Finding the right soliton for future networks

May 14 2008

European researchers say their study of self-sustaining solitary light wave packets could result in a new generation of computers and optical telecommunications networks. Using light rather than electronic or magnetic devices to store and move data is quicker, more energy efficient and cost-effective, and cavity solitons could be the key to unlocking this technology.

A soliton is defined as a wave, which once formed, maintains its shape while it travels at constant speed. Soliton waves are localised within a region and are able to react with other solitons and emerge unchanged. This is in contrast to normal waves that diffuse over time over ever larger regions of space, a phenomenon called dispersion.

Solitons were first documented in 1834 by John Scott Russell who, quite by chance, observed the phenomenon in a canal in Scotland where soliton waves formed in water. He was able to reproduce this phenomenon in a water tank.

It was not until the 1970s that scientists suggested optical solitons could exist in optical fibres. In the late 1980s French and Belgian scientists were able to transmit soliton pulses over a fibre-optic cable.

Since then there has been an increasing amount of research into solitons and their practical applications for the rapid transmission of data over long distances.

The EU-funded FUNFACS project was set up in 2005 to investigate a special type of soliton. Cavity solitons are solitary waves formed in an optical cavity capable of trapping light. FUNFACS follows on from an earlier EU funded project PIANOS, which demonstrated steady cavity solitons.

The scientists wanted to investigate fundamental properties of such optical solitons, and demonstrate a proof of principle for all-optical processing with solitons.

Prospect of exciting applications

The scientists believed there were properties unique to cavity solitons that could give rise to applications more advanced than what is possible using today’s technology. For instance, such solitons have the extraordinary property that they can be formed and destroyed – 'written and erased' – at the micrometer scale in such a cavity. The project has gone a long way toward advancing that theory.

The properties of cavity solitons are particularly applicable to the developing scientific fields of photonics and optoelectronics, which aim to use light as a method of storing, manipulating and transmitting data. The science could ultimately result in a new generation of computers and optical networks.

Optoelectronics employs the electrical effects of materials on light. The FUNFACS researchers first sought to demonstrate the viability of self-sustained cavity soliton lasers (CSL), both as continuous waves and as pulsed waves that can be switched on and off.

They worked from the premise that since a soliton in an optical fibre is self-sustaining once it has been created, a cavity soliton is similarly self-sustaining within its cavity after its creation.

Lasers (light amplification by stimulated emission of radiation) consist of a gain medium inside a highly reflective optical cavity. The gain medium, which can be solid, liquid or gas, is the major determining factor of the wavelength of operation, and other properties, of the laser.

The cavity is coupled to an energy supply directed to the gain medium. In the case of a CSL the gain medium is the semiconducting material.

The test CSL was based on an existing semiconductor laser type known as a vertical-cavity surface-emitting laser (VCSEL) which is used in a variety of applications, including those relating to optical telecommunications.

The device consists of a thin optical cavity sandwiched between two highly reflective mirrors, fabricated out of solid semiconducting material using state-of-the-art nanotechnology.

An all-optical future

The researchers were able to show that due to the self-sustaining properties of cavity solitons the energy input required to maintain them is small. They were also able to show CSLs can be switched on and off using light pulses.
The research results indicate that CSLs could play an important role in an all-optical telecommunications system, according to project coordinator Robert Kuszelewicz.

“In conventional systems data are switched and routed within the network by converting light pulses into electrical signals and back again which slows down communications and creates a lot of waste heat,” he says. “But by using CSLs the switching can be done just with the light pulses with no need to convert to and from electricity thus giving much greater transmission speed and efficiency.”

Other tests demonstrated that solitons are not restricted to a single location but could be moved across the plane of the semiconductor material with a controlled speed and direction of drift.

Multiple solitons can also co-exist in close proximity to each other without interacting. Brought closer still, they can bind to one another forming a sort of cavity soliton molecule. Finally, the tests demonstrated that an attempt to superimpose two of them results in one disappearing.

"This wealth of properties is an incomparable reservoir of new processing functions unavailable in more conventional electronic systems," says Kuszelewicz.

The discoveries could lead to an evolution from the current use of chip-based semiconductors for data processing to a more flexible type of optical processing. The advantages of optical processing stem from the way data is stored.

Once data has been imprinted on a semiconductor chip, its location is permanently fixed, while data held using cavity soliton technology can be moved without changing or losing its character.

The advance could represent a major technological breakthrough, much in the same way as transistors replaced valves and were themselves replaced by microchips.

However Kuszelewicz believes such a breakthrough is still a long way in the future. The first practical applications could be in hybrid semiconductors using current technology coupled with optoelectronic technology based on cavity solitons.

He also points out the two technologies each have their own strengths and drawbacks and will continue to exist alongside each other for a long time to come.

The FUNFACS project received funding from the EU's Sixth Framework Programme for research.

Source: ICT Results