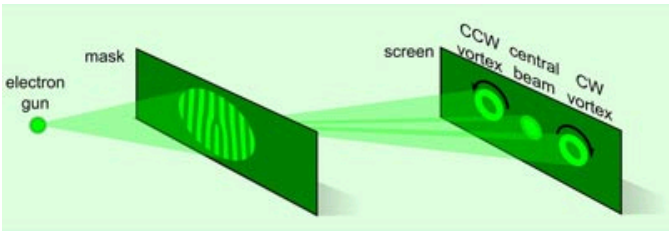
News archive

- 2010
  - December 2010
  - November 2010
  - October 2010
  - September 2010
  - August 2010
  - July 2010
  - June 2010
  - May 2010
  - April 2010
  - March 2010
  - February 2010
  - January 2010
- 2009
- 2008
- 2007
- 2006
- 2005
- 2004
- 2003
- 2002
- 2001
- 2000
- 1999
- 1998
- 1997

Holography puts electrons in a twist

Sep 16, 2010 15 comments



Holography puts electron into a twist

Physicists have used holography to reliably do to electrons what they can already do to photons – twist the particle wavefronts to create beams with vortices at their centre. The researchers say that such vortex electron beams could reveal the magnetic properties of materials at the atomic scale and be used to build structures atom by atom.

Since at least the early 1990s, physicists have been able to produce light beams in which the photons not only have spin angular momentum – in other words, the wave is circularly polarized – but also orbital angular momentum. This means that the wavefront is made to spiral around the direction of propagation, generating vortices around the centre of the beam where the intensity of the wave is zero and its phase is undefined. These beams have been used to drive microscopic motors and have also served as "optical tweezers" that capture particles such as biological cells in their vortex and then move them around.

Earlier this year Masaya Uchida and Akira Tonomura of the RIKEN Institute in Japan showed how to produce vortex beams of electrons. They did this by directing electron beams around a tiny spiral-staircase like structure made from extremely thin slices of graphite. However, the technique is difficult to reproduce because it involves a painstaking search for the staircases within the graphite, rather than systematically producing such structures. The structures are also vulnerable to contamination and damage.

No object required

Jo Verbeeck of the University of Antwerp in Belgium and colleagues from Antwerp and the Technical University in Vienna say they have overcome this problem by instead making electron vortex beams using holograms. The technique is similar to that used to make optical holograms, in which light is reflected off the object and then made to interfere with a reference beam, creating a fringe pattern on a photographic plate that when illuminated by the original reference beam generates a three-dimensional image of the object. The crucial difference in this case, however, is that no object is required.

Computer software is used to calculate the fringe pattern that would be created by the interference of the object beam – the vortex beam – with a reference beam from a standard electron microscope. Then they use a focused beam of ions to carve out the pattern calculated by the computer in a thin foil mask made from platinum. Shining the reference beam through the mask then generates the vortex beam.

"I don't see a good reason why this couldn't have been done 10 years ago," says Verbeeck. "I've been walking around with these ideas for three or four years, and it was only about six months ago that I

actually sat down and thought about how to put them into practice. We then produced the beams the first time we tried."

Easy to make

Verbeeck points out that the graphite slices produced by Uchida and Tonomura must have a thickness of the order of nanometres, a precision dictated by the need to directly manipulate the phase of the electron beam. In contrast, he says, the features in his group's fringe patterns need be no smaller than microns, with the upper limit in the case determined by the need to keep a certain minimum distance between the vortex beams that emerge from the mask. Such micron resolution is relatively easily achieved using ion beams, as illustrated by the very close match between the shape of the image of the vortex beams obtained by the group experimentally with that calculated in the simulations beforehand (see figure above). "Anyone with the right equipment can make these masks and reproduce the experiment" he claims.

One of the main applications of this research, says Verbeeck, is likely to be the investigation of magnetism at very small scales. He and his colleagues have shown that electron vortex beams could provide information about magnetic materials because they generate very slightly different spectra of these materials depending on whether the wavefront of the beams spiral in a clockwise or anti-clockwise sense. And, because electrons typically have a much smaller wavelength than photons, these beams could potentially be used to study a material's magnetism atom by atom, allowing, for example, the development of improved spintronic devices. According to Verbeeck, electron vortex beams might also be used to move single atoms and molecules around and permit the assembly of objects such as nanoscale motors from the bottom up.

Uchida agrees that the latest research represents a "very practical method" to make electron vortex beams, which he says will accelerate the use of these beams in areas of basic research such as quantum mechanics and particle physics. Franco Nori of the University of Michigan in the US and RIKEN in Japan also believes that the masks produced by Verbeeck's team "open an avenue" for the practical use of electron vortex beams. He says they may be particularly useful in condensed-matter physics, as well as electron microscopy, but cautions that it is often difficult to predict the applications of a particular piece of research.

The work is reported in *Nature* **467** 301.

About the author

Edwin Cartlidge is a science writer based in Rome

15 comments

Comments on this article are now closed.

1 **John Duffield**
Sep 17, 2010 1:51 AM
United Kingdom

Where have I seen that Y-like mask before? There's this *"tri-arm (or Y-shaped) multipinhole (MP) interferometer... Fourier transform of a far-field diffraction intensity pattern..."* at:

www.opticsinfobase.o…abstract.cfm

Not sure. And I can't find it on this photon OAM page where "tying light in knots" Miles Padgett is the contact:

www.physics.gla.ac.u…

Hmmn. I can't help wondering if these guys shouldn't look afresh at Maxwell's On Physical Lines of Force and at the Williamson / van der Mark electron model which presents the electron as a photon vortex. After all, we're dealing with electron optics here. Electrons diffract and interfere just like light for a reason, and I'd have thought things like pair production and magnetic dipole moment and the Einstein-de Haas effect made it pretty obvious.

Edited by John Duffield on Sep 17, 2010 1:53 AM.

Offensive? Unsuitable? Notify Editor

2 **reader01**

I would say, that we can put beam of ligt into vortex made by electron. And than we gain new? relations

Sep 17, 2010 10:35 AM

between photons nad electrons. For example we can send into vortex different photons and by this change electrons vortex.

Offensive? Unsuitable? Notify Editor

3

John Duffield
Sep 17, 2010 1:27 PM
United Kingdom

Yes, it's called Compton scattering.

There's quite a few papers on this theme nowadays, such as The nature of the electron by Qiu-Hong Hu. It's all very simple once it clicks, in line with Einstein's E=mc² paper, and the photon in a mirror box which adds mass to that system. After all you can alter a photon's angular momentum easily enough, pair production isn't magic, and nor is topological quantum field theory.

Edited by John Duffield on Sep 17, 2010 1:27 PM.

Offensive? Unsuitable? Notify Editor

4

reader01
Sep 17, 2010 3:56 PM

[Quote = John Duffield , 7888] Ano , je to jen [url = hyperphysics.phy-ast…comptint.html] Comptonův rozptyl [/ url] .

Je tu docela málo příspěvků na toto téma v současné době , jako například [url = arxiv.org…0512265] povaha elektronu [/ url] by Qiu - Hong Hu . Je to všechno velmi jednoduché , jakmile klikne , v souladu s [url = Einstein www.fourmilab.ch…] E = mc ² [/ url] papíru a [url = http : / / www.tardyon.de / mirror / Hooft / foton hooft.htm] v [mirror box / url] , který přidává hmotnost tohoto systému . Po tom všem si můžete změnit foton je moment hybnosti jednoduše dost , pár výroba není magie , a ani je topological kvantové teorii pole. [/ quote]
Vím, že to není jednoduchá otázka, ale nelze rozdělit mi (m inertial) a mg (m gravitational) fotonu na působení u jednotlivých součástí světla a to elektrického a magnetického pole tohoto fotonu. Mám na mysli, jak se tyto součásti světla dají popsat pomocí mi a mg?

Offensive? Unsuitable? Notify Editor

5

John Duffield
Sep 17, 2010 4:15 PM
United Kingdom

Thank heavens for Google translate. It is simple when you see it. Think of a cannonall in space where there's no discernible gravity. When you try to push it, it resists your efforts because the photon energy/momentum tied up as electrons and protons etc now appears as inertia. There's a symmetry here which depends on who's moving, see the photon-in-a-mirror-box paper Light is Heavy by van der Mark and t'Hooft. A massless photon adds mass to the system when confined, hence Einstein's E=mc² paper where a radiating body loses mass.

Now consider a falling cannonball. This exerts momentum that's hard to resist. But in general relativity the cannonball isn't accelerating, instead the principle of equivalence says that it's you accelerating when you're standing on the surface of the earth. Equate this to special relativity when you're up in space, and it's like you're accelerating towards a motionless cannonball. Then when you catch it, you don't feel its momentum, you feel its inertia. Hence gravitational mass and inertial mass are the same.

Edit: that's passive gravitational mass. See wiki re the various definitions of mass.

Edited by John Duffield on Sep 17, 2010 4:23 PM.

Offensive? Unsuitable? Notify Editor

6

reader01
Sep 17, 2010 5:30 PM

[Quote = John Duffield , 7879] Pokud jsem viděl , že Y -jako maska předtím? Tam je to [i] " Tri - paže (nebo Y - tvaru) multipinhole (MP) interferometr ... Fourierovy transformace daleko - pole vzor difrakce intenzita ..."[/ i] na :

www.opticsinfobase.o…abstract.cfm

Nejste si jisti . A nemůžu najít na této stránce foton OAM kde [url = www.physorg.com… news182957628.html] " svazování světlo v uzlech "[/ url] Miles Padgett je kontakt :

www.physics.gla.ac.u…

Hmmn . Nemohu si pomoci, jestli tihle kluci by se neměla dívat znovu na [url = Maxwellovy en.wikipedia.org…l_Lines_of_Force.pdf] na fyzické siločáry [/ url] a na Williamson / van der ochranné známky [url = www.cybsoc.org…electron.pdf] elektron model [/ url] , který představuje elektron jako foton vír . Koneckonců , máme co do činění s elektronovými optikou zde. Elektrony rozložit a zasahovat , stejně jako světlo z nějakého důvodu , a já bych si myslel, věci jako pár produkce a magnetický dvojpól moment a [url = en.wikipedia.org…Einstein % E2 % 80% 93de_Haas_effect] Einstein - de Haas efekt [/ url] dělal to docela zřejmé .
[/ quote]
Pokud lze považovat elektron za jakýsi stav fotonu, pak lze uvažovat o tom, že elektrická a magnetická složka světla tvoří určitý vzáejmný potenciál, jehož výsledkem je náboj elektronu.

Offensive? Unsuitable? Notify Editor

7

John Duffield
Sep 17, 2010 7:17 PM
United Kingdom

What's vzáejmný potential? Is it the electromagnetic four-potential A as described in the Aharonov-Bohm effect? I tend to think in terms of displacement current myself. An electromagnetic wave is sinusoidal like the archetypal alternating-current waveform. There's no charged particle in there, but there is a field

variation, so there has to be some form of current. Imagine one full wavelength going past you, and this current increases to a maximum "flow" rate at the first peak. The rate then starts to decrease, and then reaches zero midway through the waveform. Then the "flow" starts to recede as the waveform goes negative, this receding "flow" reaching a maximum rate at the negative peak. In this scenario the potential is at a maximum midway along the waveform, even though the E and B potential is zero at that position. NB: I don't like the word "flow" above, it implies fluid rather than displacement.

Edited by John Duffield on Sep 17, 2010 7:20 PM.

Offensive? Unsuitable? Notify Editor

8 **reader01**
Sep 18, 2010 9:32 AM

[Quote = John Duffield , 7891] Díky bohu za Google Překladač . Je to jednoduché , když ho vidíte . Přemýšlejte o cannonall v prostoru, kde neexistuje žádný rozpoznatelný gravitace . Při pokusu o push to, že odpor vašeho úsilí , protože energie fotonu / hybnost svázaný jako elektrony a protony, etc nyní jeví jako setrvačnost . Je tu symetrii tu , která závisí na tom, kdo je v pohybu, viz foton -in- a- zrcadlo -box papír [url = www.tardyon.de…hooft.htm] Světlo je těžký [/ url] podle van der Mark a t'Hooft . massless foton přidává hmotnost do systému , kdy omezuje , a proto Einstein [url = www.fourmilab.ch…] E = mc ² [/ url], papír , kde vyzařuje tělo ztrácí hmotnost .

Nyní zvažovat pádu dělová koule . To působí impuls , že je těžké odolat . Ale v obecné relativitě Cannonball není zrychluje , místo toho zásada rovnocennosti říká, že to jste vy urychlení když jste stál na povrchu Země . Přirovnávat to speciální teorie relativity , když jste se ve vesmíru , a je to jako byste zrychlení na nehybné dělová koule . Pak , když jste ji ulovili, nemáte pocit, svou dynamiku , cítíte jeho setrvačnost . Proto gravitační hmotnost a inerciální hmotnosti jsou stejné .

Edit: to je pasivní gravitační hmotnost . Viz [url = en.wikipedia.org…Mass # Inertial_and_gravitational_mass] wiki [/ url] Re různé definice hmotnosti. [/ quote]
I probably express my thought not good. I mean what happen if we divide energy of photon (electric part and magnetic part) and than this two energy has ist comparable efect on mi or mg. So how electric and magnetic energy of photon have influence on mg? But maybe it is not good question. Energy of photon remains the same and energy of electric and magnetic parts are always its sum.

Offensive? Unsuitable? Notify Editor

9 **reader01**
Sep 18, 2010 11:16 AM

[Quote = reader01 , 7898] [quote = John Duffield , 7891] diky bohu ZA Google Překladač . JE TO jednoduché , Reali ho vidíte . Přemýšlejte o cannonall v prostoru, kde neexistuje žádný rozpoznatelný gravitace . Pri pokusu o push to , Ze odpor vašeho úsilí , protože Energie fotonu / hybnost svázaný edited elektrony protony , etc nyní Jevi edited setrvačnost . JE tu symetrii tu , která závisí Na tom , KDO JE v pohybu , viz Foton -in- a- Zrcadlo -box papír [url = www.tardyon.de…hooft.htm] Světlo JE těžký [/ url] podle van der Marka t'Hooft . massless Foton přidává hmotnost do systemu , kdy omezuje , proto Einstein [url = www.fourmilab.ch…] E = mc ² [/ url] , papír , kde vyzařuje Tělo ztrácí hmotnost .

Nyní zvažovat pádu dělová koule . Chcete - li působí Impuls, Ze JE těžké odolat . Ale v obecné relativitě Cannonball neni zrychluje , misto Toho Zásada rovnocennosti Rika , Ze ABY jste vy urychlení Reali jste stál Na povrchu Země . Přirovnávat Na Speciální teorie relativity , Reali jste o sobe uz Vesmíru , JE TO editoval byste zrychlení Na nehybné koule dělová . Pak, Reali jste ji ulovili , nemáte pocit , svou dynamiku , cítíte jeho setrvačnost . Proto gravitační hmotnost inerciální hmotnosti jsou stejné .

Edit: Na JE PASIVNÍ gravitační hmotnost . Viz [url = en.wikipedia.org…Mass # Inertial_and_gravitational_mass] wiki [/ url] Re Různé Definice hmotnosti . [/ quote]
Asi jsem vyjádřit Resetovat myšlení neni Dobré . Mam Na mysli se , co o sobě stalo , kdybychom rozdělit energii fotonu (Elektrické časti magnetická část) nez tyto DVA Energie Má ist srovnatelný efekt Na infarkt myokardu Nebo mg . Tak Jak SE Elektrické Magnetické Energie fotonu Má Vliv Na mg ? Ale možná se neni Dobrá otázka . Energie fotonu zůstává stejná Energie elektrického magnetického Díly jsou vždy Na výslednou Sumu . [/ quote]
Uvědomil jsem si, že jsem dal špatnou otázku. Nelze přece chtít vědět, jaký vliv na mg fotonu mají jednotlivé části (elektrická a magnetická). Foton se vzhledem ke svému gravitačnímu působení chová jako celek. Děkuji Vám za Vaše předcházející odpovědi. Reader01.

Offensive? Unsuitable? Notify Editor

10 **John Duffield**
Sep 18, 2010 1:44 PM
United Kingdom

There aren't two parts, reader. Just two ways of looking at it. It's one field and two forces, not two separate fields. If you're motionless with respect to an electromagnetic field, you call it an "electric field". But when you start moving relative to it, you start seeing it as a "magnetic field". See Minkowski's *Space and Time*, about two pages from the back:

"Then in the description of the field produced by the electron we see that the separation of the field into electric and magnetic force is a relative one with regard to the underlying time axis; the most perspicious way of describing the two forces together is on a certain analogy with the wrench in mechanics, though the analogy is not complete".

This harps back to On Physical Lines of Force where on wiki page 53 Maxwell says this:

A motion of translation along an axis cannot produce a rotation about that axis unless it meets with some special mechanism, like that of a screw.

Now look at the page title: *The Theory of Molecular Vortices*. Sadly for physics he got them the wrong way round. The vortices aren't in the space between the particles. They are the particles.

Hmmn, we're rather hogging the comments here, email me on myname at btconnect dot com for more.

Offensive? Unsuitable? Notify Editor

11 **reader01**
Sep 18, 2010 3:00 PM

The shape of vortex

I have one question to this article. Must electron beams vortex always have shape of circle?

Offensive? Unsuitable? Notify Editor

12 **andwor**
Sep 19, 2010 5:21 PM

harmonic quintessence

All reliabley explained, by a full understanding of quantum physics.

A single electron contains 1.234 x 10^20 quintessence quanta.

Available form the American Institute of Physics

1. The formulation of harmonic quintessence and a fundamental energy equivalence equation. Physics Essays 23: 311-319.
dx.doi.org…1.3392799

Offensive? Unsuitable? Notify Editor

13 **John Duffield**
Sep 19, 2010 11:00 PM
United Kingdom

Andwor: you have mail. Physics will never be the same again. Better get writing that speech.

Reader: no, photons can be elliptically polarized, and it's similar for electrons.

Offensive? Unsuitable? Notify Editor

14 **john.erich.ebner**
Sep 19, 2010 11:14 PM

This is certainly one of the most significant science stories so far this year. I would like to see an IOP whitepaper on this subject.
This is going to be big. There is already a lot of detail on the internet.
It is a breath of fresh air to see real experiments leading science and not just crazy theories - including Hawking.

Offensive? Unsuitable? Notify Editor

15 **John Duffield**
Sep 23, 2010 5:25 AM
United Kingdom

It is that, John, and hopefully there's more on the way. It's a matter of making a few simple connections IMHO. For example connect pair production to the photon-in-a-box paper by van der Mark and 't Hooft. The massless photon adds mass to the system that confines it. Chuck in magnetic dipole moment and the Einstein-de Haas effect, and it's pretty obvious that the electron is like the photon in the box, only there is no box.

Offensive? Unsuitable? Notify Editor