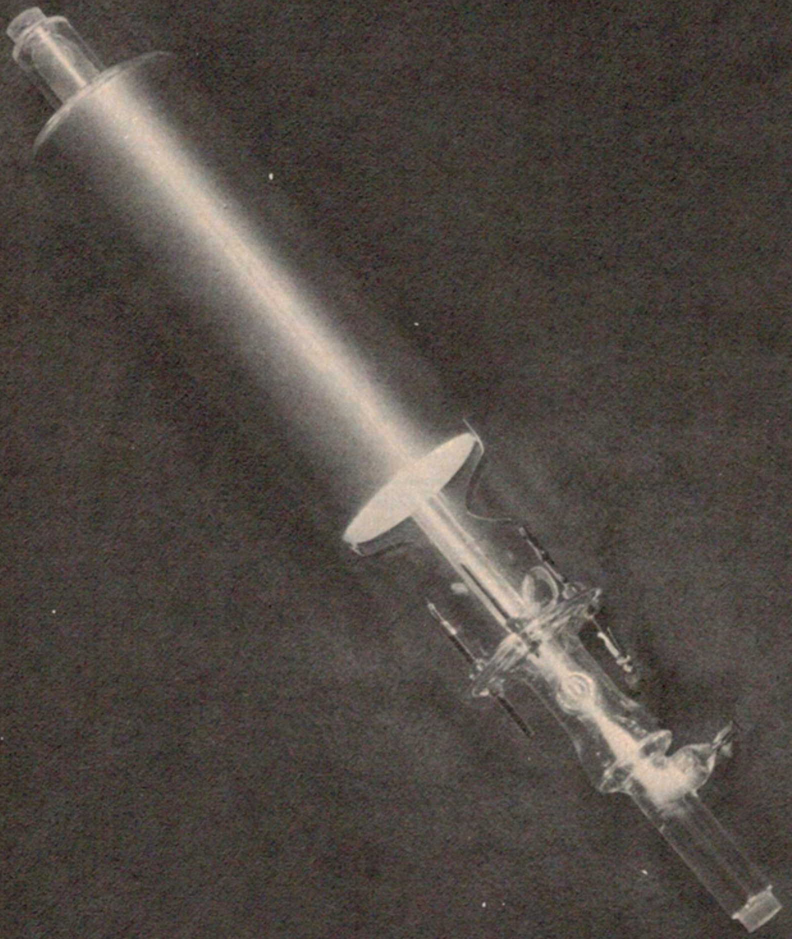


An introduction to lasers

David Tilbrook

A fascinating rundown on these devices, the physics of their operation and the various types. This article prefaces a practical construction project which follows immediately.

THE FIRST LASER was built in 1960 by Theodore Maiman, a research scientist working for the Hughes Aircraft Corporation. His research paved the way for the development of a fantastic array of fascinating devices and very useful tools. Today, lasers are used in surveying, geophysical measurements, medical applications, electronic component manufacture, atomic fusion research, precise distance measurement and a host of other applications.

The word laser stands for *light amplification through stimulated emission of radiation*. Whilst this implies that lasers are amplifiers, they are generally configured as oscillators. The light radiation they produce is very 'pure' — occurring at a specific frequency (or frequencies) — and the beam is well collimated, that is, it diverges only a tiny amount rather than spreading as does the beam from a torch or spotlight.

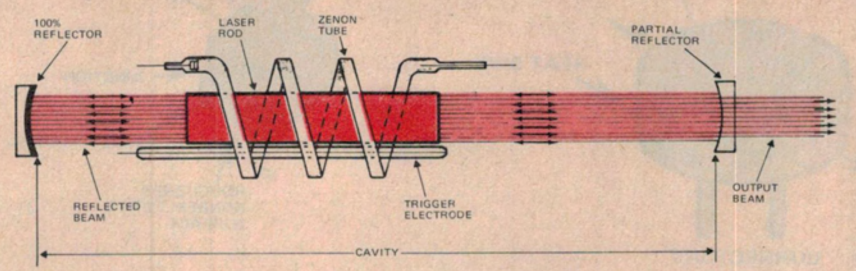
The unique properties of laser light make the laser a prime candidate for wide application in technology and physical measurement. Many different types of laser have been developed but all employ the same basic principle of operation. All lasers have two fundamental components — a 'laser medium' and an energy source. The latter is used to excite the laser medium by a process called *pumping* — but I'll explain that further when I get into the physics behind the laser. First, let's look at the various 'breeds'.

Solid-state lasers

In laser physics, solid-state does not refer to semiconductor lasers but to a breed having a laser medium that is formed by doping a crystalline or glass material with an impurity material which produces the laser action when pumped. The most common of these is the **ruby laser**.

This type of laser consists of a central, cylindrical synthetic ruby crystal made from aluminium oxide as a base material and doped with chromium as the impurity. The crystal is mounted with mirrors at each end and is surrounded by a xenon-filled flash tube (or tubes). These xenon tubes provide optical pumping — a requirement of all solid-state lasers. One of the mirrors is 100% reflective while the other is very slightly transmissive so that a small portion of the laser light produced within the crystal is tapped off.

When the xenon flash tube is fired, laser action occurs within the ruby and laser light travels back and forth down the crystal, exciting further laser action and generating an intense pulse of light that passes through the slightly transmissive mirror.



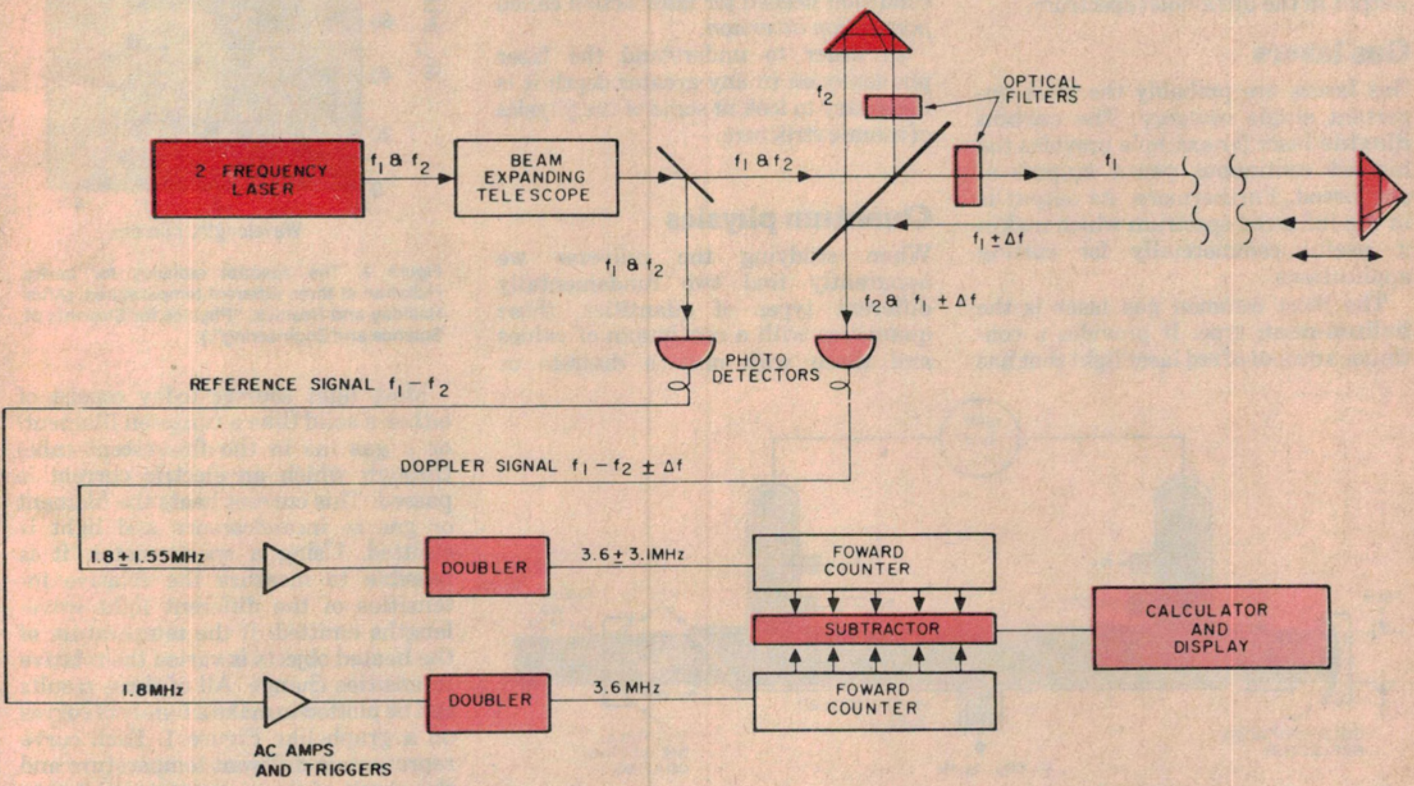
In the ruby laser, as first developed by Theodore Maiman, "pump" light from a xenon flash tube raises the energy level of chromium atoms in a ruby rod until a pulse of coherent red light emerges from the partial reflector (at right).

One of the early problems with solid-state lasers was to achieve a continuous output. In 1962 a solid-state laser was built at Bell Telephone Laboratories. It consisted of the base material calcium tungstate, impregnated with neodymium. More recently, solid-state lasers have been built with continuous outputs of over 1000 watts.

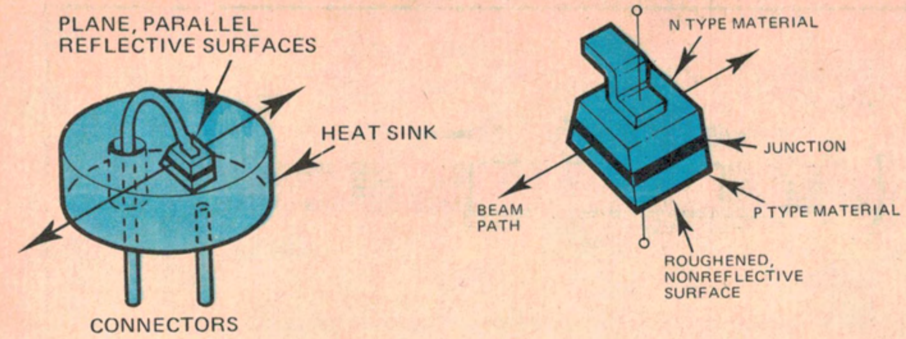
Much experimenting has been done to optimise the method of pumping solid-state lasers. One means developed by RCA in 1962 used a 300 mm hemispherical mirror to focus sunlight onto a laser crystal of calcium fluoride immersed in liquid helium. This laser produced a continuous output of 50 W, and was the first laser to use sunlight to power the device directly.

Semiconductor lasers

Semiconductor lasers are relatives of the common light emitting diode, or LED. The most common of these is the **gallium arsenide laser**, and consists of a semiconductor diode junction formed by gallium arsenide doped with two different impurities to form the p and n materials. When forward bias is applied, a large number of electrons and holes move towards the junction where they recombine and generate laser light. ▶



An important application of helium-neon lasers is in distance and velocity measurements using interferometric techniques. This block diagram shows a system devised by Hewlett-Packard for an instrument which has the ability to measure length to an accuracy of 1 part in 10^6 over a distance of 60 metres (that's 1 mm in 1 km !).



The semiconductor laser comprises a gallium arsenide junction doped with two different impurities. Construction of the junction is illustrated on the right, this is mounted on a heatsink header in the practical device, as shown at left.

Typical power outputs of gallium arsenide lasers are low, around one watt maximum, but efficiency is very high. Furthermore, they are easily modulated and for this reason should be of great importance in optical communications in the future.

Liquid lasers

Most liquid lasers use an organic dye as the laser medium and are optically pumped. Their big advantage over other types lies in the fact that the frequency of light generated can be varied. For this reason they are called **tunable lasers** and are being used experimentally to 'steer' chemical reactions.

Often the optical pumping of liquid dye lasers is done by other lasers, such as the nitrogen gas laser which has an output in the ultraviolet spectrum.

Gas lasers

Gas lasers are probably the most important single category. The **carbon dioxide** laser for example provides the highest continuous power outputs of any breed. Furthermore, its output is in the infra-red spectrum which makes it useful commercially for cutting applications.

The most common gas laser is the **helium-neon** type. It provides a continuous output of red laser light that has been used commercially in distance measuring equipment as well as a general purpose "straight line". It is also used extensively in laboratories for diffraction, for general optical experiments and in interferometers. It has evolved into an inexpensive and reliable device and it was for this reason that we chose a HeNe laser tube for the project following this feature.

The HeNe laser consists of a mixture of the gases helium and neon, placed in a sealed tube at low pressure. Originally, HeNe lasers were excited by high frequency ac current (around 28 MHz) but these days high voltage dc is used. As in most other lasers, mirrors are used at each end of the tube, so that most of the light produced is trapped within the laser itself, maintaining a special condition needed for laser action called *population inversion*.

In order to understand the laser phenomenon in any greater depth it is necessary to look at some of the physics of atomic structure.

Quantum physics

When studying the universe we apparently find two fundamentally different types of quantities, those quantities with a continuum of values and those with only a discrete or 'quantised' number of values. For instance, the speed of an object can range from zero up to the speed of light and seems to consist of an infinite number of possibilities. Similarly, the set of all numbers is infinite. These are examples of continuous quantities, but not all quantities are continuous. A dice can only show 1, 2, 3, 4, 5 or 6 on its upper face and this is a quantised quantity.

Similarly, standing waves on a violin string, resonances of a quartz crystal, or harmonics of a square wave are all quantised — they occur only at fixed frequencies.

Quantum physics is based on the discovery that a large number of quantities involved with molecular, atomic and sub-atomic physics are quantised. Many of these quantities were assumed to be continuous in "classical physics" and it has only been through the recognition of their quantised nature that modern physics has been able to achieve a reasonably workable model of atomic structure.

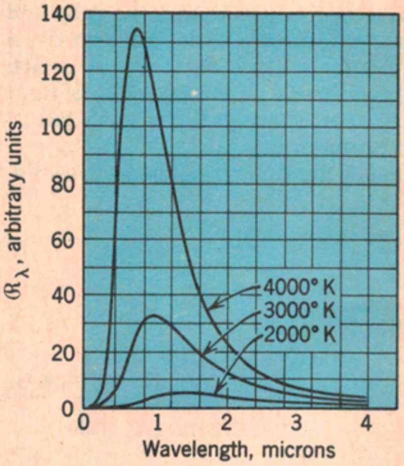
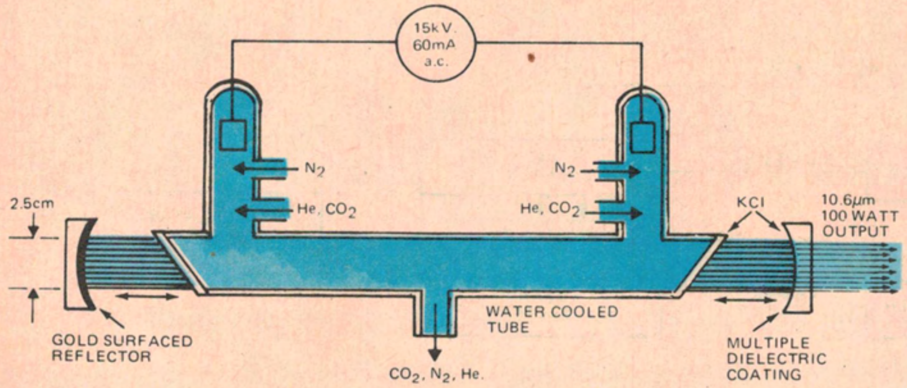


Figure 1. **The spectral radiancy for cavity radiation at three different temperatures. (After Halliday and Resnick, "Physics for Students of Science and Engineering".)**

Most light sources today consist of either a solid (like a tungsten filament) or a gas (as in the fluorescent tube) through which an electric current is passed. This current heats the filament or gas to incandescence and light is emitted. Using a spectrometer, it is possible to measure the relative intensities of the different light wavelengths emitted. If the temperature of the heated objects is varied the relative intensities change. All of these results can be plotted to make a family of curves on a graph like Figure 1. Each curve represents a different temperature and the shape of these curves is related to the particular material that is being heated.



Some gas lasers can generate enormous output powers. This diagram illustrates the general construction of a carbon dioxide laser.

The number of variables in the case of a heated solid makes any mathematical analysis unnecessarily complicated so scientists sought an idealised heated solid. They called this a *cavity radiator*, and the light emitted proved to be largely independent of the material used to make the cavity radiator. Furthermore, the light emitted was found to vary in a fairly simple way as the temperature was varied.

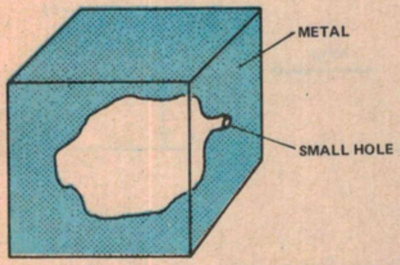


Figure 2. **Representation of a cavity radiator. At a particular temperature, light emitted from the hole is brighter than that radiated by the body of the material.**

Practical cavity radiators simply consist of a hollow container with a small hole drilled in one side (see Figure 2). If the cavity radiator is heated, more light is emitted from the hole than from the outside walls. The light emitted from the hole is called *cavity radiation* (sometimes called *black body radiation*) and was of intense interest in the later part of the nineteenth century.

The explanation of the related intensities of the various wavelengths emitted in cavity radiation was one of the outstanding problems for classical physics. Several attempts had been made but all of these had only fitted the experimental data partially.

In 1900, a German physicist, Max Planck, derived a formula that fitted cavity radiation perfectly. He was forced to the conclusion that the atoms inside the cavity radiator were acting like tiny electro-magnetic oscillators. They could emit light into the cavity and absorb light energy from it, but only at certain characteristic frequencies.

Planck was forced to make the radical assumption that an oscillator cannot have a continuum of different energies These energies were quantised so that the only possible values were given by the equation.

$E = nh\upsilon$

where 'E' is the energy
'n' is an integral number, i.e: 1, 2, 3, 4, 5, etc.
'h' is a constant (now called Planck's constant)
and 'υ' is the frequency of the oscillator.

The oscillators could not radiate light continuously but only in jumps, or 'quanta', and only when the atom jumped from a high energy state to a lower one. If the atom jumped just one energy state then 'n' in the above equation becomes equal to one, and the equation becomes:

$E = h\upsilon$

This is known as *Planck's equation* and is one of the more important equations in modern physics.

This was the start of quantum physics. A physical event could only be explained by assuming that atoms radiate integral amounts of energy.

Planck's ideas were reinforced several years later by Albert Einstein who applied the concepts of quantisation to another area of physics that was to revolutionise our understanding of the nature of light. Up to this time, light was thought of as an electromagnetic wave. Even though Planck had quantised the energies of atomic oscillators in the cavity walls, he still regarded the radiation within the cavity as a wave. This wave picture of light had been enormously successful in explaining light phenomena up to that time, but Einstein was to point out its inadequacy in some circumstances.

The Photo-electric Effect

This effect was another experiment which had not been satisfactorily explained in terms of classical physics. Figure 3 shows a circuit diagram for the apparatus used in the photo-electric experiment. If light is shone onto a clean metal surface some electrons are liberated from the metal. If the metal is placed in an evacuated glass cylinder, the liberated electrons (called *photo-electrons*) can be made to constitute a current flow, which will register on the meter. If the other electrode is now made negative with respect to the first, by connecting the two to a power supply, the negative electrode will tend to repel the photo-electrons and decrease current flow. When the voltage is great enough, the photo-electrons can be brought to a stop. If the voltage is increased even further the photo-electrons are turned back toward the anode. The voltage applied to the plates is called the retarding potential and can be used to measure the energy of the photo-electrons.

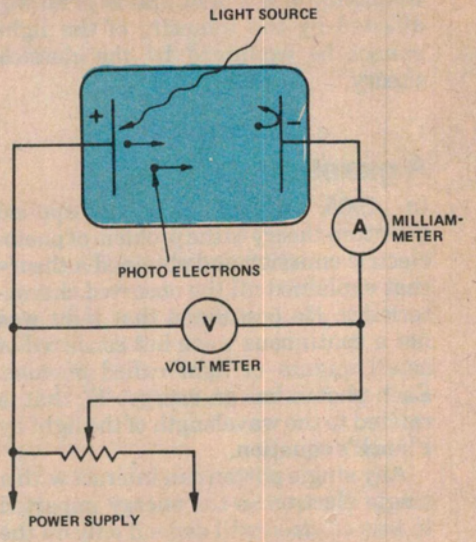
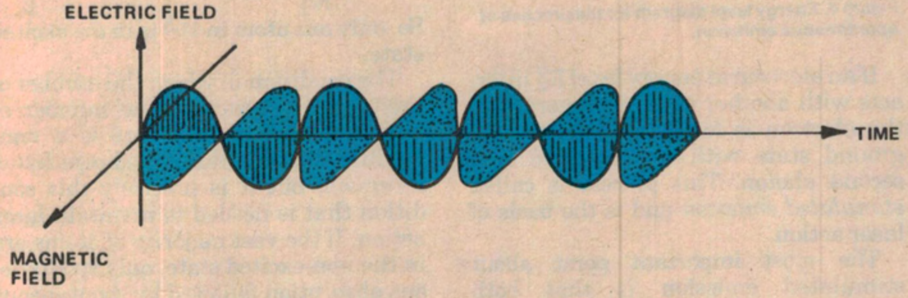


Figure 3. **Circuit diagram of the apparatus used in the photo-electric experiment.**

When the experiment is carried out it is found that photo-electrons are emitted almost instantaneously when the light is turned on. If the wavelength of the incident light and the retarding potential are kept constant, then the current flowing is found to be proportional to the intensity of the light beam. Furthermore, for any particular metal the energy of the photo-electrons is found to be independent of light intensity, but varies with the frequency of the light.

These results were difficult, if not impossible, to explain on the basis of the wave theory of light. Since light was thought of as a continuous wave, the energy absorbed on the photo-electric surface should have been proportional to the light intensity. If the intensity was decreased enough it should have taken a certain amount of time for sufficient energy to be absorbed by the electrons before any emission could start. So the wave theory of light could not explain why photo-electric emission starts instantaneously, even if the intensity of light is decreased.

Similarly, the fact that the energy of the photo-electrons varies with the ▶



According to the electromagnetic wave theory, light is seen as a continuous wave of oscillating electric and magnetic fields.

frequency of the light and is in no way affected by the intensity of the light, cannot be explained by the classical theory.

A quantum approach

In 1905, Albert Einstein applied quantum theory to the problem of photo-electric emission and obtained a theory that explained all the observed characteristics. He postulated that light was not a continuous wave but consisted of small quanta of light called *photons*. Each photon has an energy, 'E', that is related to the wavelength of the light by Planck's equation.

Any single photon can interact with a single electron so the energy imparted to this electron will depend only on the energy of the photon. i.e: its frequency. Increasing the intensity of the light beam increases the number of photons and will only increase the number of photo-electrons emitted. Emission will start instantaneously, as all the energy needed for a photo-electron to escape the surface of the metal is contained in any single photon.

The photo-electric effect occurs because the energy imparted to the photo-electron by the photon has exceeded that needed by the electron to break bonds that normally bind it to the metal surface; but it is not the only example of electron-photon interactions. In the photo-electronic effect the electron struck is a bound electron, inside an atom. The photon disappears and the electron is dislodged. However if the electron is a free electron it will recoil and cause the generation of a second photon of lower energy. This is called *the Compton effect*.

Another set of electron-photon interactions are called *pair production* and *pair annihilation*. If a photon is given enough energy it can convert into an electron and a *positron* when passing another heavy particle. A positron is an antimatter electron. It has all the properties of a normal electron except that it has a positive instead of a negative charge. This process is called pair production. Pair annihilation occurs when a positron and an electron interact. Both are annihilated and two photons are generated.

All these electron-photon interactions are manifestations of a single process, the exchange of photons, called *virtual photons*, between charged particles. Indeed, it is this effect that gives rise to the attractive and repulsive forces between charged objects. The study of photo-electron interactions is called quantum electrodynamics and is one of the major fields of research in modern physics.

Spontaneous and stimulated emission

When a photon interacts with a bound electron it may not have sufficient energy to overcome the binding forces. In this case the photon is absorbed by the electron, as would happen in the photo-electric effect, but the electron is not liberated from the atom. Instead, it jumps up to a higher energy level or orbit. Quantum physics has determined that electrons cannot have a continuum of different energy levels, only energy levels that are integral multiples of a fixed amount. When the electrons of an atom are in their minimum energy states the atom is said to be in its ground state. If an atom is in its ground state, say with energy E_1, it can be forced to a higher energy level, say E_2, by absorption of a photon. If the photons absorbed have energy $E = h\upsilon$ then the increase in electron energy will be exactly $h\upsilon$, i.e: $E_2 - E_1 = h\upsilon$.

After a certain amount of time, approximately 10^{-8} seconds, the electron will drop back down to its lower energy level, automatically emitting a photon, again with energy $h\upsilon$.

The excited atom was initially at rest and has no preferred direction in space. As a result the photon can be radiated in any direction while the atom recoils in the opposite direction. This process is called *spontaneous emission*. If a group of atoms are excited in this way they will generate photons in all directions randomly, as excited atoms return to their ground states; see Figure 4.

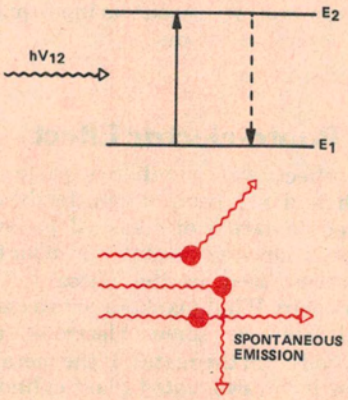


Figure 4. **Energy level diagram for the process of spontaneous emission.**

If an electron at energy level E_2 interacts with another photon of energy $h\upsilon$, the electron is forced to return to its ground state with the emission of a second photon. This process is called *stimulated emission* and is the basis of laser action.

The most important point about stimulated emission is that both photons leave the atom with the same phase and direction as the incoming photon, see Figure 5. The two photons are said to be coherent. It is essential that the two photons be coherent. If they were even slightly out of phase cancellation would occur between them, violating the law of conservation of energy. If a group of atoms is excited in this way the initial beam of photons will be augmented by additional photons, so the beam is amplified.

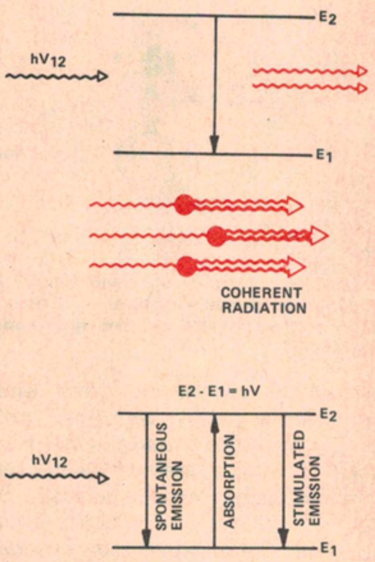


Figure 5. **Energy level diagram for the process of stimulated emission.**

Population inversion

If a material is in thermal equilibrium at a temperature T, the distribution of atoms in a lower energy state to those in a higher energy state is normally accented heavily toward the lower energy state. If N_1 is the density of atoms in the lower state and N_2 the density of atoms in the more excited state, then the ratio of N_2 to N_1 is given by the equation

$$\frac{N_2}{N_1} = \exp(-h\upsilon/kT)$$

where 'T' is the temperature of the material in Kelvin

and 'k' is Boltzmann's constant.

If the material is at 10^3K, then:

$$\frac{N_2}{N_1} = 10^{-5} \quad !$$

So, only one atom in 10^5 is in the excited state.

The condition in which the number of excited atoms exceeds the number of atoms at the ground state is a non-equilibrium condition called *population inversion*, but it is precisely this condition that is needed to maintain laser action. If the vast majority of atoms are in the non-excited state, only spontaneous absorption followed by spontaneous emission, can occur. If, on the other hand, a population inversion can be

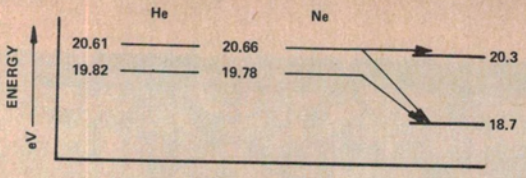


Figure 6. **Energy level diagram for the helium-neon laser.**

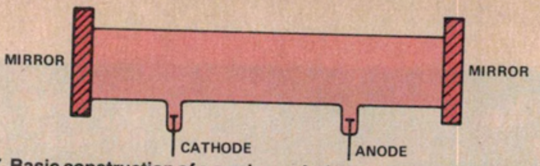


Figure 7. **Basic construction of a gas laser. A glass cylinder, containing a gas at a low pressure, has two mirrors placed at either end — one is totally reflective, the other slightly transmissive. When current is passed through the gas, population inversions of the atoms occur and laser action results.**

maintained then stimulated emission will occur leading to photon multiplication. *Pumping* is simply the process used to maintain the population inversion.

A closer look at the HeNe laser

In the helium-neon laser, population inversion is maintained by generating a glow discharge in a low pressure mixture of helium and neon gases. Figure 6 is a simplified energy diagram for a HeNe laser.

The helium energy levels at 20.61 and 19.82 electron volts (eV) are called *metastable levels*. Once at a metastable energy level an atom cannot move to a lower state by the emission of a photon. It can only be de-excited by some other process. A transition from a metastable level to a lower level is called a *forbidden transition* and the fact that these transitions are not permitted is predicted by quantum theory. So, once an atom has been excited to one of these energy levels it will stay at that energy level for a relatively long period of time, approximately 10^{-3} seconds, hence large metastable populations can exist.

Two of the energy levels of neon closely coincide with those of the metastable levels of helium, these are at 20.66 and 19.78 eV. An energy transfer will occur between helium metastable atoms and neon ground state atoms, exciting neon atoms to the 20.66 and 19.78 eV energy levels. As a result, very large populations of excited neon atoms are produced. The population of neon atoms in these energy levels vastly exceeds that achievable from direct excitation by the electric discharge. Below these two highly populated energy levels there are two lower neon levels that are only populated by direct excitation and consequently have much smaller populations, and this is a population inversion.

Whenever an excited neon atom jumps to one of these lower energy levels a photon is emitted, and the frequency of the photon will depend on the difference in energy between the two levels. The three possible transitions are shown in Figure 6 and are:

20.66 eV to 20.3 eV
(3391 nm in the far infrared)
19.78 eV to 18.7 eV
(1152 nm in the infrared)
20.66 eV to 18.7 eV
(633 nm in the visible spectrum)

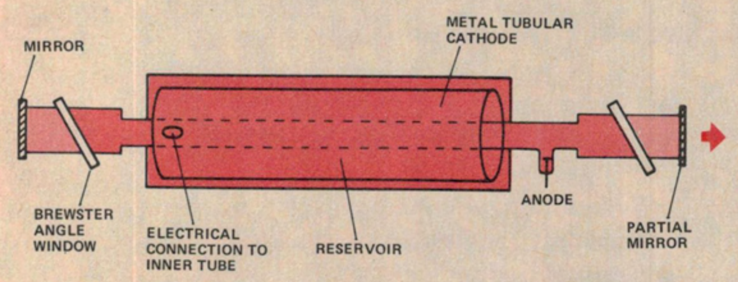
Figure 7 shows the basic elements of a helium neon laser. The tube contains roughly 90% helium and 10% neon gas at a pressure of one to three Torr.

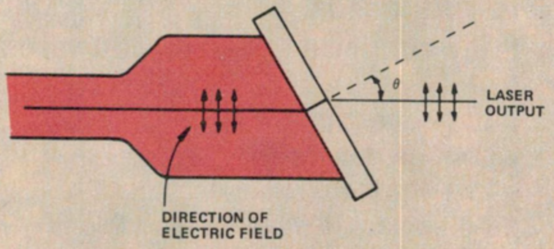
When a current is passed through the tube a variety of collision processes take place. Among these are the collisions that lead to population inversion. As neon and helium atoms jump between higher and lower energy levels, photons are emitted randomly in all directions. However, since there are large populations of neon atoms at the 20.66 and 19.78 eV energy levels, any photon with one of the above three wavelengths has a high probability of causing stimulated emission of a second, identical, photon. Those photons travelling parallel to the axis of tube are reflected back and forth between the two end mirrors, and each pass through the tube gives rise to further identical photons by the process of stimulated emission. A limit is finally reached when the rate of production of neon atoms at the higher energy levels equals the rate of stimulated emission.

If one of the mirrors is made a few percent transparent, (i.e: slightly transmissive) a portion of the coherent radiation can escape from the tube and this is the laser output. The word laser stands for *light amplification through stimulated emission of radiation,* but the helium neon laser is not really an amplifier, it's more of an oscillator generating coherent electromagnetic radiation at three distinct frequencies. ●

A practical HeNe laser tube

PRACTICAL He Ne GAS LASER TUBE



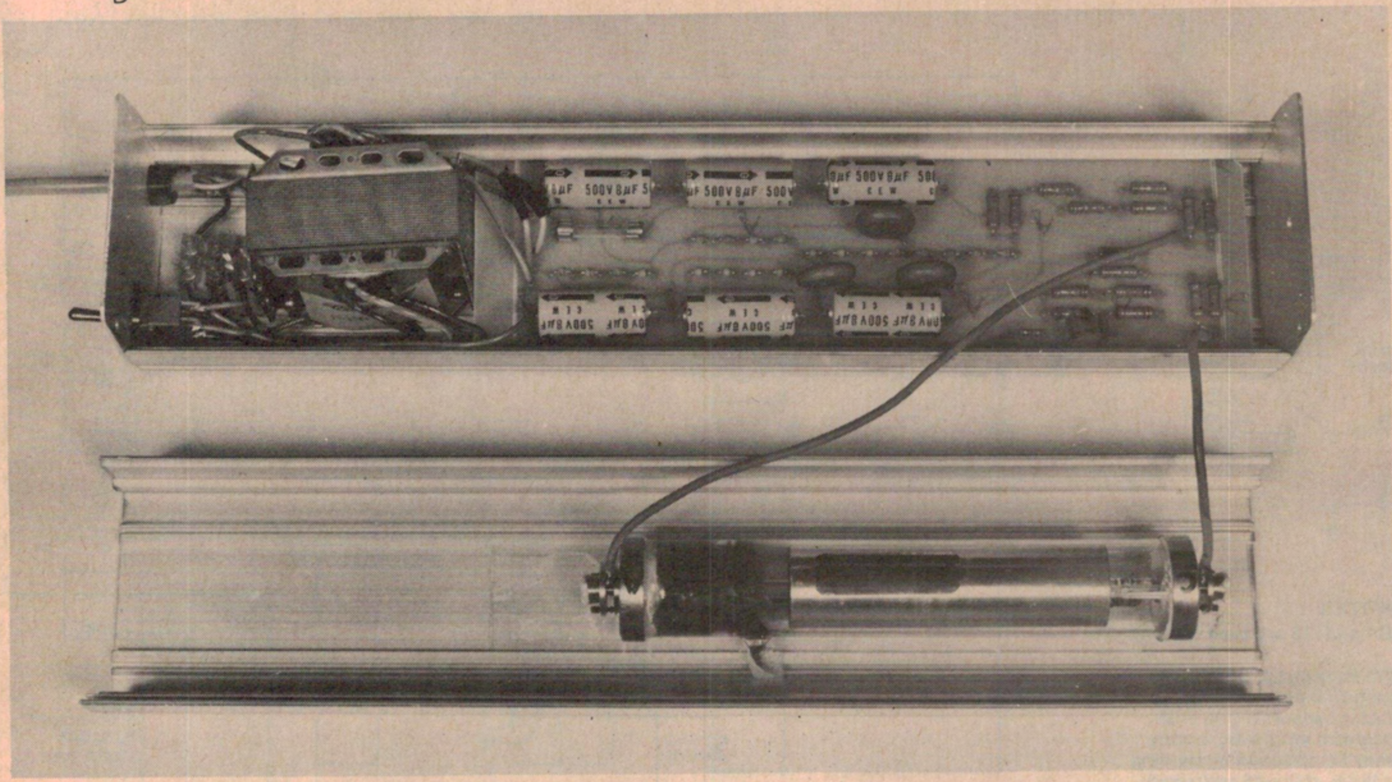


TRANSMISSION OF LIGHT THROUGH A BREWSTER ANGLE WINDOW.

A practical HeNe laser tube is shown in the diagram. It features a number of improvements over the basic system. The cathode consists of a large metal cylinder instead of a single wire electrode. This decreases the current density around the cathode and increases the rate of excitation of helium atoms to metastable states. Plane mirrors are very difficult to align accurately and a common system used to overcome this difficulty is the use of slightly concave mirrors, separated by their radius of curvature.

Another configuration employed, and the one used in the tube for the project, is referred to as a "hemispherical" configuration. This uses a totally reflective, flat-backed mirror and a concave front mirror with a radius of curvature of around 1.4 times the tube length. The mirrors used are designed specifically for laser use and constitute a significant portion of the cost of the device. The mirrors are used as bandpass filters to optimise the particular output required. The tube specified for the project uses a system like this to enhance tube operation at the 633 nm emission wavelength and to suppress operation at the other two dominant wavelengths. The front mirror is approximately 0.9% transmissive at 633 nm but considerably less transmissive at the two longer wavelengths. The rear mirror is almost totally reflective at 633 nm, but more transmissive at longer wavelengths. HeNe tubes often employ a "Brewster angle polarizing filter". This is a glass disc placed in the light beam at an angle determined by its refractive index. Light of the correct polarization is transmitted through the filter. All other polarizations suffer high reflections and are attenuated. This does not cause any loss in the light output of the laser since any one polarization will be amplified by stimulated emission to produce a full output intensity coherent laser beam with a single polarization.

Project 565



Build a helium-neon laser

David Tilbrook

This project has been designed around an Australian designed and manufactured laser tube having a 1 mW output at a wavelength of 633 nm in the red section of the visible spectrum.

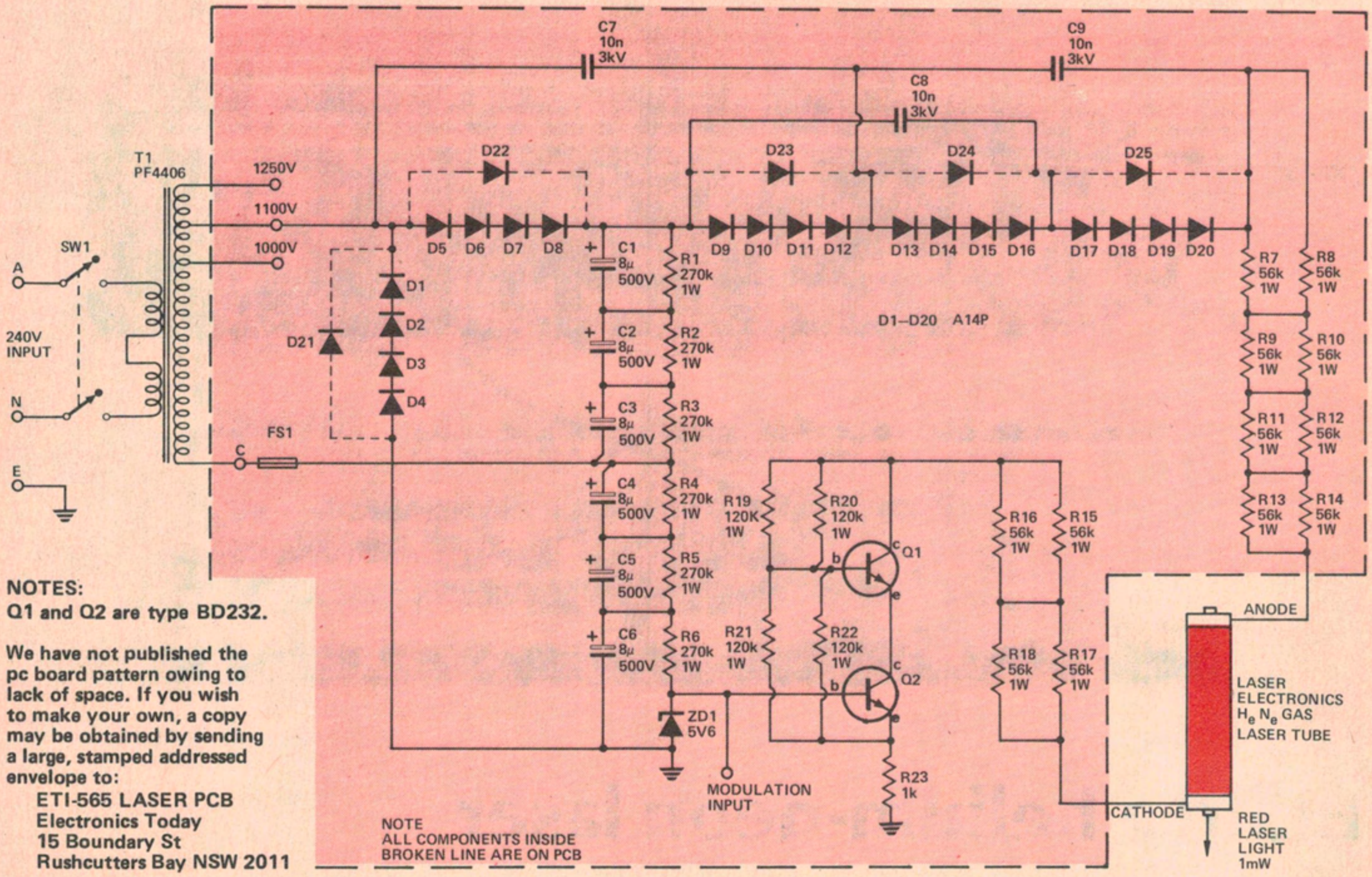
THIS PROJECT, rather than serving just as a laser "demonstration" unit, has been designed with a view to using it as the primary component of a number of devices and experiments which we shall be describing in later issues of the magazine.

When we first considered doing a laser as a construction project we approached a Queensland company, Laser Electronics, for details about laser tubes presently available in Australia. Fortunately, at that time they had just embarked on the design of a helium-neon laser tube which they planned to manufacture here. They have subsequently achieved their aim and we decided to use their laser tube in our project. Laser Electronics has been of great assistance in supplying design ideas and information on lasers in general. The particular tube used in our unit (as pictured) is a prototype only and some slight physical variations could be expected in the final production model. The laser tube used on the front cover is an imported model supplied by Laser Electronics for our experimentation.

To assist constructors, Laser Electronics have made arrangements to supply complete kits for this project, including metalwork. Their address appears at the end of this article.

Design factors

There are a number of design challenges involved in getting a helium-neon laser to operate correctly. The circuitry is really all power supply ! — but it is called on to perform a number of tasks. Firstly, helium-neon laser tubes require a high voltage pulse of around 8 - 10 kV to start ionisation. Thus, the power supply must provide a 'kick start' for the tube. Secondly, the tube requires a certain voltage supply to maintain operation once 'fired' and the current through it must be maintained at a constant value, both depending on the characteristics of the particular tube design. However, all gas-discharge tubes (and the helium-neon laser falls into this category) exhibit a *negative resistance characteristic* during operation. That is, an *increase* in the voltage applied between the anode and cathode will result in a *decrease* in current through the tube. Under certain circumstances, this property will cause the tube and surrounding circuitry to become an oscillator — an undesirable mode of operation, to say the least! To avoid this, the negative resistance of the tube is "swamped" with a large value series resistance. The value of this ▶



NOTES:
Q1 and Q2 are type BD232.

We have not published the pc board pattern owing to lack of space. If you wish to make your own, a copy may be obtained by sending a large, stamped addressed envelope to:

ETI-565 LASER PCB
Electronics Today
15 Boundary St
Rushcutters Bay NSW 2011

swamping resistance is determined from the particular tube's characteristics and, for this reason, laser tubes are supplied with details of the required minimum series anode resistance and our circuit adheres to the requirements of the tube supplied by Laser Electronics.

We have designed the power supply for this tube to deliver a constant current of 5 mA, which marginally decreases the output intensity of the laser beam, but ensures maximum tube life. At this current, the tube will maintain a voltage of around 1550 volts between anode and cathode. *A word of warning* — don't attempt to measure the voltage directly across the tube as the inherent capacitance of most high voltage probes will cause the laser action to stop, the power supply circuit will immediately ramp the tube voltage up in an attempt to re-start the tube and you'll have a 'relaxation oscillator' instead of a laser!

Physical construction of high voltage power supplies presents some unique problems. An obvious one is providing sufficient clearance between individual components having a high potential difference and between components at high voltages and conducting bodies nearby — the chassis, or whatever. Components have to be chosen with care. Adequate voltage ratings have to be specified for diodes and capacitors, as well as allowing an adequate safety margin.

Resistors used in voltage divider strings etc need to be of a size and type such that their maximum working voltage is adequate for the job. Resistor construction needs to be considered

HOW IT WORKS — ETI 565

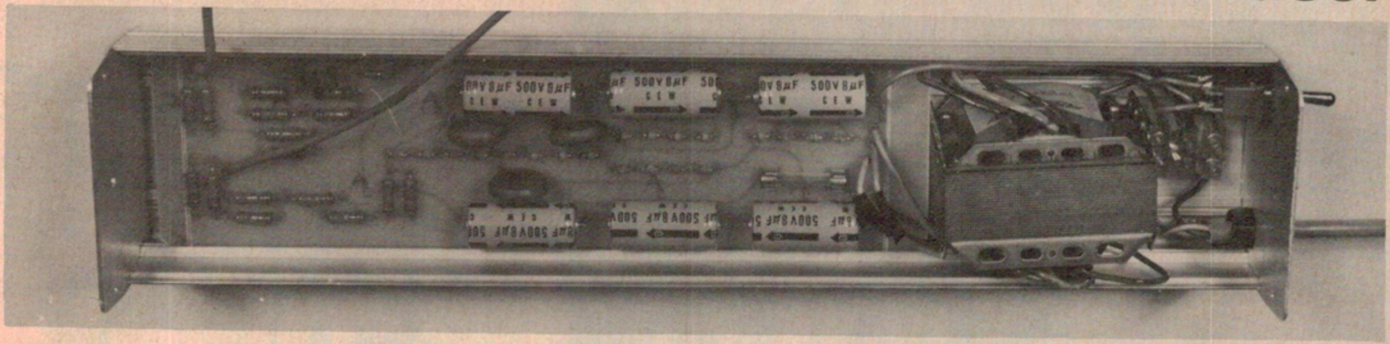
The circuit can be divided into five compartments: power transformer, voltage doubler rectifier, 'kick start' voltage multiplier, laser tube plus series resistance and constant current sink.

The power transformer has a secondary voltage of 1250 V, with taps at 1100 and 1000 volts. The 1100 volt tapping is used in this instance, the other two are provided to allow the power supply to operate different laser tubes (although we don't plan to do so).

The 1100 V transformer output drives a voltage doubler rectifier, involving diodes D1 to D8 and capacitors C1 to C6. The resistors across the latter capacitors serve as 'bleeders' to discharge the capacitors when the supply is turned off. They also serve to equalise the voltages across each capacitor. The output of the voltage doubler is around 2800 volts (cathode of D8). As two single diodes for this rectifier would be required to have a peak inverse voltage rating of at least 3 kV, we have used four diodes in series, each rated at 1 kV PIV. If suitable high voltage diodes can be found, you can substitute these as shown dotted on the circuit diagram.

The output of the voltage doubler drives the input of a three stage voltage multiplier involving diodes D9 to D20 and three 10n capacitors, C7, C8 and C9. This provides the kick start for the tube, delivering somewhat in excess of 8 kV, but at a very low current (the impedance of the 10n capacitors at 50 Hz is rather high). Very quickly after turn on, the voltage at the cathode of D20 will rise to around 8 kV and the laser tube will 'fire'. When it does, the current drawn will be too great for the impedance of the voltage multiplier starting circuit to supply and the tube will be driven directly by the voltage doubler via the D9 — D20 diode string. The tube swamping resistance is provided by the series-parallel string of 1 W resistors, R7 to R18. The voltage at the anode of the laser tube is about 2240 volts during normal operation.

The constant current sink is formed by Q1 and Q2, plus associated components. It serves to regulate the current through the laser to the required 5 mA. The base of Q2 is clamped at 5.6 volts by the zener diode. This results in a voltage at the emitter of Q2 of 5 V, setting the current through the 1k resistor, R23, at 5 mA. Although the voltage across the two transistors will vary, the collector currents, and thus the current through the laser tube, will remain fixed at 5 mA. The worst-case power dissipation in these transistors is approximately 1.5 watts.



Interior view of the electronics for the laser, mounted in the case bottom. This case will be supplied by Laser Electronics with their kit for this unit.

here, too. Carbon composition resistors typically have a maximum working voltage rating of 700 V for half-watt types, 1000 V for 1 W types. Carbon film resistors, on the other hand, are only rated at 350 V for half-watt and 500 V for 1 W types. The project's power supply has been designed such that the individual resistors in the voltage divider strings have no more than 200 V across them. Although carbon composition types have been specified — as they will be the most reliable in these circumstances — carbon film types may be safely substituted.

Construction

You will notice construction is not difficult but care must be taken to ensure that adequate insulation exists between the tube, all high voltage points and the chassis. Make certain the chassis is correctly earthed to both the printed circuit board and the ground wire of the three-core mains cable, as shown in the wiring diagram.

Construction should commence with assembly of the components on the printed circuit board. Note that all the diodes point in the same direction, with their *anodes* towards the *output* end of the pc board. Make sure the six electrolytic capacitors are inserted correctly.

Drill the bottom piece of the chassis to take a mains cable terminal block. Solder the wires from the power transformer onto the pc board. Solder two lengths of well insulated wire to the output of the pc board. These will go to the laser tube and should be kept as short as possible. The remaining pad on the board is the modulation input. This is not used in this project but will be used in subsequent articles. At this stage it is recommended that a pc board pin be soldered to this pad so that the board will not have to be removed from the chassis at a later date. The prototype laser has been constructed in a length of aluminium extrusion that we obtained from Laser Electronics. If you are not using this chassis, ensure that the chassis used is metal and well earthed. If you have purchased the kit from Laser Electronics, slide the pc board into the extrusion and mount the transformer and terminal block. Mount the power switch and finish the 240 V wiring. Ensure that the connection between the chassis and the ground wire is secure, use a solder lug and lock washer, loop the ground wire through the lug and then solder.

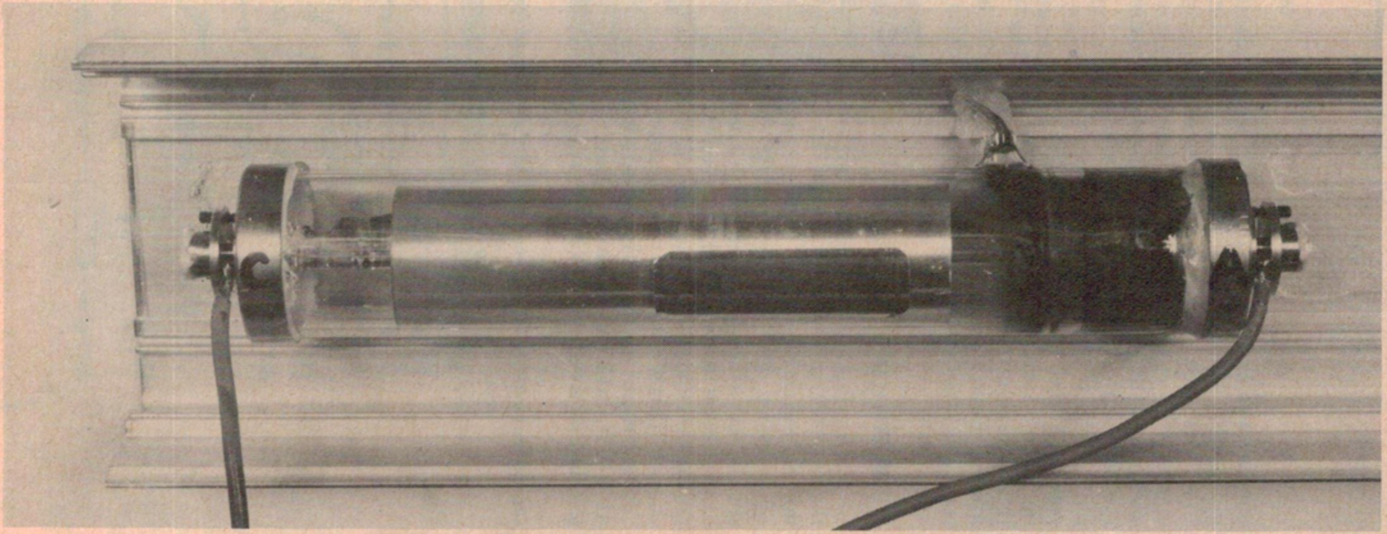
Note that you can replace the strings of A14P diodes with single high-PIV rating types, as indicated by the diodes dotted in on the circuit diagram. They should have a PIV rating of at least 3 kV and have a low junction capacitance (under 150 pF). In general, diodes rated at 5 kV PIV and less than 1 A forward current will be OK. If you elect to replace the diode strings with single diodes, they should be connected from the anode pad of the first diode to the cathode pad of the fourth diode in each string.

If you have difficulty obtaining the BD232 transistors, you can substitute some other type providing they have a collector-emitter voltage rating of 300 V or more and can dissipate up to 1.5 W.

The laser tube has metal ends used as the anode and cathode connections to the tube, so it must be totally insulated from the case. In the prototype unit,

▶

A close-up of the laser tube mounted in the case top (see text).



perspex was slid into the extrusion and glued into place with Silastic. The laser tube was then glued to the perspex, again with Silastic. This provides a cheap and highly effective mounting method. Drill a small hole in the end plate through which the laser beam will pass. Connect the wires from the pc board to the laser tube, making absolutely certain they are the correct way around. Finally, push the two halves of the extrusion together and screw in the end plates.

Powering up

Do not apply power to the laser without the cabinet assembled. If the laser doesn't operate correctly when turned on, turn it *OFF* before opening the chassis and allow sufficient time for any high voltage that may be present on the anode, to discharge before reopening the chassis. This will take several minutes.

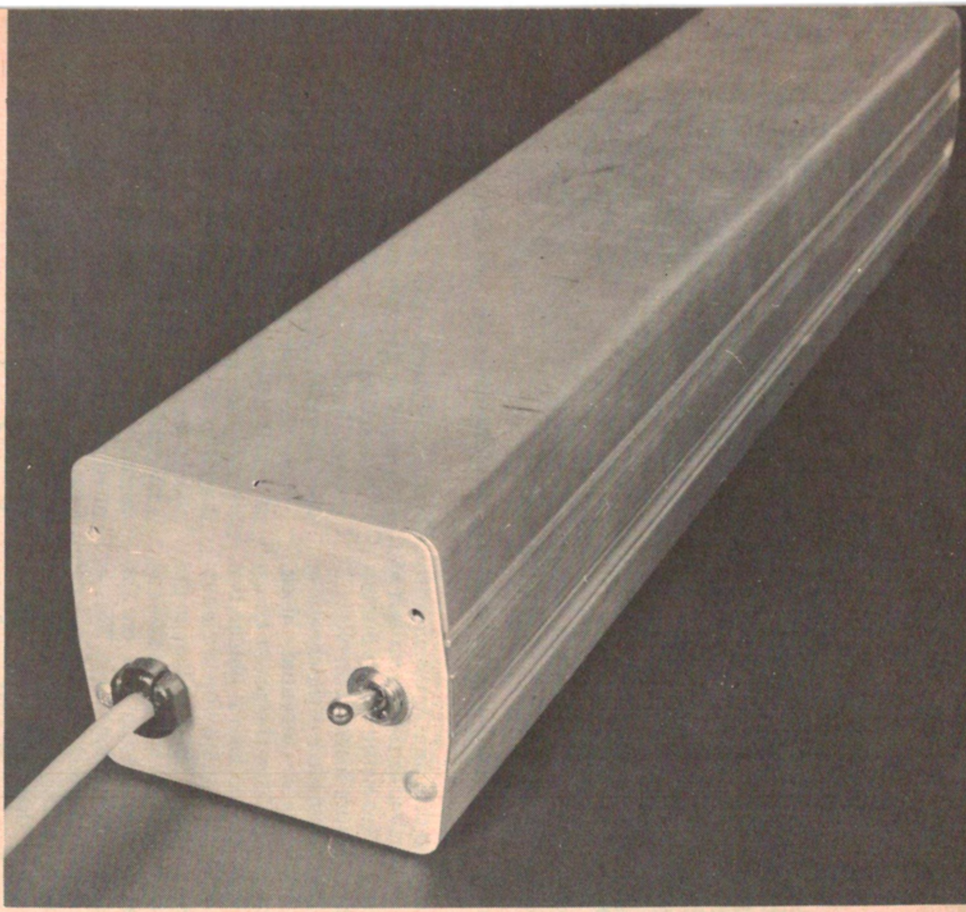
The output from this laser is rated at 1 mW and while this is not regarded as a dangerous level caution should *ALWAYS* be taken when operating any laser. *DO NOT* look directly down the beam. Be careful also of reflections that may be able to enter the eye indirectly. ●

A complete kit of parts will be available from:

Laser Electronics Pty Ltd
PO Box 359
Southport QLD
(075) 32-1699

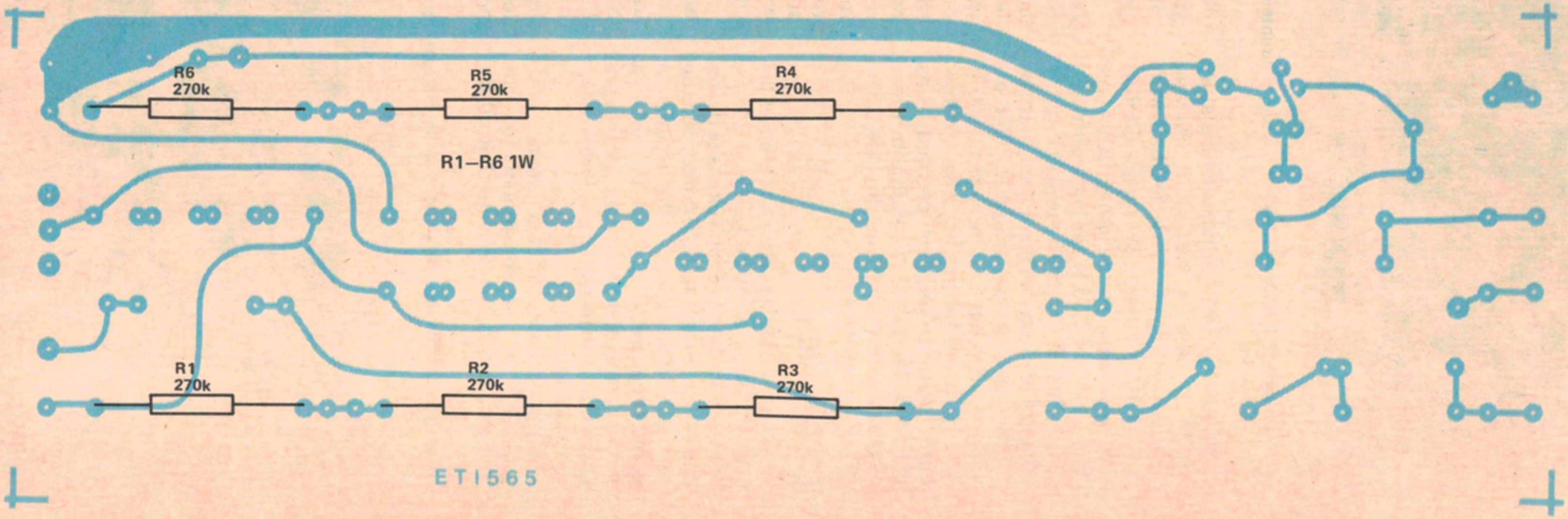
DON'T attempt to do any measurement on the power supply without a proper high voltage probe. The voltages present will break through the insulation on most standard multimeter cables.

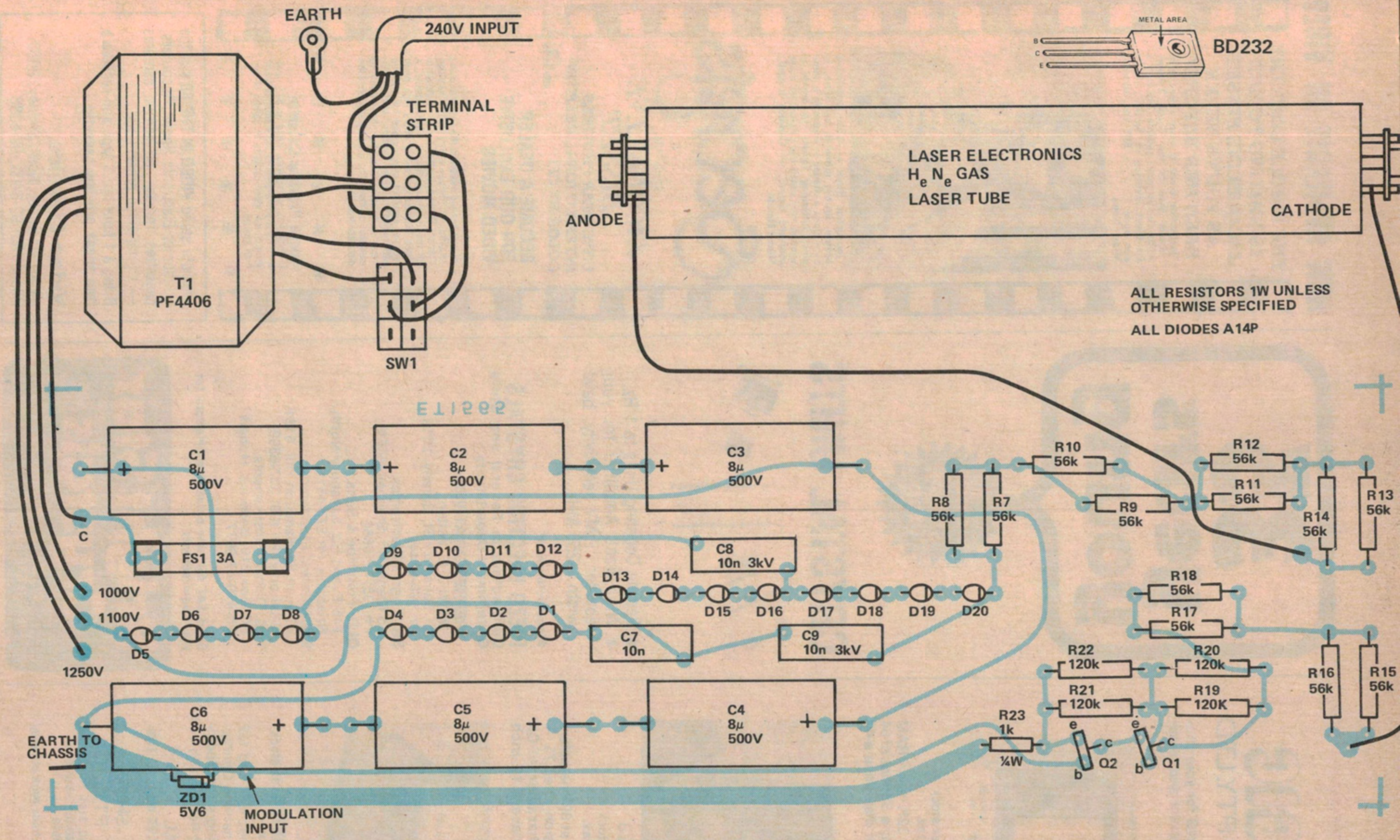
The power supply is quite capable of delivering 2000 V at 20 mA and this could be LETHAL if touched.



The assembled unit, viewed from the rear.

Component overlay for the underside of the pc board (copper side) showing placement of the resistors R1 to R6.





PARTS LIST — ETI 565

Resistors

R1-R6	270k, 1W carbon
R7-18	56k, 1W carbon
R19-R22	120k, 1W carbon
R23	1k, ½W carbon

Capacitors

C1-C6	8u, 500 V electro
C7-C9	10n, 5 kV ceramic

Semiconductors

D1-D20	A14P 1000 V PIV diodes
ZD1	5V6 400 mW zener
Q1,Q2	BD232 or equiv.

Miscellaneous

HeNe Laser tube — Laser Electronics; pc board — ETI 565; Power Transformer — Ferguson PF4406 (240 Vac pri.) 0-1000/1100/1250 V sec.) 240 Vac DPST switch, cable, cable clamp, 3-pin plug; chassis; assorted hardware, etc.