Welcome!

NANO-OPTICS
(227-0663-00)

Martin Frimmer (mfrimmer@ethz.ch)
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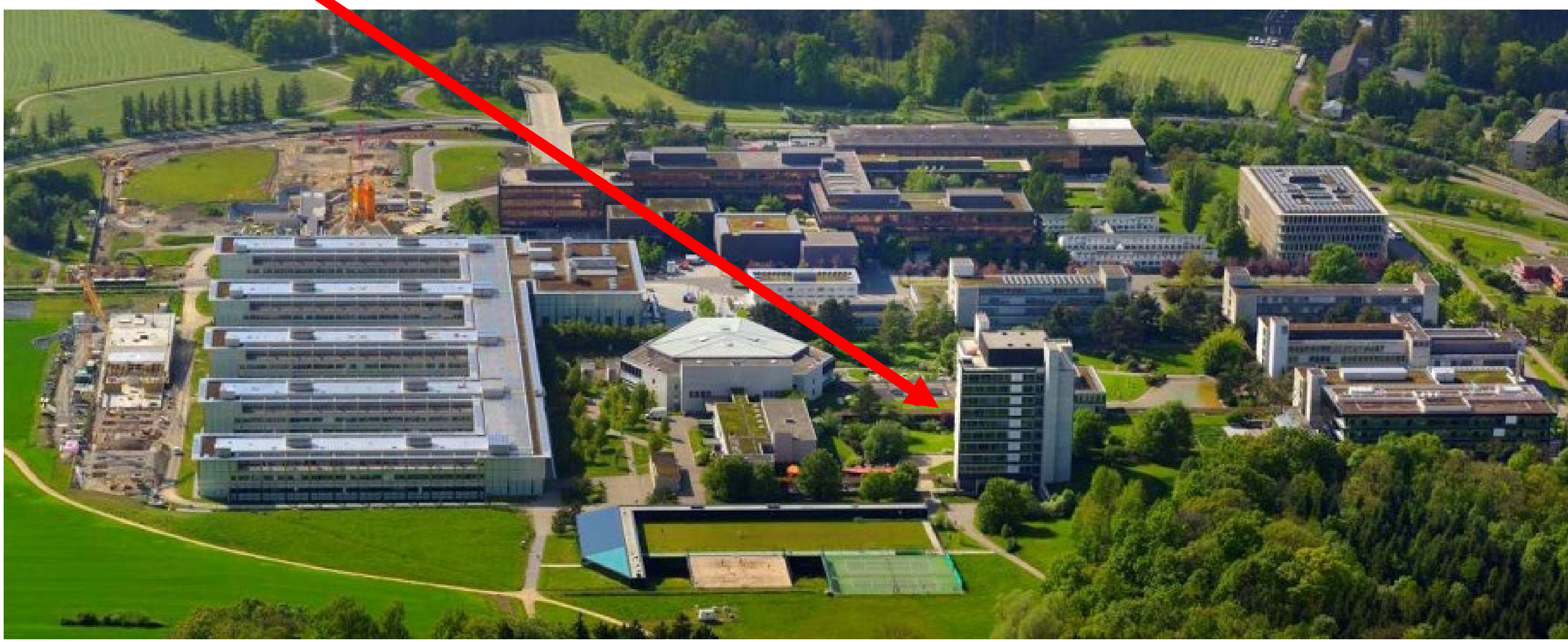
HPP, floor M



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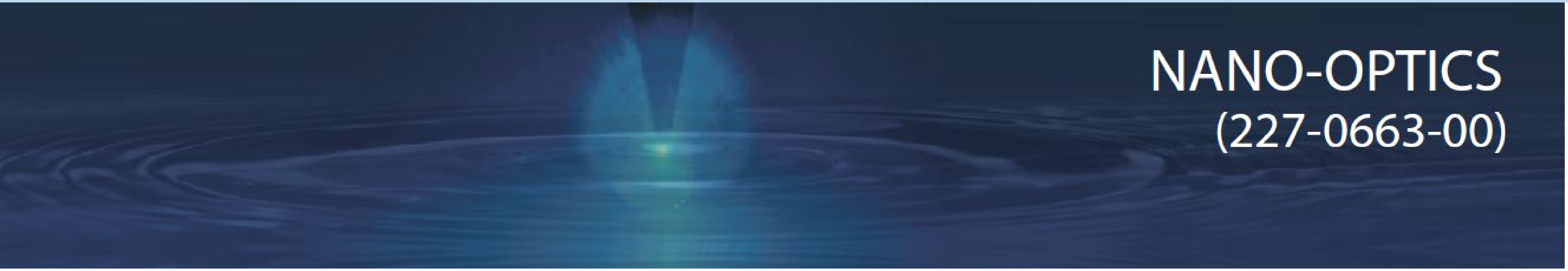

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Nano-optics studies light-matter interactions on the sub-wavelength scale. The goal of this course is to quantitatively understand some fundamental concepts of nano-optics, including

- Resolution limits of microscopy
- Quantum light sources
- Optical antennas
- Optical forces
- Nano-scale spectroscopy

Administrative details

- The lecture is the most important source of information
- Moodle is platform for further exchange
- Slack (see Moritz presentation in the break)
- Components of course
  1. Lecture
  2. Homework problems
  3. Literature projects (depends on # of participants)

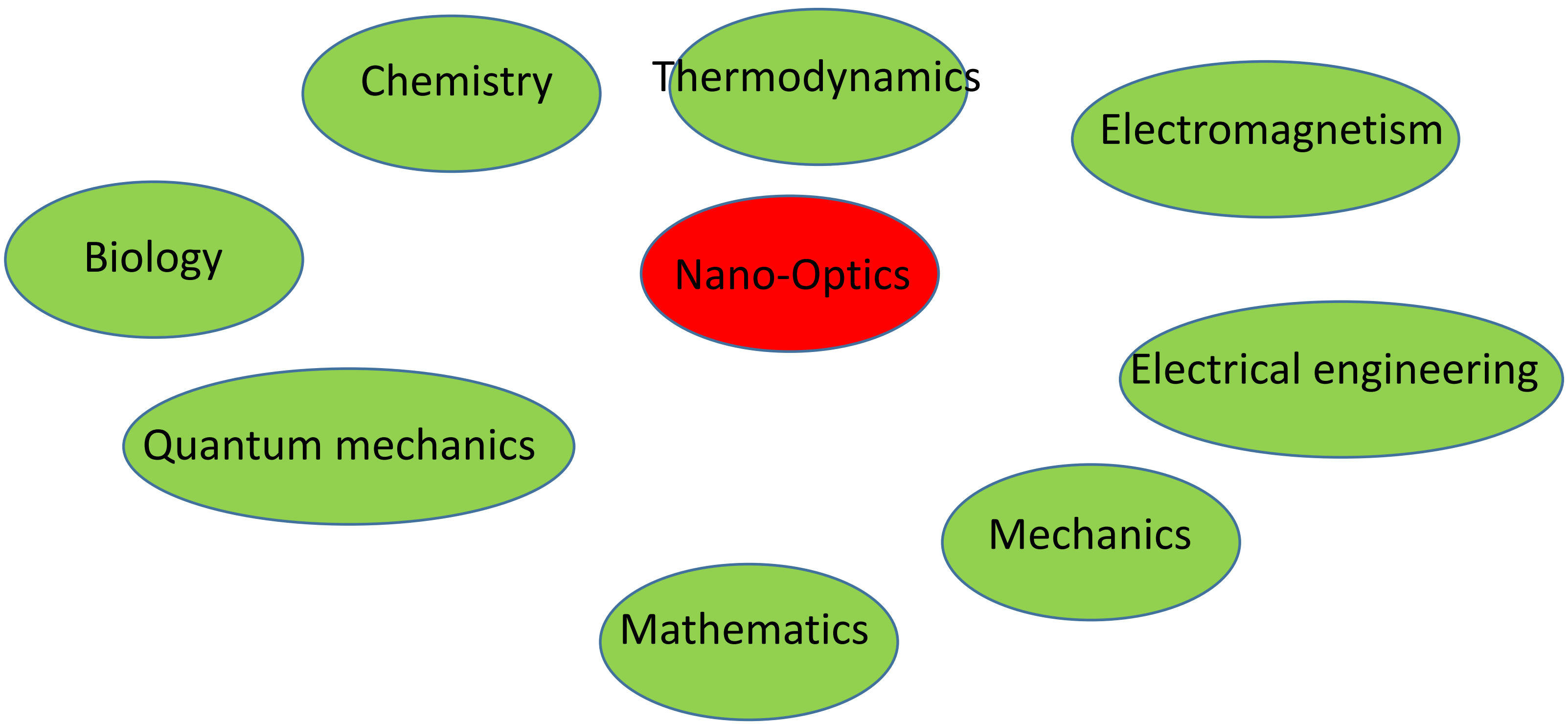
Preliminary

- Grading: homeworks, research project, oral exam

Administrative details: Lecture

Lecture

- Lecture slides will be online (just) before lecture
- Ask questions!
- Talk to each other!



Administrative details: homework problems

Homework 1

Nano Optics, Fall Semester 2020
Photonics Laboratory, ETH Zürich
www.photonics.ethz.ch

Contact: mfrimmer@ethz.ch
Due date: 2 October 2020; 10:00 a.m.

The goal of this homework is to establish the notation and refresh your knowledge of electrodynamics required to follow the course "Nano Optics". Use the lecture notes of the course "Electromagnetic Fields and Waves", available on the website of the Photonics Laboratory, to work through the following problems.
Please stick to the following points:

- Hand in your solution on time (beginning of lecture) in legible hand-written form or typeset using LaTeX (do not provide any code of any programming language, do not send your solutions by email).
- Keep your solutions in the order of the problem set.
- Show explicitly how you arrived at your answer and comment on your thoughts. Focus on the presentation of your solutions as if you were to explain them to a reader who is not familiar with the topic. Be brief but to the point.
- If you decide to generate graphs with a computer (which is encouraged), please position them at the appropriate position within your solution.
- Always label graphs and axes and provide units where appropriate.
- You can receive a maximum of 100 points for the correct solutions to the problems. For the quality of your presentation, you can receive an additional 10 points.

You are strongly encouraged to discuss the problems with your peers. In case of remaining questions, feel free to approach the course instructors.

Administrative details: Literature Projects

Preliminary

- Teams of 3—4 students present a paper to their peers
- Presentation is followed by a discussion
- Participation in the discussion counts towards your grade

- Check Moodle for literature list
- Send an Email with your 3 preferred papers (in order of preference) to mfrimmer@ethz.ch until Wednesday, 23 Sep 2020

Literature project vs homework?

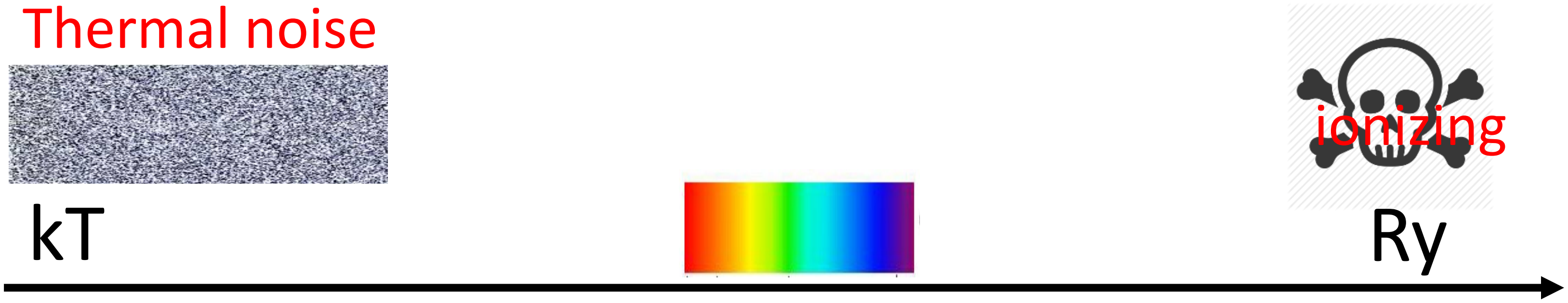
Administrative details: Grades

Preliminary

Grading : 4 Homework Sets 25%, Project Report 25%, Final Exam (oral) 50%

- Exams will take place during first weeks of January

Why nano-optics?



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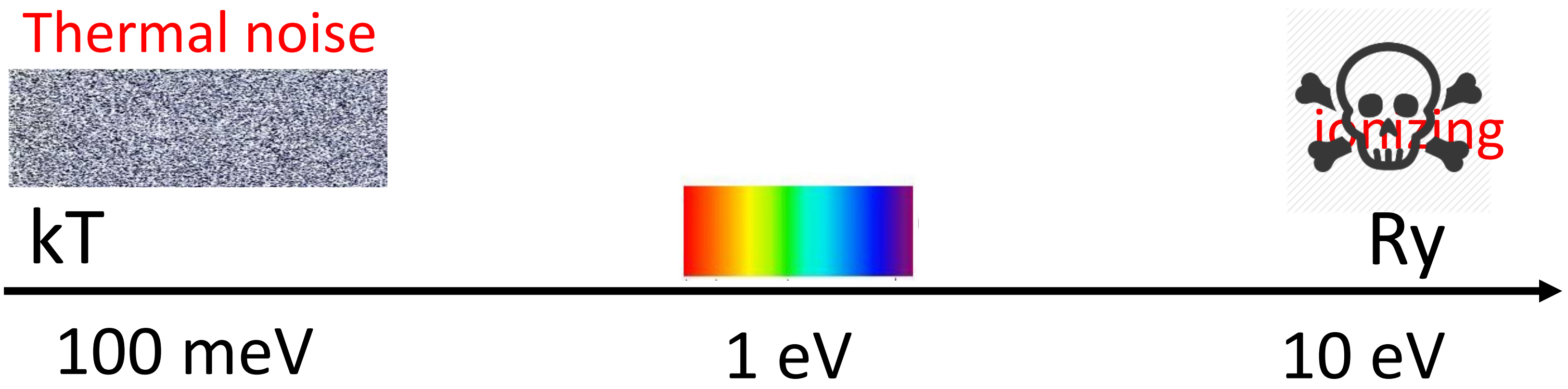
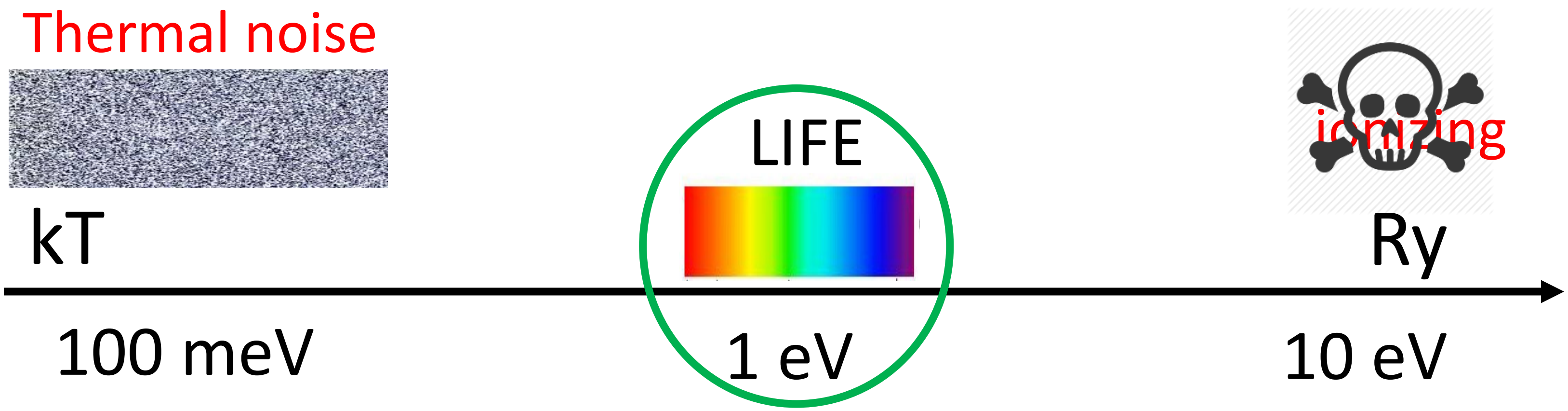


- The energy scale of our interest corresponds to about 1 µm wavelength

Why nano-optics?



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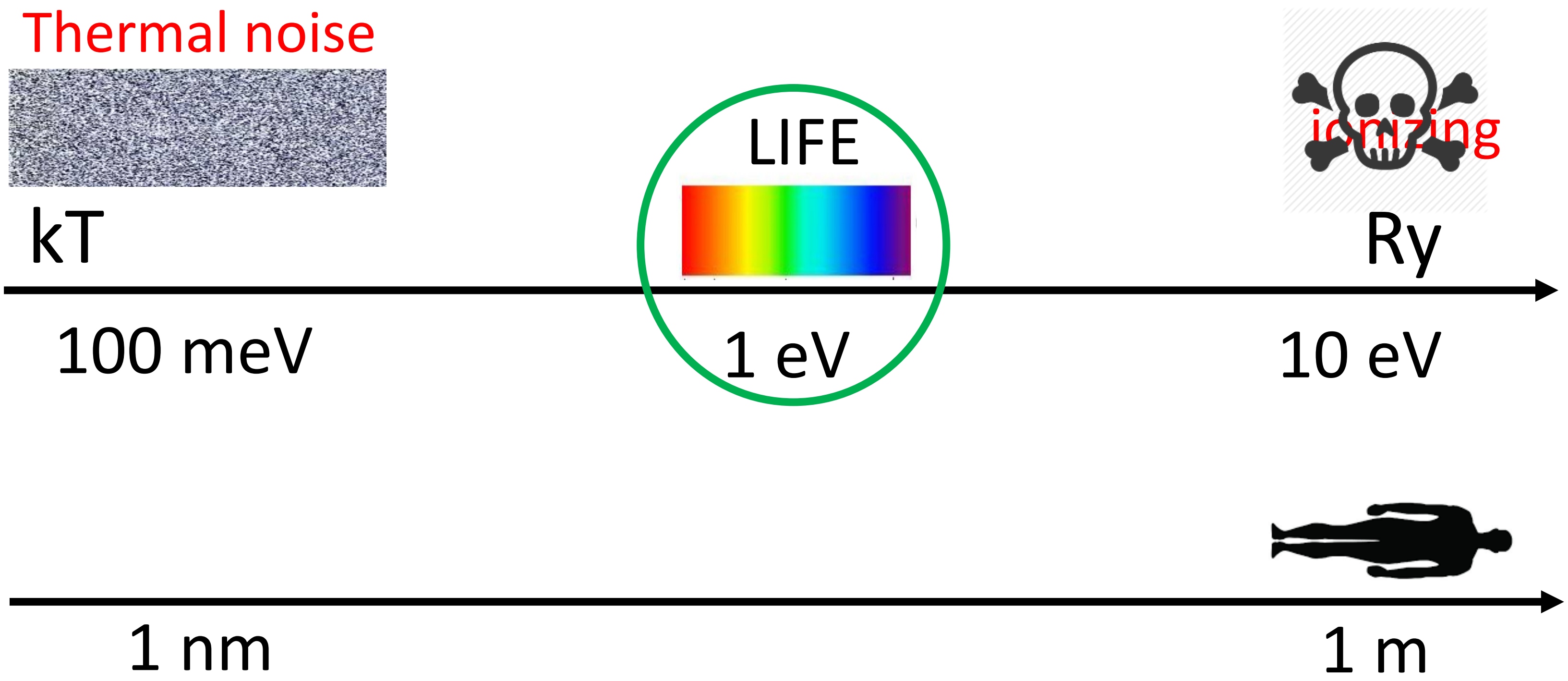

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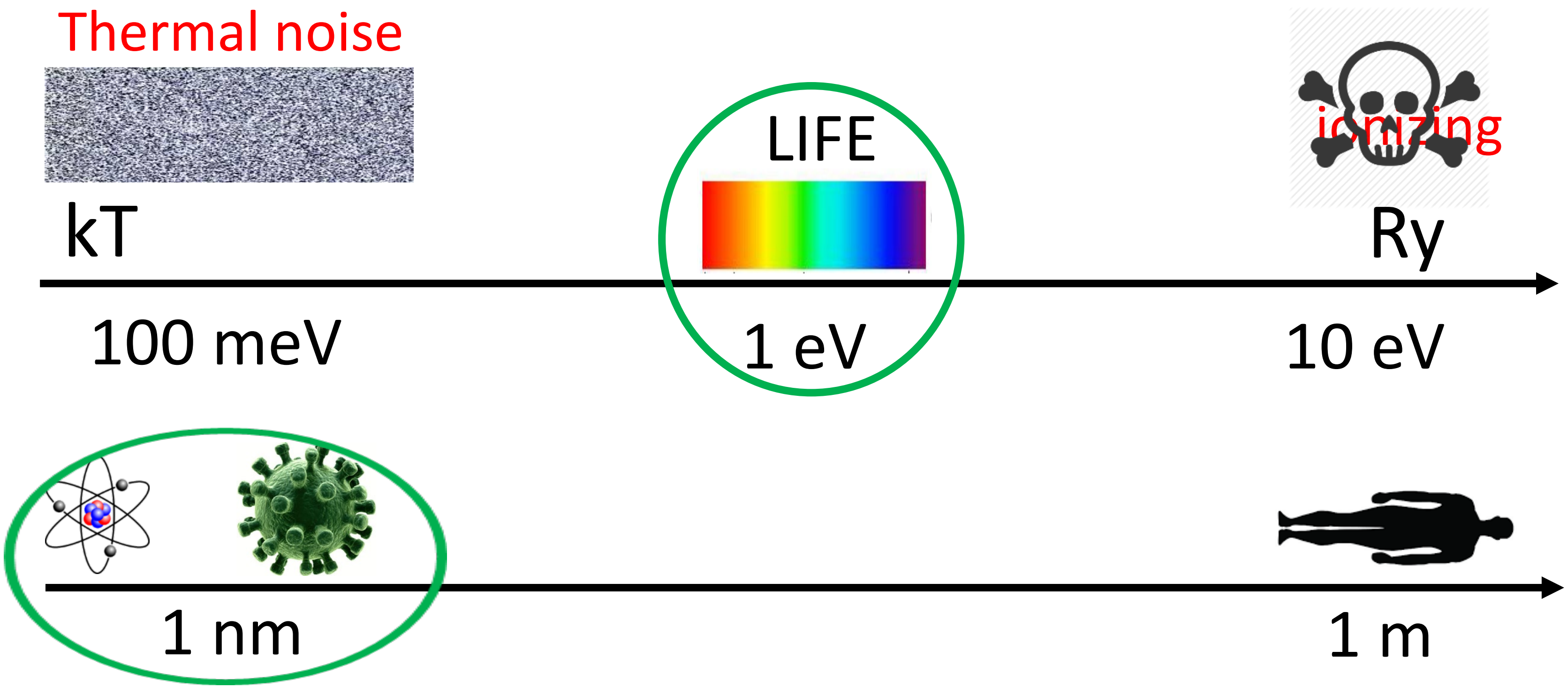
Why nano-optics?



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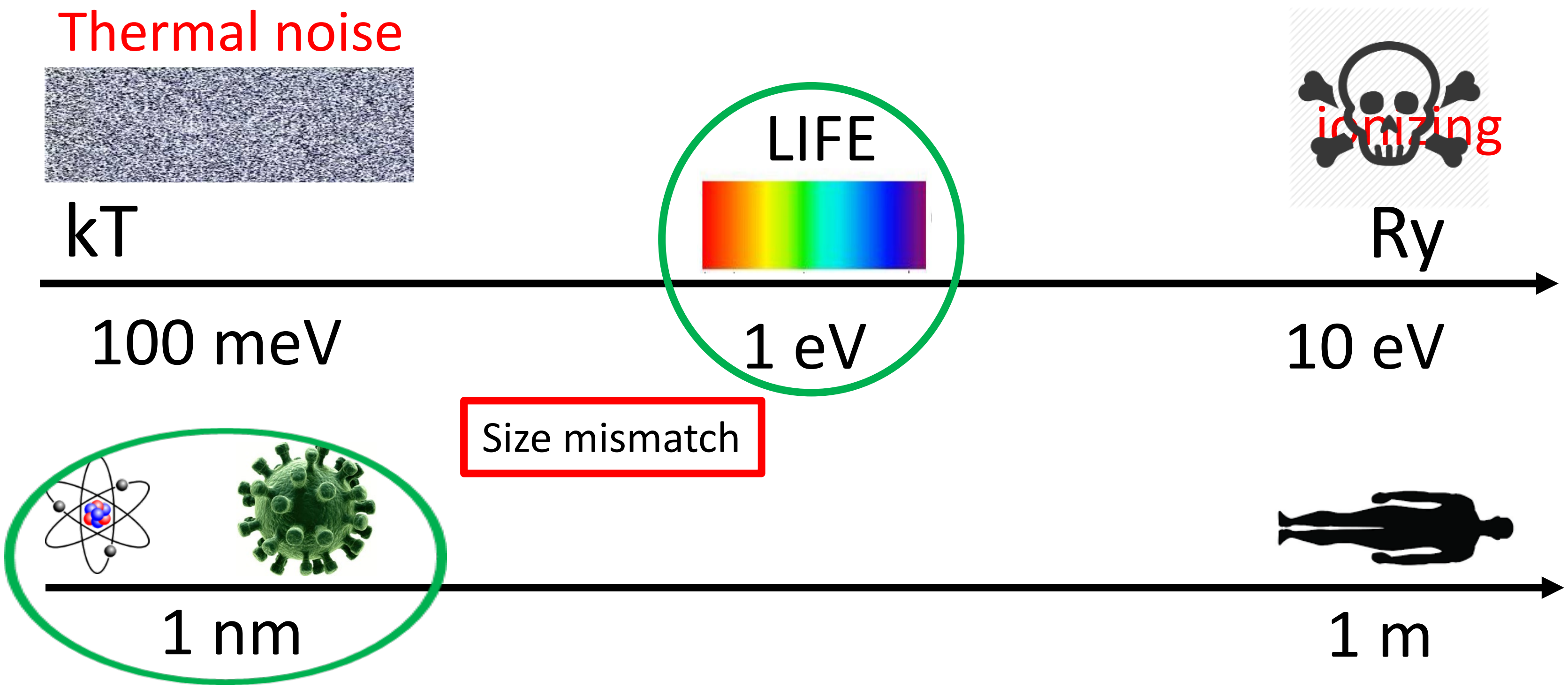
- The length scales of scientific and technological interest are approaching the atomic scale
  Read Feynman's talk "There is plenty of room at the bottom."

Why nano-optics?



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➔ We need to control electromagnetic fields and their interaction with matter at sub-λ scales.

Course topics (to be chosen)

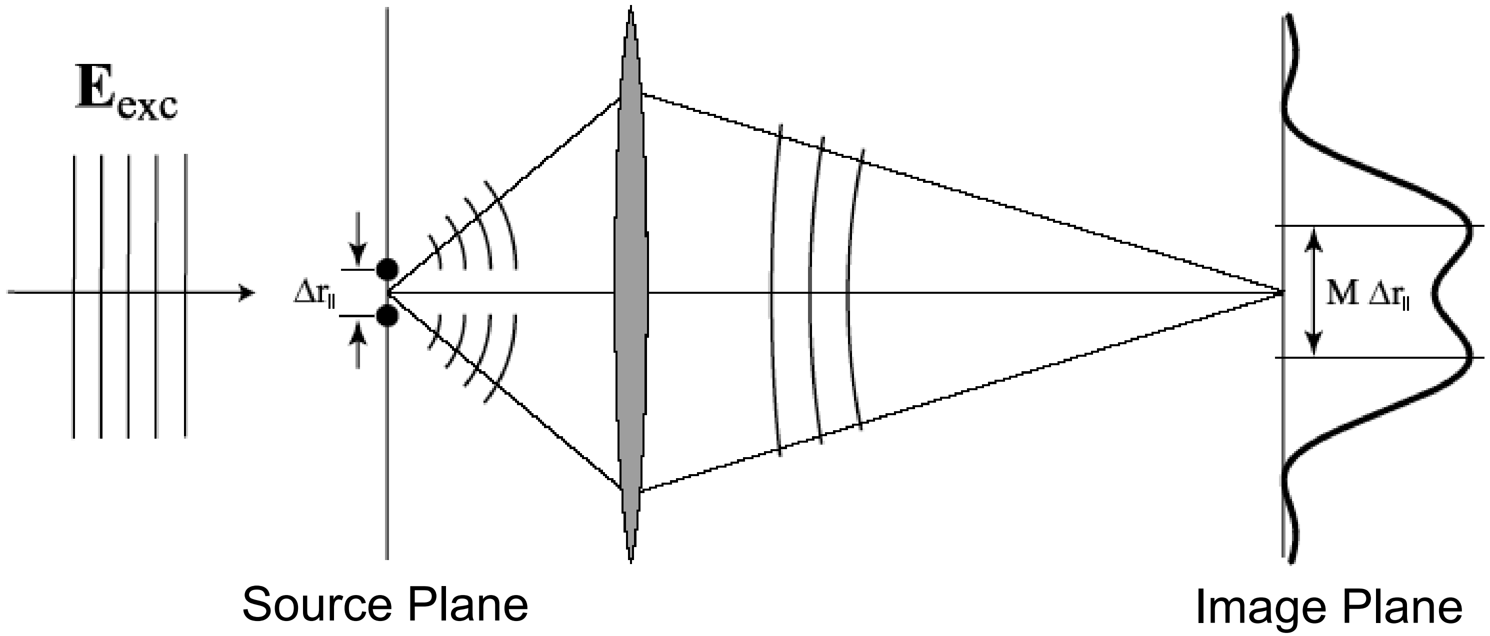
Vote for your favorite topics on Moodle!

- Optical microscopy
- Super-resolution microscopy
- The local density of optical states
- Optical antennas
- Raman spectroscopy
- Defect centers
- Chirality
- Random media
- Optical tweezers

On the menu today

- Motivation: Why nano-optics?
- Repetition: electromagnetism
- Optical imaging:
  - Focusing by a lens
    - Angular spectrum
    - Paraxial approximation
    - Gaussian beams
    - The diffraction limit
  - Fluorophores
  - Example: Fluorescence microscopy
  - Example: STED microscopy
  - Example: Localization microscopy
  - Example: Scanning probe microscopy

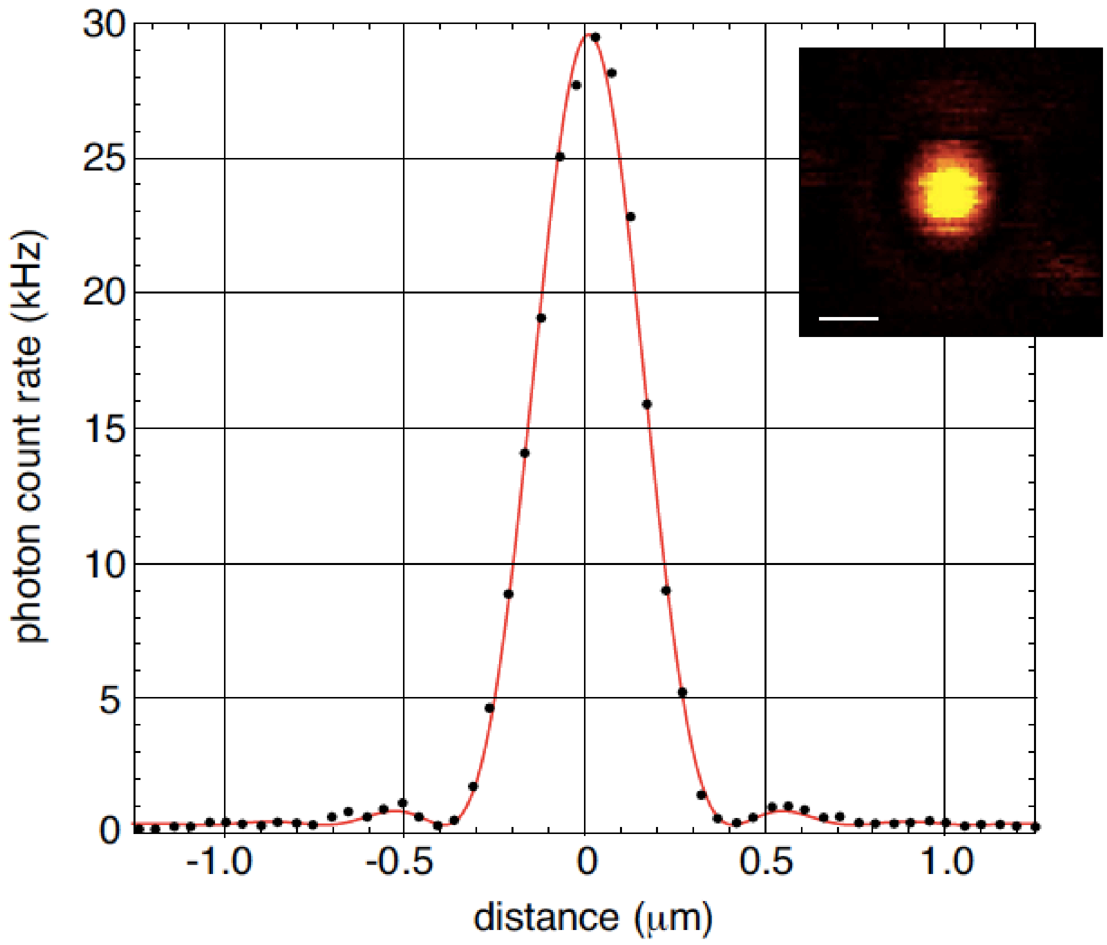
Classical resolution limit



$$\text{Abbe (1873)}: \qquad \text{Min}\,[\Delta r_{||}] = 0.6098\,\frac{\lambda}{NA}$$

E. Abbe, Arch. Mikrosk. Anat. **9**, 413 (1873).

The resolution limit



Aperitivo: Nanoscale spectroscopy

Nano Lett. 2020, 20, 6750−6755

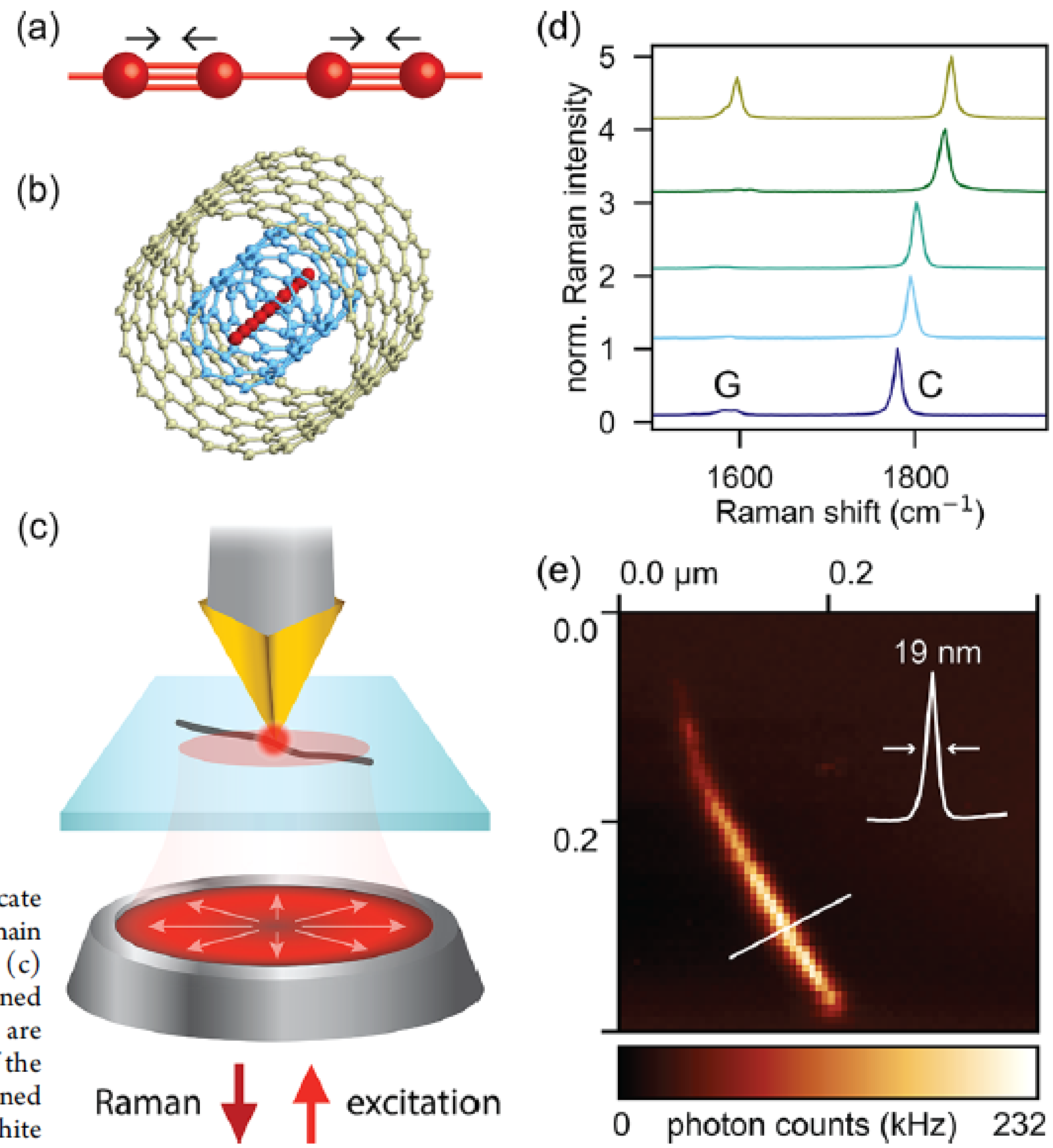


Figure 1. (a) Atomic structure of polyynic carbyne. Arrows indicate atomic displacements for the Raman-active C-mode. (b) Carbyne chain encapsulated inside a double-walled carbon nanotube (DWCNT). (c) Schematic illustration of our TERS setup. (d) TERS spectra of confined carbyne. The G-peaks arise from the DWCNT. The spectra are vertically offset for better visibility and normalized to the height of the respective C-peak. (e) TERS image of the C-mode of a confined carbyne chain. The intensity profile (inset) extracted along the white line shows a spatial resolution of 19 nm.