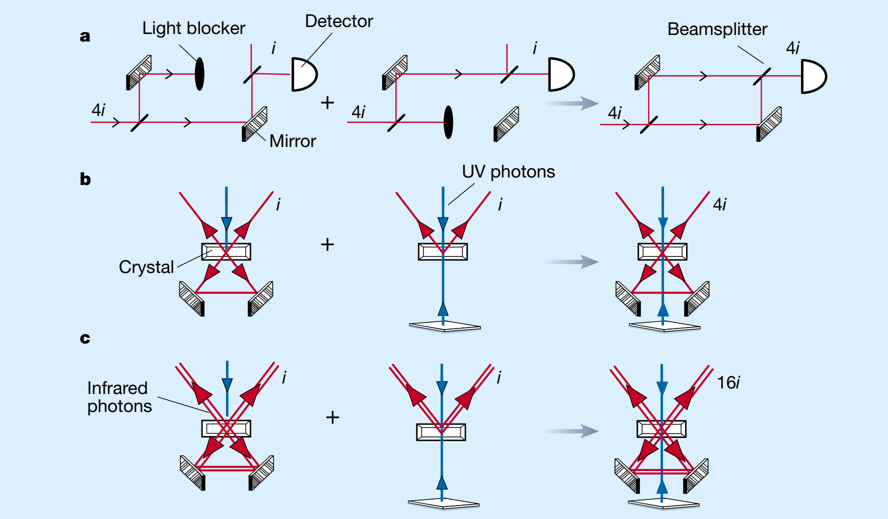

Figure 1 **In quantum mechanics, one plus one can equal zero, or four.** a, **An optical interferometer consists of two mirrors and two beamsplitters, which reflect half the light and transmit the rest. If we look at one output of the interferometer, with either path blocked we detect one-quarter of the light sent into the interferometer. If we call the contribution from each path *i*, we might expect that with both paths open the detector would see 2*i*. But in fact the intensity on the detector can range from 0 (if the contributions from the two paths interfere destructively) to 4*i* (if the contributions from the two paths interfere constructively).** b, **In a similar process, infrared downconversion pairs may be produced during the first passage of the ultraviolet (UV) photons through the crystal, or during their return passage. Because these indistinguishable processes can interfere, the final output intensity of pairs can vary from 0 to four times the pair intensity from a single passage through the crystal.** c, **Lamas-Lamares *et al.*[1] show that further enhancement is possible with the four-photon process — going through the crystal twice increases the rate of four-entangled photon production 16-fold.**

output of each crystal alone). Not so, thanks to the magic of quantum interference (Fig. 1a) and stimulated emission.

Because the two downconversion processes can interfere, the production of photon pairs can be enhanced by a factor of four (Fig. 1b). The enhancement of downconversion was first demonstrated in 1994 (ref. 7), but the new work extends this to pairs that are polarization entangled. Even more striking is the enhancement effect on four-photon processes (Fig. 1c). The simple interference analogy would again lead one to predict a maximum enhancement factor of four. But the enhancement for four-photon entanglement is higher still — a factor of sixteen — owing to the increased efficacy of stimulated emission as the number of photons increases. Loosely speaking, the photons experience more peer pressure when there are more photons to pressure them into conforming. Lamas-Linares *et al.*'s results clearly show the predicted enhancement, evidence that they have observed the stimulated emission of entangled radiation.

A word of caution: the extra enhancement by a factor of four of the quartet-photon state relative to the twin-photon state should not be misinterpreted to imply that creation of the former is more likely than creation of the latter. Lamas-Linares *et al.* report two-photon counting rates of over 10,000 per second, but four-photon counting rates of only 1 per second. Still, this is a 50-fold increase over the results of initial experiments done only a few years ago[4–6]. Equally important, the quality of the four-photon interference has seen a similar improvement — the interference contrast has been raised from about 85% to 97%.

The experiment of Lamas-Linares *et al.* is only a first step toward producing a 'laser' of entangled photons — strictly speaking, it is the analogue of a laser cavity in which the light is cycled just twice, instead of tens to hundreds of times. It will be interesting to see how far the technology can be pushed. Unfortunately, the entanglement is most visible only if a definite number of photons can be identified in each of the two beams. This becomes more and more difficult as the number increases (because of photon loss and detector inefficiency), and could limit the usefulness of the approach. Nevertheless, just as no one knew in 1960 all the possible applications of the optical laser, it can safely be said that the potential of an entangled-photon laser for quantum information applications is also largely unknown.

The authors[1] suggest that this work may lead to some new form of quantum cryptography, with higher transmission rates than are presently available using entangled photon twins[8–10]. I think this is unlikely, both because any loss will reduce the entanglement, and because the generation rate of these multiple-pair pulses is so much lower than the generation rate of single-pair polarization-entangled photons. Entanglement might also be used to improve the signal-to-

NATURE

100 YEARS AGO

Mr. W. W. Davis has a paper in "Studies from the Yale Psychological Laboratory"… on some relationships between temperament and effects of exercise. His tests and observations are scarcely sufficient to establish very definite relations, but the conclusions at which he arrives are not without interest. The observations suggest that nervous persons, in training for the development of strength, require light practice, and phlegmatic persons require vigorous practice. The phlegmatic type of temperament is apparently characterised by the presence of much reserve energy of muscle and nerve cell. The nervous type has less reserve energy but a greater ability to use the energy at hand. It is not difficult to apply these principles to practical physical training. They make necessary on the part of the trainer a knowledge, secured either by means of observation or experiment, of the temperament of each man under his charge.
From *Nature* 29 August 1901.

50 YEARS AGO

The ground-state of the hydrogen atom is a hyperfine doublet the splitting of which, determined by the method of atomic beams, is 1,420.405 Mc./sec. Transitions occur between the upper (F= 1) and lower (F= 0) components by magnetic dipole radiation or absorption. The possibility of detecting this transition in the spectrum of galactic radiation, first suggested by H. C. van de Hulst, has remained one of the challenging problems of radio-astronomy. In interstellar regions not too near hot stars, hydrogen atoms are relatively abundant, there being, according to the usual estimate, about one atom per cm. Most of these atoms should be in the ground-state. The detectability of the hyperfine transition hinges on the question whether the temperature which characterizes the distribution of population over the hyperfine doublet — which for want of a better name we shall call the hydrogen 'spin temperature' — is lower than, equal to, or greater than the temperature which characterizes the background radiation field in this part of the galactic radio spectrum. If the spin temperature is lower than the temperature of the radiation field, the hyperfine line ought to appear in absorption; if it is higher, one would expect a 'bright' line; while if the temperatures are the same no line could be detected… We can now report success in observing this line.
From *Nature* 1 September 1951.