Optik - International Journal for Light and Electron Optics 171 (2018) 605–610

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.com/locate/ijleo

Original research article

Huygens' principle may reveal interaction between light and atoms

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ARTICLE INFO

OCIS:
140.0140
140.3430
260.1960*Keywords:*
Huygens' principle
The interaction between light and atom
Light absorption
Stimulated radiation
Optical gain

ABSTRACT

We used Huygens' principle to study the interaction between light and atom, and revealed the microcosmic process of the attenuation and gain of a plane wave. We began with the shadow of a leaf, expanding to the atomic absorption plane wave, and obtained the expression of the atomic absorption photon by using Huygens' principle. Also the method of negative absorption is used to analyze the optical gain process, and we obtained the properties of a stimulated radiation photon according to the fact that the optical gain is atomic collective contribution of the stimulated radiation, the result shows that the atomic stimulated radiation is not photons cloning.

1. Introduction

The research of the interaction between light and atom is an important part of studying physics and is also the means to study the nature of light, to understand and explore the world. The theory is nowadays roughly divided into 3 categories: the classical theory, quantum theory and the semi-classical theory. The each theory above can explain some phenomena, but is also contradictory with each other, even some theories violate the concepts of common sense. However, as early as in 1917, Einstein found the quantum theory of radiation according to the existence that the radiation field does not change the Boltzmann distribution of the gas, and indirectly studied the interaction between light and atoms. The method which Einstein used is an indirect method, and the results obtained are not in contradiction with other theories, and also there is no violation of common sense [1].

Whatever medium it is, as long as there is a wave, there are wavelets and wavefronts. When light and matter are interacting with each other, there must be changes between the wavefront and the wavelet. Using Huygens' principle to study interaction between light and atoms, we can indirectly reveal atomic absorption of photons and atom stimulated radiation photon nature, providing a new method for the research of the interaction between light and atoms. We found that the new method not only can solve the problem of some optical legacy, but also reveals many mysteries of the interaction between light and atoms.

2. Using Huygens' principle to ascertain the properties of atomic absorption of photons

Atomic absorption of photons is a common phenomenon and the most fundamental form of interaction between light and atom. According to the classical and quantum theory, the photons always occupy a certain space. But how the atoms instantly absorbs a spatial distribution of photons' energy? When a photon is absorbed, the degrees of freedom for this photon state are also disappearing? These questions can't be answered in the current theory.

We use Huygens' principle to reveal the properties of the atomic absorption of photons and the expressions of atomic absorption of the photons. Using Huygens' principle to study the process of absorbing photons is similar to calculate the shadow of the leaves, and is

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https://doi.org/10.1016/j.ijleo.2018.05.102
Received 9 January 2018; Accepted 22 May 2018

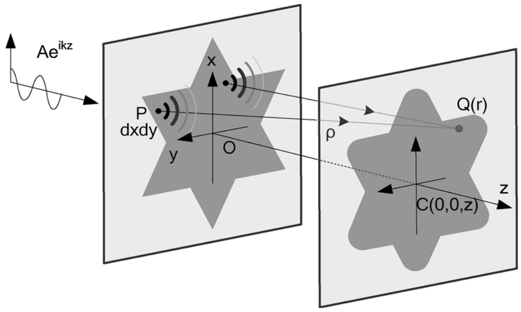

Fig. 1. The wavelet of the xy plane reaches the Q point.

more simple than calculating the shadow of a leaf.

In Fig. 1, there is an opaque Hexagram shaped leaves in *xy* plane, normalizing $t(x, y)$ to the transmittance in *xy* surface, we can get the incident light along the z-axis by using Fresnel - Kirchhoff diffraction formula [2]:

$$\boldsymbol{U}(z) = Ae^{ikz} \tag{1}$$

In the principle of Huygens, each *xy* plane can be viewed as a wavelet source, and the amplitude at the $\vec{r}$ point ($\vec{r} = x_1\hat{\boldsymbol{x}} + y_1\hat{\boldsymbol{y}} + z_1\hat{\boldsymbol{z}}$, the Q point in Fig. 1) of the wavelets emitted by the dot $P(x_0, y_0, 0)$ in *dxdy* planar is:

$$dU(\vec{r}) = -i\lambda^{-1}\rho^{-1}t(x, y)Ak(\theta)e^{ik\rho}dxdy \tag{2}$$

where $-$i stands for the π/2 phase advance of the wavelet, $\rho = |\vec{\rho}|$, $\vec{\rho} = (x_1 - x)\hat{\boldsymbol{x}} + (y_1 - y)\hat{\boldsymbol{y}} + z_1\hat{\boldsymbol{z}}$ k(θ) is the tilt factor, θ is the angle between $\vec{\rho}$ and z-axis,

$$U(\vec{r}) = -i\lambda^{-1}A\int_{-\infty}^{\infty}\rho^{-1}t(x, y)k(\theta)e^{ik\rho}dxdy \tag{3}$$

If the object in *xy* plane in the Fig. 1 is not Hexagram shaped leaves, but an atom at the point $P(x_0, y_0, 0)$ (or atomic scale leaves, as showed in Fig. 2).

When atoms absorb photons, it can be thought as the wavelets near the atoms are absorbed, which is equivalent to a very small opaque screen. If the circle of radius r_0 is represented as the range of the absorption wavelet, according to the coordinates of the atom, the transmittance of *xy* plane is:

$$t(x, y) = 1 - circ(x_0, y_0; r_0) \tag{4}$$

where $circ(x_0, y_0; r_0) = \begin{cases} 1 & (x - x_0)^2 + (y - y_0)^2 \le r_0^2 \\ 0 & (x - x_0)^2 + (y - y_0)^2 > r_0^2 \end{cases}$

Put Eqs. (4) in (3),we can get:

$$\begin{aligned} U(\vec{r}) &= -i\lambda^{-1}A\iint\rho^{-1}[1 - circ(x, y; r_0)]k(\theta)e^{ik\rho}dxdy \\ &= i\lambda^{-1}A\iint\rho^{-1}circ(x, y; r_0)k(\theta)e^{ik\rho}dxdy - i\lambda^{-1}A\iint\rho^{-1}k(\theta)e^{ik\rho}dxdy \\ &= i\lambda^{-1}\rho^{-1}\sigma Ae^{ik\rho}k(\theta) + Ae^{ikz} \\ &= U_a(\vec{r}) + U_0(\vec{r}) \end{aligned} \tag{5}$$

$$\text{Where } U_0(\vec{r}) = -i\lambda^{-1}A\iint\rho^{-1}k(\theta)e^{ik\rho}dxdy = Ae^{ikz} \tag{6}$$

$$\text{And } U_a(\vec{r}) = i\lambda^{-1}A\iint\rho^{-1}circ(x, y; r_0)k(\theta)e^{ik\rho}dxdy = i\lambda^{-1}\rho^{-1}\sigma Ae^{ik\rho}k(\theta) \tag{7}$$

When calculating Eq. (6), the Fresnel wave belt method was adopted [3]. $\sigma = \pi r_0^2$ in Eq. (7) represents the area of the circular

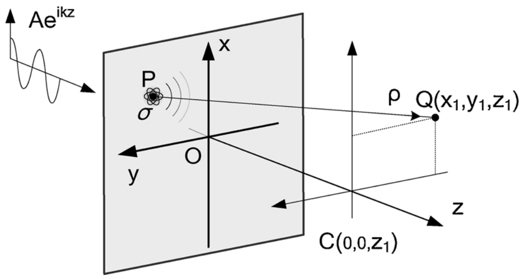

Fig. 2. The atoms absorbing the light is at the Q point.