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Plucking light out of space

November 18, 2011 by Joerg Heber 2 Comments

You may imagine vacuum as complete emptiness, as the very definition of nothing. But that's not the case at all. Vacuum is humming with activity, as has now been demonstrated impressively in a study by researchers from Chalmers University of Technology in Göteborg, Sweden, RIKEN in Japan, the University of Michigan in the US and other institutions. They have created light basically out of nothing but the electromagnetic fields existing even in total vacuum.

Where does this contradiction come from that vacuum isn't really ever empty? One of physics fundamental laws of physics, Heisenberg's principle, states that even in vacuum virtual particles can exist. These are particles that appear only for such brief moments of time that they're not noticeable to an observer. Indeed, vacuum is buzzing with all sorts of virtual particles and fields. One of Stephen Hawking's most well-known predictions is that black holes emit light, which is an effect that relies on virtual particles.

Another consequence of virtual particles is that the energy of vacuum is not really zero either, simply because as explained above the vacuum isn't empty on average. This has various implications, one of the most famous being the Casimir effect. In the classic version of the Casimir effect the finite energy of vacuum causes an attractive force between two closely spaced metallic plates that pulls them towards each other. This is because the metallic plates act as mirrors that interact with the 'virtual' electromagnetic fields of the vacuum in-between.

In addition, there is also the dynamic Casimir effect. This occurs if the mirrors are moving very fast so that the electromagnetic field in-between has no time to adjust. Instead, the ripples in the field caused by the fast mirror movement lead to the emission of a light particle. Basically, the mirrors create light out of the electromagnetic field in a similar way that a guitar player generates sounds from plucking a string. The problem with the experimental realization of the dynamic Casimir effect is that the mirrors need to move seriously fast. Otherwise the system has time to adjust to the new geometry of the mirrors, and no light will be excited. We are talking about speeds close to the speed of light!

Such fast mirror movements are simply not possible with mechanical mirrors. What is needed is an analogue that changes the dimension of the vacuum by other means. Fortunately, such systems exist in superconducting circuits, where magnetic fields applied to a so-called SQUID circuit on a chip achieve the same moving mirror function for electromagnetic fields. Moreover, fast-changing magnetic fields are no problem to create. In the present experiment the mirrors 'move' at a quarter of the speed of light, which corresponds to a driving frequency for the magnetic field of more than 10 gigahertz. The dynamic Casimir is clearly observed, with light being generated at the expected frequencies.

This is certainly a beautiful study confirming the intriguing properties of quantum mechanics. And what's more, it doesn't need Hawking's black holes to experiment with them, all that's needed is a table-top setup of superconducting circuits. This ease of experimentation will make sure we will learn much more about these virtual fluctuations in vacuum from future experiments.

Reference:

Wilson, C., Johansson, G., Pourkabirian, A., Simoen, M., Johansson, J., Duty, T., Nori, F., & Delsing, P. (2011). Observation of the dynamical Casimir effect in a superconducting circuit *Nature, 479* (7373), 376-379 DOI: 10.1038/nature10561

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