search & discovery

Simple technique produces photon echoes and optical nutation

A simple way to generate and study photon echoes, optical nutation, and other coherent optical effects has been developed by Richard G. Brewer and Richard L. Shoemaker (IBM Research Laboratory, San Jose). The work was reported by Brewer at the Esfahan (Iran) Symposium on Fundamental and Applied Laser Physics in September, and appears in *Physical Review Letters* (**27**, 631, 1971).

A photon echo is a spontaneous pulse of light from a sample that has been irradiated with two intense, coherent pulses of light from a laser. It was first observed in 1964 at Columbia University by Sven Hartmann, Isaac Abella and Norman Kurnit and is the optical analog of spin echo, a nuclear magnetic resonance effect discovered by Erwin Hahn in 1950. The Columbia experiments used a pulsed ruby-laser source.

In Brewer and Shoemaker's experiments the laser operates cw, and a pulsed electric field provides molecular level splitting. The molecules absorbing the laser light are tuned to the laser frequency by subjecting them to this pulsed field. The electric field acts on the electric dipole moment of the molecules to split their vibrational energy levels, and this tunes the molecules to the fixed laser frequency. Brewer and Shoemaker feel that this is a much simpler technique than the previous approach, which involved generating short, very precisely timed optical pulses from the laser.

To produce a photon echo, the sample is switched into optical resonance twice by means of two electric pulses. Then the photon echo follows. The first pulse produces an induced electric dipole moment in the sample. When this pulse terminates, the induced molecular dipoles begin to get out of phase with one another (because of a spread in transition frequencies caused by the pulse widths and the Doppler broadening), and the radiation produced by the dipoles undergoes destructive interference. A second pulse, lasting twice as long as the first, now reverses the dipole direction and causes them to get into phase again in just the amount of time that elapsed between the first two pulses. At this point the dipoles interfere constructively, and the sample spontaneously emits a pulse of light—the photon echo.

The related effect of optical nutation can also be observed by this technique, using a single electric pulse of long duration. Molecules that are switched into resonance are coherently excited so as to alternately absorb and emit radiation. This optical ringing or nutation effect appears as a damped oscillation in the transmitted laser light. It is the optical analog of transient nutation in nuclear magnetic resonance found by H. C. Torrey.

Using a continuously operating carbon-dioxide laser at 10 microns, Brewer and Shoemaker readily observed photon echoes and optical nutation in methyl fluoride and deuterated ammonia. From the dependence of echo amplitude on pulse intervals, the experimenters were able to examine the importance of various collisional mechanisms (rotational energy transfer, velocity-changing collisions, and so on).

Brewer and Shoemaker believe that their technique can also be used to study other optical analogs of nmr as well as self-induced transparency, an effect first observed by Hahn and Sam-

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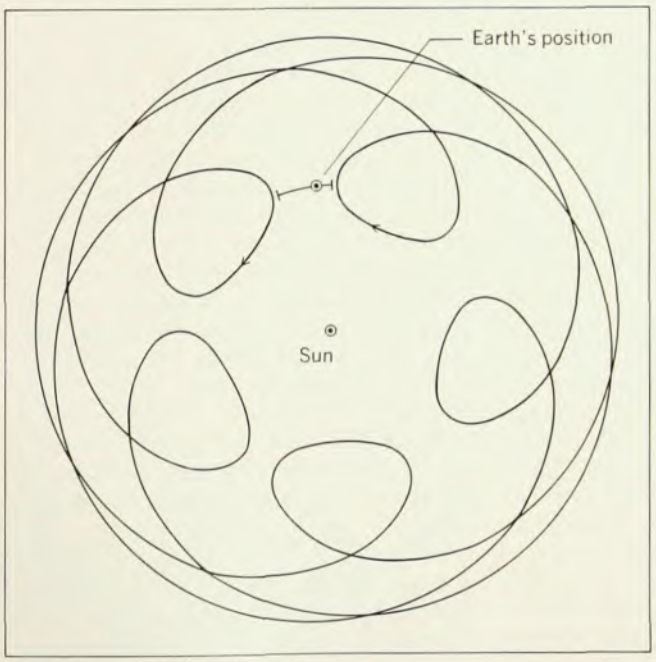
Toro makes a threesome with Earth and Moon

A small asteroid named Toro forms a triplet system with the Earth and the Moon, according to Hannes Alfvén (University of California, La Jolla and Royal Institute of Technology, Stockholm). The discovery, which was made by Lars Danielsson (Royal Institute of Technology) and W. H. Ip (La Jolla), is the first indication that another celestial body is part of the Earth–Moon system.

Whether this triplet system is permanent and was formed at the time when the solar system was born is still not known, Alfvén told us. "If it is, Toro will be of decisive importance for the understanding of how the Earth–Moon system has developed."

For the past two years Alfvén and Gustaf Arrhenius (Scripps Institution



Path of Toro from a coordinate system centered on the Sun rotating with the Earth. Loop shown is produced during eight years around the year 2020.

10) and argon ($Z = 18$) is believed possible at Princeton without further modification of the accelerator; neon and argon acceleration is planned for this month.

The AEC withdrew support of the laboratory this June, and private support runs out this month. PPA director Milton White, however, was confident at the start of November that either the National Cancer Institute or a combination of US agencies would assume support of PPA on a long-term basis.

A proposed modification at Berkeley might allow acceleration of ions up to krypton ($Z = 36$). The improvement would come from linking the Bevatron with LBL's HILAC (Heavy Ion Linear Accelerator), which is now being rebuilt as the "super-HILAC." The super-HILAC could be a copious source of fully stripped ions for the Bevatron, where they would be accelerated up to 2.7 GeV per nucleon; the combined accelerator is being referred to as "Bevalac."

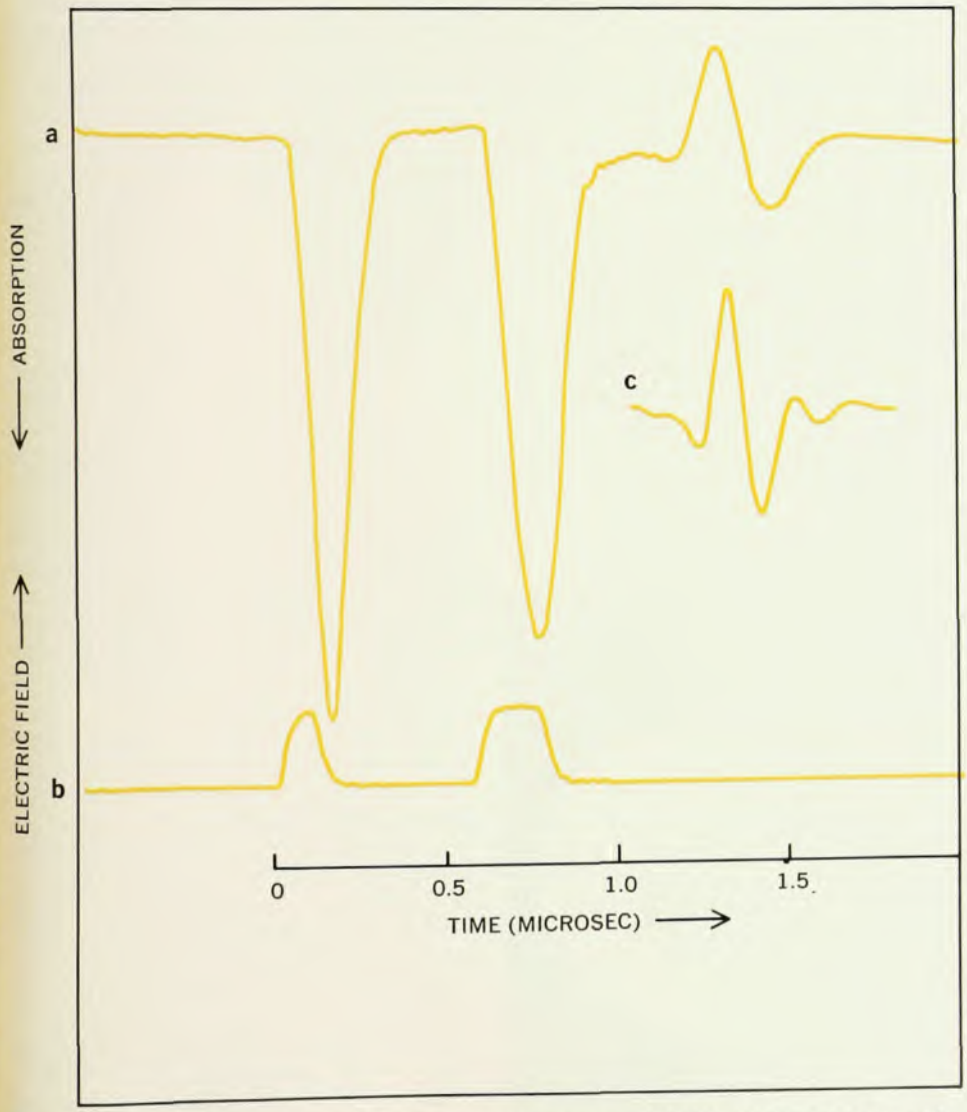
—MSR

Photon echoes *continued from page 17*

uel McCall in 1967. In their picture a pulse of light coherently excites a sample, and if the conditions of intensity and pulse duration meet certain requirements, the light pulse can propagate through the sample unattenuated—the medium becomes transparent.

Brewer says that it has been difficult to apply existing laser techniques to the study of these coherent transient phenomena (photon echoes, optical nutation and self-induced transparency), despite their potential usefulness in studying molecular or solid-state systems. He believes that the new technique, although limited to materials with an electric dipole moment, should provide new ways of studying the details of how these systems absorb and dissipate energy.

—GBL



Photon echo in methyl fluoride at 5.2-millitorr pressure. (a) Optical response to $\pi/2$ and π pulses followed by the echo beat signal. (b) Corresponding electric pulses where the delay is 570 nanosec and the pulse widths are 90 and 180 nanosec. Pulse amplitude is 35 V/cm. (c) Echo signal for a pulse amplitude of 60 V/cm. The other conditions are the same as (a), but the beat frequency is about twice as large.

Theory of early universe explains particle production

If the early universe had a strongly time-dependent gravitational field, the field would have created pairs of particles, according to Ya. B. Zel'dovich (Institute of Applied Mathematics, USSR Academy of Sciences).[1] This mechanism might explain the existence of particles in the universe, and it offers the hope of understanding why the present ratio of photons to baryons in the universe is 10^8.

Zel'dovich assumes for simplicity that the early universe is expanding in two directions and contracting in the third; the Einstein equations fix the expansion rates. Such a model is called "Bianchi type I," and its solution is called the "Kasner solution."

In the beginning of the universe all energy is concentrated in a source-free gravitational field—that is, enormous curvatures of the vacuum space-time, which is exploding out of a singularity. Zel'dovich shows that because of the different expansion rate the energy is converted into pairs. In principle any kind of particle that exists in pairs is created because all the particles are coupled to gravity, presumably including photons. The process is analogous to the pulling of positron-electron pairs out of the vacuum in the presence of a very strong electric field. But a simple static strong gravitational field, by itself, may not be sufficient to create pairs; the irregularity in expansion rate is also necessary.

In the theory particles are primarily created when they are relativistic; so the mass is just a small correction and the rate, to a crude approximation does not depend on whether protons or electrons are being produced, for example.

Early work, by Leonard E. Parker (University of Wisconsin, Milwaukee and Princeton University)[2] and by Roman Sexl and Helmut Urbantke (Institute for Theoretical Physics, University of Vienna)[3] had studied particle creation in isotropic universes. Parker found a negligible rate of particle creation in the present universe, but concluded that in the early stages of the expansion it may well have been of great cosmological significance.

Zel'dovich's theory *a priori* suggests that equal numbers of particles and antiparticles are created. Whether or not the universe does, in fact, consist of equal amounts of matter and antimatter is of course unknown.

The particle-production process appears to be highly dissipative. This dissipation would help to explain why the universe, starting out with an irregular expansion, would have ended up with a regular expansion. Although particle creation is not the only pos-