

## Subtle is the Lord

Light faster than the speed of light? Light, which you stop and then let go again. Is that possible? Was Einstein wrong after all?

These are questions, which have kept the minds of physicists busy since, in 1994, one of the authors of this book, Professor Nimtz, chased Mozart's symphony No. 40 through a so-called tunneling barrier at 4.7 times the speed of light. The sound arrived at the other end in all its beauty. Emotions were running high when Nimtz and his colleague Enderes presented their, then still rather vague, results of this so-called superluminal tunneling effect. The presentation was held at the annual spring-meeting of the "Deutsche Physikalische Gesellschaft" in Freudenstadt, Black Forest. At the time, I myself could not believe that the foundations of the Theory of Relativity could be shaken. Einstein had postulated: "*Nothing can travel faster than the speed of light.*" Now we know better. We are witnesses of a rare event, of a change of a paradigm in physics. We have to accept that even Einstein's theory of relativity is not the Holy Grail of

physics. It is a macroscopic local theory, which precisely defines its limitations. Due to its macroscopic construction it will never be capable of giving us information about the smallest processes in nature on an atomic level. This can only be done by quantum mechanics. Because of its local nature we shall never be able to find out whether the universe is finite or perhaps infinite. Even a so-called flat or hyperbolic universe, which many think is *per se* infinite, could only command a global topology, which would leave the universe only finite. Nimitz's results, which come from the quantum quality of nature, force us to accept a truth beyond the theory of relativity, which we have not yet grasped.

Does this mean that any scientific theory is wrong, as it could be replaced by another tomorrow, turning everything upside down, contrary to what we have accepted as scientific knowledge? In recent years this suspicion, which at the same time laments the degeneration of knowledge, has been put forward with growing intensity, especially by the media. The German weekly "Die Zeit" wrote in August 2001:

*"In view of the rapidly shrinking half-life period of knowledge in a world which transforms itself ever so fast, every big design of scientific theory has to face the necessity and at the same time impossibility, to regard its fate tomorrow as the intellectual fashion of yesterday."*

Here we are up against a myth, about the half-life of our knowledge, which has been bothering our society for some time. It suggests, that our knowledge is being declared in-

valid every five years by new knowledge. As our world is changing at a breathtaking speed, why not our knowledge at the same time? It sounds logical, therefore it might be true. What a grave error! Newton's theory of gravitation is still valid, even in the light of the theory of relativity. The periodic system of the elements has lost nothing of its validity over the centuries. Mathematical proof has been regarded since Pythagoras and Plato as eternal, metaphysical truth. It is also true that the quantity of scientific knowledge doubles about every five years, but knowledge which has been established in previous time is not rendered invalid by later discoveries. Instead it extends it towards frontiers which had not been discovered previously. Therefore Einstein's theory of relativity has extended theory rather than disproved Newton's theory. To this day the apple drops from the tree to the ground, not the other way round.

What is the relationship between the superluminal tunneling effect and Einstein's theory of relativity? There is no point in discussing, whether the superluminal effect contradicts Einstein's postulate or not. Einstein deals with free space, whereas the tunneling is not free space. Exactly at this point the evolution of physical theories reveals itself. As for the theory of light and gravitation, so has quantum mechanics extended the theory of relativity towards the tunneling process, forbidden ground in classical physics. So this non-classical expansion implies speeds beyond the speed of light.

Physicists could accept this reluctantly, if there wasn't another potential problem. It can be shown, that Einstein's

postulate always preserves the principle of causality, which means keeping the universal sequence (order) of cause and effect forever. If *somewhere* in this universe first cause and then effect take place, then there is *no* place in this universe where an effect would be seen before its cause. This fundamental principle of our universe has been called the “*cement of the universe*” by the philosopher J. L. Mackie. The problem now is: one can no longer guarantee causality for superluminal light waves in space. Effect can arrive ahead of cause. Man would exist before his birth!

Does the superluminal velocity, discovered by Nimtz, dissolve this “*cement*”? If superluminality were to exist in space, it would indeed be the ultimate catastrophe in physics. However, as Einstein once remarked: “*Subtle is the Lord, but malicious He is not.*” As the authors of this book prove in Chapter 5.5, even with the tunneling effect the cement stays with us *although* the tunneling signal is faster than light in vacuum. Not Einstein’s postulate but common causality seems to be the fundamental principle of everything in nature.

But even if the Lord would leave us with what is absolutely necessary, the inner logic of the universe, at the same time he forces us to part with other ideas dear to us. Even if the sequence of cause and effect may be the same everywhere, its time distance, even time itself, can change for different observers in the universe. Time is not universal! My time *was* different during my shuttle mission in 1993. It was slower than that of any other person on earth. Therefore I have experienced 0.254 milliseconds less than those who

had stayed at home. This could be measured with atomic clocks. That might sound paradoxical, but it was a fact. It is extremely difficult to understand this effect of time dilatation. The atomic clocks did not show another time, but time itself measured by atomic clocks went slower – which I myself did not notice. The result: From the biological point of view I am younger. To be honest not much, however, I am younger.

So physics is still good for a few surprises, this book is about one of them. I am convinced there will be a few more “cunning” surprises. But like Einstein I am convinced that our Lord will never turn the logic of this world upside down out of malice.

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## Preface

At the beginning of the 20th century Albert Einstein developed the Theory of Relativity and revolutionized our ideas of space and time [1]. Erwin Schrödinger's, Werner Heisenberg's, Paul Dirac's and Wolfgang Pauli's quantum theory explained the wave-particle-dualism of light and also the almost unimaginable realization, that causality and determinism are become in the world of microphysics.

Since then, fascinating new effects of these laws of nature have been discovered again and again. The *tunneling effect* is one of these exciting phenomena, as is the *zero-time in the tunnel*, which is the subject of this book.

After the results of our research on the tunneling process were first published, an unexpectedly high interest in these activities erupted. Periodicals reported, invitations to public lectures followed. Television teams tried to film the tunneling effect in dark laboratories, school classes visited us to watch our experiments. Supporters and opponents frequently and extensively discussed the phenomenon of tunneling in numerous internet fora. Not least we are now in

possession of quite a few folders of letters in which we are advised of how to build a time machine and perpetuum mobiles, all sent to us by enthusiastic fans.

On the other hand there are some physicists like Moses Fayngold, who tried hard to show that quantum mechanical tunneling does not violate special relativity [2]. Fayngold presumes the experimental physicists not to know that the relevant quantities are signal and energy velocities.

With this book set in an historic frame we intend to present the tunneling effect and its consequences without formulae but easily understandable, from the first successful measuring of the finite nature of the speed of light by Ole Rømer to the acceleration of the speed of light through the tunneling mechanism. This has led to the technical use of tunneling, for instance in the fields of optoelectronics and semiconductor technology. We are going to demonstrate not only the philosophical and technical problems and the limits of the practical use of this astonishing process, but also its potential for device applications.

Our thanks for advice and support to get this book on its way, go to Prof. Ursula Haibel, Prof. Udo Kindermann, Prof. Peter Mittelstaedt, Mrs. Beate Neugebauer and Dr. Ralf-Michael Vetter. We acknowledge gratefully the accurate translation by Dr. Hans-Joachim Nimtz.

Cologne, August 2007

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