Classical and Quantum Waves

PHYS UN2601

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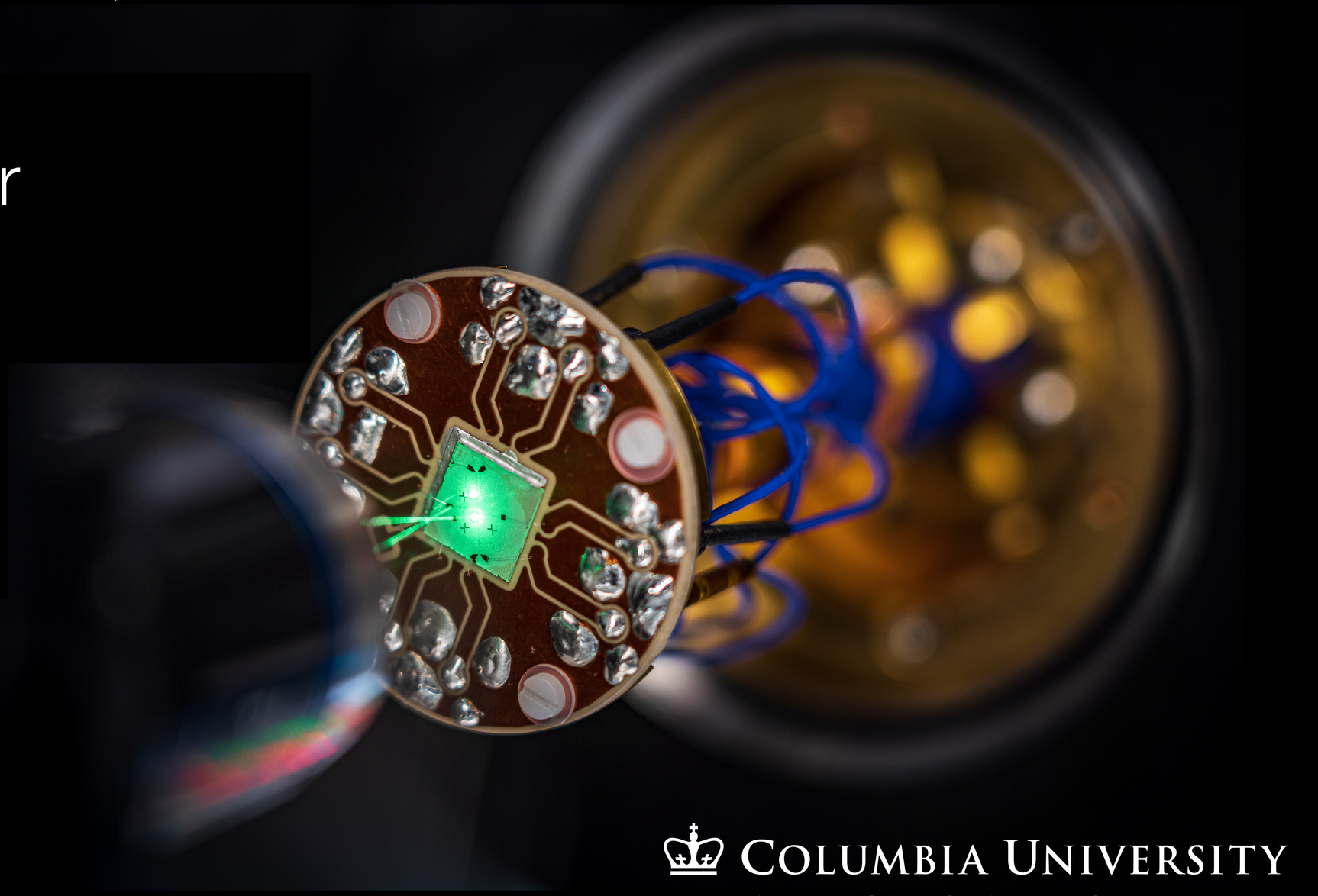

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IN THE CITY OF NEW YORK

Why should we care about waves?

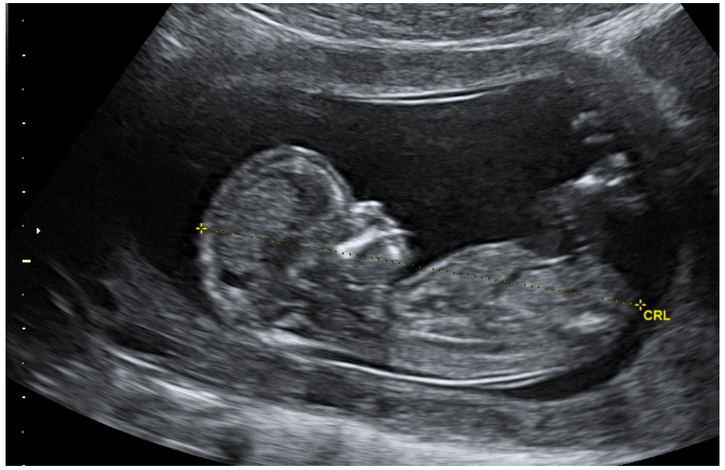
1) Because waves are everywhere around us!

2) A strong foundation in wave mechanics is critical for all areas of advanced physics and many other fields

3) Wave mechanics is utilized in much of our technology

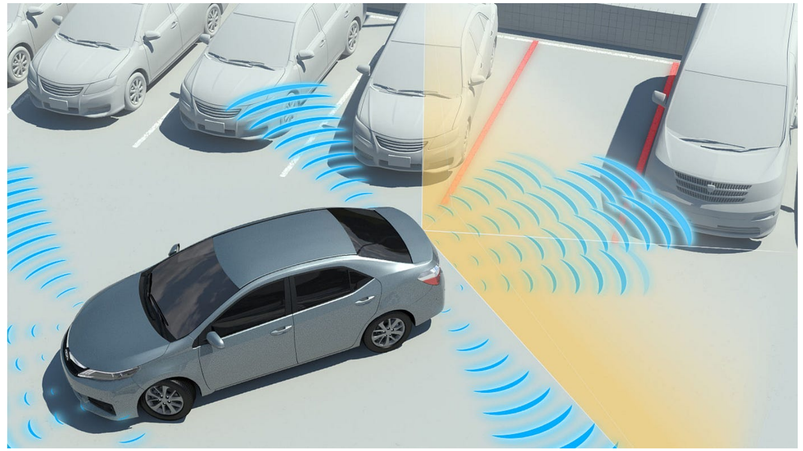
Sound

Speech



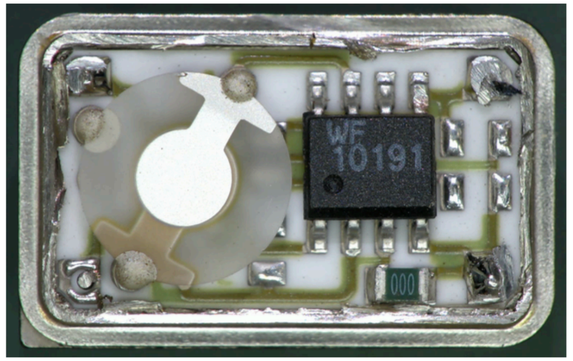
Ultrasound imaging

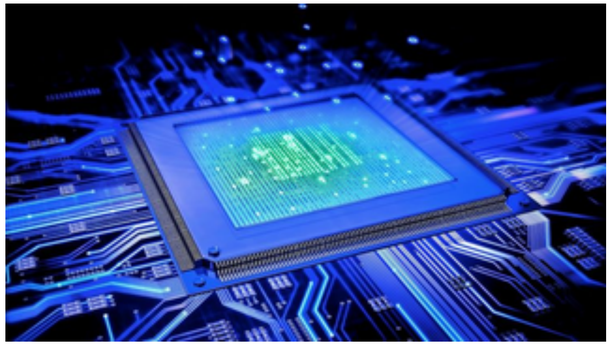
Standing waves



Sonar

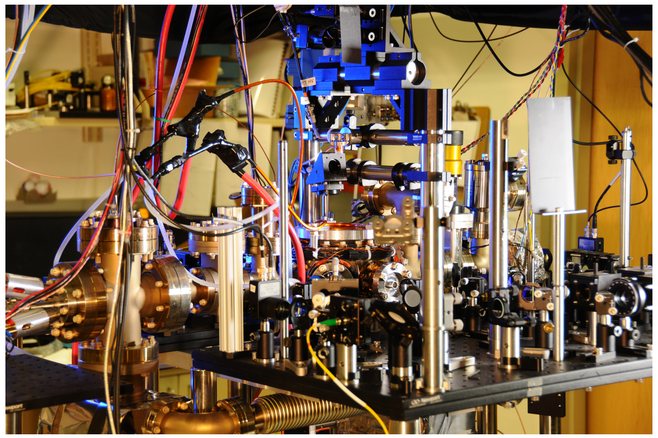
Oscillators

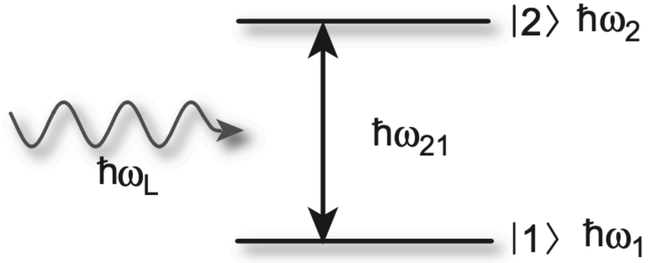




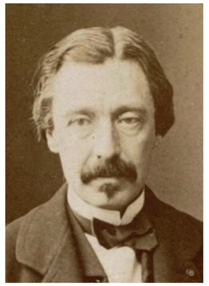
Quartz crystal oscillator

Foucault pendulum





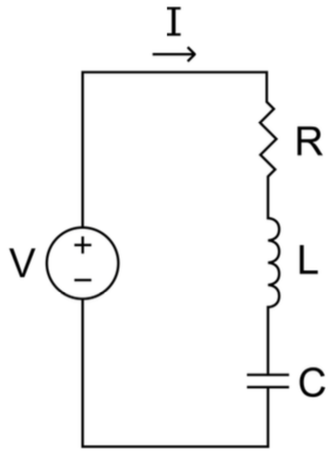
Atomic clock



Foucault
1851

Ramsey
1989

Radio waves



RLC oscillator

Antenna

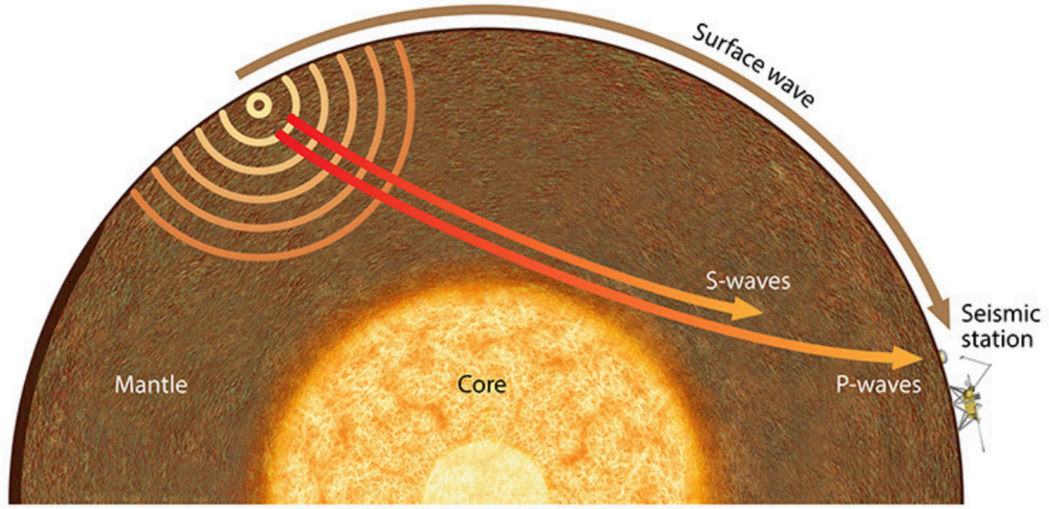
Receive information

Microwave

Radar

Surface waves on earth

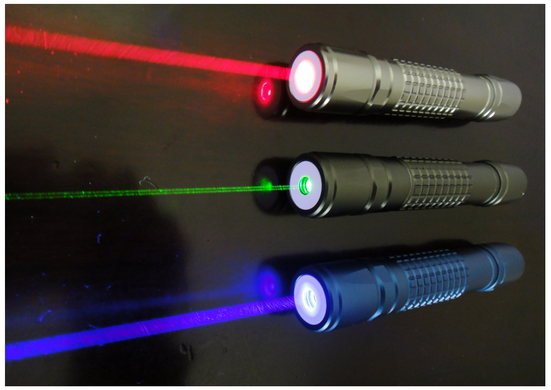
Water waves



Seismic waves (earthquakes)

Light

Light bulb
(incoherent light)



Laser
(coherent light)

Townes
1964

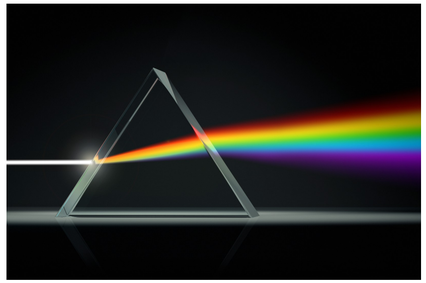
Basov
1964

Schawlow
1984

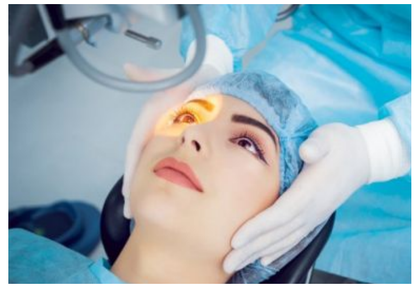
Laser technologies

Optical (quantum)
communication

Machining



Spectroscopy

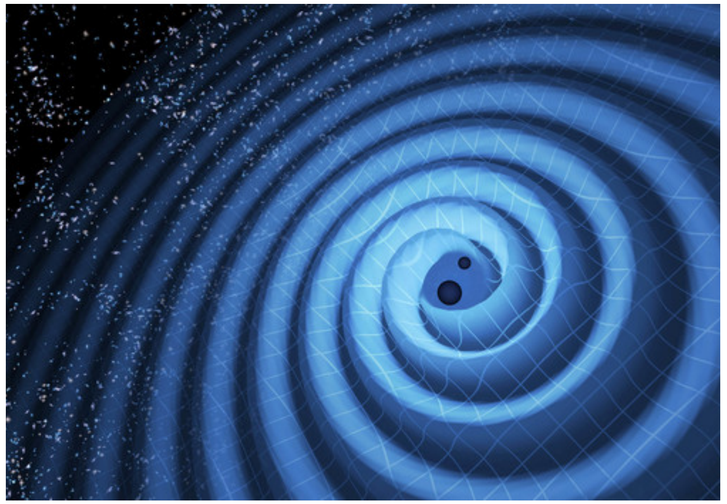


Surgery

CDs

Printers

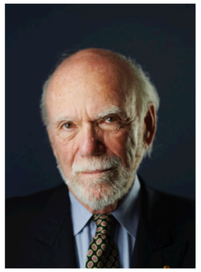
Gravitational waves



Ripples in space-time

Michelson
1907

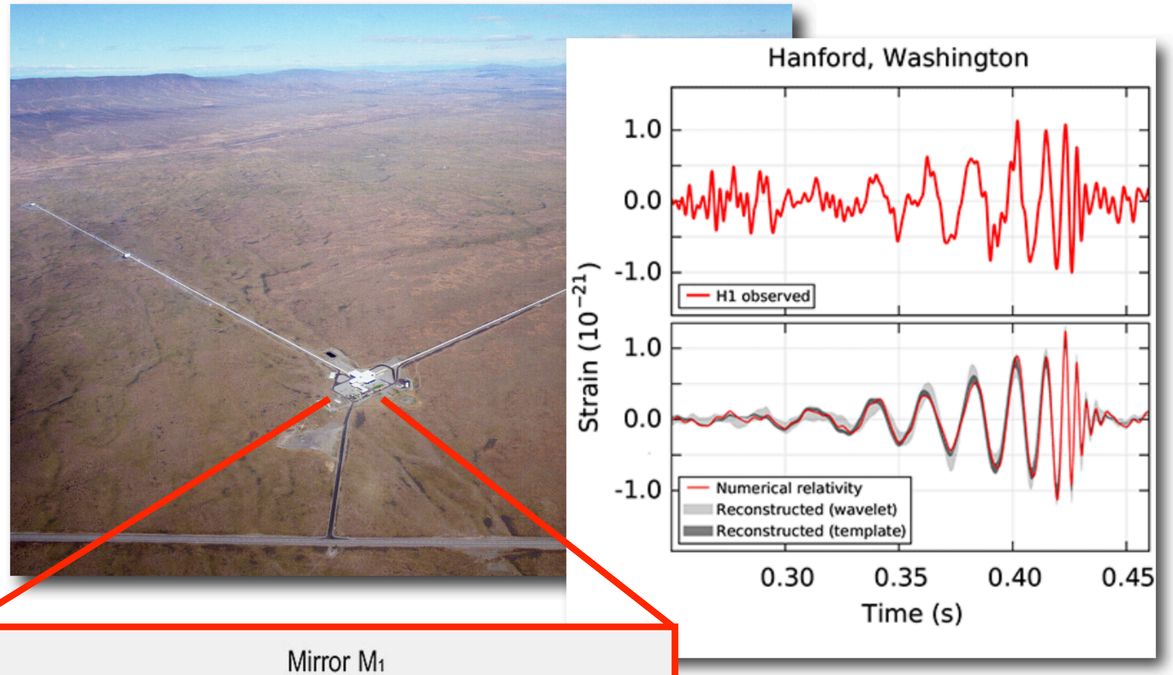
Weiss
2017

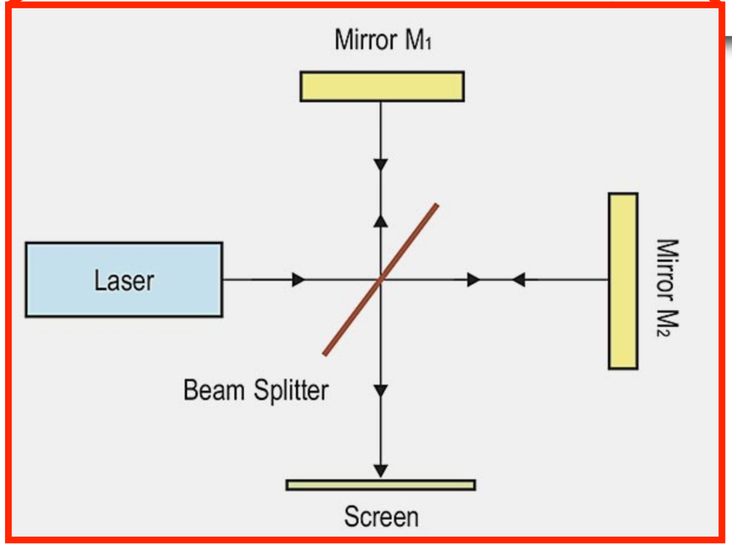


Barish
2017

Thorne
2017

LIGO: Laser Interferometer Gravitational wave Observatory



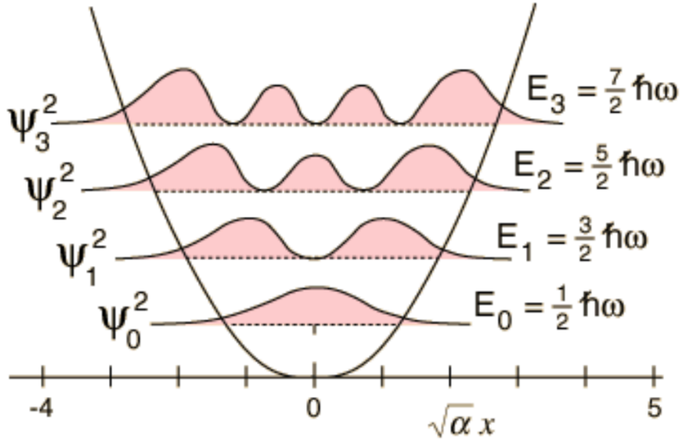


Michelson interferometer

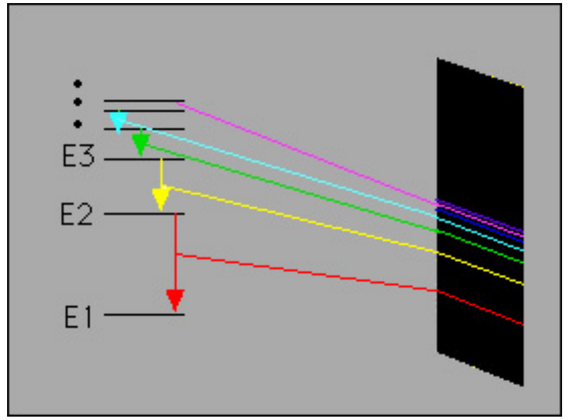
Quantum waves

$$i\hbar\frac{\partial\psi}{\partial t} = \hat{H}\psi$$

Schrödinger equation: Electrons are waves



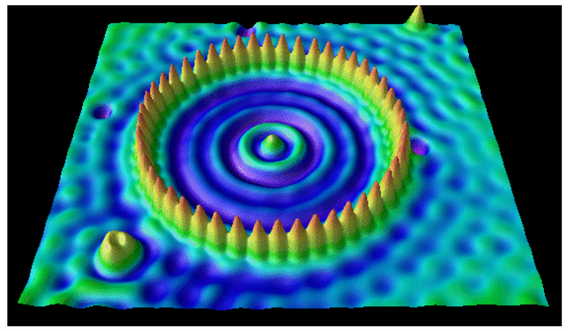
Form quantized standing waves in a potential well



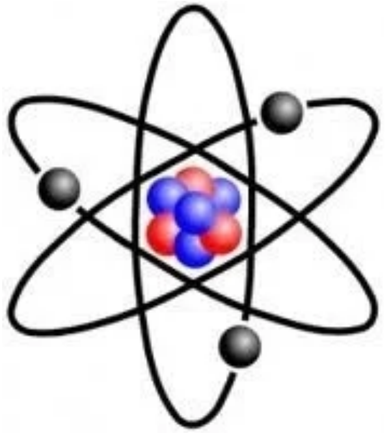
Heisenberg
1932

Schrödinger
1932

Nils Bohr
1932

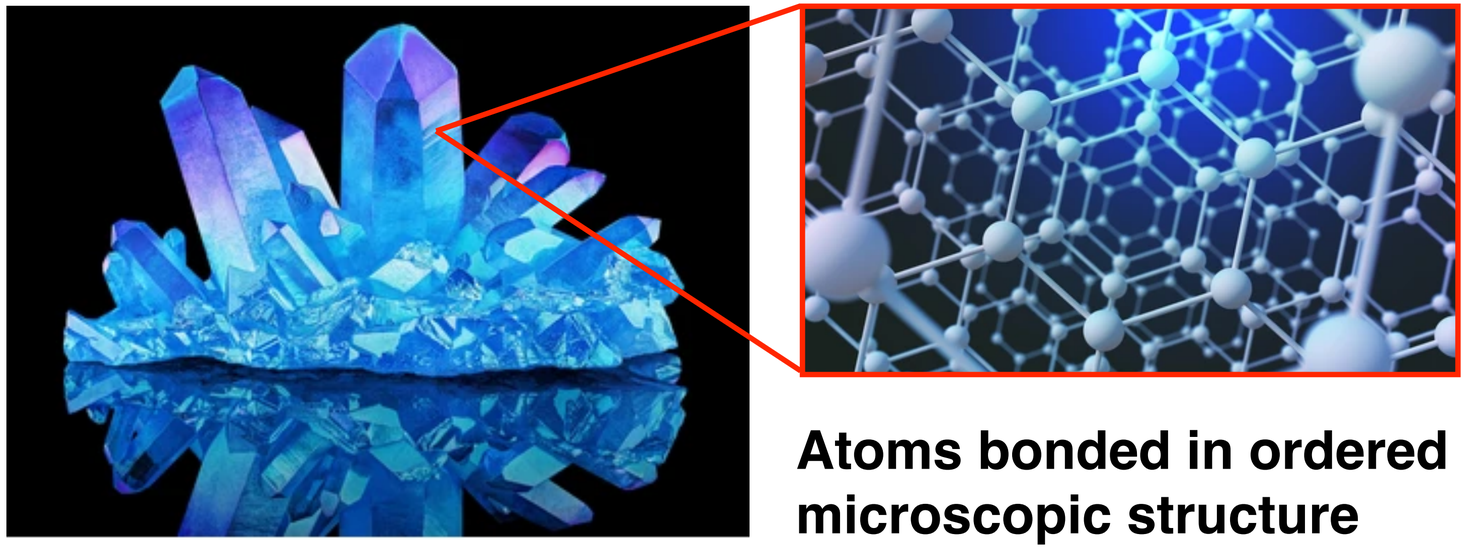


Quantum corral



Atomic spectra (Bohr model)

Waves in quantum materials

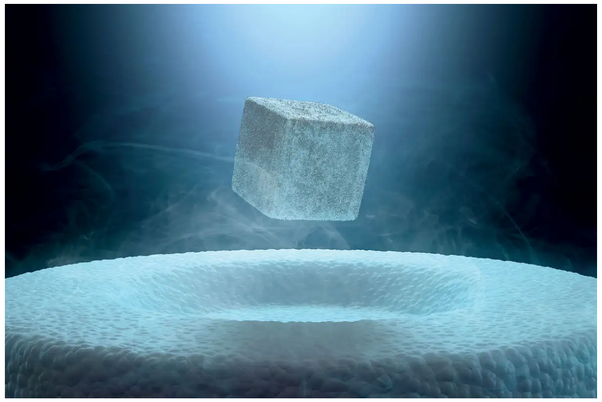


Atoms bonded in ordered microscopic structure

Microscopic Quantum waves

- Lattice vibrational waves
- Electron waves
- Spin waves
- …

Waves interact



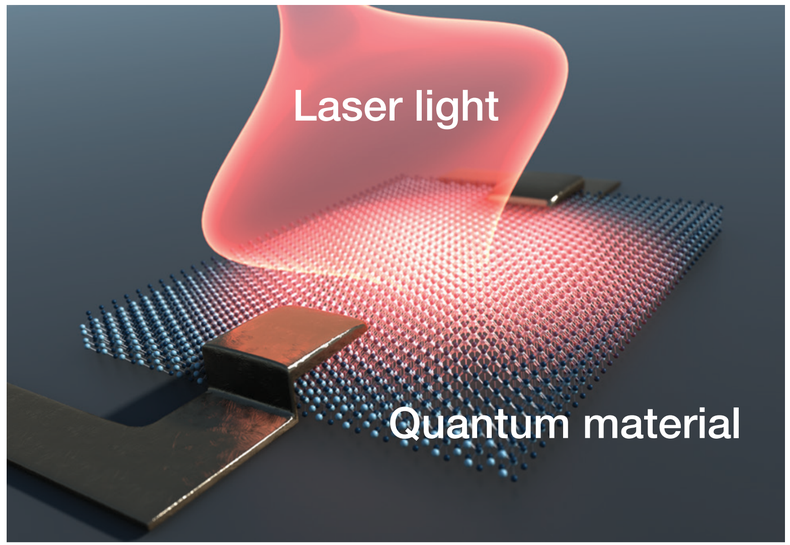
Superconductivity

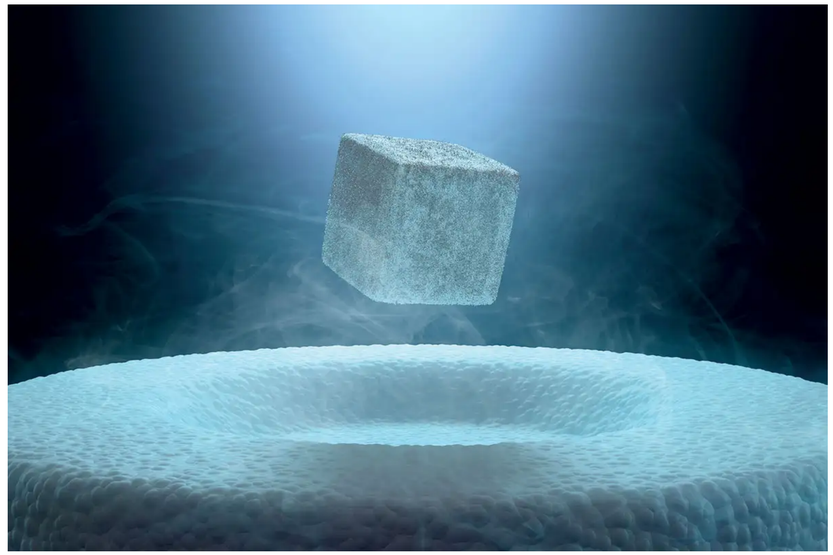
Magnetism

Macroscopic quantum phenomena

Electrodynamics of quantum materials

(my research)



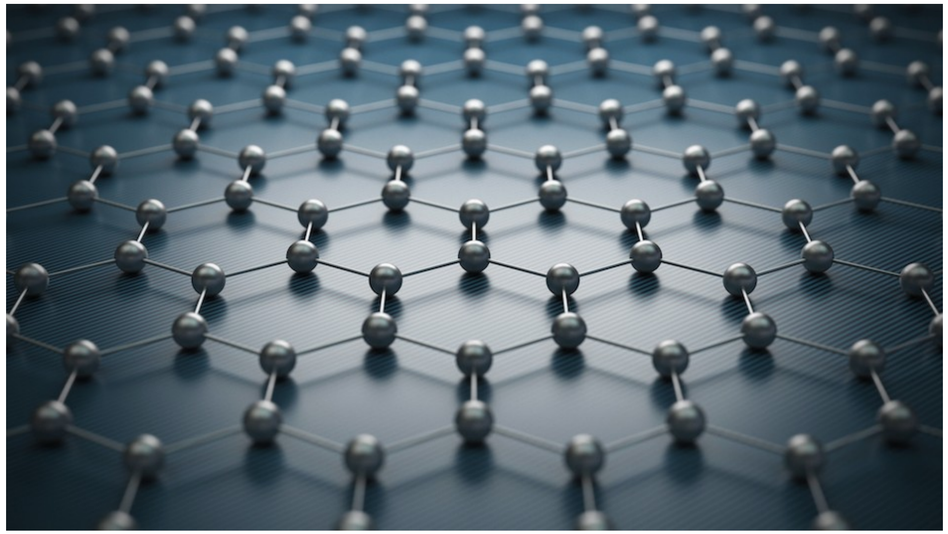


Use light to stimulate microscopic quantum waves in materials

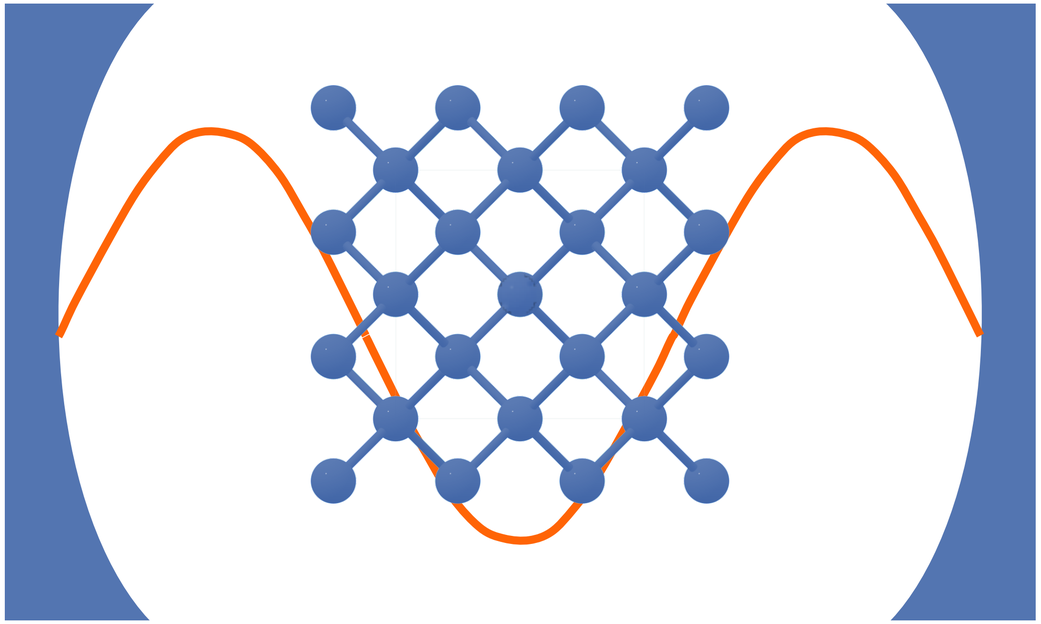
Understand and control macroscopic quantum phenomena

Electrodynamics of quantum materials

(my research)



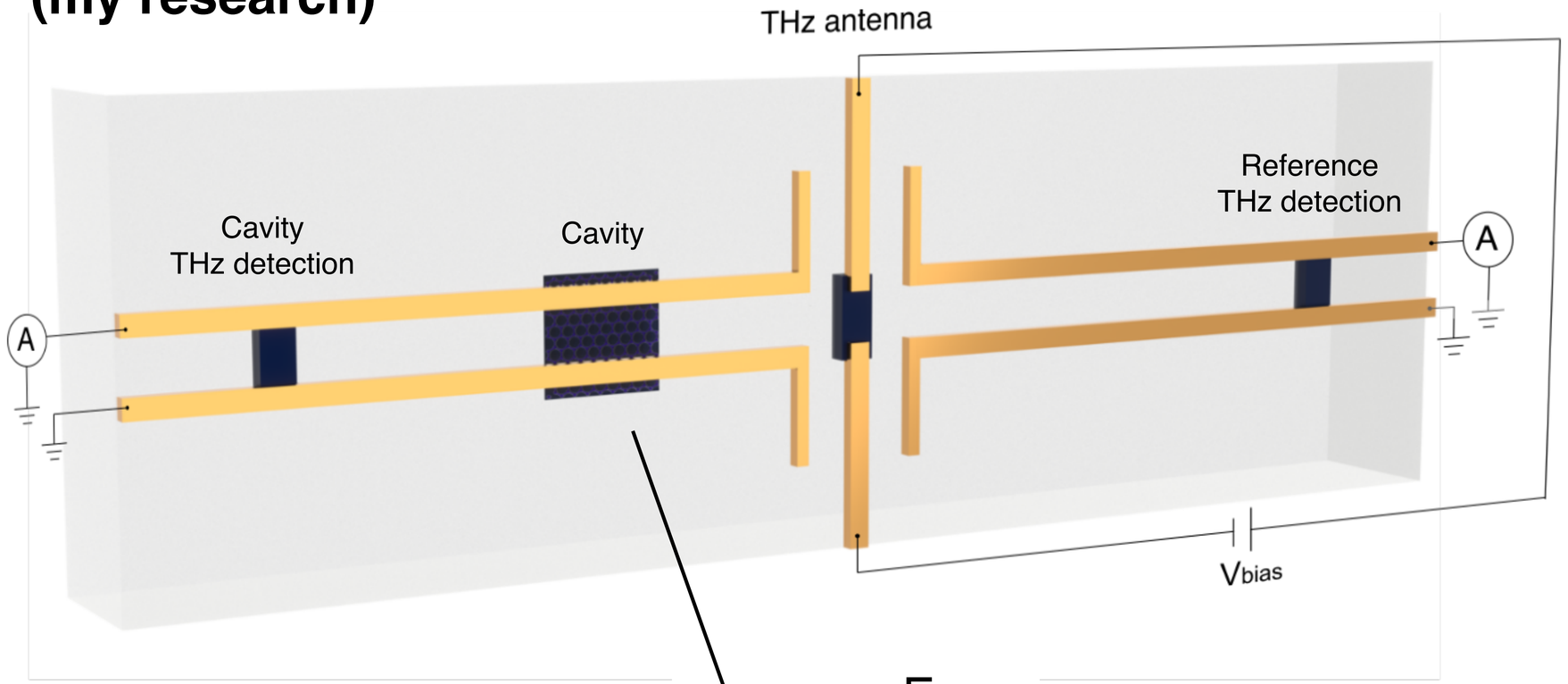
2D quantum materials (e.g., graphene)

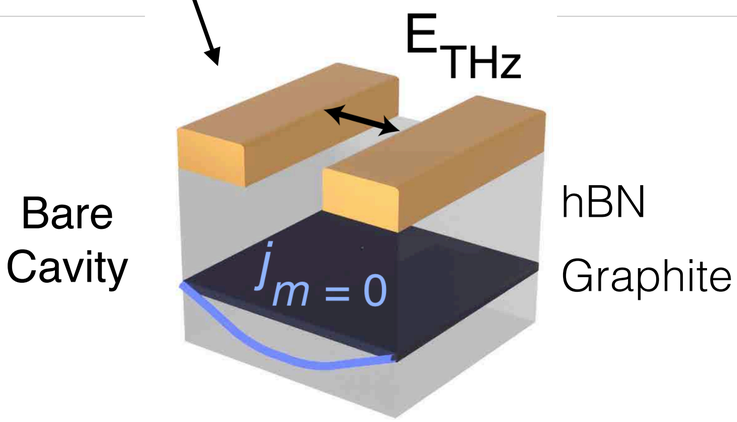


Optical cavity

Electrodynamics of quantum materials

(my research)





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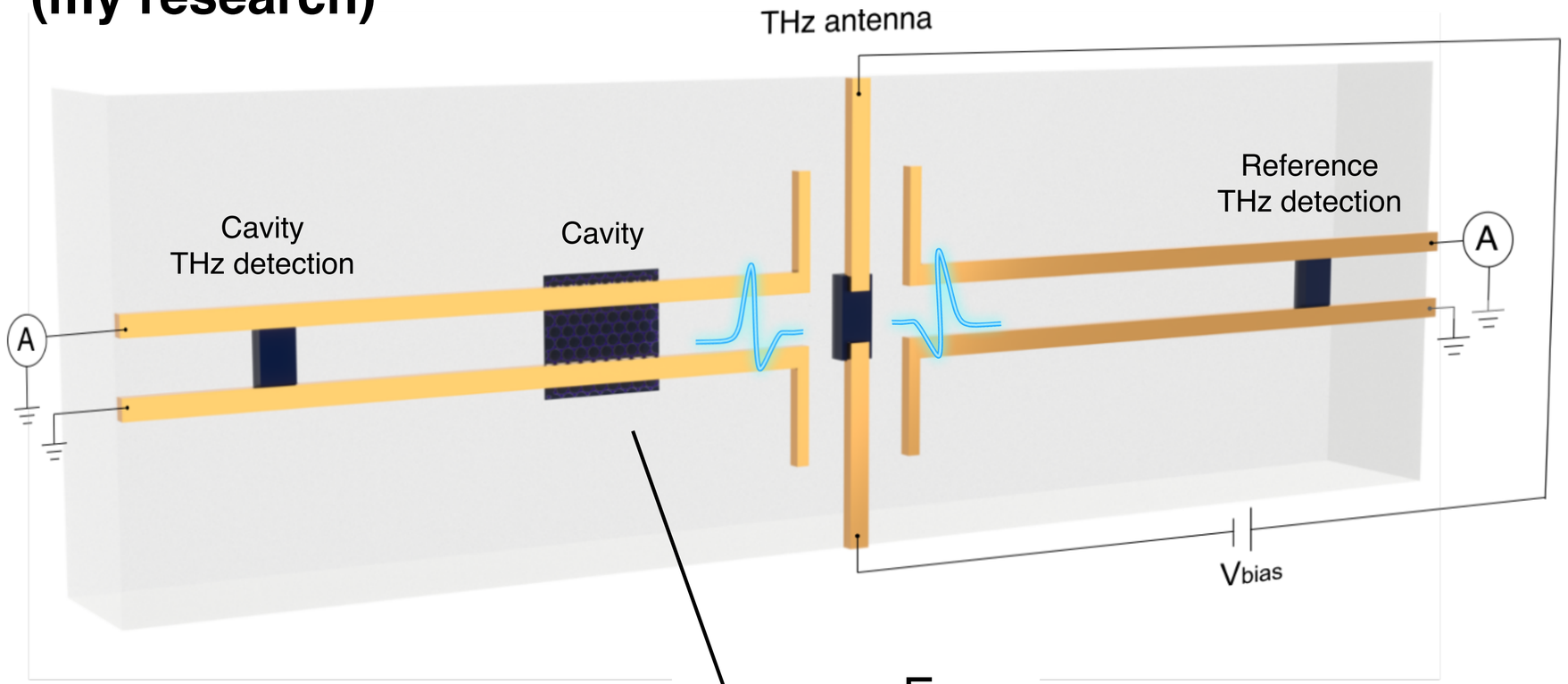
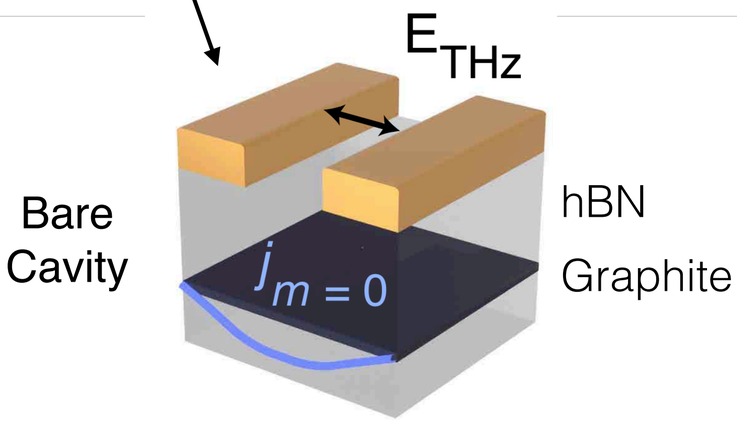
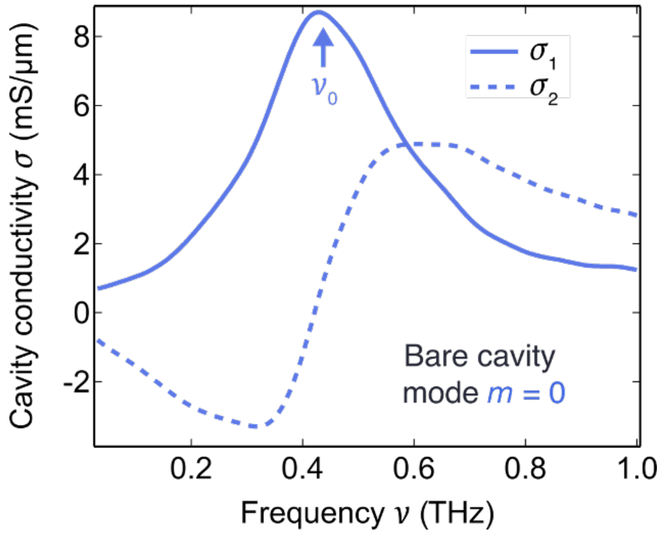
Electrodynamics of quantum materials

(my research)







Spectrum of plasmonic cavity mode

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Goal of the course

To develop theory, models and understanding of oscillations, vibrations and waves

Starting with: Simple Harmonic Motion