

500-fold reduction in each stage, and reached at least 10^{-6} G. (His magnetometer was not sensitive to fields lower than that.)

Nuclear gyroscope. Fairbank and Hamilton want to use their zero-field apparatus to do two experiments on the gyroscopic behavior of He^3 nuclei. By mixing 0.001% He^3 with He^4 one can extend the He^3 inherent relaxation time from 500 sec in pure liquid He^3 to 1 year in the solution. Then one can polarize the He^3 nuclei and see their precession.

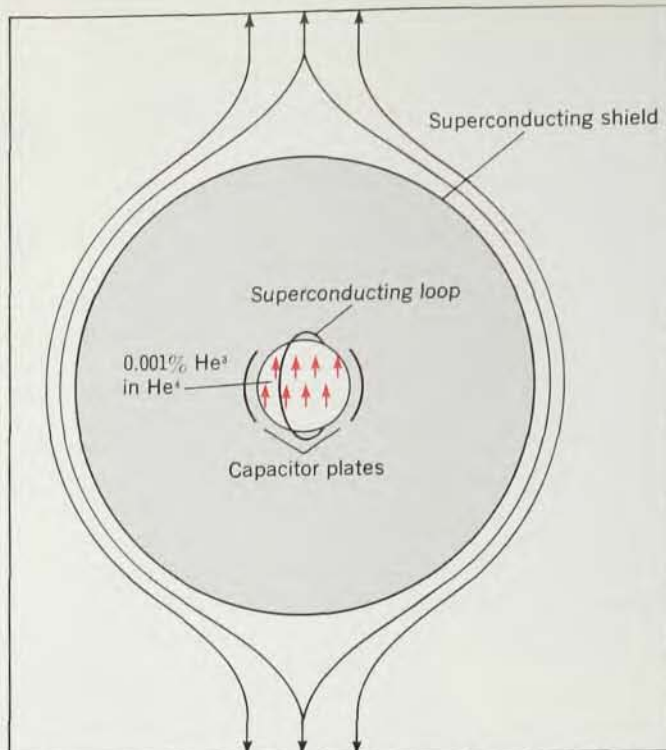
The apparatus (see figure) consists of a 30-cm-diameter quartz ball containing a small sample of polarized He^3 in a He^4 solution. The ball is coated with a superconducting magnetic shield from which the last quantum of magnetic flux will have been excluded, thus giving zero magnetic field inside. An electric field will be applied to the sample, which will cause the He^3 nucleus to move off center in the atom. If the He^3 has a permanent electric dipole moment the electric-field gradient in the atom will cause the nucleus to precess. A superconducting loop surrounding the He^3 forms part of a magnetometer to measure the precession.

Fairbank and Hamilton hope that the same apparatus will one day be good enough to try an earthbound check on general relativity. He would use the He^3 nucleus as a free-precession gyroscope inside the zero-magnetic-field apparatus, where it would be unaffected by external torques, and see how its orientation changed over the course of one year. —GBL

Tunable Infrared Source Yields Continuous Output

A team at Bell Labs has made a continuous parametric oscillator, tunable over a wide frequency range, with a barium-sodium niobate crystal as the nonlinear medium. The work is reported by Richard Smith, Joseph Geusic, Hyman Levinstein, Jerry Rubin, Shobha Singh and Lagrande van Uitert in *Appl. Phys. Letters*, 1 May.

The output of the device is continuous, coherent infrared radiation, tunable (in principle) from 0.65- to 4-micron wavelength. In this frequency range, devoid of monochromatic sources until recently, lasers have coherent output but are not tunable, and



FREE-PRECESSION NUCLEAR GYROSCOPE will be operated in zero field to look for He^3 electric dipole moment.

earlier forms of parametric oscillator provided a pulsed, rather than continuous, output. A parametric oscillator accepts an input at one frequency (the "pump") and provides an output at another (whereas an ordinary oscillator converts dc to ac). The first tunable parametric oscillators used lithium niobate as the nonlinear oscillator element, and because of this material's property of suffering optically induced refractive-index changes it could only be operated in a pulsed mode.

The new material, $\text{Ba}_2\text{NaNb}_5\text{O}_{15}$ (known in the trade as "banana"), which was developed at Bell Labs by Geusic, Levinstein, Rubin, Singh and van Uitert, can be operated continuously without adverse optically induced refractive-index effects ("optical damage") such as has been observed in other highly nonlinear material such as LiNbO_3 . On account of its optical nonlinearity it was first employed as a harmonic generator for laser light; the output from a 1.064- μ infrared YAG-Nd laser emerges from a crystal of this material as green 0.532- μ -wavelength light.

In the new parametric oscillator two $\text{Ba}_2\text{NaNb}_5\text{O}_{15}$ crystals are used. The first, 3mm long, is inside the cavity of a YAG-Nd laser, and the second-harmonic output at 0.532- μ becomes the

pump power for a second crystal, 5 mm long. This oscillator crystal lies in an optical cavity formed by one face of the crystal and a curved mirror. The pump power required to sustain parametric oscillation is 45 mW and is spread among 15 modes, for an average of 3mW per mode at threshold. When pumped with 300 mW, the output from both ends of the oscillator is 3 mW, so the overall efficiency is 1%.

The oscillator can be tuned by variation of its temperature. In the device as reported, temperature variation from 97° to 103°C gives a wavelength range .98–1.06 μ , but further variation is limited by the transmission factor of the mirrors; suitable choice of mirrors should make possible a 0.65–4- μ -frequency range.

Output from the prototype consists of spikes, each of a few microseconds duration, probably resulting from variations in the pump frequency and mode jumping. Stabilization to better than 5×10^{-8} should give continuous output in any particular mode. —JTS

Close Icarus Approach Tests Mercury Mass, Perihelion Shift

The asteroid Icarus (PHYSICS TODAY, October 1965, page 94) will be under close optical and radar scrutiny when it swings to within 6.36 million km of

the earth on 14 and 15 June. The eccentricity of its orbit provides an opportunity to check the relativistic shift of its perihelion; its close approach to Mercury and then to the earth permits calculations of Mercury's mass relative to the earth's. Samuel Herrick of the University of California at Los Angeles has provided 1-day and 2-hour ephemerides to help locate Icarus, which will never be brighter than 13th magnitude.

Neutral Excitation Seen In Superfluid Helium

Two Berkeley experimenters report they have produced a new kind of energetic neutral excitation in superfluid helium that travels centimeters without scattering. Clifford M. Surko and Frederick Reif, writing in *Phys. Rev. Letters* 20, 582 (1968) speculate that they are seeing an excited helium atom. If their interpretation is correct, the experiment is an interesting combination of atomic and low-temperature physics.

As Reif told *PHYSICS TODAY*, "For me it was intriguing to find something of this kind in a liquid. In ordinary gases people have often worried about the existence of metastable atoms, and in solids people have studied excitons, which correspond to excited atoms that can move throughout a solid. Now we may be seeing the same thing in liquids. With charged particles in liquid helium you can generate a vortex ring that moves essentially without change of size or energy for distances of many centimeters." Now Reif and Surko appear to have found a neutral particle that does the same at sufficiently low temperatures.

In the experiment they used a polonium-210 source of alpha particles in a container of liquid helium. They measured the current arriving at a collector in the vapor above the liquid and found that as they lowered the temperature below 0.7°K, the current rapidly increased with decreasing temperature. They found an anomalous current that was independent of any electric fields within the liquid, which suggested existence of a neutral excitation that traveled through the liquid and was then converted to charged particles at the surface. By time-of-flight measurements on these charged particles, Surko and Reif determined that they were He_2^+ ions and electrons. Thus the neutral must have had appreciable energy, enough to

ionize a helium atom in vacuum (24.6 eV).

By introducing directional baffles in the liquid the experimenters could establish that the neutral excitation travels through the liquid in a straight line with negligible scattering. On the other hand, they believe that the neutral excitation is not a photon since they could stop it with an aluminum film that transmits photons of appropriate energy.

What is the nature of the neutral? Surko and Reif speculate that they observed one of the long-lived metastable states of the isolated helium atom. But, Reif explains, "It's very difficult to get a handle on a neutral atom." They might be able to make a pulsed source of neutral excitations to find out how fast they move, or they might get optical evidence.

Chicago work. Stuart Rice of the University of Chicago told *PHYSICS TODAY* that he found evidence for a neutral excitation in liquid helium a few years ago, but he believes that the Berkeley experimenters found a

different species from his. The Chicago experiments, done by Joshua Jortner, Lothar Meyer, Rice and E. G. Wilson (*Phys. Rev. Letters* 12, 415, 1964 and *J. Chem. Phys.* 42, 4250, 1965), also were done by irradiating liquid helium with a polonium source. By examining emission spectra from colloiddally suspended oxygen and nitrogen, and from liquid and solid neon, argon, krypton and xenon, they concluded that energy was being transferred by the excited molecular-helium (He_2^*) triplet state.

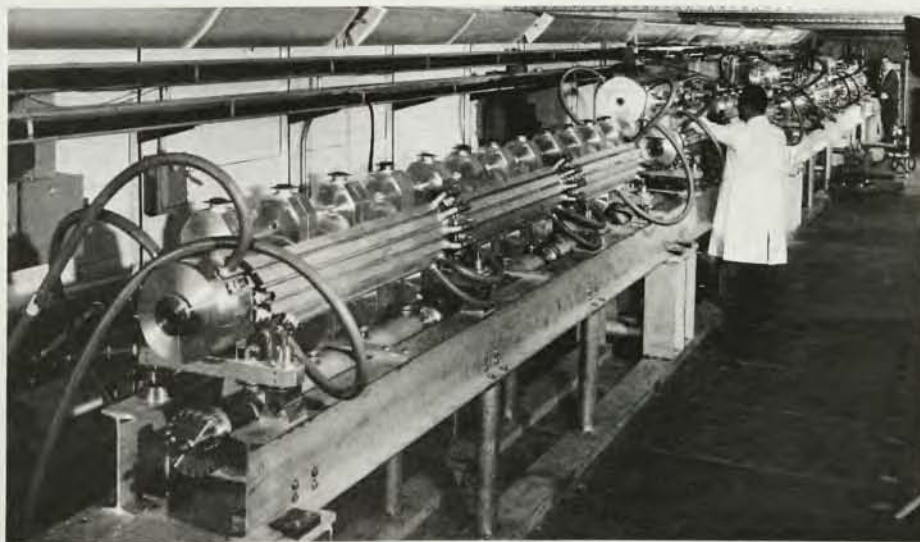
Rice and Morrel Cohen, also at Chicago, are working on a theoretical interpretation of the Surko and Reif experiment. They believe that the neutral consists of a He_2^+ ion and an electron, which are bound together above the normal ionization energy of the He_2 molecule by the repulsion of the electron from the surrounding liquid helium atoms. They believe that the trapped "bubble" migrates, and when it hits the repulsive barrier that exists at the surface, the electron flies out. —GBL

Los Alamos Prototype Tests Meson-Factory Linac Design

Something new in accelerator design is the electron linear accelerator that recently came into operation at Los Alamos. Although it produces a useful beam of its own, it is mainly a prototype for the 800-MeV, 1-milliamper proton linac that will one day be the Los Alamos meson factory LAMPF (*PHYSICS TODAY*, December 1966, page 21, November 1967, page

75 and April 1968, page 81). Louis Rosen, director of the medium-energy-physics division, is in overall charge of meson-factory development. This month a users' meeting is being held at Los Alamos.

Heart of the new design is a row of 100 resonant cavities arranged in four groups of 25 each along an 18-meter length. (LAMPF will have 4400



LOS ALAMOS ELECTRON LINAC is prototype for proton accelerator that will some day power a meson factory. 100 in-line cavities produce a 24-MeV, 1-milliamper beam. Cavities above and below main axis couple accelerating cavities.