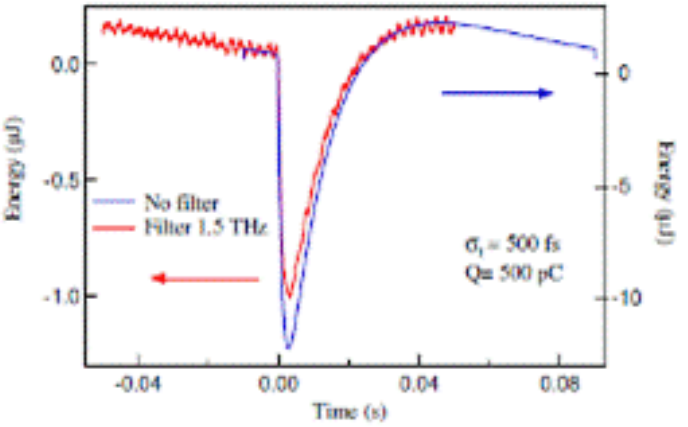
Large scale facilities: Synchrotron and Neutron sources

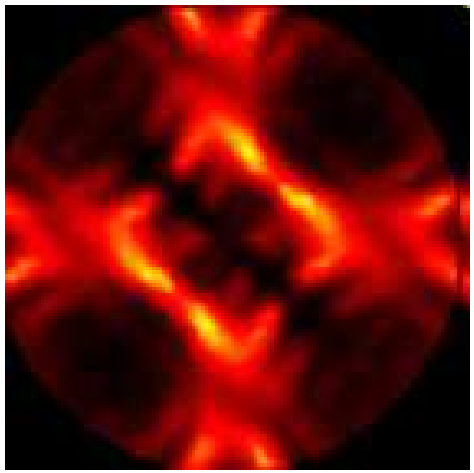
Superconductivity & strongly correlated materials



High Tc Superconductors
Insulator-metal transition
transizione metallo-isolante
Paolo CALVANI
Michele ORTOLANI
Alessandro NUCARA
…

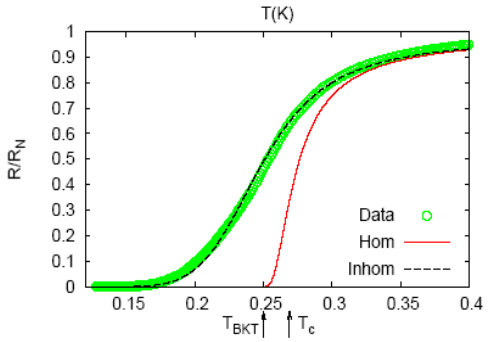
THz sources, Metamaterial
Stefano LUPI
…

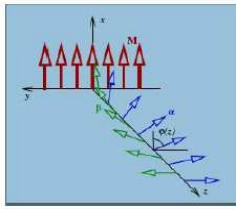


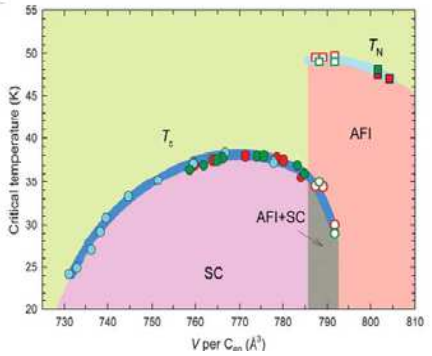


Fermi surface of the
Bi2212 superconductor
Naurang L. SAINI
…

Strongly correlated materials, theory

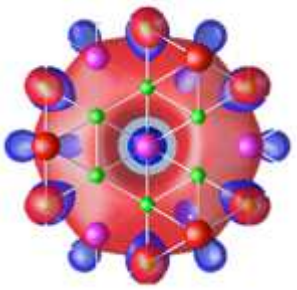




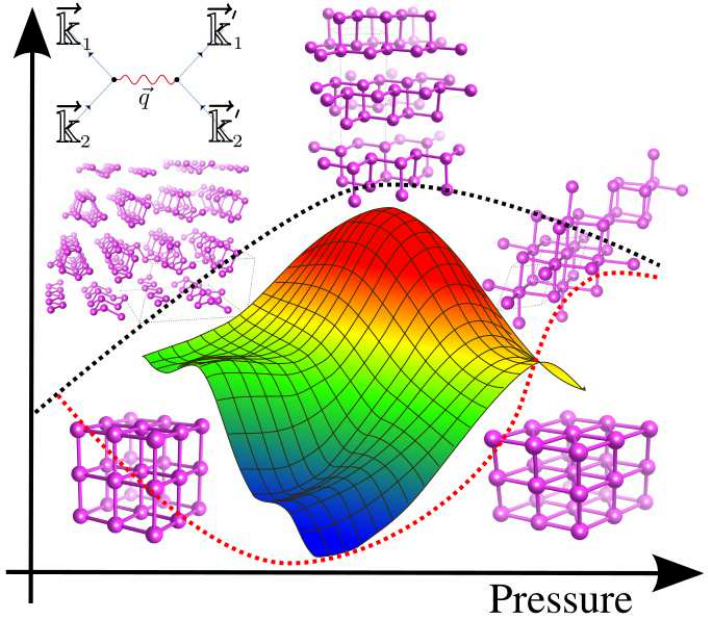


High Tc Superconductors
Elettron-Phonon coupling
Sergio CAPRARA
Claudio CASTELLANI
Marco GRILLI
...

Quantum theory of solids Density Functional Theory, Quantum Monte Carlo
Giovanni B. BACHELET
Lilia BOERI
Saverio MORONI
...

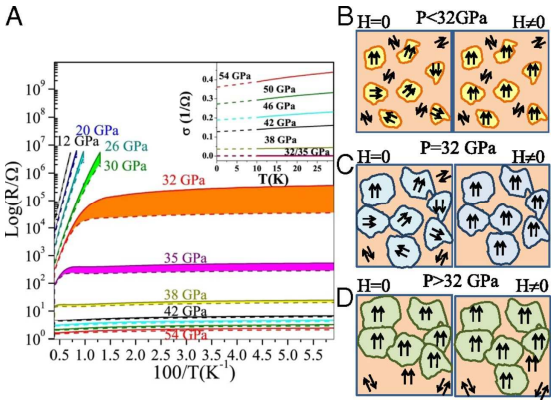


Interlayer states of intercalated graphite



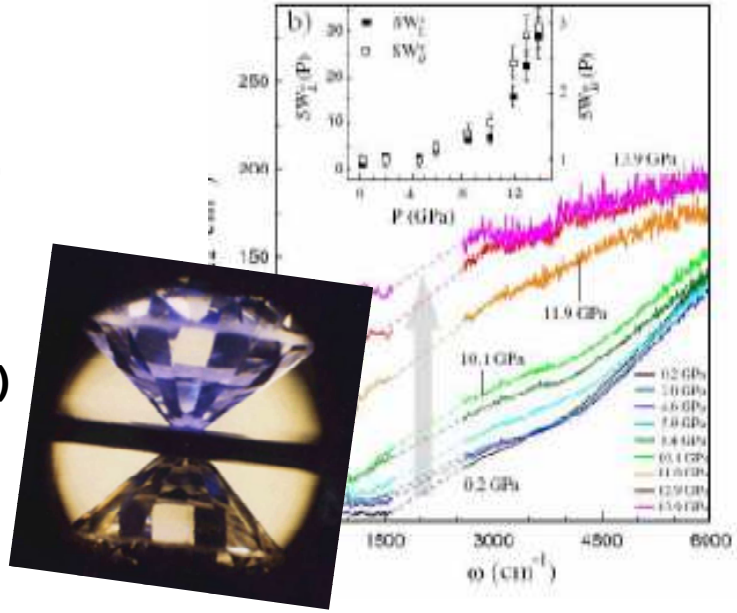
Predicted Phase Diagram of Phosphorous

Strongly correlated materials

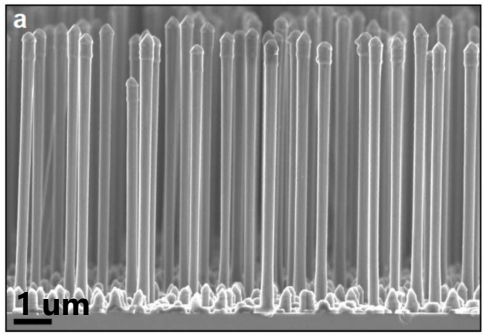


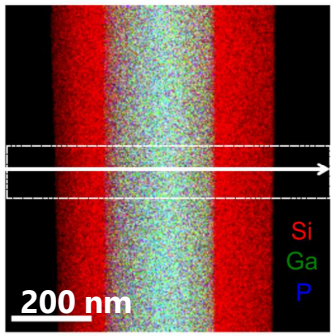
Condensed matter under extreme conditions (very high P, very high/low T)

Paolo POSTORINO
Paolo DORE
…

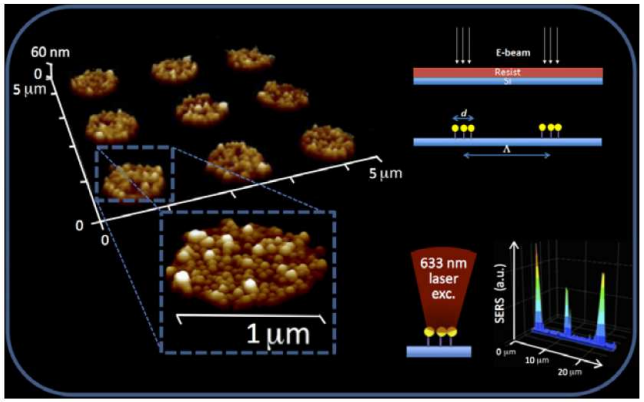


Nanostructures and low-dimensional systems

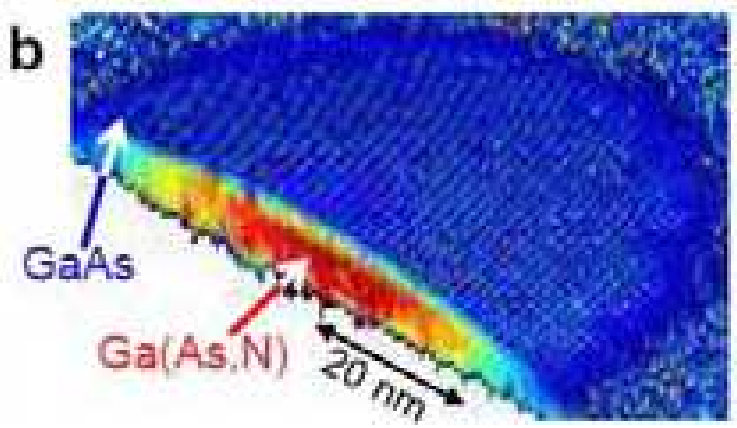


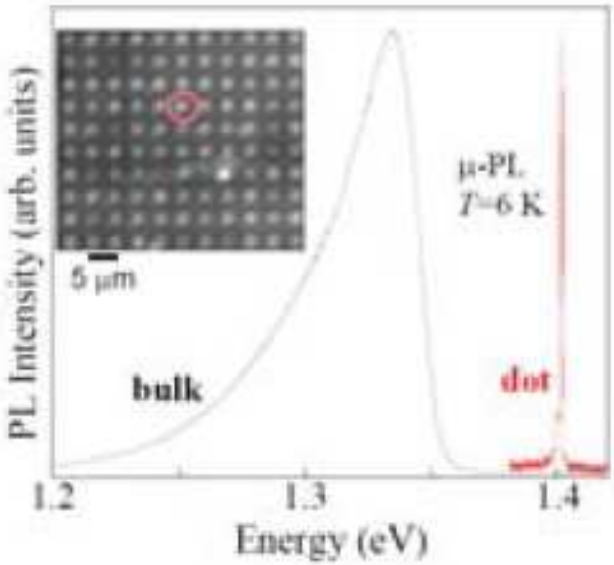


Semiconductor nanowires,
Metallic nanostructure



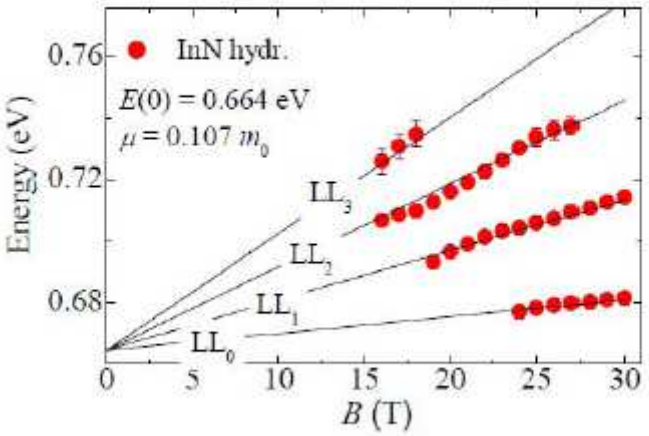
Nanostructures and low-dimensional systems



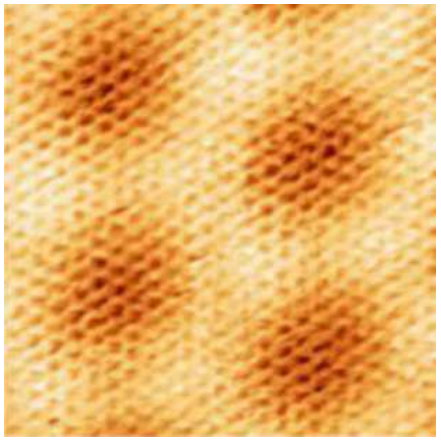


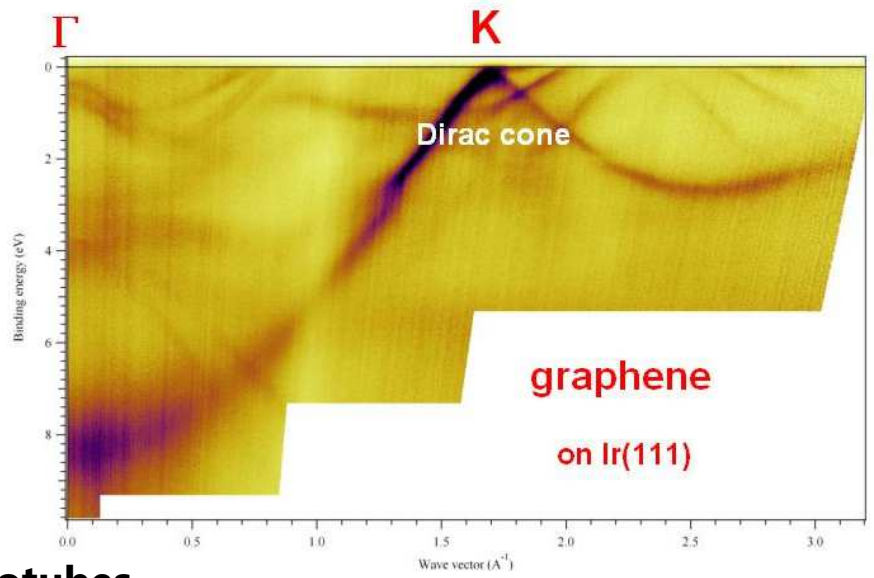
Semiconductor II-V
Quantum-dots (0D)
Antonio POLIMENI
Rino TROTTA
....

Optical properties under strong magnetic fields

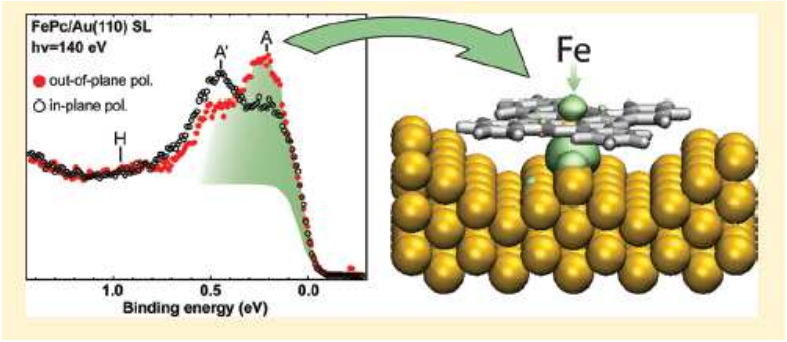


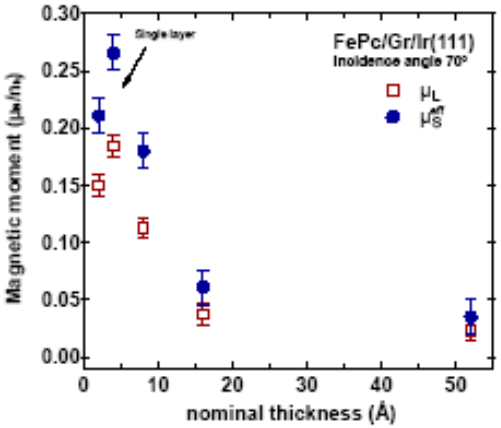
Nanostructures and low-dimensional systems





Carbon based systems: Nanotubes, graphene. Electronic properties
Maria Grazia BETTI
Carlo MARIANI
…
Molecular systems at high magnetic anisotropy



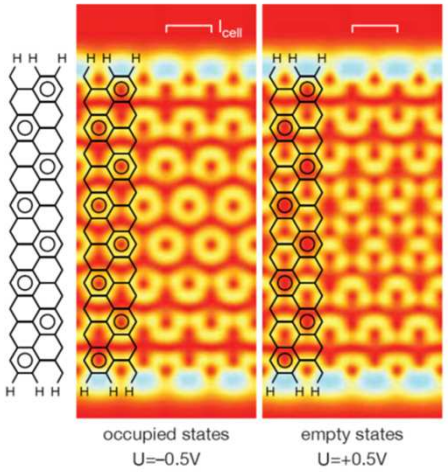


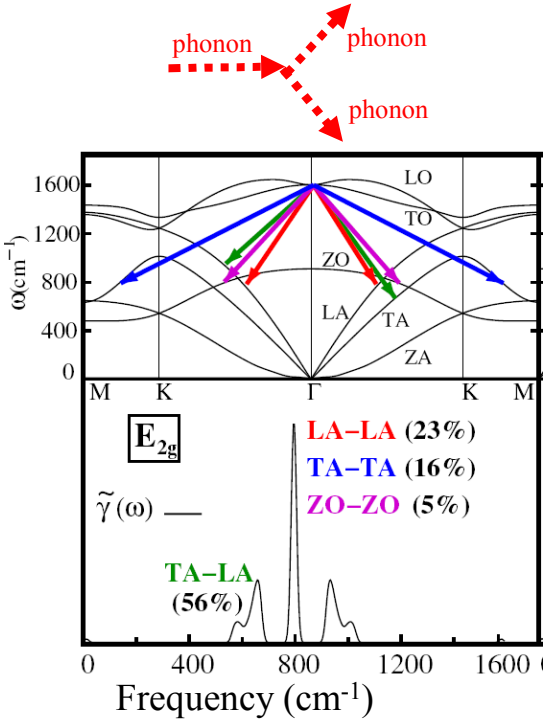
Graphene and 2D systems : first principle theory

Francesco MAURI

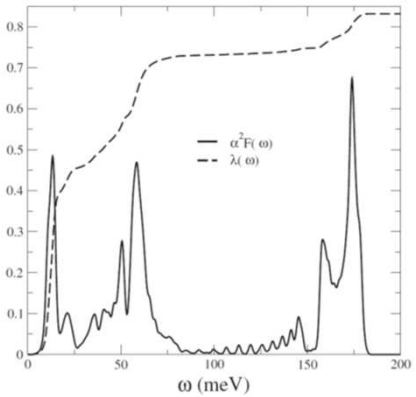
…

Graphene nanoribbons

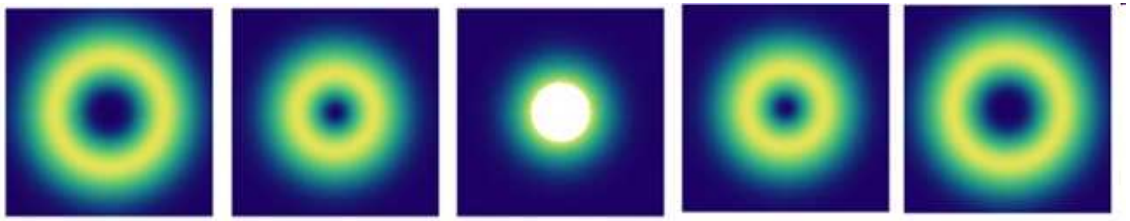




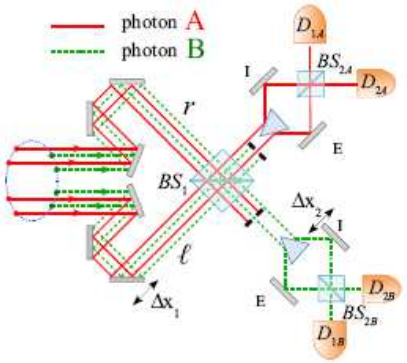
CaC_6 superconductor:
Eliashberg function

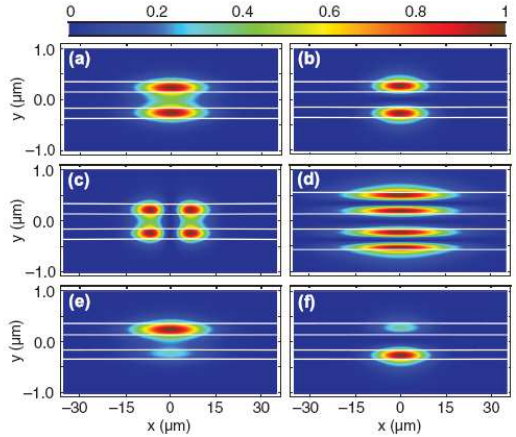


Quantum information, non-linear optics



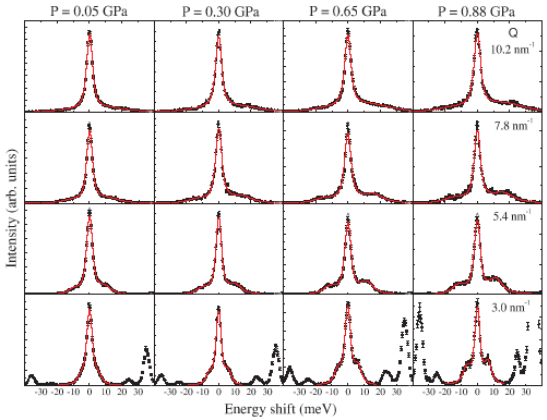
Qu-bits, quantum photonics
Paolo MATALONI
Fabio SCIARRINO
…
Optical technologies for quantum information.

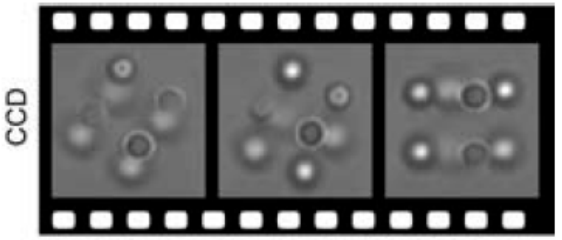




Non-linear optics, super-resolution
Claudio CONTI
Eugenio DEL RE
…

Liquidi e sistemi disordinati

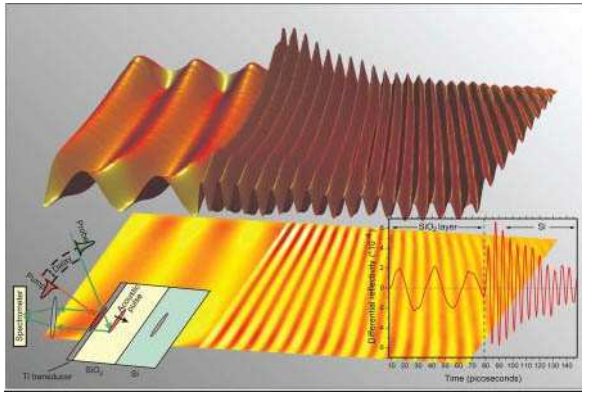




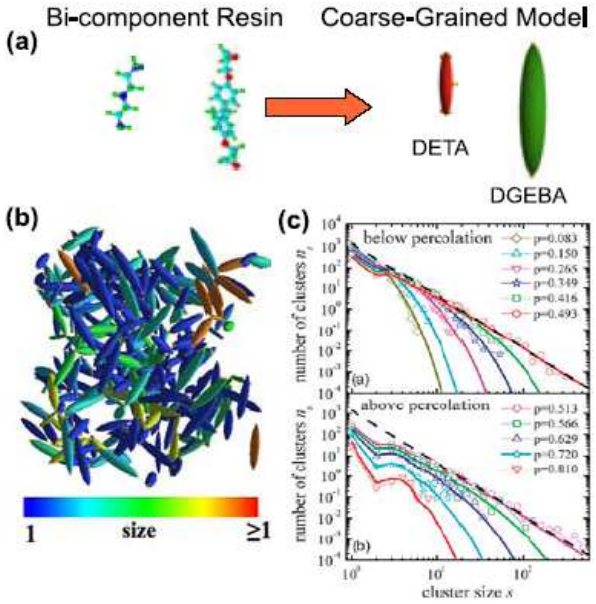
Sound velocity in liquids under extreme pressures / colloidal particle

Giancarlo RUOCCO
Tullio SCOPIGNO
…

Coherent excitation in disordered systems, femto-second spectroscopy

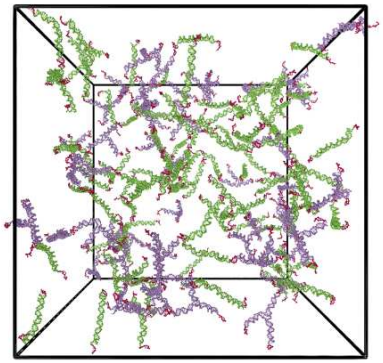


Liquids, macromolecules, disordered systems, gel

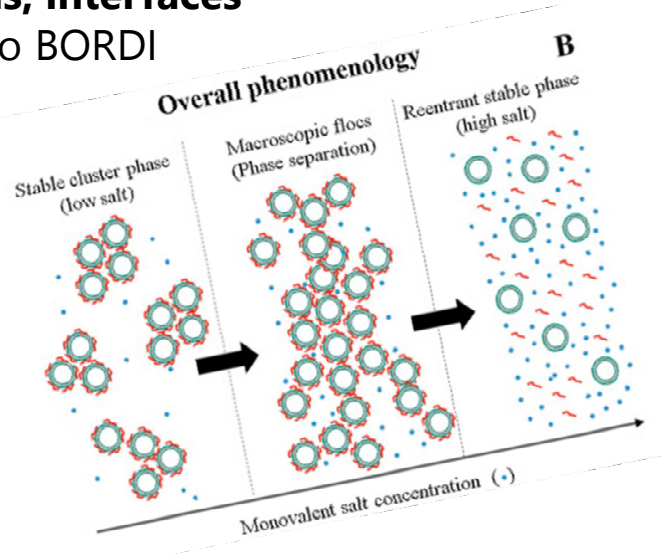


Proteins, colloids simulations
Cristiano DE MICHELE
Francesco SCIORTINO
Emanuela ZACCARELLI
…

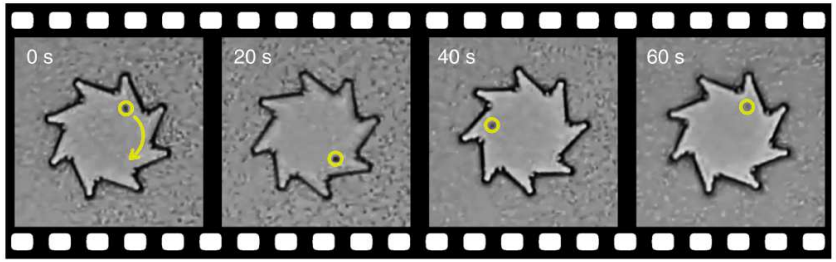
Self-assembled DNA structures: structural predictions.



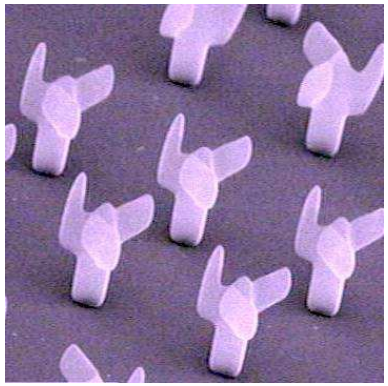
Colloids, interfaces
Federico BORDI
…



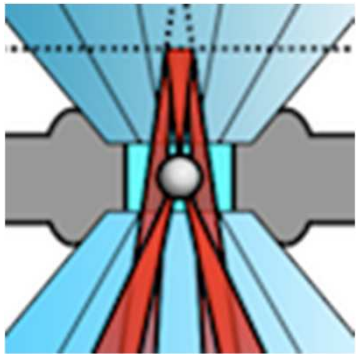
Structured matter at the microscale



Active matter, …
Roberto DI LEONARDO
…

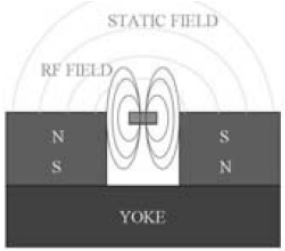


Light driven Micromotors



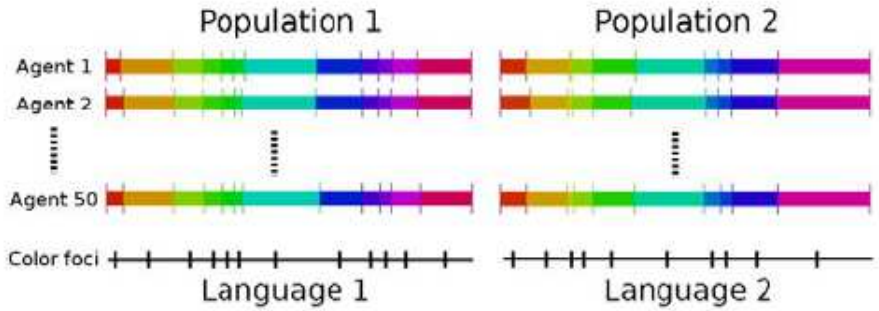
Optical trapping

Materials and methods for cultural heritage



Diagnostic for cultural heritage
Franco DE LUCA
…

Statistical mechanics and applications

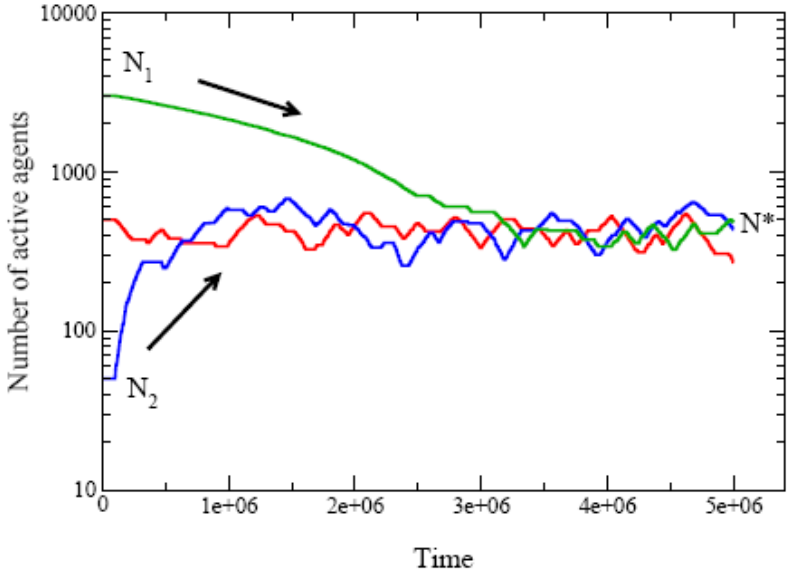


Self-organization, complexity, social dynamics

Vittorio LORETO

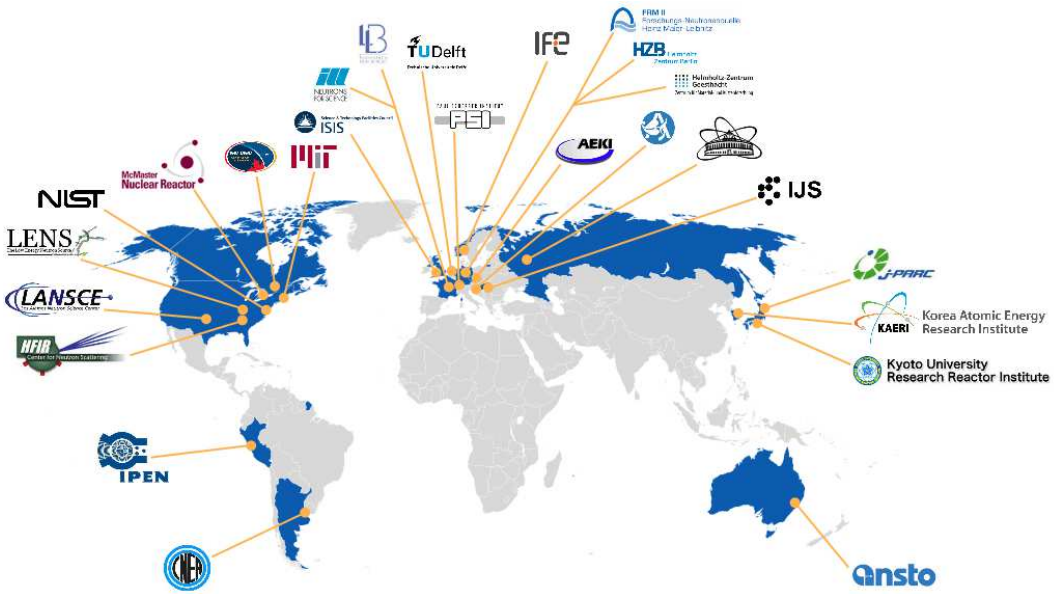
Luciano PIETRONERO

…



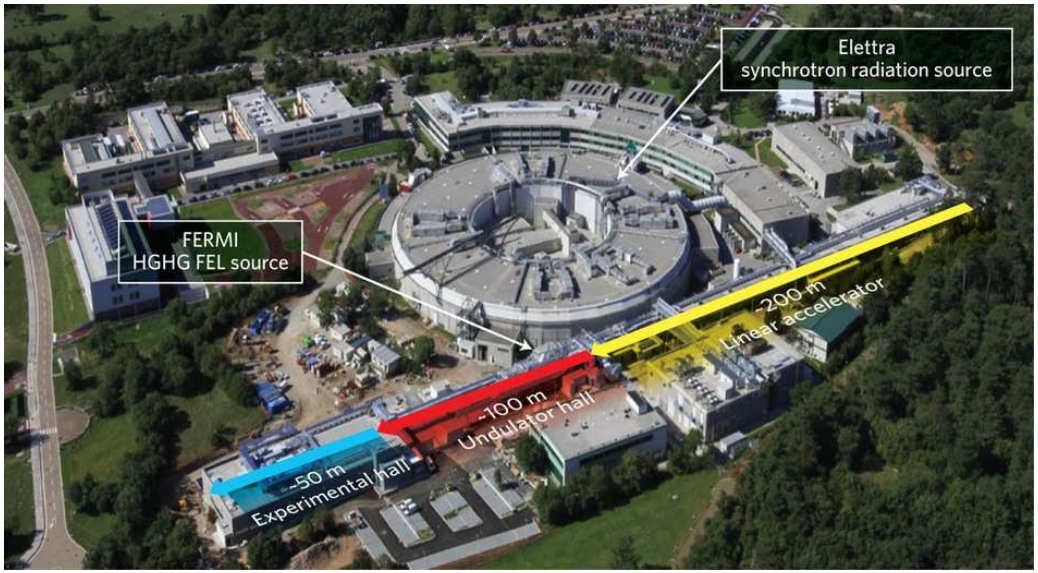
Large scale facilities in the world

Synchrotron sources

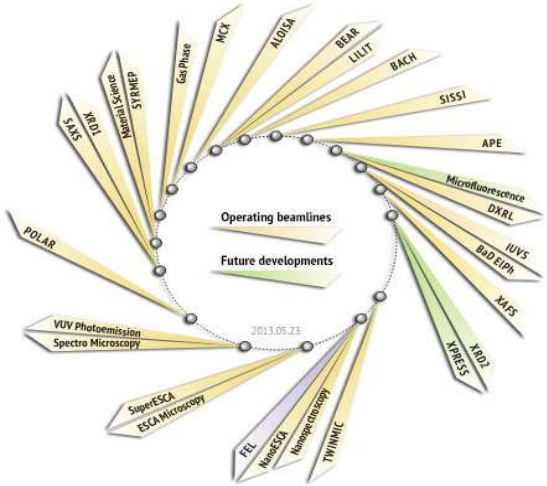


Neutron sources

Synchrotron Radiation Laboratories



ELETTRA
(Trieste, Italy)



+

Fermi FEL (Free Electron Laser)

Synchrotron Radiation Laboratories

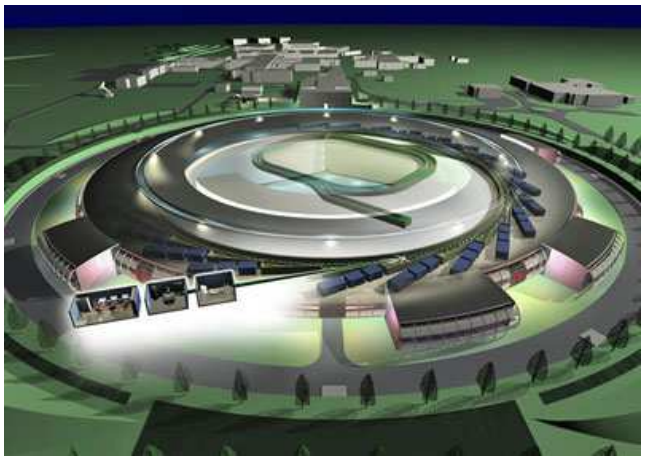
ESRF
Grenoble (France)

Synchrotron Radiation Laboratories

ALBA
Barcelona (Spain)

Synchrotron Radiation Laboratories

DIAMOND
Oxforshire (United Kindom)



Synchrotron Radiation Laboratories

SOLEIL
Paris (France)