Launching information from faster-than-light polarization currents

Although Einstein's theories place a universal speed limit on all objects in the universe, the same rules don't necessarily apply to sequentially moving disturbances which don't carry any mass. A team of researchers at Los Alamos National Laboratory led by Dr John Singleton in collaboration with Dr Andrea Schmidt, shows how polarization currents, carried by the relative displacement of charged particles within specialised antennas, can be used to generate bright bursts of light – emulating more familiar behaviours displayed by sound waves. The discoveries of the research team could lead to new innovations in wireless communications networks; and may also shed new light on a long-standing astronomical mystery.

If you've ever witnessed an aeroplane accelerating to supersonic speeds, it would have been hard to miss the intense burst of sound it created as it crossed the sound barrier. Known as a 'sonic boom,' this dramatic effect arises when the sound waves emitted by an accelerating plane can no longer keep pace with the plane itself. "As the plane overtakes the sound waves that it creates, they pile up behind it," Dr Singleton from the Los Alamos National Laboratory explains. "Then, the noise that was made by the plane over seconds of its flight path hits a well-placed observer all at once."

At first sight, analogous behaviour using electromagnetic waves, which are conventionally emitted by moving electrically charged particles, appears to be strictly forbidden. As Einstein famously pointed out, his Special Theory of Relativity imposes a universal speed limit – the speed of light — that can never be reached by any object that carries mass. This means that the electromagnetic waves emitted by a charged particle – which themselves carry zero mass – will always move faster than the particle itself. As a result, it seems impossible that these waves could somehow form an 'electromagnetic boom,' in which they pile up to form a sudden, intense burst of light. However, it turns out that this problem can be overcome using collections of particles, rather than a single one.

THE ELECTROMAGNETIC STADIUM WAVE

To understand this line of reasoning, we first need to look at the microscopic processes which play out within ionic solids and plasmas: the latter are extremely hot fluids in which atoms are stripped of their outer electrons. If an electric field is applied to a portion of one these systems, the negative and positive charges within that part will move small distances in opposite directions, creating what is known as *polarization*. If a second electric field is then applied to an adjacent bit of the solid or plasma and the first field is turned off, the polarization moves. Using suitably accurate timing, the polarization can be made to move

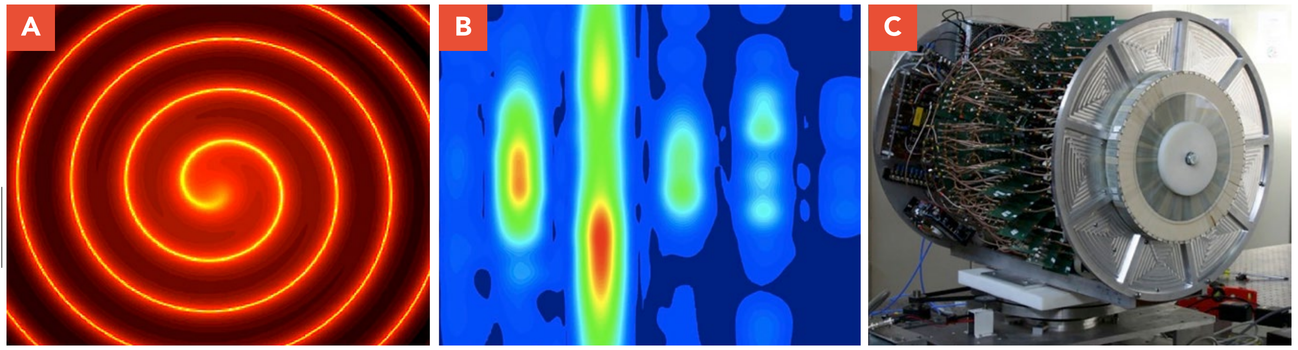


Photo credit: A.C. Schmidt.

(A) The spiral 'electromagnetic boom' produced by a large circular antenna, as predicted by Andrea Schmidt; (B) An example of the detector signal plot, demonstrating the 'information focusing' effect; (C) A circular antenna built at the Los Alamos National Laboratory.

Photo credit: A.C. Schmidt.

Examples of specialised antennas built by the Los Alamos National Laboratory team.

much faster than the speed of light. "We have easily achieved 100 times the speed of light in one of our antennas, or, for Trekkies, between warp factor 4 and 5," says Singleton.

The effect may sound like an exotic phenomenon, but in fact, only the disturbance moves very fast; the particles creating it are displaced only tiny distances. "It's like a stadium wave at a football match, where slowly moving people stand up and sit down," Dr Schmidt illustrates. "If their timing is good enough, a wave rolls round the stadium at high speed, even if the people making it hardly budge from their places."

As predicted by Maxwell in the 19th century, the moving polarization, or polarization current, emits electromagnetic waves. We therefore have a source of radiation that travels faster than the waves that it emits without breaking any laws of physics. (Of course, the electromagnetic waves emitted can only travel at the speed of light). For the Los Alamos National Laboratory research team, such a setup presented some fascinating opportunities.

As predicted by Maxwell in the 19th century, the moving polarization, or polarization current, emits electromagnetic waves.

A NEW TYPE OF ANTENNA

Conventional antennas involve electrical currents that are made up of electrons. "Travelling faster than the speed of light is impossible

5G local network concept: small antenna mounted on existing infrastructure, sends signals successively into individual apartments or rooms.

Sergiy1975/Shutterstock.com

estherpoon/Shutterstock.com

for electrons because they have mass," explains Dr Singleton. "But no such speed limit applies to polarization currents." Faster-than-light polarization currents can also be made to accelerate or decelerate in a very controllable way, meaning that electromagnetic analogues of many interesting focusing effects, including some previously known from acoustics, can now be achieved.

Starting from theoretical simulations, Schmidt, Dr Frank Krawczyk, and Singleton designed and built a specialised antenna rather like a linear accelerator (for polarization currents) at Los Alamos National Laboratory. Faster-than-light polarization currents on which a simple, repeated 'message' was encoded were sent along this antenna using a carefully controlled acceleration scheme designed to focus the emitted radiation in an unusual way.

CONVEYING SECURE MESSAGES

The key ingredient of the acceleration scheme is that the component of the polarization current's velocity in the direction of a chosen target point is always exactly the speed of light as it travels along the antenna. If we substitute sound for light, this is similar to the conditions for getting a 'super boom' in acoustics. However, "rather than aiming for an 'electromagnetic boom', we showed that the message encoded on the polarization current is received strong and understandable only at the target point," Dr Singleton describes. "At all other places, the radio waves are weak and scrambled."

The antenna could be used to spray bursts of information to specific locations in its surroundings, ensuring that the message remained very difficult to decode at all other points. For example, the team noted that such behaviour could be useful for neighbourhood 5G networks – which are planned to wirelessly transmit signals to specific target buildings. Using such an antenna would ensure that your neighbours would not be able to see what you ordered on Amazon.

In such a system, messages or data would be encoded as specially-shaped polarization currents

A pulsar (pulsating radio source) is a highly magnetized rotating compact star that emits very sharp pulses of electromagnetic radiation.

NASA images/Shutterstock.com

These antennas could one day provide a reliable basis for enhancing the security of communications networks.

which would be accelerated along the antenna – producing clear electromagnetic signals at highly specific target locations. As a result, these antennas could one day provide a reliable basis for enhancing the security of communications networks.

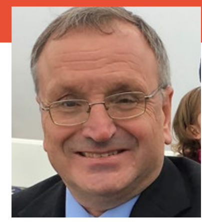
EXPLAINING AN ASTRONOMICAL MYSTERY

Elsewhere, Dr Singleton proposes that the bursts of light produced by faster-than-light polarization currents could explain a phenomenon that has long remained something of a mystery to astronomers. Pulsars are rapidly-rotating, highly magnetic remains of stars born in supernova explosions. Intriguingly, these objects transmit distinctive pulses with the same period as that of the star's rotation.

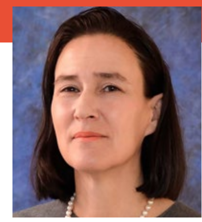
"There have been previous attempts to explain these incredibly sharp pulses using faster-than-light polarization currents driven by the intense magnetic field as it whirls through the pulsar's plasma atmosphere," Dr Singleton describes. "However, we have shown that there are fundamental mathematical problems with those prior theoretical attempts. Instead, it now seems likely that pulsars work in a very similar way to the demonstration antenna in our paper. One could even say that we have a ground-based pulsar here." The ability to play with an experimental 'pulsar' in one's own lab could help to solve the long-standing mystery as to why the equivalent astronomical objects shine in the way that they do.

Through their future research, the Los Alamos National Laboratory researchers will now aim to explore this fascinating effect in more detail; and to design more advanced antennas, capable of generating specially-shaped polarization currents even more accurately. Together, these efforts could soon lead to groundbreaking new insights into an effect which seems at first glance to defy Einstein's robust descriptions of how the universe works.

Behind the Research



Dr John Singleton



Dr Andrea C. Schmidt

E: jsingle@lanl.gov **T:** +1-505-667-4404 **E:** aschmidt@lanl.gov
W: MagLab Staff -John Singleton, maglabdata (nationalmaglab.org)

Research Objectives

Dr John Singleton and Dr Andrea Schmidt's research explores novel phenomena in electromagnetism. Their current research could lead to new innovations in wireless communications networks.

Detail

John Singleton
National High Magnetic Field Laboratory
MPA-MAGLAB, TA-35, MS-E536
Los Alamos National Laboratory
Los Alamos NM 87545
USA

Bio

John Singleton researches condensed-matter physics and electrical engineering at the National High Magnetic Field Laboratory's pulsed-field facility. Prior to this, he taught, and ran a large research group at Oxford University; he still holds a visiting professorship there. He has over 500 publications, including a text book; his h-index is 58.

Following a successful career as a linguist, **Andrea Schmidt** commenced a pioneering 15-year-long experimental and theoretical study of superluminal antennas, in parallel completing BS and MS degrees in Mathematics and a PhD in Electrical Engineering. She currently works in the Space and Remote Sensing Group at Los Alamos National Laboratory.

Funding

The experiments and calculations are supported by Los Alamos National Laboratory LDRD Projects 20200285ER and 20180352ER.
Additional support from LANL FY17 Pathfinder Fund Call for Technology Demonstration, PADGS:16-036.
Much of this work is performed at the National High Magnetic Field Laboratory, USA, which is supported by NSF Cooperative Agreements DMR-1157490 and DMR-1644779, the State of Florida, and US DoE.
JS also acknowledges a Visiting Professorship from the University of Oxford that enables some of the calculations.

Collaborators

- Kim Nichols (knichols@lanl.gov)
- **Previous students:** Connor Bailey, James Wigger
- **Recently retired:** Frank Krawczyk

References

Singleton, J, Schmidt, AC, Bailey, C, Wigger, J, and Krawczyk, F. (2020). Information carried by electromagnetic radiation launched from accelerated polarization currents. *Physical Review Applied*, 14(6), p.064046. doi:10.1103/PhysRevApplied.14.064046

Schmidt, AC. Theoretical and Experimental Studies of the Emission of Electromagnetic Radiation by Superluminal Polarization Currents PhD dissertation (2020) www.digitalrepository.unm.edu/ece_etds/497/

Personal Response

How difficult would it be to implement this technique in real 5G networks?

"The polarization current antennas are fully scalable, and for 5G could be constructed in the form of a two-dimensional array about the size of a paperback book. Such a device would be suitable for beaming focused signals in many different directions without the need to physically rotate the antenna. Moreover, in contrast to conventional phased arrays, which tend to be hand-assembled from literally tens of tiny metal components, the superluminal antenna arrays are very robust and monolithic; they can be simply constructed using CNC milling and 3D printing techniques."