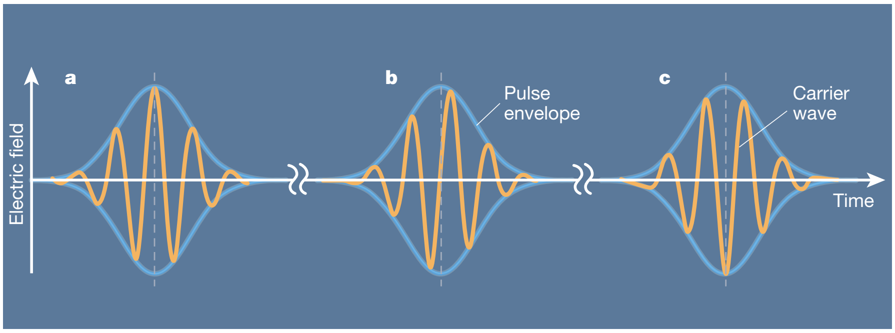

Figure 1 **Phase slip. In ultrashort laser pulses (typically of femtosecond duration), the phase between the electric-field carrier wave and the pulse envelope becomes an important factor in experiments. The phase slips between pulses: for example, in** a**, the phase is zero; at a later time** (b)**, the phase has slipped to 90°; and later still** (c)**, the phase is 180°. Mücke *et al.*[1] propose that this phase advance can be measured through optical Rabi flopping.**

itself modified by the process. For example, if a laser with resonance frequency Ω_0 is used, the flopping between the levels modulates the amplitude of the scattered light, at the Rabi frequency, Ω_R. As a result, the spectrum of the scattered laser light no longer matches that of the laser pulse used to excite the system. As Mollow showed[4], the outcome is two extra frequencies, called sidebands, which are separated from the original frequency of the incident wave by the Rabi-flopping frequency: the so-called Mollow triplet adds the frequencies $\Omega_0 + \Omega_R$ and $\Omega_0 - \Omega_R$ to Ω_0.

The latest developments in 'mode-locked' laser technology have allowed extremely short (femtosecond) pulses to be produced, with the laser power concentrated at high peak intensities. As the Rabi frequency increases with laser intensity, in this new regime Ω_R is comparable to the rapid oscillations of the laser itself, which are of optical frequency, and a phenomenon called carrier-wave Rabi flopping takes over: the Rabi cycle is now driven by the carrier wave of the laser, not by the pulse envelope. In earlier work, Mücke *et al.*[5] reported this rapid Rabi flopping in the semiconductor gallium arsenide, and similar effects in zinc oxide[6].

In carrier-wave Rabi flopping, other frequencies in addition to the Mollow triplet appear in the scattered wave; these frequencies are odd multiples (harmonics) of the original laser frequency. Each harmonic also has sidebands. Mücke *et al.*[1] have now considered what happens if Ω_R becomes as high as Ω_0 — that is, if Rabi flopping occurs at optical frequencies. In this case, the higher-frequency Rabi sideband at the laser frequency ($\Omega_0 + \Omega_R$) and the lower-frequency sideband of the third, and strongest, harmonic ($3\Omega_0 - \Omega_R$) overlap, giving rise to interference between the scattered components at around a frequency of $2\Omega_0$. Mücke *et al.* propose that, by measuring this interference (which is feasible[7]), it should be possible to derive the carrier–envelope phase advance between the pulses (and perhaps ultimately the phase itself).

A mode-locked laser generally emits a train of pulses with a fluctuating carrier–envelope phase, and the possibility of detecting and controlling the motion of this phase offers the opportunity to produce a train of truly identical pulses. If the carrier–envelope phase is stabilized, each laser mode becomes coherently linked to the repetition rate of the pulses. If the pulse repetition rate is then referenced to an atomic clock, all the laser modes are also referenced to that clock and are available for high-precision laser spectroscopy. A stable carrier–envelope phase would also be expected to reveal new phenomena in nonlinear optics[8,9].

The existing technique for measuring the carrier–envelope phase advance (though not the absolute phase value) relies on broadening the spectrum of the laser pulses in specially designed optical fibres. The lower-frequency part of the spectrum can then be 'frequency-doubled' and made to interfere with the higher-frequency part. The frequency-doubling also doubles the carrier–envelope phase advance, which can similarly be measured from the interference. This has become a standard technique, but the optical fibre itself is delicate and contributes to some instabilities, so researchers have been looking for more robust and simpler detection methods.

Other approaches have been devised, based on lasers[10,11] that already put out a sufficiently wide range of frequencies to avoid the need for spectral broadening in a fibre. But such lasers can be difficult to handle and are not yet readily available. Alternatively, improved fibre technology could simplify the spectral-broadening system. Nevertheless, the proposal by Mücke *et al.*[1] to access the carrier–envelope phase advance through optical Rabi flopping is a welcome new avenue of exploration. ■

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2. Rabi, I. I. *Phys. Rev.* **49,** 324–328 (1936).

100 YEARS AGO

In your report of the meeting of the Physical Society of October 31, I find the following sentence given as having been said by me in the course of some remarks on Mr. Ridout's paper on the size of atoms, with the four words which I underline accidentally omitted. "If the electrons, or atoms of electricity, succeeded in getting out of the atoms of matter, they proceeded with *velocities which might exceed* the velocity of light, and the body was radioactive." The omission of those four words made it appear that I had considered the velocity of the escaping electrons to be essentially the velocity of light. In reality, the electrons may escape with velocities possibly less or possibly more than the velocity of light, but certainly not all with one definite velocity... Kelvin
[The official report of Lord Kelvin's remarks was printed as received.— Editor.]
From *Nature* 4 December 1902.

50 YEARS AGO

The Darwin Medal is awarded to Prof. John Burdon Sanderson Haldane, Weldon professor of biometry in University College, London, for his work on the analysis of the causes of variation and of the mechanism of selection. The conclusions derived from his researches have permeated practically every field of evolutionary discussion, and his ideas have fundamentally altered our knowledge of evolutionary change. For many years he has insisted that a proper study of evolution involves the development of methods for investigation of the genetics of populations. His mathematical treatment of the question was the first of its kind, and has played a large part in the great development of understanding of evolution during the past twenty-five years. He has been a pioneer in applying biochemical knowledge... to problems of genetics. His contributions to strictly genetical problems are fundamental ... He made the first investigations of human mutation-rates (simultaneously with L. S. Penrose), has studied interspecific hybrids and discovered the rule by which their sex is determined. He was one of the first to develop a theoretical treatment of polyploidy and to show its evolutionary significance. He has thus made first-rate contributions by his detailed researches, his mathematical treatments and his general analysis of evolutionary problems, to the field of Darwin's work.
From *Nature* 6 December 1952.

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