

In the new approach, which in a sense is the exact opposite of Stark switching, Brewer and Genack use a stable, tunable cw dye laser that is frequency switched while the sample's transition frequency remains constant. The sample is kept external to the laser system so its performance will not be affected. Coherent transient signals appear in the forward beam. An electro-optic crystal of ammonium dihydrogen phosphate is inserted into the dye-laser cavity and is driven by a sequence of low-voltage pulses. The laser frequency follows the variations in refractive index induced in the crystal. Thus the experiment is controlled electronically.

As Brewer points out, Stark switching has been limited to the several discrete lines of the CO₂ laser. Furthermore, it is restricted to samples that have a dipole moment. The new technique is more universal because one can tune the laser over a broad spectral region, bringing the measurements into the visible and ultraviolet region, and one is no longer limited to samples with dipole moments.

Since its development five years ago, Brewer says, Stark switching has been applied to the identification and quantitative study of specific molecular collision mechanisms that previously had been hidden within the optical lineshape. Brewer and Stephen B. Grossman have now done optical pulse Fourier-transform spectroscopy, where very high spectral resolution is possible without the complication of Doppler broadening, and the relaxation or dephasing processes can be examined simultaneously for each line as in nmr. This work has now progressed to the point where the force laws that operate during elastic or inelastic molecular collisions can be obtained independently, Brewer said. Thus Stark switching has now been used to observe effects such as optical nutation, photon echoes involving two or more pulses, optical free induction decay, coherent Raman beats, optical adiabatic fast passage, and so on.

With laser frequency switching, Hahn told us, one can expect to obtain clearer measurements of damping and collision dynamics of optical systems among various levels. The technique will reveal the nature of transient coupling and damping connected with hyperfine and other higher-order degrees of freedom. In the solid state, he went on, one can measure dynamic processes, monitoring the local fields. Many other experiments previously possible with pulsed nmr should be now feasible in the visible and uv.

In general, Brewer said, with the technique one can study time-dependent phenomena of either coherent or incoherent processes in the optical region—in solids, atomic and molecular gases. Already Brewer and Genack have measured directly phase-interrupting collisions in molecular iodine. They have observed photon echoes, free induction decay and

nutation effects in many lines of the visible electronic transition of molecular iodine, similar behavior on the sodium D lines, and with Roger Macfarlane (IBM) did free induction decay in a lanthanum trifluoride crystal having 0.1% Pr³⁺ at 1.5 K temperature.

In a related development, Chung L. Tang and John M. Telle (Cornell University) reported² last year that they had electronically switched a dye laser 15 Å in a few nanoseconds and more recently 150 Å in a few nanoseconds, although they did not try to obtain coherent transients at that time. Brewer notes that this result exceeds the IBM tuning range by about five orders of magnitude. He feels the Cornell method appears promising for extending the IBM laser frequency-switching technique to the sub-nanosecond time scale. —GBL

References

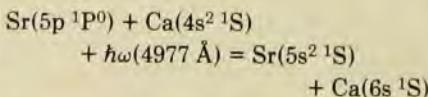
1. R. G. Brewer, A. Z. Genack, *Phys. Rev. Lett.* **36**, 959 (1976).
2. J. M. Telle, C. L. Tang, *Appl. Phys. Lett.* **26**, 572 (1975).

Laser assists excitation transfer in collisions

In an experiment that introduces a completely new approach to inelastic collisions, the transfer of excitation from one atom to another has been enormously enhanced by resonant optical irradiation. Incident laser light was tuned to a wavelength corresponding to the energy difference between the final and initial states of the colliding atoms. The experiments, in which the 5p strontium atoms transferred their excitation energy to 6s calcium atoms, was performed at Stanford University by Stephen Harris, Roger Falcone, William Green, Derek Lidow, Jonathan White and James Young.¹

The feasibility of such an experiment had been predicted theoretically. In 1972 L. I. Gudzenko and S. I. Yakovlenko of the Lebedev and Kurchatov Institutes predicted high probabilities for the closely related inverse process, radiative collision, in the presence of a resonant electromagnetic field.² In 1974–75 Harris and Lidow independently predicted³ the effect they observed.

When the Stanford experimenters illuminated with laser light a cell containing a gas of 5p strontium atoms and 4s (ground-state) calcium atoms, the Sr transferred its excitation energy to the Ca by the reaction



If no radiation is present the cross sections for reactions such as this are vanishingly small unless the two excitation energies match to within several kT . When Fal-

cone and his co-workers irradiated the system with 4977-Å light from a tunable laser at a power density of about 10⁶ W/cm², they found a cross section somewhat greater than 10⁻¹⁷ cm² for the inelastic collision.

The Sr–Ca cell, which was of the heat-pipe type, was operated at about 875 deg C. The Sr and Ca densities were about 10¹⁵ atoms/cm³. The 5p storage state of Sr was populated by single-photon pumping. Excitation of the Ca(6s) level was detected by measurement of 5513-Å fluorescence that accompanies its spontaneous decay to the Ca(4p) state. The measured cross section was linear in the incident power density of the transfer laser. The Stanford group expects to use this linearity to attain cross sections as high as 3 × 10⁻¹³ cm², by a thousandfold increase in laser power.

Earlier this year the Stanford group reported⁴ the apparent observation of this effect in a mixture of Sr and Ca. Further work indicated that because of the presence of an overlapping transition frequency within the Sr triplet series, the conclusions were in error. In the subsequent months two new successful experiments, which led to the results reported here, were accomplished.

Harris and his collaborators consider three theoretical points of view. In one, the effect is viewed as a virtual collision, followed by an electromagnetic transition. Another viewpoint considers the process as a transition between states of a quasi-molecule. Calculations of this type indicate that, for dipole–dipole and dipole–quadrupole interactions, the cross section for inelastic collision peaks when the laser is tuned to correspond to the energy defect of the infinitely separated atoms. This is in agreement with experimental results to within an experimental uncertainty of 0.2 Å. The third, *ad hoc*, viewpoint considers the effect as resulting from the near electromagnetic field of the interacting atoms.

A number of theoreticians, including Marvin Payne, C. W. Choi and Munir H. Nayfeh of the Oak Ridge National Laboratory, Sydney Geltman of the Joint Institute for Laboratory Astrophysics, and Thomas George and his collaborators⁵ at the University of Rochester, have already submitted follow-up papers.

Future applications of the new technique may include

- ▶ a radiative-collision laser using the inverse process discussed by Gudzenko and Yakovlenko;²
 - ▶ extending the Stanford experiment to multiphoton processes to reach states in the 100-Å (vacuum-uv) region of the spectrum, and
 - ▶ coherent Raman processes induced by collisions, for up-conversion of long-wavelength radiation.
- Other possible experiments include spin-exchange and charge-exchange versions of this process.

Because the Stanford technique permits collision processes that otherwise could not occur, Harris and Young feel that the most important application of the technique may be to increase the reaction rates of selected gas-phase chemical reactions. —HRL

References

1. S. E. Harris, R. W. Falcone, W. R. Green, D. B. Lidow, J. C. White, J. F. Young, in *Proceedings of the International Conference on Tunable Lasers and Applications*, 7-11 June 1976, Loen, Nordfjord, Norway.
2. L. I. Gudzenko, S. I. Yakovlenko, *Sov. Phys. JETP* **35**, 877 (1972).
3. S. E. Harris, D. B. Lidow, *Phys. Rev. Lett.* **33**, 674 (1974); **34**, 172(E) (1975).
4. D. B. Lidow, R. W. Falcone, J. F. Young, S. E. Harris, *Phys. Rev. Lett.* **36**, 462 (1976).
5. T. F. George, J. M. Yuan, I. H. Zimmerman, J. R. Laing, *Disc. Faraday Soc.* **62**, in press; J. M. Yuan, T. F. George, F. J. McLafferty, *Chem. Phys. Lett.* **40**, 163 (1976).

Neutrinos and atoms

continued from page 17

work, the requirement that the neutral currents conserve quark flavors can be satisfied in a "natural" way in only two kinds of models, those in which all left but no right-handed quarks participate in the weak interaction (as in the original Weinberg-Salam model) and those "pure vector" models in which all left and all right-handed quarks participate equally.

In models such as that of Weinberg and Salam, parity is not conserved by the neutral currents, and neutrinos and antineutrinos have different neutral-current cross sections on nuclear matter. The theory allows one to predict the strength and structure of all the neutral-current interactions, including the neutrino-nucleon interactions, both elastic and inelastic, as well as the neutrino-lepton interactions, and a parity-violating electron-nucleon interaction now under study in an atomic-physics polarization experiment. All these predictions involve a single free parameter, the Weinberg angle, θ_W , which is related to the mass ratio of the charged and neutral intermediate vector bosons.

The pure vector theories predict that parity is conserved by the neutral currents and that neutrinos and antineutrinos have equal neutral-current cross sections on nuclear matter, just as electromagnetic currents do (so that electron and positron scattering cross sections are equal).

Among those theorists who have developed theories of the general vector type are: J. J. Sakurai and L. F. Urrutia (University of Chicago); Alvaro De Rújula, Howard Georgi (Harvard) and Glashow; Harold Fritzsch, Murray Gell-Mann and Peter Minkowski (Cal Tech); Frank Wilczek, Anthony Zee, R. L.

Kingsley and Sam B. Treiman (Princeton); Michael Barnett (Harvard); S. Pakvasa, W. A. Simmons and San Fu Tuan (University of Hawaii).

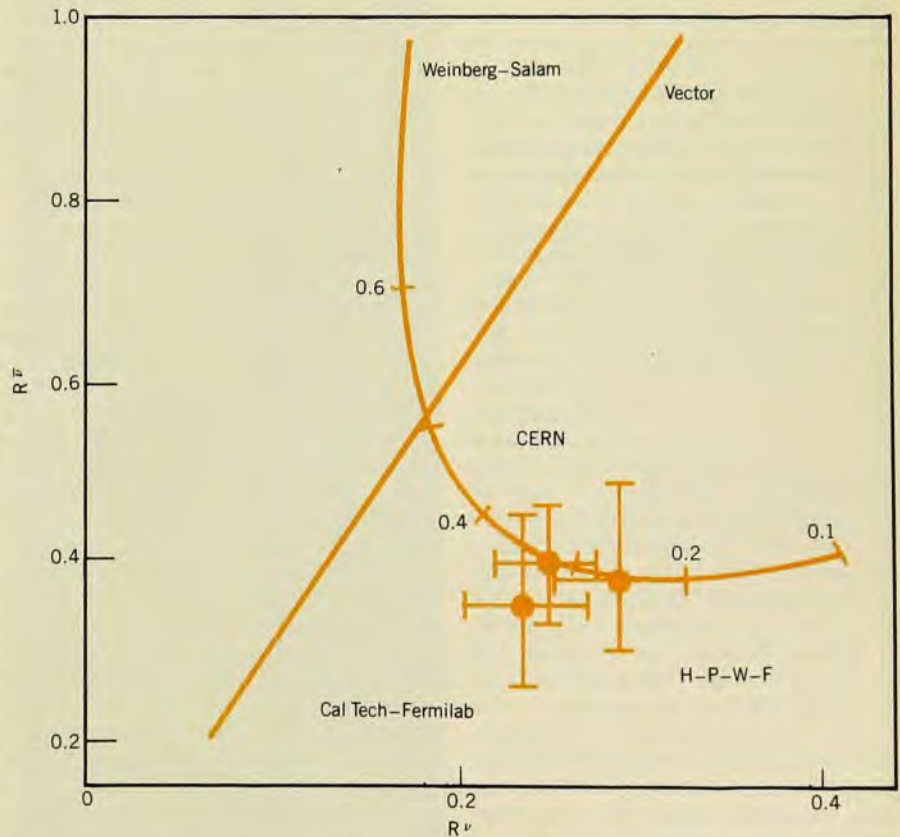
Neutrino experiments. The first firm verification of neutral-current behavior came from inelastic neutrino experiments, in which a neutrino interacted with a nucleon and, instead of producing a muon or an electron, yielded hadrons without a charged lepton. These experiments were done with the Gargamelle bubble chamber at CERN by a collaboration from Aachen, Brussels, CERN, École Polytechnique, Milan, Orsay and London; in a spark-chamber experiment at Fermilab by a collaboration from Harvard, University of Pennsylvania, University of Wisconsin and Fermilab; by an Argonne-Purdue group; in a later Fermilab experiment by Barry C. Barish and his collaborators at Cal Tech and Fermilab; in an experiment by Wonyong Lee (Columbia University) and his collaborators at Columbia, University of Illinois, and Rockefeller University and by H. Faissner and his Aachen-Padua collaborators.

In April the Harvard-Pennsylvania-Wisconsin-Fermilab collaboration reported at the Madison, Wisconsin Conference on the Production of Particles with New Quantum Numbers new measurements¹ of R^ν and $R^{\bar{\nu}}$, the ratios of neutral current to charged current neu-

trino and antineutrino inelastic cross sections, all carried out at Fermilab. This summer two groups reported elastic neutrino-proton scattering: the Columbia-Illinois-Rockefeller collaboration² and Harvard-Penn-Wisconsin.³ Both groups did their work at Brookhaven National Laboratory.

Meanwhile, Frederick Reines, H. S. Gurr and H. W. Sobel (University of California at Irvine) have done an entirely different type of experiment, which had its genesis 18 years ago. They detected and measured the purely leptonic elastic scattering of electron antineutrinos from electrons, using antineutrinos from a Savannah River fission reactor.⁴ Incidentally, this reaction, with its minuscule cross section (corresponding to a mean free path of 100 000 light years of liquid hydrogen) and its variants $\nu_e + e^- \rightarrow \nu_e + e^-$ and $e^+ + e^- \rightarrow \bar{\nu}_e + \nu_e$, and so on, is assumed by astrophysicists to play a fundamental role in the physics of supernovas.

Peter Wanderer, speaking for the Harvard-Penn-Wisconsin group at the Madison meeting, claimed that their new values of R^ν and $R^{\bar{\nu}}$ yield neutral-current rates for neutrinos and antineutrinos that are consistent with a pure (V-A) interaction but three standard deviations from pure V or pure A. He concluded that these results require a significant parity



Ratios of neutral- to charged-current cross sections for reactions initiated by neutrinos R^ν and antineutrinos $R^{\bar{\nu}}$ in deep inelastic scattering. The results presented at the Aachen conference by three groups are compared with the predictions of the Weinberg-Salam model as a function of $\sin^2 \theta_W$ and of the vector models. The figure is from Larry Sulak (Harvard).