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Magnifying the time gap

The ***time lens*** does for time what the microscope does with small things, says S.Ananthanarayanan.

The age of digital communication depends on devices that can send and detect series of pulses with high speed and accuracy. As we begin to send more and more data over communication lines, the electrical pulses need to be packed closer and the time interval between them becomes shorter and shorter. The need to capture very rapid events also arises in other fields, like imaging chemical processes.

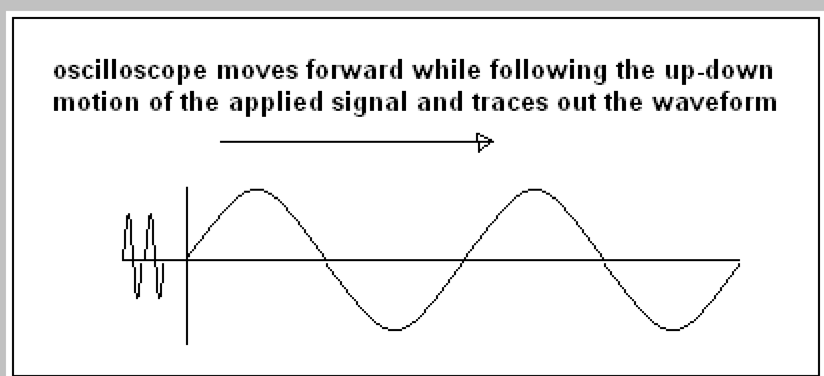
The need to detect these time gaps which are smaller than the resolution of available detectors has given rise to the device of the '***time microscope'***, which '***expands***' the time interval , to '***come into view'***, rather like a magnifying glass helps us see things that are too small to see with the naked eye.

Pico time gap

In a simple communication application, like sending a signal which says, 'yes' or 'no', every second, for instance, we need a speed of only one pulse a second. If the pulse comes, the observer reads, 'yes' and if there is no pulse, she reads, 'no', once every second. But in real communication, like transmitting voice and images, data processing and number crunching, the quantities of information handled can run into millions of bits a second. Millions of pulses would then be packed and the time gap would be measured in pico-seconds, or billionths of a second.

Photonics

These higher demands of communication and technology are now approaching the limits of the capability of electronic instrumentation. The standard method to analyse wave forms is to stretch the pattern out against time, with the help of an oscilloscope, as shown in the picture.



The state of the art oscilloscopes and high speed detectors permit a resolution of waveforms with time-gap of 30 pico-seconds. Doing any better is physically not possible, because microelectronics itself now approaches the limits of how small it can get.

The answer then lies in using purely optical methods, because pure light waves do not have limits of size, like electronic components. There is thus now great interest in integrating optical components with silicon chips, to include high speed optical components within conventional electronic circuits.

Time and space

A technique that has been developed makes use of the fact that the light wave can be considered ‘in time’, in a manner similar to its consideration ‘in space’. To explain, the electromagnetic waves of light can be described with the help of a mathematical expression which contains the parameters both of space as well as of time. Thus, the properties of the wave can be worked out, from this expression, both at any point of space at a given time, or at a given point in space, at any time. This fact suggests that some aspects of the ***spatial*** behaviour of light could be replicated in the ***temporal*** plane.

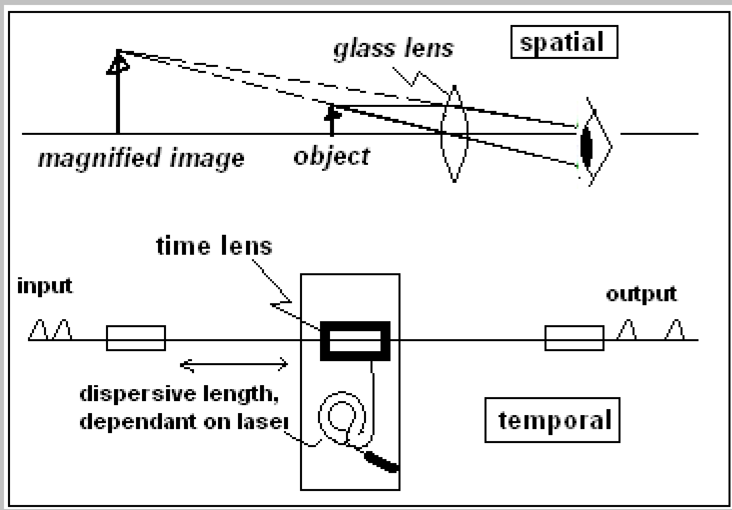
The magnifying glass, or its development, the microscope, is an example of making use of the spatial behaviour. When an object is viewed through the microscope, the image formed is larger and resolved in greater detail than when seen with the naked eye. This happens because light moves at different speeds through air and glass and the consequent bending of light rays from the object being observed. In fact, what is happening is that light waves of a certain spatial displacement are refocused at the image with different spatial displacement.

Now, how can this be done in respect of time? That is, can a pair of light pulses, one arising a short time after the other, be made to appear to be separated by a larger time gap? If this could be done, then two events that are separated by too short a time to tell apart could be separated sufficiently to be distinguished.

The time lens

The geometric explanation of the action of the magnifying glass shows where rays from a point, passing through any part of the lens, will meet. This viewpoint ignores the fact that the rays of light are in fact waves, which have a rising and falling value at every point. If we do take this aspect into consideration, then we enter the arena of interference of waves and consonance and dissonance and the formation of ‘beats’ and the adding and canceling out of waves.

Alexander Gaeta and colleagues at Cornell, USA, report that they have made a high frequency waveform interact with a ***varying frequency*** pulse generated by a laser, which resulted in a combined waveform. The 2 closely separated peaks in the incoming waveform interacted at different times with the laser pulse. As the pulse was of varying frequency (called a ***chirped pulse***), the 2 peaks generated combined waveforms of different frequencies,



which could then be separated. The separation then revealed how far apart in time the 2 closely separated peaks were.

The device has been developed using conventional silicon based components and can form part of another electronic circuit and may be the beginning of new devices that help communication and imaging technologies.