

# QUANTUM TECHNOLOGIES IN ORBIT - RESEARCH AND APPLICATIONS

**Dr. Lisa Wörner**

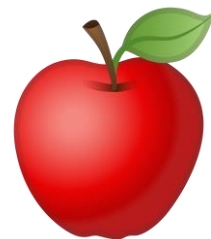
Deutsches Zentrum für Luft- und Raumfahrt (DLR e.V.), Institut für Quantentechnologien  
Wilhelm – Runge Strasse 10, 89081 Ulm  
+49 (0) 731 400 198802, +49 (0) 173 7508310, [lisa.woerner@dlr.de](mailto:lisa.woerner@dlr.de)



# Quantum Technologies

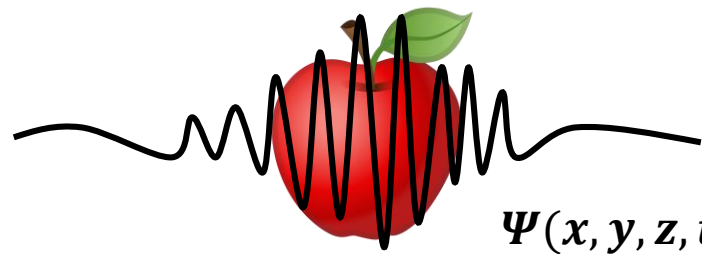
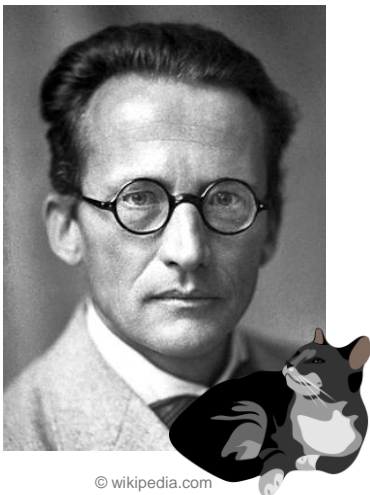
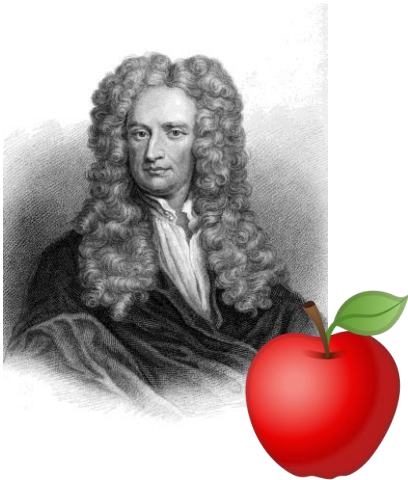


## Quantum Mechanics



# Quantum Technologies

## Quantum Mechanics



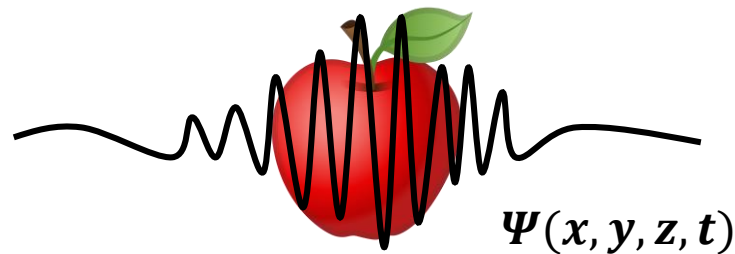
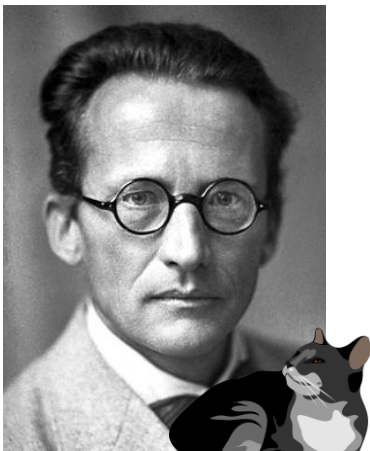
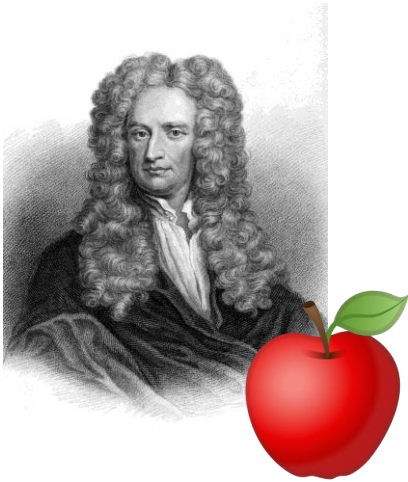
$$\left(-\frac{\hbar^2}{m}\Delta + E_{pot}\right)\Psi(x, y, z, t) = -i\hbar \frac{\partial}{\partial t}\Psi(x, y, z, t)$$

$$\Psi(x, t) = A e^{2\pi i (vt - \lambda x)} = A e^{\frac{i}{\hbar}(Et - px)}$$

# Quantum Technologies

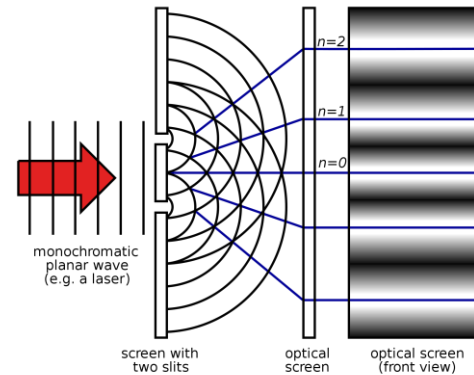


## Quantum Mechanics



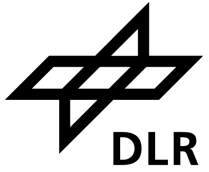
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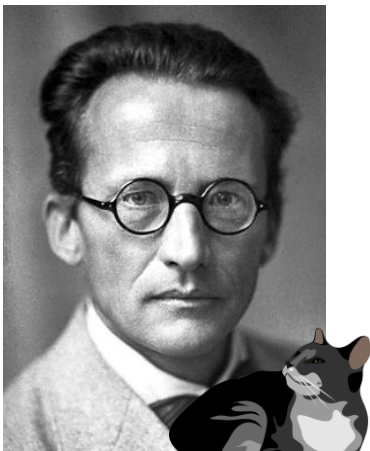
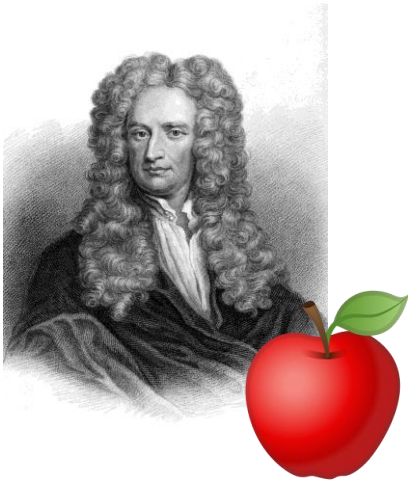




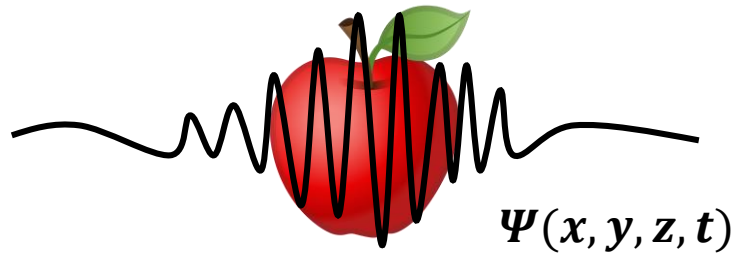
# Quantum Technologies



## Quantum Mechanics

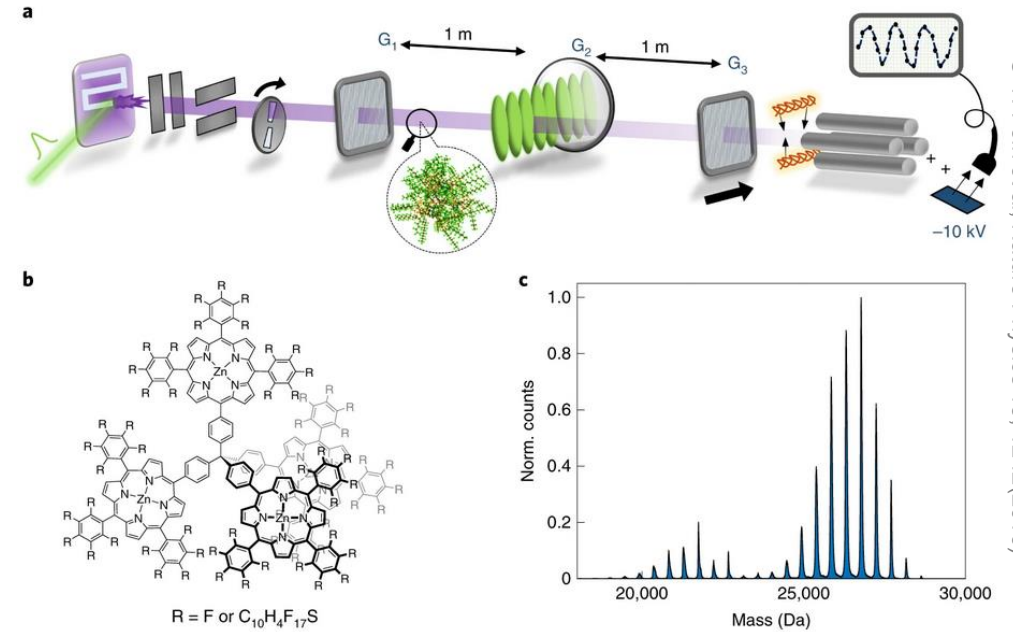


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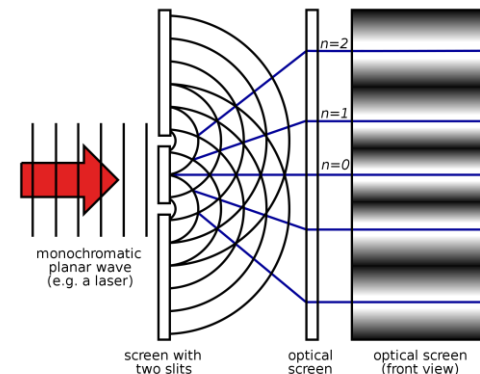


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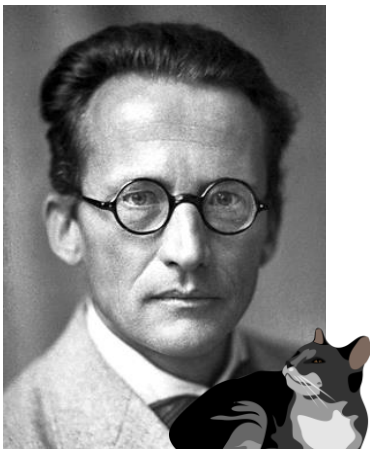
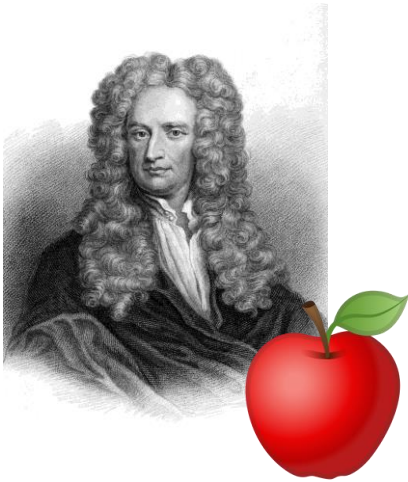


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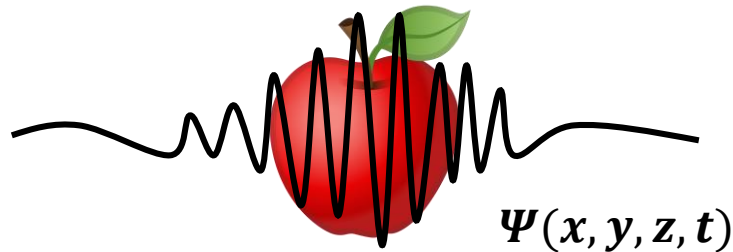


# Quantum Technologies ?

## Quantum Mechanics



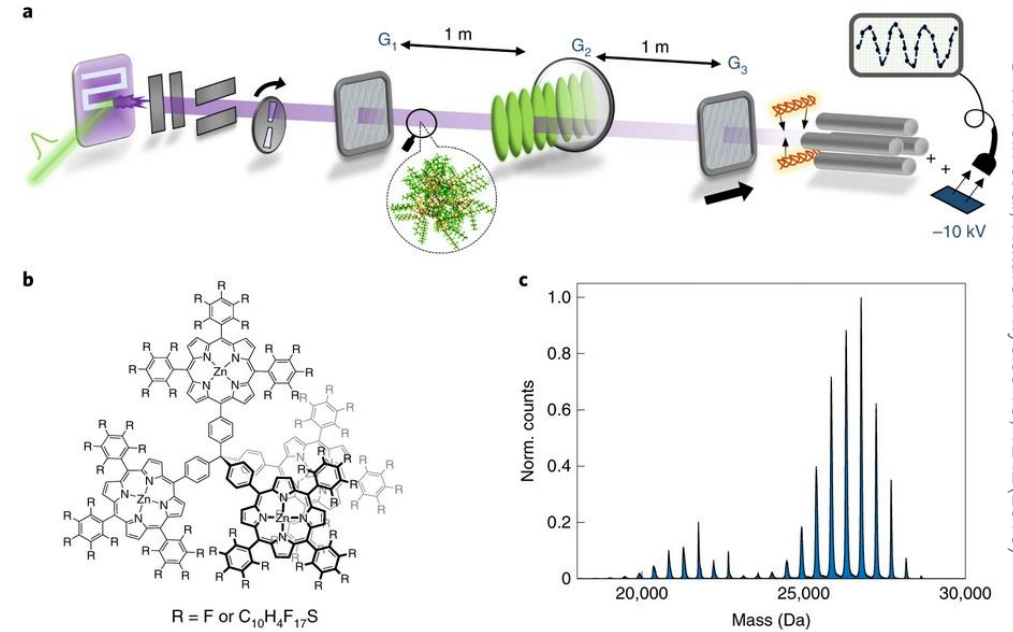
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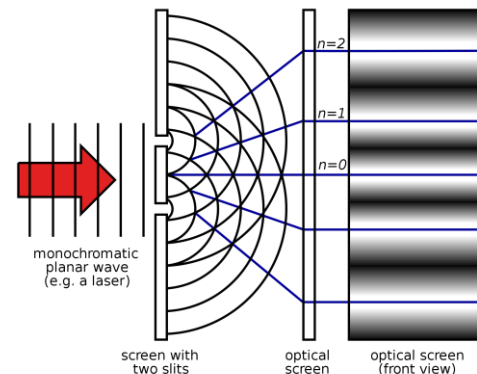
$$\Psi(x, y, z, t)$$

$$\left(-\frac{\hbar^2}{m}\Delta + E_{pot}\right)\Psi(x, y, z, t) = -i\hbar \frac{\partial}{\partial t}\Psi(x, y, z, t)$$

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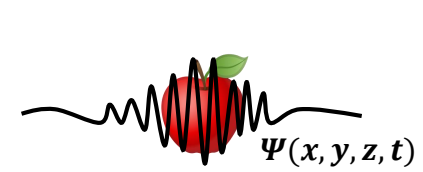


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# Quantum Technologies

## Areas of Application



Sensing



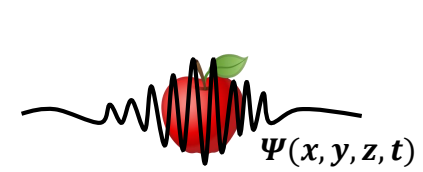
Communication



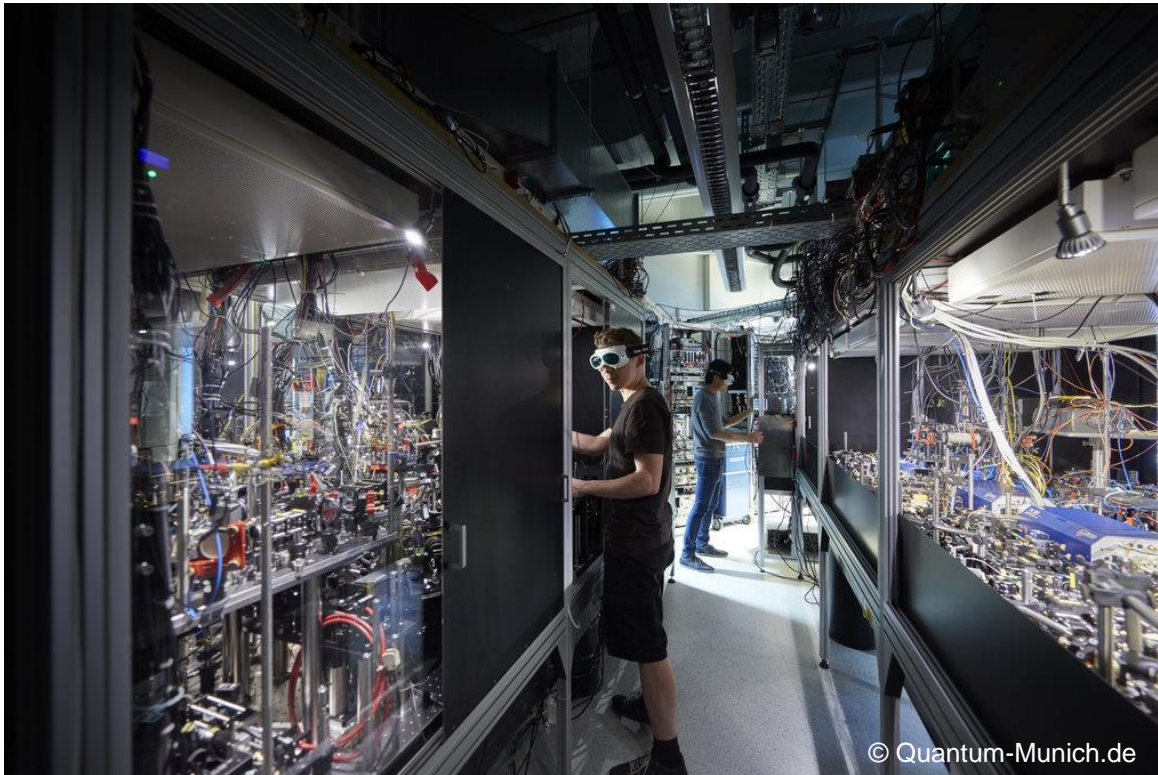
Computation



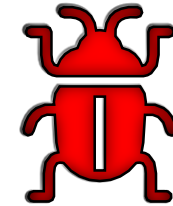
# Quantum Technologies Sensing



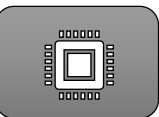
Sensing



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- Electromagnetic Radiation
- Accelerations (Gravity)
- Temperature Stability
- ...

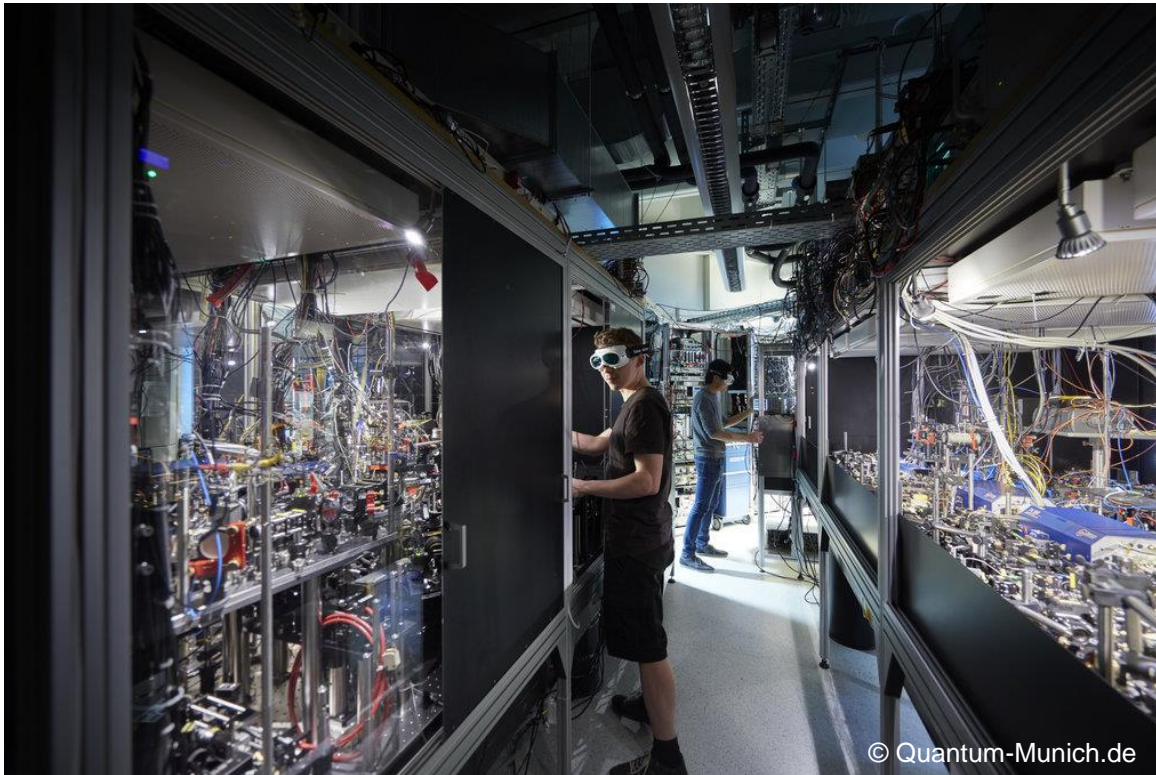




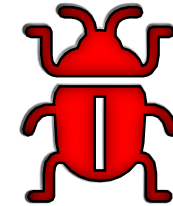
# Quantum Technologies Sensing



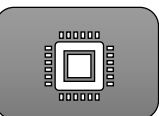
Sensing



Feature !

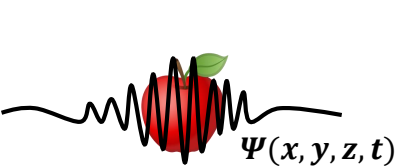


- Electromagnetic Radiation
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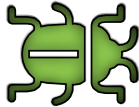


# Quantum Technologies

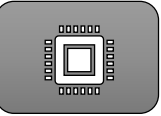
## Sensing



### Sensing



,We have solutions, we need problems‘

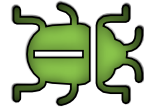


# Quantum Technologies

## Sensing

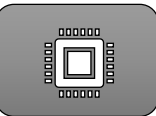


### Sensing

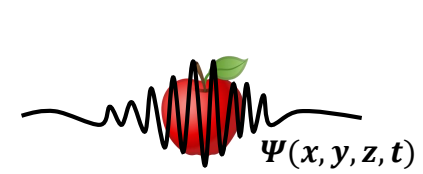


‘We have solutions, we need problems’

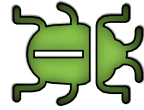
- High sensitivity to outside influences
- Other Advantages:
  - Behaviour is dominated by **fundamental constants**
  - Low to no **saturation**
  - Absence of **drift** over time



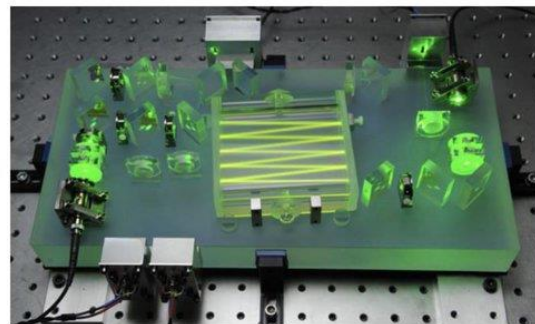
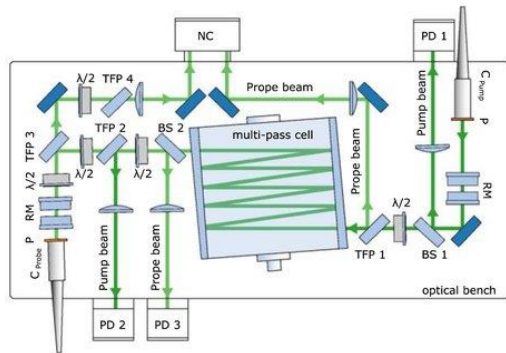
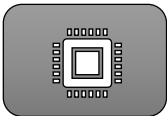
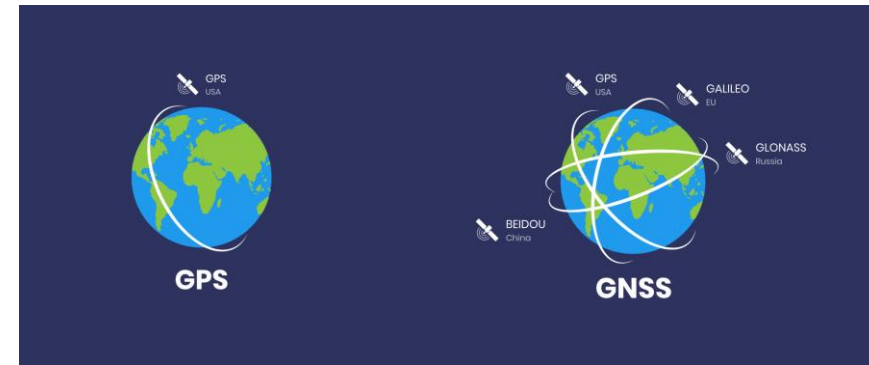
# Quantum Technologies Sensing - Navigation



## Sensing



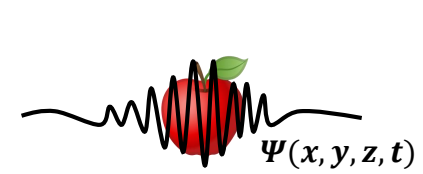
'We have solutions, we need problems'



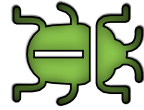
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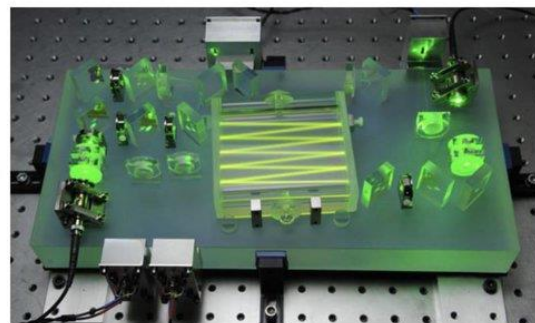
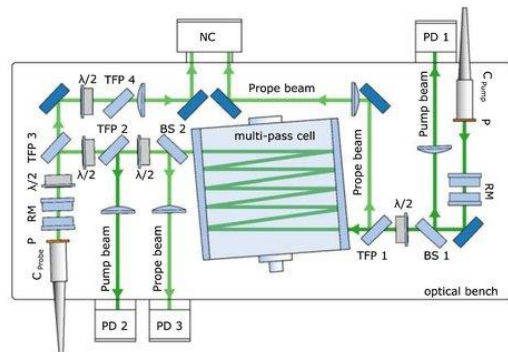
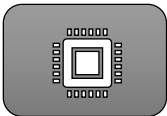
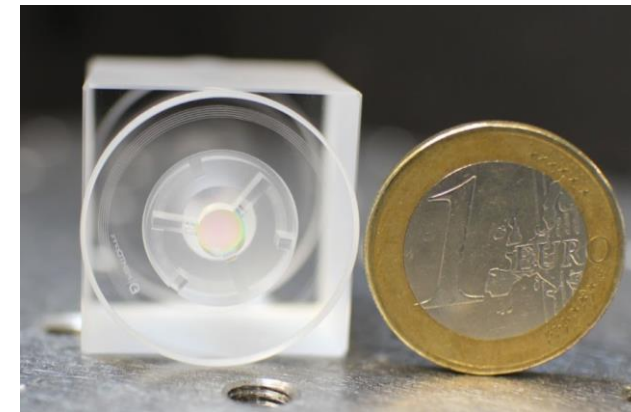
# Quantum Technologies Sensing - Navigation



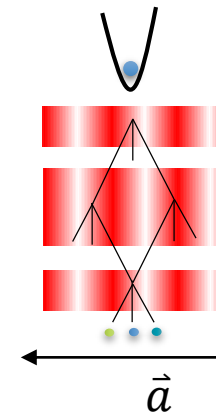
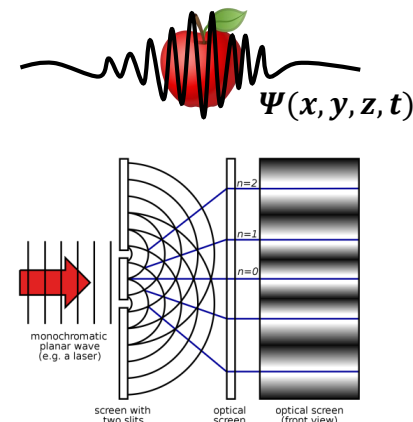
## Sensing



'We have solutions, we need problems'

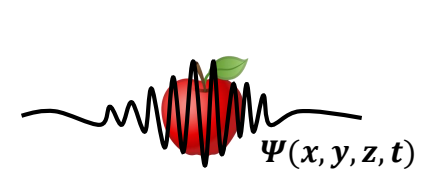


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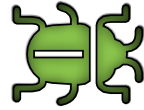


# Quantum Technologies

## Sensing – Earth Observation



### Sensing

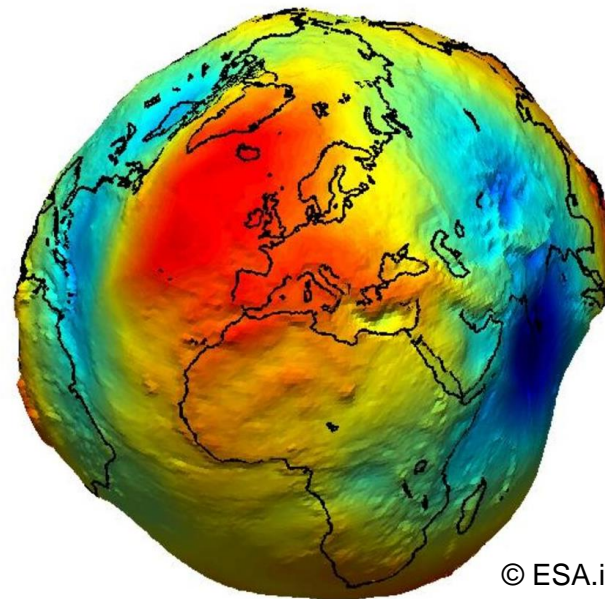
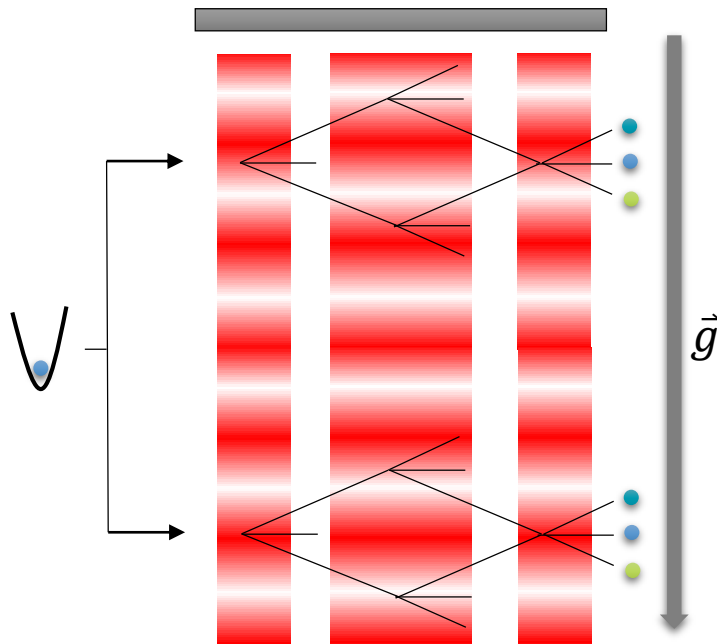


‘We have solutions, we need problems’



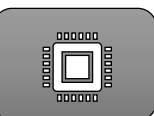
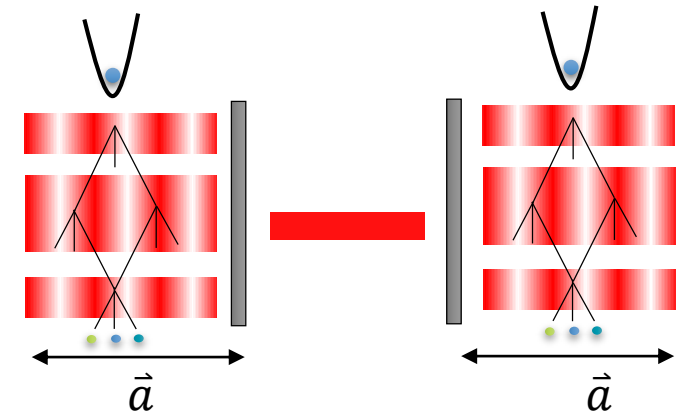
Gradiometry

‘GOCE’ - type



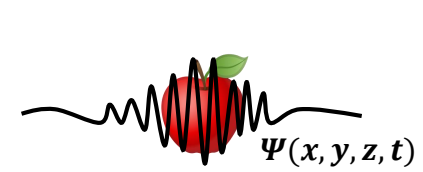
Gravimetry

‘GRACE’ - type

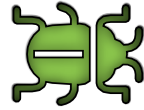


# Quantum Technologies

## Sensing – Earth Observation



### Sensing

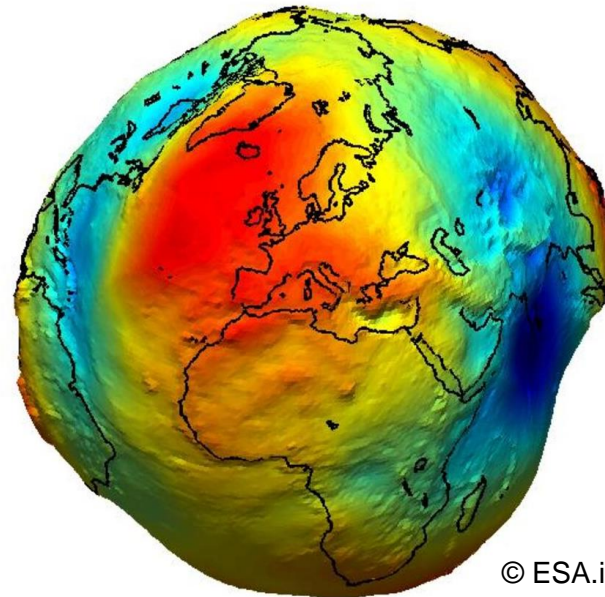
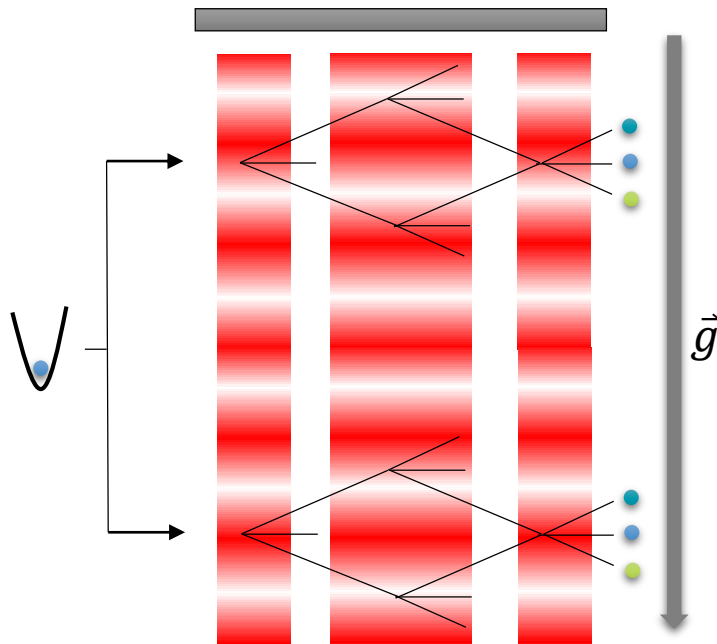


„We have solutions, we need problems“



Gradiometry

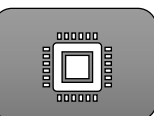
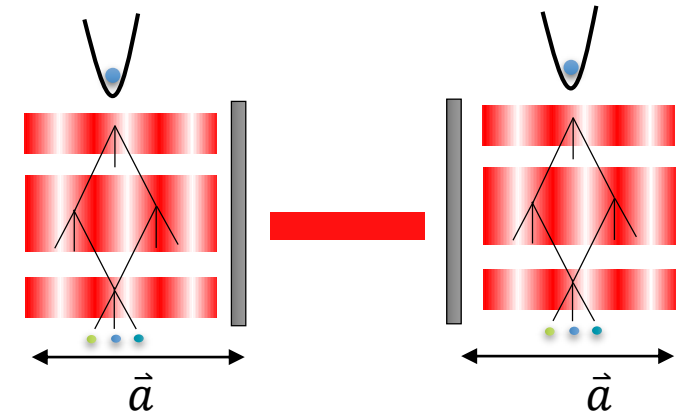
„GOCE“ - type



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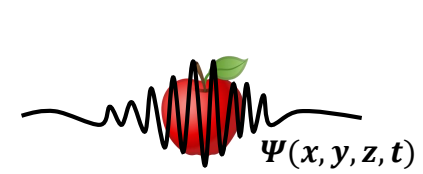
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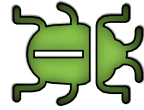


# Quantum Technologies

## Sensing – Earth Observation



### Sensing

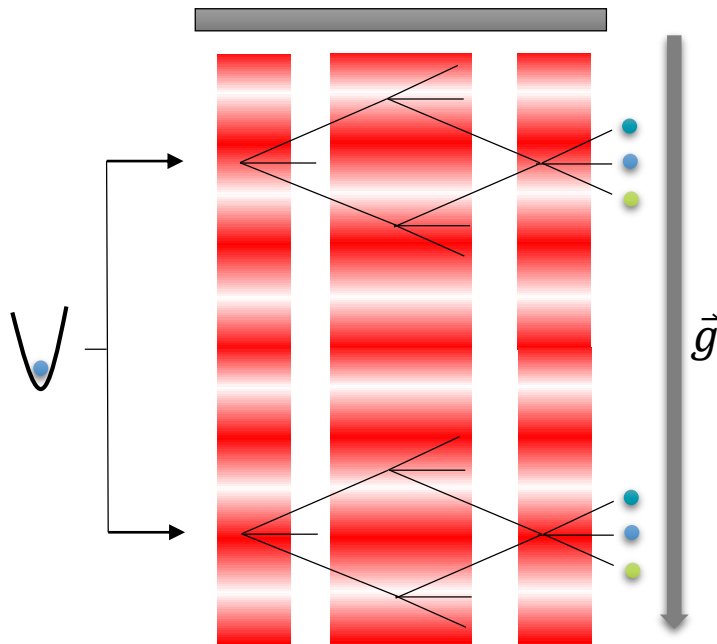


'We have solutions, we need problems'



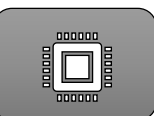
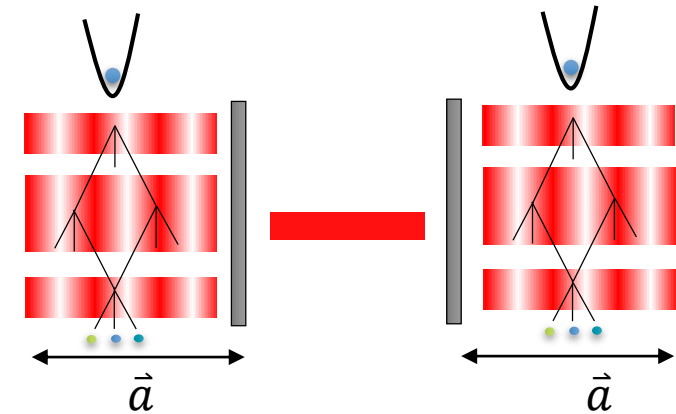
Gradiometry

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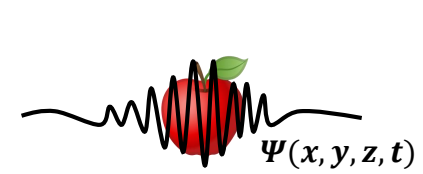
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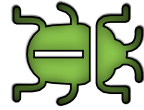


# Quantum Technologies

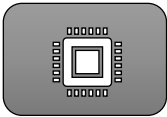
## Sensing – Fundamental Physics



### Sensing



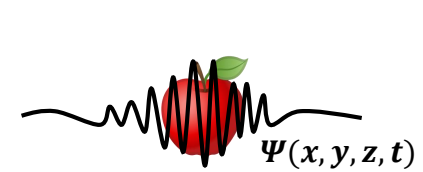
‘We have solutions, we need problems’



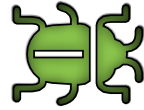
### Scientific Areas:

1. Atom Interferometry
2. Coherent Atom Optics
3. Scalar Bose - Einstein Condensates
4. Spinor Bose - Einstein Condensates and Quantum Gas Mixtures
5. Strongly Interacting Gases and Molecules
6. Quantum Information

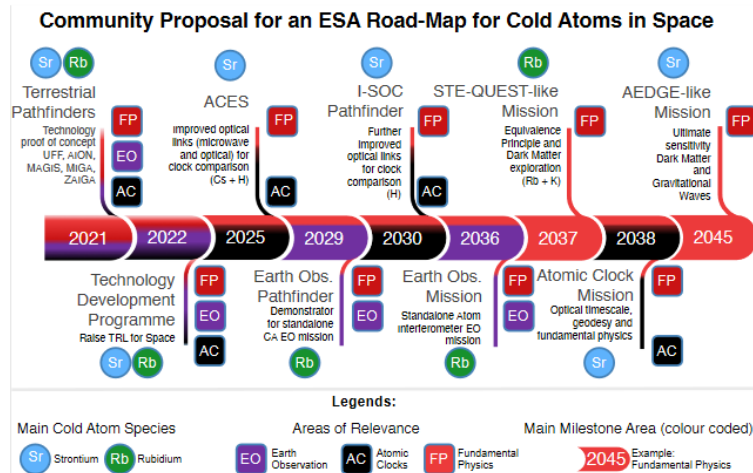
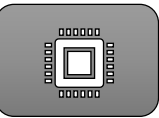
# Quantum Technologies Sensing – Pathfinder



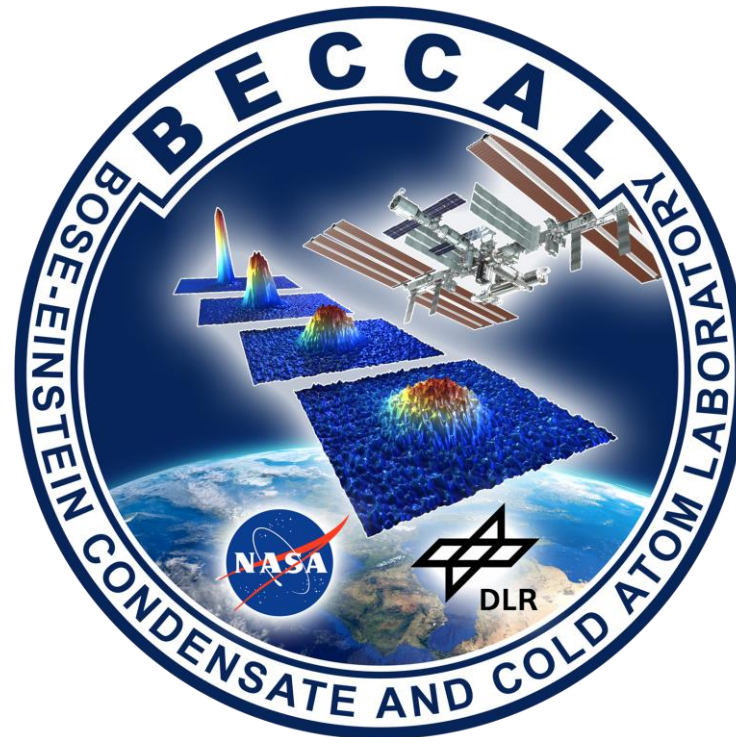
## Sensing



'We have solutions, we need problems'



<https://arxiv.org/abs/2201.07789>

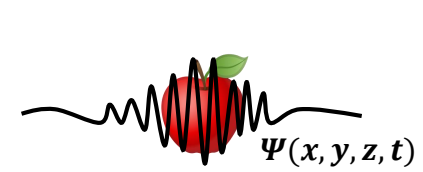


### Scientific Areas:

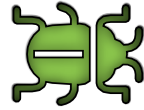
1. Atom Interferometry
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# Quantum Technologies

## Sensing



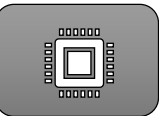
### Sensing



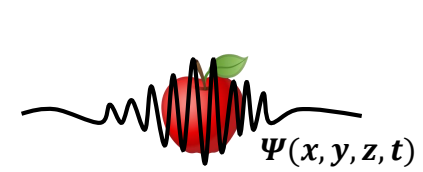
‘We have solutions, we need problems’



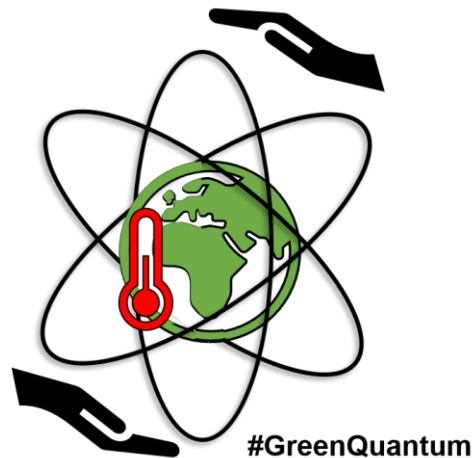
- High sensitivity to outside influences
- Other Advantages:
  - Behaviour is dominated by **fundamental constants**
  - Low to no **saturation**
  - Absence of **drift** over time



# Quantum Technologies Green Quantum



## Climate Protection



1

### Monitor

Observing the impact of climate change enables us to judge severity, predict developments, and evaluate counter measures.

Quantum Technologies foster novel Earth Observation methods and allow more precise monitoring of the planet.

2

### Protect

Climate Change has severe impacts on the planet and people living on it, ranging from droughts to floods, rising sea levels, and reduced biodiversity.

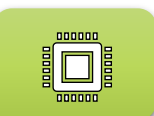
Quantum Technologies can support preventive measures, act as early warning systems, search for resources, and surveil protective infrastructure.

3

### Fight

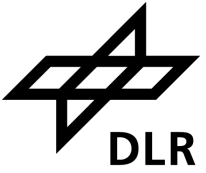
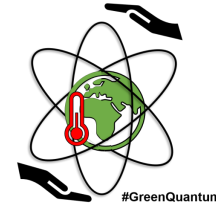
Reduction of the release of climate active gases has to be one of the most important goals for society.

Quantum Technologies enable global navigation systems, can improve current systems, and optimize resource usage as well as calculated routes.





# Quantum Technologies



## Sensing

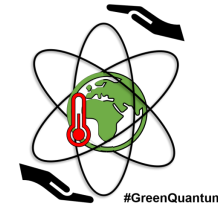


## Communication

## Computation



# Quantum Technologies



Sensing



Communication



Computation

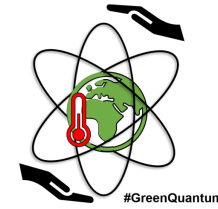


„Entanglement“

The overall state is determined, but not the states of the constituents.



# Quantum Technologies



## Sensing

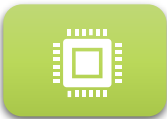
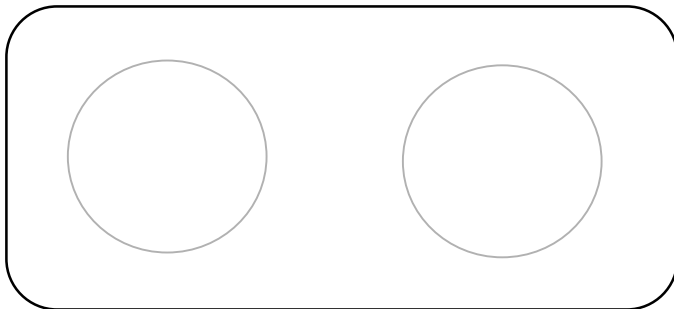


## Communication

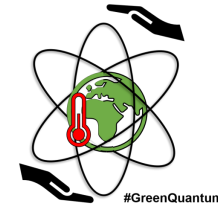
## Computation

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# Quantum Technologies



Sensing



Communication

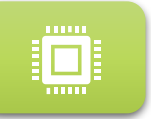
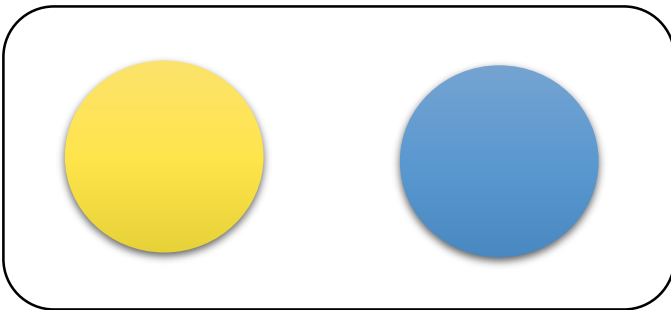


Computation



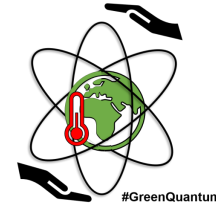
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# Quantum Technologies



Sensing



Communication



Computation

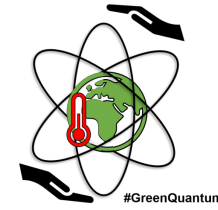


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# Quantum Technologies



## Sensing

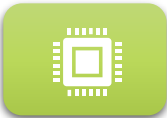


## Communication

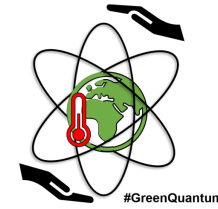
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# Quantum Technologies



## Sensing



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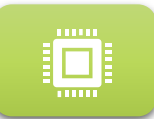


## Communication



- Quantum Random Number Generators
- (Global) Quantum Key Distribution
- (terrestrial) Quantum Computing
- Quantum – LIDAR

## Computation



# QUANTUM TECHNOLOGIES IN ORBIT - RESEARCH AND APPLICATIONS

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