AC 2012-4139: PHOTON MASS

Dr. Bert Pariser, Technical Career Institutes

Bert Pariser is a faculty member in the Electronic Engineering Technology and the Computer Science Technology departments at Technical Career Institutes. His primary responsibility is developing curriculum and teaching methodology for physics, thermodynamics, electromagnetic field theory, computers, and databases. Pariser has prepared grant proposals to the National Science Foundation, which produced the funding for a Fiber Optics Laboratory. He served as Faculty Advisor to the IEEE and Tau Alpha Pi National Honor Society. Pariser was instrumental in merging Tau Alpha Pi National Honor Society into the ASEE. In addition, Pariser co-founded five venture companies, and as a management consultant successfully catalyzed more than $100 million of new shareholder value in client businesses. He has led cross-functional client teams in projects to find and capture value-creating profit and growth opportunities. Pariser is a Trustee of Mutual Fund Series Trust and serves as a member or the audit committee. Pariser received a Ph.D. and M.S. from Columbia University and a B.S. from MIT in electrical engineering. Email: bert.pariser@gmail.com.

PHOTON MASS

The Helium Neon Laser operation is dependent on Light Amplification by Stimulated Emission of Radiation. The metastable helium atoms in the 3P2 state collide with the Neon atoms and transfer the energy to the 3S state of Neon. When the excited neon atom in 3S releases a photon it drops to the 2P energy state. The quantum of energy is emitted as a photon. Professor Willis E Lamb wrote a paper "Theory of the Optical Maser"[1]. My research on gaseous lasers "Time Development of a Laser Signal"[2] demonstrated how this transfer of energy from helium metastable atom produces an excited state in the neon atom.
Conventional physics has established that a photon has momentum, but does not have mass. I cannot find a reference in the literature for a photon mass.
By examining the propagation of the photon through the laser and out into the air I will examine the theoretical possibility of determining the mass of the photons (wavelength 6328 Angstroms, and 1.15 microns) emitted from a Helium Neon Laser.

Albert Einstein presented the world with the concept that energy and mass are related, the formula that Einstein presented[3] is shown in Equation 1

Equation 1 $$E = \frac{mc^2}{(1-(v/c)^2)^{1/2}}$$

By examining the data from a He-Ne (helium-neon) laser and using equation 1, I calculated the mass of the photon. Since the equations are complicated, I have included an excel table which is presented below as Figure 1

c	The Speed of Light in a vacuum	3.00E+08	m/s
n	index of refraction of air	1.0003	
v	velocity of light in air	299702547	m/s
v/c	v/c = 1/n	0.99970009	
(v/c)^2	(v/c)^2 = (1/n)^2	0.99940027	
1-(v/c)^2	1-(1/n)^2	0.00059973	
((1-(v/c)^2))^1/2	((1-(1/n)^2))^1/2	0.02448939	
E	Energy = h*f		
E	Energy = h*c/λ	3.14E-19	J
	The wavelength of a He Ne Laser	6.33E-07	m
	Einstein said Energy = mc^2/((1-(v/C)^2)^1/2		
h	Planck Constant	6.63E-34	JS
	photon mass = (h*/cλ)* ((1-(V/C)^2))^1/2	**8.56E-38**	**kg**

Figure 1

The speed of light in a vacuum is 299792458 m/s. In scientific notation the speed of light c = $2.99792458 * 10^8$ m/s. When I was a student at MIT as well as a Doctoral candidate at Columbia University I was always bothered by the conventional literature on photons which stated that photons have energy, photons have momentum but photons do not have mass.

As a physics professor having to teach the topic of light, I noticed that the index of refraction of light in air was 1.003[4]. This led me to reexamine Einstein's original equation for energy. With the aid of a computer and the examination of the ratio of light in a laser to the speed of light in free space I was encouraged to rethink the mass of a photon.

To explore the possibility that photons have mass, I will use Einstein's original equation. The speed of light in air is slower than light in a vacuum. To find the speed of light in a material, the speed of light in a vacuum is divided by the index of refraction[5].

Equation 2 $v = c/n$

Equation 3 $v/c = 1/n$

The index of refraction for air[4] is 1.0003.

Equation 3 $v/c = 1/1.003$

At this point the quantity v/c is squared and subtracted from 1 the result is shown in equation 4

Equation 4 $1- (v/c)^2 = 0.00059973$

The denominator of Einstein's Energy Equation is now evaluated

$((1-(v/c)^2)^{1/2} = 0.02448939$

Equation 5 Energy = Planck's constant (h) times the frequency (ν).

Equation 5 $\text{Energy} = h^* \nu$

The frequency and the wavelength (λ) are equal to the speed of light[6] (c).

Equation 6 $c = \nu * \lambda$.

Substitute this into equation 5 and the results are shown in Equation 6

Equation 7 $\text{Energy} = h^*c/\lambda$

The wavelength of light from a He –Ne (helium-neon) laser is equal to 6328 Angstroms[2] or 0.0000006328 m. Einstein said Energy = $mc^2/ (1-(v/c)^2)^{1/2}$. The laser photon's energy is equal to h^*c/λ. We can solve for the mass of the photon. The photon mass $= (h^*/c\lambda)^*((1-(v/c)^2))^{1/2}$ Using the values that were presented above, I calculate that the photon 6328 Angstroms[2] of the He-Ne (helium-neon) Laser has a mass of **$8.56*10^{-38}$ kg**.

However the Helium Neon Laser also emits photons with wavelength 1.15 microns. What happens if I do the same analysis with the 1.15 micron photons? The analysis is shown below in figure 2.

		Wavelength 6328 A		Wave length 1.15 μ	
C	The Speed of Light in a vacuum	3.00E+08	m/s	3.00E+08	m/s
n	index of refraction of air	1.0003		1.0003	
v	velocity of light in air	299702547.2	m/s	299702547.2	m/s
v/c	1/n	0.99970009		0.99970009	
	(v/c)^2	0.99940027		0.99940027	
	1-(V/C)^2	0.00059973		0.00059973	
	((1-(V/C)^2))^1/2	0.024489388		0.024489388	
E	Energy = h*f				
E	Energy = h*c/λ	3.14E-19	J	1.73E-19	J
	The wavelength of a He Ne Laser	6.33E-07	m	1.15E-06	m
	Einstein said Energy = mc^2/((1-(v/C)^2)^1/2				
h	Planck Constant	6.63E-34	JS	6.63E-34	JS
	photon mass = (h*((1-(V/C)^2))^1/2 /c *wavelength	**8.56E-38**	**kg**	**4.71E-38**	**kg**

Figure 2

The mass of the photon from a Helium Neon Laser of 1.15 microns is equal to **4.71 E-38 kg.**

This analysis shows that the photon is not a unique particle like the electron, proton or neutron. However that was never my contention. My analysis shows that the photons of different lasers have a mass. The mass of the photon from the visible 6328 Angstrom laser is the same order of magnitude as the mass of the photon from the 1.15 micron laser.

Although the mass of the photon is very small this analysis shows that it does exist and should be the basis of reexamining the current theories of gravity. Could the mass of the photons be responsible for the fact that laser light has very little divergence? To teach physics is an honor and an obligation to always try to understand the data.

Bibliography
1 Willis E Lamb, Jr, Physical Review 134, A1429- A1450, 1964
2 Pariser & T. Marshall, Applied Physics Letters, Vol 6 Number 12 June 1965

3 Giancoli, Douglass C, Physics for Scientists and Engineers Forth Edition, Pearson Education Inc. , Upper saddle River NJ,2009, Page 975
4 Giancoli, Douglass C, Physics for Scientists and Engineers Forth Edition, Pearson Education Inc. , Upper saddle River NJ,2009, Page 850
5 Giancoli, Douglass C, Physics for Scientists and Engineers Forth Edition, Pearson Education Inc. , Upper saddle River NJ,2009, Page 988
6 Giancoli, Douglass C, Physics for Scientists and Engineers Forth Edition, Pearson Education Inc. , Upper saddle River NJ,2009, Page 823