of electrons a possible occurence.

Another class of explanations assumes that the wave function of the electron is amplitude modulated and serves as a source of oscillating charge and current in Maxwell's equations. Such an explanation was proposed by Van Zandt and by others.

Despite the vast amount of theoretical effort, only briefly touched upon here, no experimental verification of the Schwarz–Hora effect has been reported in the literature.

New experiments. At Brooklyn Poly, Scarl, Gordon Gould and Larry Silverstein are using a 36-kV electron beam whose monochromaticity is estimated at a couple of electron volts. Their laser delivers 30 W at the thin film in 10-nanosec pulses. The screen is high-purity aluminum oxide. They have tried polycrystalline aluminum oxide, amorphous quartz and single-crystal mica films so far, with negative results.

At Iowa State, David Lynch, Ronald Hadley, Edward Stanek and Elmer Rosauer are using the electron beam and electron optics in an existing electron microscope. They have 60–80-kV beams whose monochromaticity is estimated at about half an electron volt; beam current is 2–4 microamp. Their laser is a 2-watt argon laser, which delivers about 1/3 watt inside the microscope. Their thin film is of mica. For the screen they have tried single-crystal sapphire, mica, a glass filter that absorbs blue light, a copper plate and powdered aluminum oxide. Their results have been negative.

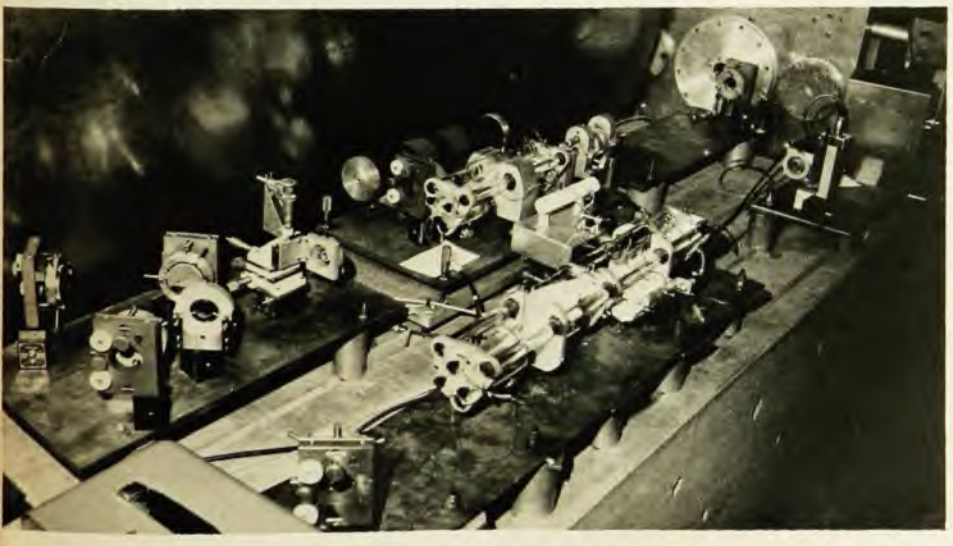
At Bell Labs Loren Pfeiffer and Denis Rousseau have a 100-kV electron gun, which they are operating at 50 kV. Their monochromaticity is limited by the cathode temperature, which depends on the type of cathode used. The whole system is contained in a 10^{-9}-torr vacuum. For a screen they are using high-purity pressed alumina. Preliminary experiments have been carried out using a 1200-A silicon-dioxide film of good optical quality. With half a watt of laser power at 5145 Å focused in the film they have seen no effect.

Schwarz points out that none of the experimenters are using an energy resolution as small as the value of 0.05 V predicted by theory. —GBL

Laser earth-strain gauge to search for gravity waves

An extremely stable laser developed at the Joint Institute for Laboratory Astrophysics, Boulder, Colorado, is providing a sensitive way to measure earth strain. Judah Levine and John L. Hall have built an interferometric strain gauge[1] whose key element is a methane-stabilized 3.39-micron helium-neon laser[2] at the Poorman's Relief Mine near Boulder. The stabilized He–Ne laser is beat against a second He–Ne laser locked to a 30-meter Fabry–Perot interferometer and fluctuations in the beat frequency are a direct measure of changes in the 30-meter path length.

One of the experiments Levine and Hall are most excited about is a search for continuous gravitational waves from the Crab pulsar at 60.4 Hz; no other strain gauge has had the right characteristics to look for these waves. But earth-strain frequencies vary over a wide range, and a feature of the JILA strain gauge is that its sensitivity extends over a significant part of the range. The mode spectrum of the earth is visible at one or a few cycles per hour; geophysicists have been searching for its "fine-structure constant," which plays the same role in the earth's spectrum as the usual fine-structure constant does in atomic spectroscopy. At about two cycles per day, the rock tides, analogous to the ocean tides, predominate. The hope of predicting earthquakes has stimulated the construction of some strain gauges; a build-up of earth strain could be a preliminary to an earthquake. And over very long time scales (much longer than the time scales of most earth-strain studies), strain measurements can indicate change in the gravitational constant.



JILA earth-strain gauge in Poorman's Relief Mine near Boulder, Colo. uses a methane-stabilized laser (foreground) as an "absolute" reference. A second laser (center) is mode matched and locked to a 30-meter Fabry–Perot interferometer (right).

Conventional earth-strain gauges measure the change in length of a quartz rod, and so are subject to drift and thermal instability. More recently, a number of physicists and geophysicists have collaborated to develop strain gauges in which a laser measures the change in length of the rod.[3] The unique feature of the JILA gauge is that both the standard and the variable "lengths" are frequencies, eliminating the problems associated with mechanical calibration and substituting a calibration in terms of molecular energy levels.

Long-path interferometer. In the JILA experiments two mirrors, each of 50-meter radius of curvature and 5 cm in diameter, form a 30-meter Fabry–Perot interferometer. The mirrors are mounted on concrete piers that are set into bedrock, and enclosed in a vacuum (10 millitorr) envelope that is thermally and acoustically isolated. A 3.39-micron He–Ne laser, radiofrequency excited and about 30-cm long, illuminates the 30-meter path. The laser mirror and bore are carefully chosen to ensure that the laser operates at a single frequency and mode, so that it can be "locked" to the long-path interferometer. The laser and long-path interferometer are carefully mode matched.

One of the laser mirrors is mounted on a piezoelectric crystal; by applying a small voltage to this crystal, Levine and Hall can tune the laser over several hundred megahertz, and can complete a servo loop that locks it to one of the transmission maxima of the long-path interferometer. This lock relates the laser frequency f to the path length d in such a way that $\Delta f/f$ is equal to $-\Delta d/d$, and measuring $\Delta f/f$ gives $\Delta d/d$ directly. For the 3.39-micron laser, f is of the order of 10^{14} Hz, and a strain change of one part in 10^8, a typical earth-tide amplitude, will shift f by about one megahertz.

"Absolutely stable" laser. To measure the frequency change a very stable reference is needed, and the reference Hall and Levine use is (through the agency of a second He–Ne laser) essentially a molecular absorption frequency of methane. The laser, developed by Richard L. Barger and Hall,[2] exploits the overlap of a resonance absorption in methane gas and the Doppler bandwidth of the He-Ne laser.

The laser cavity includes both a He-Ne gain cell and an absorption cell filled with methane at a pressure of about 12 millitorr. Although the He-Ne cell can lase over a range of about 360 MHz (the range set by the Doppler width of the line), Barger and Hall, by careful choice of cell parameters, force it to operate at a single frequency, thus setting up a standing wave in the cavity.

The standing wave in the cavity can be thought of as two oppositely traveling running waves of frequency f, not necessarily equal to the methane absorption frequency f_0. Only those methane molecules that have velocity components v_z in the direction of the traveling wave such that $f = f_0 (1 \pm v_z/c)$ can interact with the radiation, and, in general, holes would be "burned" into the molecular absorption velocity profile at *two* velocities, plus and minus v_z.

If, however, the laser is somehow tuned to f_0, those atoms with v_z equal to zero can absorb the radiation, the two running waves interact with the *same* molecules, the absorption saturates, and there is a transmission peak in the laser output. To achieve this desired coincidence between the 3.39-micron He-Ne transition and the P(7) line in the third vibrational band of methane and get their "absolute stabilization" Barger and Hall pressure shifted the 3.39-micron transition up 100 MHz.

In the earth strain studies, the stabilized laser output is heterodyned with the output of the laser locked to the long path. A fast indium-arsenide diode mixes the two signals and generates a signal at the difference frequency. Levine and Hall sample the beat frequency at regular intervals, and a computer records the data directly, along with time-of-day information. Because the output is a frequency rather than a voltage, Levine tells us, they can avoid analog-electronics problems.

The strain gauge has been used to plot rock tides, and Hall and Levine have shown the instrument's sensitivity by recording the relatively high-frequency seismic disturbance generated by the detonation of a 1-megaton nuclear device ("Boxcar") in Nevada as well. The JILA group is now busy with the gravitational-wave detection studies. —MSR

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X-ray source

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Theory. The obvious explanation for the pulsating x-ray source is a stellar rotator, which acts as the underlying clock mechanism. The object is rotating too fast for a white dwarf; so presumably it is either a neutron star or a black hole.

In the usual picture of a neutron star, a supernova occurs and the young pulsar that is formed rotates fairly fast and emits a lot of x rays. With time it slows down, the x-ray emission is cut off and only radio pulses are emitted. Cyg X-1 does not fit the usual picture: It is fairly young because it is emitting x rays and its rotation speed is fairly high. But if it is young, why don't we see the supernova remnant? As Giacconi says, "This object strains our present understanding of pulsars as neutron stars."

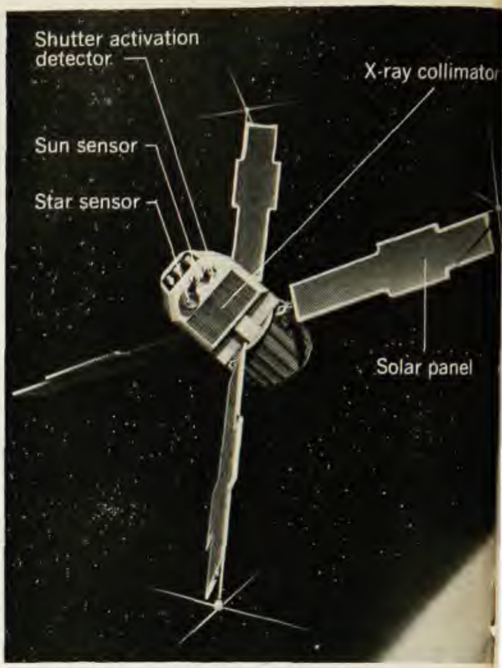
"At this point, we say maybe we're seeing some new type of compact object," Giacconi told us. But, he went on, maybe the object can also be explained by revising and generalizing on the theory of neutron stars, which is based on existing pulsar observations.

One possible explanation proposed for Cyg X-1 is that it is a pulsar whose magnetic field is so strong that what is ordinarily represented in the radio portion of its spectrum gets shifted all the way up into the x-ray region. The field would be about 10^{15} gauss, rather than the 10^{12} gauss generally envisioned for pulsars. Fields as high as 10^{15} gauss could be produced deep inside the pulsar, in the quantum crystals proposed by Hans Bethe; these are mixtures of neutron and proton lattices whose net volume magnetization would be enormously high.

Giacconi told us that Cyg X-1 is not unique. The satellite continues to pour out data, and the AS & E group is currently studying two dozen x-ray sources. He says that one or two of them are clearly pulsating.

The Explorer 42 detector did not have particularly good time resolution (96 millisec), but one can now go back and examine old rocket flights that did have better time resolution. That's what a group at Goddard Space Flight Center (Stephen Holt, Elihu Boldt, Daniel Schwartz, Peter Serlemitsos and Richard Bleach) did. By analyzing the power spectrum from a 5-sec exposure to Cyg X-1, they find two fundamental periods—one at 290 millisec and one at 1.1 sec. The x-ray source may be acting like a radio pulsar, which has two periods, one a basic rotation period and the other the period for a subpulse to march through an open window.

With the advent of x-ray satellites, a new era in x-ray astronomy opens. Until Explorer 42 was launched, the total observation time for rocket-launched x-ray detectors was about one hour. The most remarkable thing about the satellite experiment is simply the long observation time it makes possible. Its detector is slightly larger and has slightly higher angular resolution than past detectors. It also has a very good aspect system for locating objects.



X-ray satellite, Explorer 42, has found a pulsating source in Cyg X-1, which has no supernova remnant associated with it and does not emit in the radio. It could be a new type of celestial object.

Besides the exciting results on Cyg X-1, Explorer 42 has found ten new objects in our galaxy. It has confirmed and refined the observation by Herbert Friedman and his collaborators at the Naval Research Laboratory, that a Seyfert galaxy, NGC 1275, is emitting x rays, and the satellite has found two other Seyfert x-ray emitters, too. Explorer 42 also confirmed that the quasar 3C273 is an x ray emitter.

Another drastically fluctuating source of x rays has been reported by Jeffrey McClintock, George Ricker and Walter Lewin of MIT. In a balloon-borne experiment they found that a source in Crux is emitting hard x rays with great variability over periods of 15 seconds.

What about the future? The next x-ray satellite to orbit will be Small Astronomy Satellite-C, being prepared by George Clark (MIT) and his collaborators. There will also be x-ray experiments carried on some other satellites. By 1975 the High Energy Astronomy Observatory may orbit. As part of it, Giacconi feels we will need to fly focusing x-ray telescopes. He says we can already make x-ray telescopes that can image and give essentially the same resolution as that of visible-light telescopes. □