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A THEORY OF THE PHOTON STRUCTURE

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龚祖同院士在二十年前运用初等量子理论提出一种光子结构理论框架，并以此解释了折射、反射、干涉、衍射和布儒斯特角下的线偏振.论文在本刊前身《高速摄影与光子学》上发表，当时本刊为内部发行的纯技术杂志，载体为中文，加之印数过少，故反响不大.现以英文稍加订正发表，除缅怀龚先生而外，主要是期望有更多的理论模型出现，用以预言或解释一些非经典现象与效应，促进光子学这门理论性和技术性均很强的学科飞速发展.

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Abstract In this paper a theory of photon structure is proposed using the elementary quantum
theory.It is thinked a photon consists of the positive and the negative photinos ε^+ and ε^-.
Keywords Photon;Structure;Photino

光子结构论

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摘 要 本文利用初等量子理论提出了一种光子结构模型，认为光子由正负光微子ε^+和ε^-
组成，并利用此模型解释了一些经典光学现象.
关键词 光子；结构；光微子

0 Introduction

In 1930 year professor Zhao Zhongyaopublished《the absorption coefficient of γ-ray in the lead》,provided a method and the data for γ-ray measurement[1].The November 1930 year professor Zhao Zhongyao published also《the anomalous scattering of γ-ray》[2],he pointed out the wavelength of anomalous scattering γ-ray is almost monocolorific,its

wavelength is 22.5 x.u(22.5×10^{-4}nm),and the corresponding energy is 0.5×10^{6}eV (8.01088665×10^{-14}J),alsopointed out the radiation is from a heavynucleus,later it is practically demonstrated the radiation is e^{+},e^{-} annihilation radiation.

In 1933 year Rutherford explaination of Zhao Zhongyao and Gong Zutong experiment[3], two different wavelengths of e^{+},e^{-}pairannihilation measured by Gray-Tarrant[4] and Gong Zutong[5],as well as the annihilation cross-section formula of Heitler[6] had all pointed out γ -ray in a nucleus field has generated e^{+},e^{-}pair,and the annihilation of e^{+},e^{-} pair has generated the photon.From these theories and experiments the photon is consisted of $\varepsilon^{+}$and ε^{-}.Mao Zedong spoke:the electron also can be divided,and can be divided infinitelly[8].Based on the above-mentioned inspirations,using bionic genitics,the expanded idea have been pointed out for Bohr hydrogen atom luminescence model,I consider that photon structure is similar to hydrogen,
taking ε^{+} as the centre,taking ε^{-}as the satellite, ε^{+}, ε^{-}can be called the photino.

The photon itself carries electromagnetic field.Because of ε^{-} rotates around ε^{+}, anelectrical field is generated,and travels(progresses) by a helical in space,the helical is projected on a plane parallel to the travelling
direction,and a sine curve is become.Alsobecause of ε^{-}, ε^{+} travel all with velocity c, amagnetic field H is generated,H direction isvertical to the electric field E,it is the Poyntingtheorem－c,E,H each other are vertical.Due to the photinos travel rotatonally,they possess phases,therefore the interference,the diffraction and the polarization can be explained also.The Zeeman effect,the Stark effect can be explained still.

1 History

In 1 7 th century Newton proposed thecorpuscle theory of light.According to histheory,light velocity in dielectric ought to have possessed faster than in vacuum.But Foucault experiment result is quite the contrary to that.Max Planck had researched the black bodyradiation law,and discovered that one mustexplain the radiation formula by using quantum theory.Plancks′ radiation quantum theory had been used on luminescence of hydrogen atom by Bohr,the huge achievement.Einstein successfullyexplained photoeffect by using the quantum
theory of light.The quantum theory of light has been generally recognizing by the science circle,and become a base of modern physics.Compton-Wu Youxun effect lively depicted the quantum properties of light,and verified the energy and the momentum are conservation in the collision process of light-to-electrons.The photon-this particle have no a static state,its velocity is c(＝2.99792458×10^{8}m/s) in vacuum,its energy is $h\nu$ ($=mc^{2}$),its impulse is $h\nu/c$, it can beabsorbed to enhance energy of an absorber,it can be scattered,a part of self energy is transfered to scatterer.To activate electrons and to emancipate the bound electrons are went using energy i.e.the exiton or the free atom is generated.Any body is over absolute zero,all the photons are endlessly emitted or absorbed,the photons act as the courier from infinitely distance in theuniverse,we can see a faraway celestial body all by the photons.The photon is not in need of a static mass,it is not in need of an acceleration,because of it is not static

perpetually and ittravel with the constant velocity.The photons possess the phase velocity and the group velocity in a medium,and possess the extremely largerwavelength range.The photons possessing
shorter wavelengths can become one particle,and the photons possessing longer wavelengths fill the sky.One matter of this kind participates in our daily life,whether or not can it possesses a structure?The neutrino in the fundamentalparticles is considered to possess the somecommon properties with the photon;Theneutrino is neutral,and fly with light velocity[7]. This is the first enlightenment.Mao Zedong spoke:the electron can be divided also,and can be divided infinitely[8].Also it stands to reason the photon can be divided.This is the second enlightenment.

November 1933,for a letter of "Interaction of Hard γ-ray with Atomic Nuclei" of ZhaoZhongrao and Gong Zutong[3],E.Rutherford pointed out Zhao and Gong test ought to add an evidence on γ-ray generates the positive and the negative pair e^+,e^- in a strong field of neclei.In addition,on 1933～1934,Gray D Tarrant[4]
measured γ-ray wavelengths are 27x.u and13.5x.u,the data of Gong[5] are 25.4x.u and13.8x.u.The longer is the wavelength which isgenerated by e^+,e^- pair annihilation when stop,and the shorter is the wavelength which isgenerated by annihilation of e^+ and Compton
recoil electron traveling with a same velocity in a same direction.This can be explained as the monophoton annihilation,i.e.this annihilation generate only one photon.Viewing together the two tests,it is that γ-ray in the strong field of nuclei generates e^+,e^- pair,and e^+ life is very short,also annihilation is to e^- and,generate the secondary photon.i.e.one γ-photon $h\nu$ cantransform to e^+,e^- pair,and e^+,e^- pair also can transform to photon pair or monophoton.

2 Luminescence model ofhydrogen atom

Bohr′s luminescence model[9] of hydrogen atom show as Fig.1.One sheel electron fly from the orbit of n＝3　0 to the orbit n＝2 along ahelical way of the hairspring type,and emit one photon $h\nu$ halfway.

The model can be put forward the following questions:

1)The momentum of photon is $h\nu/c$,is one from where?It must have given by the transiting electron,but the electron on an orbit have not the vertical-to-orbit momentum on orbit plane.

2)In this process the energy and themomentum of photon ($h\nu$) are undoubtedly givenfrom the transiting electron,but the electron electrifies the negative electricity,also thegivable is only the negative electricity,yet the photon is neutral and chargeless.

Therefore I consider that all theluminescence model in Fig.1 is not rational.The rationaler is as Fig.2.The explaination asfollows.

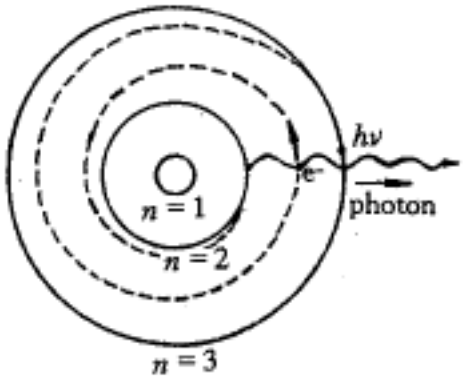

Fig.1 Bohr luminescence model of hydrogen atom

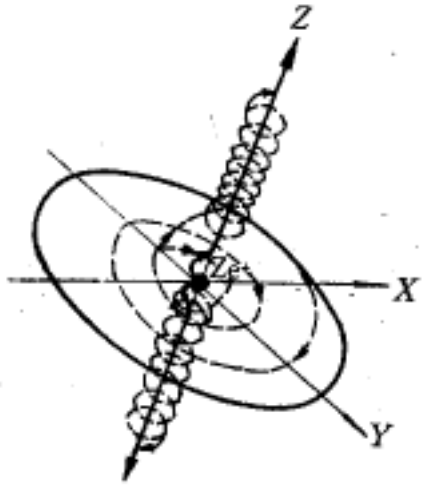

Fig.2 The luminescence model of annihilation ofhydrogen atom

1)When the electron e^- transits to the inner sheel,it separates a part masses $\triangle m = xm_e$ (m_e is the electron mass,x is a fraction) and a part charges $\varepsilon^- = \triangle e = xe^-$(the electron is divisible) from its parent;Simultaneously the atomic nucleusis compelled to separat-out a part masses $\triangle m_{e^+} = xm_{e^+}$ and carries the charge ε^+, $\varepsilon^+ = \triangle e^+ = xe^+$. ε^-, ε^+ halved all and fly separately to ±Z directions, ε_2 rotates round ε^2,this become the photon of hydrogen atom type.The energy of the photon is given by the parent.The orbit electron rotates round the nucleus originally,therefore ε^- rotates round ε^+.Due to themomentum conservation,it is needed to separate out two (±Z) photons.The special relativity pointes out

$$E=mc^2 \tag{1}$$

it is shown the energy is linear propotion with mass,one contain the instrinsic energy, thepotential energy,the kinetic energy,energy isreleased,then mass is reduced.The separated mass is

$$\begin{aligned}\triangle m_{e^+}+\triangle m_{e^-}&=xm_{e^+}+xm_{e^-}\\&=x(m_{e^+}+m_{e^-})\end{aligned} \tag{2}$$

this mass is transformed into two photons,one is the annihilation process.Set the frequency of the emitted photons is ν ,then

The energy of two photons$=2h\nu$ (3)

(2)=(3),and consider(1),then

$$x(m_{e^+}+m_{e^-})C^2=2h\nu \tag{4}$$

because of the photon is chargeless and neutral,the mass of the negative and the positive electron is same,i.e.$m_{e^+}=m_{e^-}=m_e$, m_e is the mass of electron.Also because of

$$\nu=c/\lambda \tag{5}$$

From (4),(5),one obtain

$$\lambda=h(xm_ec)^{-1} \tag{6}$$

(6) is homologous with de Broglie formula,the mass of this corpuscle is xm_e,its velocity is c (de Broglie formula is $\lambda/(mv)$).In the derivation of (6), Ⅰ assume first the electron is divisible,it can be divided infinitely;Next Ⅰ assume the electron possess the charge e^- and the mass m_e-,the e^- and the m_e- are distributed uniformly in the noumenon of electron,and $\triangle e^-$ is a direct proportion to $\triangle m_e$.

The establishment of hydrogen atom model of Bohr first assumed the centrifugal force equal the electrostatic attraction,i.e.

$$m_e u^2/r = kZe^2/r^2 \tag{7}$$

in(7),Z＝1 for the hydrogen atom,u is the linear velocity of orbit of satellite electron,r is the radius of circular orbit of electron.

The second assamption of Bohr is that the angular moments of the orbital electron must be the positive integers times of $\hbar = h/(2\pi)$(h is Planck constant),or

$$m_e ur = n\hbar \tag{8}$$

n is called the main quantum number.From(7),it is obtained the kinetic energy E_{kin}, thepotential energy E_{pot} and the total energy E of the orbital electron are

$$E_{kin} = \frac{k}{2}\frac{e^+e^-}{r}, E_{pot} = -\frac{ke^+e^-}{r},$$
$$E = -\frac{k}{2}\frac{e^+e^-}{r} \tag{9}$$

let $R = (4\pi k^2)e^4 m_e (8h)^{-1}$＝Rydberg constant,from(8) and (9) obtain

$$E_n = -R/n^2$$

(10)

(10) show E_n on n orbit is always the negative,and is in the inverse propotion with n^2.

Now using the frequency condition of Bohr

$$\triangle E = h\nu \tag{11}$$

the electron has transited from m orbit to n orbit(m＞n),and has separated out $\triangle m_e$,$\triangle m_e \times c$ ought to have equaled $\triangle E$,then

$$\triangle E = E_m - E_n = \triangle m_e c^2 = x m_e c^2 (\triangle m_e = x m_e)$$

or

$$x = (m_e c^2)^{-1}(E_m - E_n) = (m_e c^2)^{-1} R(n^{-2} - m^{-2}) \tag{12}$$

(12) point out: “ the electronic fragment ($\triangle m_e$,$\triangle e$) ” (or calling as the whelp electron) which is separated out from the orbital electron hasbecome the photon,this is also the quantization due to m and n are all the positive integers.From(6) obtain

$$x = h(m_e c \lambda)^{-1}$$

and from λ the x can be calculated,the result is shown as table 1.

Table.1 x-λ relation

λ	656.3nm	589.3nm	486.1nm	24.4×10^{-4}nm	12.2×10^{-4}nm
x	3.27×10^{-6}	4.14×10^{-6}	5.01×10^{-6}	1.00	2.00

From Table.1 one can show:in visible light wave band,the orbital electron has separated only a little part of mass,it is passable,but in X-ray wave band this need the annihilation of a whole electron or more electrons.Therefore this need the electrons(s) is(are) injected from a outside.The explanation is as follows.

The process of X-ray generation is that the fast electron (eV) is hited on a target(e.g.W-target),then W-target output the neutral X-ray($h\nu$),according to Hunt law[10],$eV=h\nu_{max}$, this is the conservation of energy,and is indisputable.If the conservation of charge is futher considered,then the input is one e^-,and yet the output is the neutral photon,there is the eigen X-photon and the bremsstrahlung X-photon,has this input electron gained the positive electricity from there to neutralite?I consider that is done only from the atomic nucleus of the target.Therefore the mentioned model of photon is also the applicable to generation of X-ray. The process can be
understanded as Fig.3,an accelerating eletrone$^-$ is attracted by atomic nucleus Z_{e^+}, theelectron has revolved around the nucleus Z_{e^+},and it carried the same quantity positiveelectricity and radiated out the photon,the
negative whelp electron or the electron yet rotate around the positive nucleus,the negative and the positive annihilated to become X-ray.In thisprocess the material of target surface generatethe isobar.It is the able to the target of theformer X-tube is analysed by a mass spectrometerto confirm the theory.

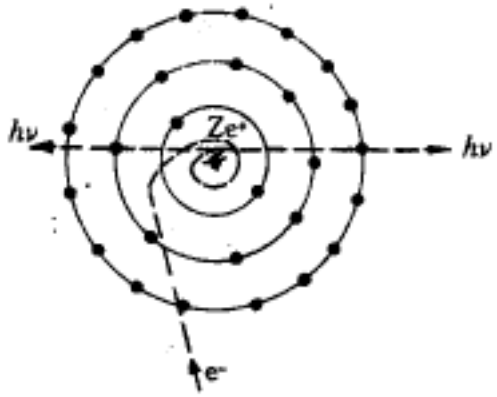

Fig.3 The accelerated electron e^- has entered the nucleus field,and has obtained the positron, then annihilated to generate X-ray

(7) is applied for the emitted photon,then

$$xm_e u = kxe^+ xe^-/r$$

xm_e is the mass of satellite of photon,xe^+ is the charge of nucleus of photon,xe^- is the charge of satellite of photon,or

$$u^2 = kxe^2(m_e r)^{-1}$$

(13)

u in (13) is a velocity of satellite($\varepsilon^- = xe^-$) on orbit,r is a radius of orbit.Continue to use a general treatment method of wave,one circle which satellite rotate around nucleus is decided on one wavelength,the phase becomes from 0° to 360° during one circle rotating around nucleus,from(8) and (13) obtain

$$r = n^2 \hbar^2 \lambda (m_e k x e^2)^{-1}$$

substituting x in(6) into the above equation,
obtain

$$r = n^2 \hbar c \lambda (2\pi k e^2)^{-1}$$

(14)

(14) show that when λ is very small,e.g.X-ray, γ -ray,then r is also very small,the photon fly by a line approximately.But when λ is very long,e.g.microwave,then r is also very long,it can spread all over the space.The wave property of longer wavelength light and the corpuscular property of shorter wavelength light are unified Eq.(14).

3 Explainning the refration,thereflection,the diffraction,theinterference, the linear polarization with Brewster angle

The photon enters a dielectric,the dielectric can damp merely the travelling velocity of photon,therefore the the light velocity in adielectric ought to be smaller than the lightvelocity in vacuum,this generated the refraction law(Fig.4)

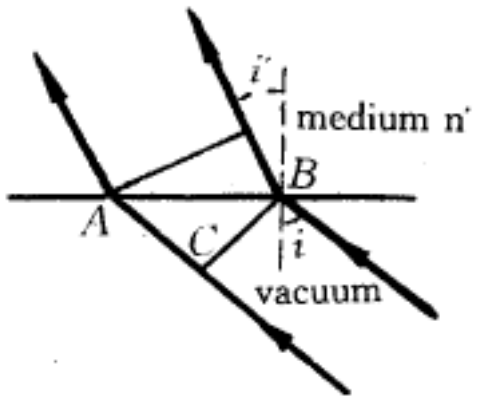

Fig.4 The refraction law

$$n' = c/v = \frac{c}{AB} / \frac{v'}{AB} = \sin i / \sin i'$$

The law of reflection can be obtained byNewton ′s treatment method.

Because of the photons have rotated,therefore they possess phases,the phases vary versus optical path,the interference and the diffraction are easily explained(Fig.5,Fig.6).

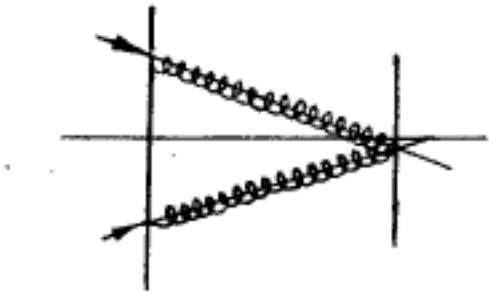

Fig.5 The interference generation

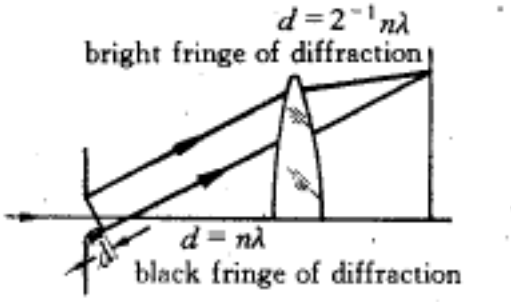

Fig.6 The diffraction generation

When the light is reflected with Brewster angle,the linear polarization has appeared,this is due to a rotation of the sideway photons,shown as Fig.7.

In the fundamental particles,there is the neutrino,in 1950 ′s its existence had been proved experimentally.The neutrino has unelectrified,on the one hand it is travelled always with light velocity,don ′t rest always as the photon[9],and on the other hand it also have more somethings in common to the electron and the muon.Thephoton in my model is the neutral, and itsvelocity is the same to the neutrino.In test,$e^{-}/3$ had been obtained,i.e.one electron is separated into three microparticles[11].

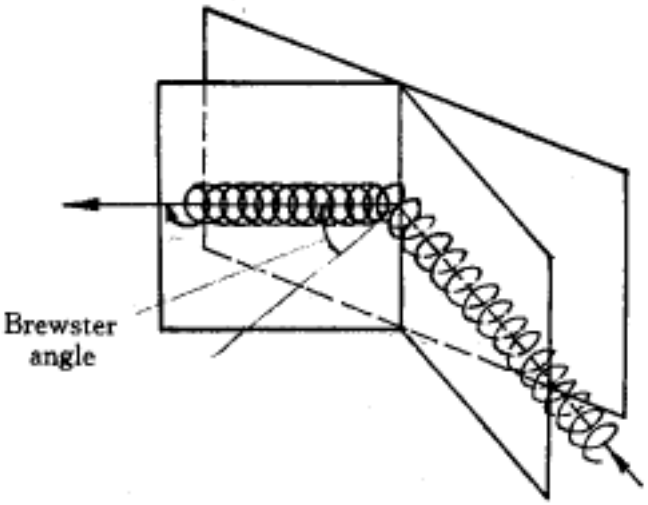

Fig.7 The linear polarization under Brewster angle

From a heredity of bionics of parent body and child body,the electron motions have how many kinds,then the photon models have how many kinds.The electron motion of circle orbit is a simplest kind of these motions.The others which shell structures of hydrogenlike atoms are shown as Fig.8 can have all to constitute thephoton models.The second kind simpler model is the rotating dipole,one travel by the straight line velocity c,up to it is absorbed or collided.An electronic pair in motion generate the magnetic field H as Fig.9,and also generate the electric field E,E and H are obviously set perpendicular to each other,and all perpendicular to motiondirection of photons,this is the Poynting theorem.

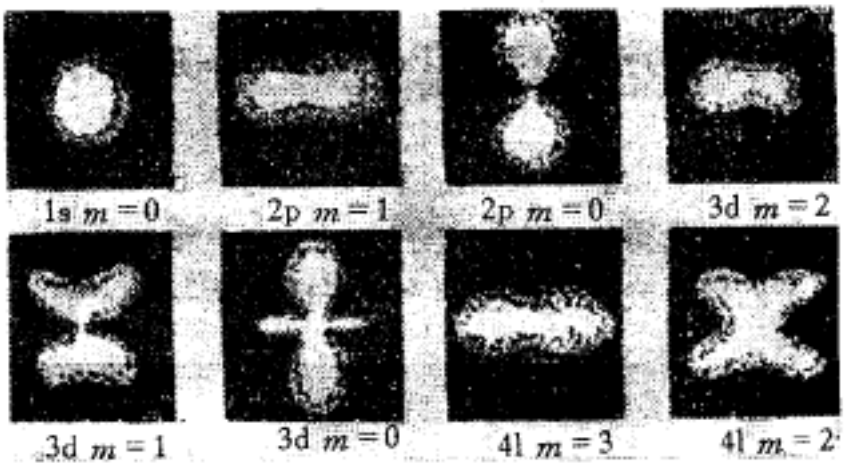

Fig.8 The probability distribution of electrons on H-atom orbit

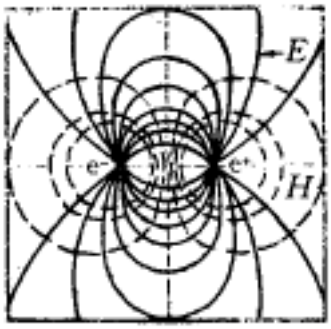

Fig.9 The positive and the negative whelp electrons travel by light velocity c and generate E and H

At last,Zeeman effect and Stark effect are explained using the mentional model of atom luminescence.

H.A.Lorentz had proposed that thetheoretical base of Zeeman effect is that electron motion in atom (e.g.H) is influenced bymagnetic field to affect luminescence state of the electron(the circular polarization,the planar polarization,the elliptic polarization).Theorbital electron of hydrogen atom in magnetic field is acted Lorentz force generated bymagnetic field,then,if the left-handed electron of orbit is acted by the centripetal force,the right-hand electron of orbit is acted bycentrifugal force＝F ＝$m\omega^2 r = 4\pi^2 \nu^2 mr$.

$$dF = 8\pi^2 \nu\, mrd\nu \tag{15}$$

and Lorentz force＝$\pm e\nu H = \pm e\omega rH = 2\pi\ \nu\, reH$,Lorentz force just is dF,then

$$dF = \pm e\nu H = \pm 2\pi\ \nu\, reH \tag{16}$$

from (15)＝(16),obtained

$$d\nu = \pm eH/(4\pi m) \tag{17}$$

This is the longitudinal Zeeman effect,due to the orbital frequencies have two kind,then original spectral line is separated to the left line and the right line,and are all the circularpolarization(Fig.10).If it is observed at the transverse,then the sides of the left and the right (two) circular polarizations,that is theplanar(i.e.linear)polarization,and also have two frequencies(Fig.10).

As for Stark effect,because of the orbital electron is acted by a force from the appliedelectrical field,its orbit is changed,this can be described using the cubic model of R. W.Wood[11].The atomic level±△E is enhanced a change of the orbit, so the symmetric split of line has generated.

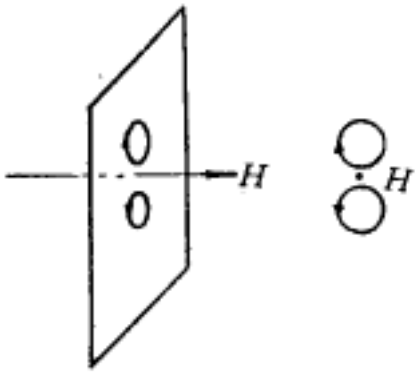

Fig.10 Zeeman effect.The left and the right circular polarizations are generated in H direction,the linear polarizations are generated in the direction popendicular to H

4 Discussion

1) The photon in this paper is analogous to positronium,the positronium is combined one positive electron e^{+} and one negative electron e^{-}.The positronium has positioned 1s state,andcarry not electromagnetic wave.

The photon in this paper has contained thepositive nucleus and the negative electric satellite,but it travel by the velocity c,and carry an electromagnetic field.This is explained asfollow:

The linear velocity,which is that of theorbital velocity u(Eq.(7))of the negativesatellite in the model of photon on the orbitclosing best to the nucleus of hydrogen atom,is 0.007 c,so the positive nucleus and the negative satellite can be considered the positive whelp electron and the negative whelp electrontravelling by the same velocity in the samedirection,from the electricity principle,this has generated the magnetic field,the magnetic field of both are added each other,and they are not counteracted each other,so the photon hascarried the magnetic field.The electron paircontaining the positive and the negative whelp electrons has carried the electric field
popendicular to H field.Therefore the photon model and positronium are two entirely different things(Fig.9).

2)Two photons are generated once in the model,this is a contradiction to the testing results of photoelectric effect seemingly,but the formula of photoelectronic effect of Einstein and the test of Milliken had all pointed out one
photon has only obtained one photoelectron,it seems the photon and the photoelectron are one-to-one correspondence,now it is a problem for the positive-negative whelp electron pair generate the photons,I consider the opportunity more to generate two photons than to do one photon.If it generates one photon,so obtain

$$\lambda = h/(2xm_e c) = h/(2\triangle m_e c)$$

the above formula is inconsistent to de Broglie formula.Therefore the probability to emit two photons is still the more.

3)The emissions of X-ray have two kinds,the first kind is the characteristic X-ray,the second kind is the continuous X-ray.Thecharacteristic X-ray is generated from theinternal shell levels of atom,e.g.thecharateristic X-photon of wolfram target $k\alpha$,the wavelength is 213x.u(0.0213nm),according to $2h\nu = mc^2$,$m = 2.06\times10^{-31}$kg is calculated,i.e.$0.2m_e$;If the accelerative electron with 2×10^6V is shoted to wolfram target,m is calculated using $eV = mc^2$,so $m \approx 4m_e$,excepet to use forgenerating the characteristic X-ray,the other all has acquired the positive charge and the mass from nucleus,and has annihilated to generate the annihilation radiation,the such energy ought to be slightly smaller than the annihilation energy of $x = 2$(Table.1).The positive electron and the mass are looted from nucleus in W-target,so this ought to appear the isobar,but this is to be proved by the mass spectrographic analysis.From the model it is infered that this kind of particle has existed in atomic nucleus, which one positive charge is carried and it has possessed a few m_e or$\times10m_e$(m_e is the intrinsic mass or the static mass of electron).

There is one atomic nucleus Ze^+in O on Fig.11,the accelerated electron e^- possess the energy eV,and fly through Ze^+ side with ahyperbola or a parabola orbit,the beelinedistance of this orbit from nucleus is ρ ,I consider that the incident electron can be trapped by atomic nucleus while $\rho \to 0$,so Ze^+ is become to $(Z-1)e^+$,the characteristic line of emission of $(Z-1)e^+$ ought to leave a shift from Ze^+.Just as Moseley law pointed out,the probability is not large,but it is the possible,this can bedetermined by an experiment.

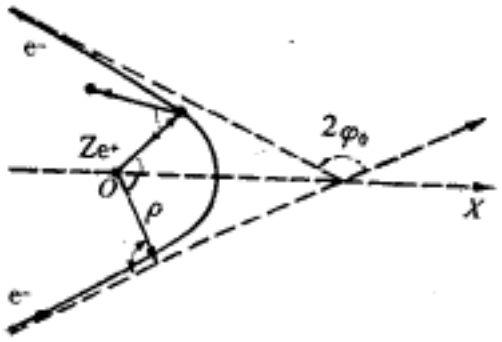

Fig.11 The emission of characteristic X-ray

Based on the experiment of annihilation of the positive and the negative electrons,I propose the conditions of a nnihilation as follows:

1) $|e^+| = |e^-|$, $|e^+| - |e^-| = 0$,this is the conservation law of charge.

2)$\triangle m^{+}=\triangle m^{-}$, $\triangle m^{+}+\triangle m^{-}=2\triangle m=2E/c^{2}$,

this is the principle on $E=mc^{2}$.E is energy or

3)$\triangle\ [x_1 m^{-}_{0}(1-\beta^{2})^{-1/2}]\ =\triangle\ [x_2 m^{+}_{0}(1-\beta^{2})^{-1/2}]$,

x_1 is the particle numbers of m^{-}_{0}, x_2 is the particle numbers of m^{+}_{0}.For e^{+}, e^{-} annihilation,$x_1=x_2=1$;For the proton and the antiproton,x_1, x_2 can reach 1830.

Based on 3),if $x_1=x_2=1$, and $\beta_1=\beta_2=0$,this is e^{+} e^{-} pair annihilation when the positron and the negatron are all in the stationary state.And if $\beta_1=\beta_2=\beta$, e^{+} e^{-} pair can annihilate also when the positron and the negatron havetravelled in the same direction and with the same velocity.

In addition,if $\beta_1\neq\beta_2$,$e^{+}e^{-}$ pair is also able to annihilate,e.g.one negatron e^{-} with 1meV can merge and annihilate to the particle which the mass inside nucleus is $3m_e$ and electrify a positive charge.It is explained as follow.

In 3),letting $x_1=1$, $\beta_1=v_1/c$, $\beta_2=0$(i.e.pointing to the static positron inside nucleus), so from 3),$x=3$.This show that if an existence of the annihilation radiation is proved with anexperiment,one can predict that the positiveparticle with the charge e^{+} and the mass x_2m_e $_{+}$ exist in the nucleus,the whelp meson can be named,$x_2=1,2,3\cdots$, correspond to eV= 0.5,1.0,1.5(meV)$\cdots$;If the electron can be separated also,so x_2 may be a non-integer number. Here the input energy is eV,and the output energy is 2eV,one eV of them is take-off from atomicnucleus.If this emission of double photons is proved using an experiment,so this is a method of take-off nucleus energy,and this is thecontrolled energy of nucleus,as well as is one controlled reaction of nucleus.Here a hightemperature is not used.

5 Conclusion

The photon model have the followingadvantages more than Bohr model of luminescence:

1) Bohr model accomplishments areabsorbed all.

2)The wave-particle duality is unified,the corpuscle property of the shorter waves(e.g.X-ray, γ -ray)and the wave property(Eq.(14)) of the longer waves(e.g.the infrared wave,the ratio wave)are explained separately.

3)It is expounded clearly:the photon carries a electromagnetic field,and have a phase, both is the neutral particle and an electromagnetic source of wave.

4)The microcosmic explanations are all made for the refraction,the reflection, thepolarization,the interference and the diffraction of light.

5) Poynting theorem is explainedmicrocosmically.

6)Zeeman effect and Stark effect can beexplained.

7)This photon generation model has used the annihilation radiation principle of the larger and the smaller electrons and,it is explained for the generation mechanisms from the longer wave(the microwave)up to the shorter wavesincluding the microwave,the far infrared,

the visible light,X-ray up to γ-ray.The all waves to be generated by the electrons inside atom are sumed into this model.

8)It is predicted a kind of particle hasexisted,which carries the positive charge e^+ and possesses a few m_e to×10m_e.

This photon model has been spreaded from the theory of annihilation radiation of professor Zhao Zhongyao,whether or not it can standtrials,this have yet to be proved from now on by direct and indirect experiments.

This paper has obtained the cordial helps of professor Zhao Zhongyao,I express heartfelt thanks to him!

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An academician of Academia Sinica,Opticist **Gong Zutong**(Kung Tsu-Tung),1904.11.101986.06.26,was born in Chuansha,Shanghai,China,had graduated from Qinghua(Tsing-Hua)University in 1930,studied the applied optics in Berlin Industrial University,Germany,and finished off school work of his doctor in the same university on 1936.He assumed office as the director of Xi′an Institute of Optics and Precise Mechanics, Academia Sinica,during his lifetime.

Gong came back to China soon after the beginning of the Anti-Japanese War and manufactured China′s first military telescopes.He successfully manufactured the first batch of optical glass in China and trained a lot of technical personnel.Later,he lead the invesigation and development of China′s first
infrared hight-vision telescope,first electronic microscope,first high-speed camera,etc.He madeoutstanding achievements in leading and guiding research on optical instruments,fiber optics,optics with variable refractive index,infrared night-vision and electronic optics and so on.

Translator resume

Professor,poet **Cheng Xiwang** was born on July 9,1942,in county of Zhouzhi,Shaanxi, China,is the managing editor of Acta PhotonicaSinica,in 1966 he graduated from department of physics,NorthwestUniversity,Xi′an,China.He published 30 optical papers,4 translative books on optics,edited An English-Chinese Terms Directionary ofOptics and Photonics,and wrote 300 Chinese poetries of classical form.The Cheng Xiwang Autoselections had been published by The Science Press and The Longmen Press.

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光子结构论

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相似文献(10条)

1. 期刊论文 张德安 论光子的结构与分布 -中国科技信息2009,""(10)

文章提出了关于光子结构与分布的假说:光子由心,核及核外的引力子云构成;光子无处不在地存在于宇宙空间及物质内,它有结合、自由,半自由三种分布状态.在此基础上产生了一些推论:光子间可以发生反应生成多光子体和电子;光子是物质的结构柱子,参与物质质量和能量的形成;光子(光)可被一切物体吸引,光的衍射、引力透镜现象就是其表现;空间(物质内)无处不在的光子可称为"光子气",它也参与万有引力的介导,它有三种运动形式;光的本质是光子气流.并应用上述观点,对光学、量子力学、相对论、天体物理学(包括宇宙学)的一些基本问题、疑难问题进行了解释.

2. 学位论文 李俊韬 微纳结构中光子的相干操控与应用 2009

随着社会发展，人们对通信的速度、容量、质量需求不断提高，但目前光电网络中信息的传输和交换，光子能量的高速与高效转换等都受较低的光电转换效率和较高的制造成本制约，在这种实际需求下，以相干理论为基础的结合光学微纳结构的一系列精确操控光子的研究应运而生。

要实现光子的精密操控，首先必须制备合适的微纳结构。目前，对于微纳结构，特别是光子晶体的制备，大部分仍停留在完整的光子晶体结构上。但实际上，具有缺陷的光子晶体才具有更高的利用价值与功能。对光场的操控可分为在时间和空间上的操控。在时间上的操控主要是指利用线性光子光子晶体中的缺陷和非线性光子晶体将光场减速或静止，减慢光的速度可应用于光延迟器，脉冲整形，光开关等方面，以及增强光与物质相互作用。在光子的空间操控领域，理论和实验都已证明，利用光子晶体带隙改变光子态密度分布的特性，可使用光子晶体控制原子自发辐射的分布。论文对以上方面都做了较深入的研究：

1.利用激光的相干性，提出了在多光束激光空间相干干涉技术中加入各光束相位的调节，得到各种不同功能的带缺陷的光子晶体结构。在实验上实现了一次曝光制作一维和二维光子晶体波导缺陷的全息光刻技术，在理论上模拟了带缺陷的三维光子晶体的制备，并在此基础上探讨了制备大面积小周期的带缺陷光子晶体的技术。

2.系统研究了线性硅平板光子晶体波导中实现慢光的方案：在二维光子晶体波导中，通过调节靠近波导的前两列孔洞的位置来改变光子晶体波导的线性色散曲线，实现了光在波导中减速和低色散传播。利用该方法，本论文实验上已制作了光传播速度为0.02c～0.03c，带宽超过10nm的低色散波导样品。同时还研究了减小波导传输损耗的方法和利用慢光制作高效光脉冲整形器的可能性。

3.在使用共振吸收布拉格周期结构静止超短激光脉冲的理论基础上，提出了利用静止光脉冲增强光的非线性转换效率的理论，并以零速超短脉冲增强受激拉曼散射为例子展示了该理论。本论文提出的一维双共振布拉格周期结构可将该过程中光子频率转换效率提高到85%，远高于一般体材料中的拉曼抽运效率。同时，提出了共振吸收布拉格反射镜具有体材料不具备的极好的滤波特性，可用于脉冲压缩和整形。

4.在实验上观测到了光子晶体一阶带隙和高阶带隙对掺杂在其中的稀土原子空间发光特性的调制作用。利用光子晶体中态密度的概念和散射理论解释了该作用的原理。

3. 会议论文 章蓓.康香宁.代涛.包魁 基于光子晶格结构的InGaN/GaN系发光器件 2008

本文综合报道我们近年来将光子晶格结构运用于InGaN/GaN量子阱发光器件即激光器和发光二极管的研究成果。我们发展了几种独特的在GaN系材料系发光器件上制备光子晶格结构的技术；运用电注入器件的显微电致发光以及扫描近场光学,探索了这些光子晶格结构对发光器件的效应。我们利用聚焦离子束刻蚀技术成功地实现了以GaN准一维光子晶体为腔镜面的InGaN/GaN脊型和条形激光二极管；同时,针对发光二极管出光光强低下的普遍难题,分别采用了包括微纳结构压印、图形化激光剥离以及大面积多孔阳极氧化铝纳米图形转移等技术,研制成功基于光子晶格结构的InGaN/GaN量子阱发光二极管,使出光强度得到了不同程度的改进。

4. 学位论文 武瑞祥 光折变光子晶格的带结构研究 2008

1987年E.Yablonovitch和S.John提出了光子晶体的概念。光子晶体是一种人造的介电函数在空间呈周期性分布的材料，由于其存在光子带隙，可以人为地改变和操控光子在其中的传播行为，因此光子晶体在光通讯、集成光学等方面具有十分广阔的应用前景，使得光子晶体成为世界范围的一个研究热点，得到了迅速的发展。但其制作工艺比较复杂，给其进一步的研究带来许多困难。用全光学的方法在光折变材料中利用光折变效应写入光子晶格是一种全新的，简便可行的方法。虽然其折射率对比度较低，但是，可以在低入射功率下一次完成，且感应出的光子晶格具有较长的暗存储时间，晶体还可循环使用，具有很高的研究价值和广阔的应用前景，为光子晶体的进一步研究和应用提供了一种新型的材料。

关于光子晶体带结构理论方面的研究已趋于成熟。但是目前对光折变非线性光子晶格带结构的研究成为了这一领域的又一研究热点。在自散焦光折变LiNbO3晶体中写入的阵列波导有类似于光子晶体的周期性结构。因此，研究LiNbO3晶体中晶格的折射率变化规律及其带结构，对制作光折变光子晶格具有重要的指导意义。

本论文中我们首先研究了利用双光束干涉在不同掺Fe浓度的LiNbO3晶体中分别用红光和绿光写入光子晶格时，晶格周期a、掺Fe浓度、光波波长λ与光致折射率调制度△n之间的关系。实验结果表明：当用红光(λ=632.8nm)写入光子晶格时，掺Fe浓度不大于0.05wt%，用绿光(λ=532nm)写入光子晶格，掺Fe浓度不大于0.03wt%时，LiNbO3晶体的光致折射率调制度△n随晶格周期a的变化存在一个极大值，并随掺铁浓度的增加，相应的折射率调制度极大值也增大，且向晶格周期小的方向移动，这与一中心模型理论得到的关系曲线的变化趋势是相一致的；掺Fe浓度若大于以上两值，理论曲线则完全与实验曲线不符，说明一中心模型的空间电荷场理论只适用于小掺Fe浓度的LiNbO3晶体；实验还发现LiNbO3:Fe晶体折射率调制度△n跟

写入光波长λ有关，用同一块晶体，绿光写入时折射率调制度△n会比红光更大，且极大值向晶格周期减小的方向移动更大。

同时我们又从理论上运用平面波展开法计算了利用双光束干涉在光折变LiNbO3晶体中写入的一维光折变光子晶格的带结构，并对比不同折射率对比度下的带结构情况。研究了折射率对比度、晶格周期、占空比对带隙位置、带隙宽度的影响。

实验中当我们用与在LiNbO3:Fe晶体中写入光子晶格时相同频率的另一激光束照射到晶体写入光子晶格的区域时，在入射光与光折变光子晶格周期方向成较大的角度(大于78°)时，观察剑了光折变光子晶格对光的局域现象。利用光在分层介质中传播时的传输特性，理论上计算了光在其中传播时的反射率R与入射角度θ之间的关系，发现只有在大入射角度下才出现局域现象。理论计算结果与实验结果是相一致的。

5.期刊论文 武瑞祥.杨立森.曹永军.陈宝东.崔俊杰.张宝光.WU Rui-xiang.YANG Li-sen.CAO Yong-jun.CHEN Bao-dong.CUI Jun-jie.ZHANG Bao-guang 一维光折变光子晶格的带结构研究 -信息记录材料2008,9(1)

利用双光束干涉在光折变LiNbO3晶体中写入折射率周期性排列的光子晶格,运用平面波展开法研究这种光折变光子晶格的带结构,并对比不同折射率对比度下的带结构情况.

6.期刊论文 阿不都热苏力.帕尔哈提 电磁波在周期介质中的传播及二维光子晶体的光子带结构 -发光学报2003,24(2)

光子晶体是光学与凝聚态物理交叉的新领域,也是近年来应用物理学的一个重要研究领域,它是一种由介电常数高的(低的)介质在另一种介电常数低的(高的)背景介质中周期排列所组成的人造多维周期结构材料,能够产生光子带隙.频率落在带隙内的光在晶体里沿任何方向都不能传播,因而具有能够抑制原子、分子的自发辐射等诱人的光电子学特性,在基础研究和实际应用上都有着巨大的潜力.本文在这一领域里进行了富有成效的研究,获得了很好的结果.主要有:(1)利用平面波展开方法来计算二维光子晶体的带隙结构.首先,我们设计正方晶胞的二维光子晶体模型.设x3方向为介质柱的轴方向,二维周期结构在x1-x2平面上.晶胞的晶格常数为a,半径为r,介质柱和空气柱的介电常数分别为εa=17和ε6=1,a＞2r.设计的核心思想是通过降低光子晶体结构的对称性,消除光子能带在晶体的布里渊区高对称点上的本征简并.(2)对于二维光子晶体的电磁波理论及周期介质中的Bloch波解做了详细的推导,给出了光子晶体中禁带存在的理论依据.同时以正方格子晶格的二维光子晶体为例,验证了电介质在空气圆孔中的排列存在E偏振和H偏振的光子带隙重叠区,称为绝对光子带隙.对于二维的光子晶体,两种本征偏振模式的光子能带结构可以独立地调节,以实现两者的光子带隙的最优重叠,从而大大提高了二维光子晶体的完全带隙宽度.

7.学位论文 毛亚显 LHC/ALICE实验中的光子-强子关联测量及碎裂函数研究 2008

在现代自然科学研究中，一项极具挑战性的研究目标是在最小尺度上探索物质的构成。一种描述基本粒子与作用力的理论，现在大家称它为标准模型，假定物质的基本结构是由夸克和轻子通过规范粒子的相互作用而组成的，认为组成物质结构的最小单元是夸克(u，d；c，s；t，b)、轻子(e，Ve；μ，νμ；T，μT)，以及传递相互作用力的媒介子，即玻色子(W士和Z0)，胶子(g)和光子(γ)。基本作用力根据规范粒子的不同划分为电磁相互作用，弱相互作用和强相互作用。正是这些基本粒子和相互作用力构建了亚原子世界。然而，这个理论并不十分完备，因为它依然无法解释某些基本的问题，比如：基本粒子质量的起源、宇宙的真实真空、以及宇宙中物质远比反物质多的问题…。

随着2008年大型强子对撞机(LHC)的运行，我们有望进一步触及这些问题。特别是，位于欧洲核子研究中心(CERN)的加速器将实现前所未有的TeV能区下的高能重离子碰撞实验(ALICE)，其目的在于研究高温高能量密度的极端条件下强相互作用的基本性质及其物理真空。而且，它还将探索基本粒子的夸克胶子自由度问题：夸克胶子等离子体(QGP)。

李政道先生早在1974年就提出：“it would be interestinq to explore new phenomena by distributing high energy or high nuclear’density orer relatively large volumes”。他认为在高能重离子碰撞中热密物质将以QGP的形式存在，那时夸克将不再禁闭在普通强子物质内，而真空中的手征对称性也将得到(部分)恢复。极端相对论重离子物理，作为一个应用标准模型于有限体积复杂演化体系来检验李政道预言的一门学科，因此诞生。

基于量子色动力学(QCD)，利用格点计算方法，人们成功预言了夸克从禁闭的普通强子物质中退禁闭到QGP相的临界温度。实验上，该临界温度首先在CERN √SNN=17.2 GeV下的SPS重离子碰撞实验中达到。进而在美国布鲁海文国家实验室(BNL)运行的质心能量√SNN=60-200 GeV下的相对论重离子对撞机(RHIC)实验中，证实了从强子物质到夸克物质的相变能在高温高密条件下发生。通过比较质子-质子碰撞和核-核碰撞的测量结果，一些能够预言QGP形成的探针被找到。例如：SPS能区下的J/ψ压低，奇异粒子产额增强，RHIC能区高横动量粒子谱的压低，反映部分子集体运动效应的椭圆流等。尽管QGP形成的证据尚需更大统计量事例和更高能区实验结果的证实，目前的实验数据分析结果显示，夸克胶子等离子体这种新物质相能够在高温高能量密度下形成，在PHIC上观测到的这种新物质相更多的表现为强相互作用下的理想液体，不同于理论预言的自由气体。

CERN/LHC将提供质心系能量、√SNN=5.5 Tev的重离子碰撞，该能量接近RHIC碰撞能量的30倍，它将允许在更高温度下形成的热密QCD物质持续更长时间。另外，LHC能区的重离子碰撞诱导产生的硬散射过程更加丰富，这些敏锐的硬探针将提供TeV能区下细致研究QGP性质的机会。比如，在核-核中心碰撞中高横动量强子产额的压低和背对背喷注之间的关联消失。正在建造并将于2008年投入运行的ALICE探测器就是为了更加系统的测量核-核碰撞中产生的末态粒子，由此反映碰撞初期出现的热密物质相的性质。特别是，通过测量相空间中强子谱的改变，可以研究硬散射部分子在穿越密度物质时的能量损失效应及碎裂函数性质。在重离子碰撞中，由于喷注淬火效应，硬散射过程产生的大横动量部分子穿越密度物质时会因为多重散射而损失能量，导致高横动量的强子产额减少，低动量强子数目会增多，引起强子谱在相空间中的重新分布。因此，通过测量核环境下部分子的碎裂函数(FF)，即测量部分子喷注产生的强子携带喷注动量份额z=PTh/EjetT的分布函数，将真空中的碎裂函数(质子-质子碰撞或核-核边沿碰撞中的碎裂函数)与被介质修正后的碎裂函数(核-核中心碰撞下的碎裂函数)分布进行比较，就可以推断核-核碰撞中的密度物质及其性质。

本论文着重开展如下两方面的工作。首先，研究ALICE实验中光子谱议(PHOS)在探测和鉴别光子时的性能表现。PHOS是一种高能量和位置分辨率的电磁量能器，其接受度范围△η=0.24，△φ=100°。由于有限的接受度，在碰撞过程中产生的某些光子落在PHOS模块的边缘使得沉积在晶体上的能量不能获得完整的重建，这些光子将不能被PHOS正确探测到。利用ALICE实验模拟和数据分析软件AliRoot进行模拟，我们得到，由于PHOS探测器的边缘效应，光子探测效率会降低约10%。同时，光子在穿越位于PHOS之前的其它探测器时与探测器物质发生相互作用而使光子转换成正负电子对（γ→e+e-)。模拟结果表明，不同探测器对光子探测效率的影响程度不一样。例如，光子在时间投影室(17PC)和内部径迹系统(ITS)的转换几率约为10%，而在跃迁辐射探测器(TRD)和时间飞行探测器(TOF)中的转换几率接近20%。该工作的第二部分，主要聚焦在硬散射过程中的光子-喷注测量，论文着重研究了PHOS对能量高于20GeV的光子的性能表现，以很好的区分硬散射过程产生的直接光子和来自强子衰变的大量背景光子，从而计算直接光子的探测和鉴别效率。为此，我们对ALICE探测器作了完整的模拟，两种类型的事件被产生。一种事件是，在每个碰撞事件的部分子硬散射过程中，一个高能光子产生于康普顿散射过程或湮灭过程，我们称该类型事件为γ-jet事件；另一种情形是，在硬散射过程中两个部分子碎裂成背对背喷注，其中一个部分子碎裂成喷注时产生一个高能π°，此过程称为歹jet-jet事件。两种事件均是通过对AliRoot软件环境中的PYTHIA产生器选择不同的硬散射过程实现。在模拟事件中，我们限制触发粒子γ(在γ-jet中)或π°(在jet-jet中)散射在PHOS接受度内。鉴别方法的性能研究表现为直接光子的鉴别效率和衰变光子误判为直接光子的几率。其中鉴别过程分为两步。首先，通过量能器上形成的簇射形状分析，对称的簇射形状标记为直接光子，不对称的椭圆形状表示衰变光子。该方法能够很好的排除衰变光子但对于高能衰变光子不够有效。因此，基于瞬时直接光子的运动学信息，本文探索了孤立截断的方法。在硬散射过程中直接光子的产生是孤立的，与直接光子不同的是，衰变光子将被部分子碎裂的强子包围。利用光子周围的不同强子行为，采用孤立截断方法，我们能够有效的扣除被误判为直接光子的衰变光子，降低污染效率，得到一个相对纯净的直接光子源。

利用簇射形状分析和孤立截断方法得到的直接光子，通过建立光子和所有的带电强子之间的方位角关联，我们发现，在γ-jet事件中存在明显的背对背关联，但没有与光子同向的关联。而在jet-jet事件中，同时存在近端(near side)关联和远端(far side)关联。

为研究部分子的碎裂函数，我们构造了光子-强子之间的非平衡分布。基于给定的运动学条件，光子背面的强子与光子之间动量的非平衡变量Zγ-h=-→PTh·→PTr/|PTr|2与领头阶运动学条件下QCD理论计算的碎裂变量z等价，这种等价性在如下运动学条件下成立：

·所有强子必须源于一个硬散射的部分子碎裂(PTh>AQCD)；在核-核碰撞中应排除伴随事件中的软粒子贡献；

·直接光子必须是从部分子的硬散射过程中直接产生(PTr>pcutTr》AQCD)，而不是从喷注碎裂而来；

·zr-h与z的等价范围由给定光子和强子的动量截断值决定。因此，为了得到最大限度的等价性，光子和强子的动量截断值应该是非对称的(PcutTr》PcutTh)。实验上，对运动学约束条件的选择也需充分考虑到能够获取数据的统计量以及采用孤立截断方法鉴别直接光子的效率。在ALICE实验中，合理选择光子能量的截断值约为～20 GeV，强子动量的截断尽可能避免软过程区域(PT<2 GeV/c)，在此区域中，碎裂函数主要由伴随事件中的软粒子决定。为了排除软粒了的影响，选取适当的强子动量截断(PT>2 GeV/c)，可以扣除测量过程中的背景粒子，从而减少系统误差。

为了证实该测量的有效性，本文进一步估计了在LHC质子-质子运行一年的统计误差以及来自衰变光子污染的系统误差。同时，通过验证研究，证实了非平衡分布是对喷注碎裂函数的一个很好近似，其中喷注的碎裂函数是通过事件产生器PYTHIA中的喷注寻找算子UA1计算理想的碎裂函数得到。结果显示，在√s=14 TeV的质子-质子碰撞中，采用γ-强子关联方法测量的非平衡分布与部分子喷注碎裂函数在z=0.12-0.75的范围内一致。

利用光子-强子关联方法研究碎裂函数，极大的降低了在标准喷注算法下对喷注能量范围的限制，显著提高了事件统计量，增加了观测结果的可信度。因此，光子-强子关联测量是实验上研究碎裂函数的黄金探针，该测量在LHC/ALICE实验上是可行的。

8.会议论文 谭长华.许铭真.何燕冬 超薄栅介质MOS结构中的电致光子泵效应 2003

自1968年起,对于SiO<,2>的蜕变与击穿是由于电应力导致缺陷产生的论点,已经历了长达三十多年的研究,产生了多种模型解释.其中有两种主流模型可用于TDDB(时变相关介质击穿).

9.学位论文 帅一辰 光子循环效应对LED芯片发光效率的影响 2008

发光二极管(LED)是一种固体冷光源，具有体积小、耗能少、响应速度快、抗震性好和寿命长等优点，在光电、通信系统中得到广泛应用。最近二十年，以AlGaInN材料为基础的白光LED取得重要突破和快速发展，被誉为“21世纪照明光源”，有望取代白炽灯、荧光灯等传统光源。在背光源、汽车前照灯和通用照明市场等领域也有广泛的应用。

探讨如何提高LED器件的发光效率仍然是LED业界研究的焦点和热点。发光效率高低是一个LED芯片质量的重要表征，因此：优化芯片整体设计，进一步提高LED发光效率是一个极具意义的课题。

具有高有源区材料质量、设计合理的LED芯片结构当中，大部分的光损耗主要来源于以下几种原因：第一，与有源区相邻的透明限制层材料的吸收；第二，窗口层材料的吸收。第三，有源区的吸收。然而，有源区吸收的光子具有再发射的过程，即对所发射光子的再次吸收及再次发射，光子因此得以循环利用。这一效应将最终决定LD的阈值和LED功率转换效率。

然而LED光提取效率依赖于光子循环效率因子。有源层通过光子的再吸收而产生的载流子通过辐射复合使得光子再生，这一再生光子将再次获得出射的机会，并以同样的出射几率逃逸出半导体材料结构。因此，光子的出射几率依赖光子循环效率，与有源层厚度，器件结构、材料生长质量等因素有关。从能量的角度而言，通过光泵浦或电注入的能量，在最终转化为逃逸的光子或源于非辐射过程的热损耗这两种形式之前，将被平均的循环利用多次。

光子晶体辅助技术被用于高亮度高效率的LED当中，这源于光子的产生和循环，即对自发辐射的控制，实际上，作为反射镜腔和衍射元，光子晶体的利用有效提取了波导模，增加了光子的提取效率。

本论文主要研究内容主要包括如下几方面。其中，着重探讨了光子循环问题对LED发光效率的影响。

1.提出了：对具有高自发辐射率有源区材料的LED，光子循环效应对光提取效率的进一步提高起着重要作用。考虑光子循环效应的速率方程时，需要计及电注入和自身光泵浦两方面作用。

2.明确了：其他研究小组将传统观念的内量子效率根据光子循环的观念给与了修正和新的定义。

3.建立模型，理论计算：利用平板模型计算讨论了光子循环效应对实际LED光提取效率的影响，给出更加合理的LED外量子效率模型。

4.对比实验结果与模拟分析：利用Thomas Swan MOCVD system生长的小同高质量LED芯片。对生长的LED芯片进行测量和分析。

5.分析结果表明：更加合理的有源区结构及厚度设计，整体外延层生长参数的优化、高反射率DBR结构或底叫金属反射镜、衬底处理是进一步提高LED外量子效率的有效方法。

10.期刊论文 张少武.是度芳.陈建松 含原子运动非简并双光子JCM的光子统计性质 -光子学报2003,32(8)

利用全量子理论,研究了与双模压缩真空场作用的含原子运动非简并双光子JCM中双模光场的光子统计性质.着重讨论了不同初始态下原子的运动速度、模场结构和初始光强对光场的光子统计性质的影响,由此得到一些新的结论.

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