# PS Builds a LASER ...and so can you

The incredible ruby ray is the hottest scientific discovery of the decade, but practical uses are still scarce. Here's your chance to join the search

-June, 1960: Dr. T.H. Maiman, of the Hughes Aircraft Co., reports the development of the first successful ruby laser.
-November, 1964: Popular Science publishes plans for the first do-it-yourself ruby

## By Ronald M. Benrey

T MAY sound like science fiction but it's really science fact: You can build a working ruby laser. It could be the most challenging—and rewarding home-workshop project that you have ever tackled.

A ruby laser is a source of coherent light. All of the light waves in the pencil-thin, bright-red ruby laser beam are in phase—or in step—with each other. This extraordinary property of the laser beam—shared by no other light source—has spurred a world-wide search for practical uses.

Ordinary light sources—a light bulb, for example—generate incoherent light; the light waves are out of phase with each other.

Drop a pebble into a still pond, and the waves ripple out smoothly in all directions. This represents a single light wave from a light source. All light sources produce more than a single wave, however.



PS laser fires at the touch of a pushbutton (upper right on panel), but not unless you first arm the trigger circuit by turning the key-locked safety switch to "on." Variable-voltage transformer (upper left) and 0-1,500-volt DC panel meter let you set precisely the energy-storage capacitor—bank voltage. Neon lights warn that the power is "on," the capacitors are charged, and the trigger circuit is ready to fire.

# **CAUTION!**

Never look into a laser beam. The lens in your eye will focus it to a pinpoint spot on your retina, causing severe retinal burns and permanent eye damage. Never aim at a shiny surface capable of reflecting the beam back at you or others,

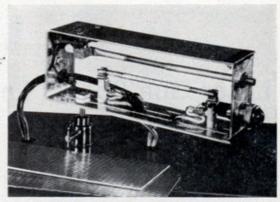
The high voltages in this project can kill! Each electrolytic capacitor can store enough energy, even when partially charged, to deliver a lethal shock. Don't cheat the safety interlocks. They turn off the power and rapidly discharge the capacitors if the laser head is opened.

They act as if you dropped a handful of pebbles at once: You get a jumbled clutter of waves one on top of another. This clutter of waves is analogous to incoherent light.

Suppose, though, you dropped your handful of pebbles one pebble at a time, each in exactly the same spot in the pond. The waves would continuously radiate from that point. All of the wave crests would be in phase. This is coherent radiation.

A ruby laser generates a coherent light beam by a similar process. Laser is an acronym for Light Amplification by Stimulated Emission of Radiation. Inside the ruby laser rod—heart of the ruby laser—excited atoms are stimulated to emit light waves in phase with each other.

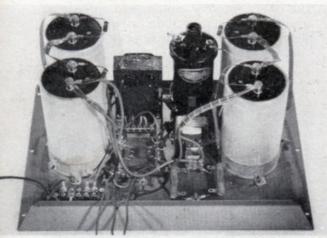
A coherent beam can be focused to a needle-sharp spot with a simple lens system, concentrating the beam's energy into a tiny area. Focused laser beams have seared holes in wooden blocks; burned holes in diamonds; performed delicate eye surgery by "welding" damaged retinas.



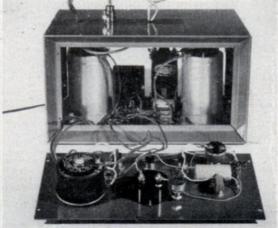
Single-flashtube laser head has a two-inch-long ruby rod in a brass-tube holder. Microswitch interlocks inside top of case shut off power, discharge capacitors if sides are removed.

The PS laser won't duplicate the feats of strength of large, powerful professional models—but then, it costs only 1/50 as much. You can assemble the PS laser for a total cost of under \$175.

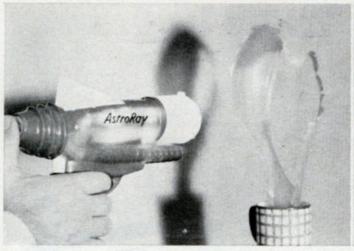
What can it do? We've left that up to

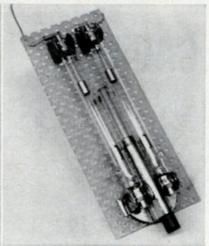


Energy-storage capacitors tower over powersupply components. Wide-open layout is good high-voltage wiring practice. Automotive spark coil (center rear) serves as flash-trigger coil.



Trigger circuitry (except coil) mounts on back of control panel. The fully enclosed steel case keeps fingers away from high voltage and makes a solid base for mounting heavy parts.





# Laser Gun Sparks Lectures

By K. H. Sherwin

Department of Physics, Stanford University

Our balloon-busting laser "ray gun" keeps physics lectures popping. A lens in the muzzle focuses the beam; it will burst blue

balloons (but not red ones, which won't absorb red light).

Chassis (right) holds two flashtubes and ruby rod. Not shown are 200-watt-second power supply and degreased foil reflector that wraps around flashtubes and ruby.

.........

you. The PS laser is an open-end project: There is room for you to experiment, modify the basic design, and add your own ideas.

While developing the PS laser, we consulted Prof. Arthur Schawlow of Stanford University, coinventor (with Dr. C. H. Townes) of the maser-a microwave amplifier that led directly to the laser's discovery.

Inside the PS laser there is:

 A cigarette-size ruby laser rod cut from a single crystal of man-made ruby. Both end faces are ground parallel to each other and polished optically flat. One end face is coated with a totally reflecting mirror surface; the other with a partially transparent mirror surface. The best mirror surfaces are the multiple-layer dielectric type made by vacuum-depositing a sequence of thin layers of transparent material on the end faces. Constructive interference of light waves inside the layers makes the mirror reflect red light, but pass other color light. The layers are very expensive to apply, and amateur-quality ruby rods are usually supplied with silvered mirror surfaces. (See Dr.

[Continued on page 228]

#### PARTS LIST

R1, R2, R3, R4-100-ohm, 10-w. wire-wound re-sistor R5, R6, R7, R8-100,000-ohm 1-w. carbon resistor R9, R10, R13, R14-220,-000-ohm, ½-w. carbon resistor

resistor R11-680,000-ohm, 1/2-w. carbon resistor R12-1,000,000-ohm, lin-

ear taper potentiometer
R15, R16-330,000-ohm,
½-w. carbon resistor
C1, C2, C3, C4-3,000mfd., 250-totl electrolytic capacitor (Mallory
CG33T250G1)

C5-1-mfd., 400-v. paper capacitor D1, D2, D3, D4-1N2071 or equivalent silicon rec-tifier (Texas Inst., G.E.) T1-Filament transformer, 6.3-v. AC secondary (Stancor P-6465)

T2-Power transformer, 650-v. AC secondary (Stancor PC-8407)

T3-12-v. automotive igni-tion coil T4-variable autotrans-

former (Superior type 10-B Powerstat) RL1-DPDT relay, 6-v. AC coil (Potter & Brumfield KA11AY) S1-SPST toggle switch

S2, S3-SPST microswitch S4-SPST key-operated lock switch S5-SPST snap-action

54-5FSI Rey-operatea lock switch

55-SPST snap-action pushbutton switch M1-O-1 milliampere milliammeter calibrated with O-1,500-w. scale.

PL1, PL2, PL3, PL4-Neon pilot-light assembly with built-in resistor Cabinet-Bud SB-2140 "shadow cabinet" Laser head is built into Vector type 28-X aluminum sliding side case Flashtubes-E.G.G. FX-38A xenon flashtube (for single lamp head) available from Schweber from Schweber

Electronics, Westbury, N.Y.

PEK XE1-2 xenon flashtube (for dual lamphead) PEK Labs Inc., 825 E. Evelyn Avenue, Sunnyvale, Calif.

Laser rods—ruby rods are available from Linde, Co., Crystal Prod. Div., 4120 Kennedy Ave., E. Chicago, Ind. (prices range from \$30-100, depending on size)

CaWO4 rods are available from Isomet Corp., Palisades Park, N.J. (\$100 for 1"-by-4"-dia. rod), and Perkin-Elmer Co., Norwalk, Conn.

Norwalk, Conn.

# How the Ruby Laser Works

### By Prof. Arthur Schawlow

Department of Physics, Stanford University

A ruby is an aluminum oxide crystal in which a few aluminum atoms have been replaced by chromium (Cr) atoms. If a chunk of ruby (not a laser rod) is bombbarded by a bright flash, it responds with a

diffuse incoherent red glow.

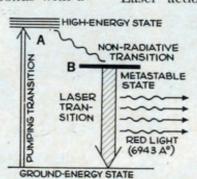
Here's why:

Many chromium atoms absorb a photon—bundle of energy—of green light. These atoms are pumped to a high energy level (A on diagram). They quickly fall to a metastable (partly stable) energy level (B), where they remain for a relatively long time: a few thousandths of a second, before they decay spontaneously and randomly back to ground state. Each atom emits a photon of red light

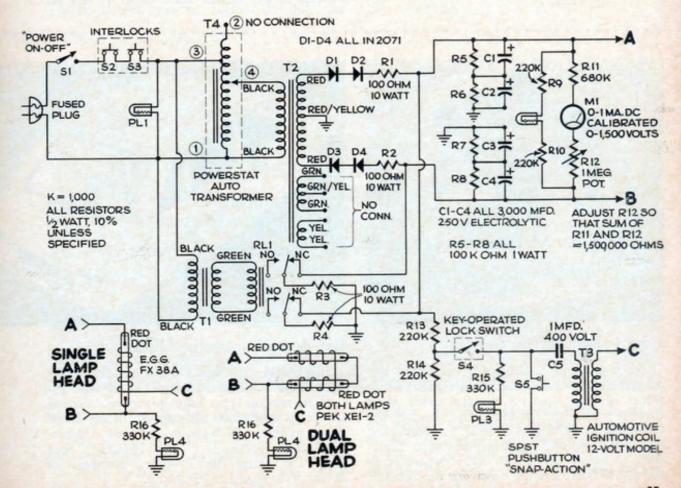
(wavelength, 6943 Angstroms) as it decays. You convert an incoherent glow into a coherent beam by synchronizing the excited Cr atoms so they emit photons in phase. The secret is stimulated emission: An excited Cr atom will emit its photon if

it "sees" a similar photon pass by.

Laser action can occur in a ruby rod equipped with parallel mir-rored end faces (see text) if well over half of the Cr atoms in the rod have been pumped into the metastable state. It begins when an excited Cr atom decays spontaneously, and emits its photon parallel to the ruby rod's axis. As the photon is reflected back and forth, it stimulates the emission of light waves in phase with itself. In a split second it stimulates an avalanche of in-phase light waves: a coherent light beam.



Photoflash pumps chromium atoms to energy level A. Cr atoms loose energy to crystal and fall to B.



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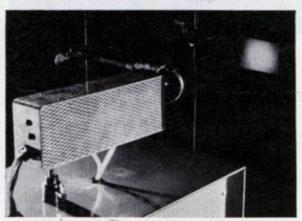
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Schawlow's explanation of the ruby laser on another page.)

 A powerful electronic photoflash unit, similar in light output to a studio-size photographic speedlight. Its circuit contains: a high-voltage power supply; a bank of four high-quality computer-grade electrolytic energy-storage capacitors; a trigger circuit; and one (or two) xenon flashtube(s) (straight-line flashtubes, not the familiar curlicue-shaped tube).

The flashtubes are wired across the capacitor bank, which is charged to 1,000 volts DC by the power supply. Pressing the



Invisible infrared beam from CaWO, laser rod excites a bright visible orange glow on a Kodak I-R phosphor screen. Before use, the phosphors are "charged" by holding the screen close to a fluorescent light for a few moments. The I-R beam striking the charged phosphors makes them fluoresce visible light. A two-by-three-inch screen costs \$25, never wears out. Coherent light reflected off the screen could cause eye injury. Kodak recommends that you view the screen through a piece of 7mm-thick heat-absorbing glass (Pittsburgh type 2043).

"fire" pushbutton trips the trigger circuitthe trigger coil generates a very-high-voltage spark that ionizes the xenon gas inside the flashtubes, changing it from an insulator to a conductor. The capacitor bank discharges through the flashtubes, producing a burst of white light. The capacitor bank stores 373 watt-seconds of electrical energy when fully charged. By comparison, average amateur flash units are rated at about 50 W-S.

The ruby rod and flashtubes are mounted side by side in the laser head, and wrapped with a piece of aluminum foil that has been degreased by cleaning it with acetone. Degreased foil is a must since the ultra-

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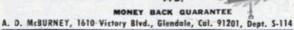
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#### PS Builds a Laser . . . and So Can You

violet light output of a flashtube quickly blackens grease spots. This simple foil reflector concentrates most of the flashtube's light output and directs it into the ruby.

When the flash unit fires, the intense blast of white incoherent light directed at the ruby rod pumps energy into it. If the ruby absorbs more than a critical-threshold quantity of energy, it lases: The ruby spits out a short burst of coherent red light, lasting 1/1,000 second, through its partially transparent mirrored end face.

A ruby's threshold value is measured in terms of the minimum pumping poweror electrical-energy input to the flashtubesthat will make it lase. Ruby quality, size, and type of end-face mirrors all affect the threshold.

In addition to ruby, several other crystal materials that will lase coherent light have been found. Most are still in the experimental stage or are too expensive for amateur use. One material that can be used instead of ruby in the PS laser is calcium tungstate (CaWO<sub>4</sub>) doped with neodymium. These rods lase an invisible infrared beam.

CaWO4 has a much lower threshold value than ruby, but it's less efficient.

Ruby and CaWO4 laser rods can be ordered in a wide range of sizes and qualities (see parts list). To allow you the widest choice, we have designed two laser-head circuits that can be used interchangeably:

- 1) A single flashlamp circuit, simple and inexpensive. Use it to lase thin ruby rods (about % inch) that are over two-inches long, and any CaWO4 rod. Its single flashtube has a three-inch-long arc length, so that it is most efficient when pumping laser rods between two and three inches long.
- 2) A double flashtube circuit that is slightly more expensive, but is also more efficient. Its two flashtubes each have twoinch-long arcs, so that it's most efficient when pumping shorter laser rods. Use it to lase the popular-size two-inch-long by %inch-diameter ruby rod.

Building it. An experienced electronics hobbyist could duplicate the PS laser by working from the circuit diagram and photos in this article. For readers who plan to build it and want more information, we have prepared a supplementary data sheet. If you would like a free copy, send a stamped, self-addressed legal-size (9½-by-4inch) envelope to: Laser, POPULAR SCIENCE, 355 Lexington Ave., NYC 10017.