Could network framework, advocated by theory, be a reason of causality, solving some long-standing physical-optical enigmas?

JAN HAISMA[1]

72 Kornoeljelaan, NL-5552 RD, Valkenswaard, The Netherlands

Abstract This paper confronts some physical-optical observations with network frameworks. Recent theoretical results of string and loop quantum gravity theory suggest the existence of network entities, the first one with branes, the second one with space levels, time levels and spacetime levels. The aim of this paper is to project network frameworks onto the realm of visualizable dimensions. An attempt is made to solve some basic enigmas in physical optics: the double-slit experiment and photon entanglement. The possibility of imprintable networks having affinity to laser physics is considered. In a specific case, a comparison is made with some phenomena known from gas dynamics.

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Résumé Cet article confronte quelques observations physico-optiques aux réseaux caractéristiques. Des resultats récents portant sur la théorie des cordes (string theory) et la théorie de 'loop quantum gravity' suggèrent l'existence de réseaux caractéristiques. La première théorie considère des 'branes', la deuxième des réseaux d'espace, de temps et d'espace-temps. Le but de cet article est de projeter de tels réseaux dans le domaine des dimensions visibles. On tente de résoudre ainsi quelques énigmes de base dans l'optique physique: l'expérience des fentes de Young et l'entrelacement des photons. Par ailleurs, on considère l'existence des réseaux entrelacés lié à la physique des lasers. Dans un cas particulier une comparaison est faite avec des phénomènes, observés dans la théorie de la dynamique des gaz.

[1] Retired principle physicist of Philips Research, the Netherlands and France

Physical reality, its tangible and untangible dependent variables such as mechanical, chemical and physical properties are all, in terms of their rational behavioural qualities, founded on a basic hypothesis, the so-called **'Cause and Effect'** or briefly the **'Causality'** principle. String theory [1] [2] [3], and especially loop quantum gravity theory [4] [5] [6], have recently extended the gamut of dependent substantials by the independent-variables space, time and spacetime. They have become flexible, discontinuous networks, manifest in e.g. space levels, which are comparable to the well-known atomic energy levels. So, at least loop quantum gravity theory brings space and time into the *realm* of substantiability as flexible intermediates. Therefore, the question to be treated briefly in this paper is: 'What could be the consequences of such a novel issue in a context of relevant physical phenomena, if discrete network dimensions are assumed to be of a visualizable order?'

To start with, at least two mysteries could in principle be made **causal** by it:

- the famous double-slit experiment of Thomas Young (1773-1829), if time-separated single bosons, e.g. photons, or fermions, e.g. neutrons, are applied, and
- the phenomena relating to split-photon entanglement.

Recently, Anton Zeilinger [7] gave a description of a double-slit diffraction pattern of cold neutrons of a wavelength of 2 nm. Behind a **third** slit in the detection plane, parallel to the **double** slit (slit widths: slit one 22 and slit two 23 microns; slit distance: 104 microns), neutron transmission is measured as a function of place for a certain length of time at every measurement position. The time scale of the emitted neutrons is about two seconds time interval between two emissions. Nevertheless, a clear diffraction pattern is observed. A reliable top experiment of a physical mystery. And the mystery comprises the profound question: 'Why does a later neutron have any knowledge of an 'unseen' previous one?' If the possibility of self-interference of a **particle** through two slits evoking a diffraction pattern is for the time being excluded (but see below), the answer is basically straightforward: there must be some 'causality' effect, in other words, somewhere an **imprint** with a **memory function** must govern this empirical situation, most probably an imprint (or influence) of a dimensional order of the particle's size or wavelength.

Ordered network-framework structures

Network frameworks of space/time levels suggest the following explanation for the diffraction of particles behind a double slit. The slits function as transducers, transducing particles arriving recta linea into diffractively scattering ones, more or less in the crystal-optical-lattice sense. Space networks can be thought of as invisible (micro)dynamic entities having affinity to electromagnetic radiation. This affinity may manifest itself as an inducible space-level imprint phenomenon, having a memory function for (in principle) an undefined length of time. Photons in the slit are thought to excite not an electromagnetic wave but a **space-level lattice-like network,** in such a way that the photons remain energetically intact. In this sense Fig. 1a shows a thought-defining situation before electromagnetic imprint, Fig. 1b one after imprint of a first slit, and Fig. 1c one after imprint through both the first and the second slit by diffracted, but e.g. time-delayed, photons, which penetrate the same area.

The causality here is salient; three effects play a role:

- the photon-transmitting slits are going to constitute a three-dimensional space-level network, or rather a lattice;
- two slits are necessary to form a diffractive space-level lattice for $photons_1$ (from slit one) on $lattice_2$ (constituted by photons through slit two) and $photons_2$ on $lattice_1$ and
- the superposed space-level lattices scatter the penetrating photons, e.g. in a crystal-lattice/X-ray way.

The final result is a photon (or neutron) diffraction pattern. Given the fact that space-level lattices are thought to be time-independent, the moment of arrival of the photons is unimportant. This (hypo)thesis was foreseen in 1993 without any network-theoretical background. For, under comparable circumstances Greenberger, Horne and Zeilinger [8] alluded to it as a **'virtual crystal'**. What is added here, is that the supposed virtuality could be more a **network reality** than a **crystal virtuality**:

First argument of plausibility.

Such diffractive patterns are thought to be time-independent. A most interesting experiment now would be to apply a double-slit run with a non-coherent source (not a laser), which never has both slits open **at the same time**. In such a case a diffraction pattern should be measured. A 'delayed-slit' experiment instead of a 'delayed-particle' one. But both delay functions applied together would be even more convincing.

This issue of non-simultaneously both slits open has been investigated theoretically [9] [10] and experimentally [11] [12]. The latter not in the simple way proposed here (the employed source was a laser and anti-phase modulation [11] or a two-photon entangled cascade [12] case). The results seem to confirm the basic assumption of diffraction, but it should be added that they are actually dealing with a combination of coherence/entanglement and diffraction [11] (see below). Let us take as a starting point the type of double-slit experiment described by Zeilinger [7] with two seconds mean time delay between two neutron emissions. Now place a **fourth** slit before slit one or slit two and switch the fourth one as a function of time between the two slits. This should result in diffraction.

If a network framework may show something like a decaying diffraction phenomenon, a following **most interesting aspect** could possibly be measured. Give the switch a position midway between the two slits so that the slits can be kept closed for a certain length of time: t_{c1}. In such a set-up measurements can be made as a function of t_{c1}, of the open slit time of slit one: $t_{op,s1}$, of that of slit two: $t_{op,s2,}$ for the cases $t_{op,s1}$=$t_{op,s2}$ or $t_{op,s1}$ unequal to $t_{op,s2}$.

A next question concerns the functionality of a slit: 'Generally speaking, do we know of phenomena in which a slit could function as a lattice generator?'

a. Well, let us consider the following as possibly a somewhat **comparable** circumstance for such a phenomenon. In **gas dynamics** we encounter subsonec, transsonic and supersonic waves. In electromagnetics (light) we encounter sublumenic (the light equivalent of subsonic) waves: for, in dispersive media with a refractive index n, the sublumenic velocity equals c/n and further (trans)lumenic waves (velocity c) exist in vacuum (ambient). Now, if a space network could act in a manner comparable to that of a gas in gas dynamics, then a photon could evoke a translumenic **network-wave behind a rim**; like a two-dimensional shock wave, curiously enough, creating behind a rim a large whirl, composed of smaller whirls in its curl, and those again composed of even smaller whirls and so on, see Fig. 2.
b. Such a gas-dynamic whirl is created at the dividing line of the wedge, where the shock-wave is partially transmitted and partially reflected. A similar phenomenon might happen if a photon were to entail a space-network front wave whose radius of action becomes much larger than that of the photon itself. In such a case a **point-like structural network front wave** might be partially reflected

and partially transmitted, resulting in the diffracting whirls at the dividing rim. In such a case the resemblance to a shock wave behind a rim might be striking. And if the radius of action of such a structured network wave behind the rim were to be broader than the double-rim width of a sheet, a form of self-interference might come into play from the **rear side**, not the front side. Figure 3 gives an example of such a phenomenon in gas dynamics, where the whirls, however, do not interact.

c. But in the case of a photon, we do not have a 'shock-wave' **plane**, for a photon acts as a 'shock-wave' **point**. And if we have a single slit, i.e. a **double rim**, this might act as a local two-sided generator of such a double network wave; therefore, a *double slit* acts as a *double double rim*. But now a second question arises: 'What might evoke such a double wave in a space network?' If this could be a standing wave pattern, consisting of something like nodal points (e.g. the whirls mentioned above, but now rotating in a space network devoid of energy, i.e. of absorption of electromagnetic energy, possibly like vortices in a superconductor), then they might create a space-network lattice, with the 'nodal points' representing the scattering points of a space-network-framework lattice. Behind the rim the impinging/passing photons function as point sources of a local space-vortices generator. The next question is: 'Do space networks conform to Bose-Einstein statistics like photons and superconductivity?' If they do, that would enhance the plausibility of this issue.

d. **A verifying experiment**
If we assume that a rim can produce some type of trans1umenic wave, then a small *sheet*, having a width equa1 to the usua1 slit distance, shou1d create immediately behind itse1f a type of diffractive network framework from both sides; see Fig. 3. For a sheet is basically a doub1e slit with outsides ad infinitum. The resu1t may be that a diffractive pattern will be measured or something e1se, dependent on the inf1uence of the outside rims in the case of a double double rim.

e. Maybe such whirl complexes are self-constructing to a type of lattice, basically not too different from an ionic one (also a moving/spinning entity) as known from X-ray diffractive materials. Then Zeilinger [8] was correct in previously referring to it as a lattice (see the first argument of plausibility). For if the sheet's width is smaller than the extension of the primary gas-dynamic

whirls from both sides (i.e. both rims), a situation may arise in which both whirls' clusters overlap and self-construct a network of a **point-like** whirling structure, somewhat comparable to the **line-like** gas-dynamic one, as can be seen in figures 2 and 3.

f. It should however be added that gas-dynamic approaches to this issue have in the past been proposed in the literature, but they were never really accepted.

Dynamic spin-network structures

A1bert Einstein (1879-1955) described [13] [14] stimulated emission in 1916/1917. In the 1950s and 1960s this theory found application in laser physics. Four of its very special correlated radiation properties, which are at least va1id for high-quality flat-mirror gas lasers [15], shou1d be mentioned here:

- coherence, i.e. photons congruently mutually attach to each other so as to have an optimum phase correlation (spacetime-network determined?);
- sma1lness of laser line width (about 5 kHz), being much smaller than the Doppler-broadened width of the optical transition (about 1000 MHz), and even smaller than that of the Fabry-Perot cavity (about 4 MHz) (time-network [16] contracted?);
- minimum divergence of the geometrica1-optically diffraction-limited laser beam, (cavity-determined, space-network contracted?), and
- fixation of its linear polarization [17,18] (cavity-determined?).

Such strong1y coupled laser beams have a most intriguing property. In a well-adapted non-linear external medium a laser beam may show additivity and divisibility, i.e. its frequency can be doub1ed, tripled, mixed, ha1ved [19] [20] etc. So, light as a partic1e is transformab1e through up-conversion, down-conversion, even up-and-down-conversion. The latter has been demonstrated in a short, stable, tunable gas laser in which two modi of frequency, f_1 and f_2 (f_2 being larger than f_1), were found to give rise to combination tones (optica1 overtones) of frequencies $2f_1$-f_2 and $2f_2$-f_1 in a cavity-internal anomalously dispersive medium [21] [22] [23] (in an entangled state?).

This brings us to the general question: 'Could laser radiation be represented as being confined/contracted in a moving (spinning?) network framework?' Or, 'Cou1d stimu1ated emission be the driving force for radiation amplification and, moreover, cou1d, within the optical cavity, radiation be wave-congruently, network-congruently and resonatingly the

contracting driving force for the 'finesses' of coherence, divergence, line width and polarization in a type of network-framework set-up?'

So, it would be causal and understandable for stimulated emission in a contracting framework to resonatingly form a bridge between network entities, and that in two significations: energetically and spacetime-chronically. Resonant network-framework action evidently drives the 'finesses' which are not affected by the quality of the optical cavity alone, as once thought, but the latter certainly co-drives it:

Second argument of plausibility.

Final general remark: in the 1980s and 1990s single-photon phenomena were studied in greater detail and frequency down-conversion, e.g. halving, and up-conversion, e.g. doubling, were realised, creating bar-bell-type coupled twin-photons as a **single entity** (see below), inherently having different wave functions in a most strongly correlated, rigidly anchored way, which, as already mentioned, was called *entanglement* [24] [25].

Provided with the knowledge we think a physical picture allows us to assume, there is a dynamic option for a plausible solution for it via interaction and feedback within a **spacetime-level network**.

Entanglement

Serge Haroche, professor at the Ecole Normale Supérieure in Paris, remarked [26] that the wave function of a pair of particles, flying apart from each other, is entangled into a non-separable superposition of states. But the quantum formulation asserts that detecting one of the particles has an immediate effect on the other, even if they are very far apart.

Again a mystery in physical optics. And the obvious question is: 'Which causality principle might form a fundamental basis of measurable, mutually correlated, bar-bell-type-coupled, spatially separated photonic twins, i.e. entangled photons?'

It is conceivable that entangled photons, proceeding at the speed of light (in vacuum), induce a spacetime-level coupled network [27]. This is indeed the case with twin-photons as soon as they are split into a non-linear phase-matched, birefringent medium. Consider this spacetime-level imprinted trace as an *imprinted string* [28]. Now, as soon as one of the photons is annihilated (say by measurement), the mutual correlation disappears. At that moment the entangled circumstance is cancelled, but probably not yet the spacetime-level-imprint trace. Therefore one might imagine that the spacetime-level imprint annihilates itself like a recoiling string.

A spacetime-level network

So, spacetime too is assumed to have a discrete spacetime-level network. And it is quite conceivable that the bar-bell-type-coupled entangled photons remain imprint-correlated via the spacetime domain, possibly undisturbed by matter and space. Fig. 4a shows the entanglement imprinted linea recta in the spacetime domain, Fig. 4b a situation immediately after de-entanglement of one of the twin photons with the spacetime-level imprint partially annihilated. In Fig. 4c de-entanglement is complete. The velocity at which annihilation occurs is an open question. All this suggests an entangled photon pair to an entity to be considered as a single particle but now in the broader sense of the word.

Accordingly, experiments have already (1999) shown, without reference to any string or network theory, that, if entangled photon pairs create a diffractive pattern by one cluster of such a pair passing a double-slit, its twin cluster, too, will, even without a double-slit in that twin-beam(!), exhibit a diffractive image as would be expected in the case of a single rigidly anchored entity, e.g. a dumb-bell or rather a bar-bell-type particle (see e.g. Ref. 7, his Fig. 4 and our Ref. 29). A string or loop quantum gravity consequence? Curiously enough, in Ref. 8 this particle circumstance was already referred to as a **single entity**, called a **'two-photon'**:

Third argument of plausibility.

The following experiment may provide some insight into the influence of solid material on a spacetime-network connection. Place a metal wall between the two measuring sites of twin-beam-one and twin-beam-two, perpendicular to the line of connection, and measure the influence on the diffractive pattern in the double-slit-free twin-beam.

After de-entanglement of the photons in double-slit twin-beam one, the diffractive circumstance in slit-free twin-beam two must prove to be cancelled too, exactly in agreement with the measurements (see again Ref. 7, his text and his Fig.3 for the experimental conditions):

Fourth argument of plausibility.

A most interesting measurement, **after de-entanglement** in beam one, would now be the measurement of the decay time of the diffractive pattern in the slit-free twin beam as a function of distance from the splitting source, exceeding the de-entanglement distance of beam one. If no diffractive pattern is found anymore, this must mean that its de-entanglement has taken

place at the same unique moment without any time delay: an unparalleled fact in velocity (at a superlumenic speed?). But if it (or something else) is found, a novel basic annihilation velocity feature of a spacetime-level network would be a unique result.

All this brings us to some *possible* ways of physical thinking, which will be briefly characterized below.

Generally speaking:

- network frameworks are intermediates for standard dependent variables; networks have discrete space/surface/time/ spacetime levels; they may be a key function for causality;
- it is assumed that such networks in space/surface/time/spacetime can develop into visualizable dimensions to accommodate observable phenomena [30];
- a physical-optical resonance is a reflection of a finesse's constructing/contracting network; stimulated emission together with coherence of the emission-stimulated radiation in a lasing cavity is such a phenomenon;
- network adaptability and congruently network-contracting interconnectivity (by level systems) to a greater extent determine entity 'interweaving', e.g. resonatingly inside a laser cavity in space, time and spacetime by light and matter;
- a photon is a moving (spinning?) [27] spacetime-network entity whose additivity, divisibility and transformability of frequency manifest some of its own energy network (hν!), i.e. frequency network and hence its visualized time-network framework;
- light's frequency transformability is possibly an example of visualizable characteristics of a network-framework item;
- most probably coherence does mean entanglement and entanglement does mean coherence: coherence may be a longitudinal spacetime-network-entangled phenomenon, being a composition of electromagnetic energy, in principle behaving itself in free space as a perpetuum mobile; twin photons are, from a frequency-transforming viewpoint, entangled by a transverse spacetime network, possibly in principle behaving itself in free space as a perpetuum mobile:

Fifth argument of plausibility.

- Inside a laser cavity lasering energy is evoked by stimulated emission, but the ‘finesses’ of its frequency’s line width, beam-divergence,

coherence and polarization are brought about by conformity contractions of a combined time network, space network and spacetime network, co-driven by the cavity's quality; the polarization (perpendicular) direction(s) is (are) exclusively determined by second-order quality effects of the cavity, e.g. by some misalignment of the mirrors or by the earth's magnetic field;

- triple entanglement: combination tones (optical overtones, see above and Fig. 5) as found in short stable gas lasers [21-23] may be governed by three types of entanglement:
  a. as to their geometric energetic shape, by a space-network framework, driven by stimulated emission of radiation in an inverted population of a local-intracavity excited, non-linear, anomalously dispersive medium of ions (the modi of frequency $2f_1 - f_2, f_1, f_2, 2f_2 - f_1$ must be optical-path-length adapted inside the cavity),
  b. as to their specific frequencies ($2f_1 - f_2, 2f_2 - f_1$), by a time-network framework, driven by the same non-linear intermediate,
  c. as to its coherence, by a spacetime-network framework, driven by stimulated emission and all three co-driven by the cavity's properties, which all together function as a space, time, spacetime constructing/contracting generator:

Sixth argument of plausibility.

To the point:

- matter is sensitive to atomic networks driven by interatomic forces, e.g. in heteroepitaxy [31] and direct bonding [32], fulfilling causality;
- for flying past particles, a single slit (as a double rim) represents itself as a transmitter and, at the passing moment, as a generator of a nodal-point-like lattice-type space network;
- photons in a double-slit or double double-rim experiment, under the right geometrical transmitting-generating conditions, can be diffracted, driven by a mutual self-producing space-network lattice, hence fulfilling causality;
- entangled photons do manifest themselves more as a single rigidly anchored entity in a multiform composition than a characterization of a duality of particles, coupled but not rigidly anchored;
- entangled photons remain a single entity as long as both frequency-transformed components continue to exist, driven by a spacetime-network framework, and hence fulfilling causality.

Basically:

- network-frameworks are probably much more prominent and indispensable in nature than ever thought; so space/time/spacetime discontinuity embedded in physical reality will once defeat its prepossessed continuity, while network theories, including those of string and loop quantum gravity theory, combine in a network-type way dependence of physical reality;
- duality: during diffraction in a network framework, particles most probably have and retain a particle's character, but their evoked network-framework structures have and retain, as an intermediate for particles, a character in conformity with a diffracting network. If so, that would be a crowning piece of a long-standing enigmatic physical problem:

Seventh argument of plausibility.

- Light is much more exclusively sensitive than the human eye; it senses network frameworks which the human eye fails to see;
- string as well as loop quantum gravity theory may in this respect once become a novel impact of (or for) a great theoretical invention, if not victory, providing a much more general picture of an observable physical reality than is now accepted. Could this finally be considered a string/network-upgraded 'eather theory' as once assumed to exist by J.C. Maxwell (1831-1879)?

Final question:

- are all entities in nature network-framework related?
  Examples: electric fields (are quantum dots a reflection of a network framework?), electromagnetic fields (photons; see above), force, gravity, magnetic fields (are magnetic bubbles a visualized reflection of a magnetic network framework?), space, time, etc.

Table I gives a survey of network frameworks as they are **assumed** to be related to entities discussed above.

The experimentalistic view expressed in this paper suggests that network frameworks are far more prominent in physics than previously thought, though it should be admitted that the string and loop-quantum-gravity

contribution is merely theoretical. But the verification of a theory is ultimately **based** on phenomenological observations, i.e. physical reality.

This paper is an **attempt** to combine theoretical results and existing measurements in order to arrive at a better understanding of what may really have happened. It may be a rational confrontation point for fine future theoretical as well as phenomenological physics.

It was once believed that the physical mystery of light and photons had been unravelled. Physical optics presented their clear wave-type characteristics, so familiar to all of us. But upon reflection of the hypotheses presented above, according to which electromagnetic energy and network frameworks are thought to be interrelated, light and photons appear to be an even greater mystery than previously assumed.

That secret is still **nature's monopoly!**

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Table I

Most probable relations between some entities and network frameworks

Entity \ Network Framework	Time-network framework related?	Space-network framework related?	Spacetime-network framework related?
Electromagnetic energy(=hν)	Yes, light/photons	-	-
Geometrical energy distribution	-	Yes, see laser modi	-
Coherence and Entanglement	-	-	Yes, see laser radiation and twin photons
Frequency transformations	Yes, under transformation of the time-network composition	-	-
Polarization	-	Yes, photon-internally energy-structured related	-
Higher-order Modes in a laser cavity	-	Yes, geometrically energy-distribution related	-
Twin photons (entangled)	-	-	Yes
'Finesses' of laser entities concerned	Yes, for its line width	Yes, for its divergency	Yes, for its coherence

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[16] The Fabry-Perot interferometer is e.g. 'closed' by a pair of high-reflective loss-free mirrors (e.g. 99.6% reflection), consisting of several alternating high/low refractive-index quarter-wave layers. Does such a stack of layers show that light is a spacetime-level network which is time-interlockedly quarter-wave-networkwise reflected?

[17] In a single-mode laser the polarization is linear. Higher-order modes are sequentially, alternatingly, perpendicularly polarized. But higher-order modi in e.g. a short stable gas laser also have a geometrical aspect, so its broader physical consequences are more interwoven than a simple statement may suggest.

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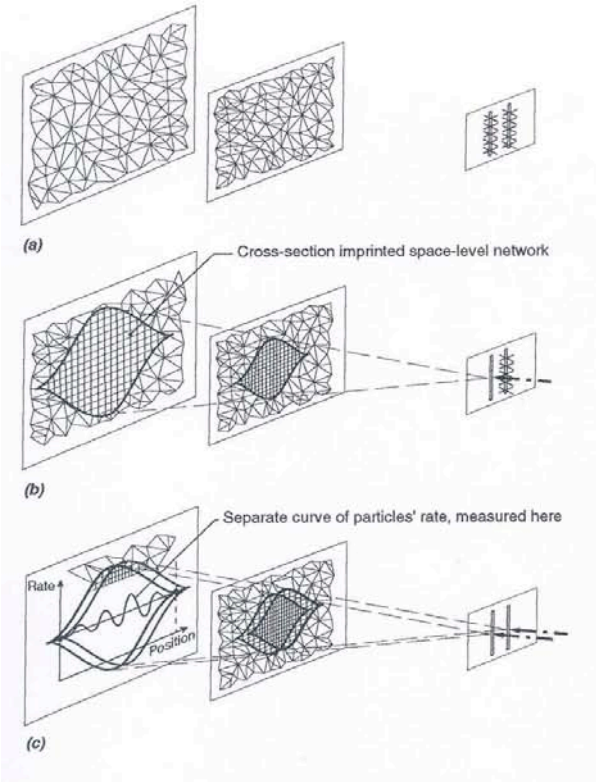
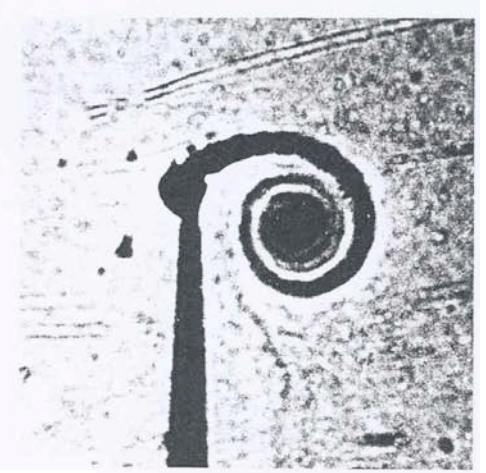


Figure 1
Thought-defining representation of e.g. photons, diffracted in a three-dimensional space-level lattice:

a. both slits obscured, no lattice silhouette visible in the two-dimensional surface-level cross-sections;
b. only one slit obscured; diffraction-pattern silhouette visible in the 2d-cross-sections;
c. double slit open; double diffraction pattern silhouette visible in the 2d-cross-sections; superposed, the curve of measured rate of particles as a function of in-plane position.



(a)

(b)

Figure 2

A two-dimensional Schlieren projection of a three-dimensional diffraction pattern of a shock wave, diffracted behind a rim.

a. A large rotating whirl has been formed, in which are clearly visible secondary whirls in the curl of the primary one and so on in the secondary whirls. The rim's height is about 8 mm.

b. Secondary whirls, developed from the primary whirl, are clearly visible.

Results of investigations at the Laboratory of Aero- and Hydrodynamics at the Technical University of Delft.

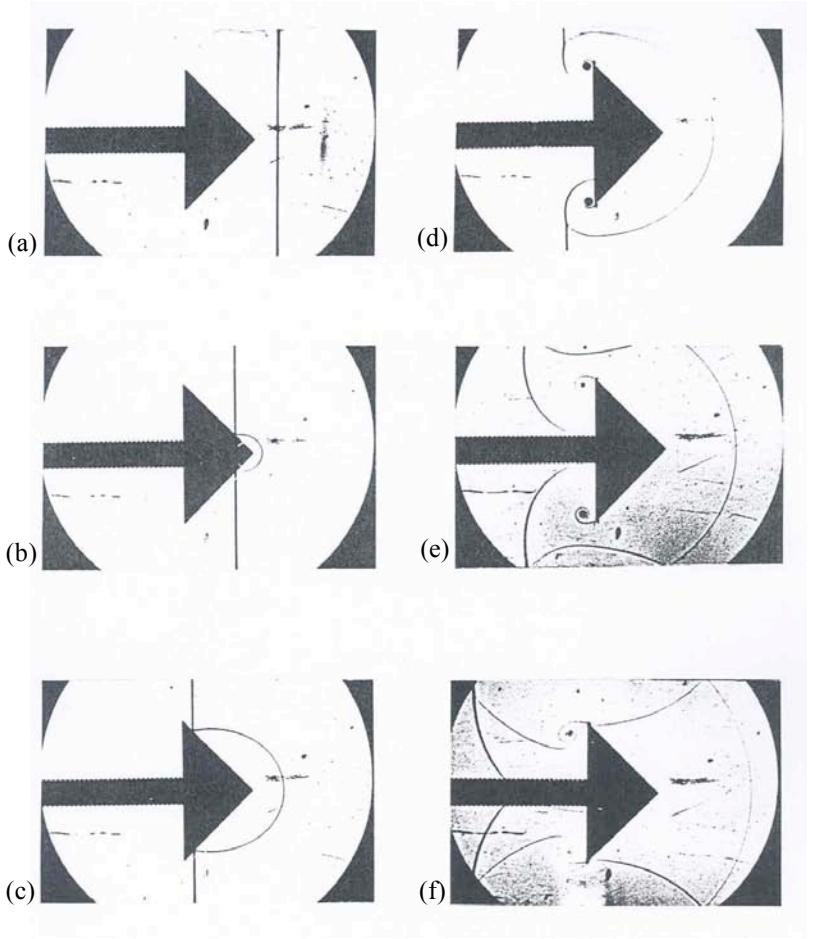


Figure 3
Diffraction of a shock wave, moving from right to left, around a wedge. The shock-wave velocity is about 400 m/s. Note the development of whirls behind both rims of the wedge.
Results of investigations at the Laboratory of Aero- and Hydrodynamics at the Technical University of Delft.

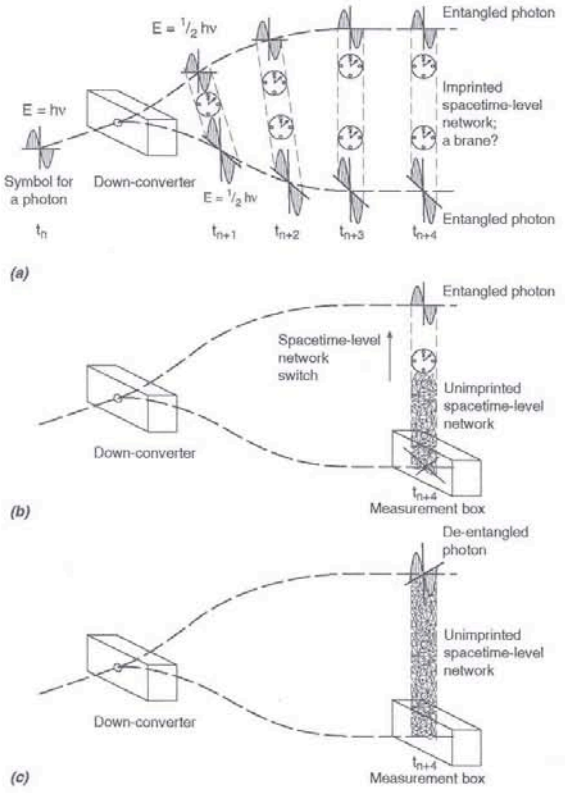


Figure 4
Thought-defining representation of a spacetime-level imprinted (structured) trace of entangled twin photons:

a. before annihilation of a twin photon, represented as a function of spacetime steps at t_n,...,t_{n+4};
b. after annihilation (measurement) of one of the twin photons: the spacetime-level trace has been partially annihilated;
c. the spacetime-level trace has been completely annihilated, bringing the remaining photon into its own degree of freedom i.e. into its de-entangled state.

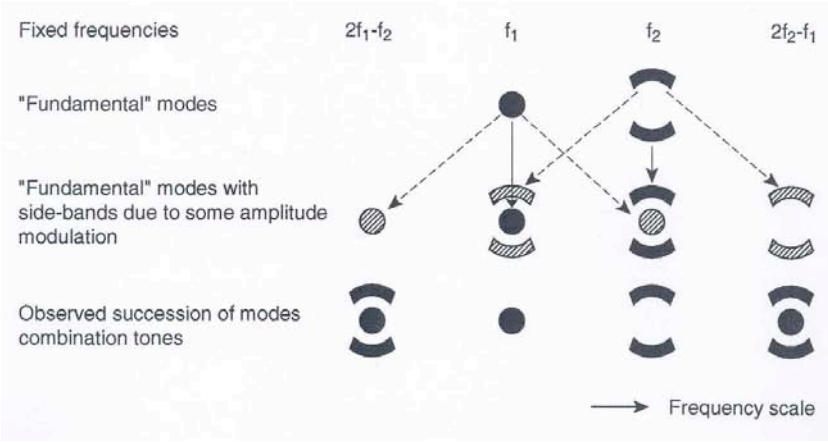


Figure 5
Schematic representation of two successive laser modi of different energy distributions in a short stable flat-mirror gas laser: next their geometrical composition in the case of a modulated circumstance and finally the geometrical composition as measured, evoked by a non-linear interaction in the active medium, representing the curious and rare phenomenon of geometrically discernable combination tones.