oratory Astrophysics—in Boulder, Colorado. He's confident that can be done. Whether the promise of great science is enough to convince Congress is another matter: DOE's budget is already feeling the strain of another major project, the $1.3 billion Spallation Neutron Source, which is expected to be completed in 2005. –ROBERT F. SERVICE

QUANTUM MECHANICS

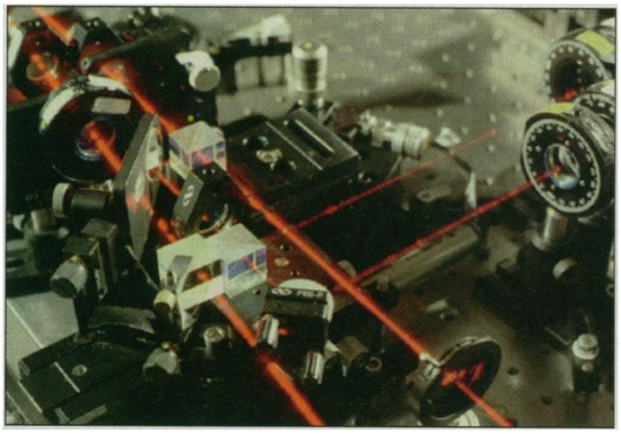
Entangled Trio to Put Nonlocality to the Test

One of the strangest claims of quantum mechanics is that two particles can be "entangled"—inextricably linked at birth. In theory, a measurement on one entangled particle is linked to a degree that defies common sense to a measurement on the other, even though the pair may have traveled to opposite sides of the cosmos. Now physicists at the University of Innsbruck in Austria have created the same eerie link among a trio of photons, so detecting two of the photons preordains the result of the third measurement.

The feat, which the Innsbruck group reported in the 15 February issue of *Physical Review Letters*, allows researchers to close some loopholes in tests of the strange predictions of quantum mechanics. By studying pairs of entangled photons, physicists have already tested the quantum prediction that a measurement on one of the pair will instantly affect the outcome of a measurement on the other, even if they have traveled great distances apart since being created. But these tests have to be run over and over to be sure these "nonlocal" effects aren't due to chance, and purists find such statistical evidence dissatisfying. The entangled trio opens the way to a single measurement that will give one result if nonlocality is true and another if it is not. "This could be like a single shot test of quantum mechanics," says Vlatko Vedral of Britain's University of Oxford.

Because of these stakes, says Daniel Greenberger of the City University of New York, City College, a "race" was on to create such three-photon states. The winning Innsbruck team "did a phenomenal job," he says. "I think it's very significant," agrees Vedral. Besides allowing a yes-no test of quantum nonlocality, three-photon entanglement should also offer more efficient quantum communications, says senior team member Harald Weinfurter. Quantum communications, which promises to be more efficient and secure than normal optical signals, uses entangled states to pass information between participants using carefully prepared sets of photons shared among them in advance. "We are moving toward quantum communications," says Vedral. "It's got implications for quantum computing and all kinds of fundamental experiments," adds Greenberger.

The Innsbruck experiment begins with the same kind of crystal that spawns entangled photons in pairs. When a photon is fired into it, the crystal can split the photon into two daughters that each have half the frequency of the parent. Their common parentage means that the photons' properties are linked. For example, if the first one is horizontally polarized, the other has to be vertical. However, according to quantum mechanics, such properties remain indeterminate until they are actually measured, so if a measurement on one photon finds that it has vertical polarization, its sibling instantly "knows" that its own polarization is horizontal.



Photon tangle. Beam-splitting apparatus which muddles the identity of photons from two entangled pairs.

CREDIT: HARALD WEINFURTER

To entangle three photons, Weinfurter and his colleagues direct a high-frequency laser beam onto the photon-splitting crystal and wait for two photons to cleave simultaneously, giving two entangled pairs. Each time this happens, three of the four photons pass through a system of polarization-sensitive beam splitters and other optical elements, which tangle together the photons in such a way that it is impossible to tell them apart. "We interfere the particles in such a way that in the end you cannot decide any more which of the particles belongs to which pair," says Weinfurter.

Each entangled trio then heads toward three single-photon counters, each with a polarization filter in front of it. These are primed to look out for the trio, amongst other photons, by the detection at a fourth detector of the fourth, unentangled photon of the two pairs. The orientation of the polarization filters is set so that, if the photons are entangled, the counts in two of the detectors are correlated with those in the third—so simultaneous detection in all four detectors flags three-photon entanglement. Three independent photons would show no such correlation.

Recent theoretical work by the University of Calgary's Richard Cleve and others suggests that entangled trios could make quantum communication systems more efficient, reducing by a third the amount of communication required to share information. Equally tantalizing for quantum purists is the possibility of a simple yes-no test of nonlocality. Three-photon entanglement means that the experiment in effect registers a photon in one detector if nonlocality is operating, but in a different one if it isn't. "It's no longer a statement about probabilities, but it's really a statement about one event," says Weinfurter. The team has already made a first stab at the measurements and is analyzing the results, he says. The early news: "Quantum mechanics is correct." –ANDREW WATSON

INDIA BUDGET

Big Increase Seen as Answer to Sanctions

NEW DELHI—Indian researchers are feeling buoyed by a new budget unveiled last weekend that hands science its largest increase of the decade. A 20% hike that would benefit both civilian and defense sectors is seen as a shot in the arm for domestic efforts to overcome foreign sanctions imposed in the wake of last spring's nuclear tests. These large increments "reflect India's determination to fight … the sanctions and denial of technology," says Raghunath A. Mashelkar, director-general of the Council of Scientific and Industrial Research (CSIR).

The increases stand in sharp contrast to last year's budget, which favored the atomic, space, and defense R&D sectors but didn't provide enough for other departments to even keep pace with inflation (*Science*, 5 June 1998, p. 1520). Science and Technology Minister M. M. Joshi told *Science* that this year's planned outlay of $2.56 billion is proof that the prime minister's slogan of "hail science," coined after the blasts, "was not a hollow promise." Still, not everyone is pleased. M. G. K. Menon, a physicist and former science and technology minister, says that the overall budget "lacks any bold new initiatives," such as downsizing the general bureaucracy, and that it fails to invest sufficiently in civilian R&D. "The government has its priorities all wrong" through its emphasis on strategic research related to national security, he says.

To be sure, defense research still receives the lion's share of the government's science and technology investment, rising