Mindset

NO!

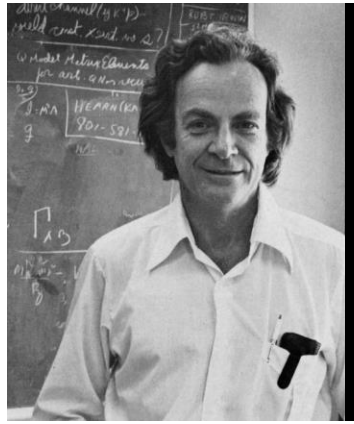
If quantum mechanics hasn't profoundly shocked you, you haven't understood it yet.

- Niels Bohr

I think I can safely say that nobody understands quantum mechanics.

- Richard Feynman

Yes



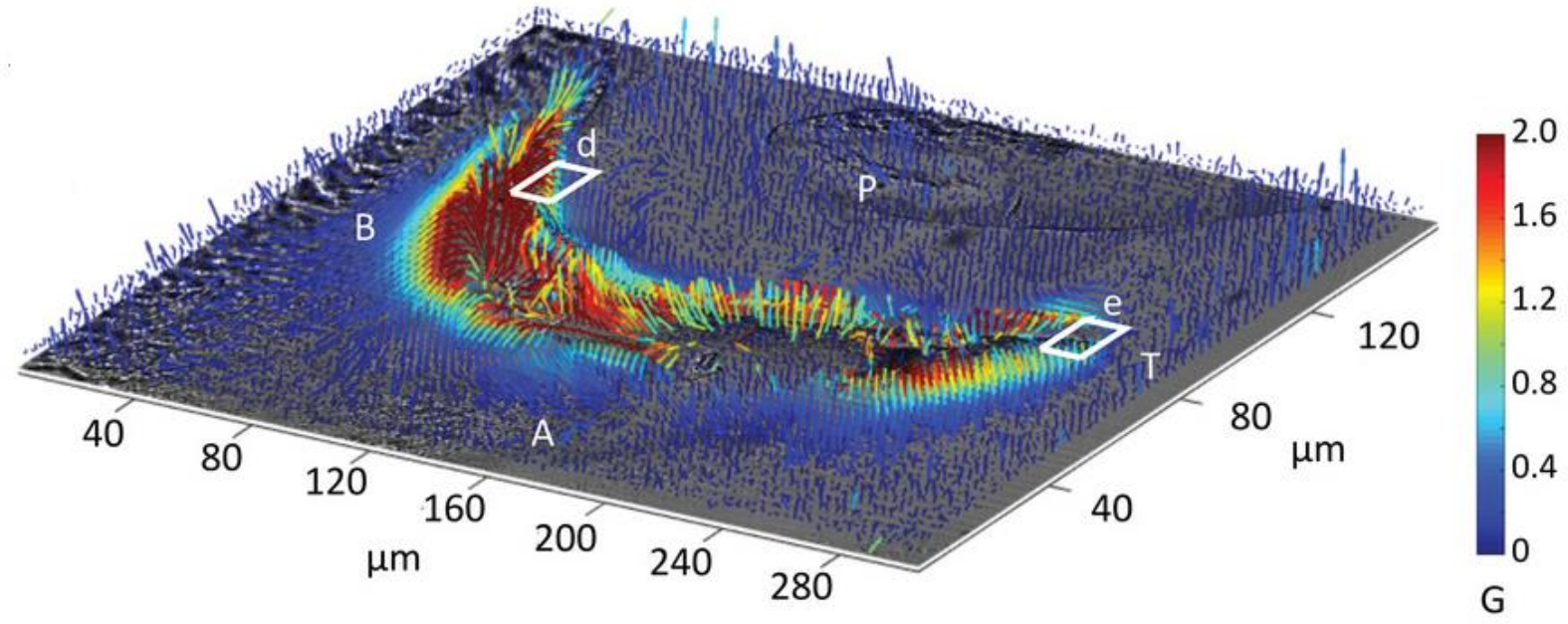
Students should be made to think, to doubt, to communicate, to question, to learn from their mistakes, and most importantly have fun in their learning.

- Richard Feynman

Quantum Ready!

QDNL 3.6 Symposium 24 May 2024

Lodewijk Koopman
In colaboration with: Rutger Ockhorst & Henk Buisman



Julia M. McCoey, Mirai Matsuoka, Robert W. Gille, et al., *Quantum Magnetic Imaging of Iron Biomineralization in Teeth of the Chiton Acanthopleura hirtosa*, Copyright © 1999-2024 John Wiley & Sons, Inc, licensed

ONDERWIJS NETWERK ZUID-HOLLAND ONZ

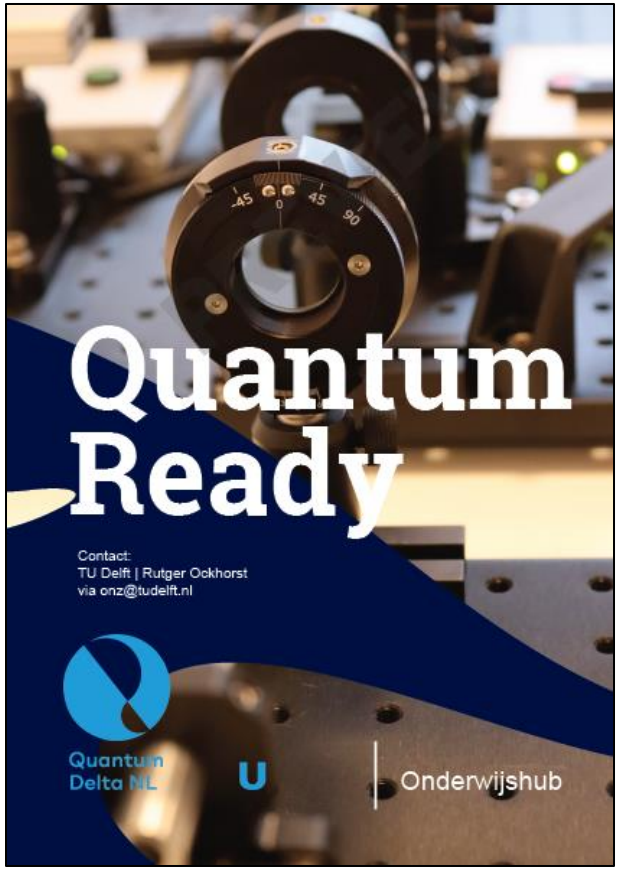
Bètasteunpunt Zuid-Holland

Quantum Delta NL

TU Delft

Erasmus+

Two NLT Modules



HAVO 4 / 5
In development

VWO 6
Already functional

ScholierenLab Leiden

www.quantumrules.nl

Experiments for 6 vwo on location at University Leiden

Link with ‘quantum 1.0’ / final exams vwo

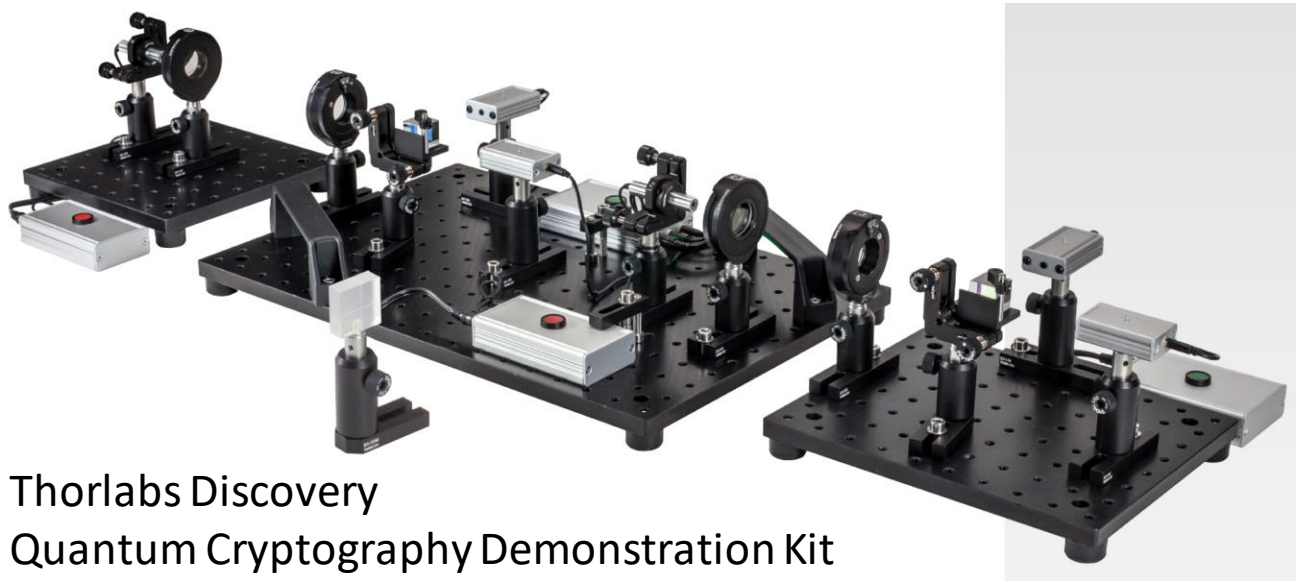
TU Delft

ScholierenLab Delft

In development

Workshops to support NLT and Profielwerkstuk (final thesis), for example:

- Quantum Sensing / Cryptography / Computing
- Fluorescence & Spectroscopy
- Atomic Force Microscopy



Thorlabs Discovery
Quantum Cryptography Demonstration Kit
https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=9869

Contact: scholierenlab@tudelft.nl (Lennard Duynkerke)

Beam splitters

Pepper's Ghost illusion:
Beam splitters in primary school!

Leonie Sonneveld (TU Delft) et al.
https://maken.wikiwijs.nl/205281

As part of havo 4 Optics module

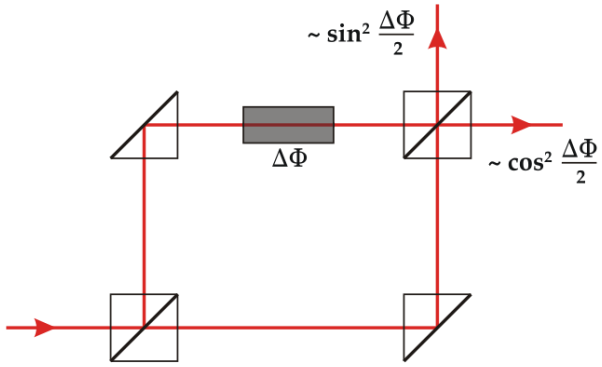


Image: public domain

Jeroen van den Ende (TU Delft, De Populier)

NLT module HAVO: Quantum Ready!

NLT module for havo 4 / 5

Quantum is all around us: discover through examples from biology and technology. Hands-on student activities are central.

Whatever quantum we can introduce for havo is a win! There is no quantum in the curriculum.

Ch1 - Ch3: Biomimetics, Photons, Energy Level Diagrams, Fluorescence (Version 1)
Ch4 - Ch5: Magnetism, Quantum Sensing, and NV centers (Version 0)

Testing: 2024 – 2025

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Some questions and challenges

Is it quantum enough?

How much diversions and details?

What would be a good end point (context, objective) for the module?

Understanding how tech works is not really needed to use tech…

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Current end point: NV center

Two modes:

- All optical: measure magnetic field strength (now functional)
- With rf signal (resonance): measure magnetic field strength, temperature, mechanical stress, … (in development)

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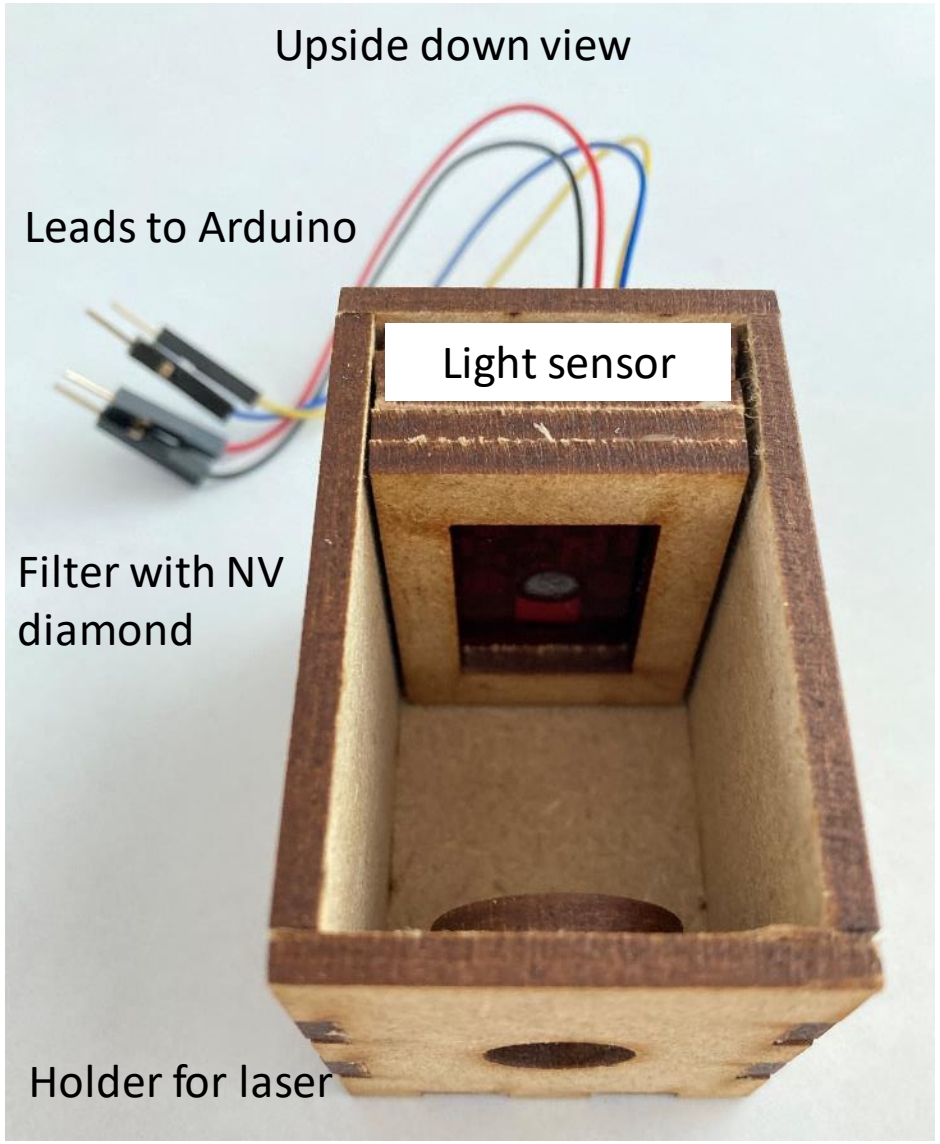
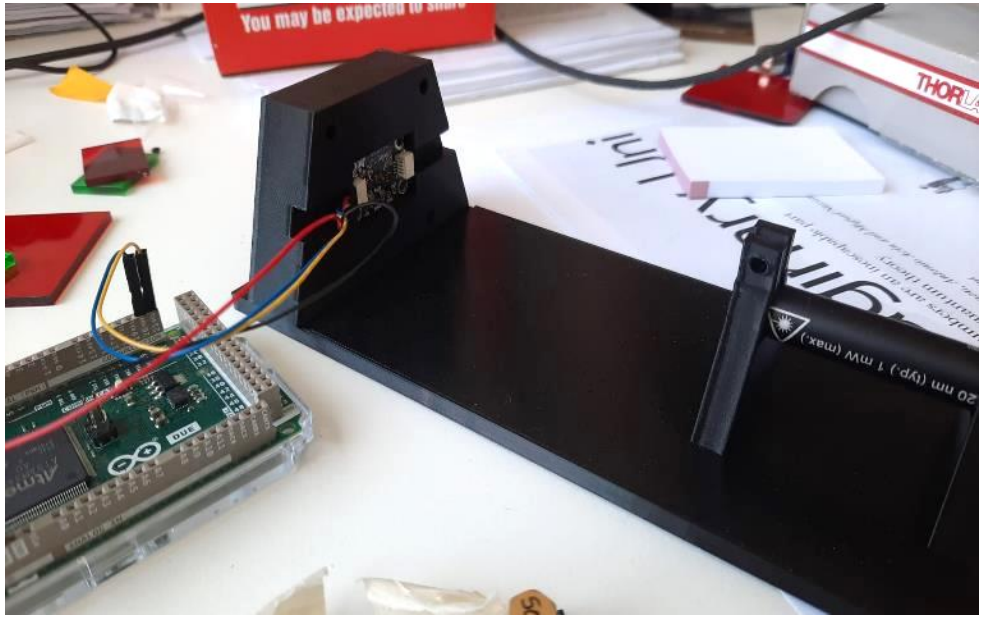
Hands-on NV center experiment



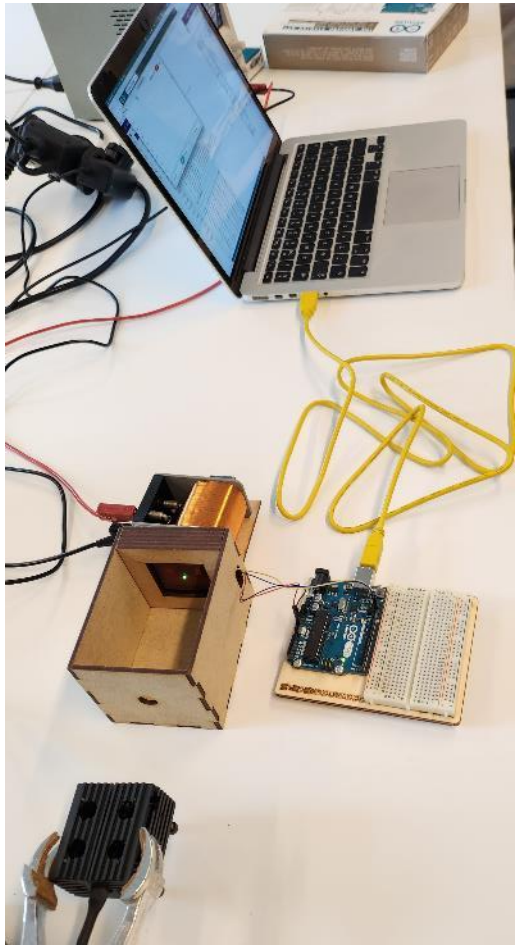


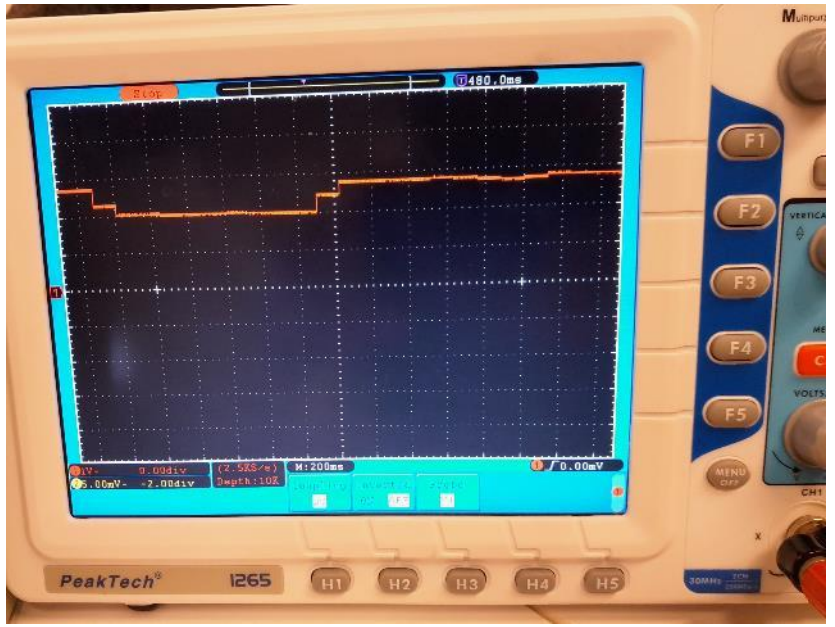
3D-printed version by DEMO (TU Delft)

HvA version: crack the code

Wouter Spaan et al.

Context: optimize signal/setup, focussed on potential polytechnics students





Problem: strong B-field needed, electromagnet runs hot!

Gamification implementation:

- Pulsed B-field
- Duration = Code
- Students have to decipher the code

images: Wouter Spaan

Chapter 1: Biomimetics and sensors

Rutger Ockhorst (CC BY-SA 4.0)

Pierre Selim (CC BY-SA 3.0) (cropped)

Derek Keats (CC BY 2.0) (cropped)

Better Power Plant Efficiency Thanks to a Beetle? Biomimicry in the Energy Sector
https://youtu.be/2pU5Yksk-po

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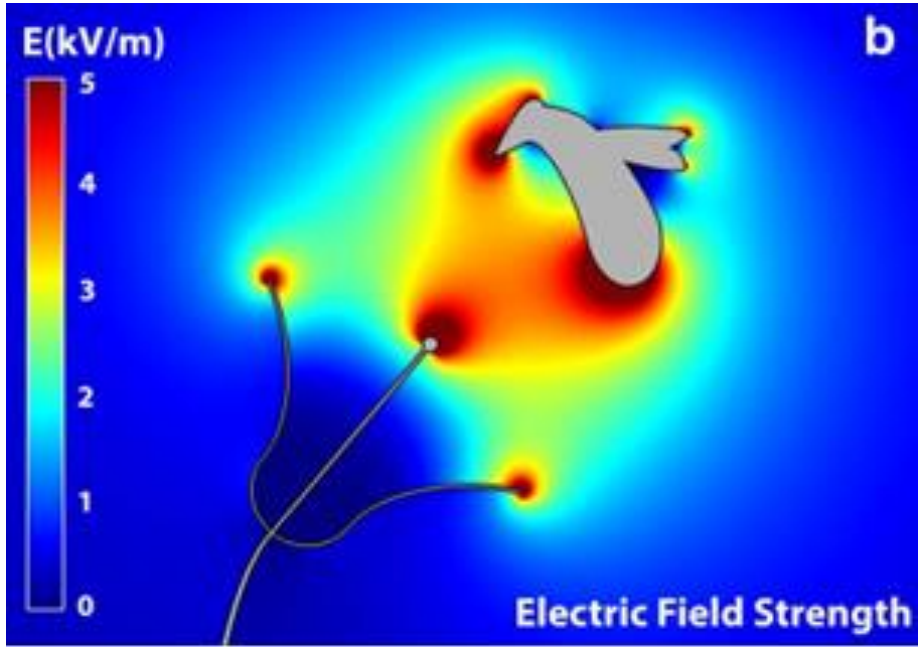
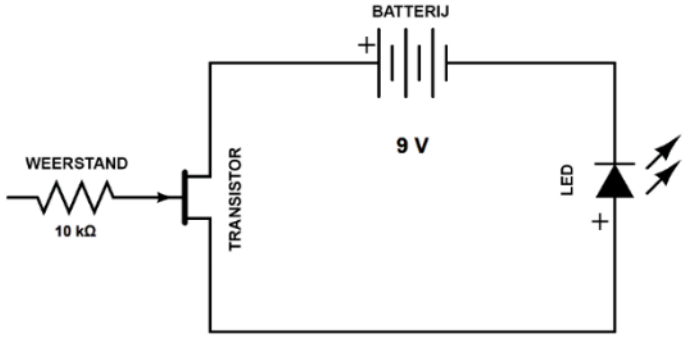
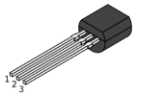
Chapter 1: Biomimetics and sensors



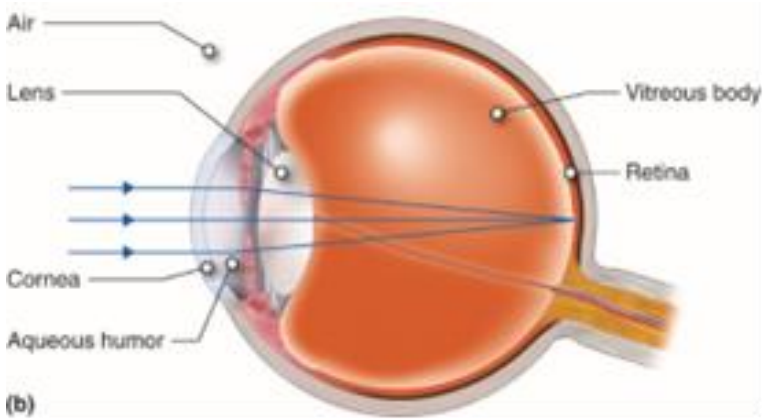
https://doi.org/10.1007%2Fs00359-017-1176-6 (2017) (CC BY 4.0)



Onderdeel	Functie	Onderdeel	Functie
	JFET Transistor: regelt de stroom in het circuit. Dit is de eigenlijke sensor.		Levert energie om de led te laten branden
	led: is een indicator voor de hoeveelheid negatieve lading. Als er geen lading in de buurt is dan brandt de led. De lange pin is de plus (+)		Batterijclip om de batterij aan te sluiten.
	Weerstand: werkt als antenne en beschermt de transistor tegen statische elektriciteit.		Breadboard: Wordt gebruikt om de onderdelen in te klikken en met elkaar te verbinden.

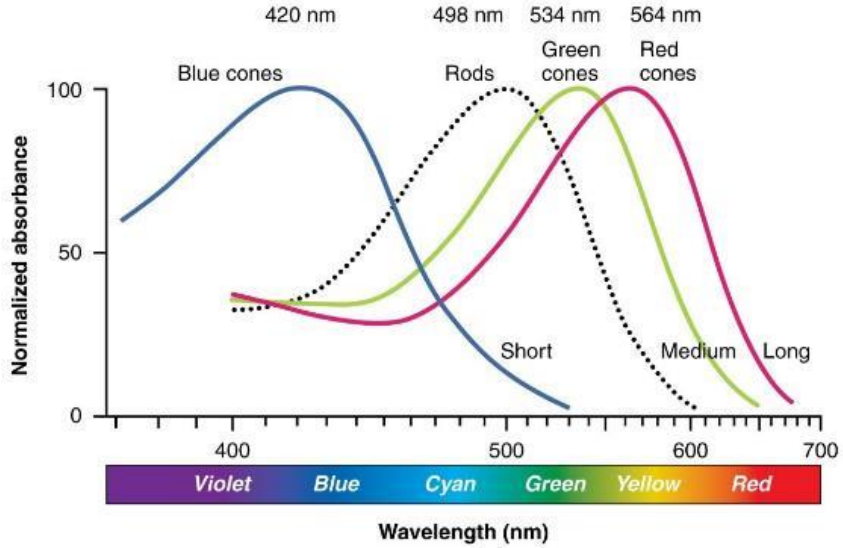
Chapter 2: light, the eye and the led

LED as source and receiver



Cenveo CC BY 3.0 US

Public domain

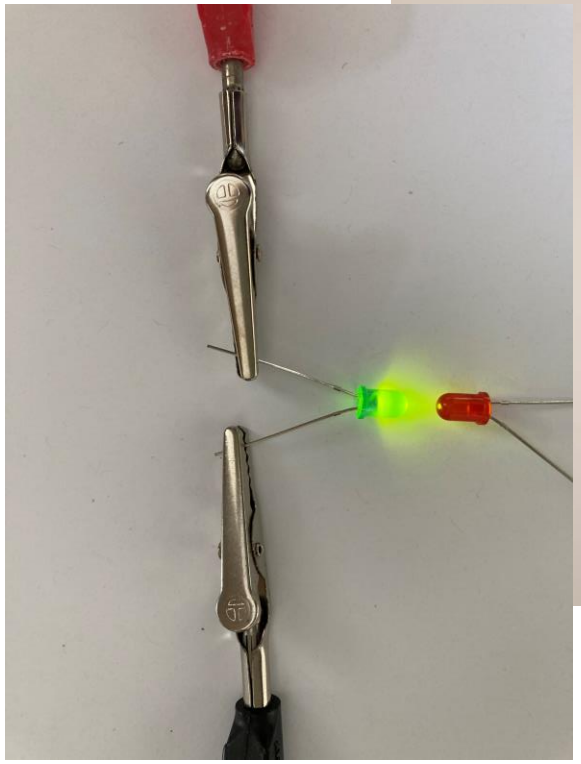


Bowmaker & Dartnall CC BY-SA 3.0

Chapter 2: light, the eye and the led

LED as source and receiver

Created by students of the Leidse Instrumentmakers School



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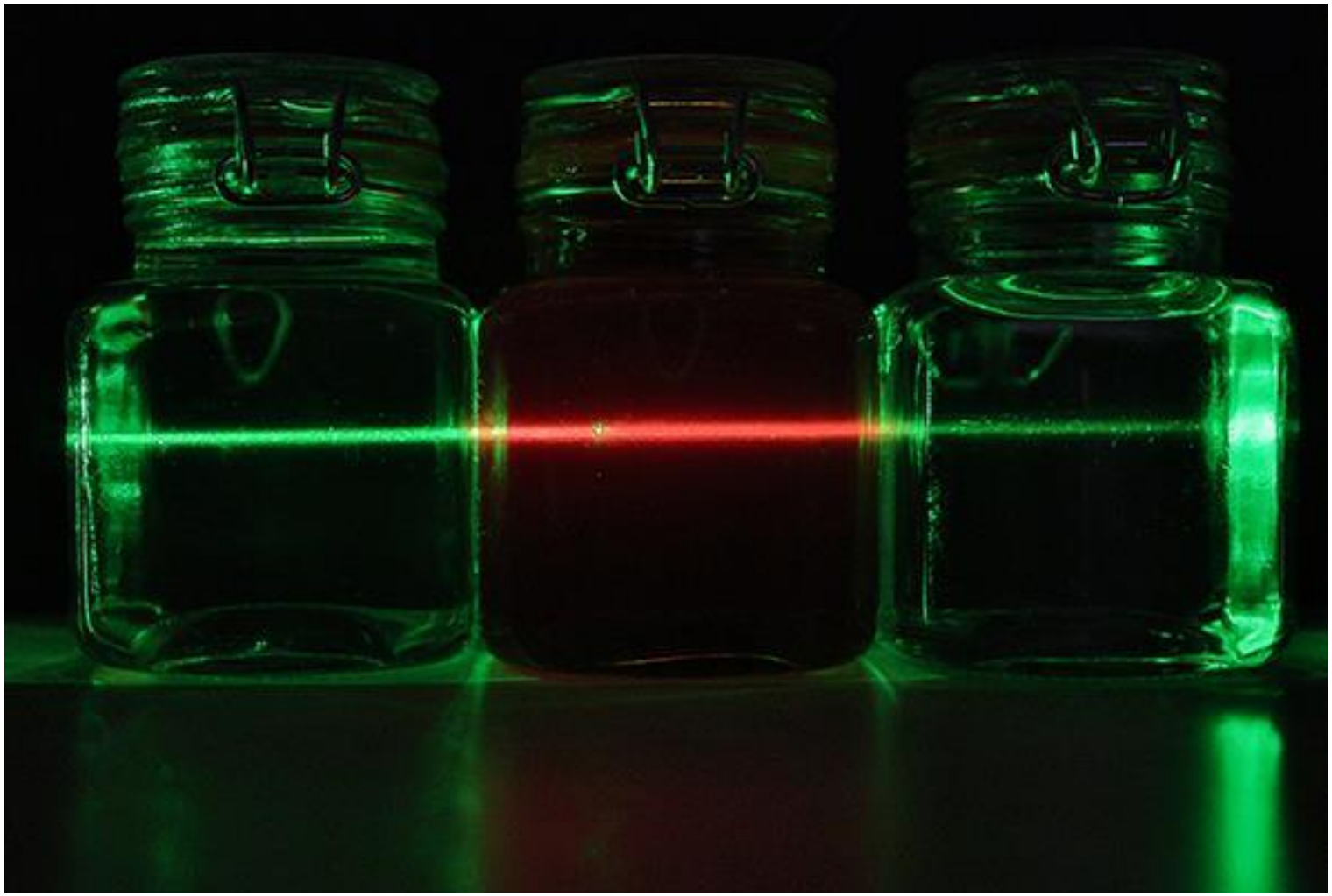
Chapter 3: Fluorescence



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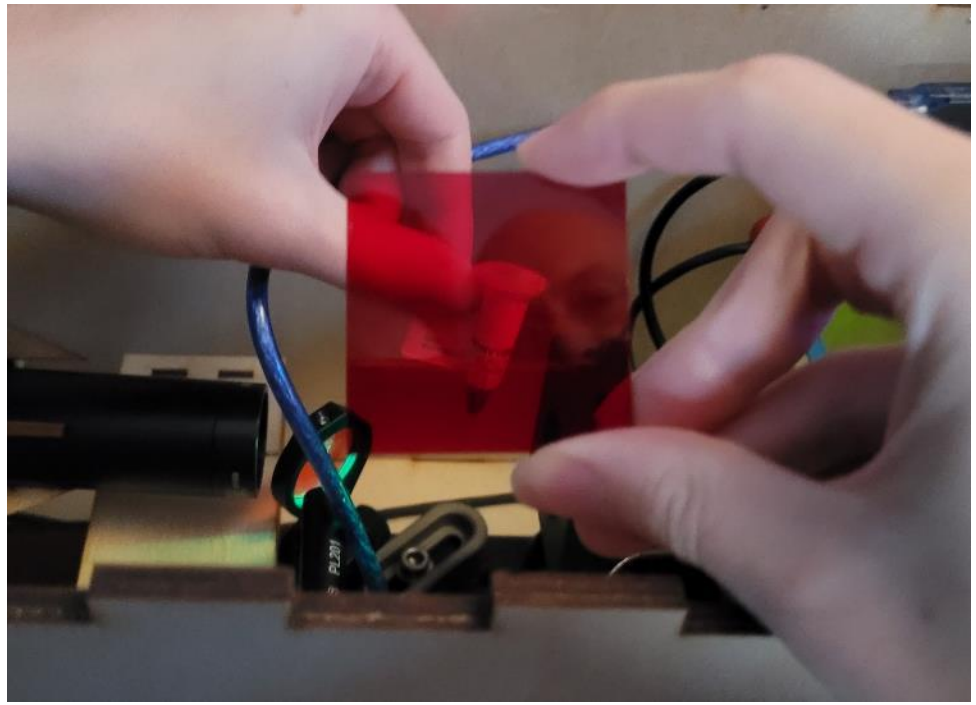
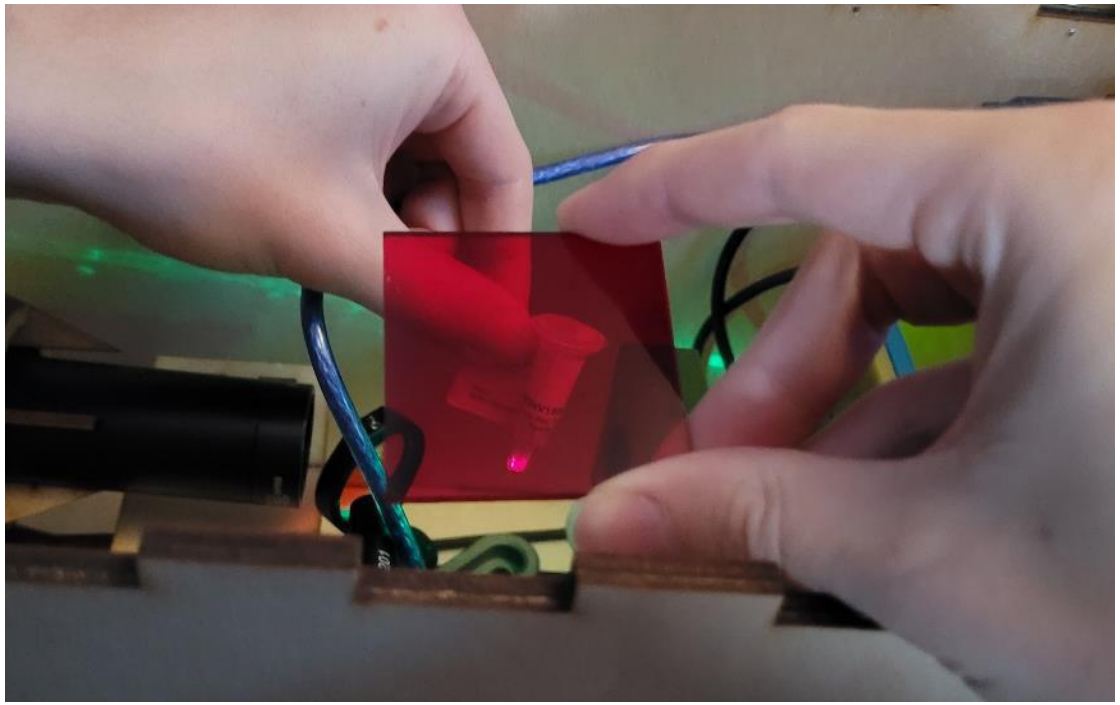
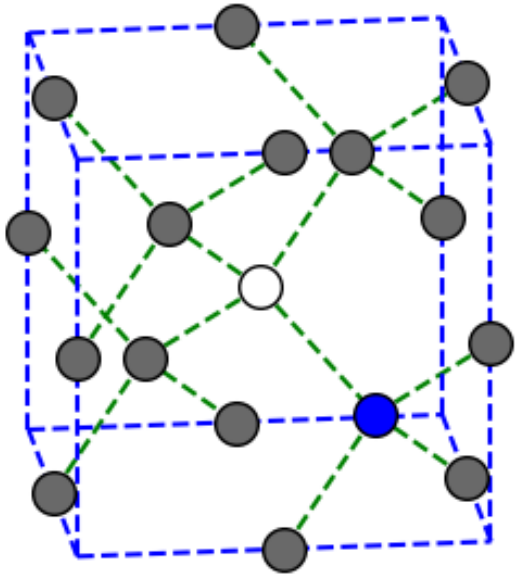
Chapter 3: Fluorescence

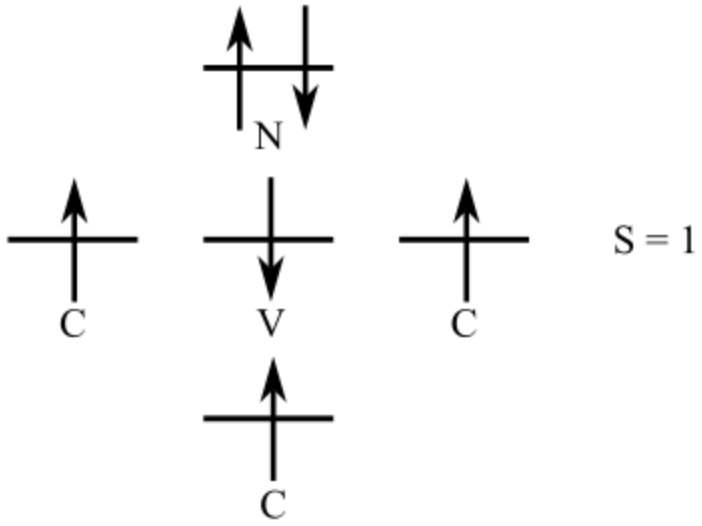
Fluorescent diamond powder

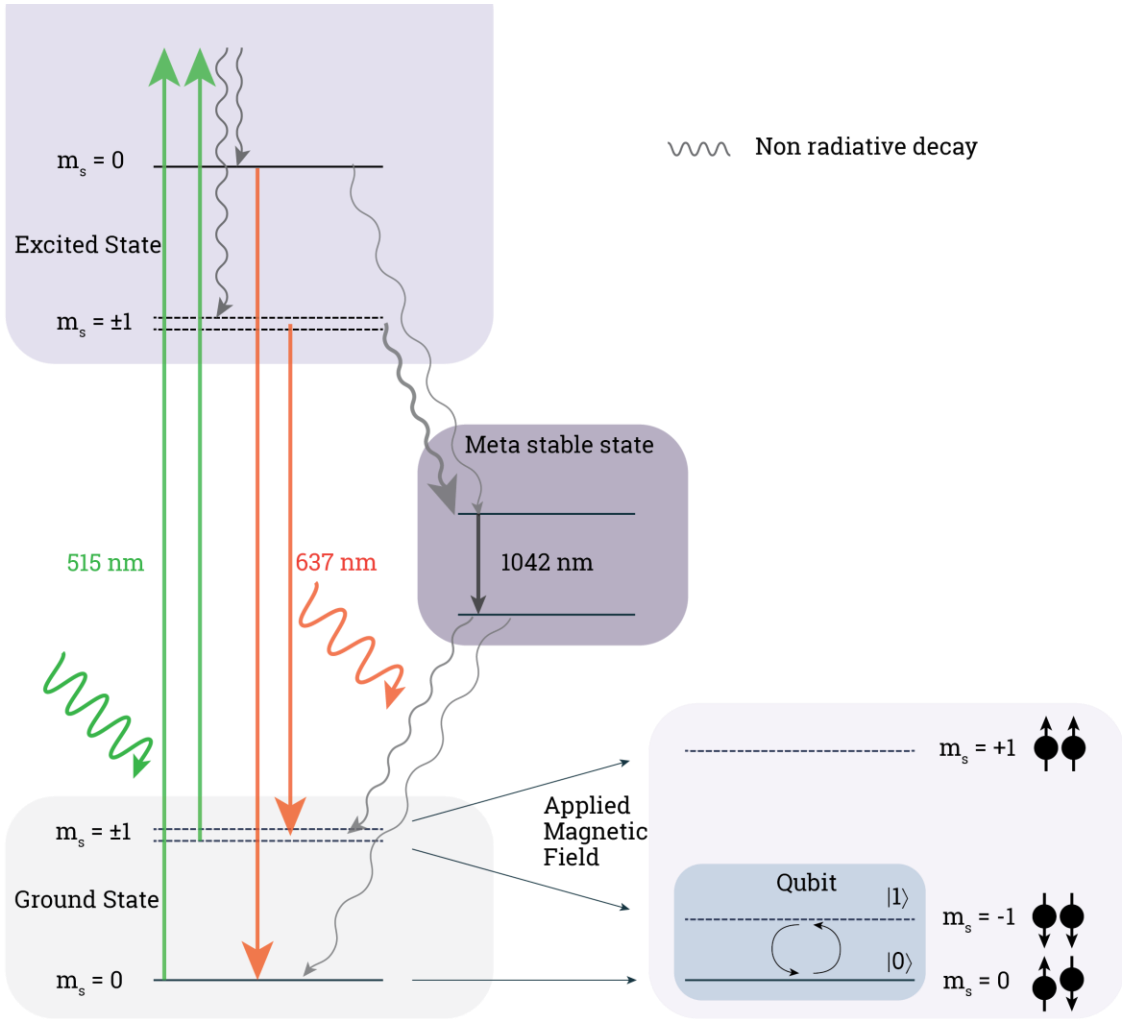




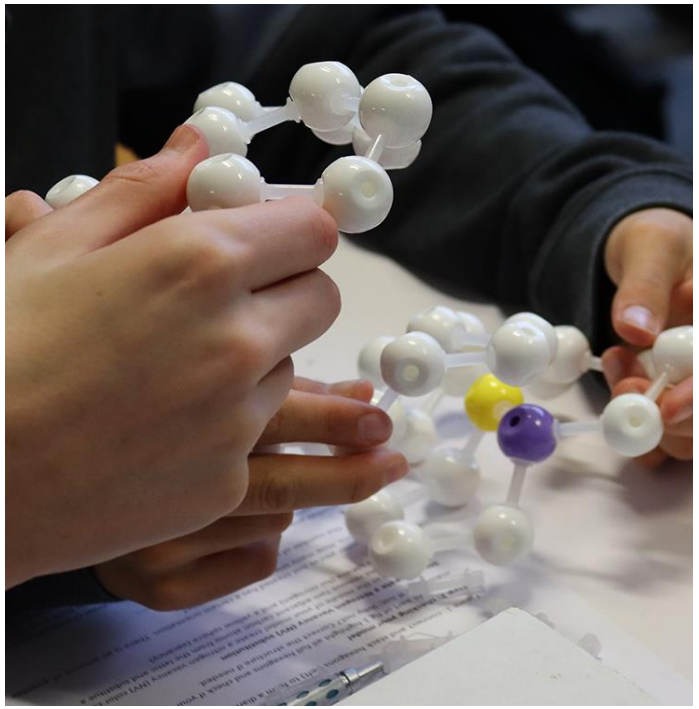
Chapter 4: Magnetism

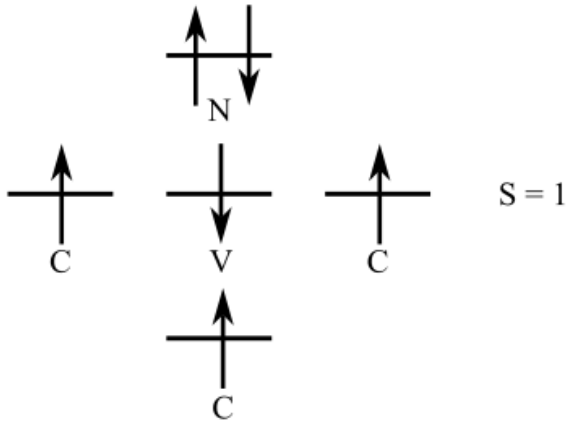


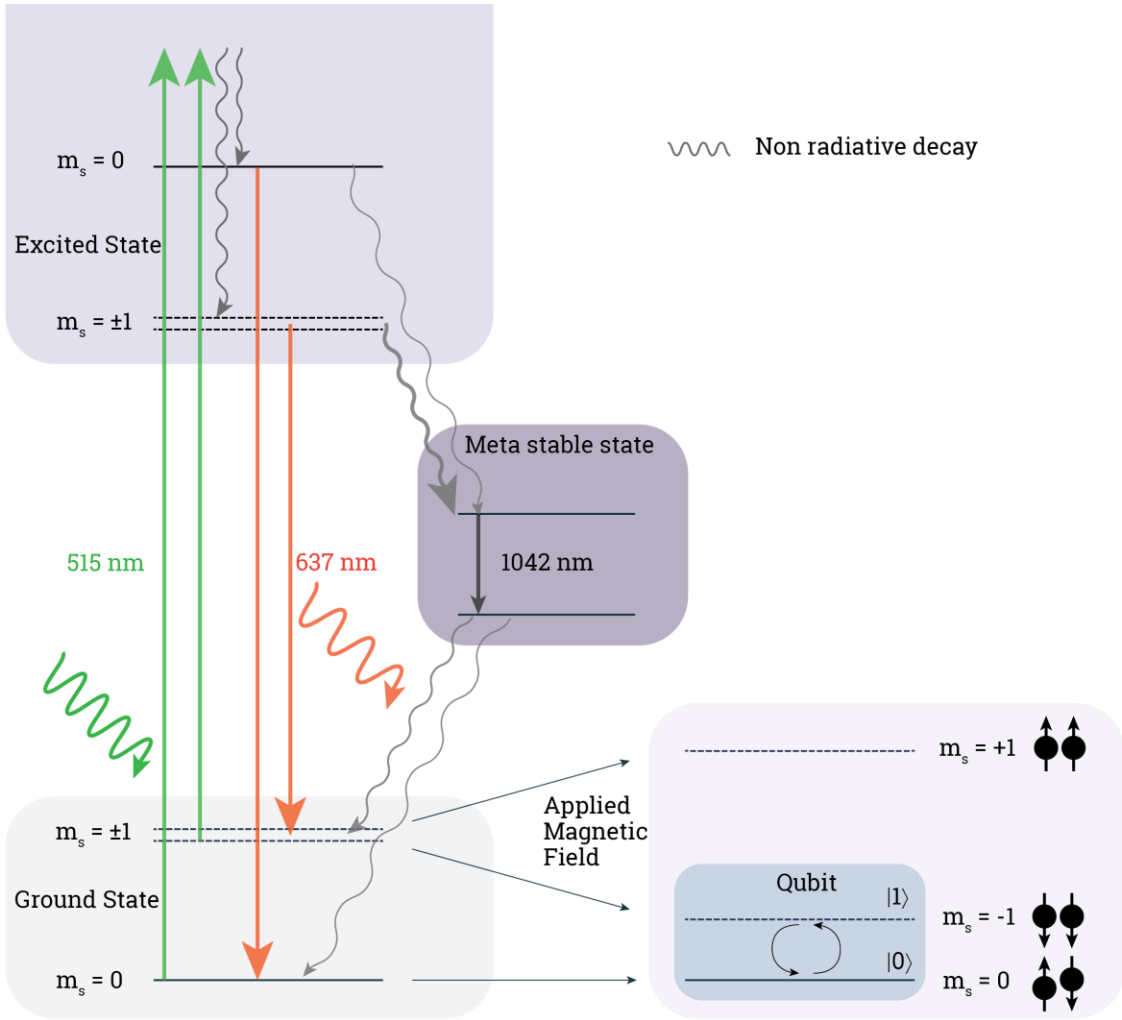




Chapter 4: Magnetism

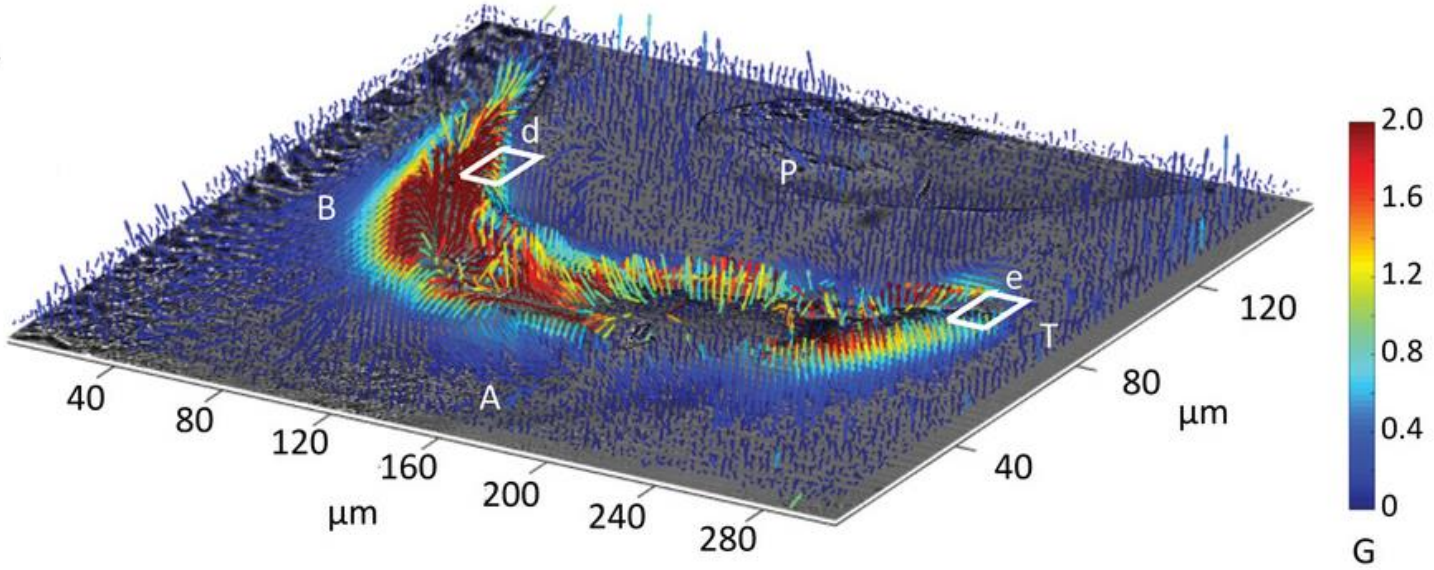






Chapter 5: Imaging with NV centers

Acanthopleura Hirtosa



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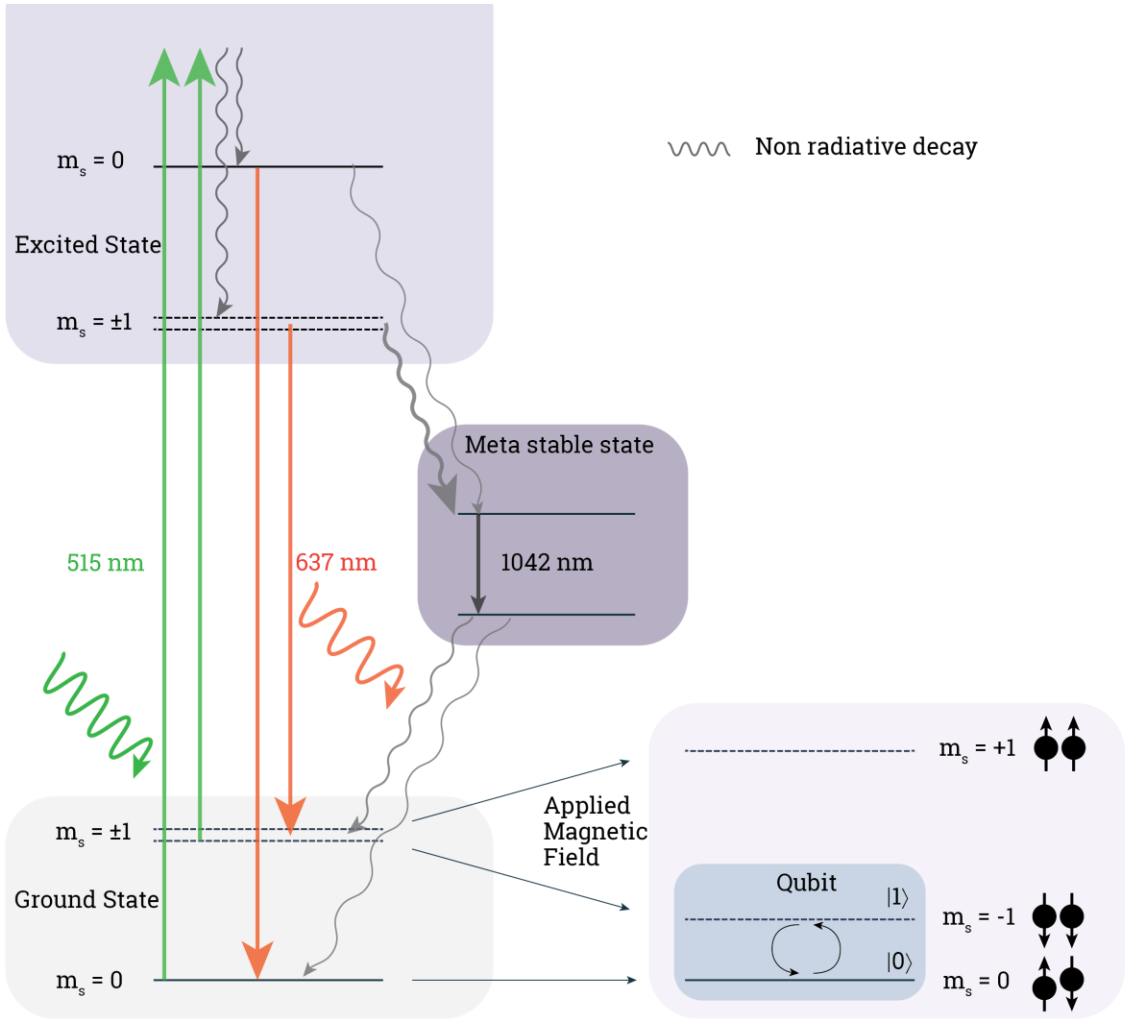
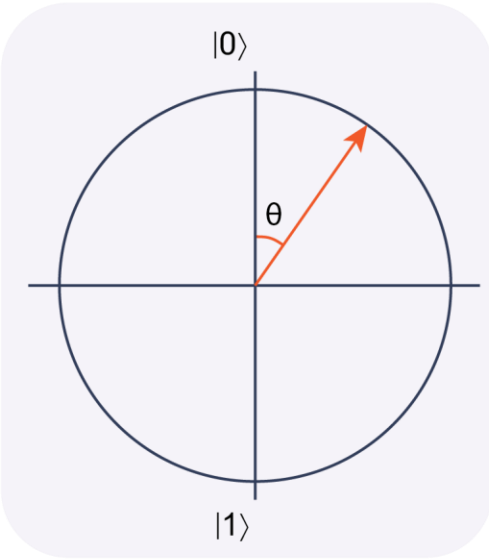
Link with Quantum Computing: Qubits





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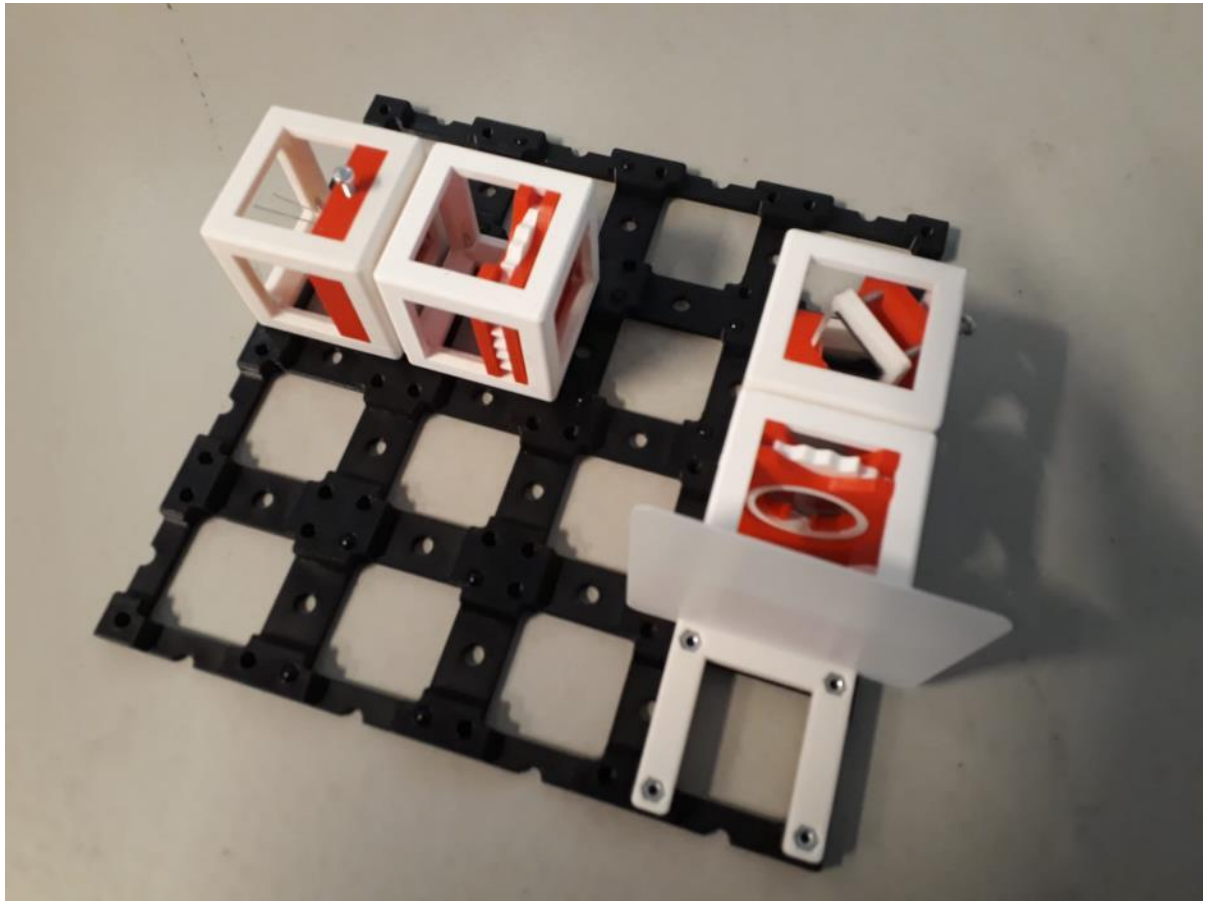
Malus' Law

Towards Quantum Cryptography



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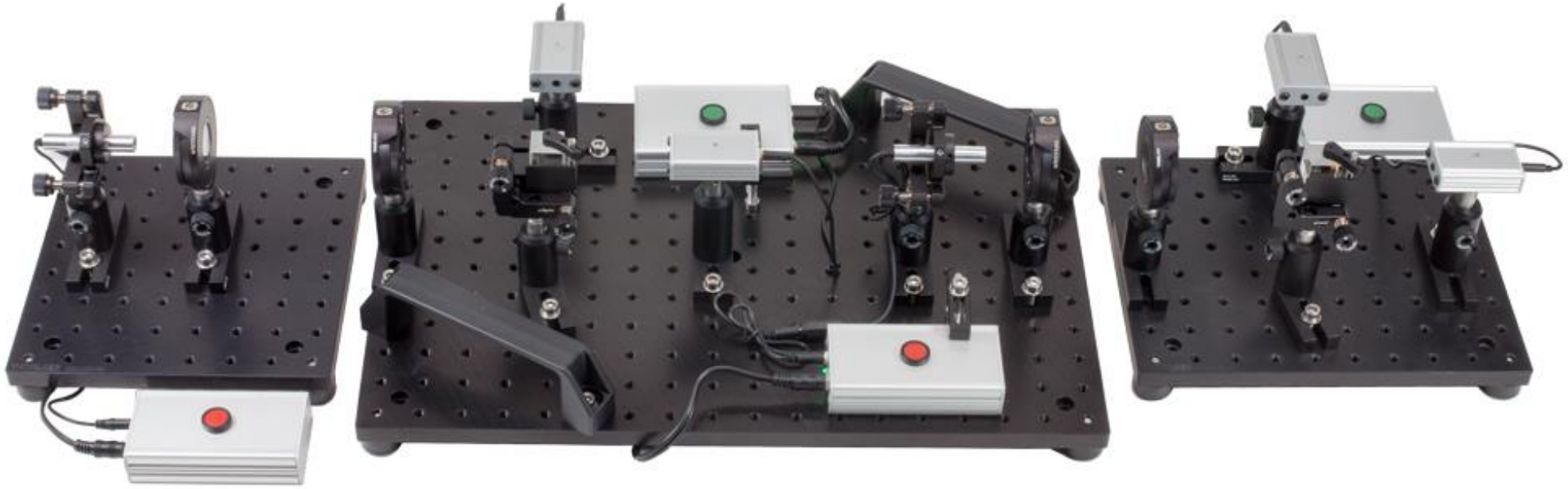
Alice, Bob & Eve

Quantum Cryptography: BB84



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