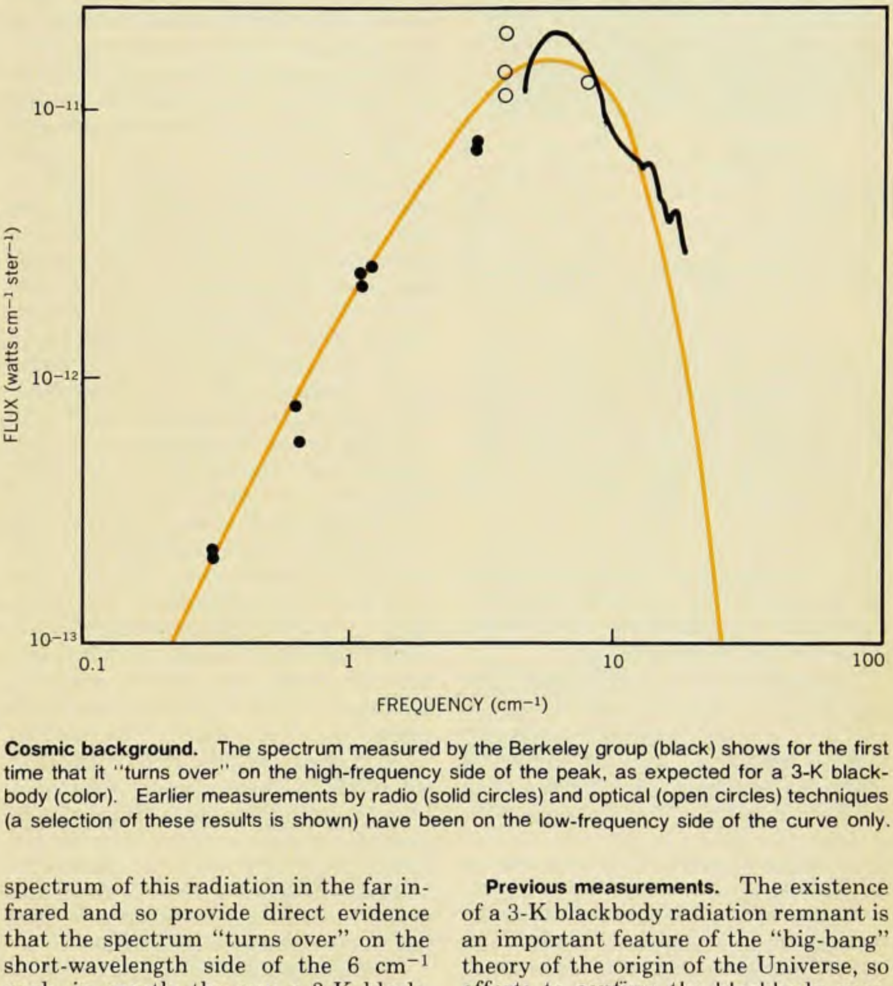
search & discovery

Cosmic background radiation reveals its blackbody shape

Experimenters from Berkeley, California, have measured the spectral shape of the submillimeter cosmic background radiation beyond the 6 cm^{-1} peak and found it to be consistent with the emission from a blackbody at 2.99 K (+0.07, −0.14 K at the 90% confidence limits). Their work comes several months after the balloon flights of a group from Queen Mary College, London, who studied the same spectral region and also found a blackbody shape. The QMC and Berkeley studies, however, disagree in their observations of, and correction for, atmospheric and (in the QMC case) window emission, and the Berkeley results are believed by most workers in the field to give a more likely picture of the nature of the detected radiation. The British group (E. I. Robson, D. G. Vickers, J. S. Huizinga, J. E. Beckman and P. E. Clegg) reported their studies in the 18 October 1974 issue of *Nature Physical Science.*[1] The Berkeley group—David Woody, John Mather (now at the Goddard Institute for Space Studies, New York), Norman Nishioka and Paul Richards of the University of California, Berkeley and the Lawrence Berkeley Laboratory—reported their balloon-borne experiments in the 21 April issue of *Physical Review Letters*[2] and at the Washington, D.C. meeting of The American Physical Society. Although the first measurements to point out the existence of a 3-K background were done over a decade ago, these two new studies are the first continuous measurements of the spectrum of this radiation in the far infrared and so provide direct evidence that the spectrum "turns over" on the short-wavelength side of the 6 cm^{-1} peak, in exactly the way a 3-K blackbody should.



Cosmic background. The spectrum measured by the Berkeley group (black) shows for the first time that it "turns over" on the high-frequency side of the peak, as expected for a 3-K blackbody (color). Earlier measurements by radio (solid circles) and optical (open circles) techniques (a selection of these results is shown) have been on the low-frequency side of the curve only.

Previous measurements. The existence of a 3-K blackbody radiation remnant is an important feature of the "big-bang" theory of the origin of the Universe, so efforts to confirm the blackbody spectral character of the observed back-

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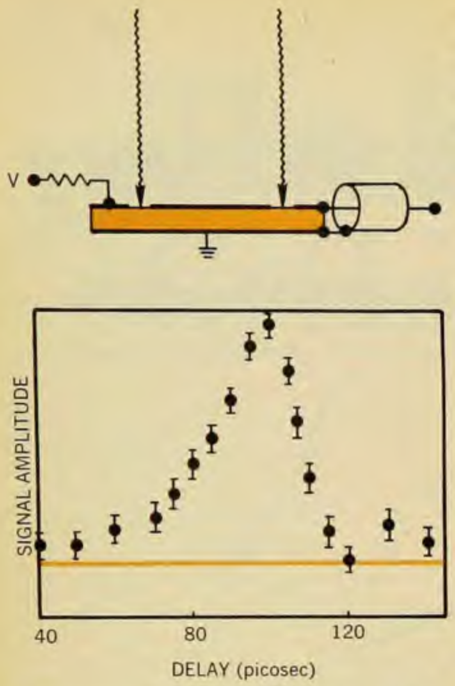
Extended range for ultrashort laser pulses

New areas of interest may be opening for ultrashort, or picosecond duration, laser pulses. These pulses have already been used for many years in research ranging from molecular lifetime studies to nonlinear optics (see PHYSICS TODAY, July 1971, page 19). Recent applications to biophysics, condensed matter and plasma physics are reviewed in the article that begins on page 30 of this issue. One new area, recently reported by David H. Auston of Bell Labs,[1] is the application of these optical pulses to electronic switching functions; they can switch a signal in about 10 picoseconds, one or two orders of magnitude faster than semiconductor junction devices. A second area is the development of ultrafast pulses from the highly efficient carbon dioxide laser, thus extending the ultrafast pulses from the visible and near infrared, where they are currently available, toward the far infrared. Most recently at the Conference on Laser Engineering and Applications in Washington, DC from 28–30 May, one group announced a technique for fast optical switching of pulses from a carbon-dioxide laser.

The optoelectronic switch developed by Auston consists very simply of a layer of high-resistivity silicon on which a microstrip transmission line has been fabricated. The microstrip has a uniform aluminum ground plane on the bottom and a narrow strip for a conductor on top. The upper strip has a gap that prevents conduction of a signal.

For the switching signal Auston starts with a 1.06-micron pulse from a Nd: glass laser and doubles it in a KDP crystal to provide a second pulse at 0.53 microns. The pulses are separated and delayed relative to one another. The shorter wavelength turns the signal on because its photocarriers lower the resistance of the top surface of crystal and allow transmission of the current. The



Measurement of switching speed. In left gate 0.53-micron pulse allows signal to cross gap; 1.06-micron pulse stopped it 15 picosec later. At right, a similar pair of pulses samples signal after a given delay, with result shown in the graph. The colored line is the signal that is produced without a bias.

longer wavelength pulse turns the signal off because it has a greater absorption depth and penetrates the crystal to the ground plane, shorting the line.

To measure the switching time, Auston had to build a second optical switching gate downstream from the first to sample it. His measurements indicate a switching speed from 10 to 15 picosec. Auston told us he has applied a similar technique to the generation of short bursts of microwaves, on the order of 10 picosec.

Auston looks upon the switching technique as a research tool and is himself interested in using it to study properties of high-density semiconductor plasmas. Others, however, feel it may have eventual potential for communications systems.

Ultrashort CO_2 pulses are important primarily for their applications to laser-induced fusion and to the measurement of very short lifetimes of molecular processes in the infrared. One approach to producing such fast carbon-dioxide pulses is the mode-locking method, which is used to produce most of the current ultrashort laser pulses. In mode locking, one rearranges the phase relations between axial modes of the laser. One type is active mode locking, in which a periodically driven modulator couples the modes together so that the peak power is concentrated in a train of short bursts. The other type is passive mode locking. Here, a saturable dye is placed inside the laser. It reduces the gain of the laser until there appears one peak in a noiselike signal that is large enough to saturate the dye; this pulse is then transmitted at high gain because the dye no longer affects it.

A group from the University of Essex, England, successfully used p-type germanium as a passive mode-locking element with a carbon-dioxide laser at one atmosphere of pressure.[2] Their most recent paper reports generation of a 300-picosec pulse, and describes a high-resolution detection system to measure its duration. Still shorter pulses—about 80 picosec—have been produced by John Alcock and Andrew C. Walker of the National Research Council (NRC) of Canada in Ottawa.[3] They operated the carbon-dioxide laser at pressures of 10 to 15 atmospheres, and also developed a detection system with a resolution of 40 picosec by combining the use of a streak camera with a technique of upconverting the 10-micron carbon-dioxide signal to 0.96 microns.

Alcock and Walker also tried active mode locking with an acousto-optic Brewster-angle germanium modulator and the 10- to 15-atmosphere carbon-dioxide laser but found that the pulse length was limited by the gain time of the high-pressure laser: The gain time was too short to allow the light pulse to traverse the laser cavity as many times as is required for full mode locking to occur. NRC experimenters (Alcock, Paul B. Corkum, Douglas J. James and Kurt Leopold) have also developed a technique to switch infrared pulses with pulses of visible light: The carbon-dioxide laser strikes a slab of germanium at the Brewster angle. When a 2-nanosec ruby-laser pulse shines on the crystal, it causes the light from the carbon-dioxide laser to be completely reflected, producing a pulse of 2-nanosec duration. The group feels this method can be extended to shorter pulses.

A second approach to producing ultrashort carbon-dioxide laser pulses is to exploit the very fast switching action inherent in laser-induced breakdown in gases. In this phenomenon, the laser first rapidly ionizes a neutral gas. As the ionization density increases, the index of refraction decreases toward zero, and the laser light is no longer transmitted. The plasma cutoff time is on the order of 30 picosec; exact measurements of this time are now under way. This effect was applied to the generation of ultrashort pulses by Eli Yablonovitch (Harvard).[4] He recognized that one must use the resulting step-function signal in conjunction with a spectral filter that will reject the incident laser light and transmit only the sidebands produced by sudden plasma growth. Experimenters have used various devices such as the Michelson interferometer[5] or Fabry-Perot etalon as filters, and Yablonovitch points out that each filter will produce a characteristic pulse shape. Combinations of these filters may be required to generate complicated pulse shapes such as those required for laser fusion work.

Yablonovitch and Julius Goldhar (MIT) have developed a carbon-dioxide absorption cell as a filter that they feel has a much better rejection ratio (of the transmitted to the pre-cutoff laser light) than the conventional filters.[6] The resonantly absorbing cell emits a signal that destructively interferes with the input signal prior to the plasma cutoff of the light. At the cutoff, the cell emits a signal that is no longer cancelled; this signal has a duration that is determined by the molecular collision time and by the optical thickness of the carbon-dioxide absorber. Both these factors can be adjusted by varying the gas pressure and the length of the cell, respectively. With this filter, Yablonovitch has generated picosecond pulses from laser-breakdown plasmas. —BGL

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Macroscopic yields by laser isotope separation

Laser separation has for the first time produced macroscopic amounts of isotopically enriched compounds of such elements as boron, chlorine and sulfur. Last fall experimenters at the Institute for Spectroscopy, Moscow[1] and the National Bureau of Standards[2] both described experiments on boron isotope separation from boron trichloride. An NBS group has also done work on separating chlorine isotopes. This past March the Moscow group reported their recent successes with sulfur. Shortly thereafter the Los Alamos Scientific Laboratory made public similar sulfur experiments. Results at all three places indicate that significant progress has been made since we last reported on laser isotope separation (PHYSICS TODAY, September 1974, page 17).

The people involved at the three laboratories are R. V. Ambartzumian, N.