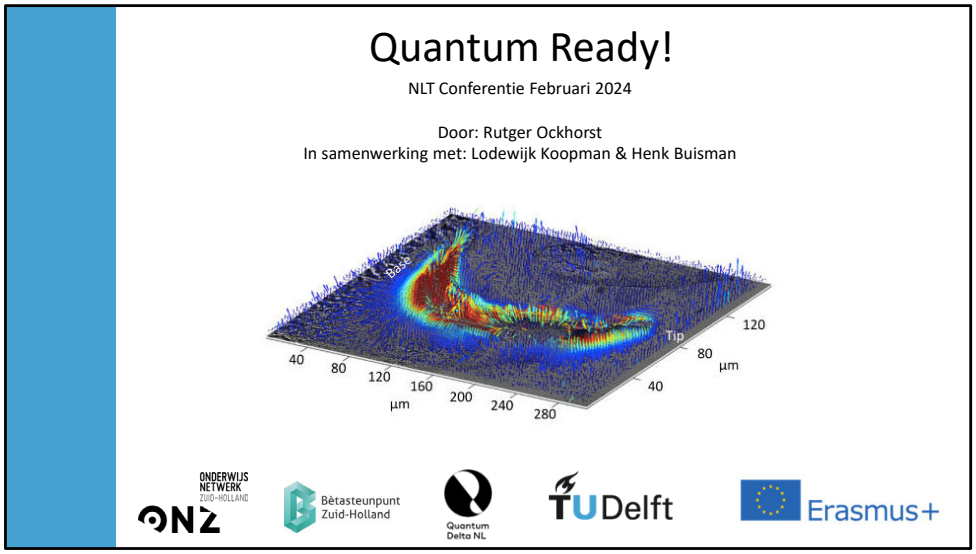
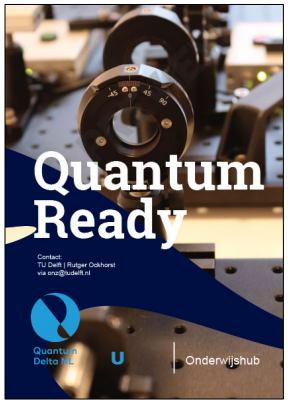


Bronvermelding bij afbeelding zoveel mogelijk vermeld. Afbeeldingen worden hier alleen gebruikt voor onderwijsdoeleinden en vallen derhalve onder *fair use* / legitiem gebruik en/of het reprorecht.

Bron: David Simpson, *Magnetic Teeth Revealed Using Quantum Imaging*
https://pursuit.unimelb.edu.au/articles/magnetic-teeth-revealed-using-quantum-imaging

Twee Modules



HAVO 4 / 5

VWO 6

Informatie over Quantum Ready: ONZ@tudelft.nl
Informatie over Kansen met Quantum: https://quantumrules.nl/kansen-met-quantum-2/

ScholierenLab Leiden

www.quantumrules.nl
Experimenten voor 6 vwo op locatie bij Universiteit Leiden
Aansluitend bij ‘quantum 1.0’ / eindexamen vwo

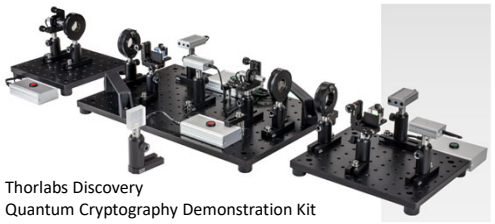
TU Delft

ScholierenLab Delft

in aanbouw

Workshops ter ondersteuning van NLT en Profielwerkstuk, onder andere:

- Quantum Sensing / Cryptography / Computing
- Fluorescentie & Spectroscopie
- Atomic Force Microscopie



Thorlabs Discovery
Quantum Cryptography Demonstration Kit

TUDelft

Contact: scholierenlab@tudelft.nl (Lennard Duynkerke)

Bron Thorlabs kit: https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=9869

Mindset

NO!

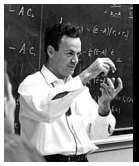
If quantum mechanics hasn't profoundly shocked you, you haven't understood it yet.

- 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

NLT module HAVO: Quantum Ready!

NLT module voor havo 4 / 5

Quantum is overal om ons heen en dat ga je ontdekken met voorbeelden uit biologie, technologie. Leerling(activiteiten) staan centraal.

Module H1 t/m H3: o.a. Biomimetica, Fotonen, Energiediagram, Fluorescentie
(concept: voorjaar 2024)

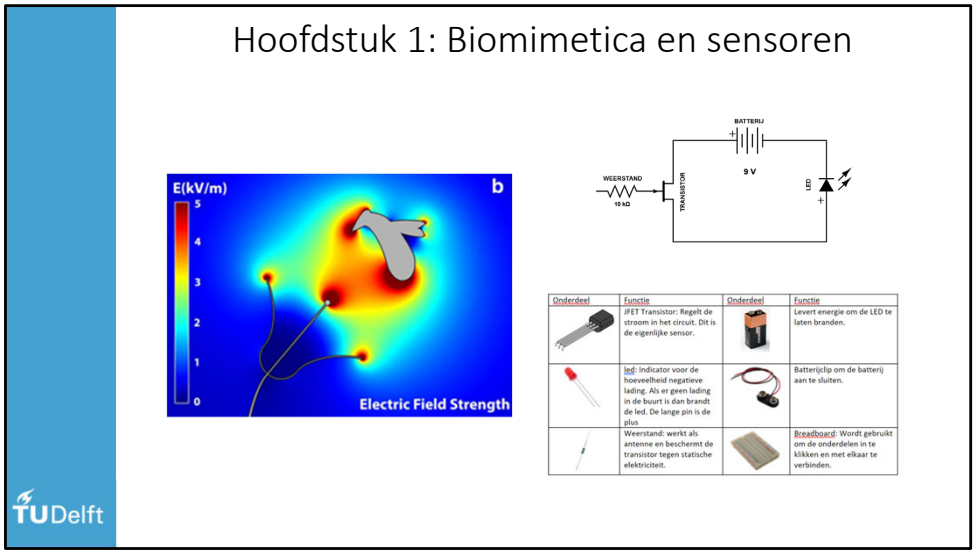
Module H4 + H5: Magnetisme en Quantum Sensing
(concept: najaar 2024)

Testen: 2024 – 2025 (bij u op school?)

Quantum Delta NL

TU Delft

Figuur 1: Vliegtuigvleugel Aviodrome 2022 door Rutger Ockhorst (CC BY-SA 4.0) (bijgesneden)
Figuur 2: Embraer 190 – Wing and winglet door Pierre Selim (CC BY-SA 3.0) (bijgesneden)
https://commons.wikimedia.org/wiki/File:Embraer_190_-_Wing_and_winglet.jpg
Figuur 3: Verreaux's Eagle at W. Sisulu Nat. Bot. Garden door Derek Keats (CC BY 2.0) (bijgesneden)
Video: https://youtu.be/2pU5Yksk-po



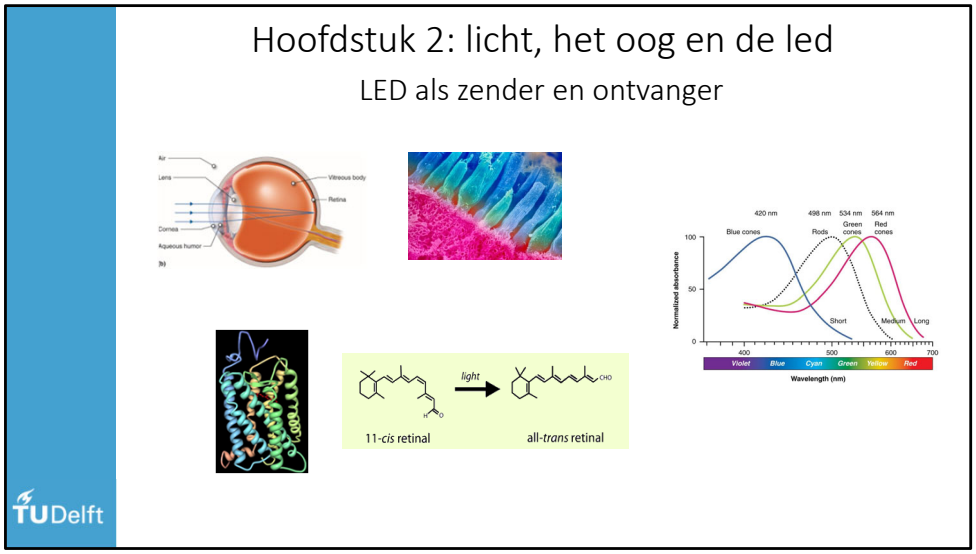
Bronnen illustraties:

Clarke, Morley, Robert, *The bee, the flower, and the electric field: electric ecology and aerial electroreception*, https://doi.org/10.1007%2Fs00359-017-1176-6 (2017) (CC BY 4.0)

Transistor: publiek domein
https://commons.wikimedia.org/wiki/File:TO-92_Front_with_Pin_Numbers.svg

LED door oomlout (CC BY-SA 2.0)
https://commons.wikimedia.org/wiki/File:5mm_Red_LED.jpg

Weerstand door hidro (CC BY-SA 3.0) (gedraaid)
https://commons.wikimedia.org/wiki/File:Metal_film_resistor.jpg
Batterij door Ashley Pomeroy (CC BY 3.0)
https://commons.wikimedia.org/wiki/File:Duracell_9_Volt_0849.jpg
Batterij clip door oomlout (CC BY-SA 2.0)
https://commons.wikimedia.org/wiki/File:9_volt_Battery_Snap.jpg
Breadboard door oomlout (CC BY-SA 2.0)
https://commons.wikimedia.org/wiki/File:400_points_breadboard.jpg



Oog: Cenveo https://www.coursehero.com/study-guides/cuny-csi-ap-1-2/special-senses-vision/

Netvlies: https://www.sciencephoto.com/media/308755/view/false-colour-sem-of-rods-and -cones-of-the-retina

Rhodopsine: https://nl.wikipedia.org/wiki/Rodopsine#/media/Bestand:Rhodopsin_3D.jpeg

Retinal: http://photobiology.info/Crouch.html

Gevoeligheid kegeltjes en staafjes: Bowmaker & Dartnall CC BY-SA 3.0 https://commons.wikimedia.org/wiki/File:Cone-response-uk.svg

Hoofdstuk 2: licht, het oog en de led

LED als zender en ontvanger

Gemaakt door studenten van de Leidse Instrumentmakers School

Cheek, G. T. (2015). Demonstrations of frequency/energy relationships using LEDs. *Journal of Chemical Education*, *92*(6), 1049-1052.

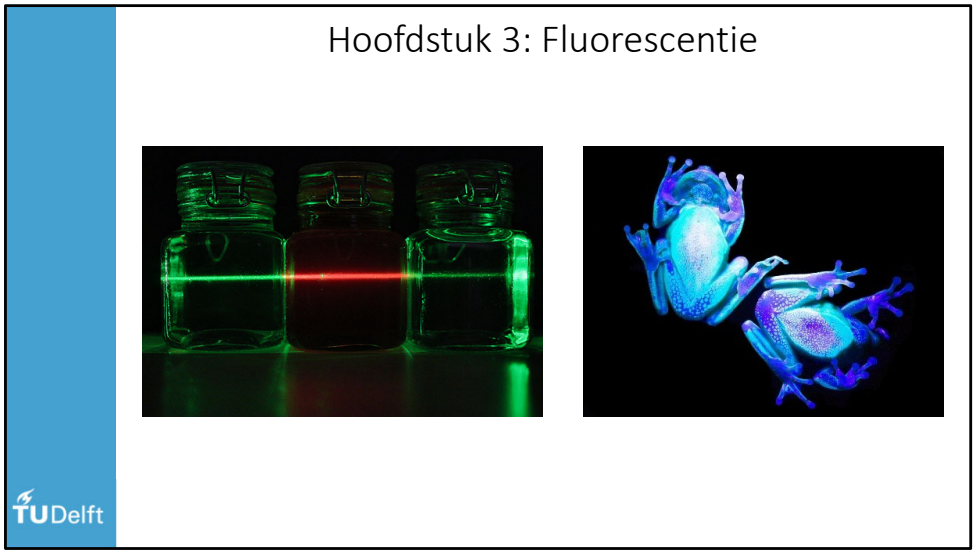
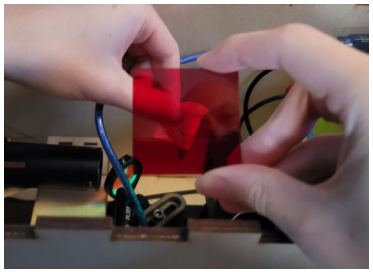


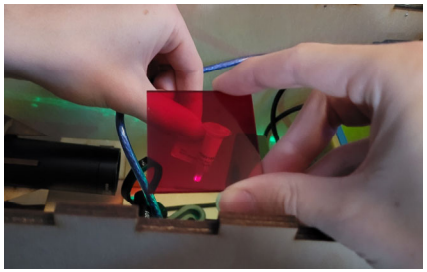
Foto olijfolie door Rutger Ockhorst

Bron kikkers: Bron: https://www.nu.nl/dieren/6276482/lichtgevende-kikkers-in-zuid-amerika-hebben-voor-elk-signaal-een-andere-kleur.html door Linda van Beest, foto door BioPhotoNature

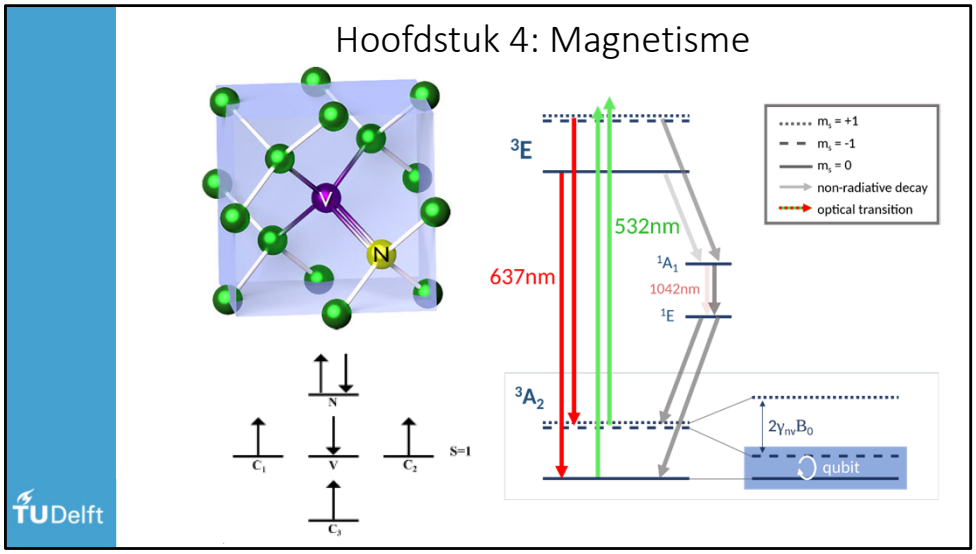
Hoofdstuk 3: Fluorescentie

Fluorescerend diamantpoeder





Foto’s door Mark Melotto



Illustratie rooster: NIST, publiek domein (https://www.nist.gov/programs-projects/diamond-nv-center-magnetometry)
Spinconfiguratie: https://researchgate.net/figure/Schematic-representation-of-the-electron-spin-configuration-of-NV-center-in-which-it_fig1_346766528
Energiediagram door BonPhire,BY-SA 4.0, https://commons.wikimedia.org/wiki/File:NV-transitions.svg)

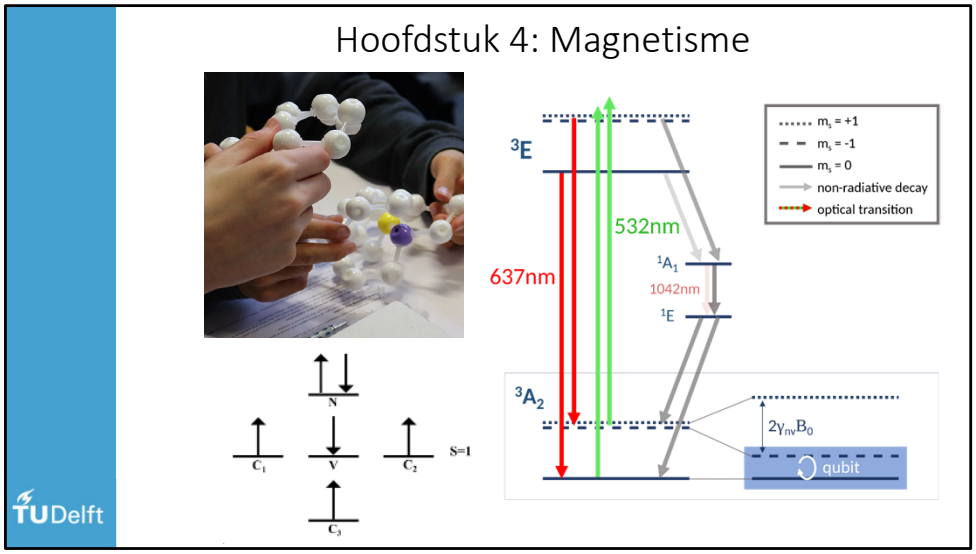
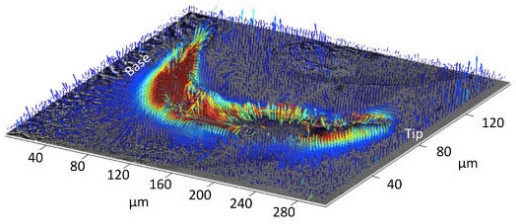


Foto atoommodel knutselen door Rutger Ockhorst

Energiediagram door BonPhire,BY-SA 4.0, https://commons.wikimedia.org/wiki/File:NV-transitions.svg)

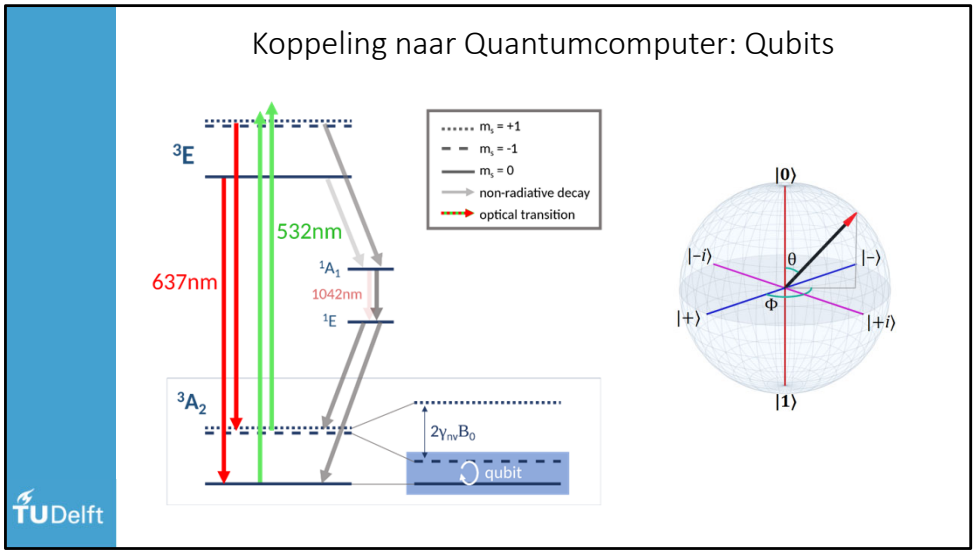
Hoofdstuk 5: Beeldvorming

Acanthopleura Hirtosa



Bron: David Simpson, *Magnetic Teeth Revealed Using Quantum Imaging*
https://pursuit.unimelb.edu.au/articles/magnetic-teeth-revealed-using-quantum-imaging

TUDelft

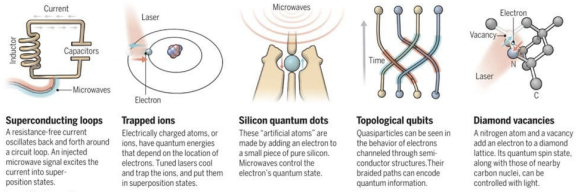


Energiediagram door BonPhire,BY-SA 4.0, https://commons.wikimedia.org/wiki/File:NV-transitions.svg)

https://logosconcarne.com/2021/03/15/qm-101-bloch-sphere/

Qubits in soorten en maten

Maar allemaal dezelfde wiskunde en mogelijkheden



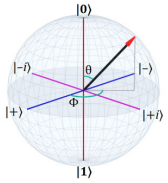
Superconducting loops
A resistance-free current oscillates back and forth around a circuit loop. An injected microwave signal excites the current into superposition states.

Trapped ions
Electrically charged atoms, or ions, have quantum energies that depend on the location of electrons. Tuned lasers cool and trap the ions, and put them in superposition states.

Silicon quantum dots
These "artificial atoms" are made by adding an electron to a small piece of pure silicon. Microwaves control the electron's quantum state.

Topological qubits
Quasiparticles can be seen in the behavior of electrons channeled through semiconductor structures. Their braided paths can encode quantum information.

Diamond vacancies
A nitrogen atom and a vacancy add an electron to a diamond lattice. Its quantum spin state, along with those of nearby carbon nuclei, can be controlled with light.

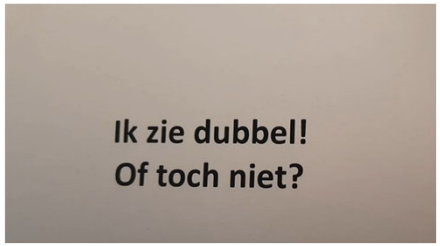


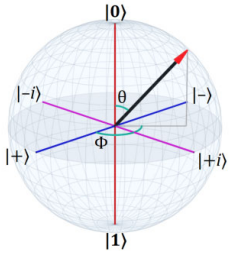
TUDelft

Bron: https://www.forbes.com/sites/moorinsights/2019/09/16/quantum-computer-battle-royale-upstart-ions-versus-old-guard-superconductors/
https://imageio.forbes.com/blogs-images/moorinsights/files/2019/09/Picture1-8.png by C. Bickle / Gabriel Popkin

https://logosconcarne.com/2021/03/15/qm-101-bloch-sphere/

Qubit: analogie met polarisatie



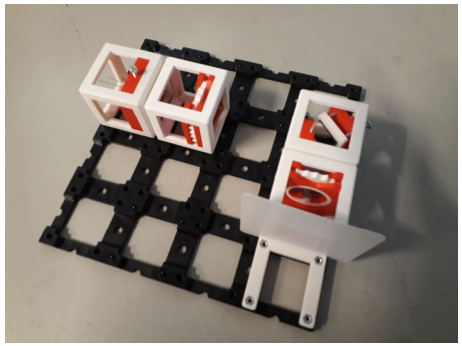


Video polarisatie door Rutger Ockhorst

https://logosconcarne.com/2021/03/15/qm-101-bloch-sphere/

Wet van Malus

Opstap naar Quantum Cryptografie

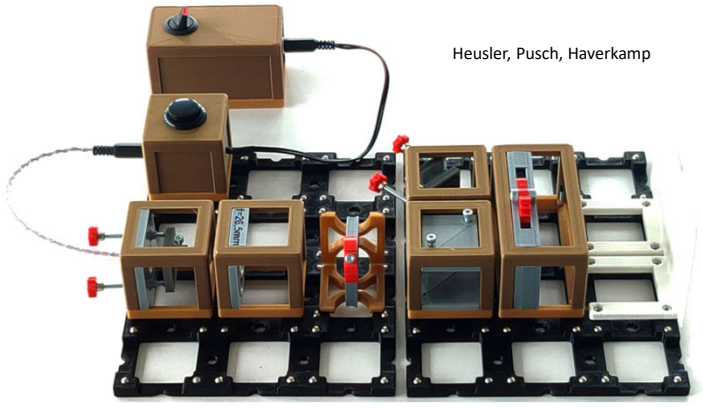


TU Delft

Bron: https://www.thorlabs.com/images/tabimages/QC_Kit_Components_A2-1000.jpg / https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=9869

Alice, Bob & Eve

Quantum Cryptografie: BB84



Heusler, Pusch, Haverkamp

TU Delft

https://o3q.de/bb84/

Ruimte voor Vragen
Discussie & Experimenteren