search & discovery

X-ray parametric conversion—two photons for one

Nonlinear optical effects with visible light have long been known; the first laser was developed 12 years ago. Now Peter Eisenberger and Samuel McCall of Bell Telephone Laboratories have demonstrated[1] nonlinear optical effects at x-ray frequencies. In an experiment that verifies the calculations of Isaac Freund and Barry F. Levine,[2] Eisenberger and McCall have achieved the x-ray analog of optical parametric conversion. They have shown that a single x-ray photon of frequency ω_p incident on a crystal can result in the coincidental emission of two x-ray photons ω_1 and ω_2, where $\omega_1 + \omega_2 = \omega_p$, and the crystal as a whole takes up the recoil, so that both energy and momentum are conserved. A prime reason for interest in the result is the anticipation[3] that the work might be extended to a mixed x-ray–visible experiment that could reveal microscopic details of the behavior of outer-shell electrons in these nonlinear interactions.

X-ray parametric conversion is observable because the interaction cross section depends both on the magnitude of the nonlinear susceptibility of the crystal and the strength of the zero-point fluctuations in the electromagnetic field. Although the nonlinear susceptibility for x rays is only about 10^{-8} of the value for visible light, the strength of the zero-point fluctuations is correspondingly greater.

McCall and Eisenberger aimed a 17-keV x-ray beam at a beryllium crystal oriented slightly (about 15 minutes of arc) off the Bragg scattering angle. They analyzed the emitted radiation for coincident 8.5-keV pairs in the directions consistent with momentum conservation, and found a conversion efficiency of about 10^{-8}. (Typical optical parametric oscillators can have an efficiency of about 10^{-1}.) Beryllium was used because, with its low atomic number, it has a low x-ray absorption constant and allows a large volume for

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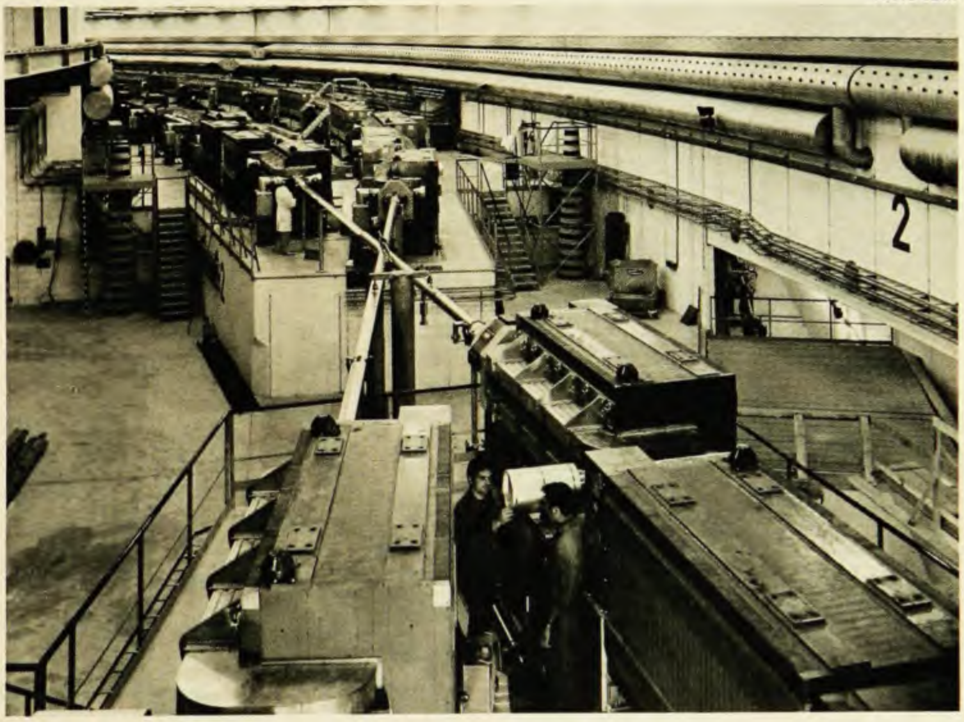
ISR collisions at CERN; experiments start this summer

CERN's Intersecting Storage Rings have produced collisions between protons several months ahead of schedule, and experiments are scheduled to begin with the rings around the middle of the year. The first successful collisions occurred on 27 January with 15-GeV protons, and by 17 February the energy had been boosted to 22.5 GeV. When operated at the full energy of 28 GeV, the collisions will correspond to a beam of 1700 GeV hitting a stationary target.

The storage rings consist of two interlaced rings of magnets, each 300 meters in diameter, which enclose doughnut-shaped, highly evacuated vacuum chambers. Protons from the 28-GeV proton synchrotron are injected into a transfer channel and guided into one of the two rings. An rf system allows the pulses to be stacked. At full intensity the ISR is expected to have circulating currents in each ring of about 20 amps.

In commissioning the ISR the big question was what effect the two beams would have on each other. Beams were first circulated and stored in ring no. 1 at the beginning of November. On 11 January lifetimes of several days were recorded. Trials on ring no. 2 began on 25 January, and soon beams were accumulated with currents of up to 1 amp. Although not all the components were connected nor all of them baked

PHOTO CERN



Intersection point I-2 at the CERN Intersecting Storage Rings, where some of the first experiments are now being installed. Here and at point I-8, the tunnel is widened on the inside (left) by 3 meters, and the floor is lowered by 2.4 meters to accommodate experimental equipment. At center right is the end of one of the beam-transfer tunnels, which brings protons from the synchrotron to the ISR. The injection point for one of the rings is at the next crossing point, 100 meters off the bottom of the photograph. The striped towers on either side in the rear are survey monuments, which are used for high-precision alignment of the ISR magnets and other equipment.

controlled rotation of a half-wave plate selects the polarization direction of the light, and an adjustable lens matches the laser-beam diameter to the molecular-beam diameter.

The detecting is done by a mass spectrometer that selects fragments with the looked-for mass and rejects all others. Those of the looked-for fragments that recoil at a preselected angle with respect to the electric vector of the light are ionized and pass through the mass spectrometer to an electron multiplier, whose output pulses are counted every microsecond for 500 microsec after the laser is fired. From the time of arrival and the distance between the spectrometer and the point where the beams cross, the translational energy E_{trn} of the fragments is measured. And from the energy conservation relation

$$E_{\mathrm{par}} + h\nu = D_0{}^0 + E_{\mathrm{ele}} + E_{\mathrm{trn}}$$

(where E_{par} is the initial internal energy of the parent molecule, $h\nu$ is determined by the laser and $D_0{}^0$, the dissociation energy, is usually known) for a diatomic molecule, Wilson calculates the energies E_{ele} of the electronic states of the atomic fragments. For a polyatomic molecule, Wilson can determine the total internal energy—only for special cases can he distinguish between electronic, vibrational and rotational levels. The angular distribution of the recoiling fragments gives information about the dissociative molecular excited state, for example, its symmetry and lifetime.

Other chemical physicists have studied the recoil spectroscopy of photodissociating molecules. At Harvard, Richard N. Zare (now at Columbia) and Dudley R. Herschbach[2] showed theoretically that the angular distribution of recoiling photodissociated fragments is linked to the symmetries of the excited states. Jack Solomon and Richard Bersohn[3] (Columbia) have studied a variety of molecules with a method they call "photolysis mapping," which gives them the angular distribution of the fragments but not the translational energy. And Ronald Diesen, John Wahr and S. E. Adler (Dow Chemical Co) have reported[4] results on NO_2 and Cl_2 from a method similar to the one Wilson uses.

Some earlier errors in spectroscopy have been corrected with the recoil method. Iodine in its main visible continuum, for example, was thought to dissociate almost entirely from the $B^3\Pi_{0u}{}^+$ state into one excited and one ground-state atom, but the energy and angular distributions that Wilson finds indicate a major contribution from a $^1\Pi_{1u}$ state, giving two ground-state atoms. This preferential population of the ground state helps explain why no iodine photodissociation laser has yet been successful.

The sun produces in the atmosphere many of the reactions that Wilson reproduces in his laboratory; NO_2 and ethyl nitrite (C_2H_5ONO) for example, have been extensively studied, and some of Wilson's support is from the Government agencies that are interested in controlling air pollution. Photodissociation reactions are also of interest to atmospheric scientists because these reactions help shield the earth from uv radiation and maintain the heat balance in the upper atmosphere.

Within the next few months, Wilson expects to start experiments with a high-power ultraviolet laser (1 joule per pulse at 2655 Å). This laser will be used to study ozone, which Wilson finds particularly interesting because of the spin conservation problems in its breakup and the importance of its photodissociation both to air pollution and to processes occurring in the upper atmosphere. —MSR

References

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interaction. Eisenberger and McCall were pleased to find that they could observe conversion even in their slightly imperfect crystal.

A major experimental difficulty was reducing the random Compton-scattered background radiation to allow discrimination between the background and the coincident 8.5-keV pairs. Sodium-iodide detectors were chosen for their combination of energy resolution and speed of response, but their energy resolution was not quite sufficient to ensure rejection of all the random 17-keV photons. The Compton rate was about 3000 per sec, whereas the coincidence count rate was about one per hour, so that great care in experiment design was needed.

McCall and Eisenberger are now attempting to do an experiment mixing x-ray and visible photons. Neither ordinary x-ray scattering experiments nor nonlinear techniques at visible frequencies give microscopic details about outer electrons because both are dominated by the bulk properties of the material. An experiment that mixed x rays and visible light would, however, allow the x rays to probe the outer-shell electron distortions produced by the visible light.

What about the relation of their work to the possibility of an x-ray laser? "I don't know how to make an x-ray laser," says McCall, "nobody does . . . but working in a related field just might help." —MSR

References

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New telescope at Palomar

The first major addition to Mount Palomar since the 200-inch telescope was completed in 1948 is a 60-inch telescope, which was dedicated in October. A Raytheon 703 computer controls operation and acquires data. An unusual optical system of six mirrors and a corrector lens enables the telescope to combine the maneuverability advantages of a short tube (154 inches) and the higher magnifications possible with a long focal length of 1800 inches (at the coudé focus) or 525 inches (at the Cassegrain focus). The telescope, built largely in the Cal Tech shops, cost more than $1 million; funds came from NSF, the family of the late Oscar G. Mayer, NASA, Cal Tech and the Carnegie Institution.

The Hale Observatories operate the new telescope as well as the 200-inch and 48-inch Schmidt telescopes at Palomar and the 100-inch and 60-inch telescopes at Mount Wilson.

Paramagnetic temperature scale in 1–20 degree K range

A new temperature scale in the range from 1 to 20 degrees K has been developed by T. C. Cetas and Clayton A. Swenson of Ames Laboratory and Iowa State University. The new scale, which is preserved for use by germanium resistance thermometers, is based on precise susceptibility measurement of two paramagnetic salts, chromic methyl-ammonium alum and manganous ammonium sulfate. Based on the National Bureau of Standards 1955 platinum resistance thermometer scale, the Iowa scale is believed to be accurate to better than 1 millidegree K over the specified range. □