system at a given position z in the sample. Energy is first absorbed from the leading edge of the pulse by the ions, and the ions then return the energy to the lagging edge of the pulse. The pulse will thus linger at z until the polarization produced by the ions decays to zero as the electric-field energy is finally returned to the traveling wave pulse. Thus the pulse is delayed, and when it reaches the next group of ions to be excited the process repeats itself.

To achieve greater delays one can increase the number of chromium atoms or increase the pulse width. There is a limit to the applicable pulse width, however, since it cannot exceed the energy damping time of the system. To achieve greater transparency and overcome damping one must apply a shorter pulse with a width much less than the damping time.

The effect is understood to apply only to absorbing transitions in insulators where the wavelength of light is short compared to the overall attenuation length that one would have with a weak beam being absorbed according to Beer's Law. An extremely granular medium (with discontinuities greater than a wavelength) would not work.

In principle, Hahn and McCall note, the transmission effect could be seen in any two-level system involving magnetic or electric multipole transitions that are resonant to traveling waves in the form of radio, microwave or phonon pulses.

The delay should be useful for studying short-duration atomic and electronic motion. Now that mode-locked laser pulses as short as 10^{-12}–10^{-13} sec are available, the transparency effect could be produced in media with damping times just as short. The delay effect may also have commercial applications in communications and computers.

Hahn and McCall's analysis also covers the dynamics of a pulse sent into a sample that is prepared initially in the excited state—the sample will behave as a laser amplifier. —GBL

US, USSR Venus Probes Await October Encounters

As this issue of PHYSICS TODAY reaches you, two Venus probes have completed about half of their 340-million-km journeys to the cloud enshrouded planet. Venus 4 left the Soviet Union on 12 June on a journey that the Russian news agency Tass said was to take "more than four months." Mariner 5 left Cape Kennedy two days later and is intended to encounter Venus on 19 Oct. Eight hours after launch Tass reported that the Soviet automatic space station was in a proper trajectory to reach Venus and all equipment aboard was functioning properly. After course correction, made on 19 June, Jet Propulsion Laboratory, project manager for the National Aeronautics and Space Administration probe, said that Mariner 5 could be expected to pass within 4100 km of Venus.

Venus, our evening star, is the planet nearest to earth and the brightest body in our heavens except the sun and moon. It circles the sun in an orbit three quarters the size of earth's and has about earth's diameter and mass. Recent measurements indicate that it rotates about once every 250 earth days.

Nevertheless Venus remains largely unknown because of the density of its cloud cover. Its atmosphere is estimated to be from five to several hundred times the density of the earth's. Atomic hydrogen and oxygen are assumed to exist in the upper portions, but 99% of the atmosphere is unknown.

Much of what is known about the Venus environment has been determined by four earlier probes: Venus 1, a Soviet probe that went by at about 100 000 km in 1961, Mariner 2, which passed within 32 000 km in 1962, Venus 2, which came within 40 000 km in February 1966 and Venus 3, launched four days after Venus 2. Venus 2 was apparently on a picture-taking mission, but its radio failed. Venus 3 failed to respond to commands that would have ejected a soft-landing device and crashed into the planet.

Mariner 5 is designed to determine precisely the mass and position of Venus, to measure the density and

the temperature of the planet's exosphere, to observe its trapped radiation and magnetic fields if they exist, to observe protons and electrons forming the solar wind and to refine presently accepted values of the mass of the moon and the astronomical unit (mean sun-to-earth distance). Venus 4, Tass reported, is scheduled to fly near Venus and not land on the planet's surface. The Soviet spacecraft will use both ultraviolet and infrared radiations to investigate the surface.

Experiments that will be performed with the probe are as follows:

S-band occultation. When the probe encounters the planet, transmission through the Venusian atmosphere of the telemetry signal will, it is hoped, determine the density of the atmosphere and how it varies from top to bottom. The frequency shift that occurs should give this information at least down to the level at which density is so great that it traps the radiation and does not let it escape to earth.

Dual-frequency propagation 423.3- and 49.8-MHz signals are being transmitted from the Stanford 46-meter antenna to the spacecraft where a receiver compares phase shifts. Comparison reveals the number of electrons encountered by the signals between earth and satellite.

Solar-plasma measurement. A proton detector will determine energy and direction of protons boiling off from the sun in the solar wind. Particle energies from 45 to 9400 eV are separated into 32 bands by voltage filters, and direction is determined by a three-sector detector.

Trapped radiation detection. Three Geiger-Müller tubes and a cosmic-ray telescope will try to search space for protons, alpha particles, electrons and solar x rays. They will look for distributions in space and energy and especially for any belts around Venus or disturbances in its solar wake.

Magnetic-field measurement. Mariner 2 showed that if Venus has any magnetic field, it is weaker than one tenth that of the earth. A helium magnetometer capable of measuring direction and magnitude of a field as weak as half a gamma (0.5×10^{-5} oersted) per axis is searching interplanetary fields and at encounter will look for the Venus field and any disturbances that the solar wind causes in it. The magnetometer operates by measuring the effect of a magnetic field on polarized-light transmission through helium.

Ultraviolet photometry. Three photomultiplier tubes with different filters will measure emissions from atomic hydrogen and oxygen that are excited by solar radiation. The intention is to observe hydrogen and oxygen densities as functions of altitude and use them as clues to the Venusian atmosphere.

Celestial-mechanics experiment. The closeness of Mariner 5 to Venus at encounter will enable a better measurement of the mass of Venus. Tracking data will also improve accuracy in the positions of Venus and the earth, in the astronomical unit and in the mass of the moon.

The vehicle that is now Mariner 5 was originally built as a backup for Mariner 4 and then modified for the mission on which it is now flying. It started as a 14.5-kg octagonal framework with one compartment for its propulsion system and seven for electronics. Now it is nearly 3 meters high, 5.5 meters wide (including solar panels) and has a mass of 246 kg. Venus 4 has a 1106-kg mass.

Data acquisition and transmission in several modes are available for different periods of the flight. The 100-channel telemetry system samples 90 engineering and science measurements. Transmissions will include engineering data only during maneuvers, two thirds science and one third engineering during launch and cruise, all science at encounter and science playback from tape after encounter.

The total encounter sequence will take about 27 hours, half before and half after closest approach. Then playback begins, and if all encounter data are received, the mission will be accomplished. Nevertheless Mariner 5 will continue on toward the sun and continue to transmit data until high temperature or malfunction make further experimentation impossible. Anything it can learn after passing Venus will be welcome addition to the solar lore we now have.

Astron Experiment Makes 5% of a Magnetic Bottle

The Astron experimental facility recently reached a milestone when its E layer, a cylinder of rotating relativistic electrons, produced 5% of the current density needed to make a linear magnetic bottle for controlled fusion. The first stage of a new injection accelerator was authorized by AEC this spring; the accelerator will ultimately be capable of building up the E layer to 100%.

In an invited paper at the APS Washington meeting, Nicholas Christofilos, who heads the Astron program, noted that in three years of experiments at Lawrence Radiation Laboratory, Livermore, neither hydromagnetic nor wave-particle instabilities have appeared under normal operating conditions.

Astron's confining field is produced by two oppositely directed currents. External coils create a nearly uniform magnetic field within a cylindrical chamber. Then an accelerator injects electrons into the chamber where they are trapped in helical paths between weak magnetic mirrors. The self-field of the E (for "electron") layer opposes the field of the external coils; so as the E layer is built up the net field inside the E layer is reduced more and more. If the current density in the E layer is high enough, the net magnetic field in the center will reverse direction.

Such a magnetic-field arrangement is an excellent and unique magnetic bottle because (a) it is a true minimum-B field (in which field intensity increases outward in all directions), which is hydromagnetically stable, and (b) the lines of force are closed so that diffusion losses are minimal and microinstabilities are discouraged. Last year Christofilos suggested that such a magnetic bottle can be built in a toroidal configuration with only 5% of the E-layer electron density required for a linear bottle.

Besides serving as a bottle the E layer will create the plasma it holds.

When the facility was finished three years ago (PHYSICS TODAY, June 1964, page 74) the 4-MeV electron accelerator had a 120-A beam current, $0.3\text{-}\mu$sec pulse length and repetition rate of 5 pulses/sec. Within a few weeks E-layer lifetimes had grown from microseconds to several milliseconds. Typical current density was 2 A/cm or 0.5% of the E layer needed for a bottle.

By modifying the accelerator the Astron group showed that pulses could be overlapped. During the injection phase, experimenters found a negative-mass instability, but it quenched itself in a fraction of a microsecond.

An interesting E-layer property turned up. Because of the strong self-magnetic-field gradient of the E layer, the electrons clamp together and the E layer acts like a solid coil oscillating coherently and in phase in the negative gradient of the external field.

In the next stage of experiments, the accelerator was modified to yield a 400-A beam current. Experimenters were soon making an E layer with 20 A/cm (5% of the bottle), ten times the previous current density, even though injection current had only tripled. The trick was to shorten the E layer (from 400 to 150 cm).

Convinced that the electron injection rate was the only limitation on building the E layer to full strength, the Livermore group proposed a new accelerator, to be built in two stages. In the first stage, approved by AEC this spring, the injection current will be raised to 1000 A at the present energy of 4 MeV (using existing electronic equipment). LRL will submit a proposal this fall for a second stage, to extend the accelerator to 15 MeV; it would yield 480 pulses/sec at 1000 A. After approval the accelerator would take three or four years to build.

With the complete accelerator Christofilos expects to build the E layer to 100%. Then the magnetic bottle can be used to do plasma-confinement experiments that will test the feasibility of the Astron approach to controlled fusion. □