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News

Faster than light



Scientists at the NEC Research Institute in Princeton have carried out an experiment in which a pulse of light appeared to emerge from a cloud of gas before it even entered.

If our fundamental understanding of cause and effect is not to be contradicted, the word "appeared" is crucial. Indeed, it's generally thought that information can't travel faster than a fixed speed, the speed of light in vacuum. (We know from Einstein's laws that no particles can travel faster than this speed.) So what exactly is going on here?

The experiment exploited the fact that a pulse of light of finite duration is necessarily the sum of an infinite number of waves of different frequencies. (This is a well-known theorem in physics, known as the bandwidth theorem.) These waves will be of various phases and frequencies. They interfere constructively in some places and destructively in others, to form the pulse.

In the NEC experiment, a light pulse was passed through a cell filled with a gas of caesium atoms, in which a region of "anomalous dispersion" was created using laser beams.

In such a region, the refraction undergone by a wave passing through depends on its original wavelength: shorter wavelength components of the light pulse become longer, and vice versa. As a result, the way in which the constituent wavelengths of the pulse interfere changes as the pulse passes through the region.

In this case, the constituent waves "rephase" so that the area of least interference – the peak of the pulse – is recreated well in front of its original position. What happens is that the forward rising edge of the light pulse travels into the caesium gas cell, experiences anomalous dispersion, and rephases so that in this part of the wave packet, where previously a lot of interference took place, now only a little takes place. It leaves the cell as a peak – before the original peak of the wave packet even enters!

In the NEC experiment, the peak was seen exiting the cell 60 nanoseconds before entering – which sounds like an extremely short time gain, until you put it in context. The light pulse would have taken only 0.2 nanoseconds to travel the width of the cell in a vacuum, so comparatively speaking, the time gain was very large.

The authors have put together [a helpful FAQ](#) about their experiment, and also (for QuickTime-capable browsers) an [animation](#) illustrating a light pulse passing through the anomalous region.

Group and phase velocities

We can distinguish between the speed of the light pulse, or "wave packet" as the ensemble of waves making up the pulse is sometimes known, and the speed of the individual waves in the packet. The first is called the *group velocity*, the second the *phase velocity*.

You can see the difference between group and phase velocity when you drop a pebble into a pond. The pebble creates a ring which moves outwards, slower than the actual ripples which make up the ring. The group velocity is the speed at which the ring expands, whereas the phase velocity is the velocity of the individual ripples making up the ring. There is a nice [applet](#) demonstrating the difference on the University of Virginia's website.

In a vacuum the phase and group velocities are the same for light, so as far as the speed at which a light pulse travels is concerned there is no particular need to distinguish between the two. But when a light pulse travels through a highly charged or dispersive medium, the two can differ. In normal dispersive media (such as in glass), the group velocity is slower than the phase velocity, and is the speed at which information can be transmitted. The NEC experiment shows faster-than-light group velocity. But since in the anomalous region the group velocity is *faster* than the phase velocity, it is no longer equal to the speed of information transfer.

There is a slightly more detailed and very clear [explanation](#) of group and phase velocities, and their significance for this kind of experiment, on Kevin Brown's excellent maths pages.

In short – and in spite of appearances – no energy or information has travelled faster than the speed of light in vacuum. Rather, the anomalous region has rephased components already present in the rising edge of the signal, but well ahead of the peak, to recreate the peak ahead of its original position.

Although the experiment doesn't show us how to move back in time, such an effect might be helpful in speeding up signalling in electronic circuits. Lijun Wang, who performed the experiment with colleagues Alexander Kuzmich and Arthur Dogariu, has applied for a patent. The full consequences of the experiment are not yet understood, and research continues.

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