QUANTUM TECHNOLOGIES IN / FOR / FROM / OF SPACE

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

DLR

Quantum Technologies in / for / from / of Space

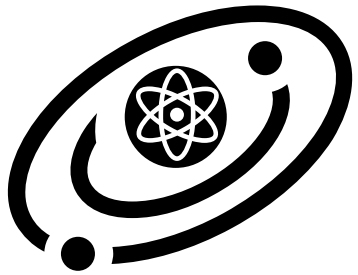
Introduction

Quantum Technologies in Space

- Fundamental Physics
  - Bell Tests
  - High Mass Interferometry (MAQRO)
  - Fundamental Quantum Mechanics
  - Equivalence Principle Tests (STE – QUEST, BOOST)

Quantum Technologies for Space

- Navigation without GNSS
- Prospection



Quantum Technologies from Space

- Earth Observation
  - Gravimetry / Gradiometry, Magnetometry, LIDAR
- Quantum Communication (Global Dissimination)
- Global Navigation
- Space Weather Observation

Quantum Technologies of Space

- Exploration
  - Planetary Observation
  - Comet / Asteroid Investigation
- Astronomy
  - Gravitational Wave Detection

Quantum Technologies in / for / from / of Space

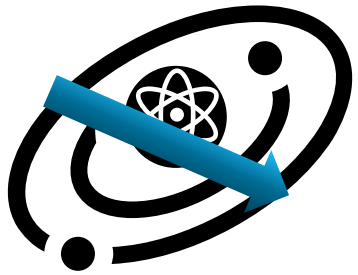
Introduction

Quantum Technologies in Space

- Fundamental Physics
  - Bell Tests
  - High Mass Interferometry (MAQRO)
  - Fundamental Quantum Mechanics
  - Equivalence Principle Tests (STE – QUEST, BOOST)

Quantum Technologies from Space

- Earth Observation
  - Gravimetry / Gradiometry, Magnetometry, LIDAR
- Quantum Communication (Global Dissimination)
- Global Navigation
- Space Weather Observation



Quantum Technologies for Space

- Navigation without GNSS
- Prospection

Quantum Technologies of Space

- Exploration
  - Planetary Observation
  - Comet / Asteroid Investigation
- Astronomy
  - Gravitational Wave Detection

Quantum Technologies in / for / from / of Space

Introduction

Quantum Technologies in Space

- Fundamental Physics
  - Bell Tests
  - High Mass Interferometry (MAQRO)
  - Fundamental Quantum Mechanics
  - Equivalence Principle Tests (STE – QUEST, BOOST)

Quantum Technologies from Space

- Earth Observation
  - Gravimetry / Gradiometry, Magnetometry, LIDAR
- Quantum Communication (Global Dissimination)
- Global Navigation
- Space Weather Observation

Quantum Technologies for Space

- Navigation without GNSS
- Prospection

Quantum Technologies of Space

- Exploration
  - Planetary Observation
  - Comet / Asteroid Investigation
- Astronomy
  - Gravitational Wave Detection

Quantum Technologies in / for / from / of Space

Technology Driver (BECCAL)

Bose Einstein Condensate and Cold Atom Laboratory

- State-of-the-Art quantum mechanical Laboratory
- Operation in Microgravity Environment on ISS
- Multi-User & Multi-Purpose Facility

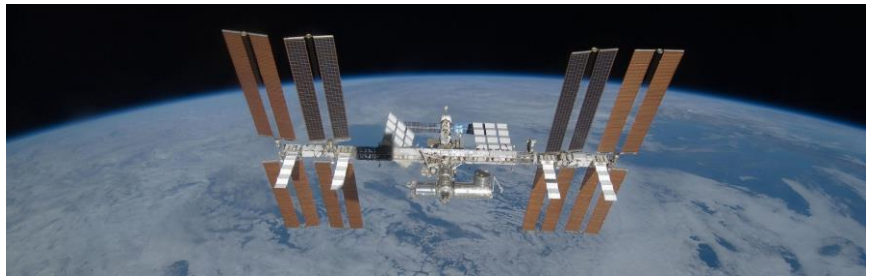
BECCAL: K. Frye et al., EPJ QT 8, 1 (2021) Lead: Caroline Lösch

Quantum Technologies in / for / from / of Space

Technology Driver (BECCAL)

Bose Einstein Condensate and Cold Atom Laboratory

- State-of-the-Art quantum mechanical Laboratory
- Operation in Microgravity Environment on ISS
- Multi-User & Multi-Purpose Facility



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

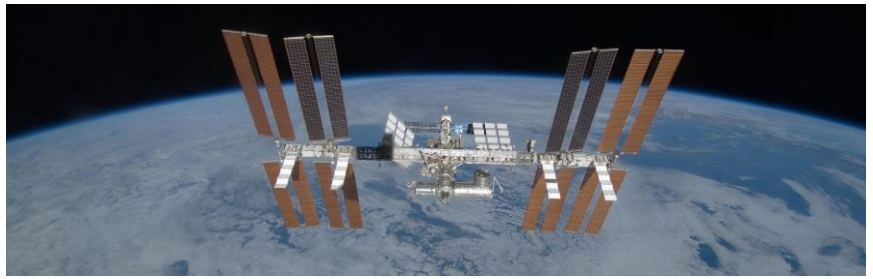
BECCAL: K. Frye et al., EPJ QT 8, 1 (2021) Lead: Caroline Lösch

Quantum Technologies in / for / from / of Space

Technology Driver (BECCAL)

Bose Einstein Condensate and Cold Atom Laboratory

- State-of-the-Art quantum mechanical Laboratory
- Operation in Microgravity Environment on ISS
- Multi-User & Multi-Purpose Facility



Definition of Payload

- Science Envelope Requirements Document (SERD)
- Science Definition Team
- Overview: K. Frye et al., EPJ QT 8, 1 (2021)

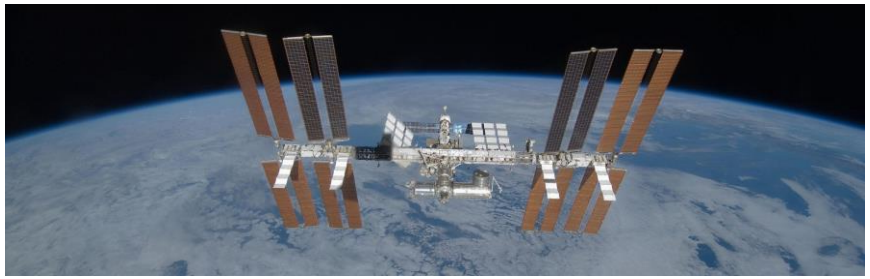
BECCAL: K. Frye et al., EPJ QT 8, 1 (2021) Lead: Caroline Lösch

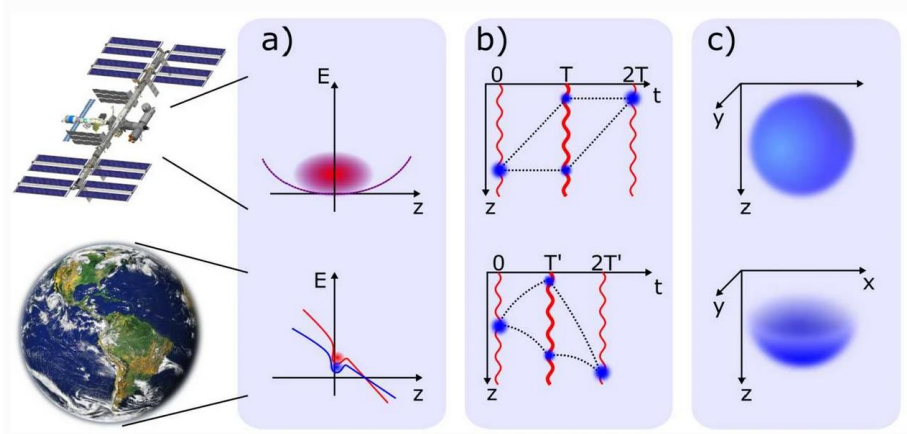
Quantum Technologies in / for / from / of Space

Technology Driver (BECCAL)

Bose Einstein Condensate and Cold Atom Laboratory

- State-of-the-Art quantum mechanical Laboratory
- Operation in Microgravity Environment on ISS
- Multi-User & Multi-Purpose Facility





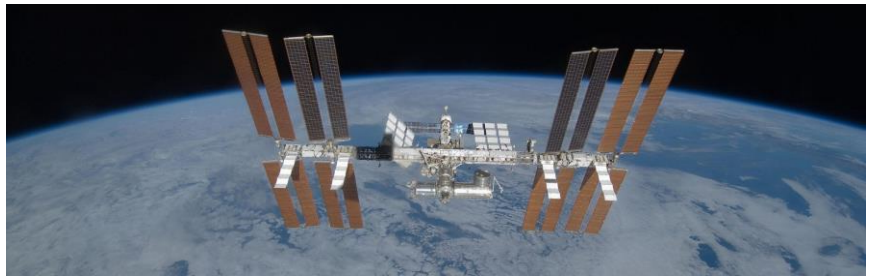
BECCAL: K. Frye et al., EPJ QT 8, 1 (2021) Lead: Caroline Lösch

Quantum Technologies in / for / from / of Space

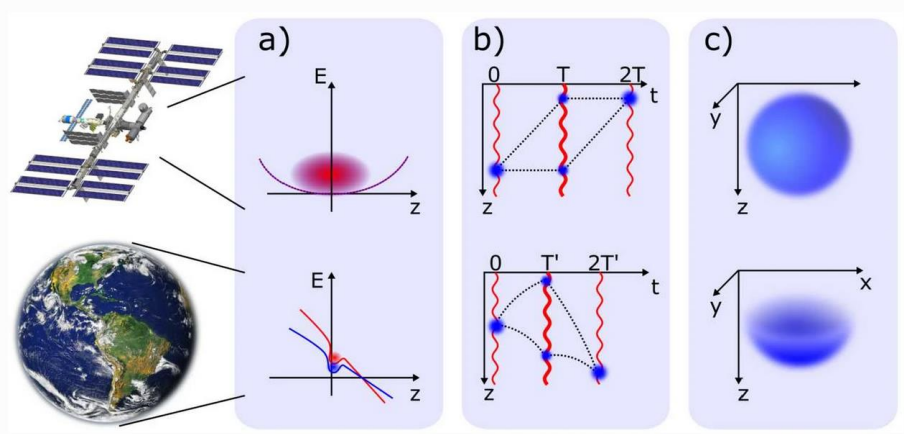
Technology Driver (BECCAL)

Bose Einstein Condensate and Cold Atom Laboratory

- State-of-the-Art quantum mechanical Laboratory
- Operation in Microgravity Environment on ISS
- Multi-User & Multi-Purpose Facility



© ardmediathek.de



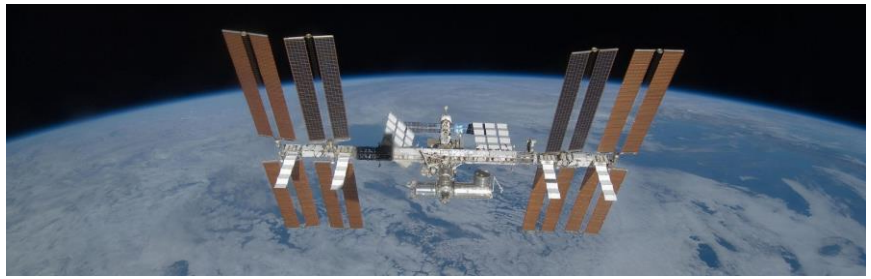
BECCAL: K. Frye et al., EPJ QT 8, 1 (2021) Lead: Caroline Lösch

Quantum Technologies in / for / from / of Space

Technology Driver (BECCAL)

Bose Einstein Condensate and Cold Atom Laboratory

- State-of-the-Art quantum mechanical Laboratory
- Operation in Microgravity Environment on ISS
- Multi-User & Multi-Purpose Facility



Definition of Payload

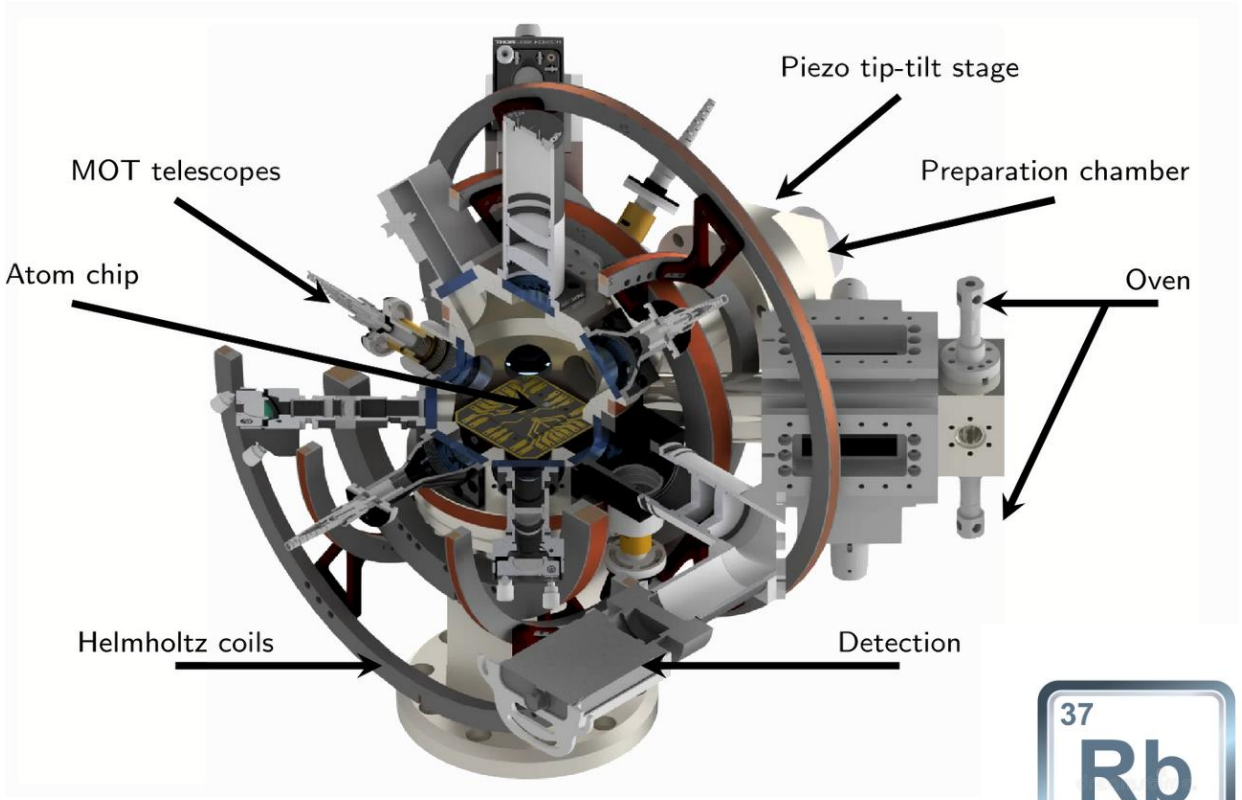
- Science Envelope Requirements Document (SERD)
- Science Definition Team
- Overview: K. Frye et al., EPJ QT 8, 1 (2021)

- Kollaboration: NASA, DLR, DLR - RfA

BECCAL: K. Frye et al., EPJ QT 8, 1 (2021) Lead: Caroline Lösch

Quantum Technologies in / for / from / of Space

Technology Driver (BECCAL)



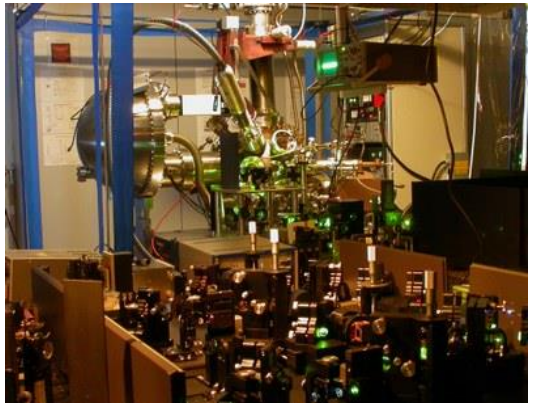
37 Rb Rubidium 84.468

19 K Potassium 39.098

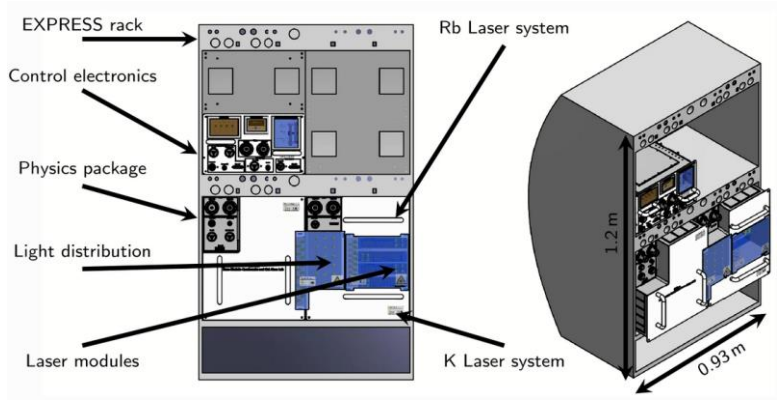
BECCAL: K. Frye et al., EPJ QT 8, 1 (2021) Lead: Caroline Lösch

Quantum Technologies in / for / from / of Space

Technology Driver (BECCAL)



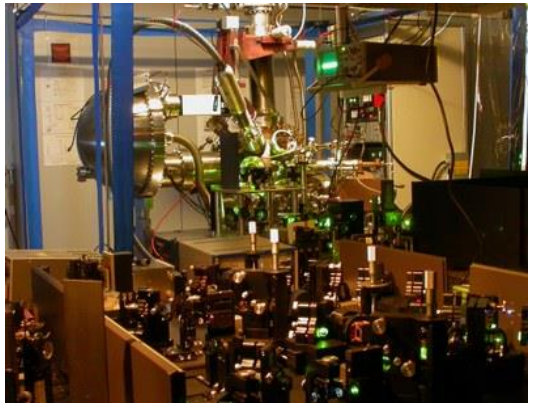
© uni-marburg.de



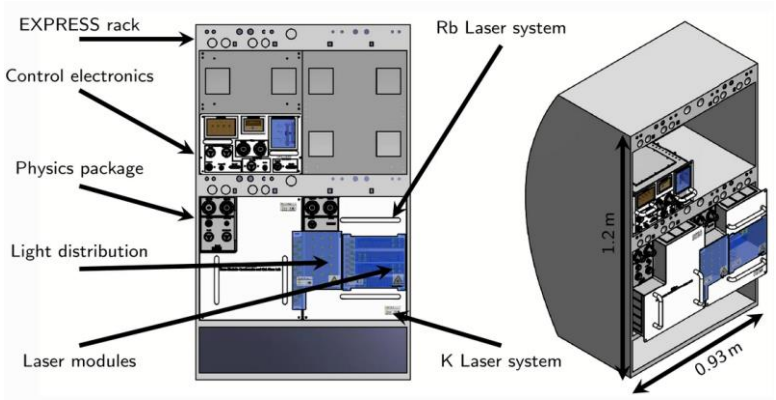
BECCAL: K. Frye et al., EPJ QT 8, 1 (2021) Lead: Caroline Lösch

Quantum Technologies in / for / from / of Space

Technology Driver (BECCAL)



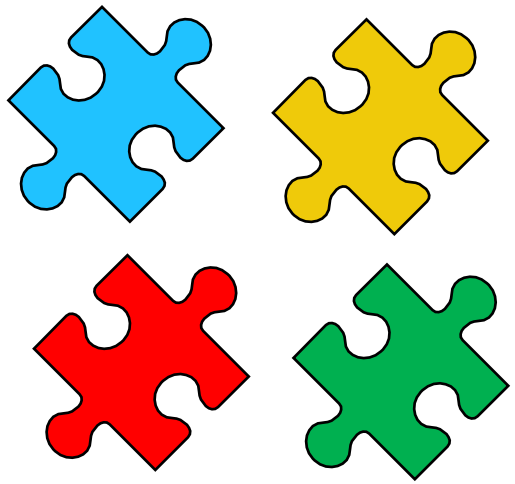
© uni-marburg.de

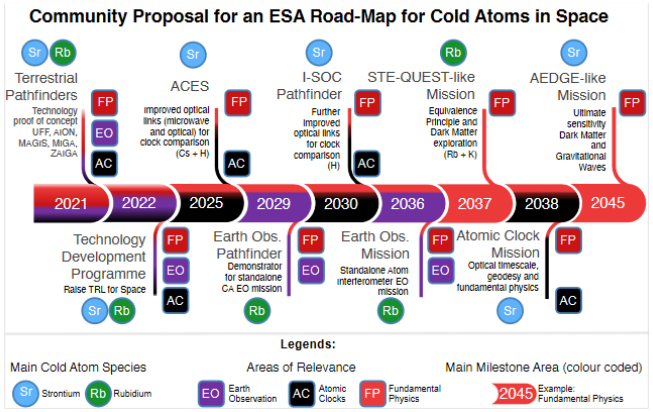


BECCAL: K. Frye et al., EPJ QT 8, 1 (2021) Lead: Caroline Lösch

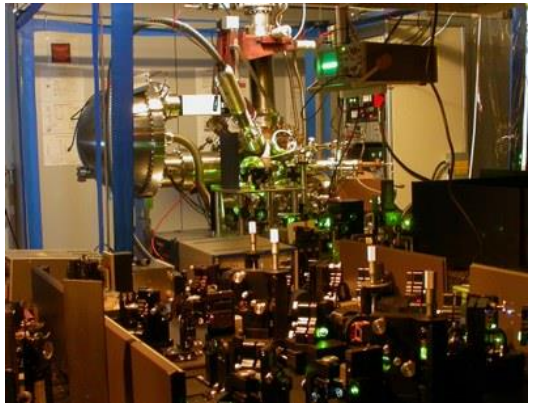
Quantum Technologies in / for / from / of Space

Technology Driver (BECCAL)

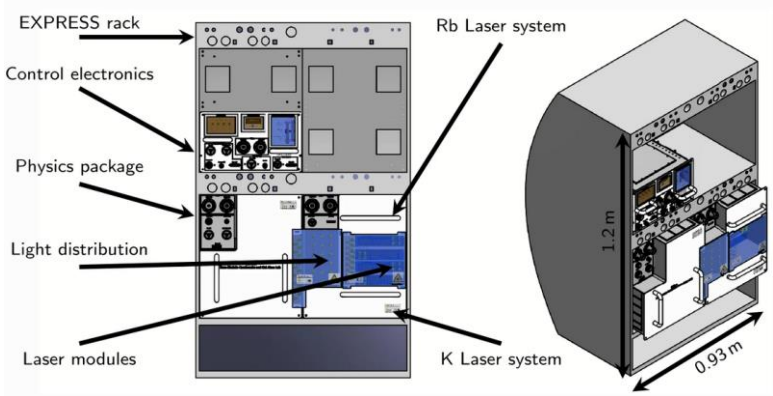




https://arxiv.org/abs/2201.07789



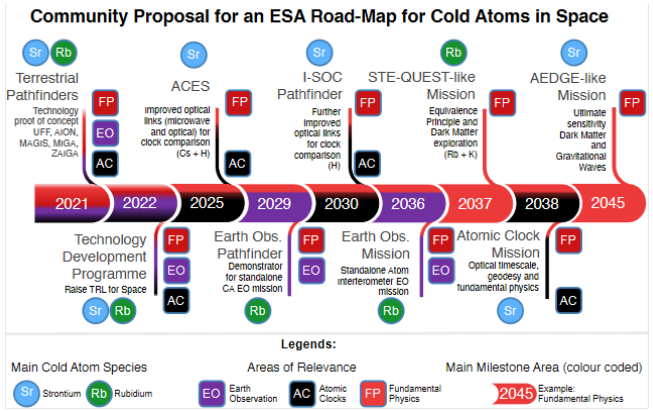
© uni-marburg.de



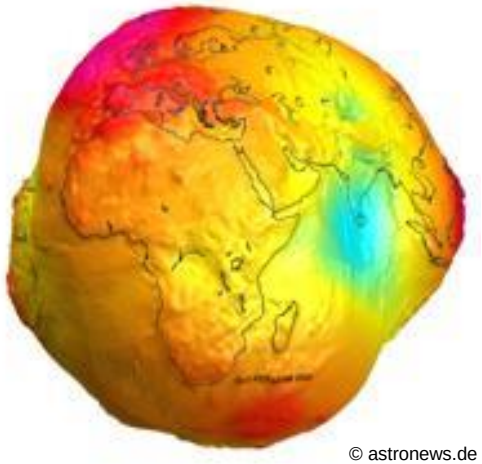
BECCAL: K. Frye et al., EPJ QT 8, 1 (2021) Lead: Caroline Lösch

Quantum Technologies in / for / from / of Space

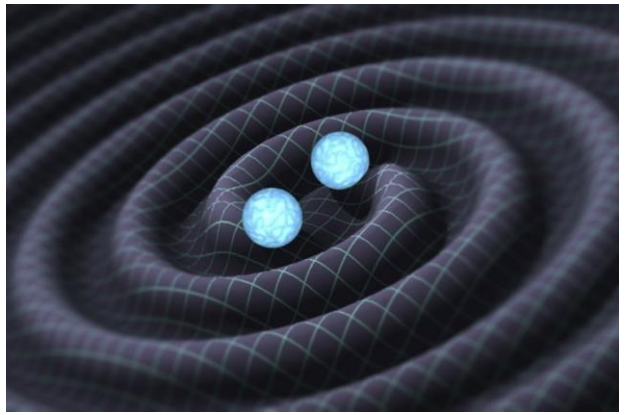
Technology Driver (BECCAL)



https://arxiv.org/abs/2201.07789



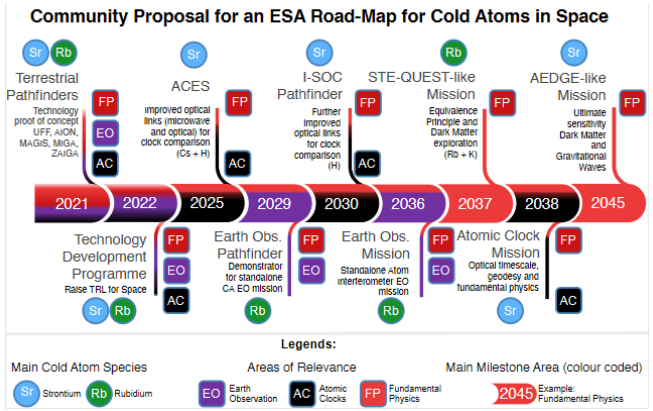
© astronews.de



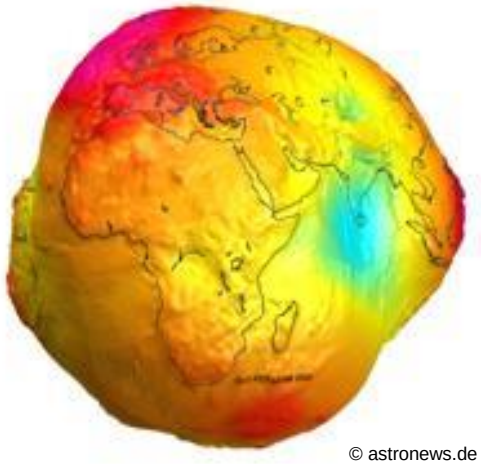
© theatlantic.com

Quantum Technologies in / for / from / of Space

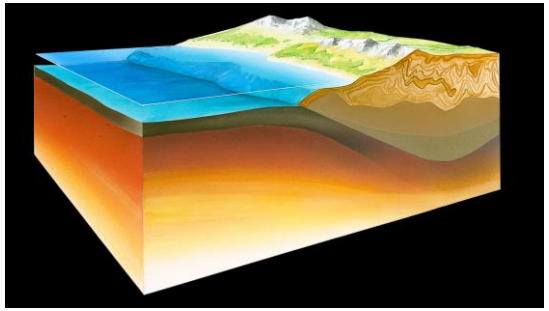
Technology Driver (BECCAL)

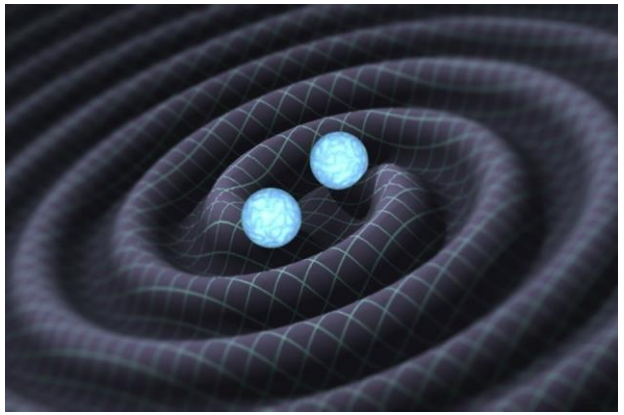


https://arxiv.org/abs/2201.07789

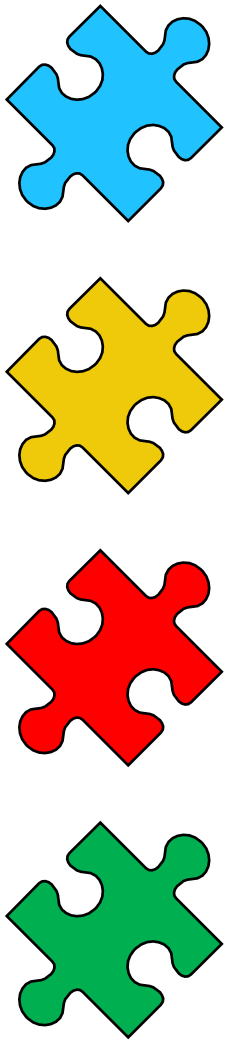


© astronews.de





© theatlantic.com



Quantum Technologies in / for / from / of Space

Prototyping (COMPASSO)

DLR

AIRBUS DEFENCE & SPACE

STI

MenloSystems

FBH Ferdinand Braun Institut

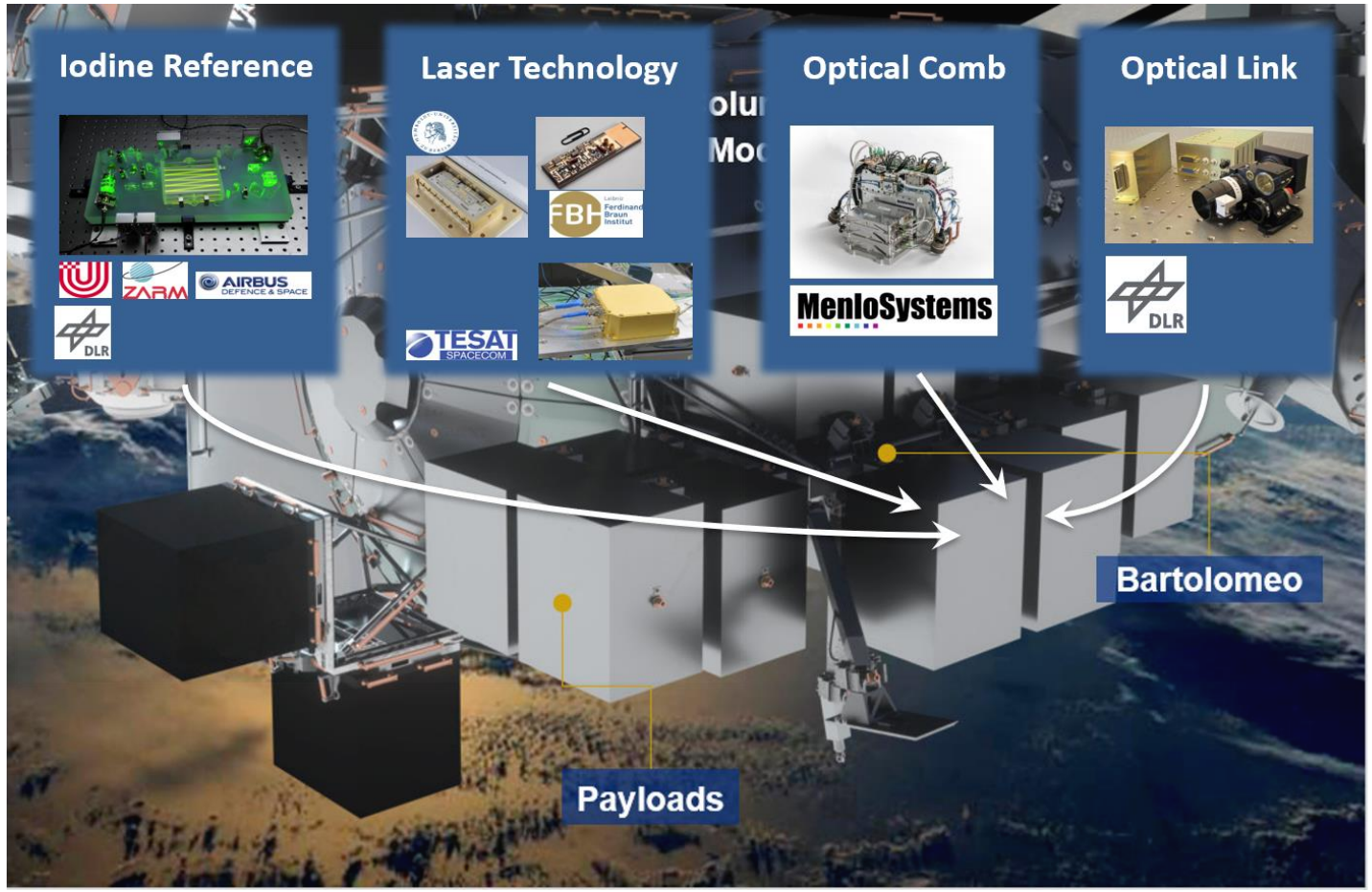
Humboldt-Universität zu Berlin

Institute of Scientific Instruments Academy of Sciences of the Czech Republic

meopta

TESAT SPACECOM

Universität Ulm



Quantum Technologies in / for / from / of Space

Introduction

Quantum Technologies in Space

- Fundamental Physics
  - Bell Tests
  - High Mass Interferometry (MAQRO)
  - Fundamental Quantum Mechanics
  - Equivalence Principle Tests (STE – QUEST, BOOST)

Quantum Technologies for Space

- Navigation without GNSS
- Prospection

Quantum Technologies from Space

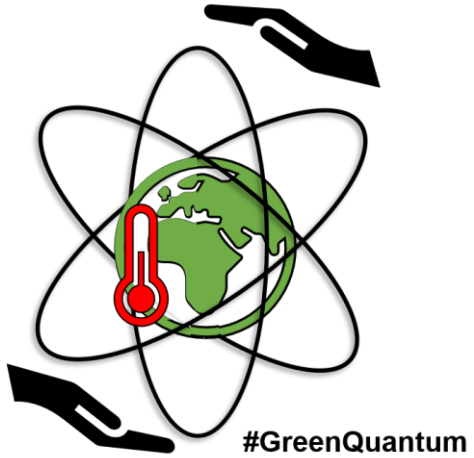
- Earth Observation
  - Gravimetry / Gradiometry, Magnetometry, LIDAR
- Quantum Communication (Global Dissimination)
- Global Navigation
- Space Weather Observation

Quantum Technologies of Space

- Exploration
  - Planetary Observation
  - Comet / Asteroid Investigation
- Astronomy
  - Gravitational Wave Detection

Quantum Technologies in / for / from / of Space

Green Quantum



1. Navigation
2. Earth Observation (Gravitational and Magnetic Fields)
3. Local Prospecting
4. Catastrophy Prevention / Early Warning Systems
5. Optimization (Quantum Computing)
6. Situational / Environmental Maps (Air, Sea, Land / Trains)

Quantum Technologies in / for / from / of Space

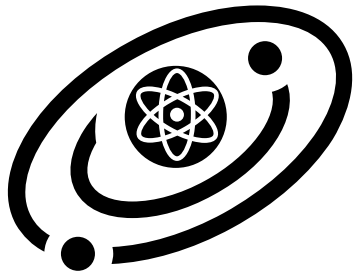
Introduction

Quantum Technologies in Space

- Fundamental Physics
  - Bell Tests
  - High Mass Interferometry (MAQRO)
  - Fundamental Quantum Mechanics
  - Equivalence Principle Tests (STE – QUEST, BOOST)

Quantum Technologies for Space

- Navigation without GNSS
- Prospection



Quantum Technologies from Space

- Earth Observation
  - Gravimetry / Gradiometry, Magnetometry, LIDAR
- Quantum Communication (Global Dissimination)
- Global Navigation
- Space Weather Observation

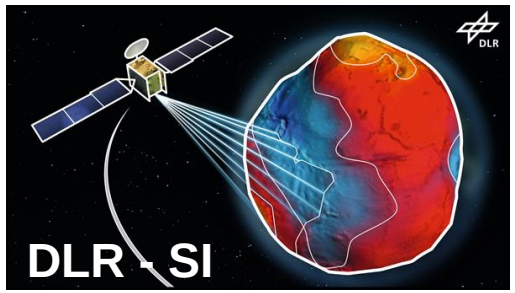
Quantum Technologies of Space

- Exploration
  - Planetary Observation
  - Comet / Asteroid Investigation
- Astronomy
  - Gravitational Wave Detection

Quantum Technologies in / for / from / of Space

@ DLR

… and many more



QUANTUM TECHNOLOGIES IN / FOR / FROM / OF SPACE

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

DLR