qutools

# Quantenkoffer®

## Pack your suitcase for the future

# Quantum Physics - Revolution of our Worldview

**Describing the world exactly in all its details has always been the ambition of physics. Quantum physics pushes the boundaries of this view and opens a completely new perspective.**

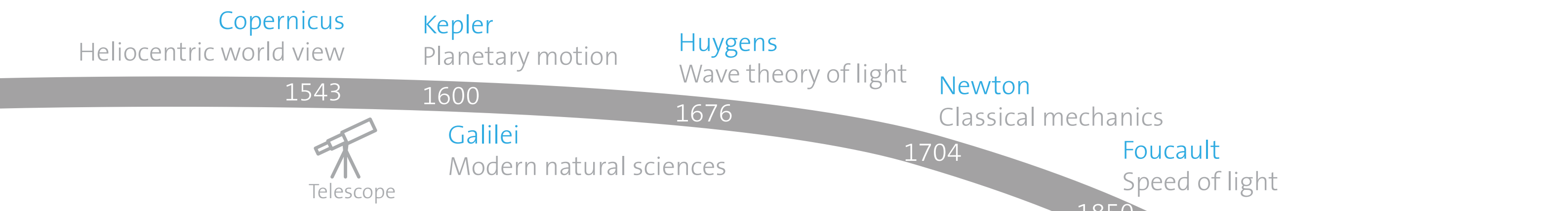
There is hardly anything that has preoccupied mankind as much as light. Whether it is described in the Bible as the origin of all life, or by the philosophers of antiquity as a symbol for absolute knowledge, whether we describe certain historical periods as "Dark Ages" or the age of reason as "Enlightenment" - in the struggle for knowledge, faith and our place in the universe, light has always been a welcome metaphor.

*"Let there be light! And there was light." –*
*Old Testament, The First Book of Moses*

*"A missionary of the Middle Ages recounts that he had found the point where the heavens and Earth touch each other..." –*
*Camille Flammarion: L'atmosphère, Paris 1888, Coloration: Hugo Heikenwaelder, Vienna 1998.*

However, light only became a subject of investigation as the modern natural sciences, particularly physics, started rising and developing.

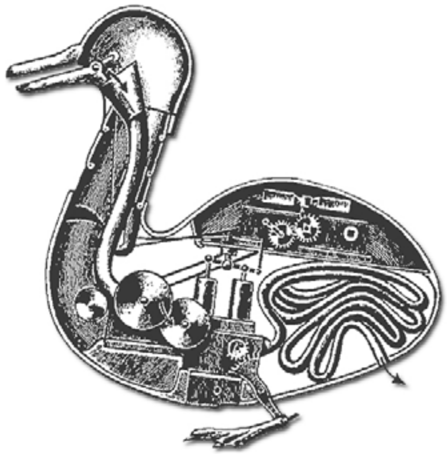
Up to the mid of the last century though, it was still relatively unclear what light actually was. Its accurate exploration was only made possible by an understanding of science that had its origins in the early stages of the Enlightenment: the reduction of observations to simple laws - a principle also used by Isaac Newton in the formulation of classical mechanics.




*"That I can see what holds the world together at its core." –*
*Johann Wolfgang von Goethe*

Classical mechanics had led to a world view which, from that point on, also changed the understanding of culture, state, society or spiritual life. Humanity attained a whole new self-confidence, detached from religious dogma and inspired by the spirit of the Enlightenment. For if the world follows definite physical laws and humanity is able to decipher them, it would not be long until all phenomena would eventually be fully explained and predicted.

And so began during the Enlightenment a scientific quest for causality. The aim was to put everything into relation to one another, such that, as Goethe puts it, it would be possible to find out "what holds the world together at its core".



In 1738, Jacques de Vaucanson created in Paris a mechanical duck which fluttered its wings, drank water and even had a digestive tract. His dream was to create an artificial man - Mechanical Duck, Jaques de Vaucanson, 1738.

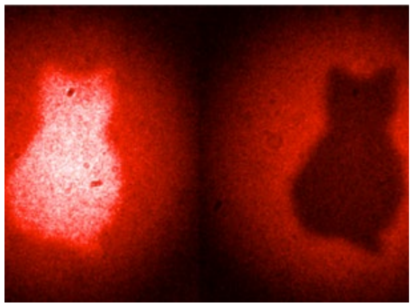
There lies a certain irony in the fact that light served as the first source of evidence for undermining this world view at the beginning of the 20th century, through the rise of quantum physics. Suddenly, there were theories that, under certain conditions, refuted the assumptions previously anchored in classical mechanics and in the theory of relativity. The unambiguous determinability was replaced by uncertainty and the exact calculation was replaced by probability.

*"God does not play dice with the universe" –*
*Albert Einstein*

Where the former principles promised to determine movement curves of flying objects - such as a celestial body - precisely, quantum theory limits itself to the prediction of curves weighted with probabilities. An understanding that shocked the physical world at the time. "God does not play dice with the universe" is one of Albert Einstein's most famous quotes, who himself made valuable contributions to quantum physics. Also the phrase „spooky action at a distance" that refers to the completely new phenomenon of entanglement belonged to Einstein's view.

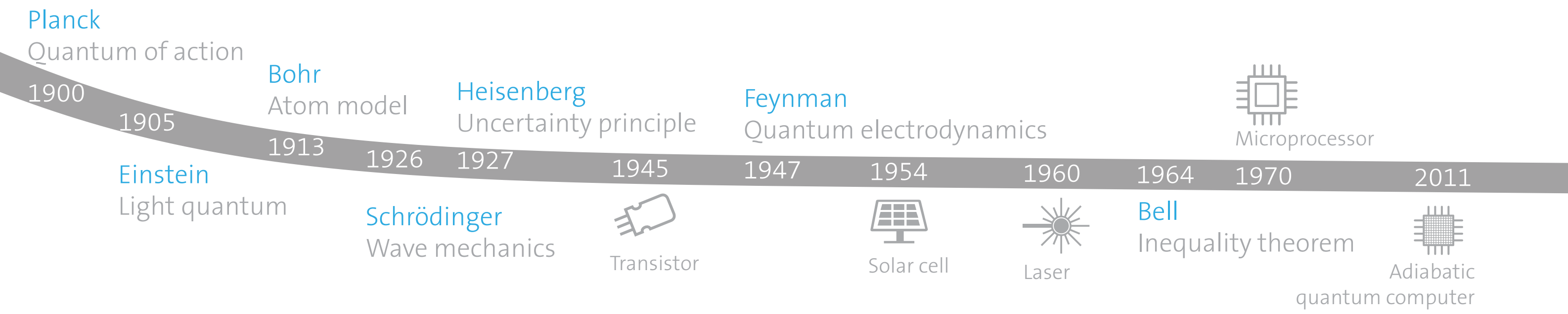
As many puzzles as quantum physics posed, its benefits are obvious: in everyday life it meets us in most technical devices, in electronic semiconductor elements and that way in every microchip, in magnetic resonance tomography, but also in lasers or light-emitting diodes. Quantum physics is therefore one of the best experimentally tested theories in physics.

*"Understanding often goes much further than reason" –*
*Marie von Ebner-Eschenbach*



Viennese researchers play on "Schrödingers Cat" with entangled photon pairs and an aperture. The red photons never "interacted" with the object, but they show the cat shape - Patricia Enigl, IQOQI, Vienna.

However, that has not led yet to the questioning of the absolute, deterministic conception of the world and the universe. Quantum physics is now over 100 years old and it is very easy to find many good quotes by its founders from the time of the beginning. In this day and age however, its understanding is limited to peripheral areas of physics and has not yet really come to enter other sectors of society. For that to happen, young people should come in touch with quantum physics and have the chance to understand its phenomena using a learning-by-doing approach. This is the "Enlightenment claim" of the Quantenkoffer.



# Quantenkoffer - Trust and Fascination ...

## A portable and user-friendly quantum photonics laboratory

## Experiment Flexibility

On the high-precision board with 86 slots various setups can be individually created by placing the optical tokens into the electromechanical slots. Conducting well-known photonics experiments or setting up new ones can be as easy as playing.

## Intuitive Operation

After the automatic detection of the inserted tokens, a setup display appears on the touch-pad. The user-friendly software supports the user in choosing from a wide range of diplay-widgets, four of which are active on the large monitor.

## Motorized Adjustment

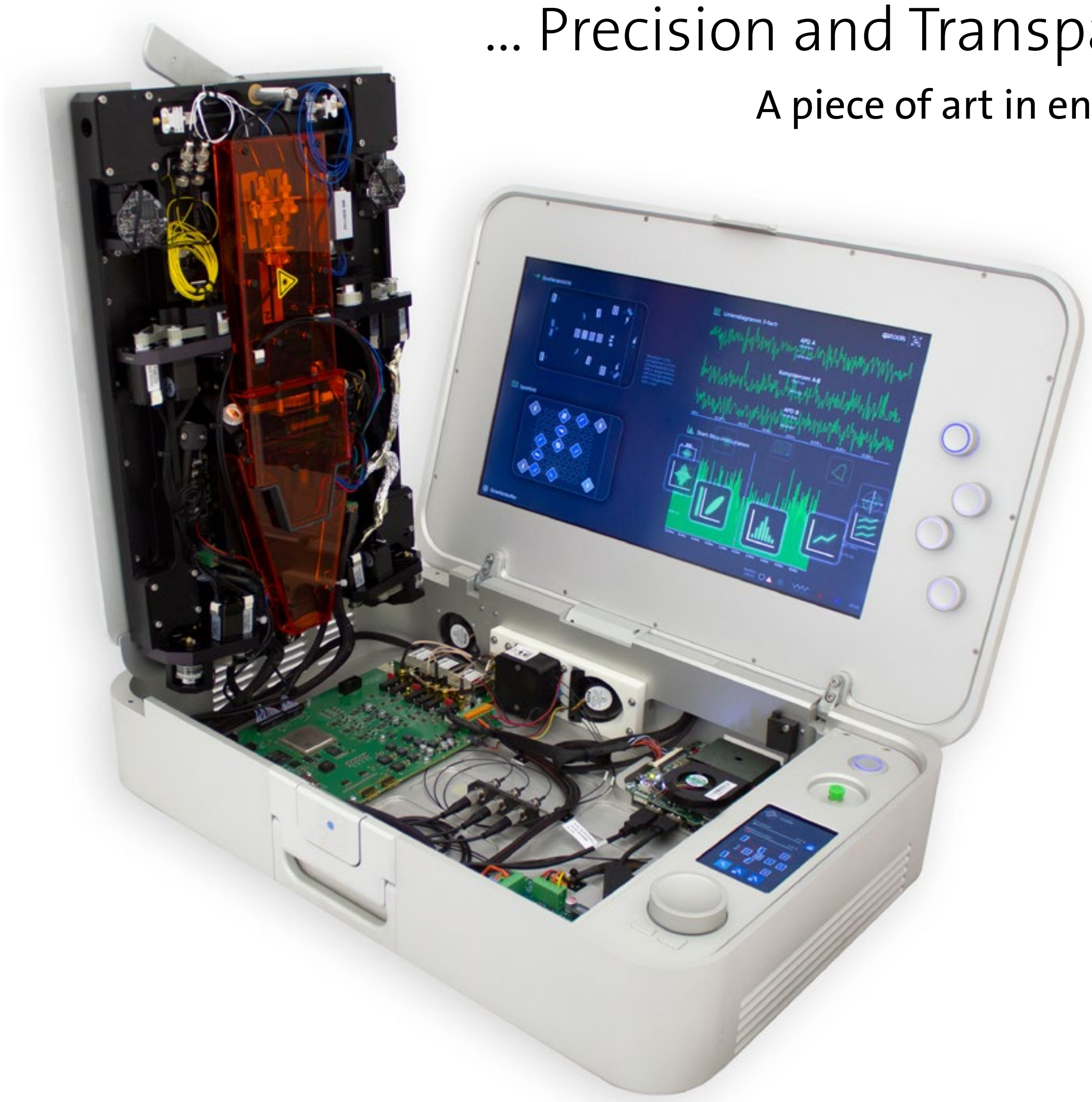
The possible automatic adjustment through actuators and sensors facilitates the setup of experiments and the quick realization of measurements, allowing for the playful immersion into the fascinating world of quanta.

## Picosecond Range Timing

The ultra-fast processing of the measured events, enabled through powerful digital technology, allows the detection of time differences in the picosecond range, for example to measure the speed of light on the board with few tokens.

# ... Precision and Transparency

## A piece of art in engineering



## Single-Photon Detectors

Four avalanche photodiodes with upgraded electronics enable the detection of single photon pairs with a high time resolution and the measurement of bright light sources. The four detectors allow for more complex experiments.

## Mobile, Robust and Safe

The sensitive optics and electronics are mounted safely and shockproof in the interior of the robust case, which makes it a mobile lab. Flexible, precise and quickly ready to use - explore playfully the world of quanta with the Quantenkoffer.

## Single Photons, Entangled Pairs

A set of lasers and optical crystals form the core of the photon source, which the user can view by flipping the optical setup board. Single pairs of photons are generated through nonlinear processes within optical crystals. Each element of the precise source can be adjusted by the user or automatically optimized by the Quantenkoffer. Additional red laserlight follows the path of the single photons for proper adjustment of the optical setups.

# Optical Tokens - the quBricks

## Perform experiments with a wide range of different tokens and create exciting setups yourself.

A multitude of optical tokens can be placed on the high-precision board and combined into various experiments. The Quantenkoffer recognizes, reads out and digitally controls the tokens though the electronics around the partially motorized optical elements. Moreover, a touch sensor on top of each quBrick introduces a physical involvement for broader cognitive activation during the learning process.

### Periscope

- Connects board to source and detectors
- High-precision: Simply plug in and get started
- Two to four periscopes needed on the board for all experiments

### Mirror 45°

- Deflects the beam by 90°
- Fine adjustment, manually or motorized
- Basic token for many experiments such as interferometer and speed of light

### Beam Splitter

- Splits or merges the laser beam
- 50:50 or polarization-dependent
- Basic token for interferometer and random number generator

### Piezo Mirror 90°

- Reflects the beam in itself
- Piezoelectric adjustment of mirror position
- Essential for Michelson interferometer and quantum eraser

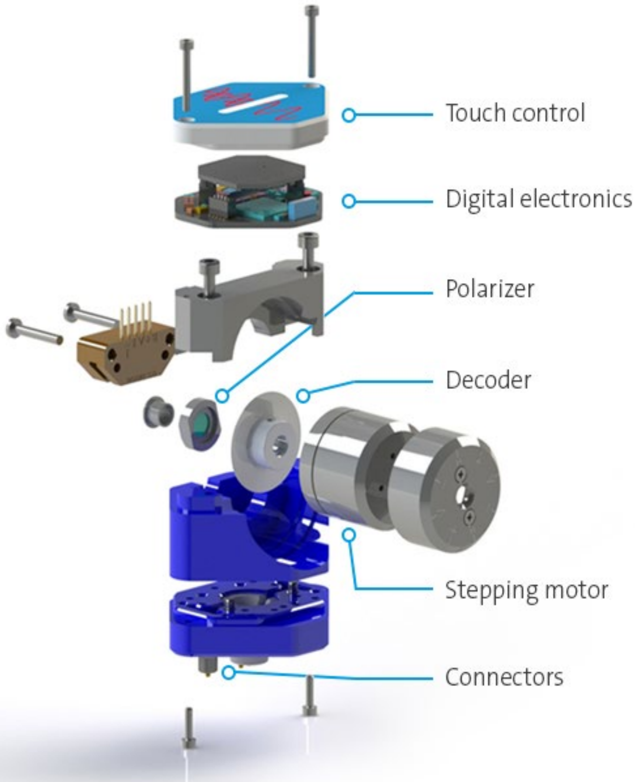
### Waveplate

- Lossless polarization manipulation
- λ/2 or λ/4 integrated plates
- For advanced polarization experiments such as quantum cryptography & tomography

### Polarizer

**Properties**

The polarization of an electromagnetic wave refers to the direction of oscillation of its electric field. This token is a type of filter that transmits only the light of a certain polarization.



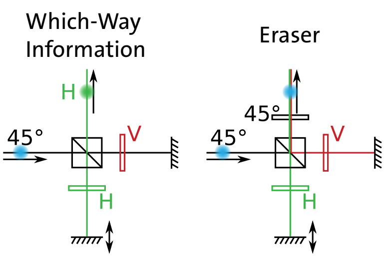

**Application**

This token constitutes the basis for all polarization experiments such as measurement of Bell's inequality, quantum eraser or quantum cryptography.

*Versatile, modular, precise, and playful to operate – due to the large number of different tokens, both the most famous experiments and the ones that you design yourself can be conducted, without limiting your creativity.*

### Assembly & Handling

A tap on the token activates its control panel on the touch display of the Quantenkoffer. The core of this token is a polarizer that is mounted on the optical axis and that can be rotated by hand or through the integrated stepping motor via the Quantenkoffer. Inside the token, next to the electronics assembly, a decoder is located for reading the current angular position of the polarizer. Through the connectors on the bottom side, the Quantenkoffer recognizes the position and the type of token on the board, which makes the design of complex setups and experiments user-friendly and playful.




## Glass Wedge

- Changes the optical path length
- Offset adjustable with µm accuracy
- Special token for interference experiments, Hong-Ou-Mandel effect

## Camera

- Measurement of the laser beam
- View via display & external devices
- Beam adjustment, interference phenomena with bright light

## Fiber Coupler

- Couples the beam into optical fibers
- Efficient, automatic fiber coupling possible
- Enables the connection of further detectors and the combination with external setups

## Double Slit

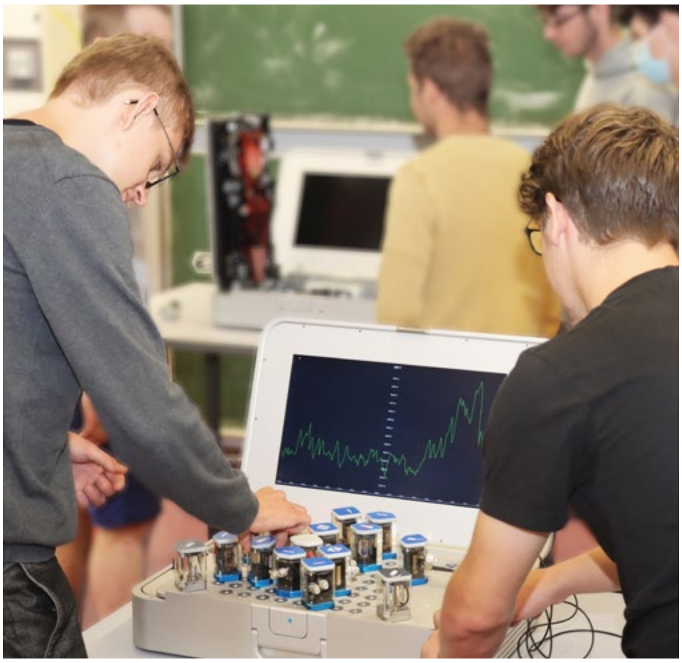
- A classic for interference phenomena
- Different slit widths, grids, individual slits
- Special token for double-slit experiments with single photons or bright light

## Tunnel Effect

- Distance-dependent prism transmission
- Controlled via Quantenkoffer & external devices
- Special token for the tunnel effect based on the frustrated total internal reflection

# Experimenting with the Modular Science Kit

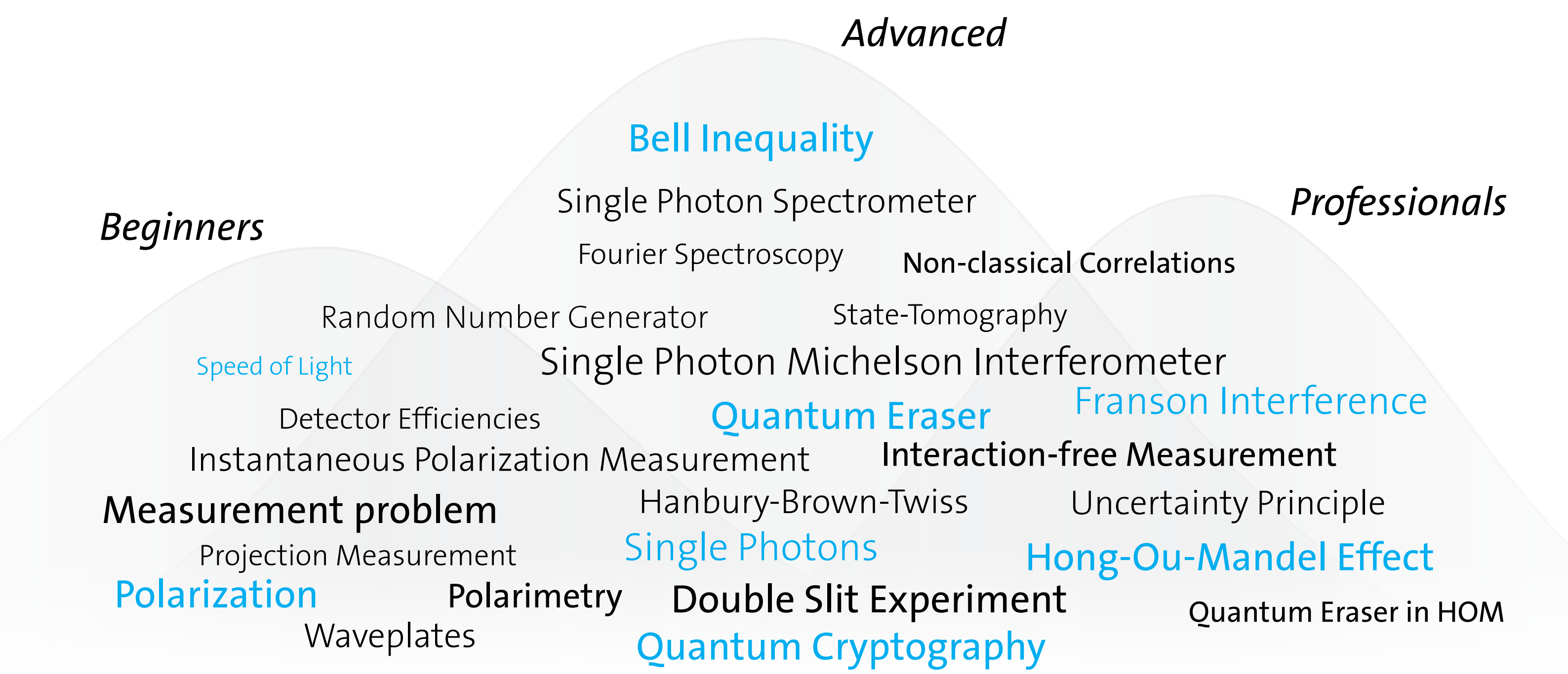
## Learn complex topics from famous experiments and use your own creativity to reveal the essence of quantum physics.



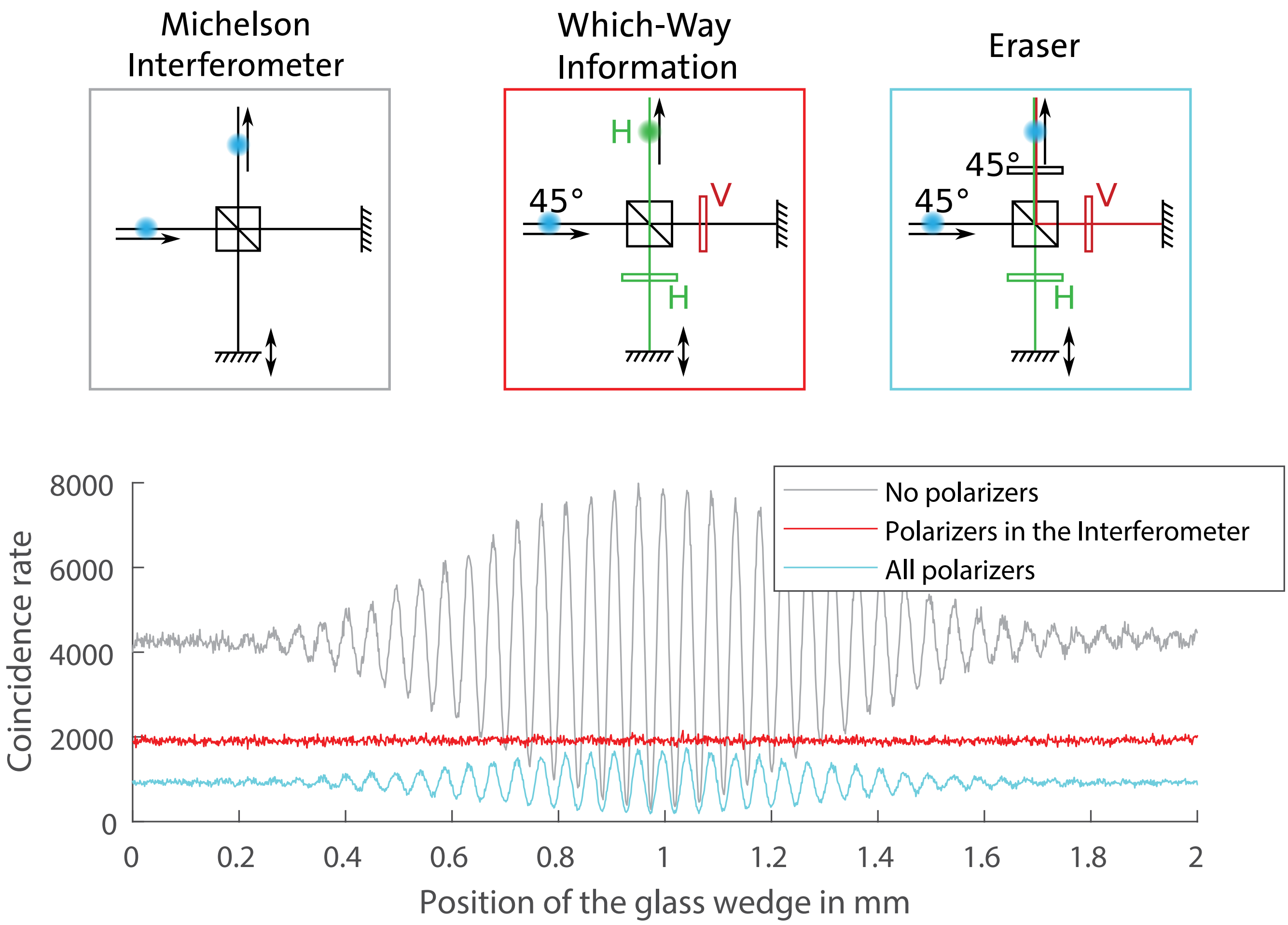
*Students unravel the peculiarities of the quantum world on their own.*

The smart technology built in the Quantenkoffer allows for playful setting up and operation of a multitude of experiments for all levels of difficulty. A special highlight is the adjustable source of entangled photons underneath the optical set-up-board. The opportunity to view and adjust every degree of freedom of the complex process of spontaneous parametric down conversion (SPDC) deepens the understanding of physics and gives transparency to the functionality of the Quantenkoffer.

The Quantenkoffer and its modular design offer different approaches. You can choose to follow ideas and well-known experiments from 100 years of quantum physics, or you can use its intuitive operation to design experiments from scratch. For delayed evaluations, the software of the Quantenkoffer offers the possibility of storing the measured data or exporting it to external devices.




*Various exciting experiments with single photons or entangled photon pairs for all levels of difficulty enable a comprehensive preoccupation with the characteristics of quantum physics and its technical application in the near future.*




*The three measurement steps in the quantum eraser experiment: First, a clear interference pattern from a single-photon Michelson interferometer without any polarizers in the beam path (gray). Second, with the implementation of polarizers in the interferometer arms, the which-way information is available and the interference pattern disappears (red). Finally, the polarizer after the interferometer "erases" the which-way information before detection and the interference is again visible (blue). In all three setups the optical length of one of the interferometer arms is changed by continuously shifting a glass wedge in the beam path.*

An example of an amazing experiment is the so-called quantum eraser, which is based on a Michelson interferometer. In a single-photon Michelson interferometer we observe an interference pattern from many consecutive single photons after passing through the identical arms of the interferometer. The interference disappears as soon as we have information about the path taken by the quantum objects through the interferometer. The path information can, for example, be determined by the polarization of a photon. This can be done by inserting a polarizer in each arm of the Michelson interferometer. Interestingly, the polarization information can be "erased" again after merging of the two interferometer arms but before detection of the photon by another polarizer placed at a certain angle. In this case, the interference pattern is visible again!

Besides the complementarity – either interference is present or information about the path is available – the installation can raise and answer further questions as well. What happens if the taken path can be determined with a certain probability? Why is it impossible to erase the information after the detection of a photon? Which properties of the photon source can still be determined from the measurement data?

# Observe - Experience - Change!

## Quantum physics thrives on observation. Imparting it in an understandable way encourages not only enthusiasm for natural sciences, but can also generate real value for the society.

The discovery of quantum physics over 100 years ago represents more than just a change of knowledge in the natural sciences. The entire world is now beginning to reevaluate its relationship to our surroundings and the environment. After centuries of resource exploitation as a result of the industrial revolution, today the environmental protection, sustainability and the search for alternative forms of energy have become firmly anchored in the social consciousness. And the natural sciences will play a central role in achieving these goals.

GaudiLab, Herrndorff/Shutterstock.com

Politics and business have also joined forces as, for example, numerous initiatives for the promotion of MINT subjects in schools show. But in order to be able to change the world positively, one should first understand it - or at least become aware of where today's knowledge has its limits. The confrontation with the mysteries of quantum physics can thus contribute decisively to arouse curiosity for natural sciences and convey early on an understanding of the nature and configuration of the universe.

## Quantum physics changes our view on the world

In order to convey the importance of quantum physics to future generations, it is necessary to make its basic principles accessible to society as a whole. This doesn't work only with theory, but rather through practical mediation.

The Quantenkoffer enables a practical revision of the basic principles of quantum physics and ensures that this knowledge reaches the people - in schools, universities, but also into public space. The experiments that can be carried out with it are so diverse, that its possibilities of use are also very flexible:

Through "Quantenmobiles" – vehicles equipped with the Quantenkoffer – designed to bring the knowledge of quantum physics beyond small school classes or seminars, a small investment can help reach a large group of people - for example at science fairs, MINT-promotion initiatives, girls' days and many other events that encourage scientific thinking.


Matej Kastelic/Shutterstock.com

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The mobile demonstration lesson should be only the beginning though. The purpose of the Quantenkoffer is not just to fascinate young generations about quantum physics. By interacting with quantum physics basic principles, people of all ages and levels of experience gain valuable knowledge which should be available in a broad range.

The aim is making quantum physics permanently accessible and tangible, either by establishing local training centers or by using the Quantenkoffer in adult education centers or presenting it at exhibitions and fairs. Additionally, the possibility of on-site loaning also makes it possible to bring the knowledge to enterprises, associations and all other institutions - without complex experimental set-ups, complicated theory or long lecture series. Thus, with the right measures, maximum coverage can be achieved with a minimum of resources. From events aiming for transfer of knowledge to campaigns for a large-scale spreading of quantum theory, the Quantenkoffer supports every conceivable form of public sensitization.

## Social added-value

The Quantenkoffer is therefore not just another training instrument, but a step towards disseminating the findings of quantum physics to the public sphere - with the positive consequences of a scientifically thinking society, more awareness for mankind, nature and our existence in the universe.

Our vision is to keep the quantum revolution running. That the findings of more than 100 years of quantum physics become part of social debates and the engagement with physical phenomena finds a way into culture and entertainment. The key is "grasping" and *"experiencing"* quantum physics. And the Quantenkoffer ensures that everyone get the chance to do it.

### In a nutshell

- *The basic principles of quantum physics should be made accessible to the entire society.*
- *Quantenmobiles bring fascination to schools, universities and public sphere.*
- *Training centers enable the deeper and long-term study of quantum physics.*
- *Rental systems allow the use in classrooms, in companies in seminar practical work.*
- *Information campaigns provide for a positive image of quantum physics among the public.*

# Physics and Philosophy

## The qutools interview with the hobby philosopher Bjoern Habrich from Darmstadt.

### Metaphysics and Enlightenment

**Mr. Habrich, what is the relationship between physics and philosophy from your point of view?**

*Unfortunately, this relationship, along with the word metaphysics, got lost within the Enlightenment. The emergence of quantum theory has made physicists reflect on philosophical questions once more, which however did not really make it to the philosophers.*

**What within the Enlightenment led to this split?**

*In Newton's absolutely deterministic worldview, basically everything is calculable. Therefore, there is no more room left for philosophical questions about the heart of the matter. That is why I often plead for the metaphorical "removal of the Newtonian condom of determinism". I prefer "unprotected thinking".*

### Mindful Decoherence

**New physical worldviews often draw social change after themselves. What influence does quantum physics have on our life together?**

*Unfortunately, none so far!*

**... and which one will it hopefully have?**

*Mindful decoherence! This expression unites philosophy and physics: decoherence is a term from quantum physics that describes the line between the unlimited freedom of thought and determinism usable in reality. This shift is smooth, but usually irreversible. Being aware of the reality of this decoherence leads to an increased mindfulness in dealing with it.*

### Social Influence

**Does an understanding of quantum physics help improve our coexistence?**

*Yes, of course!*

*Of most concern to me is the acceptance of true coincidence. The acceptance that "orbital equations" are affected by a probability that increases with the size of the object, but for some things it does not reach 100%.*

*The implied assumption of being able to calculate everything leads to an arrogance in dealing with each other and with nature. I call that "two-faced determinism".*

*„Watch your thoughts,
for they become words.*

*Watch your words,
for they become deeds.*

*Watch your deeds,
for they become habits.*

*Watch your habits,
for they become your character.*

*Watch your character,
for it becomes your destiny."*

*Talmud*

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