Faster-than-light time tunnels for photons

To see a ball on one side of a wall suddenly vanish and almost instantly reappear on the other side smacks more of magic than physics.

But in the quantum-mechanical realm of atoms, electrons, and photons, such "tunneling" behavior has a small but significant probability of occurring. A particle having too little energy to surmount a barrier may still get through, ending up on the other side without disrupting the barrier in any way.

Physicists have long wondered how much time it takes for a particle to tunnel through a barrier. Now, advances in optical techniques for generating photons and measuring travel times are providing remarkably direct means of determining photon tunneling rates.

Recent experiments by Raymond Y. Chiao, Paul G. Kwiat, and Aephraim M. Steinberg of the University of California, Berkeley, show that photons tunnel through a barrier at velocities considerably greater than the speed of light in a vacuum. Chiao discussed the implications of this and related results at a meeting on fundamental problems in quantum theory held last week at the University of Maryland, Baltimore County.

The researchers race two simultaneously created photons along different paths down a course. One photon travels unimpeded through air. The other strikes a special kind of mirror, which nearly always reflects incoming photons. On rare occasions, however, a photon may tunnel through the mirror and continue on to a detector.

By comparing the arrival times of a photon tunneling through the mirror and its companion traveling the same distance just through air, researchers can determine how quickly tunneling occurs.

The surprising result is that most of the time, tunneling photons arrive at a detector before those traveling through air. On average, photons tunnel through the mirror at 1.7 times the speed of light.

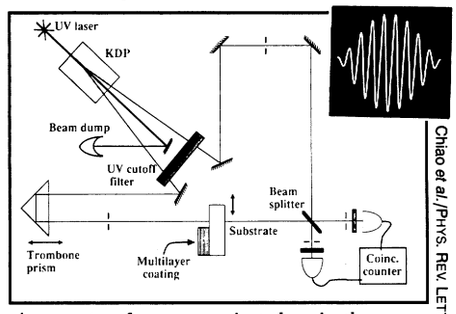
Such a speed is possible because, according to quantum mechanics, a particle can be represented by a wave packet (see diagram), whose length corresponds to the intrinsic uncertainty of the particle's position. The height of the wave packet along its length indicates the probability that the particle occupies a particular position.

Tunneling apparently reshapes a photon's wave packet, shifting its peak forward, Chiao says. Therefore, detectors that respond to a wave packet's peak — where the photon is most likely to be found — often end up observing a tunneling photon in advance of its unobstructed companion.

This result doesn't necessarily violate the notion that cause precedes effect. To send a message or cause a real effect, a shutter must be opened or something else happen to create a sharp break in a wave packet. A wave packet's peak can never overtake this boundary.

The front velocity — how quickly the boundary travels — never exceeds the speed of light, Chiao says. It's this speed that conveys information and ensures that cause comes before effect.

In theoretical studies, Chiao and his colleagues have found a similar faster-than-light effect in another, closely related phenomenon involving photons passing through a certain kind of transparent medium. The researchers are now performing an optical experiment to test their theory. — *I. Peterson*



Chiao *et al.*/PHYS. REV. LETT.

Apparatus for measuring the single-photon tunneling time. Inset: A photon represented by a wave packet.

Male rats find alcohol a fertility downer

In the not-so-distant past, a man's sperm was thought to be virtually impervious to a variety of reproductive hazards. Researchers now believe that paternal exposure to some pesticides and other chemicals can slash a couple's chances of pregnancy.

A new study in rats raises the additional possibility that alcohol can reduce a man's shot at fatherhood.

Theodore J. Cicero and his colleagues at Washington University School of Medicine in St. Louis didn't start out to do a fertility study. They began their investigation with the knowledge that women who drink heavily during pregnancy run the risk of delivering a child with fetal alcohol syndrome. The team wondered if a father's drinking habits could also cause such deficits.

It would be unethical to advise men to drink heavily in order to study the effects on their offspring, so Cicero's team turned to a rodent model of an alcoholic binge.

The researchers injected 75 male rats with a large amount of alcohol — the equivalent of giving humans enough liquor to produce a 0.2 percent concentration of alcohol in their blood. (Legal intoxication for people is typically a concentration of 0.1 percent.) Soon after their shot of booze, the rats passed out or seemed groggy. "They gave every appearance of being rather drunk," Cicero says.

The team waited 24 hours and then mated the male rats with 75 female rats that had not been treated with alcohol. The drunken bout didn't affect the male rodents' interest in sex: The hungover males copulated with the same vigor as 75 control males that were also paired with female rats. The control rats had not received alcohol.

Initially, the researchers intended to simply keep tabs on the rat pups born to alcohol-treated fathers. After the pups grew up, the team would begin testing them to see if they appeared to have learning deficits.

Team members never dreamed they would see an effect on fertility after males got a single dose of injected alcohol.

But during initial experiments, the researchers observed a sharp decline in the pregnancy rate of female rats mated with the alcohol-treated males. At first, Cicero thought there was something wrong. But when the group repeated the experiments, they came up with the same results.

In the end, the team found that the pregnancy rate declined by 50 percent for rodent couples in which the male had been injected with alcohol. Cicero reported those results last week at the annual meeting of the Neurobehavioral Teratology Society held in Las Croabas, Puerto Rico.

In addition to the fertility problem, researchers found, pup litters in the alcohol group appeared to be smaller than those in the control group. And individual pups in the alcohol group tended to weigh less than control pups.

What caused the dramatic drop in pregnancy?

The researchers don't know yet. However, Cicero points out that seminal fluid bathes the egg for several days after egg and sperm unite. The researchers suspect that alcohol or one of its metabolites may create a poisonous environment for the vulnerable embryo.

Alternatively, high concentrations of alcohol may damage the sperm itself. Such injury could slow the sperm's motility, the active wriggling needed to propel the sperm on its long journey through the female reproductive tract.

It's difficult to jump from rodent studies to implications for humans. Yet the new results suggest that researchers should take a look at alcohol and a human male's ability to father a child, Cicero says.

"No one really knows why humans abort," he says, adding that a lot more research must be done to unravel the paternal contribution to conception.

— *K.A. Fackelmann*