The photon - More physical reality than so far assumed?

Karl Otto Greulich Fritz Lipmann Institute Beutenbergstr. 11 D07745 Jena Germany

kog fli@leibniz.de www.fli-leibniz.de/greulich

What have we learned so far

- **In the first talk it was shown that interpretations of experiments used to develop the concept of the wave particle dualism do not work as they were thought to do.**
- **Single molecule experiments show that multi - atom / molecule light sources cannot emit isolated photons ingle molecules**

The next step

Arguments in favour of a point like, non dividable photon are not stringent.

the accumulation time argument has not yet been proven experimentally and

experiments thought to prove a non - dividable photon have been interpreted in a too handwaving manner.

A model of the photon as a cloud of charged matter
oscillating like a simple LC oscillator carrying the energy $h\nu$ is presented.

A radius of $r = \lambda / 2\pi$ and a spin of $1\ \hbar$ can be derived.

What the mainstream takes as physical reality

The photon is fundamentally a quantum mechanical object, and any model that fails to take this into account is very badly flawed. There is a huge body of research in quantum optics that demonstrates this. (A very influential mainstream physicist)

The EARTH is fundamentally a DISC, and any model that fails to take this into account is very badly flawed.

There is no experiment definitely requiring a particle like photon

- **In the development of the model of light essentially three effects have been thought to make it necessary to invoke a particle aspect of light.**

- **i) The photo effect.**
- **ii) The Compton effect.**
- **iii) The accumulation time argument.**

- **The first two arguments have turned out not to be sufficiently stringent to postulate a particle like photon.**
- **The photo effect only shows the quantisation of energy exchange between light and matter. The Compton effect can be well described with wave packets.**

- **For the accumulation time argument it will be shown below, that it's experimental basis is missing.**

The accumulation time argument

- At reasonable illumination intensities (for example sunlight) it would take milliseconds until the energy portion hn has hit a single absorbing atom / molecule. This accumulation time is much longer than the fly - by - time and thus the atom / molecule would never absorb.

- In the pre - single - molecule - spectroscopy era it was assumed, that even in a solid state detector the absorption process is accomplished by one individual (quasi) isolated atom. With similar reasoning as for the two molecule emission process it can be shown that this assumption is not allowed.

- Only if it were possible to excite a single (truly) isolated atom by low intensity radiation, the accumulation time argument were valid. So far, single atoms have, however, been excited only with high intensity illumination which in a very classical way allows for accumulation of the required energy.

What happens when the photon ..... hits a beam-splitter? Does it take both paths? That would contradict the first half of the Grangier experiment (Europhys. Lett. 1 (1986) 173). Does it take only one? That would violate the second half of the Grangier experiment, as well as many other single-photon interference experiments.

The 2007 paper of the Grangier / Aspect group has again tested the single particle behaviour of photons at a beam splitter.

A zero coincidence rate between the two paths would be expected, if the photon were non - dividable. The result is a non zero coincidence rate, which would indicate that at least a few photons were split. In the paper this is explained by experimental problems.

If so, the only solid interpretation is that we simply do not yet know how a single photon behaves at a beam splitter. Anybody who claims to konow that has to prove it in detail on the basis of clearly defioned experimental reality

Photons are dividable !!

V.Jacques, E.Wu, F.Grosshans,F.Teussart P.Grangier, A.Aspect, J.F.Roch 2007 SCIENCE 315, 966 - 968

When the beam splitter sends non dividable photons unambiguously into either path 1 or path 2, $N_{coincidence}$ should be zero.

Indeed $\alpha = N_{Trigger} * N_{coincidence} / N_1 * N_2 = 0.12 \pm 0.01$

This has been set with some handwaving arguments to zero.
If one does not accept this step, $N_{coincidence}$ is non zero, i.e

there is a fraction of photons which have been divided

What have we learned so far

- In the whole history of physics, a particle like, non dividable, highly localised photon has not yet been proven stringently enough to govern discussions on the nature of light.
- Therefore, there is no stringent need of invoking a particle like photon
- The surprising consequence is that there is no need to invoke a wave particle dualism of light.

The next step

Since the photon is a building block of light, an electromagnertic field, an attempt is made to construct a photon model which itself is made of an electric and a magnetic field --- an LC oscillator

The photon of quantum mechanics is non - satisfying

- **Hundred years of research on the photon have not succeeded in providing a satisfying model which explains experimentally known details such as it's energy or it's spin, not to mention details on it's shape or size.**

- **Albert Einsteins desperate sentence in the 1950 s *These days every Tom, Dick and Harry thinks he knows what a photon is, but he is wrong* (translated from German) has become famous and notorious.**

- **William Lamb (Lamb shift) has formulated it more drastically: *Only a comedy of errors and historical accidents led to its popularity***
  (1995 Appl.Phys.B, Festschrift on occasion of the 60. birthday of late Herbert Walther)

- **But mainstream physicists are sure:**

The photon is fundamentally a quantum mechanical object, and any model that fails to take this into account is very badly flawed. There is a huge body of research in quantum optics that demonstrates this.

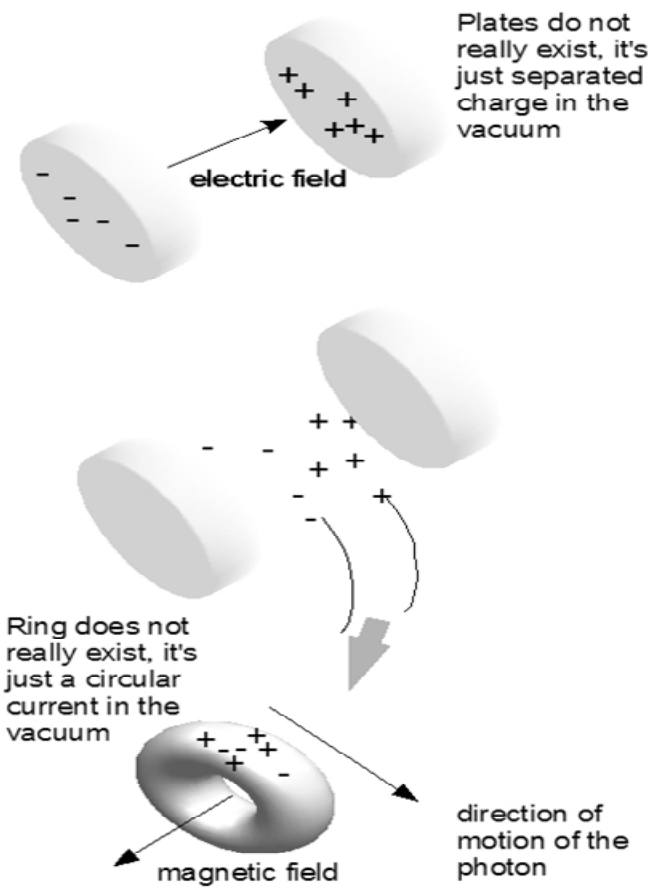
What do we really know about the photon

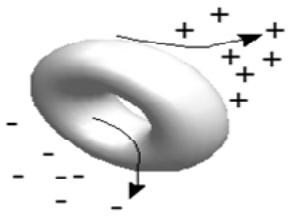
- Since Einstein's and Lamb's statements, nothing has changed.
- The photon is the result of field quantisation
- The photon can be described as a Fourier wave packet
- It is generated by a photon generation operator
- surprisingly little is known on details of light absorption and emission by single atoms or molecules The internal structure of such a photon has so far escaped experimental tests. An attempt has been made to characterize theoretically this "birth of a photon
- Two photons interfere (perhaps one with itself) with each other after travelling different paths in a double slit, Michelson - or Mach Zehnder interferometer. Do they really, or only their action ???
- **An attempt** (not new, but more quantitative)
- A model of the photon, which is the building block of electromagnetic radiation, as an emitter - antenna system, i.e. as a sort of LC oscillator.

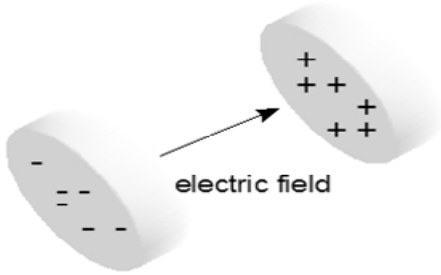
- **A photon which is the building block of an electromagnetic field and thus closer to physical reality than the photon of quantum mechanics should itself be made of such a field**

- **So far known photon models do not allow for this fact**

Physical reality of the LC oscillator model







The energy of any self similar LC oscillator is a function of its frequency and, surprisingly, the Planck constant

- One assumption has to be made: the oscillator has to be s self - similar, i.e. the spatial dimensions of the capacitor are the same as for the coil (F / d = A / l).
- Thus, $C = \varepsilon_o F / d$ and $L = \mu_o F / d$ $L / C = \mu_o / \varepsilon_o$ (1)

- The oscillation frequency of any LC oscillator is
- $f = 1 / (2 \pi \sqrt{LC}) = 1 / (2 \pi \sqrt{\varepsilon_o F / d \ \mu_o F / d}) = c\, d \ / 2 \pi F$ (using $c = 1 / \sqrt{\varepsilon_o \mu_o}$) (2)
- In the following the energy in the LC oscillator will be calculated. For that, it is useful to rearrange the definition for the fine structure constant

- $\alpha = 2 \pi k_o e^2 / h c = e^2 / 2 \varepsilon_0 h$ *Textbook definition of the fine structure constant*
- into
- $\varepsilon_o = e^2 / 2 \alpha h c$ $\mu_o = 2 \alpha h / e^2 c$ $\mu_o / \varepsilon_o = 4 \alpha^2 h^2 / e^4$ (3)

- The square of the energy in the LC oscillator can be formally written
- as the product of the maximum energy in the capacitor with that
- of the maximum energy in the coil, which are equal,
-
- $E^2 = 1/2 \ L I^2 * 1/2 \ Q^2 / C = 1/4 \ L / C * Q^2 * (Q * f)^2 = 1/4 \ \mu_o / \varepsilon_o f^2 Q^4$
- $E = \alpha Q^2 / e^2 h f$ (4)
- *Note: so far not a single assumption on a photon has been made*

The trick with which
$E = \alpha\, Q^2/ e^2\, h\, f$ becomes $E = h\, \nu$

When $\alpha\, Q^2/ e^2 = 1,$

i. e. when the total number of charges in the oscillator is

$1 / \sqrt{\alpha}$ * **the elementary charge**

the energy in the oscillator becomes

$E = h\, f$

Note that we still are speaking of LC oscillators, just of a subclass with a certain charge. Now we can claim that this oscillator describes a photon. We formally do this by writing, from now on

$E = h\, \nu$

Can such a crazy result be physical reality ??

At a first glance this result on the number of charge pairs appears to be strange.

$1 / \sqrt{\alpha}$ however is exactly the inverse of the coupling constant of Quantum Electrodynamics

or, in other word, the amplitude for a real electron to emit or absorb a real photon.

Thus, there is a relationship between QED and the LC oscillator model.

Even more: this result explains the fine structure constant α as the inverse square of the number of charge pairs in a photon.

The linear dimension of the oscillator follows solely from the assumption that $E_C = h \nu$

- $E_C = 1/2\ Q^2 / C = 1/2\ Q^2 / e_o\ F / d = 1/2\ \mathit{Q^2}\ 2\ \mathit{\alpha}\ h\ c\ _o\ F / d\ \mathit{e^2} = 1/4\ h\ c\ F / d$
- Using the finding above that the quantities in italics combine to 1 this can be re – written into
- $F / d = h\ c / E_C$ (5)
- Now a second assumption on the oscillator has to be made: the size of the capacitor has to be the same in all three dimensions, i.e. it has to be quasi - spherical (an assumption, which could have been put into the model *a priori*).
- F is then $r^2\ \pi$ and the length is 2 r, i. e. $F / d = r\ \pi / 2$.
- $r\ \pi / 2 = h\ c / E_C$ (6)
- As above, the only assumption is made that the energy of the photon is given by the energy in the oscillator, i.e. $E_C = h\ \nu$.
- $r\ \pi / 2 = h\ c / h\ \nu\ = \lambda$ or $r = \lambda\ /\ 2\ \pi$ (7)

Energy and the angular momentum

For such an LC oscillator, at a given time, all energy is in the coil.

The speed of the current is

$$v = 2 \pi r f = 2 \pi (\lambda / 2 \pi) (c / \lambda) = c$$

The oscillator's angular momentum M of the relativistic mass

$$m_{Photon} = h / (c * \lambda) \text{ is}$$

$$M = m_{Photon} * r * v = h / (c * \lambda) * (l / 2\pi) * c = h / 2 \pi$$

What have we learned so far

- No need to invoke a particle like ”photon”.
- Even light of a single emitter can be described as a sort of spatially extended wave packet and needs no non – dividable particle like ”photon”.
- Wave – particle dualism -- a technical dualism of light sources

- **An LC oscillator can formally model a local electromagnetic field.**

- **The relativistic photon mass is given by the energy in the oscillator.**

- **The oscillator’s s linear dimensions are λ / 2 π, its speed of propagation is c, and its angular momentum is 1 h / 2π.**

- **Transversal electric and magnetic fields, as in electromagnetic radiation, are required for the oscillator and thus for an individual photon described by such an oscillator.**

- **The formal charge, independent of photon energy, is e / $\sqrt{\alpha}$ where α is the fine structure constant and 1 / $\sqrt{a}$ the inverse coupling constant of quantum electrodynamics.**

The next step

The need for charge in a photon appears to be the nail in the coffin of the presented photon model.

Now it will be shown, that charge needs not to be correlated with mass.

Assuming an LC oscillator requires that some charged matter is oscillating in a spatially self - confining, self - propelling manner. Assuming such. a cloud of charged matter may appear, at a first glance, to be very speculative. However, it is in full agreement with the Maxwell equations, which imply that any electric field can only be generated by a true physical charge and a magnetic field by a true physical current.

Can massless particles be made of charge ?

- **Many believe : charged matter is necessarily correlated with mass, (One electron charge has one electron mass !!).**

- **For elementary particles, mass differences upon a change of one elementary charge range from –10.76 m_e in X baryons via –7.85 m_e in p mesons and less than 1 m_e in B mesons to + 9.39 m_e in D mesons,**
- **A difference in two electron charges between the negative and the positive form of elementary particles is often, though not always, related to a zero mass change.**

- **Thus, charge with almost any, including zero, rest mass is readily conceivable.**

The amount of charge in a photon

- **The maximum energy in the capacitor is $W = 1/2\ Q^2 / C$**

- **$Q^2 = 2\ WC = 2\ W\ \varepsilon_0\ r = 2\ W\ r\ e^2 / 2\ \alpha\ h\ c$**
- **with α = fine structure constant, e = elementary charge,**
- **h =Planck constant and c = speed of light.**
- **For a photon, $W = h\ \nu$**
- **$Q^2 = 2\ r\ h\ \nu\ e^2 / 2\ \alpha\ h\ c = e^2\ r\ \nu / \alpha\ c = e^2\ \lambda\ \nu / 2\ \pi\ \alpha\ c = e^2 / 2\ \pi\ \alpha$**

- **$Q = e / \sqrt{2\ \pi\ \alpha} = e\ \ m_K/m_\mu$**
- **The right (blue) part is the result of a so far solely empirical observation that $\sqrt{2\ \pi\ \alpha}$ is exactly the ratio of the masses of the K Meson and the μ Lepton, perhaps indicating that the approach of an LC oscillator might also describe these elementary particles.**

Charge e^- needs not to have one electron mass m_e

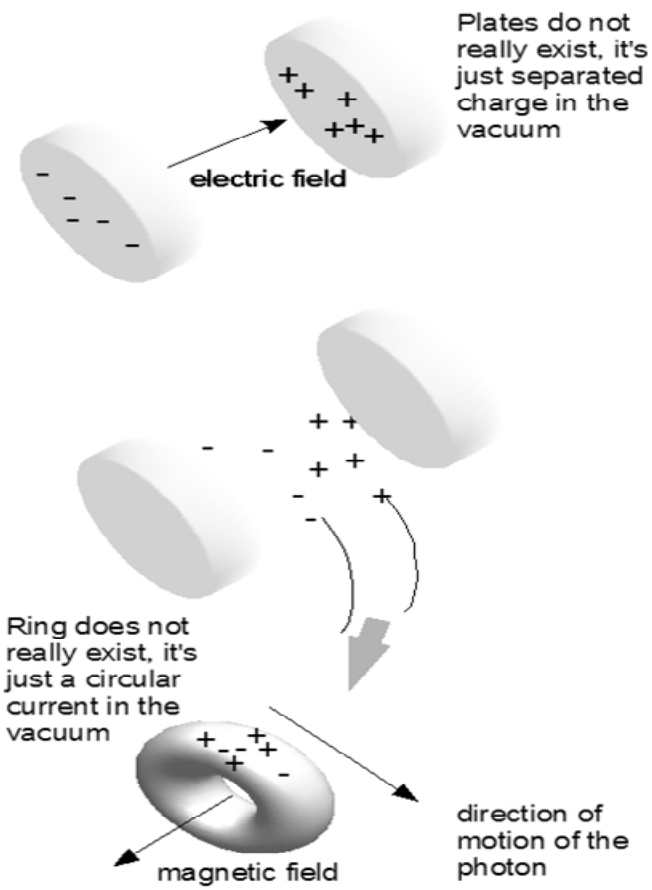
Change of charge of elementary particles by 2 often results in zero change of mass

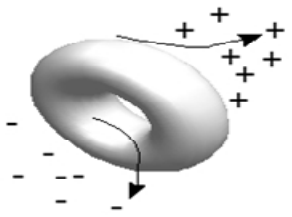
- We are used to correlate the electron charge e^- with the electron mass m_e. This is obviously not generally true, since for a number of elementary particles changes in charge by ± 1 lead to almost arbitrary changes in mass. Change by ± 2 elementary charges often has $\Delta m = 0$

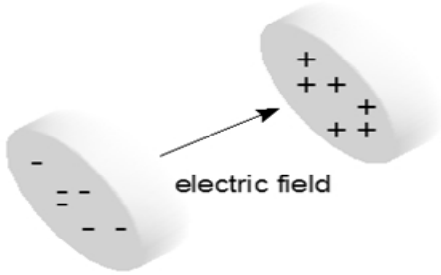
	positive	neutral	negative
pi -Meson -8,-16	- 8,95 m_e	264,15 m_e	- 8.95 m_e
K -Meson -8,-10	+7,77 m_e	966,11 m_e	+ 7,77 m_e
Proton / Neutron 36,3	- 2,55 m_e	1836,12 m_e	
Σ Baryons -10,-20	- 6,40 m_e	2333,93 m_e	+ 9,41 m_e
Ξ -10, -10 1.64 < 2.9		2573,05 m_e	+ 12,68 m_e
D Mes. -13,-13 10.4 > 4,1	+ 9,39 m_e	3648,92 m_e	+ 9,39 m_e
Σ_c -22,-22 -22 2,95..1.43..2,95	+0,59 - 1,76	4798,82 m_e	
Ξ_c -22, -22 4,42 > 1,12	- 10,76 m_e	4837,18 m_e	
B Mes. -13,-13 16,71 > 15.36	- 0,78 m_e	10330,72 m_e	- 0,78 m_e

- Either only charged or uncharged : ε , ρ, ω, Λ, Λ_c^+, Ω^-, Ω_c, Λ_b, $D_s^\pm$
- Exponent of lifetime in seconds -19 ,-24, -23 -10 -13 -10 -13 -13 -13

Physical reality of the LC oscillator model







What have we learned so far

No need to invoke a particle like ”photon”.

- Even light of a single emitter can be described as a sort of spatially extended wave packet and needs no non – dividable particle like ”photon”.
- Wave – particle dualism -- a technical dualism of light sources

- An LC oscillator can formally model a local electromagnetic field.
- The relativistic photon mass is given by the energy in the oscillator.
- The oscillator’s s linear dimensions are $\lambda / 2\pi$, its speed of propagation is c, and its angular momentum is $1\ h / 2\pi$.
- Transversal electric and magnetic fields, as in electromagnetic radiation, are required for the oscillator and thus for an individual photon described by such an oscillator.
- The formal charge, independent of photon energy, is $e / \sqrt{\alpha}$ where α is the fine structure constant and $1 / \sqrt{a}$ the inverse coupling constant of quantum electrodynamics.

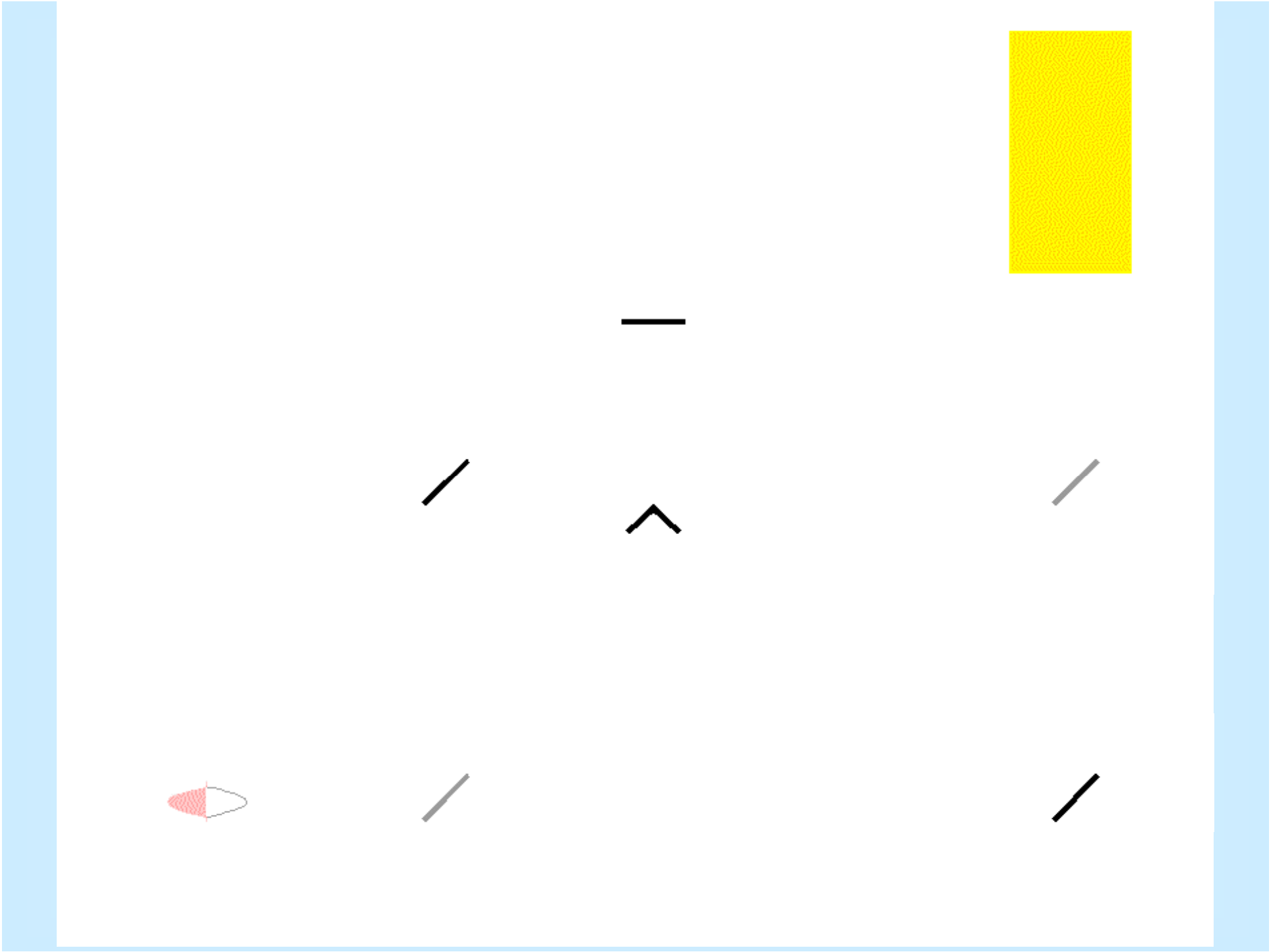
- **Invoking electric charge in the massless pghoton does not contradict physical reality**

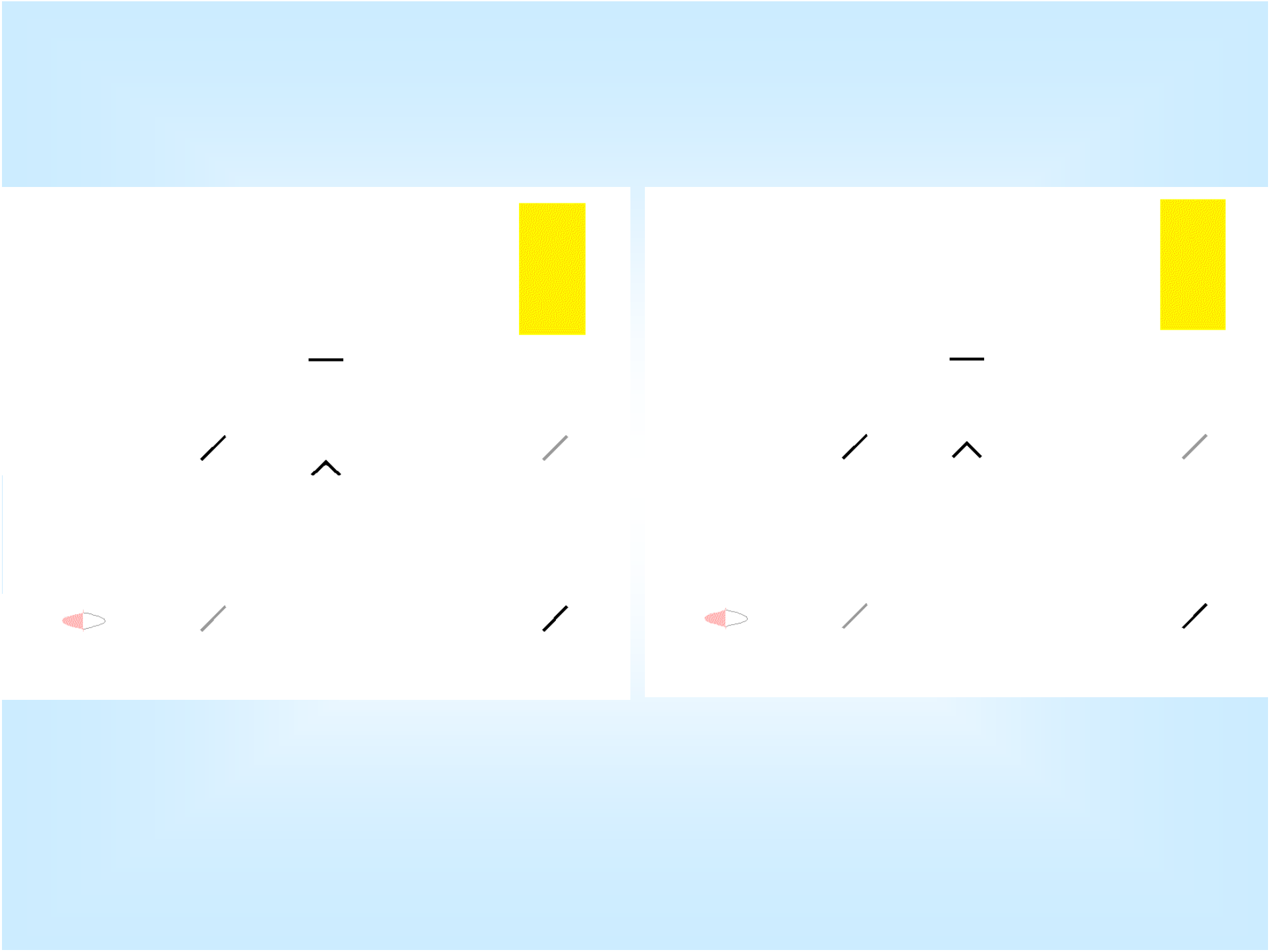
The next step

The results of double slit etc. experiments can be explained with the new photon model without invoking a wave particle dualism of light

A re - interpretation of double slit experiments etc.

- We have now a photon roughly resembling the wave packets of quantum mechanics which are dividable and require space
- Much more experimental reality of a photon can be explained
- Explaíning double slit experiments no longer requires wave parrticle duality





Summary

No need to invoke a particle like ”photon”.

- Even light of a single emitter can be described as a sort of spatially extended wave packet and needs no non – dividable particle like ”photon”.
- Wave – particle dualism -- a technical dualism of light sources

- An LC oscillator can formally model a local electromagnetic field.
- The relativistic photon mass is given by the energy in the oscillator.
- The oscillator’s linear dimensions are $\lambda / 2 \pi$, its speed of propagation is c, and its angular momentum is $1\ h / 2\pi$.
- Transversal electric and magnetic fields, as in electromagnetic radiation, are required for the oscillator and thus for an individual photon described by such an oscillator.
- The formal charge, independent of photon energy, is $e / \sqrt{\alpha}$ where α is the fine structure constant and $1 / \sqrt{a}$ the inverse coupling constant of quantum electrodynamics.

- Invoking electric charge in the massless photon does not contradict physical reality

- Double slit experiments can be explained without wave particle dualism

- Thank you