Zentrum für QuantenEngineering (ZQE) Garching

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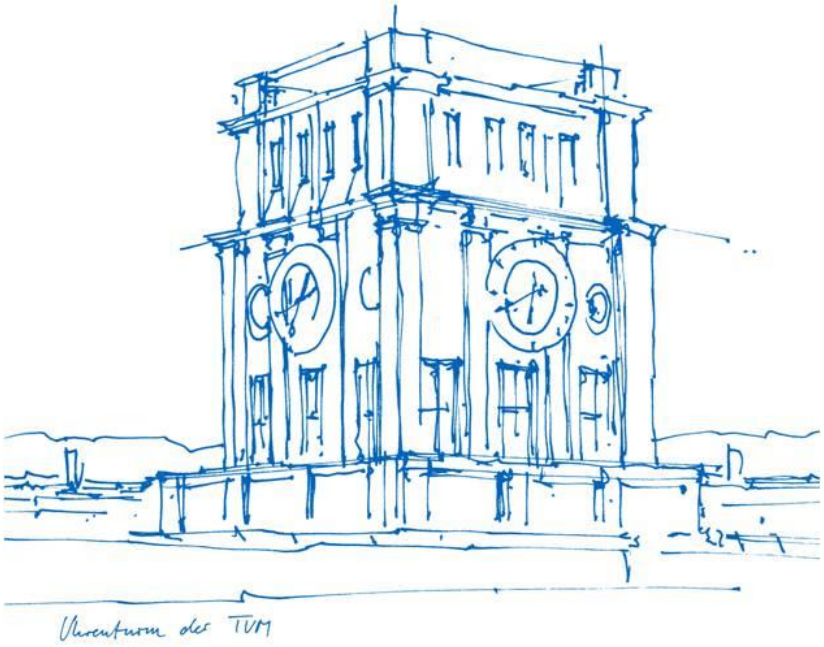


Zentrum für QuantenEngineering (ZQE)

Center for Quantum Engineering comes to Garching

In recent years, a globally esteemed research focus on quantum technologies has developed on the Garching campus. The German Council of Science and Humanities now supports the creation of a new central institute at the Technical University of Munich (TUM) that will link this focus with the engineering sciences and aims to transfer quantum systems into real-world applications more quickly. Should the Joint Science Conference (GWK) follow this recommendation on 29 June, the German Federal Government and the Free State of Bavaria will share the costs of around 40 million euro equally.

https://www.tum.de/nc/en/about-tum/news/press-releases/details/34621/

Overview

- Motivation
- Zentrum für QuantenEngineering

Quantum Technology

= Technology derived from science that cannot be explained by classical physics

First Quantum Revolution

"Devices relying on effects of quantum mechanics" (energy quantization, tunneling,…)

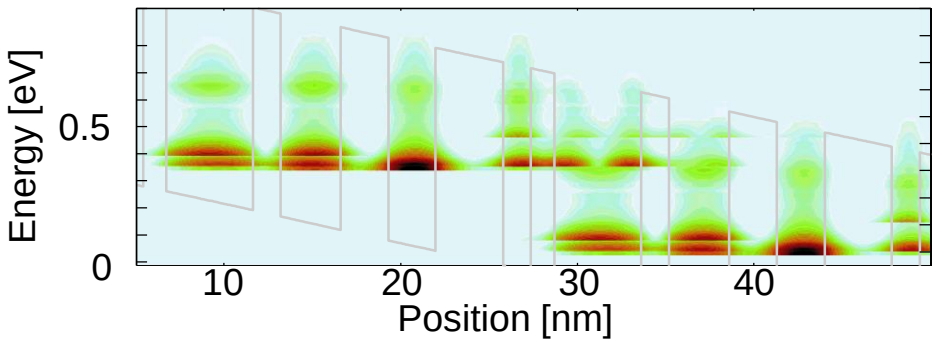
- Lasers
- Transistors
- Magnetic Resonance Imaging (MRI), e.g. NMR
- …

Second Quantum Revolution

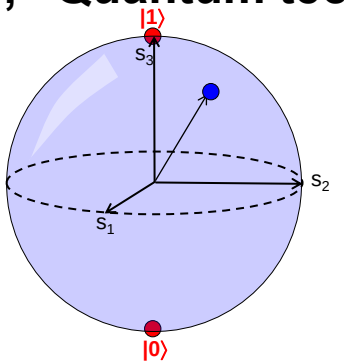
"Devices exploiting quantum weirdness" (especially superposition, entanglement)

- Quantum computing
- Quantum sensors
- Quantum communication/cryptography
- …

Quantum 1.0

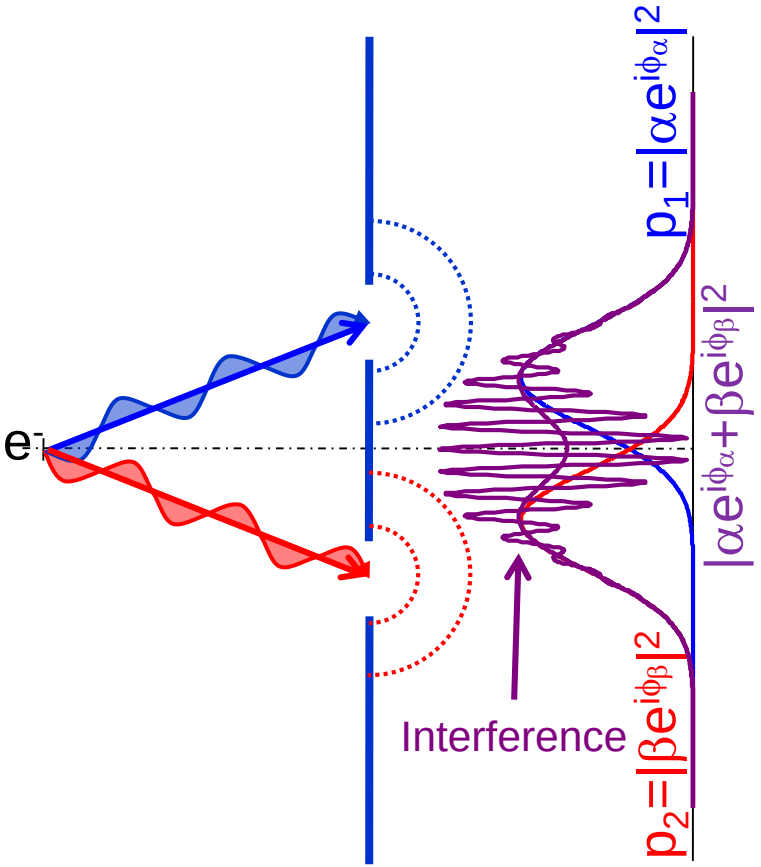


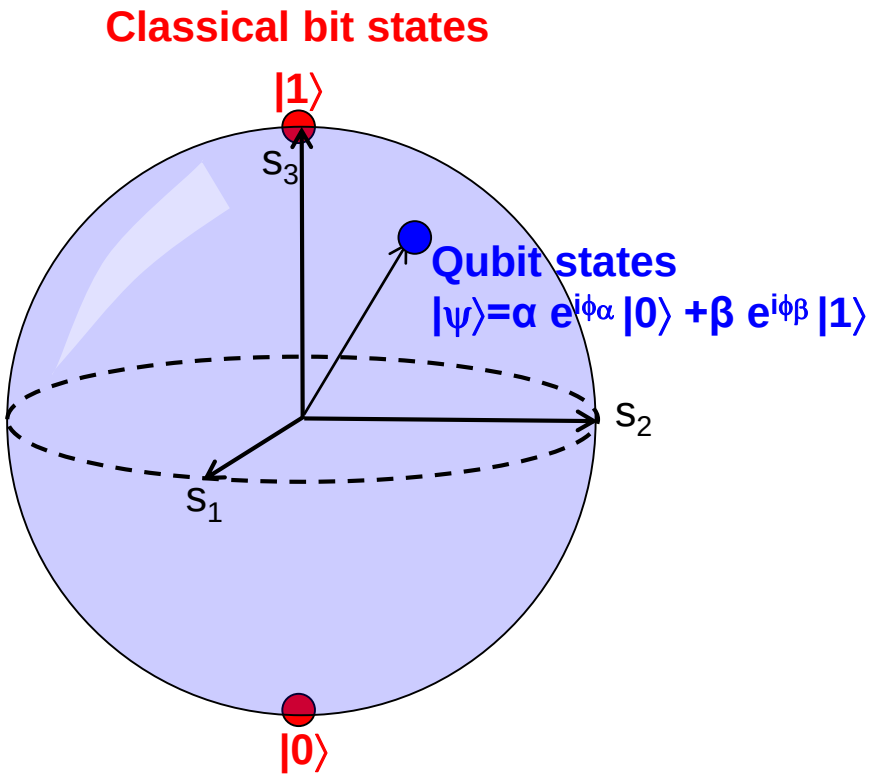
Quantum 2.0, "Quantum technologies"



J. Pritchard and S. Till, "UK Quantum Technology Landscape 2014." DSTL/PUB75620 (2014)

Example Superposition





Examples for Governmental/Industrial Activities

Governmental initiatives

- UK National Quantum Technologies Programme: £270 million to accelerate the translation of quantum technologies into the marketplace (2013)
- US National Quantum Initiative Act: $1.2 billion to fund activities promoting quantum information science (2018)
- European Commission Quantum Technologies Flagship: €1 billion to support quantum technologies research in Europe (2018)

List of companies involved in quantum computing or communications

Company	Date initiated	Area	Technology	Affiliate University or Research Institute	Headquarters
1QBit	December 1, 2012	Computing			Vancouver, Canada
Accenture[11]	June 14, 2017	Computing			
Airbus[12]	2015	Computing	Algorithms		Blagnac, France
AT&T[13]	2011	Communication		California Institute of Technology, Fermilab[14]	Dallas, TX, USA
Alicun (Alibaba Cloud)[15]	July 20, 2015	Computing/Communication[16][17]	Superconducting	Chinese Academy of Sciences[16][18]	Hangzhou, China
Alpine Quantum Technologies[19]	2018	Computing	Trapped Ion	University of Innsbruck	Innsbruck, Austria
Atom Computing[20]	2018	Computing	Neutral Atom Quantum Computing		Berkeley, CA, USA
Atos[10][11]		Computing/Communication	Quantum Programming, Classical Simulation, Cryptography		Bezons, France
Baidu[21][22]	2018	Computing	Algorithms	University of Technology Sydney[21][23]	Beijing, China
Bit^[24]	2017	Computing	Algorithms		Kraków, Poland
Booz Allen Hamilton[25]		Computing			Tysons Corner, VA, USA
BraneCell[26]	2018	Computing Hardware			USA
BT[27][28]		Communication			London, UK
Carl Zeiss AG[29]				University College London	Oberkochen, Germany
Cambridge Quantum Computing[30]	2014	Computing	Quantum Algorithms Quantum Cybersecurity	University of Cambridge	Cambridge, UK London, UK
D-Wave	January 1, 1999	Computing	Superconducting Quantum Annealer		Burnaby, Canada
Dyon[31][32]	June 6, 2018	Computing	Algorithms		Dubai, UAE
Fujitsu[33][34]	September 28, 2018	Communication	Quantum Dots	University of Tokyo	Tokyo, Japan
Google Quantum AI[35]	May 18, 2013	Computing	Superconducting	UCSB	Mountain View, CA, USA
HP[36][37]		Computing[38]/Communication[39]	Algorithms, NMR		Palo Alto, CA, USA
Hitachi		Computing		University of Cambridge, University College London	Tokyo, Japan
Honeywell[40][41][42][43]	2017	Computing	Trapped Ion	Georgia Tech,[43] University of Maryland[44]	Morris Plains, NJ, USA
HRL Laboratories		Computing			Malibu, CA, USA
Huawei Noah's Ark Lab[45]		Communication		Nanjing University	Shenzhen, China
IBM[46][47]	September 10, 1999[48]	Computing	Superconducting	MIT[49]	Armonk, NY, USA
ID Quantique	July 1, 2001	Communication			Geneva, Switzerland
imec[50]		Computing	Superconducting		Belgium
IonQ[51][52]		Computing	Trapped Ion	University of Maryland, Duke University	College Park, MD, USA
InfiniQuant[53]		Communication		Max Planck Institute for the Science of Light, University of Erlangen-Nuremberg	Erlangen, Germany
Intel[54]	September 3, 2015	Computing		TU Delft	Santa Clara, CA, USA
IQM[55]		Communication			The Hague, Netherlands
Lockheed Martin		Computing	Quantum Annealing	University of Southern California, University College London	Bethesda, MD, USA
MagiQ		Communication			Somerville, MA, USA
Microsoft Research QuArC	December 19, 2011	Computing	Algorithms	TU Delft, Niels Bohr Institute, University of Sydney, Purdue University, University of Maryland, ETH Zurich, UCSB	Redmond, WA, USA
Microsoft Research Station Q	April 22, 2005	Computing	Superconducting	UCSB	Santa Barbara, CA, USA
Mitsubishi[56]		Communication			Tokyo, Japan
NEC Corporation[57]	April 29, 1999[58]	Communication	Quantum Dots	University of Tokyo	Tokyo, Japan
Nokia Bell Labs[59][60]		Computing		University of Oxford	Murray Hill, NJ, USA
Northrop Grumman		Computing			West Falls Church, VA, USA
NTT Laboratories[61]		Computing/Communication	Photonic Quantum Computing, Quantum Communication	Bristol University	Tokyo, Japan
PsiQuantum[62][63]	2016	Computing	Photonic Quantum Computing	Bristol University	Palo Alto, CA, USA
Oxford Quantum Circuits[64]	2017	Computing	Superconducting	University of Oxford	
QCI[65][66][67]	2017	Computing/Metrology	Superconducting		Sydney, Australia
Qblogo Internationa[68]	2014[69]	Computing			Atlanta, GA, USA[70]
QC Ware[30]	2014[71]	Computing	Algorithms		Palo Alto, California, USA[71]
QNTM	2019	Information Technology and Services			Belgium, Leuven, Kortrijk
Quantum Benchmark Inc.[72][73]	2017	Computing	Algorithms	University of Waterloo	Kitchener-Waterloo, Canada
Quantum Circuits, Inc.[54][55]	2015	Computing	Superconducting	Yale University	New Haven, Connecticut, USA
Quantum Xchange[74]	2018	Information Technology and Services	Information security and quantum encryption		Bethesda, Maryland, US
Quintessence.ala		Communication			Deakin, ACT, Australia
Quintessence.ala	2017	Communication	Room-temperature quantum devices	Stony Brook University	New York, NY, USA
QxBranch	2014	Computing			Washington, D.C., USA
Rahko	2018	Computing	Quantum Machine Learning		London, UK
Raytheon BBN[75]		Computing/Communication	Superconducting	MIT	Cambridge, MA, USA
Rigetti Computing		Computing	Superconducting	Berkeley	California, USA
R QUANTECH+	2018	Computing	Algorithms	Polytechnic University of Madrid	Geneva, Switzerland
Riverlane[57]		Computing	Superconducting	Tokyo University of Science	Wako, Japan
Silicon Quantum Computing[58][59]	2017	Computing	Quantum Dots	University of New South Wales	Sydney, Australia
Strangeworks[60]	2017	Quantum computing	Developer platform		Austin, Texas, USA
Toshiba[61]		Communication	Quantum Dots	University of Cambridge	Tokyo, Japan
Xanadu[62][63]	2016[64]	Computing	Photonic Quantum Computing, Quantum Programming[65]	University of Toronto, MIT, University of Paris	Toronto, Canada
Zapata Computing[66][67]	2017	Computing	Algorithms	Harvard University	Cambridge, MA, USA
Quantemo Technologies FZC LLC.r	2019	Communication	Quantum communication and encryption		Abu Dhabi, UAE

https://en.wikipedia.org/wiki/List_of_companies_involved_in_quantum_computing_or_communication

Quantum Technology at Our Department

Lectures

- Quantum information theory
- Simulation of Quantum Devices
- Quantum Nanoelectronics
- Photonic Quantum Technologies
- …

Research Projects

- **Q.Link.X**: BMBF joint project "Quantenrepeater für eine abhörsichere Kommunikation über große Distanzen"
- **QuaDiQua**: BMBF joint project "Fehlertolerante Quantenkommunikation mittels Diamant Quantenphotonik“
- **Qombs**: European Commission Quantum Technologies Flagship project "Quantum simulation and entanglement engineering in quantum cascade laser frequency combs”
- **MOQUA**: BMBF project “Modulare Photonische Quantentechnologien“
- …

Newly established professorships

- Quantum Electronics and Computer Engineering
- Nano and Quantum Sensors

Overview

- Motivation
- Zentrum für QuantenEngineering

Building


Wiesäckerbach
Ernst-Otto-Fischer-Straße
Am Coulombwall
Boltzmannstraße
Lichtenbergstraße
James-Franck-Straße
Campusmitte
Walther-Meißner-Straße
Gießenbachstraße
Ludwig-Prandtl-Straße
Römerhofweg
Freisinger Landstraße
Garchinger Mühlbach
Isar
Isarradweg
Sportflächen
P+R
5111
5112
5115
5107
5103
5101
5200
5203
5204
5212
5219
5413
5409
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5414
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5500
5700
5620
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7910

Key Data

Costs (50% Federal Government, 50% Bavaria)

- Overall cost € 39,8 million
  - Building costs € 31,3 million
  - Large equipment € 6,5 million
  - Initial fixtures € 2 million

Space

- Floor space 2.510 m²
  - Lab space 1.400 m²
  - Office space 835 m²

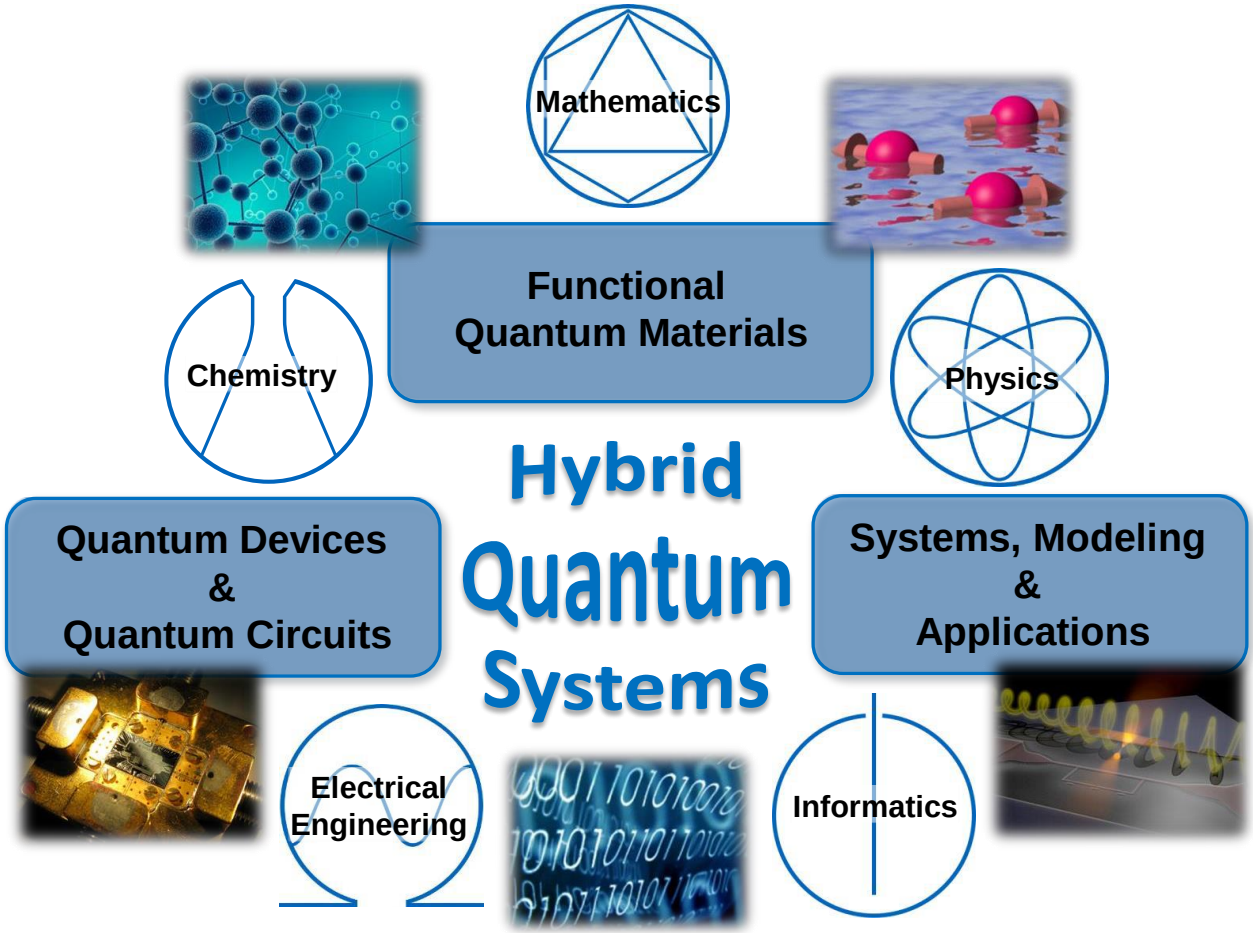
Staff

- Founding directors Prof. Pfleiderer (Physik)/ Prof. Boche (Electrical and Computer Engin.)
- ~100 persons
  - ~10 principal investigators
  - Several junior research groups

Completion 2023

Concept

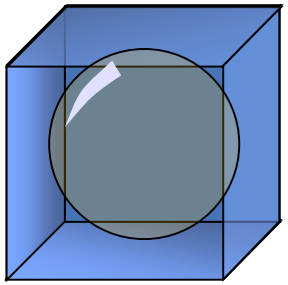
Focus on solid state hybrid quantum systems and their development for applications



Examples For Solid State Hybrid Quantum Systems

Combine different physical platforms to benefit from their respective strengths

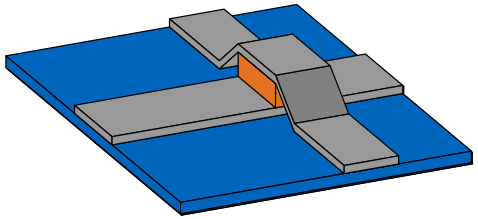
Photonic



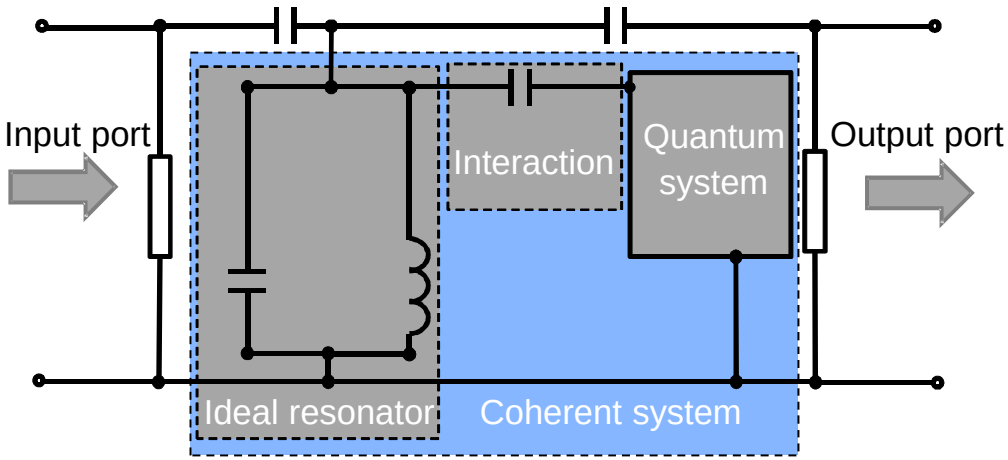
Quantum dot

Optical resonator

Superconducting



Josephson-based quantum system
(e.g., superconducting qubit)

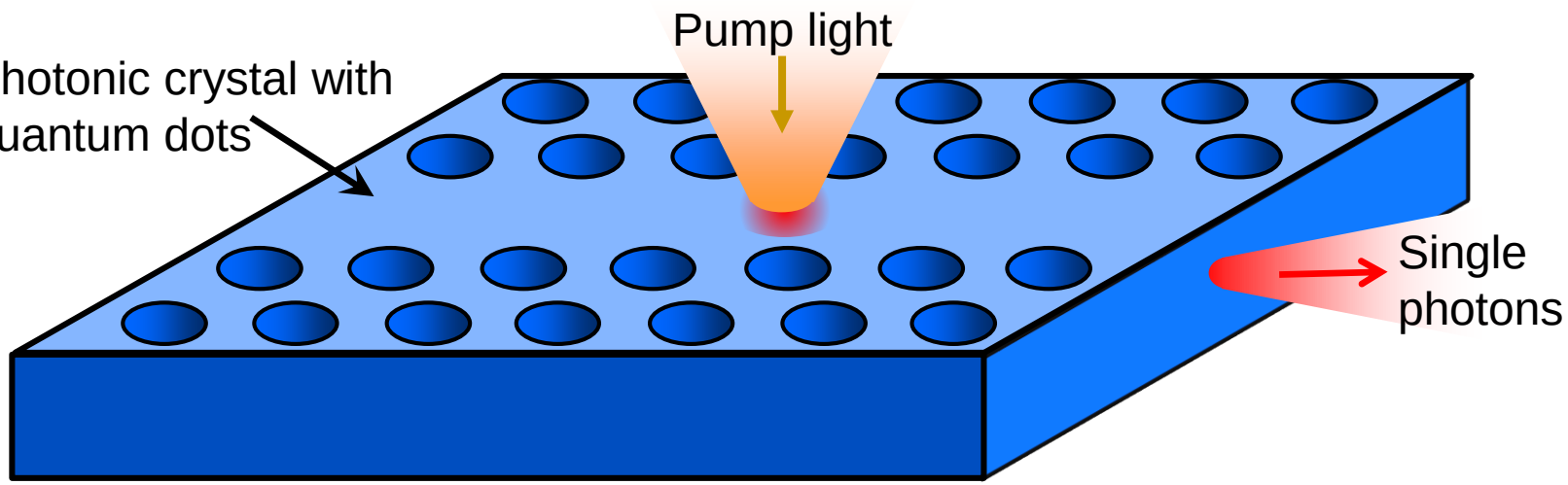


Microwave resonator

Example for Interdisciplinary Task

Semiconductor-based single photon sources

- Applications: quantum computer, quantum cryptography, quantum random number generators,…
- Goal: Reduction of error rate

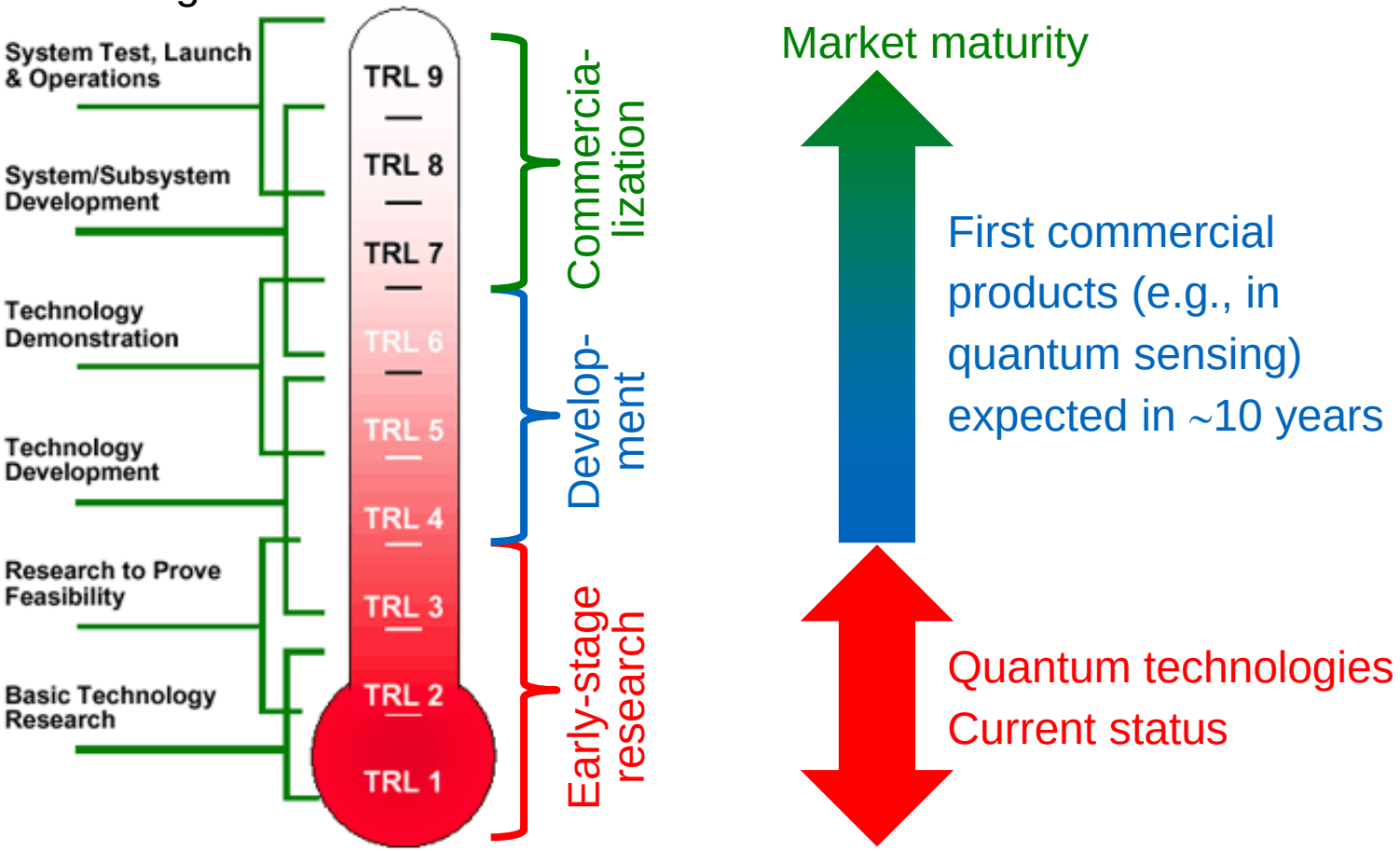


Physical realization (Physics) ⟷ Modeling & quantum post processing (Engineering)

Professorship for Computational Photonics
Department of Electrical and Computer Engineering
Technische Universität München

Development for Applications

ZQE will bridge between basic research and commercialization



NASA Technology Readiness Levels (TRL)

Summary

- Zentrum für QuantenEngineering (ZQE) focuses on solid state hybrid quantum systems and their development for applications
  - Hybrid quantum systems combine different physical platforms to benefit from their respective strengths
  - Applications involve quantum sensors, quantum communication/ cryptography, quantum computing,…
- For quantum technology (Quantum 2.0), the engineer must have expertise in quantum theory