On Instantaneous Photonic Tunneling Through Opaque Barriers.

By Ed Dellian, D-14169 Berlin, Bogenstr. 5. (ed.dellian@t-online.de)

I Introduction

A current theoretical explanation of superluminal photonic tunneling wants microwave signals to travel through opaque barriers with superluminal velocities (the faster the longer the barrier). Tunneling is even said to represent a "nonlocal process" [1], which notion implies the idea of not only *superluminal*, but *instantaneous*, or *timeless*, transferring of excitations, or propagation of signals. The matter provokes to remind of an example which is as striking as it is simple: the opaque rigid rod of any length AB. Obviously (according to ordinary experience) an impulse impressed at A will be recorded at B at the very moment of its operation on the rod at A. So a bell-pull from A to B will transmit an excitation instantaneously from A to the distant bell at B, and the signal might be understood as "traveling" from A to B without consuming time. Correctly, however, one should see that this signal doesn't *travel* at all, but rather the excitation *is present* at B *the very moment* when impressed at A. How is that possible to happen? Doesn't the simultaneous existence of a signal at A and at B violate the principle of causality?

II Analysis of impression and transmission of signals in rigid bodies.

1. *The impression* of a certain quantity of an impulse on the end A of a rigid rod AB to generate a certain quantity of motion mv (momentum p) of the rod (in order to make its mass m move into the direction of B with the velocity v) does *not* happen *instantaneously*, but "in time and space": that is, the process *requires time*, and while it happens in time, the body will cover some space. The process of generation of a certain quantity of motion, or momentum p, accordingly will proceed with a certain *velocity of generation,* given through the quotient "space of generation" over "time of generation". As a consequence, the process of transmitting a signal from A to B, observed from its very beginning, when the signal starts to be impressed at A, will always, and even if the full signal, as soon as it is generated at A, should appear at B *instantaneously,* happen at least with the said finite velocity v of the signal's generation. However, if one calculates the velocity of the whole transmitting process through the quotient of the whole distance AB over the whole time it takes, one will certainly obtain finite velocities > v due to the fact that "the whole time" is *just the time of generation* of the signal,

since its *transmission* from A to B was assumed to happen instantaneously, i.e. *without consuming any time*.

2. Now this analysis answers our question concerning "causality": As the generation of momentum *p* always happens *in time and space*, and consequently according to a certain *velocity of generation*, the generated motion, i.e. *the effect*, will always follow *the generating cause*, and there will always lie a certain small span of time, Δt, and also a certain small span of space, Δs, between "cause" and "effect". Now, the "effect" being a certain quantity of momentum, Δp, what physical entity will represent the corresponding quantity of "cause"? Let me just state that this entity is what quantum mechanics calls "energy", ΔE, this ΔE being defined *proportional to the generated effect* Δp according to

$$\Delta E : \Delta p \;=\; \Delta s : \Delta t \;=\; constant. \qquad (1)$$

Eq. (1) is a known true part of the theory of radiation pressure (light-matter interaction), and the constant, according to that theory, is equal to *c*, i.e. to the vacuum velocity of light. By the way, one should see how close Eq. (1) is to the Heisenberg relations, insofar as (according to proportion theory) the product of the outside terms, ΔE and Δt, as well as that of the inside terms, Δp and Δs, results in Planck's constant, *h*.

Consequently we may infer that generally *every process of generation of a signal or excitation should impy an energy-momentum proportion* that is characterized by a constant of proportionality *c*, which may in all known interactions be numerically equal to the vacuum velocity of light. As a result we obtain a most general *law of cause and effect* (the law of causality) to read

$$\Delta E : \Delta p \;=\; c\;\; . \qquad (2)$$

3. Surprisingly or not, the photonic tunneling process, as it has been described e.g. in Ref. [1], shows an exciting analogy to my above analysis of the "rigid rod signal transmission". For instance, in photonic tunneling through opaque barriers there appears a "universal tunneling time" [2] *independent of frequency and of the type of barrier studied.* The theoretical background exactly fits in with my above demonstration of a universal *law of causality* (Eq. (2)), characterized through a universal constant *c* of dimensions "space over time", to govern as

"vacuum velocity of light" every interaction process hitherto known. It is also clear that due to the "universal tunneling time" one will obtain superluminal signal transmission when including this time in the measurement of the whole process, from the beginning of the interaction of the wave with the barrier to the arrival of the signal at the back of the barrier. It is true that microwaves partly interact with the barrier according to Eq. (2), and that the opaque barrier works much in the way of the above-described "bell-pull" or "rigid rod".

4. Is Special Relativity (SR) at stake, if we accept the above considerations? Insofar as SR forbids superluminal *interactions*, it is not affected, since we have seen that the tunneling process (as well as any other interaction) is governed by the law of causality given in Eq. (2), and consequently doesn't display a *superluminal velocity of generation* > *c of a signal.* But SR, insofar as it should *without exception forbid* any instantaneous *signal transmission*, would seriously be at stake. I cannot see, however, that the mathematical formalism of SR in fact requires such an interpretation. Only some over-zealous Einsteinians will have to give in who, erroneously believing that instantaneous signal transmission through rigid bodies, or through opaque barriers, might contradict SR, in the past have extended the egotism of this theory to the dogmatic claim that *no really rigid rod could exist* [3,4].

III How to understand the instantaneous tunneling process.

One question remains: How are we to understand the instantaneous tunneling of photons through opaque barriers? How can a microwave signal pass through an opaque barrier from A to B as if it were transmitted instantaneously *by a rigid body* extended from A to B? For this to explain I shall in the following refer to - well, Isaac Newton, Principia, 3rd ed. London 1726, and Optics, 2nd ed., London 1717.

1. Once again referring to the rigid body example, it must be stressed that the "classical" idea as if such a body should represent an insurmountable potential barrier, is not Newton's. Macroscopic bodies, according to Newton's "atomistic" matter theory, are composed of elementary material particles and void [5]. Consequently, at the microphysical level they appear in a lattice structure. So an elementary particle, e.g. a photon, can in principle find its way through the void parts of the lattice. And this the easier the thinner the barrier is, in accordance with ordinary experience.

2. The void spaces between the material particles of macroscopic bodies are not void of everything. They are filled with *fields of forces*, or simply "*forces*", as Newton says, e.g. in the 1686 preface to the 1687 "Philosophiae naturalis principia mathematica": "I am induced by many reasons to suspect that (the phenomena of nature) may all depend upon certain forces by which the particles of bodies, by some causes hitherto unknown, are either mutually impelled towards one another, and cohere in regular figures, or are repelled and recede from one another. These forces being unknown, philosophers have hitherto attempted the search of nature in vain; but I hope the principles here laid down will afford some light either to this or some truer method of philosophy" [6].

Today, thanks to the progress of experimental physics, it is manifest that these forces really exist. I refer mainly to the so-called binding energy of elementary particles here and in the following, and to the so-called "near field" [7].

3. There is no doubt in the reality of "light" and "matter" interactions. Says Newton: "Do not bodies and light act mutually upon one another; that is to say, bodies upon light in emitting, reflecting, refracting and inflecting it; and light upon bodies, for heating them, and putting their parts into a vibrating motion, wherein heat consists?" [8]. We may infer, then, that a microwave may of course interact with an opaque macroscopic body to appear as an obstacle in its way.

4. The light-matter interaction, however, does not take place between light and *matter itself*. Says Newton: "Do not bodies act upon light at a distance… and is not this action strongest at the least distance?" [9]. "Do not the rays of light, which fall upon bodies and are reflected or refracted, begin to bend before they arrive at the bodies?" [10]. Obviously "something" in macroscopic bodies interacts with light, which "something" is not represented by the elementary *material particles* of the bodies. So we may infer that the light-matter interaction actually takes place between "light" and the "forces" of the "near field" that make material elementary particles cohere in regular figures to form rigid bodies. And this inference is strongly supported by Newton when he e.g. says: "It remains a problem how glass … can reflect light so regularly as it does. This problem is … to be solved … by saying that the reflexion of a ray is effected, not by a single point of the reflecting body, but by some power of the body which is evenly diffused all over its surface, and by which it acts upon the ray without immediate contact" [11].

5. The said "power diffused all over a body's surface", if understood as a *coherent field of force* to represent e.g. the *binding energy* of the body's elementary particles, then may well serve as an interaction counterpart of the incident photons. And due to its *coherent* diffusion all over the body's surface, this "near field", if excitated at the point A of the macroscopic body, will certainly appear instantaneously excitated, in a same manner as at A, at any cohering distant point B of the body.

6. So far my explanation "from the Newtonian point of view" of the instantaneous transmission of excitations, or signals through opaque rigid bodies, e.g. a bell-pull, or a rigid rod, from A to B. It is meant as an encouragement for scientists always to take into consideration the most powerful achievements of Sir Isaac Newton's philosophy of nature, as it is present in his "Principia" of 1687, and "Opticks" of 1704. I cannot see any difficulty in applying this theory to photonic tunneling experiments such as e.g. with resonant barrier structures (photonic lattices), and undersized waveguides. The instance of the double prism deserves a special treatment which, however, will find many good arguments in Newton's "Opticks", where he deals a lot with double prisms, and probably will not differ on principle from what has been written above.

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References

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