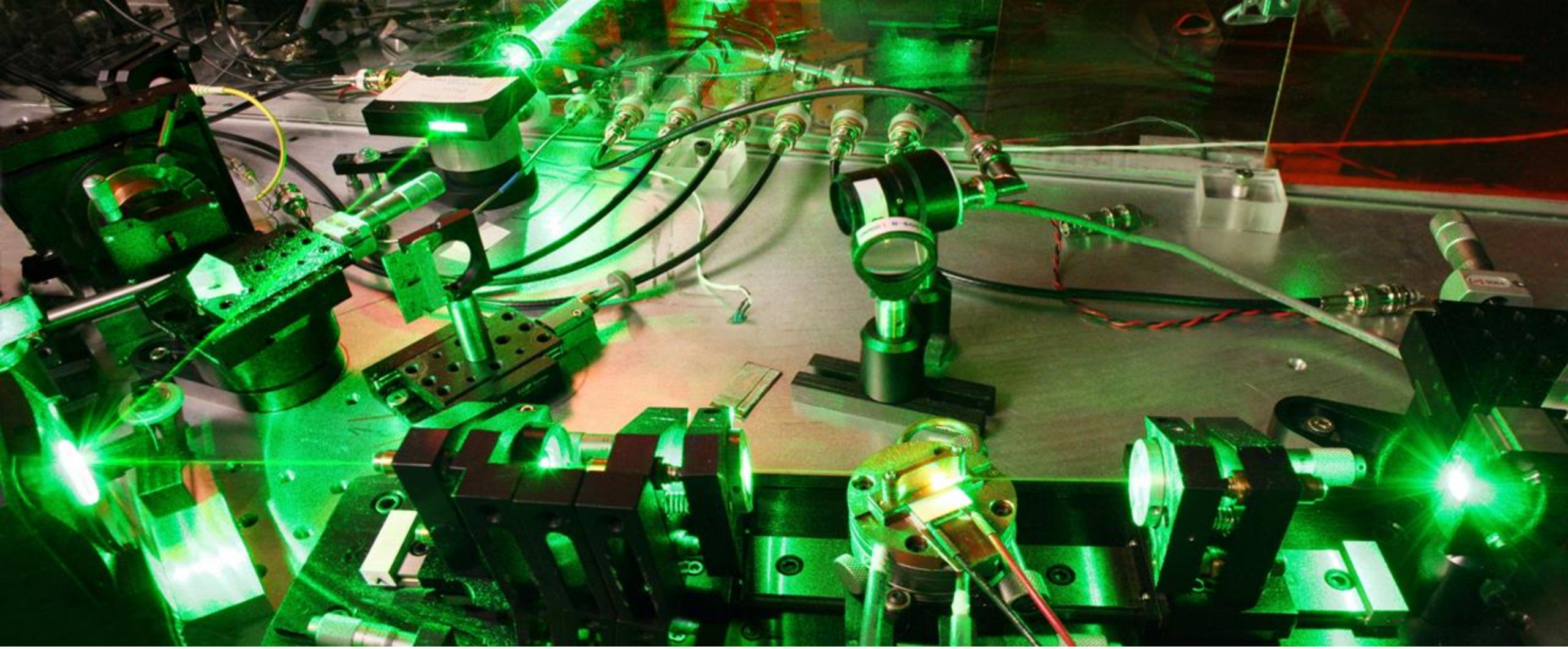

Condensed Matter Physics Laboratory

Contacts

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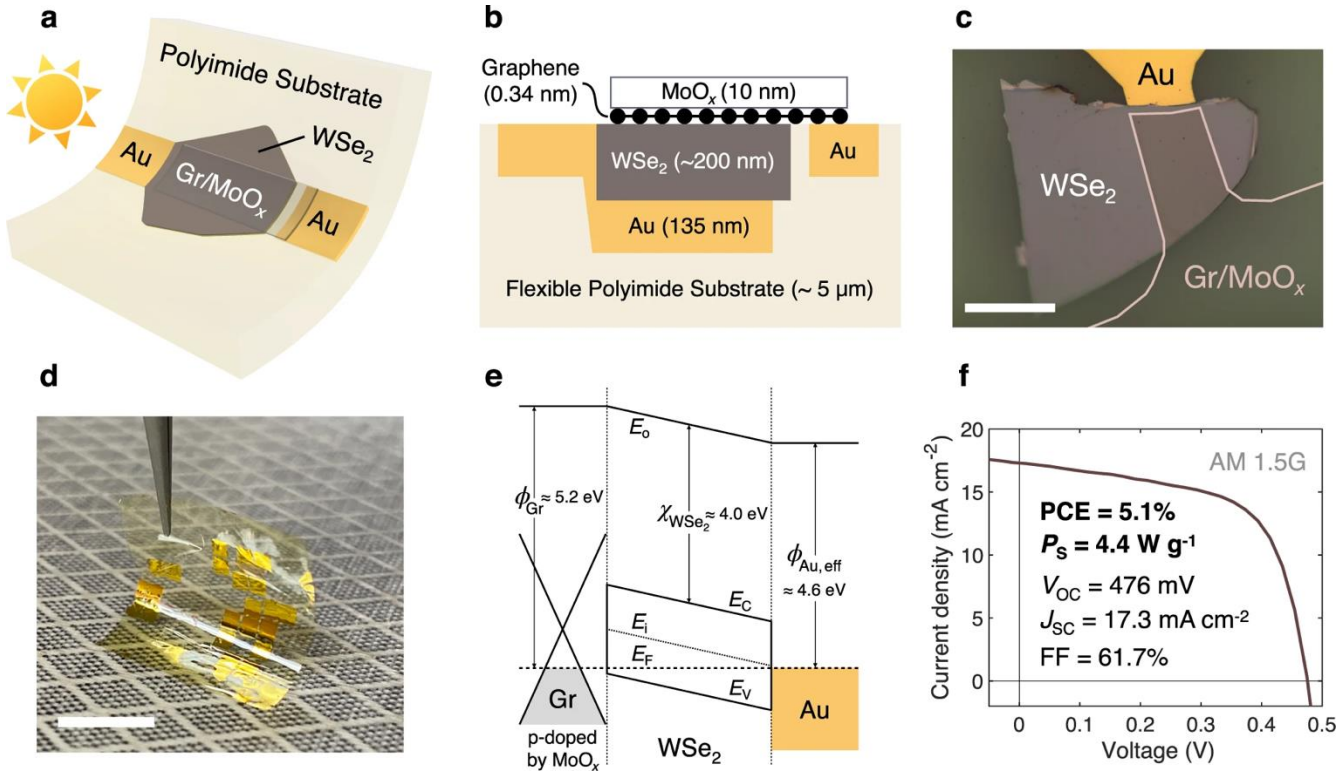
Introduction I

The development of new functional materials is linked to the study of their physical (and chemical) properties, to their response to external stimuli, etc.

The characterization of a material allows us to obtain useful information to improve its properties:

- avoiding oxidation/contamination or performance losses
- improving the synthetis protocols
- finding strategies to tailor the electronic properties on demand...

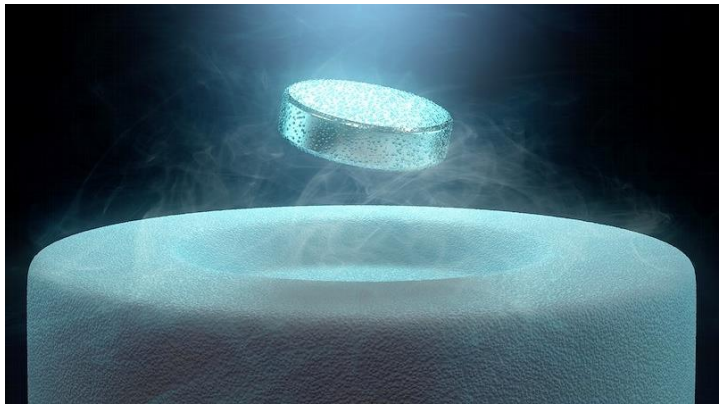


Nassiri Nazif, *et al. Nat Commun* **12**, 7034 (2021)

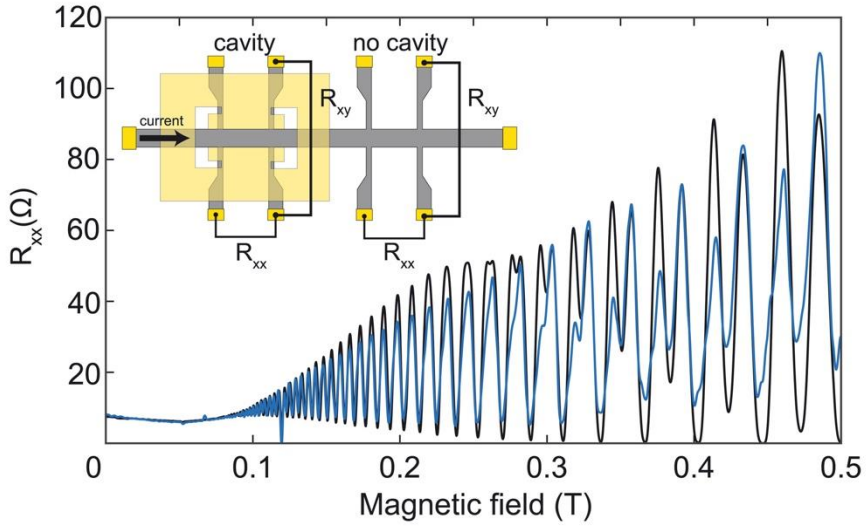
Introduction II

Some synthetic and/or nanostructured material allow for studying fundamental physical processes, for example:

Superconductivity

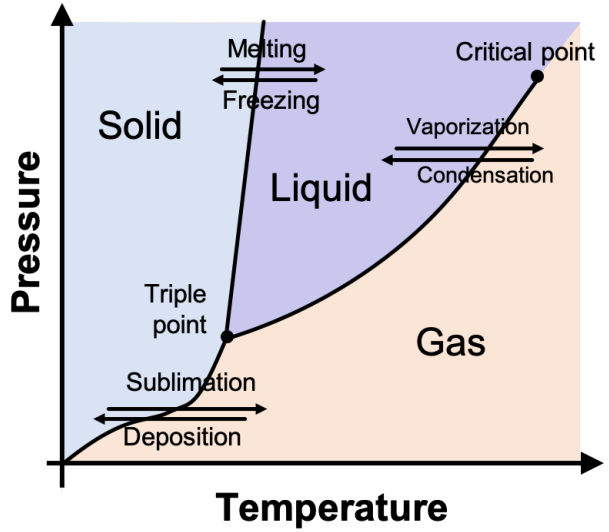


Quantum Hall effect



Appugliese *et al.Science* **375**,1030 (2022)

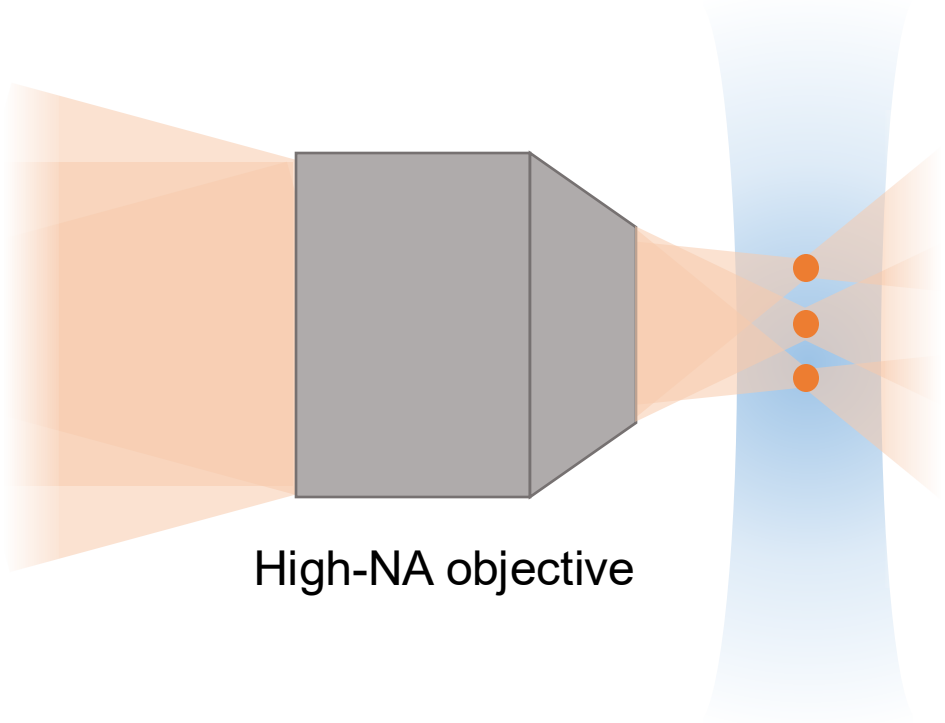
Phase transitions



Introduction III

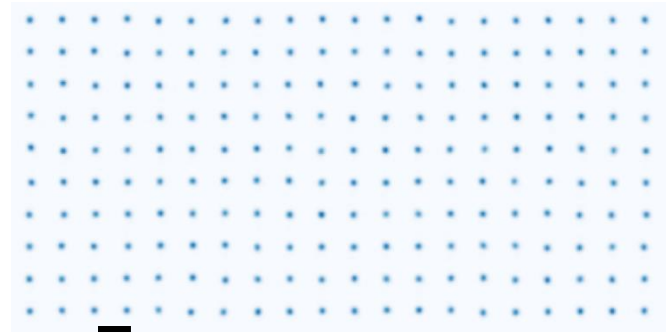
Atoms are trapped by virtue of light-matter interaction

Laser beams are used to manipulate atoms and for fluorescence detection



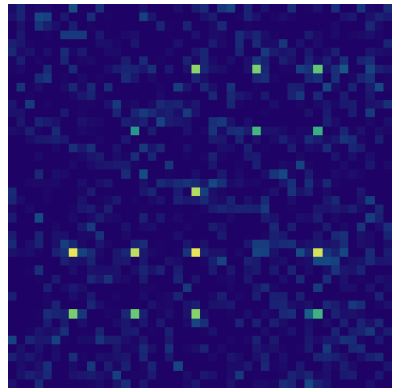
High-NA objective

20 x 10 atom array

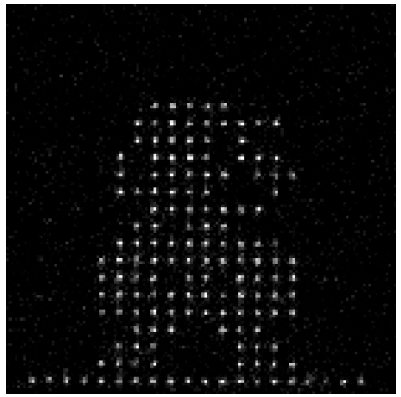


5 μm

JILA

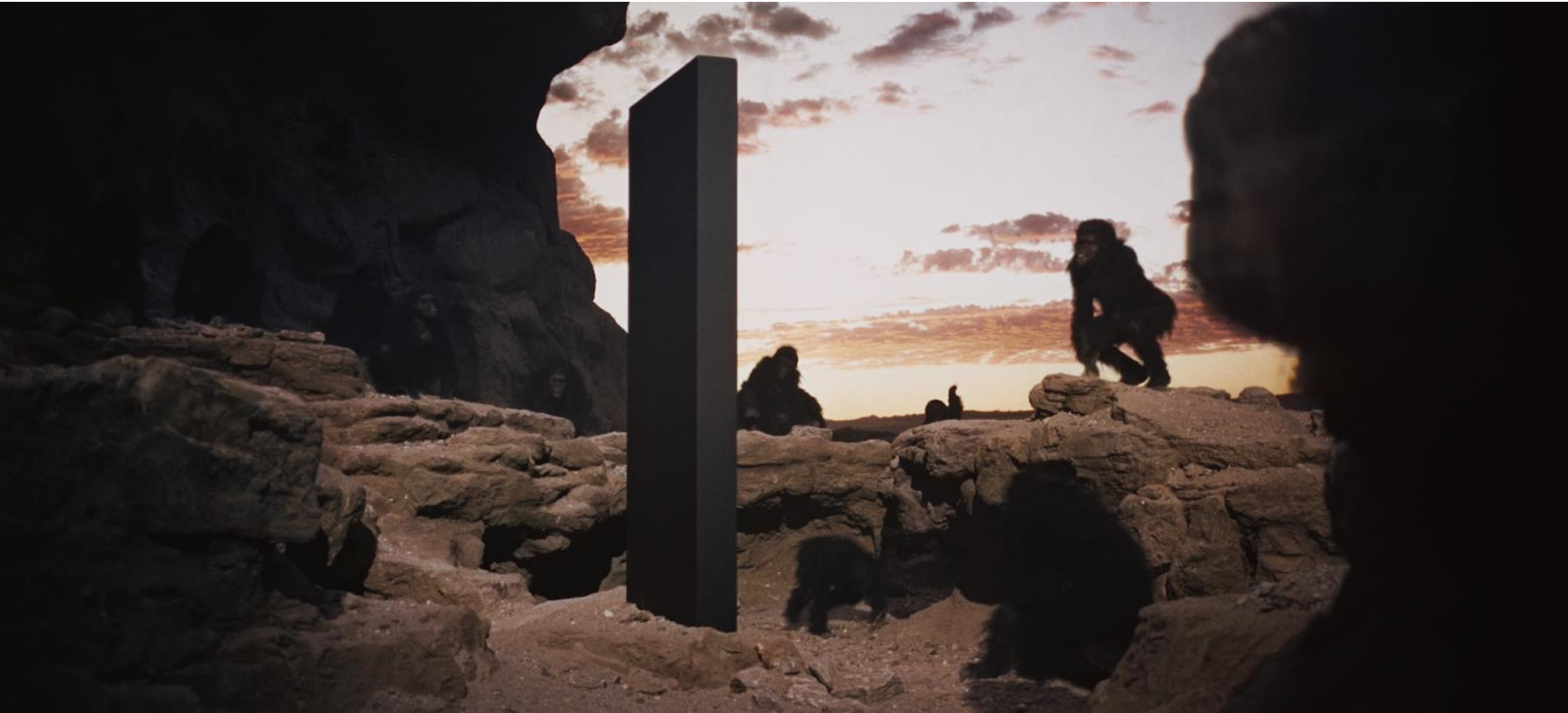


Harvard

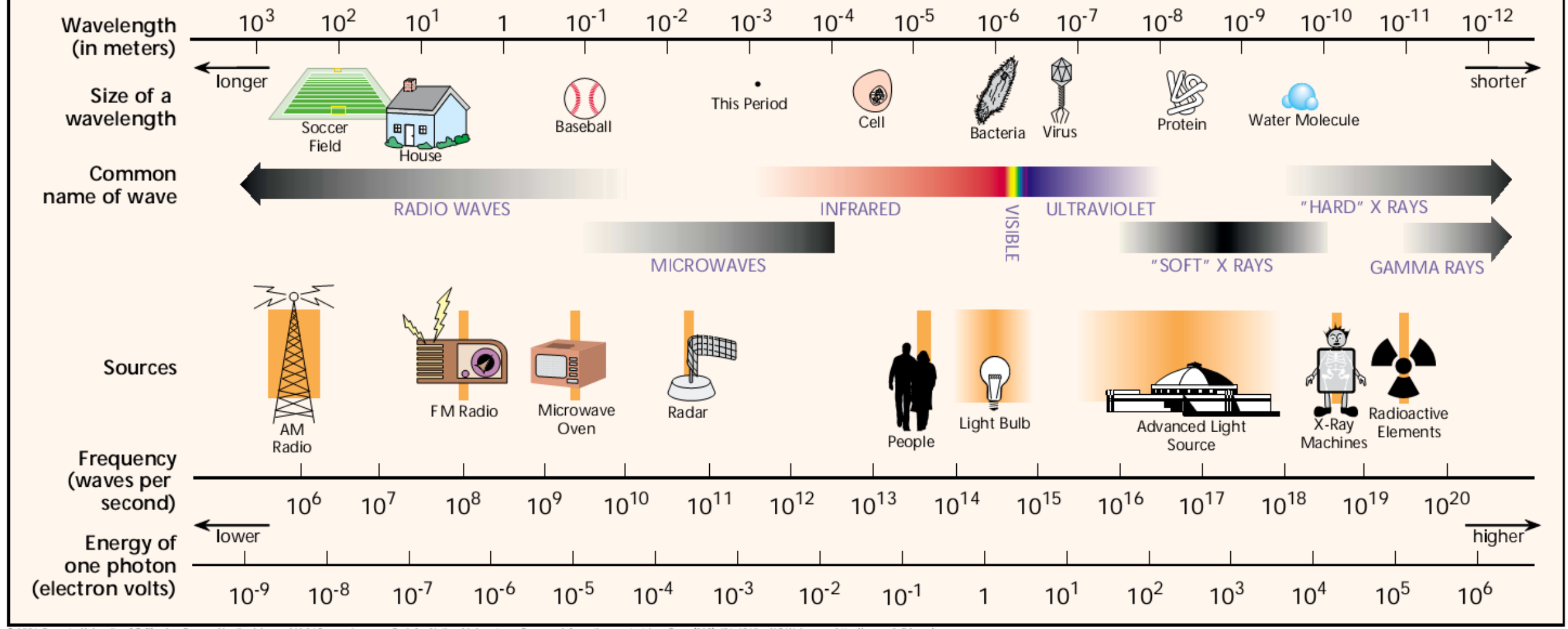


Pioneering technology from Grangier group

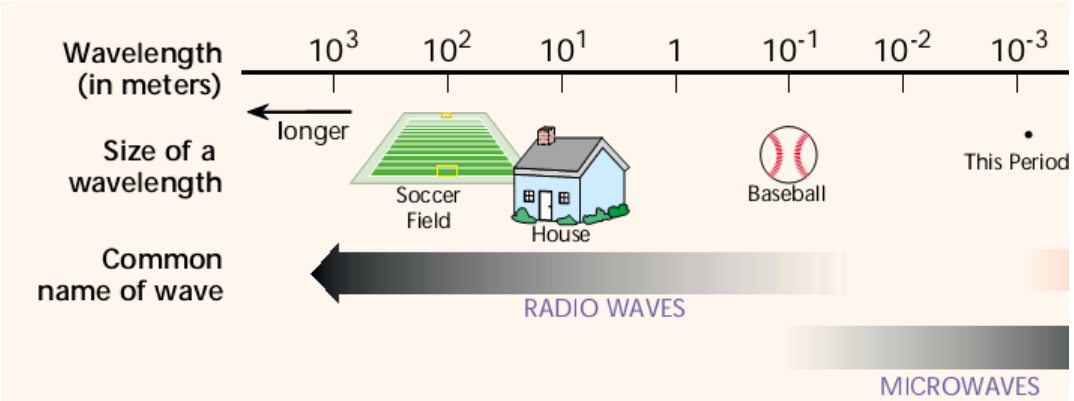
How do I analyze a material?



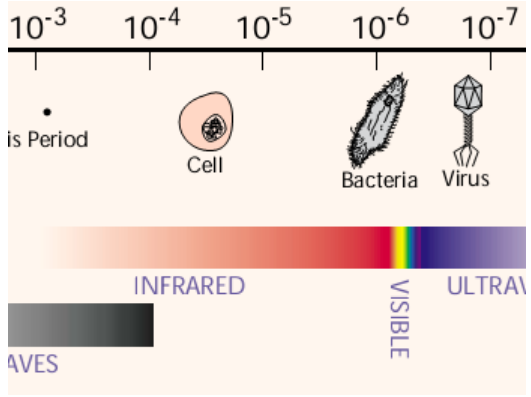
THE ELECTROMAGNETIC SPECTRUM



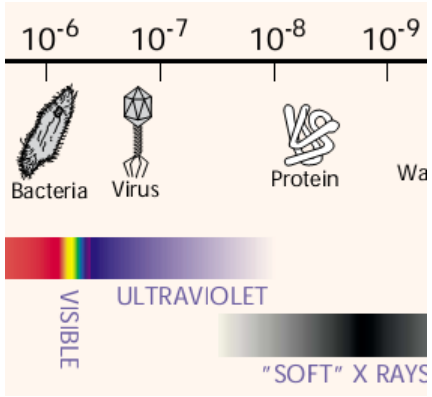
Physical dimensions



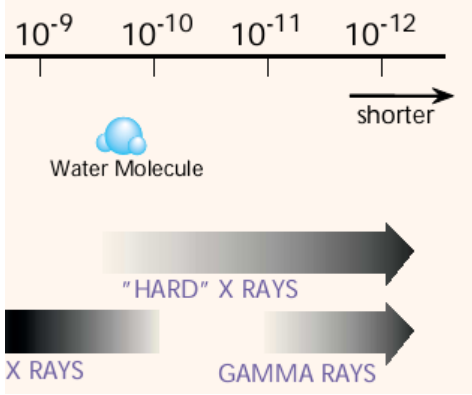
Macrostructure (>mm)
Topography, composition, macroscopic properties (temperature, conductivity,...)



Structure/microstructure (mm-0.1µm)
Optical and electron microscopy, optical spectroscopies, ...

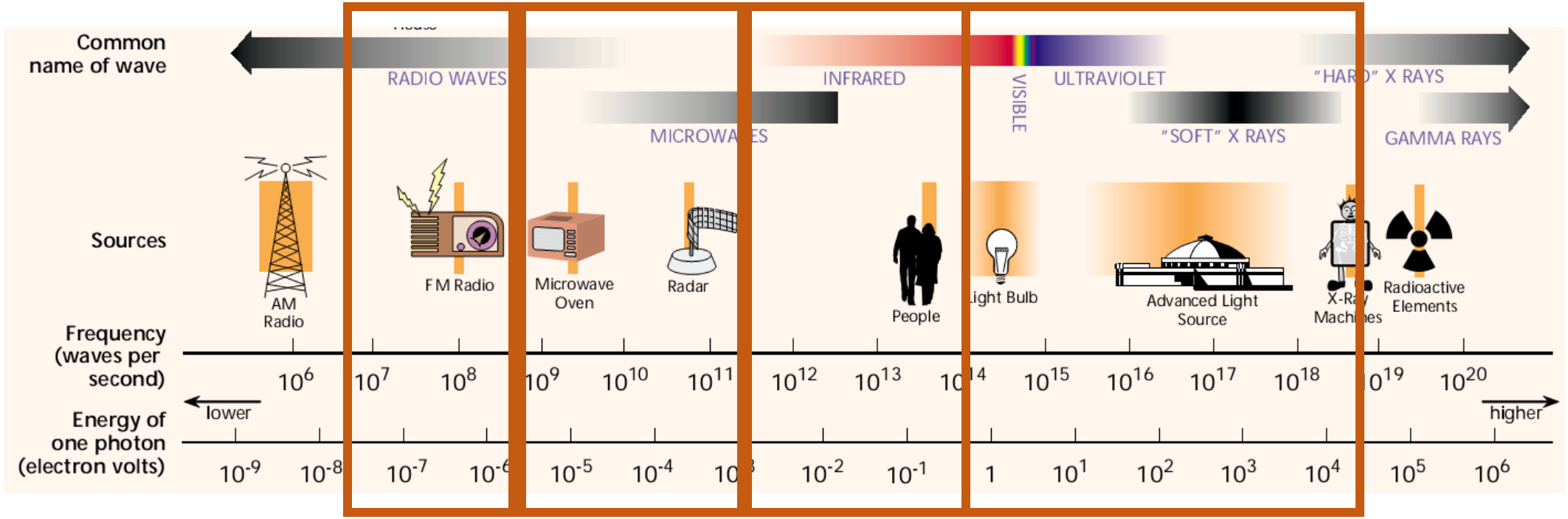


Microstructure (µm-nm)
Electron microscopy, scanning probe microscopies (AFM, STM, ...), optical spectroscopies, small angle X-ray scattering (SAXS), ...



Atomic structure (nm-fm)
High-resolution electron or scanning probe microscopy, X-ray/electron/neutron diffraction, ...

Energetic intervals



Nuclear spin transitions (NMR)

Molecular rotations

Molecular vibrations

Electronic transitions
Core levels and valence-conduction bands

Some experimental techniques

Diffraction	Microscopy	Spectroscopy
• X-rays • Neutrons • Electrons	• Optical • Electronic • X-ray • Scanning probe (STM, AFM)	• Visible-IR-UV • Raman • Photoemission (X-ray o UV) • X-ray absorption

And many more...

Measurement parameters (technical criteria)

- **Precision**: Absence of casual errors. Closeness between obtained in different measurements.
- **Accuracy**: Absence of systematic errors. Closeness between measured values and real values.
- **Resolution**: Ability to discriminate between close values of a quantity.
- **Detection limit**: Minimum value of a quantity that is detectable with an experimental setup, for a set accuracy level.
- **Signal-to-noise ratio (SNR)**: A measure of the interferences and of the intrinsic/extrinsic noise that characterizes the measurement.
- **Dynamic range**: Range of values of a quantity that is measurable with an instrument (with a proper calibration).
- **Selectivity:** Ability to discriminate different signal, or real signals from interferences.

Elements of an experimental setup

Signal generator – perturbation

- Particles (electrons, neutrons, ions), EM fields, applied forces, ...

Sample – signal emission

- Radiation, particle emission, property change, ...

Transductor + signal processor

- The signal is converted (e.g. thermocouple, piezoelectric, ...) and/or processed (amplified, filtered, integrated, ...)

Reading device (output transductor)

- Depending on the type of signal, it is converted into a measurable quantity: photographic plate, CCD, photodiode, multimeter, ...

Some other examples

Perturbation	Technique	Output signal
Electrons	Auger electron spectroscopy (AES), electron microscopy (SEM, TEM, ...), electron scattering (LEED, EELS, ...)	Electrons
Electrons	X-ray microanalysis (EDX, WDX), cathodoluminescence	Photons
Photons	X-ray photoemission spectroscopy (XPS) or ultraviolet photoemission spectroscopy (UPS)	Electrons
Photons	X-ray diffraction (XRD), X-ray fluorescence (XRF), UV-VIS-IR absorption spectroscopy, Raman spectroscopy, photoluminescence (PL)	Photons

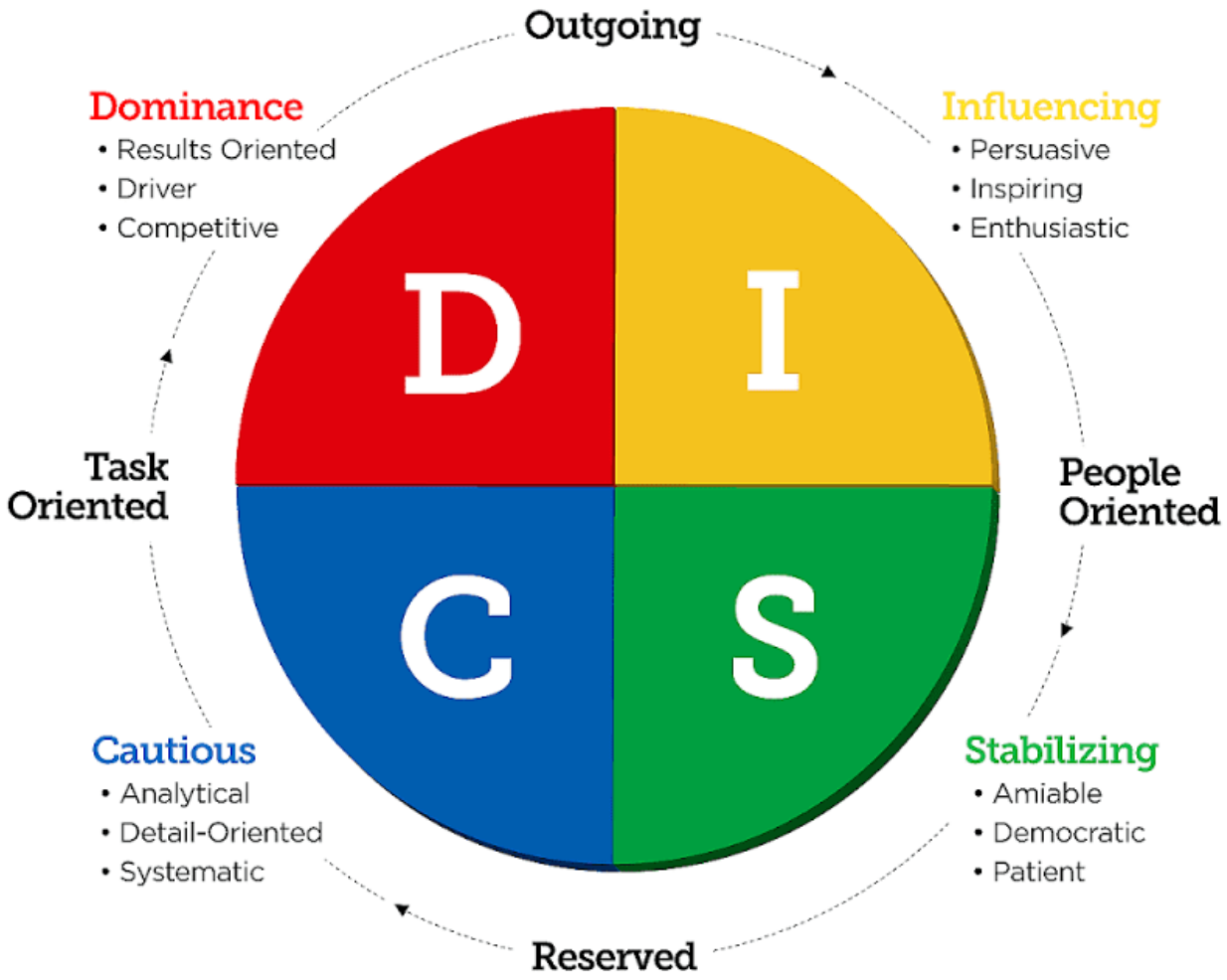
What to do

- Divide in groups: ideally 3-4 groups, to work independently on the photoluminescence setup
- Planning: 72h in total, ~20h theory + ~52h practical

Suggestions

- Compile a laboratory logbook, in which you report all details on the instruments and the measurement parameters. Something may be obvious in the moment you are measuring, but when it is time to write the report you might forget it…
- Make questions!

The personality DISC



In each group, ideally:

1 red

1 yellow

1+ green and/or blue

Timetable

	lunedì	martedì	mercoledì	giovedì	venerdì
08:00					
08:15		MACHINE LEARNING MEDVET Eric Aula B [Edificio C7] 08:00 - 10:00			
08:30					
08:45					
09:00					
09:15		MECCANICA STATISTICA IMPARATO ALBERTO Aula 5A [Edificio H2bis] 09:00 - 11:00	FISICA DELLA MATERIA CONDENSATA I PERESSI MARIA Aula D [Edificio F] 09:00 - 11:00		FISICA DELLA MATERIA CONDENSATA I PERESSI MARIA Aula D [Edificio F] 09:00 - 11:00
09:30					
09:45					
10:00					
10:15	LABORATORIO DI FISICA COMPUTAZIONALE - Lezione PERESSI MARIA, BECCA FEDERICO Aula D [Edificio F] 10:00 - 12:00				
10:30					
10:45					
11:00					
11:15		LABORATORIO DI FISICA DELLA MATERIA CONDENSATA SCAZZA FRANCESCO, MORGANTE ALBERTO, COSTANTINI ROBERTO, MARINELLI MATTEO	INTERAZIONE RADIAZIONE-MATERIA E LUCE DI SINCROTRONE VESSELLI ERIK Laboratorio T20 [Edificio F] 11:00 - 13:00		LABORATORIO DI FISICA COMPUTAZIONALE - Lezione
11:30					
11:45					
12:00					
12:15				COMPUTAZIONE QUANTISTICA BASSI ANGELO Aula C [Edificio F] 12:00 - 14:00	ATOMI, MOLECOLE E FOTONI SCAZZA FRANCESCO Aula B [Edificio F] 12:00 - 14:00
12:30					
12:45					
13:00					
13:15	TEORIA DEI CAMPI I BASSI ANGELO Aula A [Edificio F] 13:00 - 15:00		MECCANICA STATISTICA IMPARATO ALBERTO Aula 3B [Edificio H2bis] 13:00 - 15:00		ATOMI, MOLECOLE E FOTONI SCAZZA FRANCESCO Aula B [Edificio F] 13:00 - 16:00
13:30					
13:45					
14:00					INTERAZIONE RADIAZIONE-MATERIA E LUCE DI SINCROTRONE VESSELLI ERIK Aula 4A [Edificio H2bis] 13:00 - 15:00
14:15				LABORATORIO DI FISICA DELLA MATERIA CONDENSATA SCAZZA FRANCESCO, MORGANTE ALBERTO, COSTANTINI ROBERTO, MARINELLI MATTEO	
14:30					
14:45					
15:00					
15:15		TEORIA DEI CAMPI I BASSI ANGELO Aula C [Edificio C7] 15:00 - 17:00	LABORATORIO DI FISICA DELLA MATERIA CONDENSATA SCAZZA FRANCESCO, MORGANTE ALBERTO, COSTANTINI ROBERTO, MARINELLI MATTEO Laboratorio di Fisica [Edificio C1] 15:00 - 18:00	LABORATORIO DI FISICA COMPUTAZIONALE - Laboratorio PERESSI MARIA, BECCA FEDERICO Lab. informatico Poropat [Edificio F] 15:00 - 18:00	
15:30					
15:45					
16:00					
16:15	STRUMENTI INFORMATICI A COSLOVICH DANIELE Aula A [Edificio F] 16:00 - 18:00				FISICA DELLA MATERIA CONDENSATA I PERESSI MARIA
16:30					
16:45					
17:00				MACHINE LEARNING MEDVET Eric Aula C [Edificio C7] 16:00 - 19:00	
17:15		COMPUTAZIONE QUANTISTICA BASSI ANGELO Aula C [Edificio F] 17:00 - 19:00			
17:30					
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