Article From the *Albuquerque Journal*, Sunday, November 19, 2000

Uncovering a Loophole in Einstein's Law

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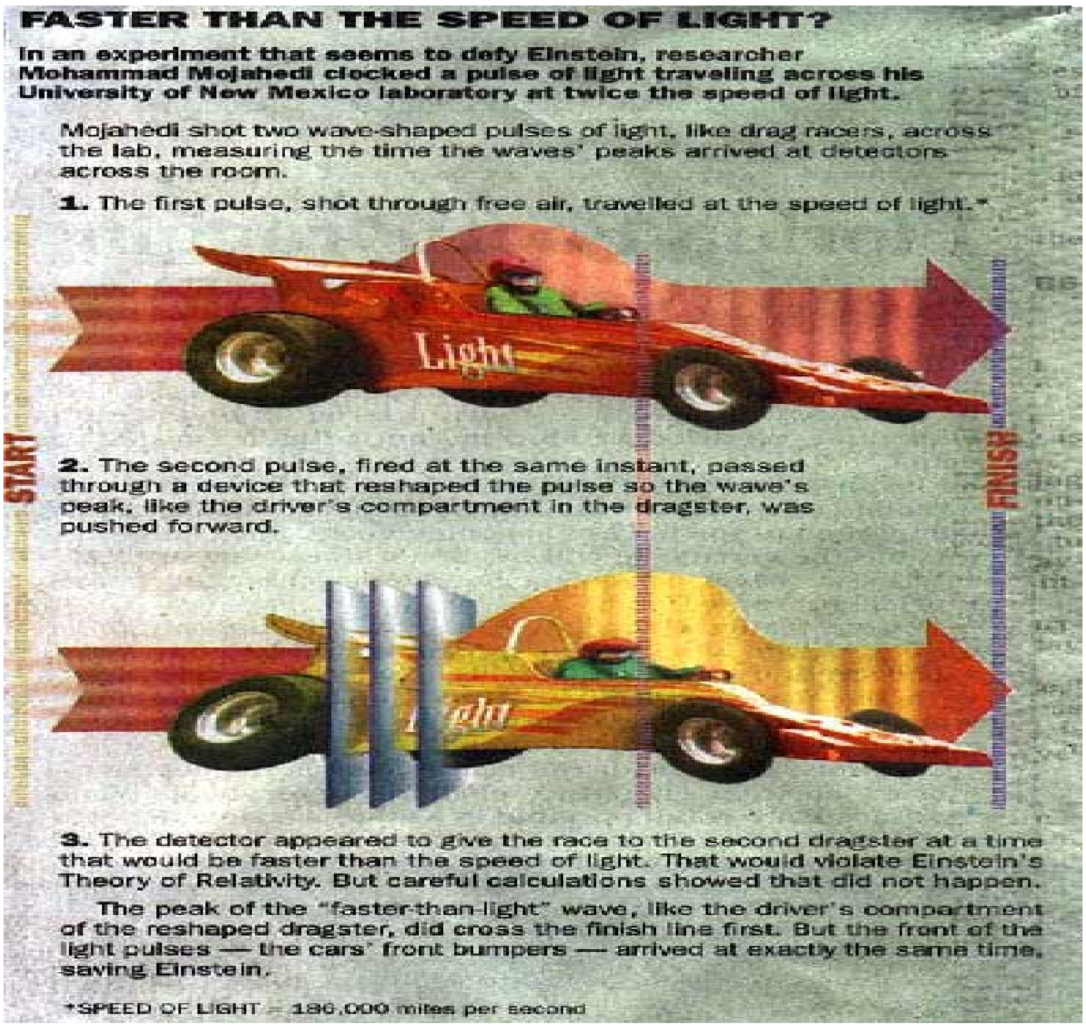
It is one of the sacred rules of Physics 101 - nothing can go faster than the speed of light. Find a way to break the rule, it is said, and you could travel backward in time. Albert Einstein's Theory of Relativity demands it. University of New Mexico scientist Mohammad Mojahedi has once again proven that rules are made to be bent, if not broken. In an enigmatic experiment, Mojahedi and his colleagues clocked a pulse of light that seemed to streak through their lab at more than twice the conventional speed of light. "It is," Mojahedi said in a recent interview, "unintuitive." Don't worry.

Einstein's theory is still intact, Mojahedi said in a carefully worded paper published last month in the prestigious physics journal "Physical Review E." There is no traveling backward in time in his New Mexico lab, no way to send a signal faster than the speed of light. "The answer to that is emphatically 'no,' " said University of New Mexico physicist Ivan Deutch. Don't expect the work to lead to a faster-than-light warp drive for some futuristic spacecraft, said University of Toronto physicist Aephraim Steinberg. But the paper raises thorny questions about what physicists really mean when they talk about "the speed of light." And at a practical level, the work, funded by a NASA grant aimed at developing breakthrough technologies, offers a trick that could be exploited to build faster computers, Mojahedi and others say.

Explaining the physics

The 37-year-old Mojahedi can barely sit still. Like the physics teacher he is, he repeatedly grabs a felt pen and bounds up to a wall board in a UNM conference room, sketching the graphs and fragments of equations that explain the physics of his experiment. The basics are elegantly simple. He shoots a pulse of light across his lab. Half the beam travels through the air. It does nothing surprising, its arrival time at an instrument across the room exactly matching what would be expected by a conventional understanding of the speed of light. The other half of the beam passes through a cleverly designed set of clear plastic window panes. It travels the same distance as the free-space, speed-of-light pulse. But the second pulse trips the detector first, and it's not even a close race. It seems to have exceeded the speed of light, and by a hefty margin. While it was burrowing through Mojahedi's window panes, the light pulse seems to have been traveling more than twice the speed of light, the scientist and his colleagues wrote in their Physical Review E paper. The details of how that happened are buried in the mysteries of wave physics - the same set of mathematical rules governing sound and ocean waves. The fact the second half of the pulse beat the first half across the room - and there seems little question it did - is enough to send freshman physics students into their professor's office, scratching their heads. The first time Kevin Malloy saw the data, "he didn't believe it," recalled Mojahedi. "I was very cautious," said Malloy, associate director of the Center for High Technology Materials and a co-author of the paper. But a careful analysis convinced Malloy the effect was real, and the paper subsequently withstood the strict standards of peer review at Physical Review E.

A fast peak



If you suspected Mojahedi has a trick up his sleeve, you were right. What he and his colleagues demonstrated was that some, but not all, of the speedy pulse traveled faster than the speed of light. The pulse is shaped like a wave, with a peak in the middle. The peak traveled faster than the speed of light. But the slim front edge of the wave obeyed the speed limit, preserving Einstein's laws. Imagine the side-by-side pulses as two dragsters racing down a track. As the faster-than-light dragster passes through Mojahedi's window panes, the car's passenger compartment speeds up. But the bumper never speeds up, so it is as if the passenger compartment slides forward on the car's frame, toward the front bumper. The bumper - the front edge of the light pulse - never exceeds the speed of light, and both cars' front bumpers hit the finish line at the exact same instant. But because the driver's compartment of one car speeded up, the driver - in this case the fat middle of the light pulse - hit the finish line first. Detecting the front edge of a pulse of light is difficult, because it is tiny. So experimenters usually define the speed by the time at which the fat middle - the passenger compartment - arrives. But Mojahedi's experiment shows that definition isn't always good enough. Measuring that fat middle part of the pulse - physicists call it the pulse's "group velocity" - creates the appearance of faster-than-light travel. But if someone claims that violates Einstein's rules, Mojahedi said, they're missing the importance of the front bumper - the "front velocity" of the wave. The front bumper obeys the speed limit, saving Einstein's place as the icon of 20th century physics.

Behavior of waves

What happens between the window panes to speed up the pulse's peak is hard to understand without the mathematical equations that describe the behavior of the waves. When Einstein talked about "light" and "the speed of light," he was really talking about more than the visible light you can see with your eye. The physicists' "light" spans spectrum from low-frequency radio waves to high-frequency gamma rays, and it all travels at the same speed. For his experiment, Mojahedi's "light" was really a pulse of microwaves - low-frequency light. Mojahedi carefully selected the materials he used for the window panes, and the gaps between them, to create a sort of echo chamber that rearranges the microwaves inside the pulse, pushing the pulse's peak forward in the process. "It gets taken apart and put back together," Malloy said.

Exploiting a loophole

Mojahedi's experiment is the latest in a series that began almost 20 years ago in the lab of Stanford physicist Steven Chu. In the years since, researchers in the Berkeley laboratory of physicist Raymond Chiao picked up the hunt in a series of experiments laying the foundation for Mojahedi's work. Steinberg, who worked in Chiao's lab in the 1990s, remembers doing calculations showing the peak of a light pulse could exceed the speed of light. That seemed wrong. There must be an error in the calculations, they thought. "When we started the experiments, we were convinced that couldn't be the case," he recalled. But in experiment after experiment, their calculations were right, and their intuition was wrong. It became, Steinberg said in a recent interview, a matter of testing their understanding of what Einstein's law really meant. Once they understood what was going on, they found they were exploiting a loophole in the definition of the speed of light, rather than a flaw in Einstein's law. "It turns out there are loopholes," Steinberg explained. ”It doesn't fundamentally change the theory, but it helps us understand it, what it means and what it doesn't mean," Steinberg said. Said Malloy: "We're revalidating Einstein, not overturning him - making Einstein more precisely understood."

A center for research

The University of New Mexico's Center for High Technology Materials, where Mojahedi serves as a research assistant professor, seems an unlikely place to be challenging the fundamental laws of physics.Perched on an Albuquerque hillside near the Pit, the center is home to 30 researchers and another 60 graduate students working on electronics. Its goals are practical - how to build faster computers - rather than being a hotbed of theoretical physics where thinkers toy with Einstein's fundamental rules. But there is a very practical application to what Mojahedi is doing. In the bowels of a computer chip, engineers don't care about the arrival time of the dragster's front bumper. Their circuits are built on detecting the fat part of a pulse of light or electrons. So even if they can't move information through the insides of an electronic circuit faster than the speed of light, speeding up the fat part of a pulse might buy a speed-up. "The promise is there to make electronic circuits that are faster," Mojahedi said.