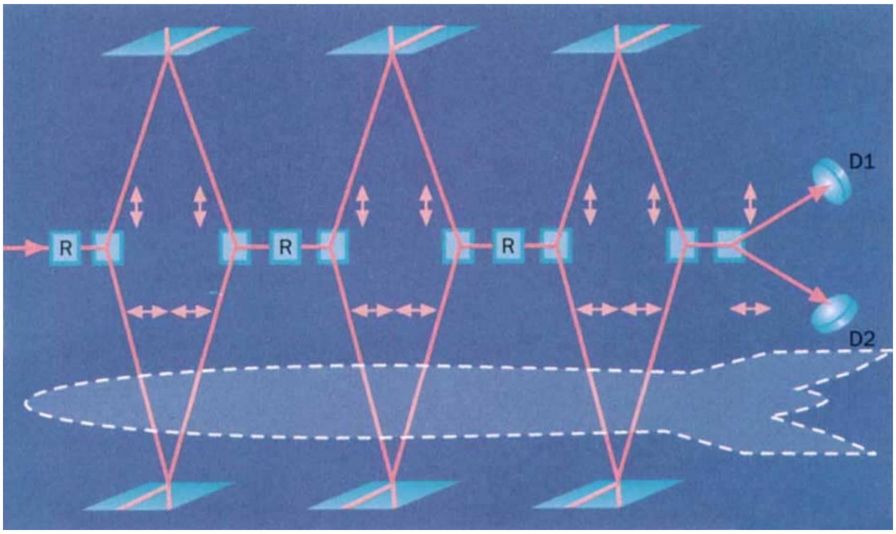

FIG. 3 Innsbruck–Stanford group's improved bomb-testing apparatus.

time it reaches the first filter, the photon's polarization is 9° off vertical. The filter forces the photon to choose between two outcomes: with probability $\cos^2 9^\circ \approx 0.976$ it is transmitted and becomes repolarized vertically; or with the complementary probability $\sin^2 9^\circ \approx 0.024$ it is absorbed by the filter. If unabsorbed, the photon continues through the second 10 cm of syrup, again having its polarization rotated by 9°; the second filter again repolarizes it vertically with probability 0.976 or absorbs it with probability 0.024. Repeating these steps eight more times, one can see that two overall outcomes are possible: with probability $0.976^{10} \approx 0.78$ the photon is not absorbed by any of the filters, and emerges vertically polarized from the last one; with the complementary probability $1 - 0.976^{10} \approx 0.22$ the photon is absorbed along the way. In the limit of many equally spaced filters, the probability $1 - \lim_{n\to\infty} \cos^{2n}(90/n)$ of absorption goes to zero and the photon always emerges vertically polarized. Repeated interaction with the filters has prevented the syrup from rotating the photon's polarization: this is the watchdog effect.

If one regards the stack of n equally spaced filters as a single object, which might or might not be present in the syrup, the watchdog effect provides an unobtrusive way of testing for its presence: the photon will emerge vertically polarized if the stack is present, and horizontally polarized if it is absent, and only rarely will be absorbed.

The Innsbruck–Stanford scheme (Fig. 3) provides a way of using the watchdog effect to test for arbitrary opaque objects (such as a bomb) rather than special ones such as polarizing filters. A single vertical photon entering on the left passes through a small thickness of syrup, sufficient to rotate its polarization $90/n$ degrees, then is split by a polarizing beamsplitter into vertically and horizontally polarized beams. These beams are later recombined by another polarizing beamsplitter. If no obstruction were present in the beam paths, and if both were of equal length, the original rotated polarization would be reconstituted exactly at the second beamsplitter. However, in the Innsbruck–Stanford scheme, one of the paths — the one containing the horizontal component — is sent through the suspected bomb location. Therefore the beam leaving the second polarizing beamsplitter is rotated $90/n$ degrees if the bomb is absent but remains vertically polarized if the bomb is present.

This process is repeated $n - 1$ more times, so that the photon emerges horizontally polarized if the bomb is absent but vertically polarized if the bomb is present (and has not exploded). A final polarizing beamsplitter and two detectors allow these two outcomes to be reliably distinguished. The explosion probability is $1 - \cos^{2n}(90/n)$, approaching zero for large n. Practical applications of the scheme remain to be developed; perhaps it could be used in airports, to look for bombs without exploding them and without harming even the most sensitive photographic materials carried by innocent passengers.

My other childhood question remains outside science, but it symbolizes a similarly vexing and metaphysical question in quantum mechanics: in any given trial of a probabilistic quantum experiment, why does one outcome occur and not another? Some physicists find comfort, others only further vexation, in the view that 'in reality' all outcomes occur in superposition, but our status as a subsystem of the Universe allows us to perceive only one of them, somewhat as our status as individuals causes each of us to perceive a unique self. ☐

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DAEDALUS

Maritime slime

THE maximum speed of a working ship gradually declines. Weeds, shellfish and other marine organisms steadily spread over its wetted surface, greatly increasing its drag. They adhere tenaciously, and are very hard to scrape off. The standard defence is antifouling paint, which releases poisonous organotin compounds. This poses ecological hazards, especially in inland waterways. Daedalus now has a greener solution.

He sees a ship's hull as a specialized marine habitat. He wants to cover it with a coating of organisms of very low drag that are so perfectly matched to this habitat that they colonize it to the exclusion of all rivals. Then their strong adhesion, rapid spread and self-renewal would no longer be exasperating, but beneficial. Instead of having to fight ecology, the marine engineer could welcome it cheerfully on board.

The green, scummy marine rock-algae seem ideal for the job. As many bruised beachcombers can testify, they are extremely slippery. Daedalus reckons that marine plants exude slime to reduce the drag of moving water, which might otherwise dislodge them in rough weather. This is the Toms effect, the reduction of liquid friction by low concentrations of a high-molecular-weight polymer. It has already been used to smooth the flow of water through fire hoses and reduce the drag of torpedoes.

So DREADCO's biologists are creating an algal paint for ships. One team is studying marine algae, seeking species that form the smoothest layers on a submerged surface. They hope to optimize a ship's bottom perfectly to the chosen algae by giving it a surface finish and chemical composition that welcome the algae but discourage their rivals. The algae should then displace alien weeds, shellfish and so on.

Another team is looking at seaweed slimes, and identifying the genes that produce them. When they have found the slimiest slime, they will insert multiple copies of its gene into the chosen algae. The result will be a tenacious, self-renewing, unbelievably slippery marine paint. Ship owners will dance a joyous hornpipe as their slimy vessels steam the world faster, longer, and with less maintenance.

Slippery algae will be happiest on translucent fibreglass hulls, through which light will leak to aid their photosynthesis. They may also find their slimy way into translucent plastic pipes inland, speeding the flow of industrial cooling water, outfall discharges and so on. They might even act as a biological filter and purifier. David Jones