Laser communicator

Get active on the 472THz band!

PHOTO 1: Cheap pointers are an ideal source of laser diodes and optics.

LIGHTEN OUR DARKNESS. The idea of sending messages by light is familiar to us all, from ancient civilizations flashing sunlight off mirrors, to messages being sent between ships by means of signalling lamps, to the latest high-tech uses of fibre optic cables used by telephone companies. The communicator presented here makes use of a cheap laser pointer to transmit speech digitally modulated onto a beam of light.

Red laser pointers are readily available from market stalls, rallies, eBay and numerous other sources. They typically run on three 1.5V cells and give a milliwatt or two of light output. A pointer need to be partially stripped to get at the 'works' – see **Photo 1**. Disassembly is discussed later in this article.

On the grounds that it is easier to detect the presence or absence of a signal than to detect a varying amplitude, it was decided to use on/off signals to send our wanted audio signal. The simplest way of doing this, both in terms of modulating and demodulating, is to use a (relatively) high speed pulse train and varying the length of light pulses in sympathy with the incoming audio.

TRANSMITTER CIRCUIT. The transmitter circuit shown in **Figure 1** uses a mixture of digital and analogue techniques to convert the analogue AF input to a digital output to run the laser.

IC3 is a free running clock oscillator, operating at around 110kHz. This frequency is not at all critical to either the transmitter or the untuned receiver.

The audio input is first amplified by IC1a then fed to a delta modulator circuit formed by comparator IC1b and flip-flop IC2. A DC voltage of half the supply is added to the output of IC1a by R5 and R6. This is fed to the non inverting input of op-amp IC1b, which compares the voltage to that on C4. The comparator output is connected to the D input of IC2, a D-type flip-flop, and the Q output of the flip-flop is fed back via integrator R7/C4 to the inverting input of the comparator.

At switch on, with no input signal, C4 is uncharged so IC1b has zero volts on its inverting input and half supply volts on its non inverting input. Due to the comparator action, the op-amp output swings almost to the voltage of the positive supply rail. On the rising edge of the first clock pulse to IC2, this high input is transferred to the Q output, which goes into the 1 condition. This high is fed to the integrating circuit R7/C4 and the voltage on C4 begins to rise as the capacitor charges. This state of affairs continues until such time as the voltage on C4 rises above the voltage supplied to the non inverting input of the comparator, at which time the comparator output switches from the positive to the negative supply rail.

At the next clock pulse, the flip-flop is reset and its Q output switches from 1 to 0. C4 now starts to discharge via R7 and does so until the voltage across it falls below the voltage on the non inverting input. The cycle repeats itself at a rate determined by the charge/discharge times of R7/C4 and the

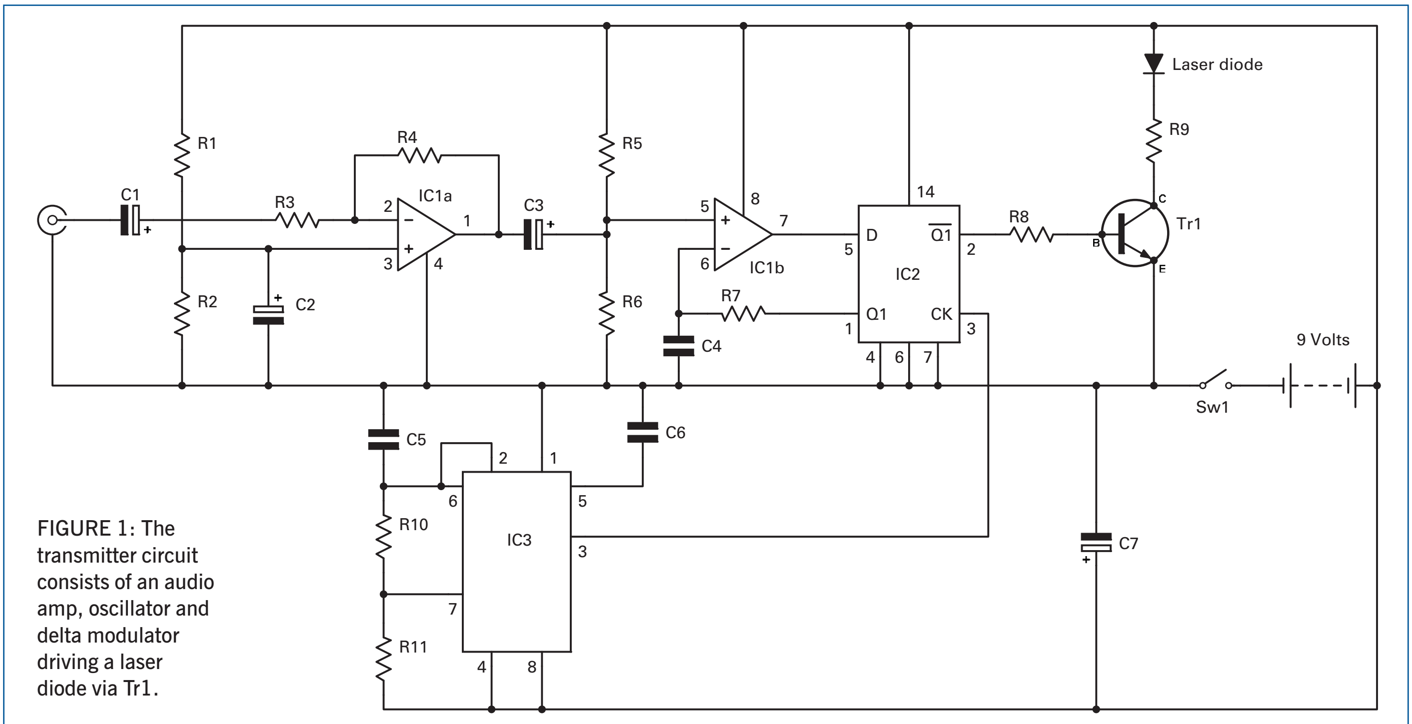

FIGURE 1: The transmitter circuit consists of an audio amp, oscillator and delta modulator driving a laser diode via Tr1.

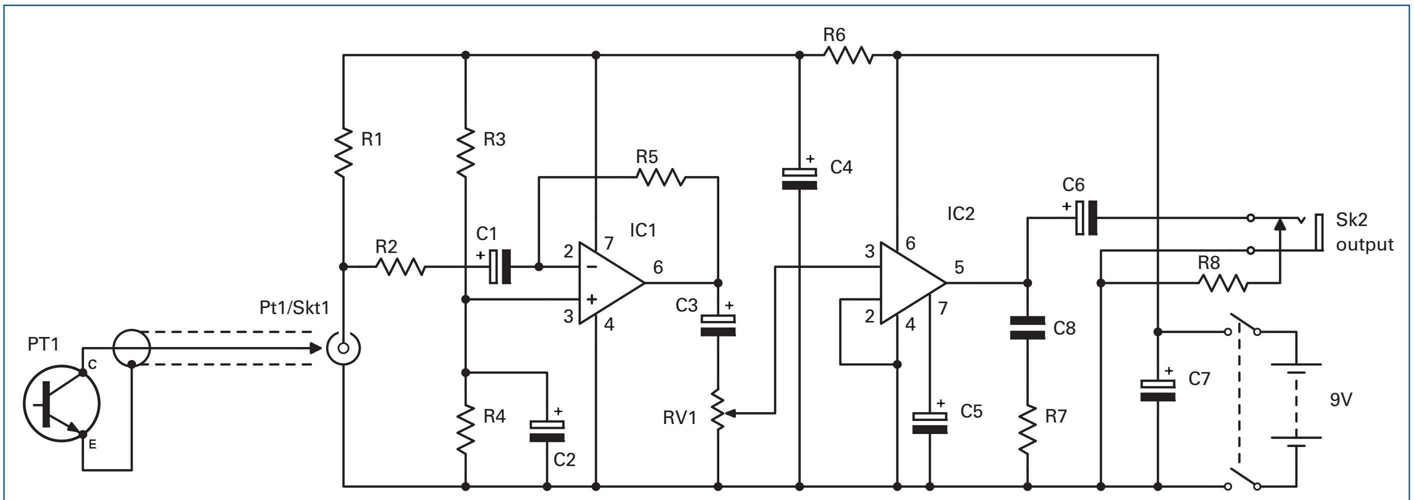

FIGURE 2: The receiver circuit integrates and amplifies the output of the phototransistor sufficiently to drive a speaker.

frequency of the clock pulses from IC3. The Q-not output of IC2 is connected via current limiting resistor R8 to the base of TR1, which in turn switches the laser on and off, thus producing a modulated beam of light.

When an audio signal is connected to the transmitter, the amplified input voltage appears on the non inverting input of IC1b. Assuming for the moment that this is a positive voltage, it will be necessary for C4 to charge up for a longer period until the voltage upon it exceeds the voltage on pin 5. IC2 will be in the set condition for a longer period and this in turn will keep the laser turned off for a longer period. If the input voltage stays at the same level then the flip-flop will continuously set and reset as the voltage on C4 at the comparator inverting input goes slightly above and slightly below the voltage on pin 5. This set and reset will continuously turn the laser off and on so that a string of light pulses is transmitted. When the audio input falls below the voltage on C4, the comparator output switches to the low condition and this is fed through the flip-flop again on the next clock pulse, and the laser is switched on by Tr1 whilst C4 discharges.

The clock pulses must be at a higher frequency than the maximum audio frequency. The higher this clock frequency is, the more accurately the integrator voltage will follow the input voltage.

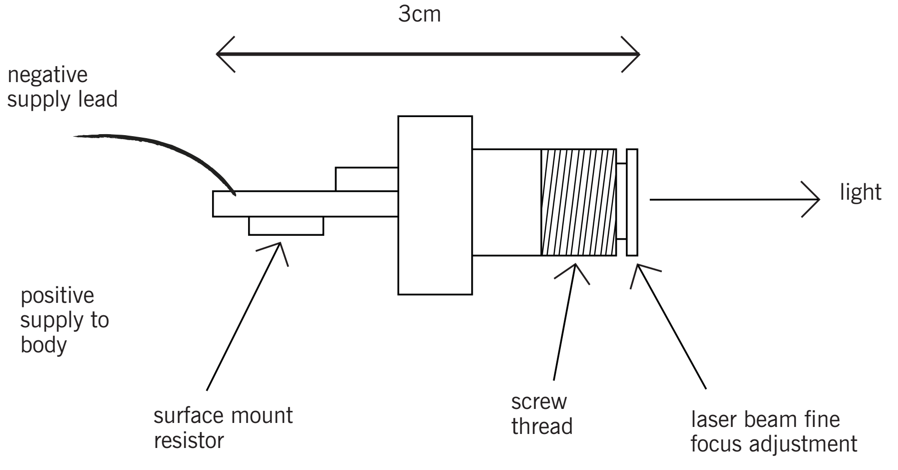

FIGURE 3: General form of construction of laser diode modules.

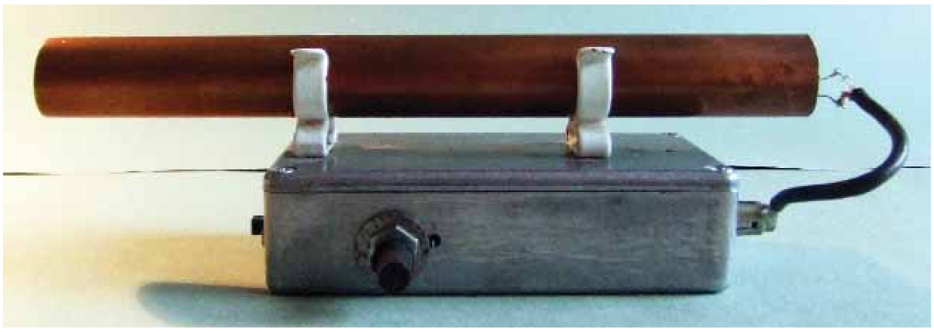

PHOTO 2: The receiver uses a length of tube to shield the phototransistor from extraneous light.

RECEIVER. The circuit of the receiver is shown in **Figure 2**. The modulated laser light beam is received by phototransistor PT1, whose conductance varies with the incident light level. This causes the voltage at the collector to change, essentially as a small amplitude square wave, as it 'sees' the modulated laser beam from the transmitter. The varying mark:space ratio represents the audio signal, which is recovered by R2 and C1. This signal is then fed to opamp IC1 for voltage gain and then, via volume control RV1, to IC2, a standard circuit audio amplifier. If attempts are to be made to squeeze extreme range from this circuit, or a different phototransistor is used then the gain of the receiver can be easily increased by changing R5 to a higher value. However, it was not found necessary in the prototype as there were up to several volts AF at the output of IC1.

CONSTRUCTION. Both the transmitter and receiver are constructed on small pieces of stripboard and built into diecast boxes measuring 3 x 6 x 11.3cm. The receiver looks a bit odd, having a length of pipe fixed to the lid as shown in **Photo 2**. The interior of the transmitter is shown in **Photo 3** – note the spring that retains the battery.

The heart of the transmitter is the laser, which was removed from a laser pointer that I bought for a few pounds on the seafront at Blackpool. Similar devices are often obtainable at radio rallies and from many other sources.

Photo 1 shows four different laser assemblies removed from these cheap pointers. All of them are orientated so that the light beam shines straight downwards towards the bottom of the picture. The one on the left shows the laser with the lens assembly removed. The laser diode on its heatsink is mounted directly onto the PCB

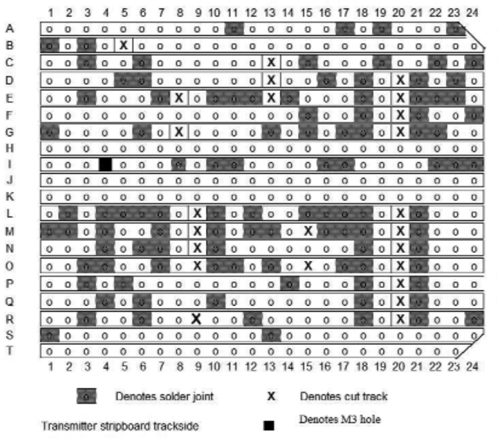

FIGURE 4: Transmitter track cutting pattern.

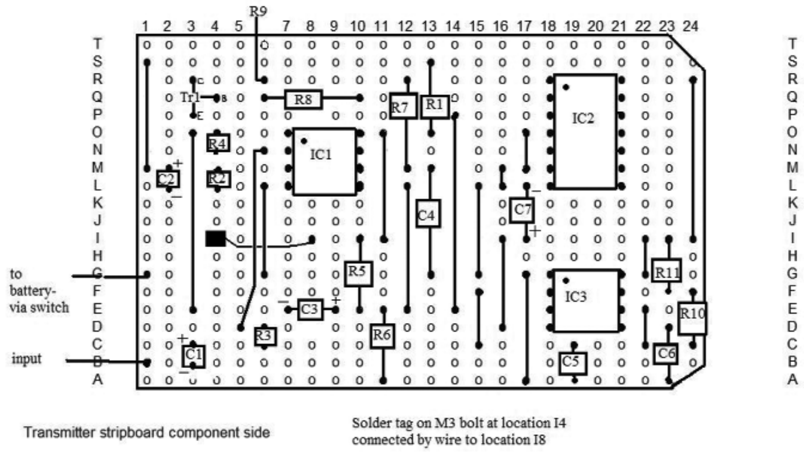

FIGURE 5: Transmitter component overlay.

PHOTO 3: A look inside the transmitter. Note the laser diode module screwed into the top right of the case.

COMPONENT LISTS

Transmitter

IC1 TL072CN
IC2 HCF4013BE
IC3 TS555N
R1, 2 120k
R3 10k
R4 56k
R5, 6 330k
R7 560k
R8 4k7
R9 220Ω (see text)
R10, 11 27k
C1, 2 22μF 16V
C3 10μF 16V
C4 3.3nF
C5 150pF
C6 10nF
C7 33μF 16V
TR1 2N2218 (see text)
Laser - see text
On/off switch
Phono socket (input)

Receiver

IC1 TL061CP
IC2 LM386N
R1 22k
R2, 5 27k
R3, 4 120k
R6 120Ω
R7, 8 10Ω
C1, 2, 3, 5, 6 22μF 16V
C4 100μF 16V
C8 22nF
PT1 SFH300-2
RV1 4k7 variable (see text)
On/off switch
Phono socket (input)
3.5mm jack socket (output)

and is very small, showing at the bottom. The on/off switch can be seen in the middle, whilst the spring presses against the negative end of the battery. The surface mount series resistor is located on the underside of the board, as shown in **Figure 3**.

The second from the left is constructed with a laser module connected to the PCB. Second from the right has a laser diode mounted directly onto the PCB, as the first one, but with the lens assembly still attached. The last, on the right has a three terminal laser module with a current limiting control circuit.

Before disassembly, the current in each pointer was measured and all were found to be between 25 and 30mA. The transmitter uses the laser straight as it comes out of the laser pointer, with no additional lenses (there is a very small one already inside the laser package). Judicious use of a junior hacksaw is necessary to extract the laser module from the pointer case. Be very careful at this stage as one "came apart in my hands". Do not attempt to remove the printed board from the housing and lens assembly, as it is VERY fragile.

In its original form, a pointer contains three button cells supplying 4.5V to the laser via a surface mount resistor. Due to the increased supply voltage in this application the original resistor has been increased by adding a 150Ω resistor (R9) in series with it, or if you wish you could remove the surface mount resistor and replace it with one of 220Ω. The body of the laser is its positive connection and this connects through the metal body of the diecast box, via a switch to the battery positive connection. So yes, the case is positive earth.

Before drilling the diecast case to take the laser module it is advisable to ascertain if you have a nut that will fit the thread on the laser. Mine was a spare one from a small potentiometer. If a nut of the right thread cannot be located, then an alternative mounting method will have to be found.

Transistor TR1 can be almost any NPN device that will sink 50mA or more. Gain and frequency response are not an issue here.

The single fixing screw that holds the stripboard in place also holds a double ended solder tag. One side of the tag connects to a short wire to the stripboard, while the other side of the tag has a spring attached that is used to keep the battery in place.

The first prototype transmitter used LM393 op-amp, 74LS74 dual D-type flip-flop and NE555 clock generator and operated around 30kHz but the current consumption was unhealthy for batteries, so the ICs were changed to those shown here, resulting in a current drain of 16.5mA.

The laser assembly with R9 mounted on it can be seen at the top right of Photo 2, and the input socket and on/off switch can be seen mounted on the left side. The diecast box also contains a PP3 battery. However, these still don't last too long, so if mains power is available where the communicator is to be used, then a simple 9V 50mA regulated power supply would be a more economical long-term proposition.

Constructing the board should not pose any great problems provided attention is paid to **Figures 4** and **5** and a methodical method is employed. After cutting a piece of

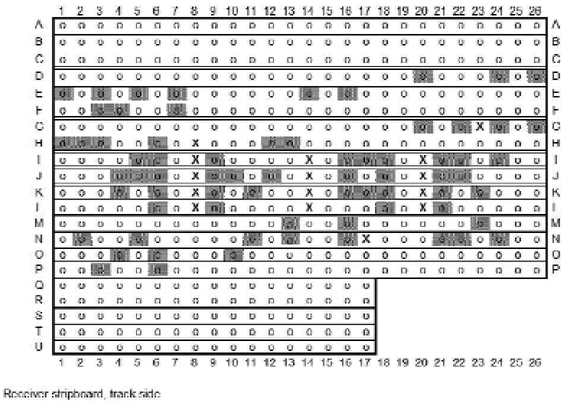

FIGURE 6: Receiver track cutting pattern.

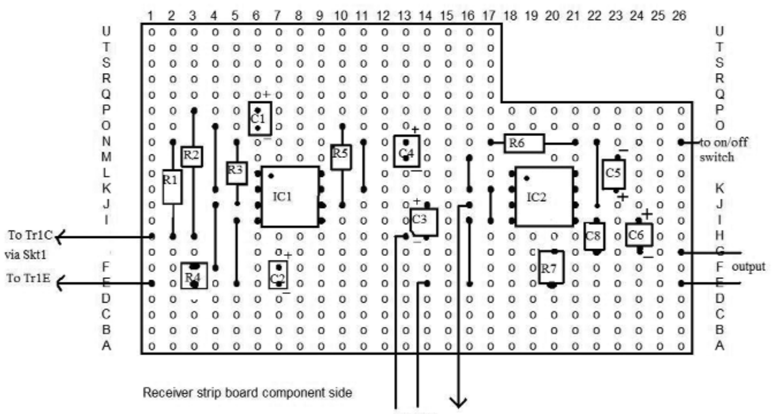

FIGURE 7: Receiver component overlay.

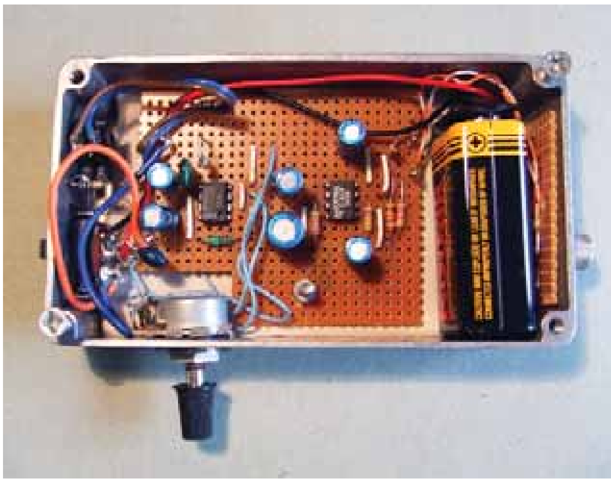

PHOTO 4: The receiver is fairly simple too. It's probably worth drilling a small hole to accept the 'tang' on the volume pot.

stripboard to size, make all the necessary track cuts (denoted by an X in Figure 4). Next, add the wire links, resistors and capacitors in that order. Finally, fit the semiconductors. You may want to use sockets for the ICs but this isn't essential.

After a quick check that you've put everything in the right place and that there are no short circuits, fit the board into the case and make the final wire connections.

RECEIVER CONSTRUCTION. As shown in **Photo 4**, basic construction is quite simple, being based on stripboard. The component and track sides are shown in **Figure 6** and **7**. Some of the resistors are placed flat on the board and some are standing upright, which explains the differing sizes shown on the drawing.

R8 is mounted on the output socket on the left side of the case and C7 is mounted on the on/off switch.

The laser communicator may be used in any light conditions, day or night, but to do this with any success the phototransistor must be shielded from ambient light. The prototype was originally made with a large Fresnel lens measuring 26 x 18cm and, although this worked fine at night, it was impossible to use in daylight due to the large amount of ambient light overloading the phototransistor. Attempts were made to compensate for the excess light input by replacing R1 with a transistor and automatically varying its emitter/collector resistance, but even this was defeated by direct bright sunlight, as was an attempt to replace it with a light dependant resistor. It is for this reason that the phototransistor is placed inside the end of a tube - see Photo 2.

Now comes the part that makes it all worth while: drink a bottle of wine and save the cork. Why? Well, you will find that a normal size wine bottle cork is a good push fit inside a 22mm pipe. Cut a one centimetre thick circular slice of the cork and push the two wire leads of the phototransistor through it (making sure that they do not touch one another). Push this slice into the end of the water pipe so that the phototransistor is inside the tube and its leads are pointing outwards. The longer lead is connected to the emitter; the collector lead is next to the flat on the case and there is no access to the base. Connect the collector and emitter of Tr1 via a short length of lead to a phono plug, which mates with the socket fitted to the end of the diecast box. Fix the pipe to the case using spring clips.

The volume control, RV1, is shown mounted at the bottom of the case. Please take note that a physically small potentiometer must be used in order for it to fit inside the case. In order to save room inside the case, a PCB mounting phono socket was mounted on a small piece of stripboard and mounted on the right side of the case.

The receiver does not require any lenses, but if you want to try experimenting with a large Fresnel lens as mentioned before, and don't know where to get one, try asking at your local library. I bought mine at a library, several years ago, where it was sold as a whole-page magnifier for people with sight problems. Use of one of these lenses requires the construction of a large box to hold it and allow it to focus inside the box, but the plus side of the equation is that due to its larger size, aiming at it with the laser is considerably simpler.

The current consumption of the receiver is approximately 5.2mA with no input signal, rising to 6.0mA at good earphone volume, rising again to approx 50mA if a loudspeaker is used. The wavelength of the laser is approximately 650nm, bright red, whilst the spectral response of the phototransistor is between 420nm and 1130nm with a peak at 850nm, infrared.

OPERATION. LASERS CAN BE DANGEROUS – TAKE CARE. Looking directly at a laser, especially along the beam, can seriously and permanently damage eyesight. Do not use the transmitter where there is **any** risk of a stray or reflected beam hitting anyone's eyes. We strongly recommend that you do not use a laser in a public place, near a road, or anywhere that you might put any person or animal at risk.

Apply a test signal to the input of the transmitter. I used the output of a MW radio. Point the laser directly at the front of the pipe on the receiver so that the light beam travels down the pipe and then falls onto the phototransistor. Check that you get audio out of the receiver (but note that it takes the transmitter 3 to 4 seconds to become operational after switch-on due to the charge-up time of the integrator capacitor).

You will find that it is very easy to line up the transmitter and receiver over a distance at night but practically impossible to do in daylight due to the difficulty in seeing the red spot from the laser. If you wish to use it in the daytime then I suggest that you set it up after dark first. The prototype achieved a range of 150 metres at night and 50 metres in daylight: you may well achieve better.

For those interested in transmitting signals by amplitude modulation of a light beam then the article Seeing is Believing by G4OPB and G4DWF in the December 1998 issue of *RadCom* is recommended.