January 2001 Meeting: Faster than Light???

by Dave Thomas

New Mexicans for Science & Reason (NMSR) heard Dr. Mohammed Mojahedi, UNM Physics Department, speaking on "Superluminal Velocities and Einstein Causality" at our January 10th meeting.

Before the meeting got started, reporter John Fleck was called up to receive NMSR's first-ever "Honorary Electron" award, in honor of his excellent expositions of neat science stories in the Albuquerque Journal.

Dr. Mojahedi works at the University of New Mexico's Center for High Tech Materials (CHTM) near University and César Chávez. His group has done a fascinating experiment, reported in the October 2000 issue of "Physical Review E," in which pulses have been measured as traveling faster than the speed of light in vacuum, some 300 million meters per second.

Dr. Mojahedi described the background of the work, starting with Maxwell's development of the theory of electromagnetic waves, and Hertz's confirmation of their existence. Einstein's special theory of relativity said that the laws of physics were the same in all inertial reference frames, and that the speed of light in vacuum was constant in all inertial frames; Einstein also showed that matter could not be accelerated to exceed the speed of light. Sommerfeld and Brillouin analyzed several different kinds of "velocity," including phase velocity, group velocity, energy velocity, Sommerfeld signal velocity, and the velocities of Sommerfeld and Brillouin "forerunner" signals. There are many ways to define velocity, and Mojahedi wondered which ones were subject to Einstein's laws.

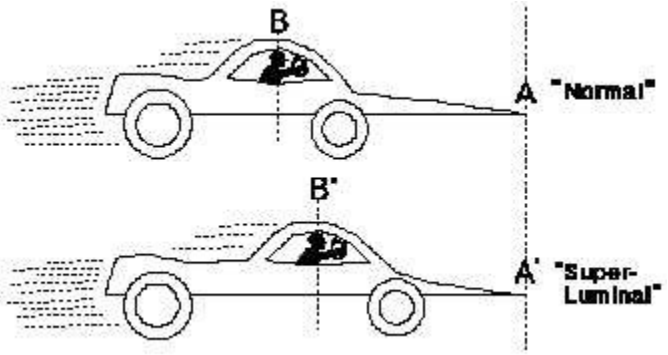
In Mojahedi's experiment, a beam of microwaves was split into two, and the path lengths for the two beams calibrated. Then, a special array of plastic window panes was inserted into one of the beams. One might expect that the array of windows might slow down the pulse, delaying the arrival of that beam. But, just the opposite happened. Mojahedi's group consistently measured the window-path beam's main pulse as arriving half of a billionth of a second before the pulse from the vacuum-path beam; for the small distances involved on the lab table, this amounted to a speed of 2.38c - over twice the speed of light!

The effect is due to quantum tunneling effects in the window materials, dielectric photonic crystals. Mojahedi exploited a curious property called "Evanescent Mode Propagation" to achieve his surprising results.

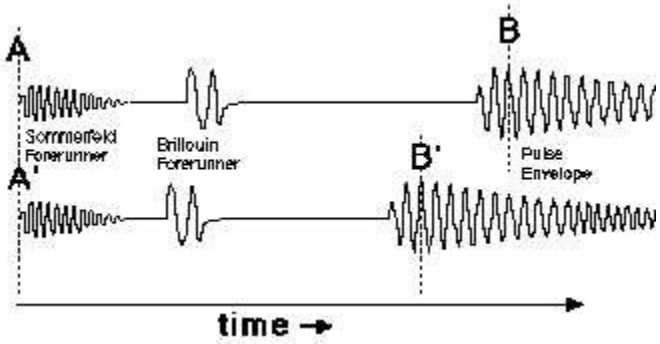
But, how surprising were the results? Was Einstein causality violated? Mojahedi said "No." The faster-than-light-speed ("superluminal") propagation was observed only for the main part of the pulse signal. This is the large-amplitude part of the pulse that is easy to measure. It's much harder to measure the very beginning of the signal - the "forerunner" or "precursor" - because those signals have very small amplitudes. Yet, the forerunner signals are the ones that obey the cosmic speed limit of the universe, the speed of light.

Mojahedi used an analogy involving race cars. The forerunner signals correspond to the sharp front edge of the race cars, while the main section of the race cars, containing the driver, correspond to the

main pulse of the signals. In both the "normal" and "superluminal" paths, the forerunner signals arrive at the same time - both travel at the speed of light, no faster. (See points labeled A and A' on the diagrams below). However, the main pulse is accelerated in the photonic crystals, with the result that it arrives earlier in the superluminal path (going through the special windows) than through the vacuum path. (See points labeled B And B' on the diagrams below).



The figure below shows signals like the ones Mojahedi's group measured. The Sommerfeld forerunner signals arrive at the same time for both the normal path (A, top) and "superluminal" path (A', bottom). The Brillouin forerunners arrive next, with the superluminal path's signal winning that race by a small amount. The main envelope of the superluminal pulse arrives earlier (B') than the envelope for the normal pulse (B). And so the velocity of the forerunner pulse does not exceed that of light, but the "group velocity" (for the main pulse envelope) does.



Mojahedi described how his work challenges some of the earlier thinking in this field, such as comments by Borne and Wolfe, and Brillouin, that superluminal group velocities had no physical significance or meaning. Does this work suggest that faster-than-light communications might be possible? Unfortunately, no. While the superluminal pulse (B') might arrive before its vacuum counterpart (B), it will never precede the arrival of its precursor (A'). That would be like the driver of the race car reaching a point before the leading edge of the car does. However, the work may hold promise for speeding up detection of pulses in applications such as computing.

Thanks to Dr. Mojahedi for a delightful talk.