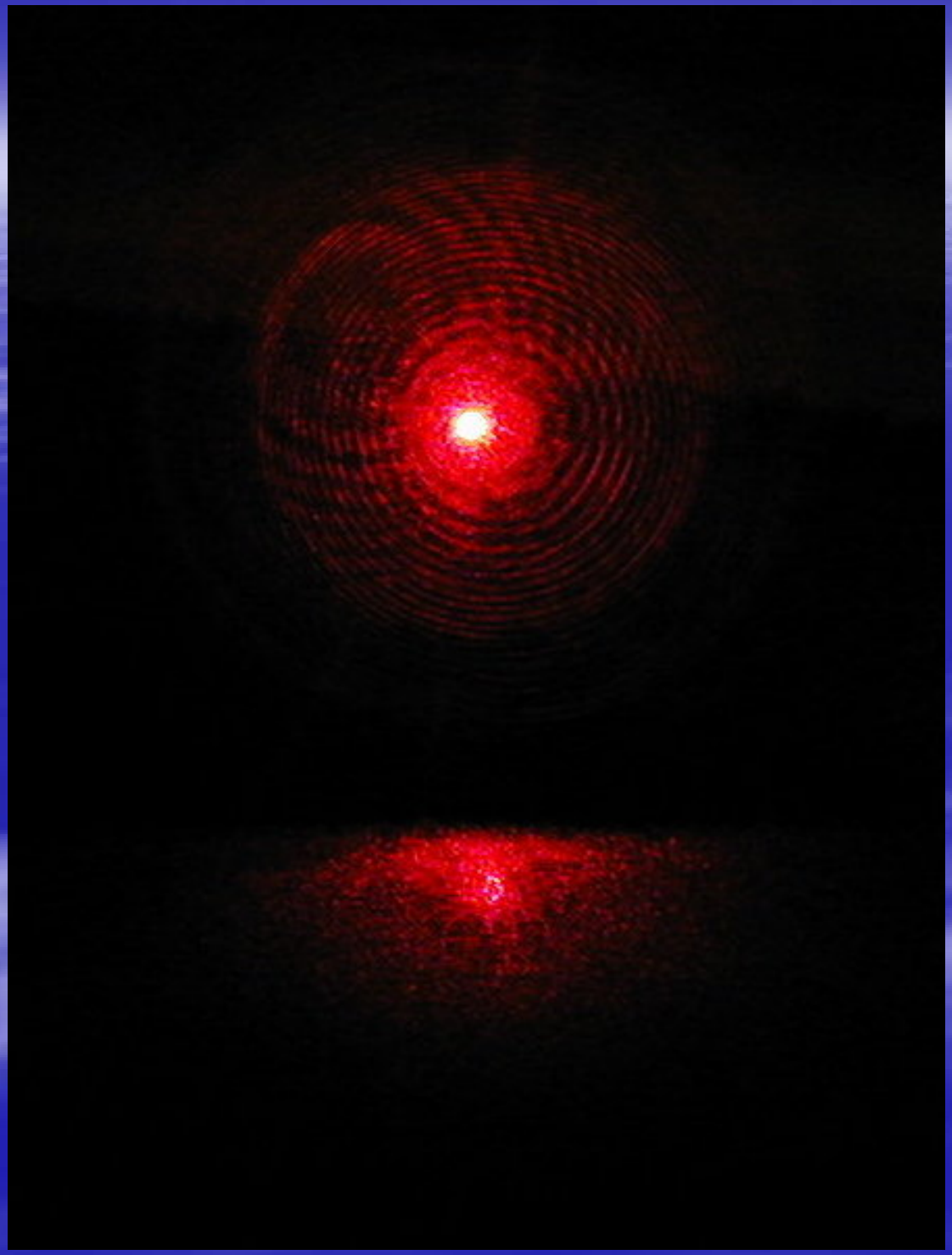
AMATEUR LIGHTWAVE COMMUNICATIONS

by Peter Day, G3PHO
and
Barry Chambers, G8AGN



This talk will deal with …

- What are lightwaves?
- How can we generate lightwaves?
- The laser
- Safety considerations
- Is it “radio”?
- Simple transmitter and receiver designs
- Practical results
- Sources of information

Dec. 1899: British heliograph corps signalling from the beseiged town of Ladysmith, Boer War, South Africa.

Lightwaves ~ yes, there was life before amateur radio!

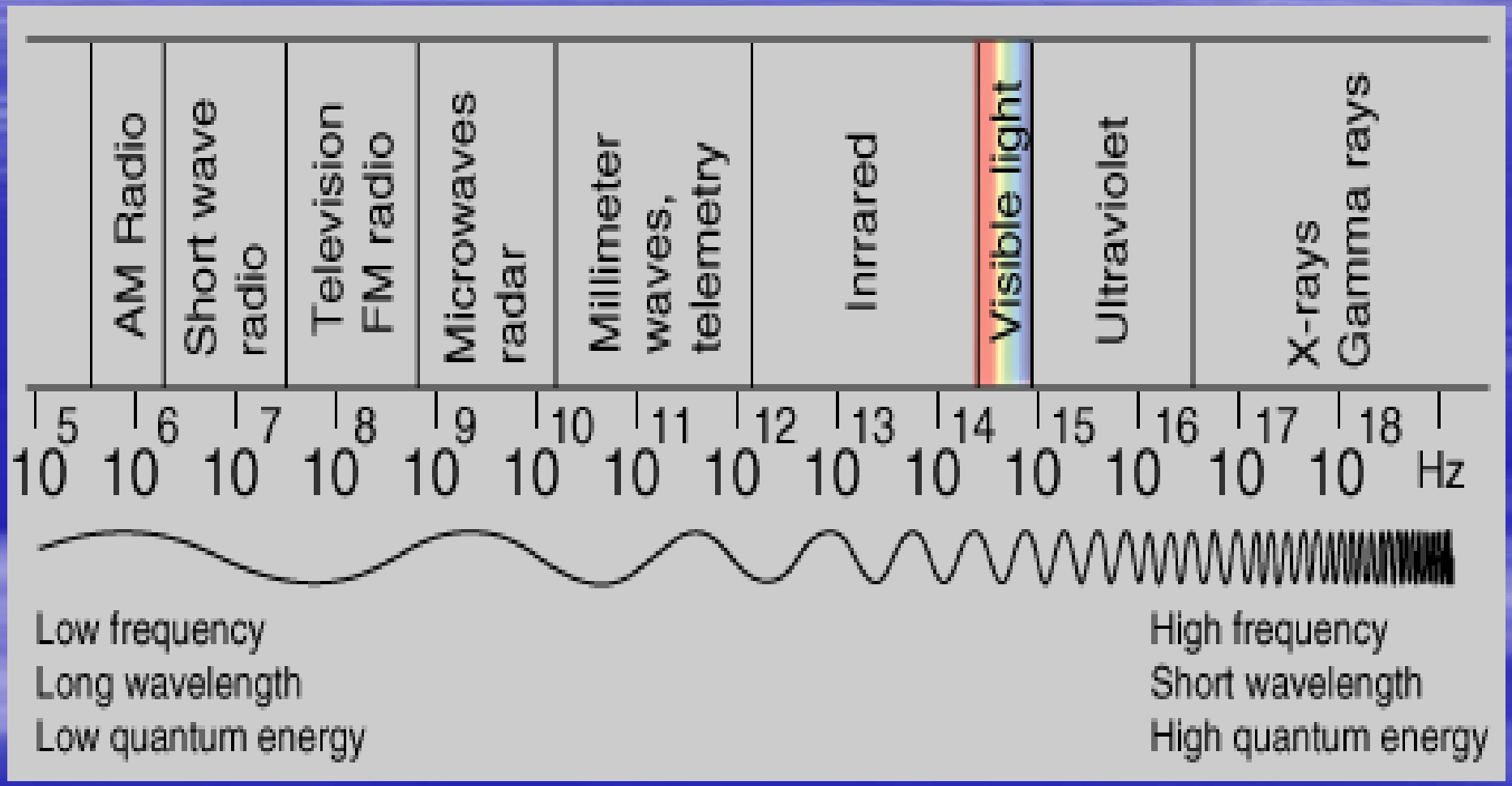
- an ancient form of communication
- Origins go back at least to Ancient Greece

No licence is needed to use lightwaves!

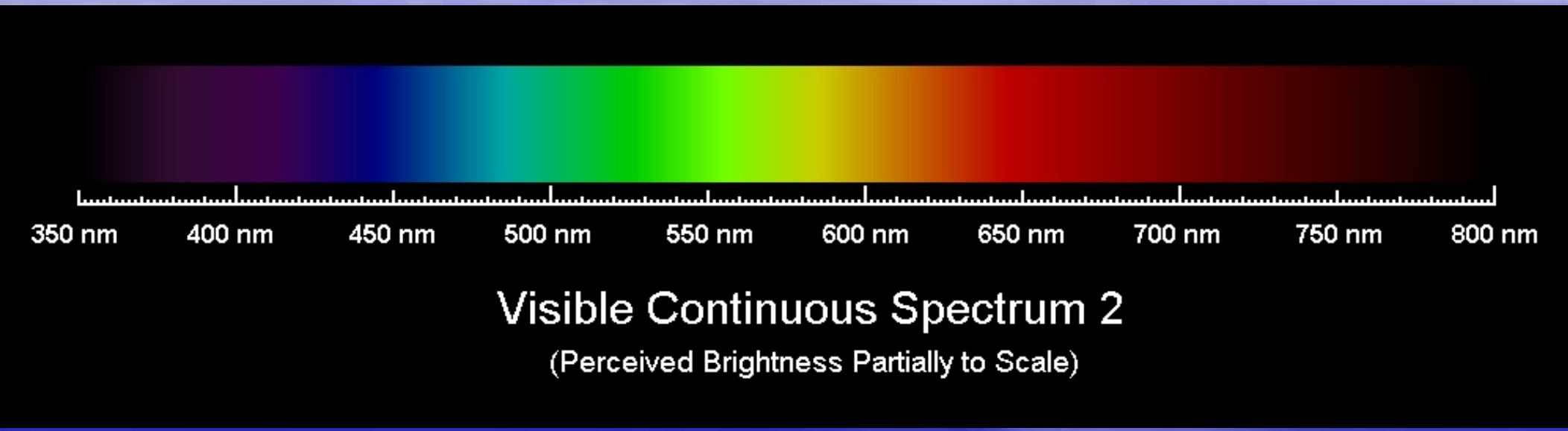
- Anyone, licensed amateur or not, can transmit and receive at lightwave frequencies
- All kinds of data can be transmitted:
  - * CW
  - * Speech
  - * video
  - * computer data
  - * the list is endless!

So just what are lightwaves?

The Electromagnetic Spectrum

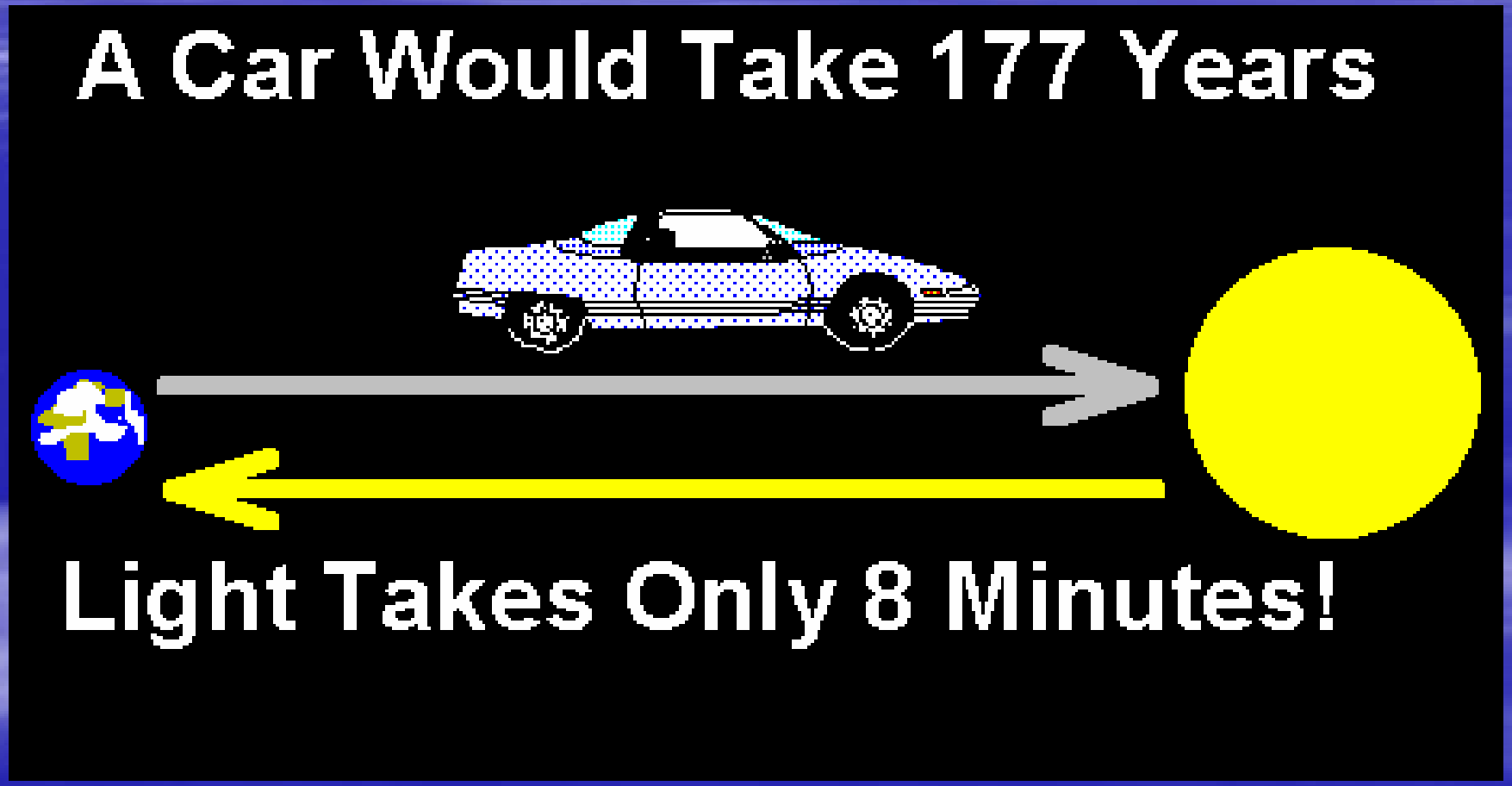


The Visible Spectrum



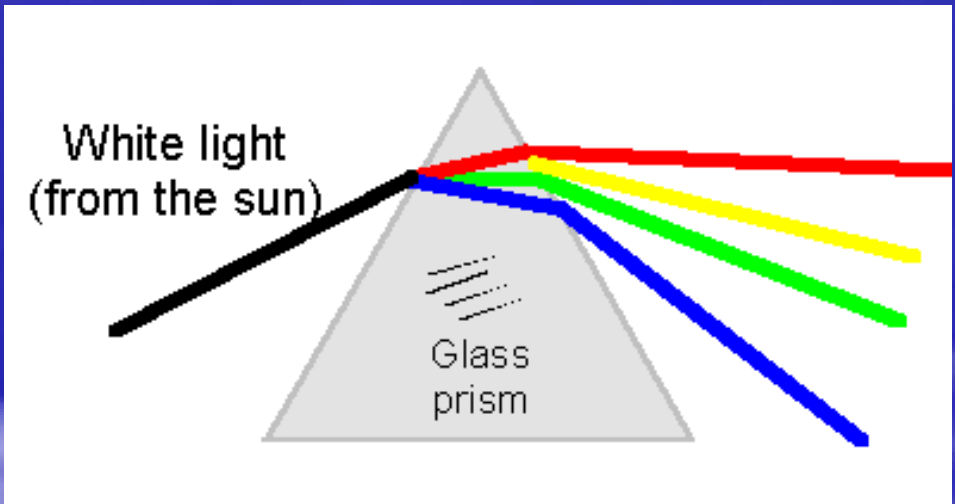
- Amateur lightwave communication takes place on frequencies between 350THz and 680THz (Terahertz).
- In wavelength terms = 700nm (deep visible red light) to 400nm (visible violet)
- 1THz= 1million MHz !

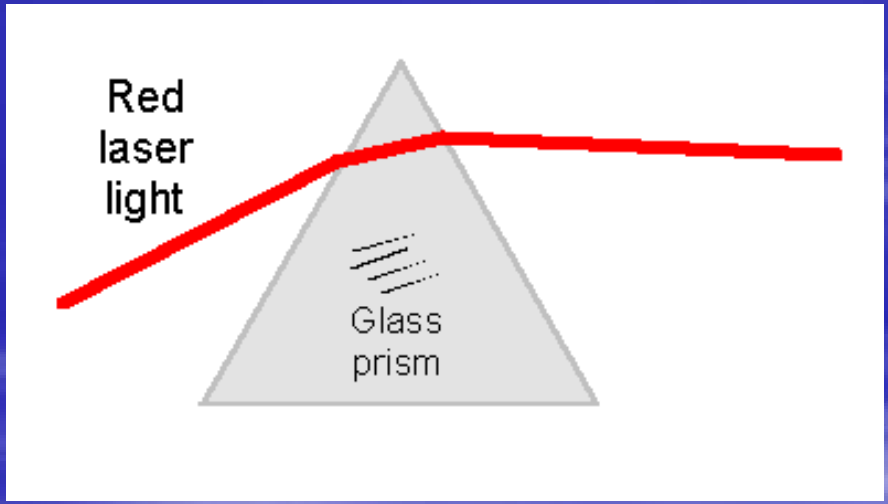
Light travels fast!



Types of lightwaves

Non coherent and coherent light





Non coherent …many frequencies, not in phase.

Spread out

Single or almost single frequency, in phase

Narrow beam, highly directional

Non coherent and coherent light

- Coherence is one of the unique properties of **laser** light. It arises from the stimulated emission process which provides the amplification. Since a common stimulus triggers the emission events which provide the amplified light, the emitted photons are "in step" and have a definite phase relation to each other.

- Ordinary light is not coherent because it comes from independent atoms

HOW TO GENERATE LIGHTWAVES

- Almost anything can be used but some are much better than others eg:

  * Quartz iodine car headlamps: Can be seen for miles but difficult to modulate the heated element. Non coherent.

  * High powered LEDs: high outputs available (watts!). Easily modulated. Needs beam narrowing (collimation). Not coherent.

  * Lasers: Coherent light. Narrow beam. Cheap in diode form.

THE LASER

Light

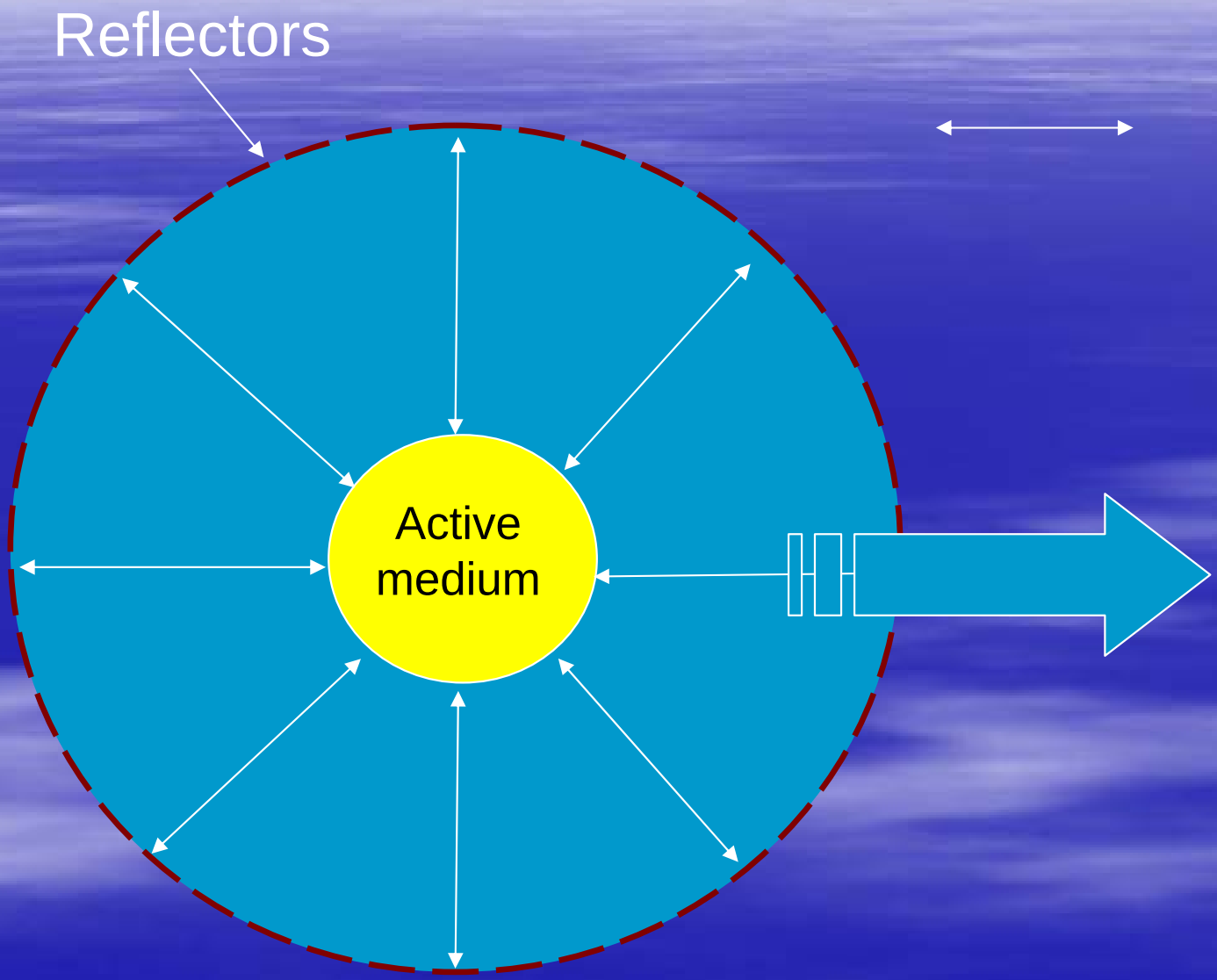
Amplification by

Stimulated

Emission of

Radiation

LASER BASICS



= reflected light is amplified by medium

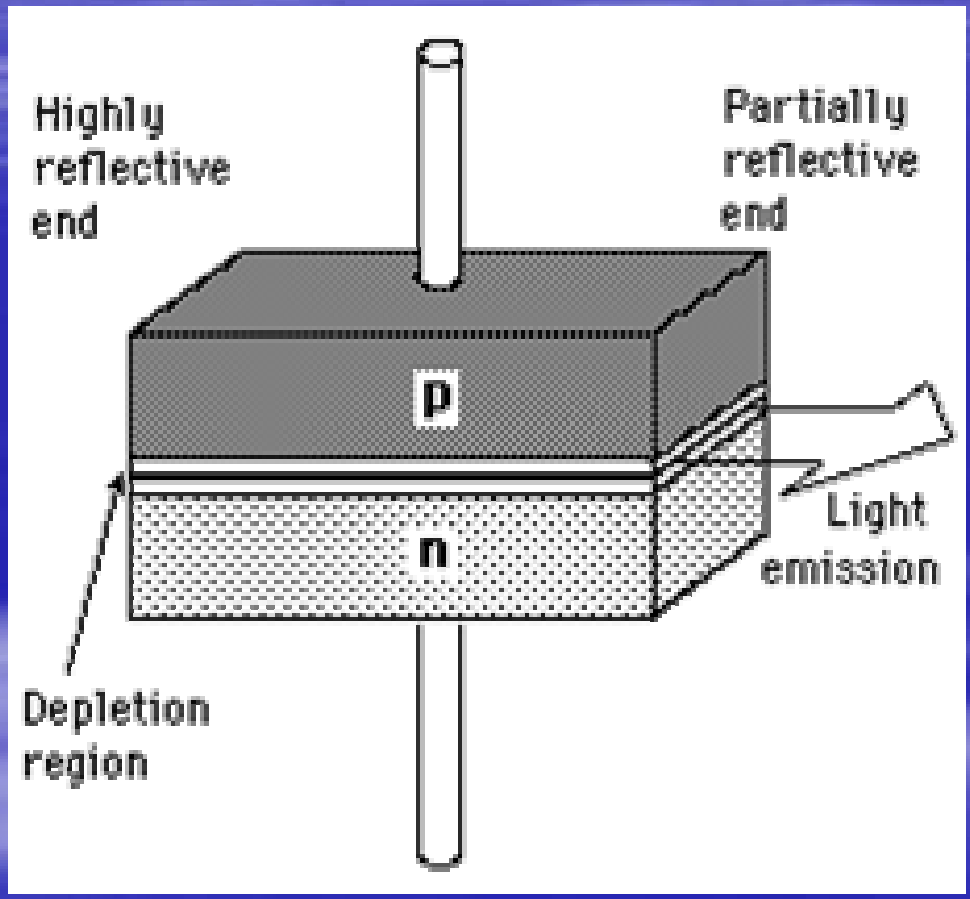
Small portion of amplified light escapes into a beam of highly directional coherent light

An active medium stimulates and amplifies light

Examples include:

- Solid-state (ruby)
- Liquid (dye laser)
- Gas (Helium-Neon or Argon
- Semiconductor (laser diode)

SEMICONDUCTOR LASER



- Laser action (with the resultant monochromatic and coherent light output) can be achieved in a p-n junction formed by two doped gallium arsenide layers. The two ends of the structure need to be optically flat and parallel with one end mirrored and one partially reflective. The length of the junction must be precisely related to the wavelength of the light to be emitted. The junction is forward biased and the recombination process produces light as in the LED (incoherent). Above a certain current threshold the photons moving parallel to the junction can stimulate emission and initiate laser action.

The Wavelength of the emitted light is a function of:

- The active medium
- Mirror (reflector) spacing

Characteristics of Laser Light

- 1. **Coherent:** Different parts of the laser beam are related to each other in phase.
- 2. **Monochromatic:** Laser light consists of essentially one wavelength, having its origin in stimulated emission from one set of atomic energy levels.
- 3. **Collimated:** Because of bouncing back between mirrored ends of a laser cavity, those paths which sustain amplification must pass between the mirrors many times and be very nearly perpendicular to the mirrors. As a result, laser beams are very narrow and do not spread very much.

Commonly used lasers …

- Helium-Neon (HeNe)

- Semiconductor (diode)

Pros and Cons

- **Helium-Neon Laser:**
  - Can generate reasonable power levels
  - Very narrow beam width (1milliradian) without external optics

  BUT

  - Fragile
  - Inefficient (around 2%)
  - Difficult to modulate with speech
  - Needs high voltage power supply (1KV+)

Pros and Cons

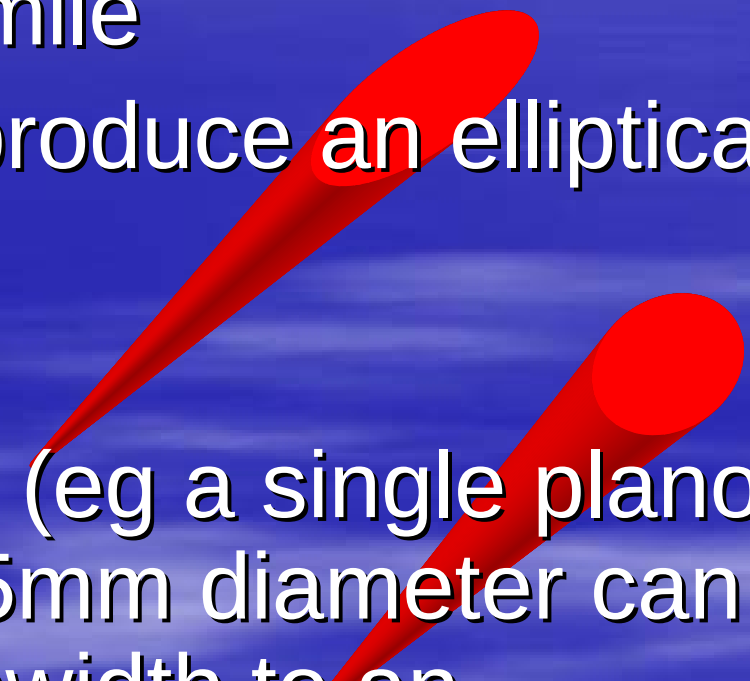
- **Semiconductor (diode) laser**
  - Greater efficiency that HeNe (80%, above lasing threshold)
  - Physically rugged
  - Compact size
  - Light weight
  - Long life (over 50,000 hours)
  - Easy to modulate up to 1GHz
  - Simple and safe power supply (3 to 12VDC)

  BUT

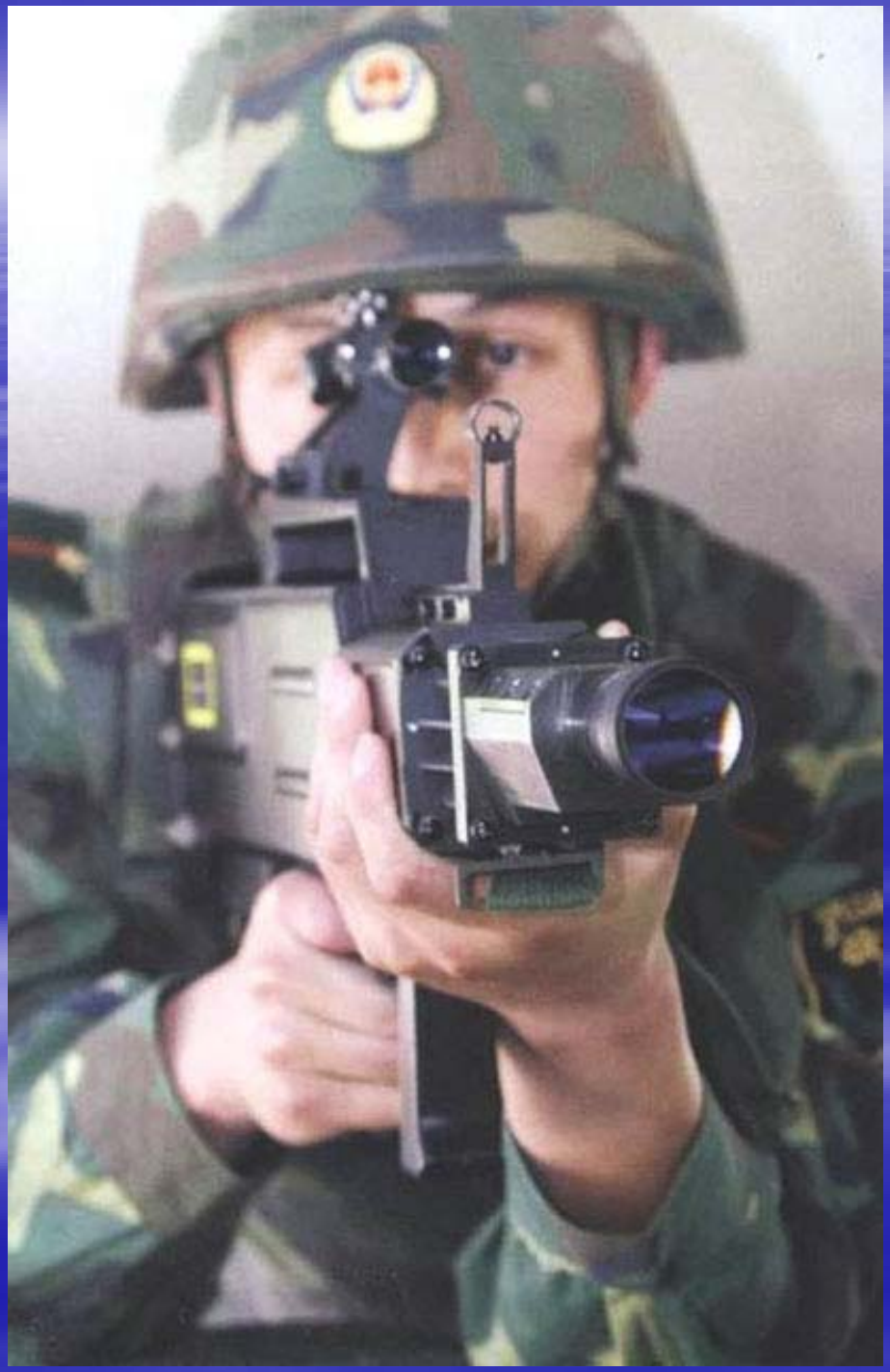
  - Wider light beam than HeNe laser.. may need collimator

Importance of beamwidth

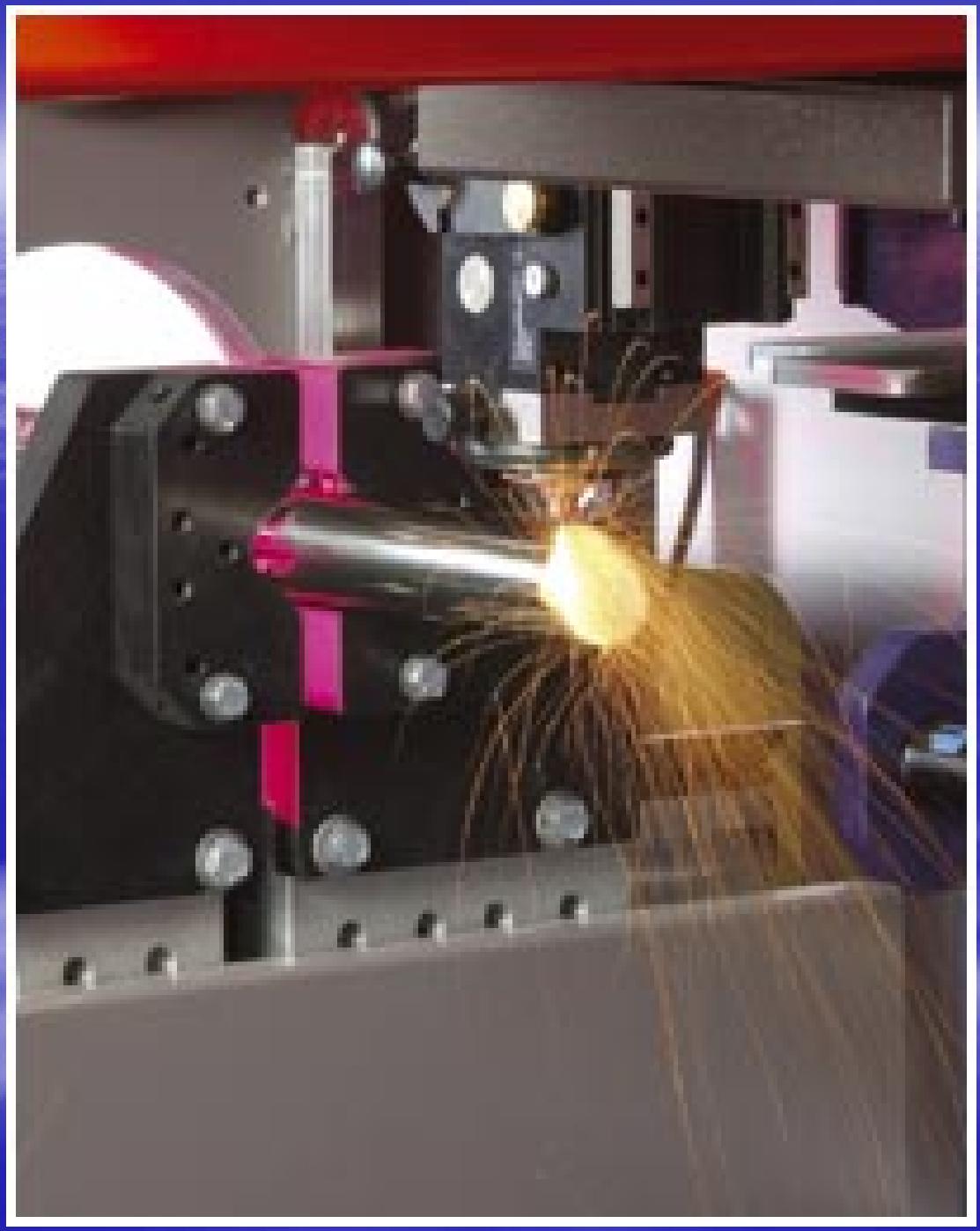
- A beamwidth of 1 milliradian produces a 5 foot diameter “dot” at 1mile
- A diode laser tends to produce an elliptical, divergent cone of light



- Therefore simple optics (eg a single plano-convex lens of around 5mm diameter can often improve the beamwidth to an acceptable 1 x 3 milliradian beam



Lightwaves can harm you!



Light can cut through steel!

The most vunerable parts of your body are your eyes

DANGER

LASER RADIATION

AVOID DIRECT EYE EXPOSURE

DIODE LASER

5 mW MAX OUTPUT at 670 nm

CLASS IIIa LASER PRODUCT

LASER SAFETY - 1

The Sun's visible output is about 1000 watts per square metre at the Earth's surface

Your 2m hand-held has an r.f. output of 1 to 5 watts

Typical laser output is nominally 1 to 3 milliwatts
– why is this dangerous ?

BEWARE
All lasers should be labelled with their output optical power, but the output of cheap lasers may be very much larger than the label suggests as they are not checked after manufacture

LASER SAFETY - 2

The maximum safe optical power level for the eye is
18 watts per square metre for 1 second.

The receiving diameter of the eye varies with light level
7mm at night, maybe 3mm on a bright day

MOST DANGEROUS AT NIGHT WHEN USING A TELESCOPE OR BINOCULARS TO VIEW A LASER

e.g. at night 7 x 50 binoculars can collect about 50 times more light than the naked eye

LASER SAFETY - 3

If the eye is open to 7mm and the maximum safe level is 18 watts/ sq metre, then the maximum input light power to the eye is about 0.7 milliwatts.

Our 5 milli-watt laser is dangerous because the beam is tightly collimated (it doesn't spread out like a torch beam) and so much more light energy can be collected by the eye even if the laser is a long way away (especially if viewing through binoculars or a telescope).

The eye has natural defence mechanisms – a bright light makes the iris contract and makes your head turn away
DON'T DEPEND ON THIS FOR YOUR SAFETY

Safe viewing distances (metres) for a red laser of 2mm beam diameter,1.5millirad divergence and a viewing time of 1 second

Laser output power (mW)	G= 1 (naked eye)	G=7 (binoculars)
1	5	38
5	12	87
10	17	123

IS IT RADIO?

- To qualify as “radio” the received signals must be demodulated by electronic means

  i.e … NOT BY EYE!
- The received light can be translated into audio (loudspeaker or phones) or video (TV) or data (computer screen)
- The ARRL insist that amateur radio lightwave transmissions must be via coherent light if they are to count for DX records and contest entries
- Any form of modulation is allowed

SIMPLE LASER EQUIPMENT

G8AGN's LASER TRANSMITTER

Sighting scope

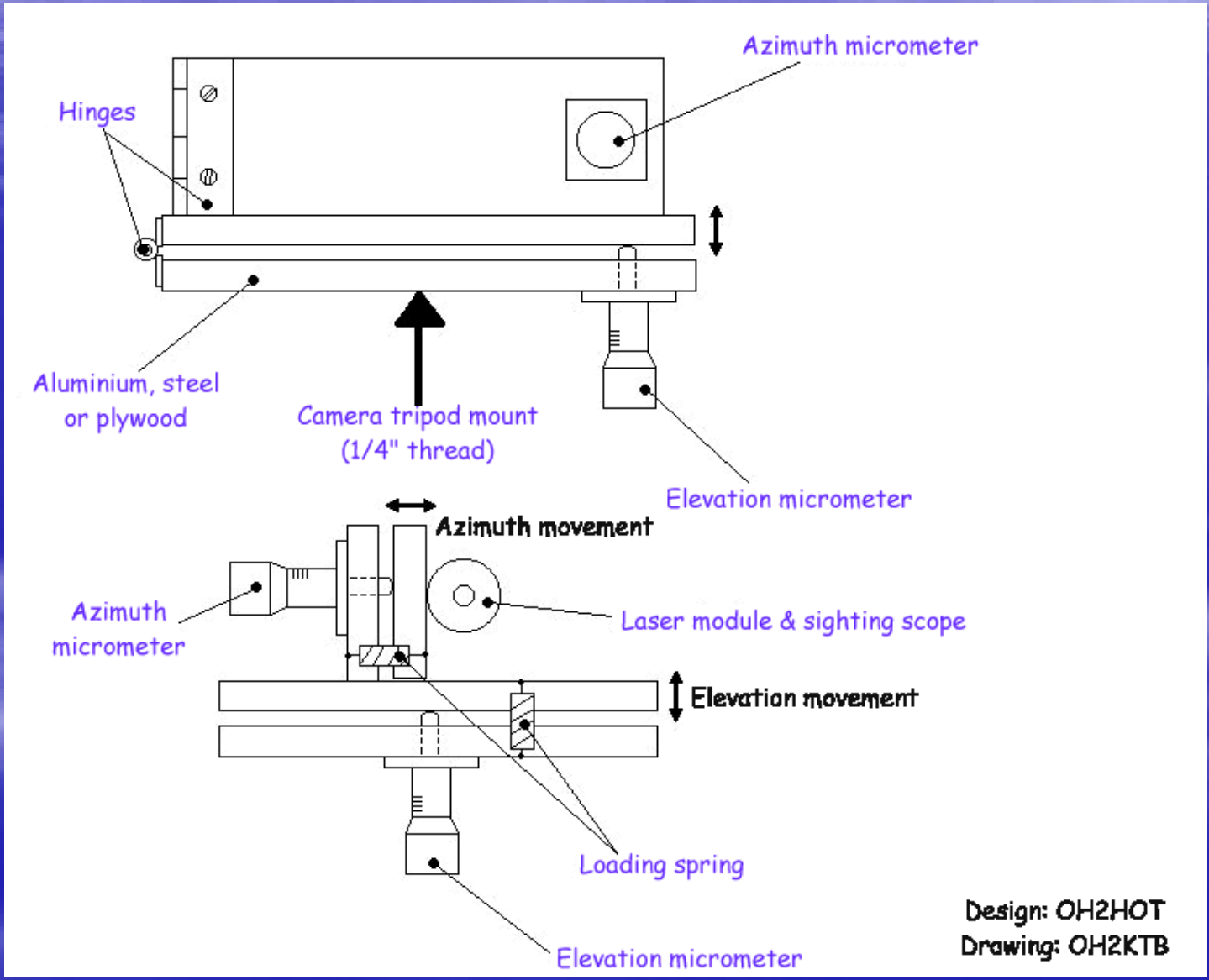
Laser output

Azimuth fine adjust

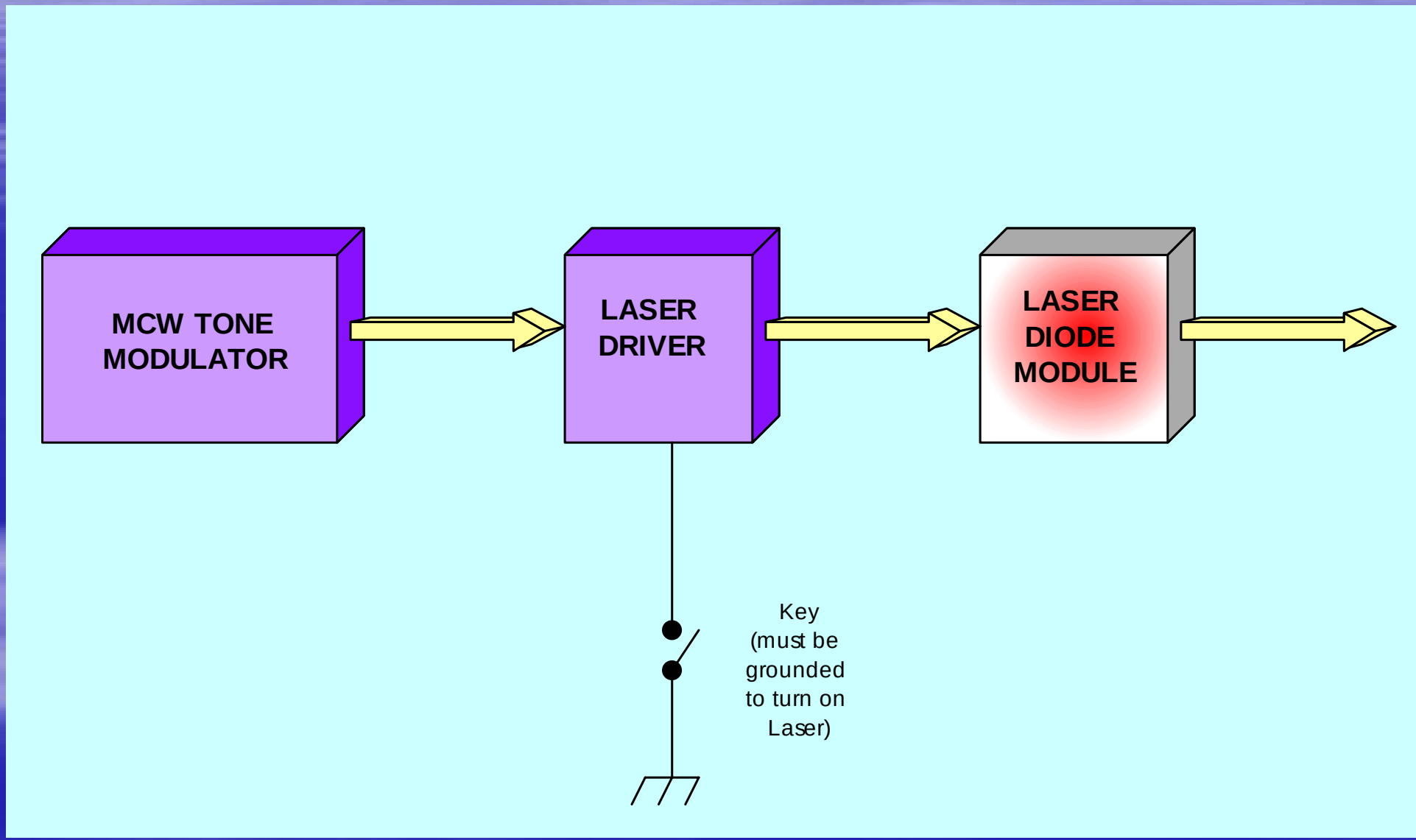
Elevation fine adjust

Tripod pan and tilt for coarse az/el adjust

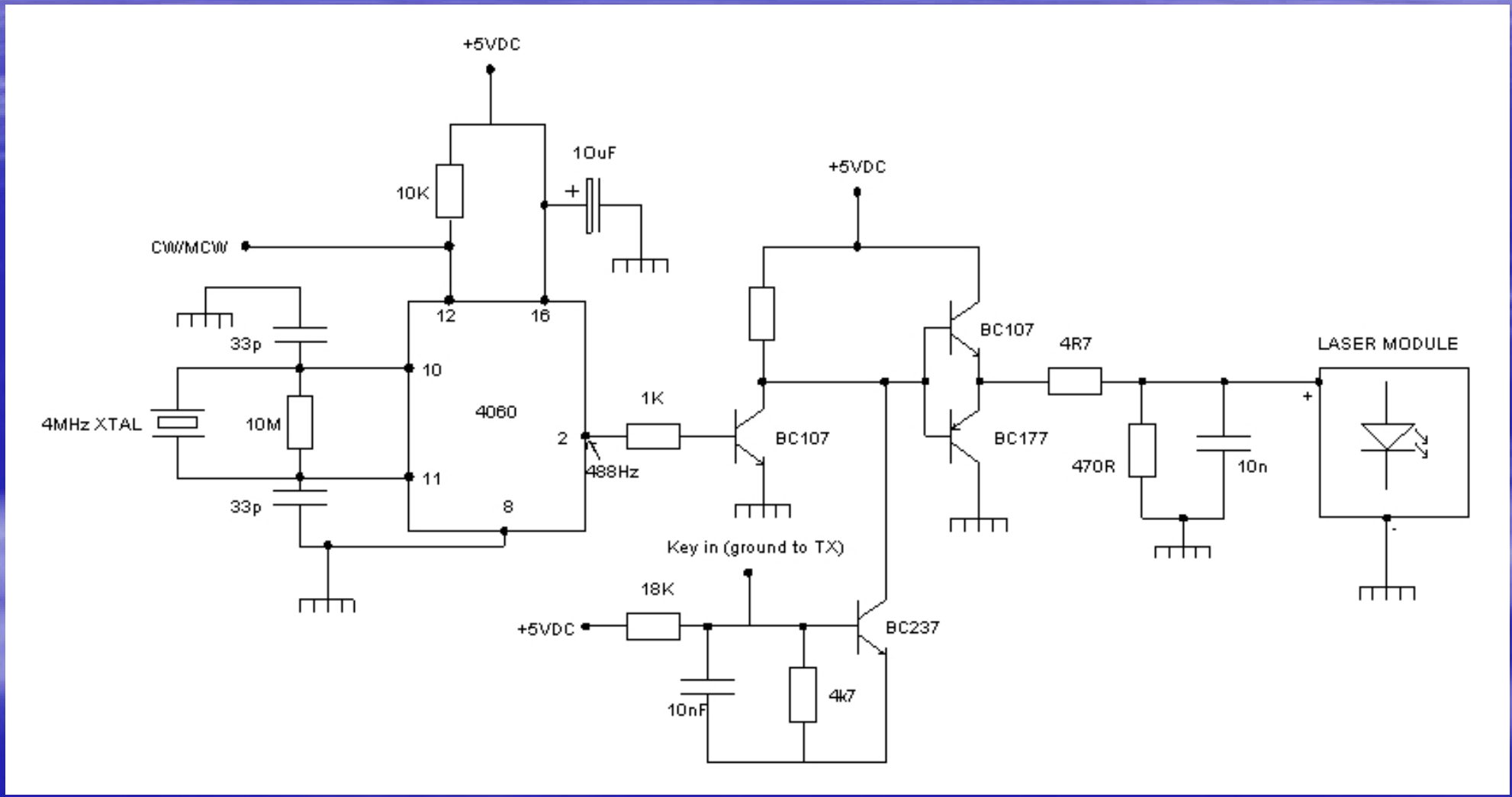
Azimuth and Elevation adjustment is very critical ….



SIMPLE LASER DIODE TRANSMITTER

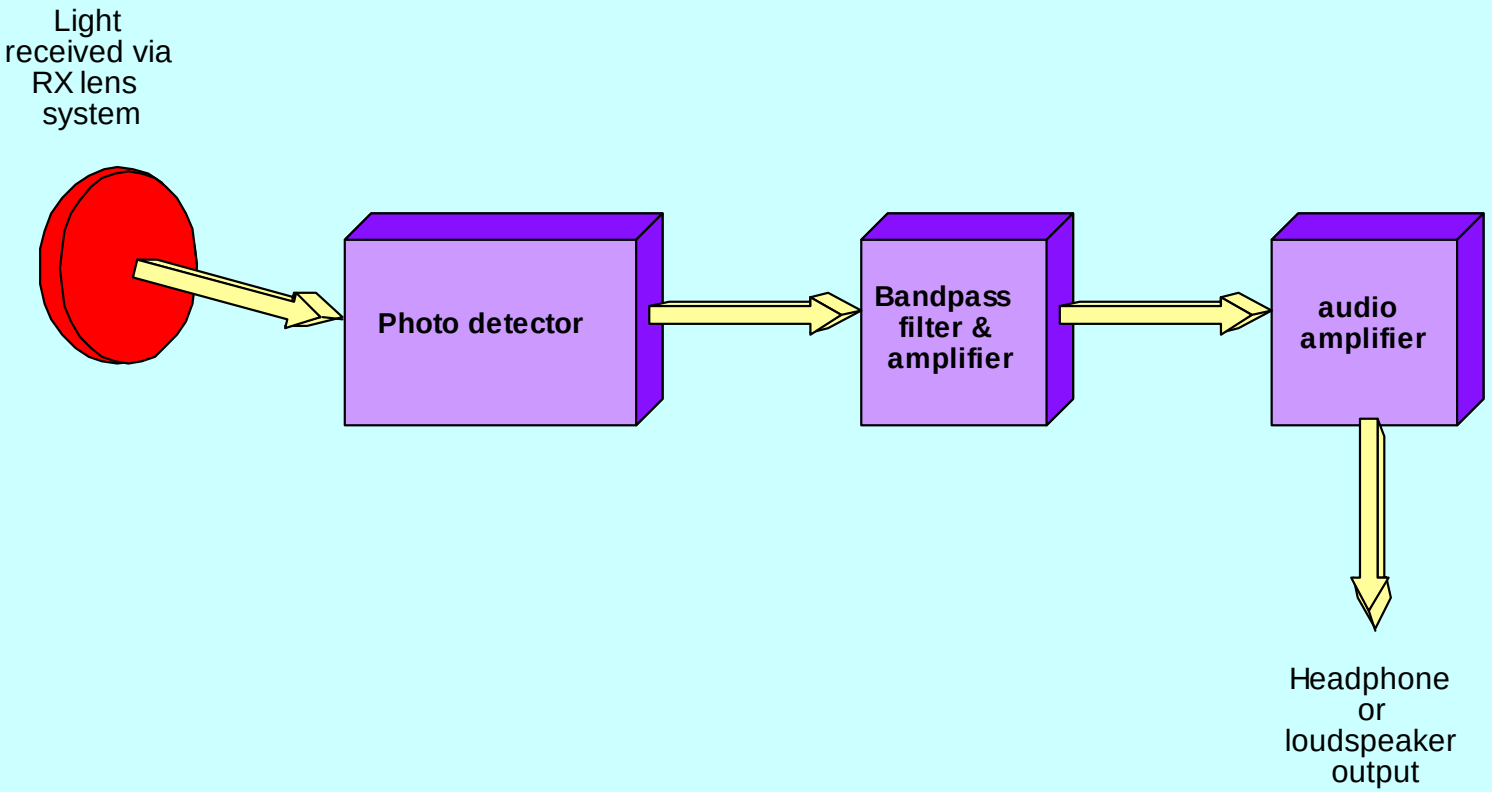


G8AGN LASER MCW TRANSMITTER

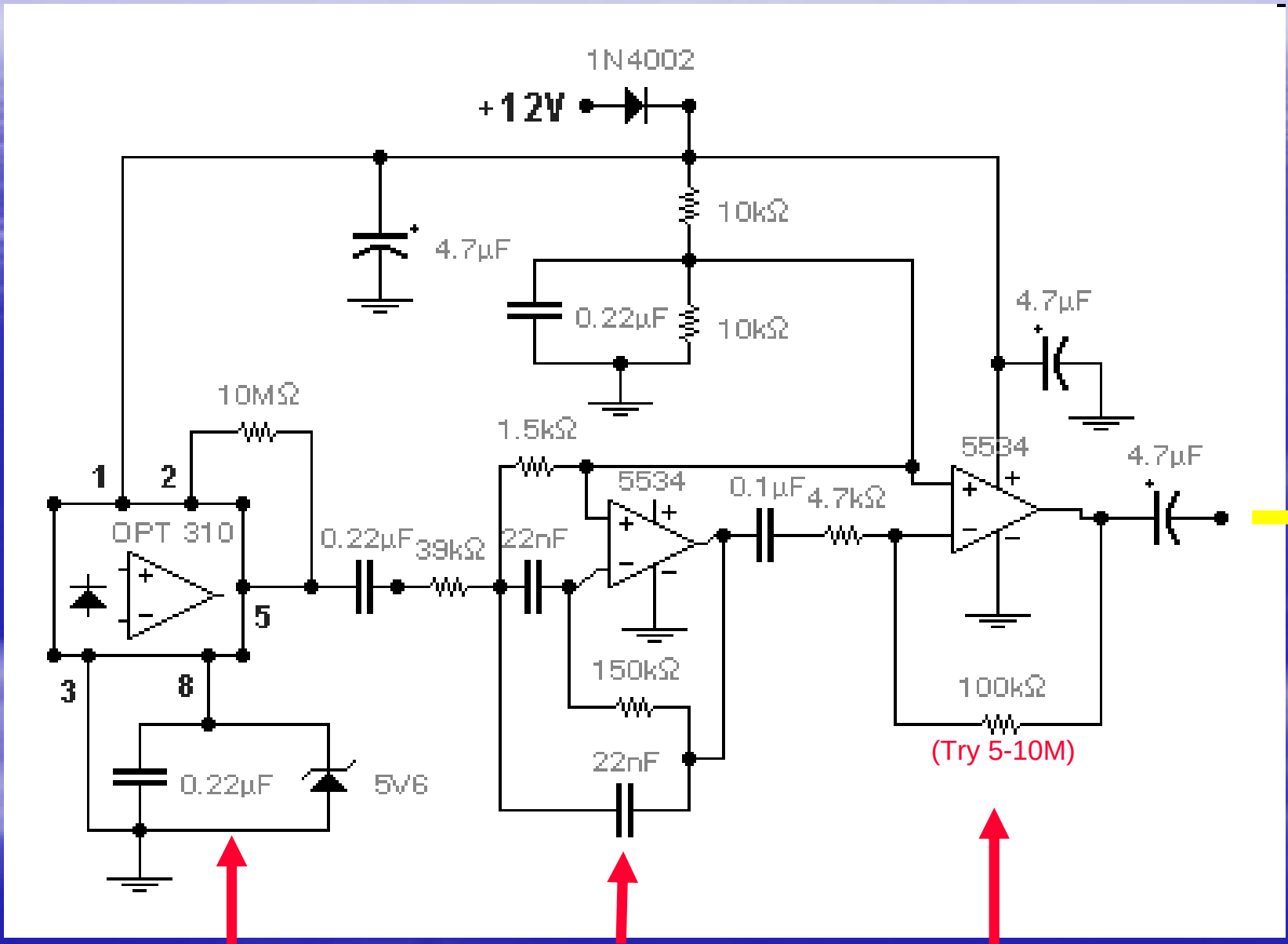


G8AGN/G3PHO
Light wave Receiver

SIMPLE LIGHTWAVE RECEIVER

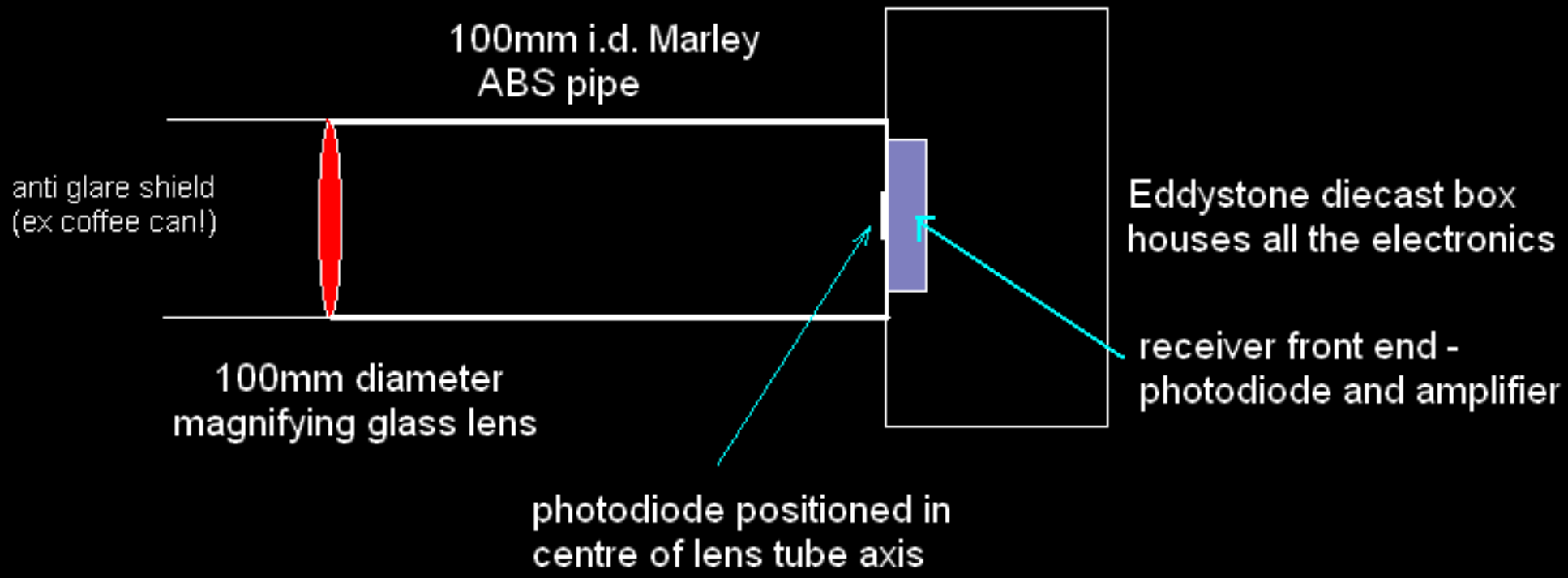


G3PHO Light wave Receiver



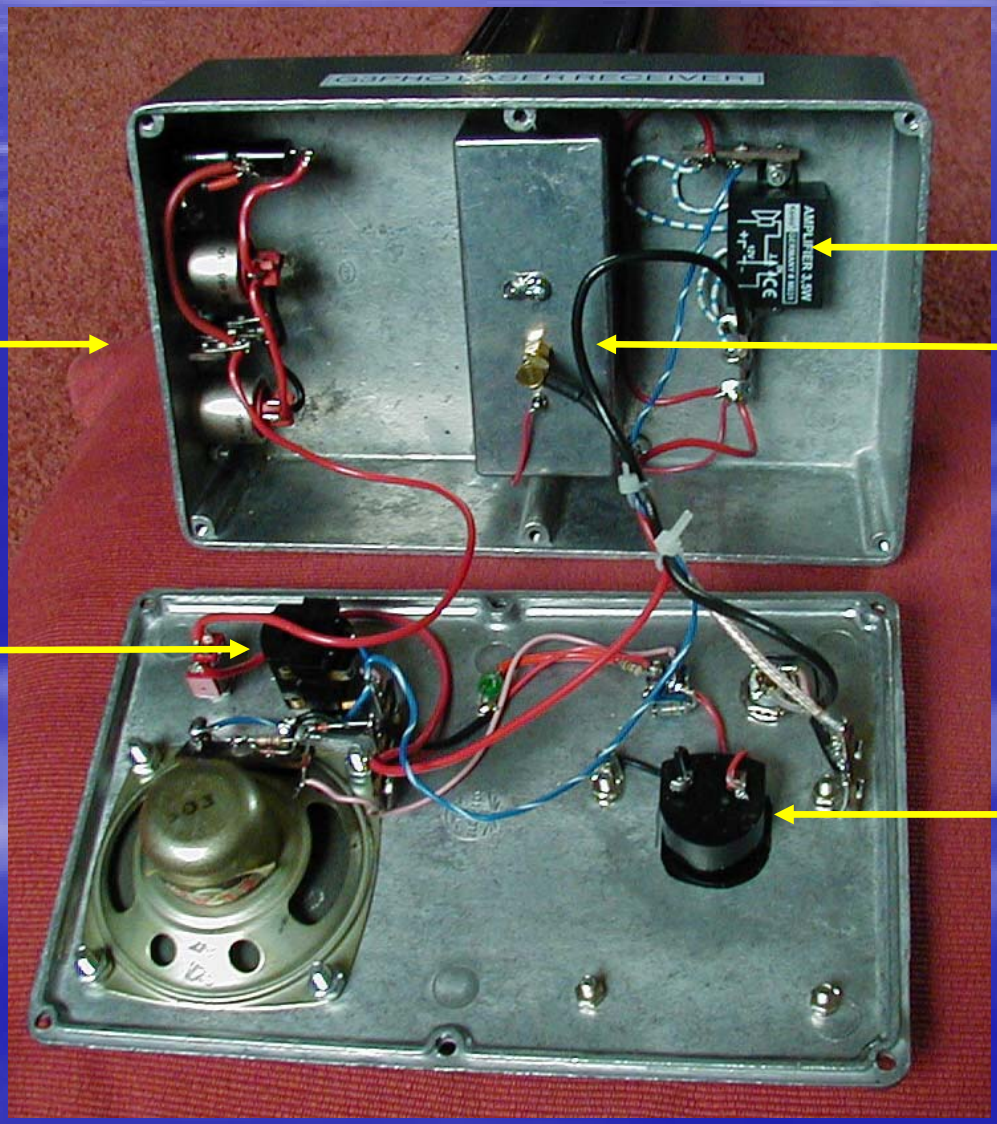
G3PHO Light wave Receiver

G3PHO Light wave Receiver

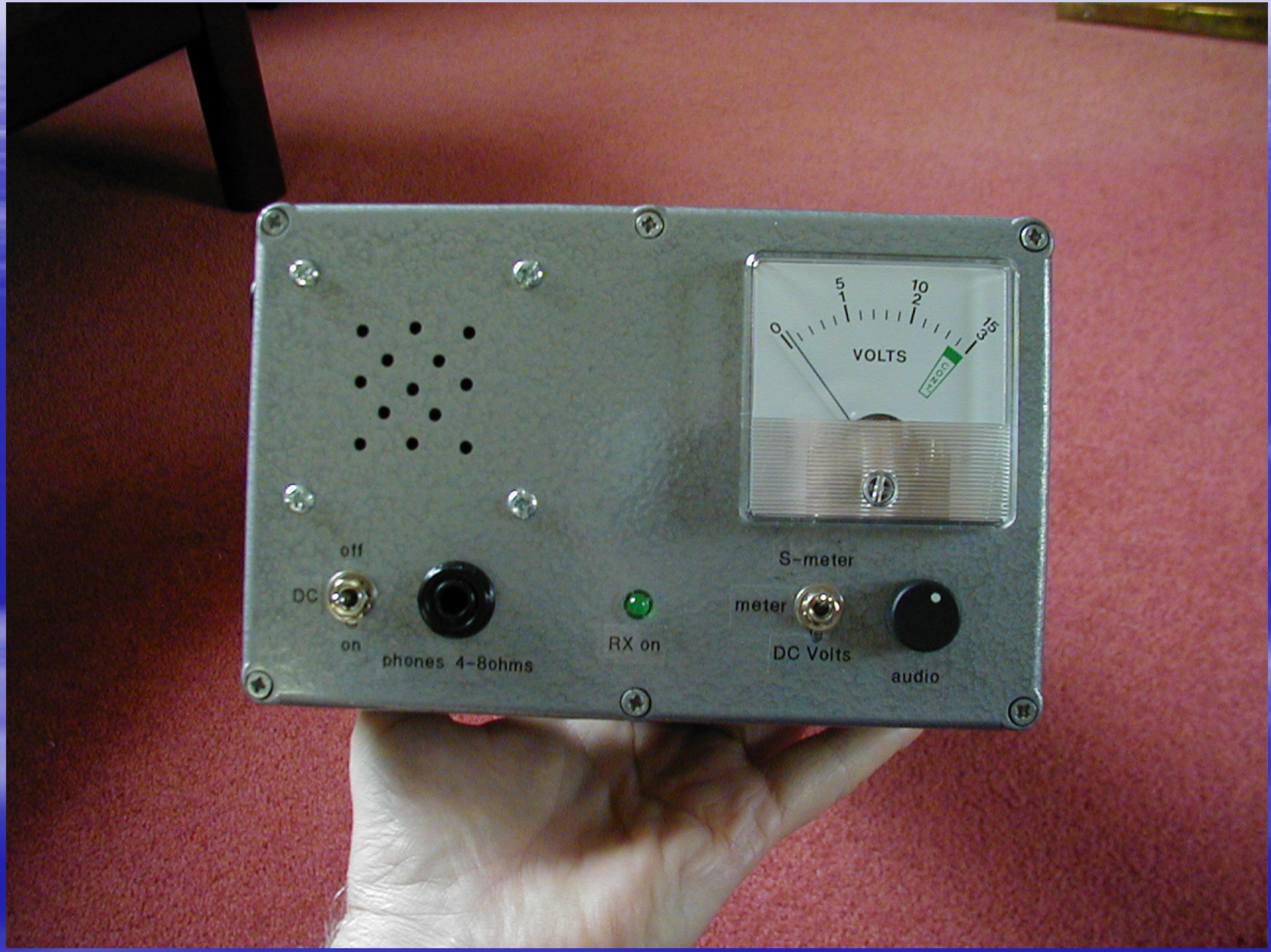


LIGHTWAVE RECEIVER - MECHANICAL CONSTRUCTION

G3PHO Light wave Receiver



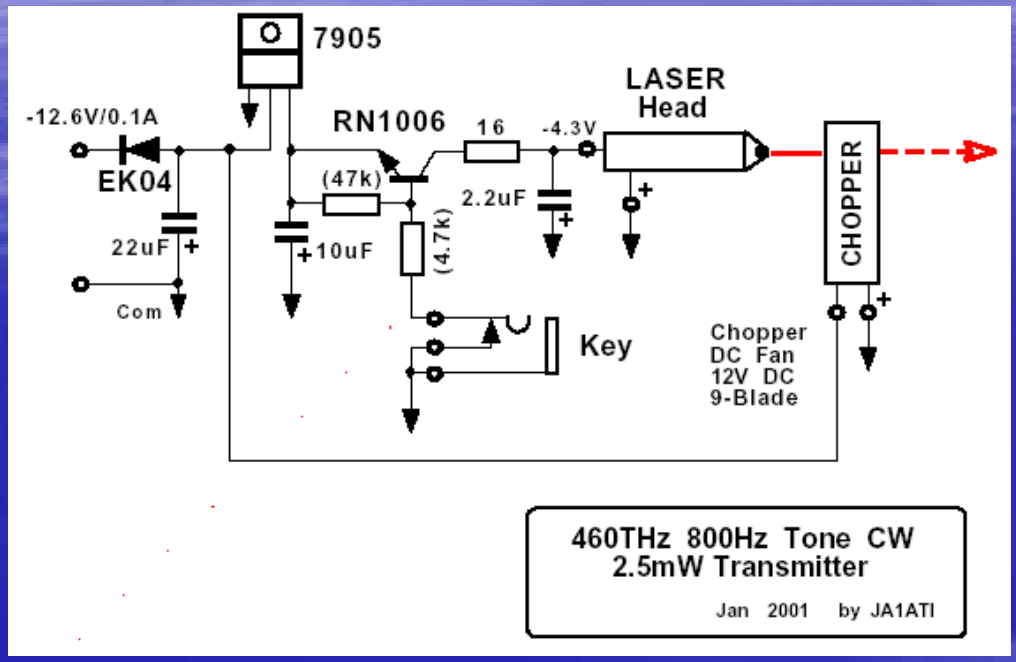
G3PHO Light wave Receiver

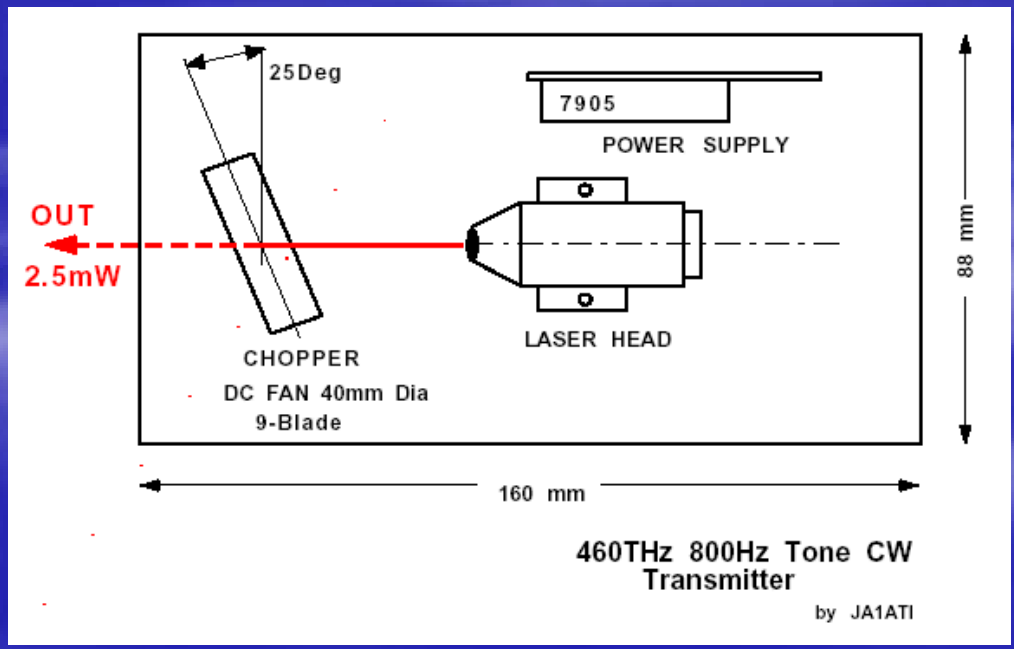


G3PHO Light wave Receiver

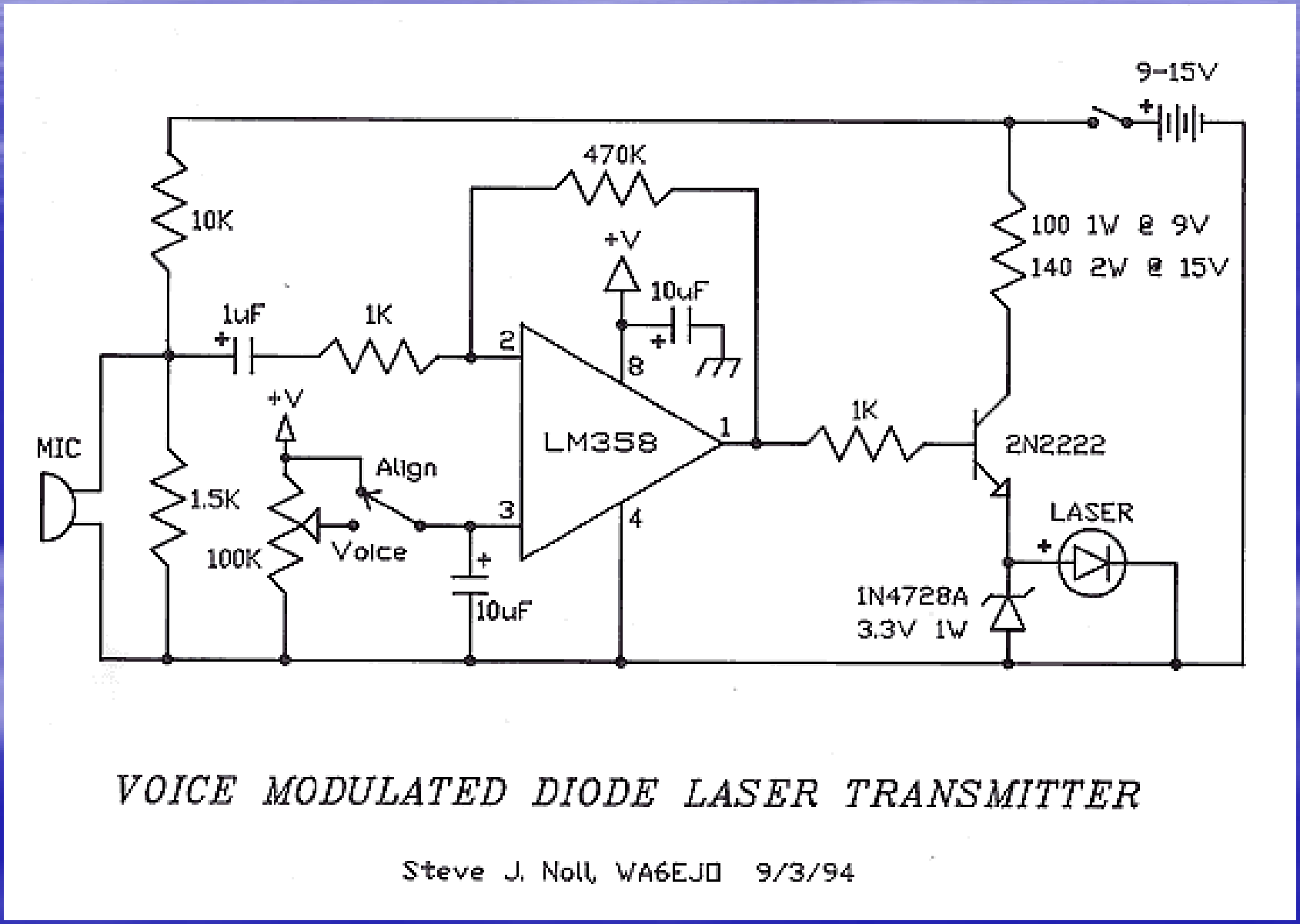
A sturdy tripod is essential

ALTERNATIVE CIRCUITS





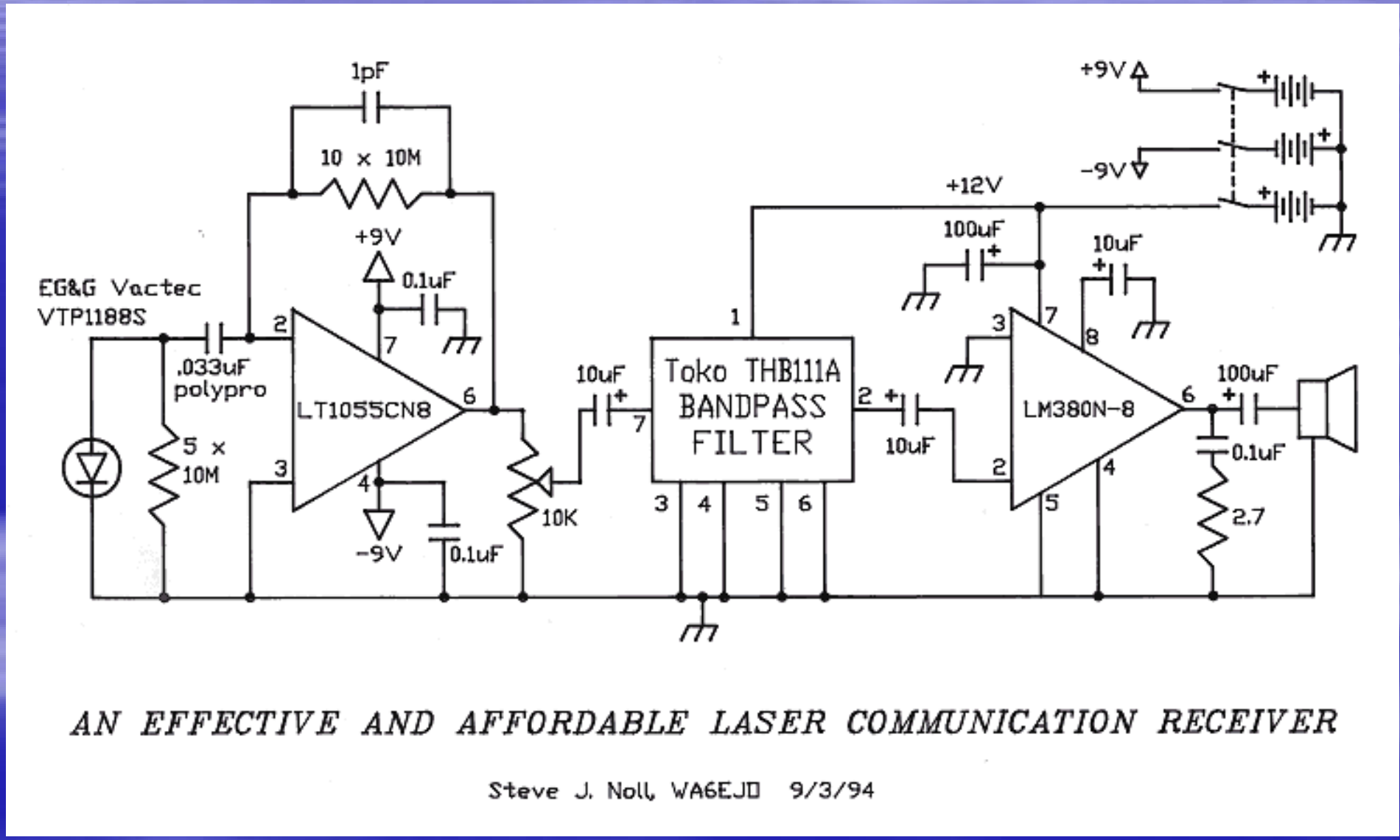
ALTERNATIVE CIRCUITS



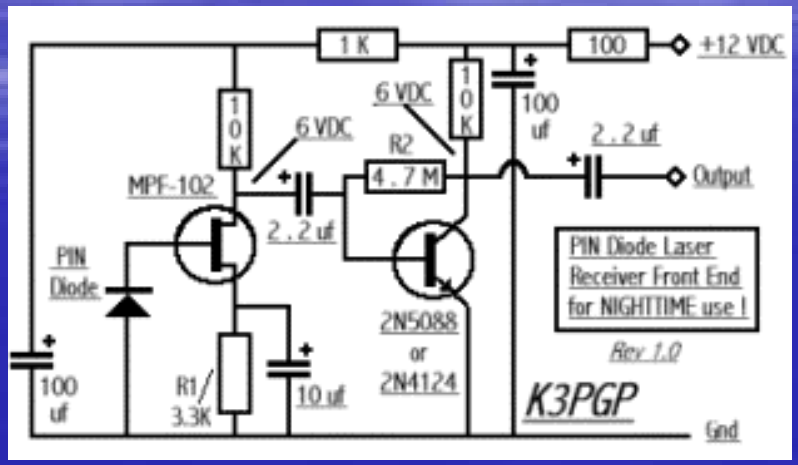
VOICE MODULATED DIODE LASER TRANSMITTER

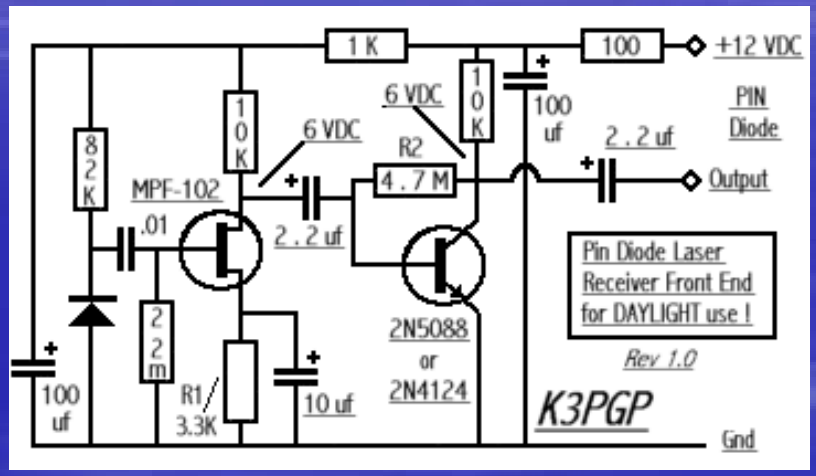
Steve J. Noll, WA6EJO 9/3/94

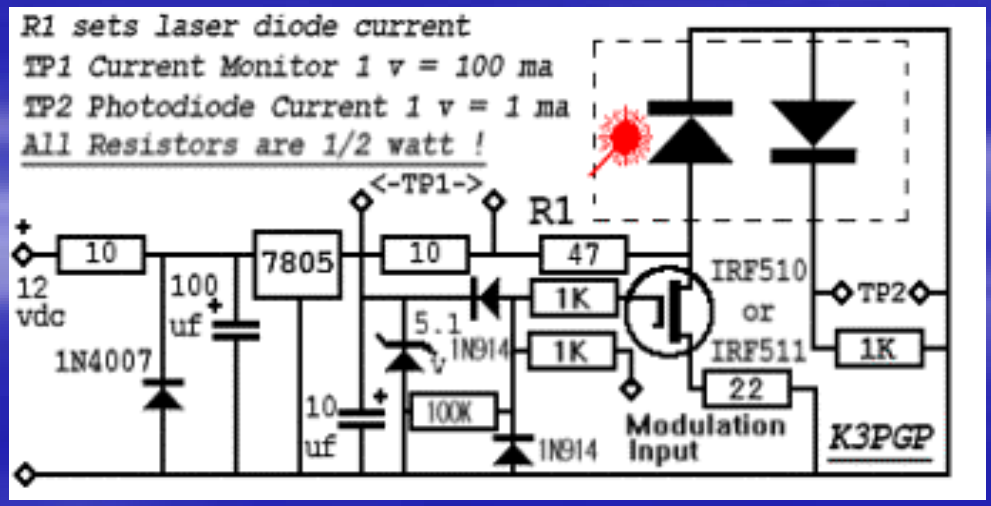
ALTERNATIVE CIRCUITS



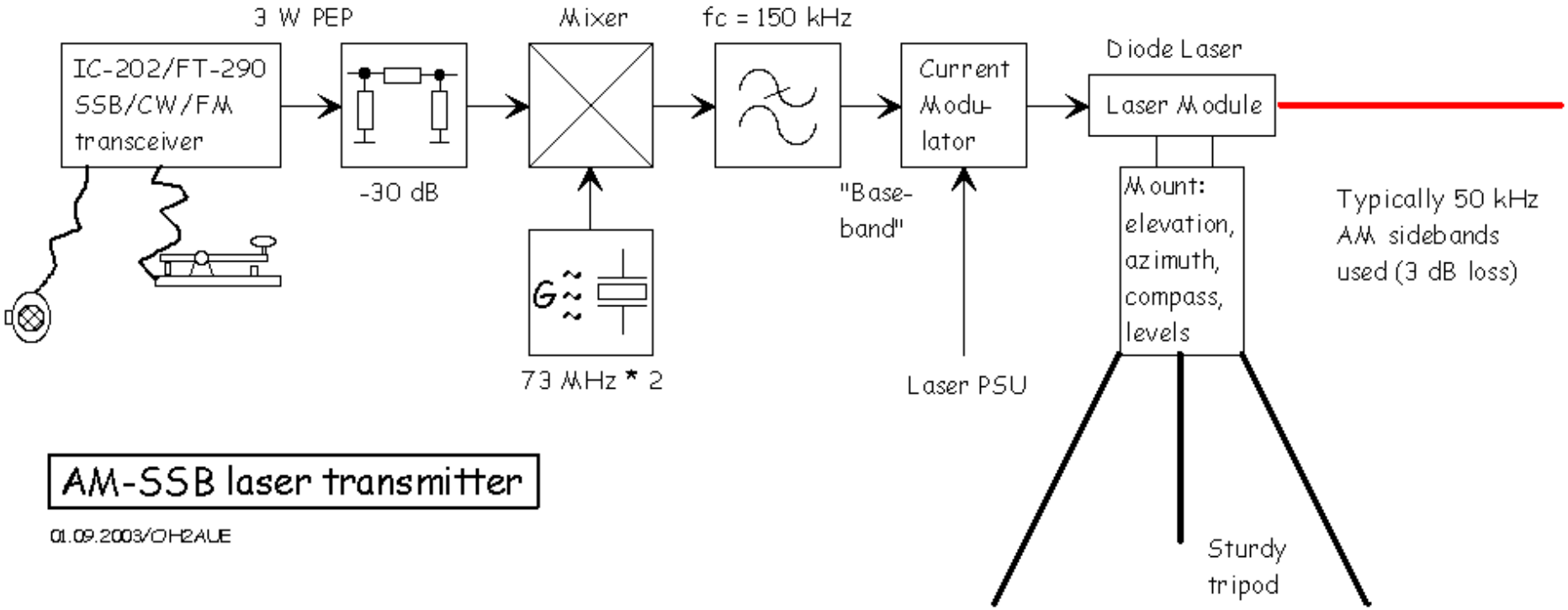
K3PGP LIGHTWAVE CIRCUITS





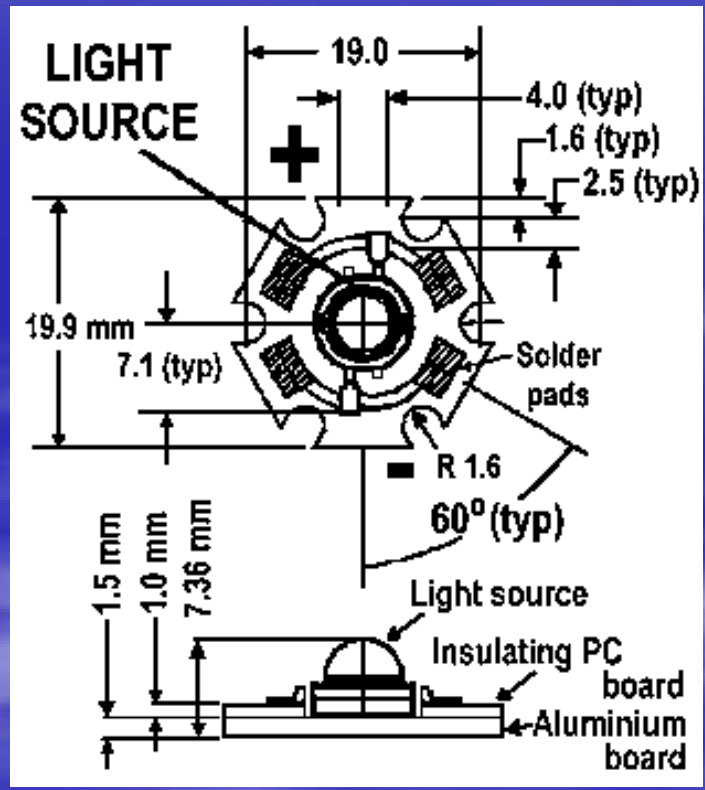


MULTIMODE LIGHTWAVE TRANSCEIVER



Laser Transceiver by G6UAJ

High power light source – the Luxeon



PRACTICAL RESULTS

- How far can we communicate by light?
- What Dx records have been achieved?
- Local lightwavers..G8AGN, G3PHO and G0EWN
- UK record and “firsts”

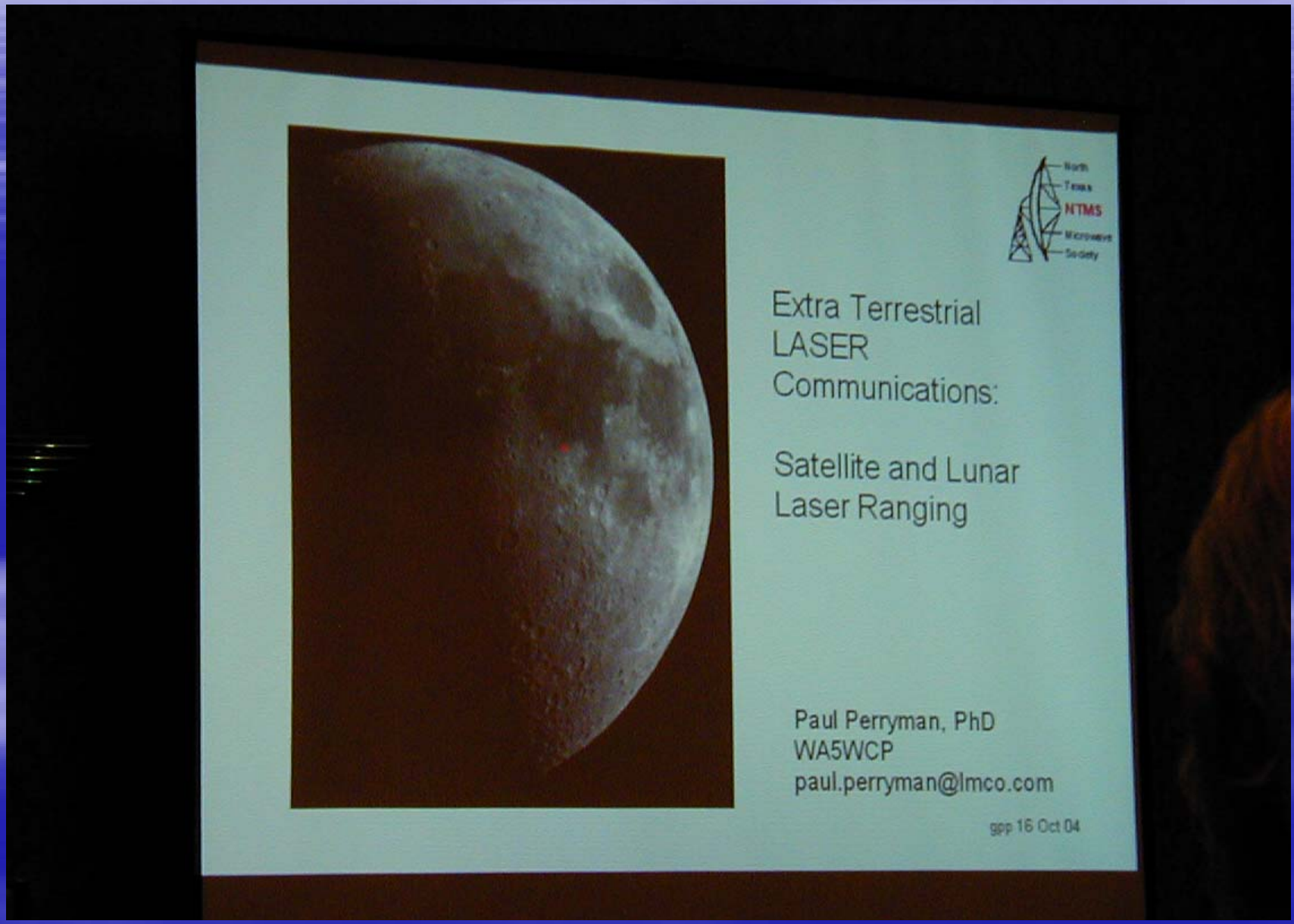
How far can we get by light?

- The all-time record for optical communications using Morse code via light was made by heliograph (mirror!).
- This record was established by the United States Army Signal Sergeants, from Uncompaghre Peak, Colorado to Mount Ellen in Utah.
- The distance 183 miles or 294.7km !
- The date 1896 !!!

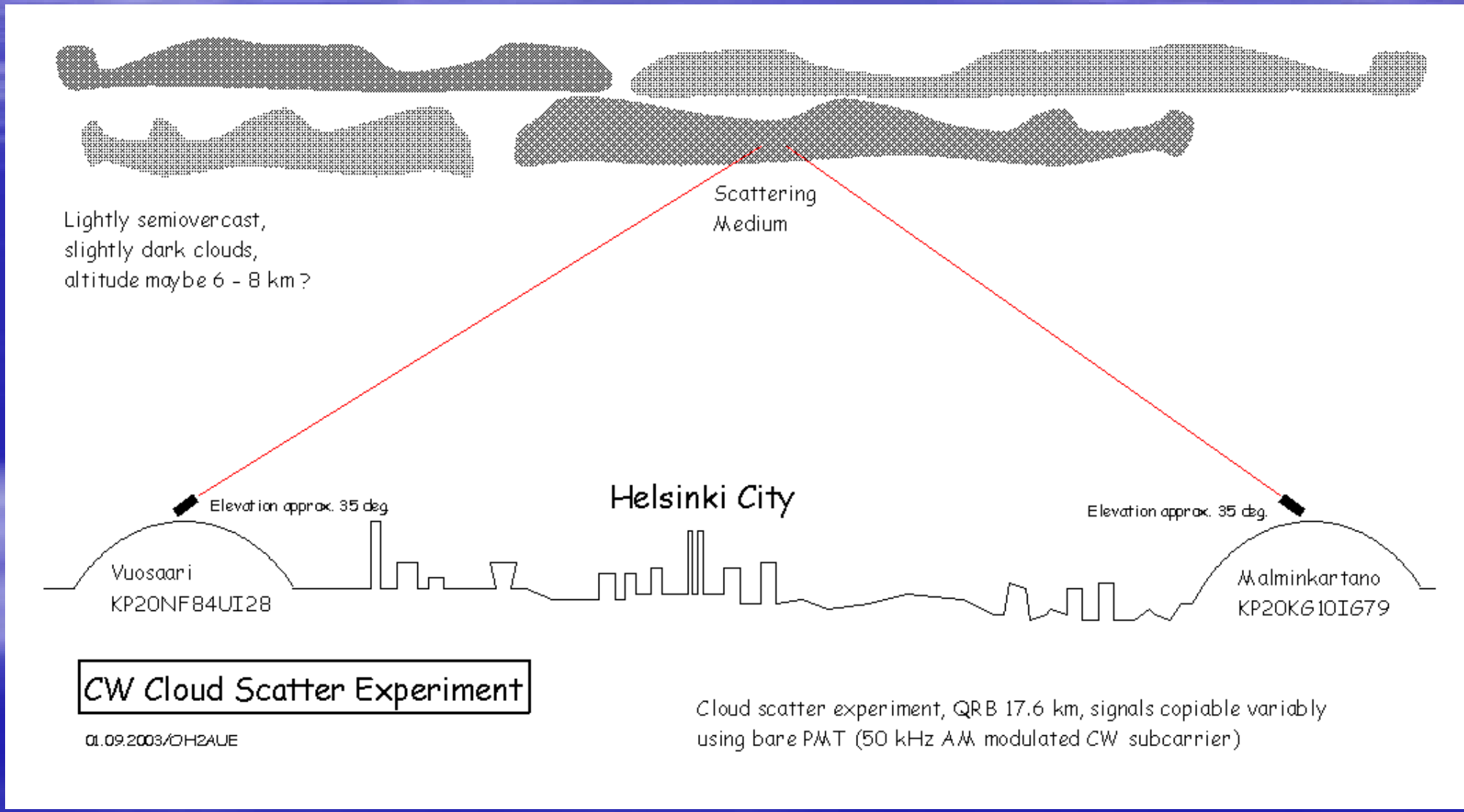
AMATEUR LIGHT WAVE DX

- **Two way audio modulated coherent red light (474THz or 630nm) = 92km. WA6EJO and K6MEP in June 1991**
- **Two way MCW record using red HeNe lasers = 192.4km (KC7AED to WB7VVD)**
- **World record optical DX is 248km (WA7CJO, KY7B/7 and WA7YLI. Used violet light (678THz or 442nm). 15mW HeCd laser. MCW modulated**
- **One way audio DX record = 190km (by the EOS Amateur Radio Club in California in May 1963). Used a 125 microwatts HeNE red laser!**
- **World two way audio using non laser (non coherent) light was set up on the 19 February 2005 in Tasmania by VK7MJ and VK7JG: 167.7km**

Whose for moonbounce?



Non Line of Sight Lightwave Communication



LOCAL LIGHTWAVE EXPERIMENTS

- 2004:G8AGN built separate RX and TX and tested both with G3PHO up to 45km
- Early 2005: G3PHO complete his RX
- Early 2005: G0EWN completed his RX
- Feb 2005: Several one way tests between G8AGN and G3PHO and G0EWN
- Presently investigating Luxeons (high power red light generators)

Test across Redmires Reservoir July 2004

G3PHO/P

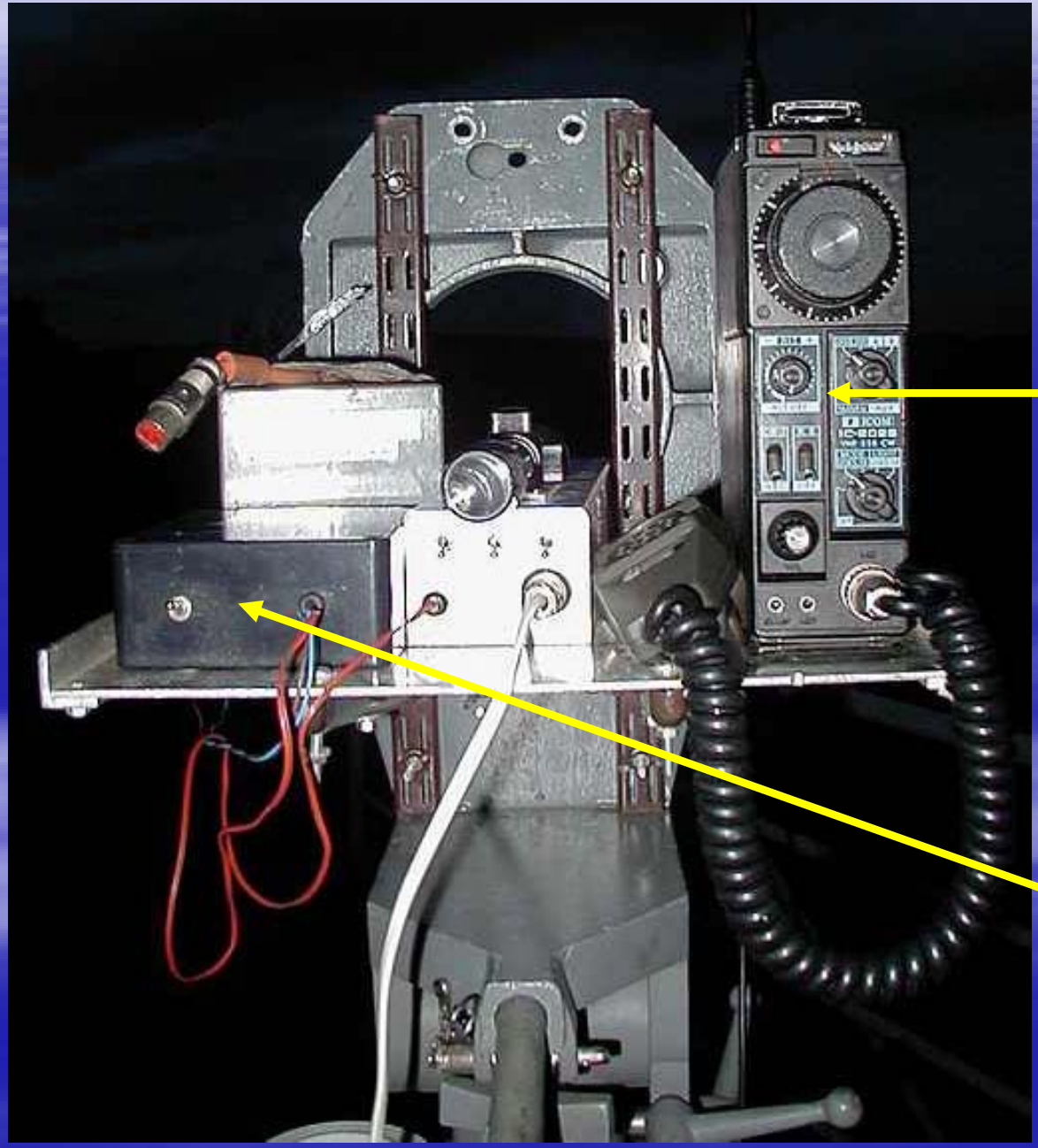
G8AGN/P

Test across Redmires Reservoir July 2004

Bradfield to Roper Hill
August 2004 - 6.7km

G3PHO/P Roper Hill

Setting up a contact



2m talkback:
IC202S

PSU and keyer

Setting up a contact

SIGHTING UP USING A 3 MILLION CANDLE POWER LAMP

Bradfield to Emley Moor
15 September 2004
(approx 25km)

Roper Hill to Gringley on the Hill 8th October 2004

G3PHO and G8AGN's best DX so far: 45.9km

Listen to G3PHO/P's CW signals as heard at G8AGN/P at Gringley on the Hill

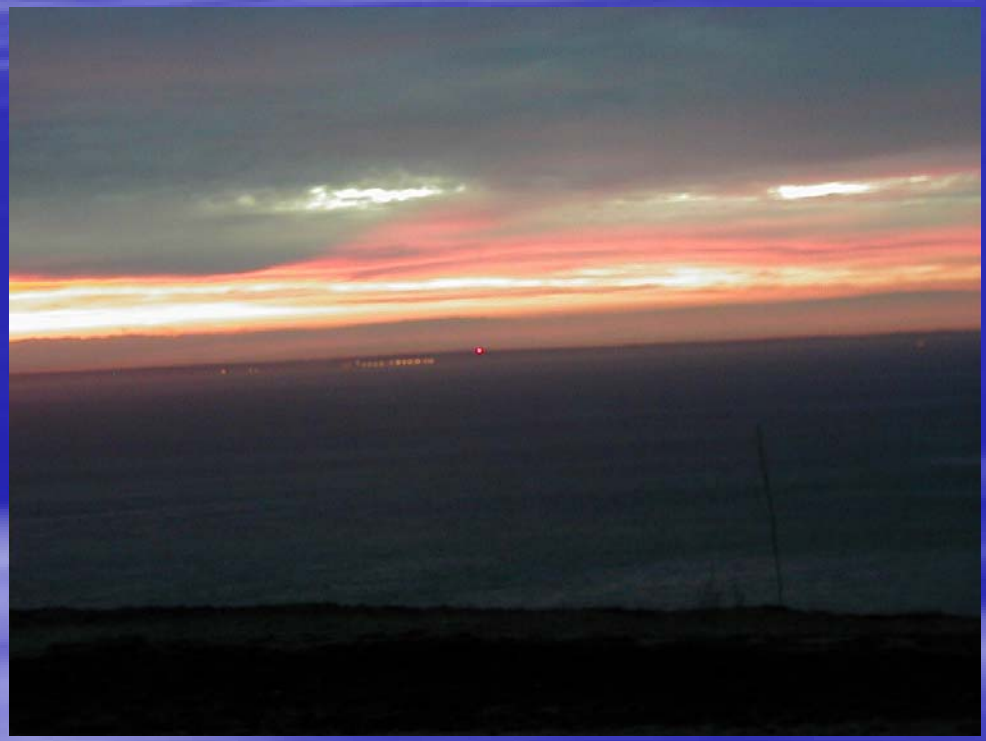
Bradfield to Roper Hill
February 2005

Bradfield to Roper Hill February 2005

G8AGN’s laser as seen at Bradfield

France to England on lightwaves

G8LSD and G0MRF make a world first

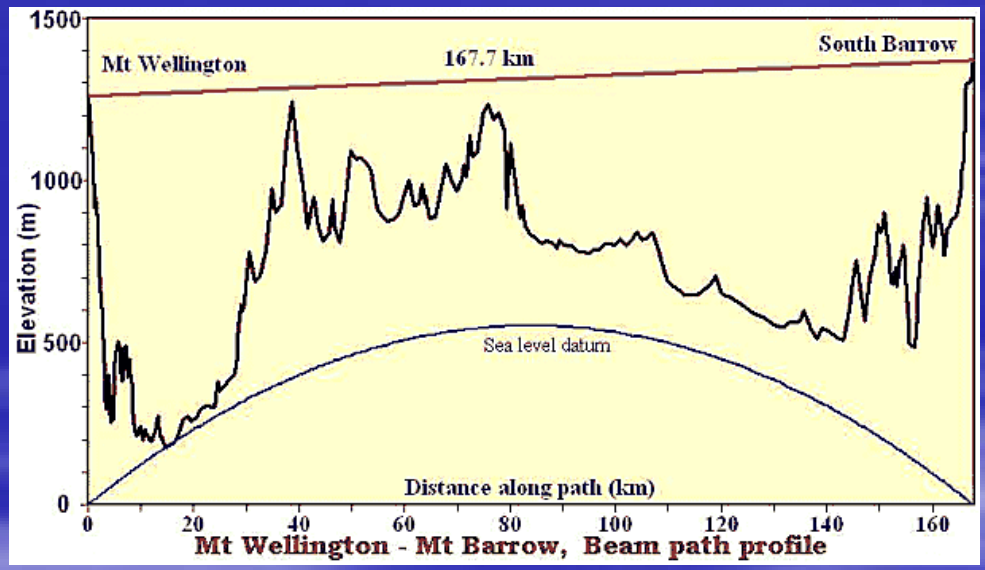


G8LSD's laser as seen from the French side

F/G0MRF/P's laser transmitter and receiver setup

G0MRF and G8LSD
UK Red light Record Holders at 74km

World voice over lightwaves record



World voice over lightwaves record

167.7km (104 miles)

Note: this record used non coherent light … high power luxeons!

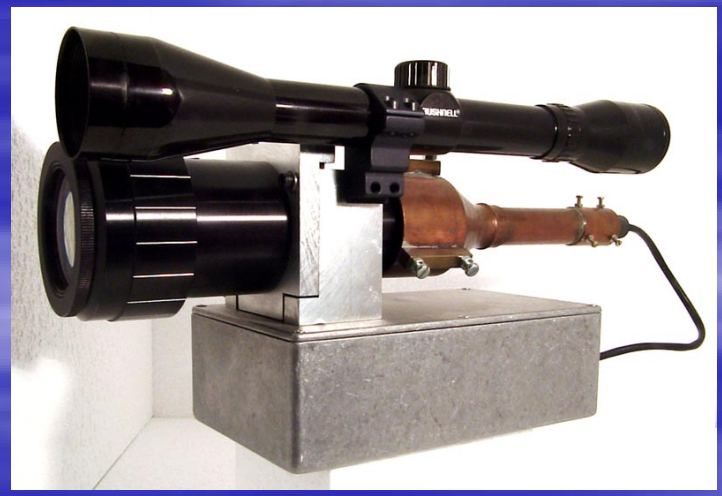
How to make a start on lightwaves

Useful purchases to get you going ..

Cheap laser levels …

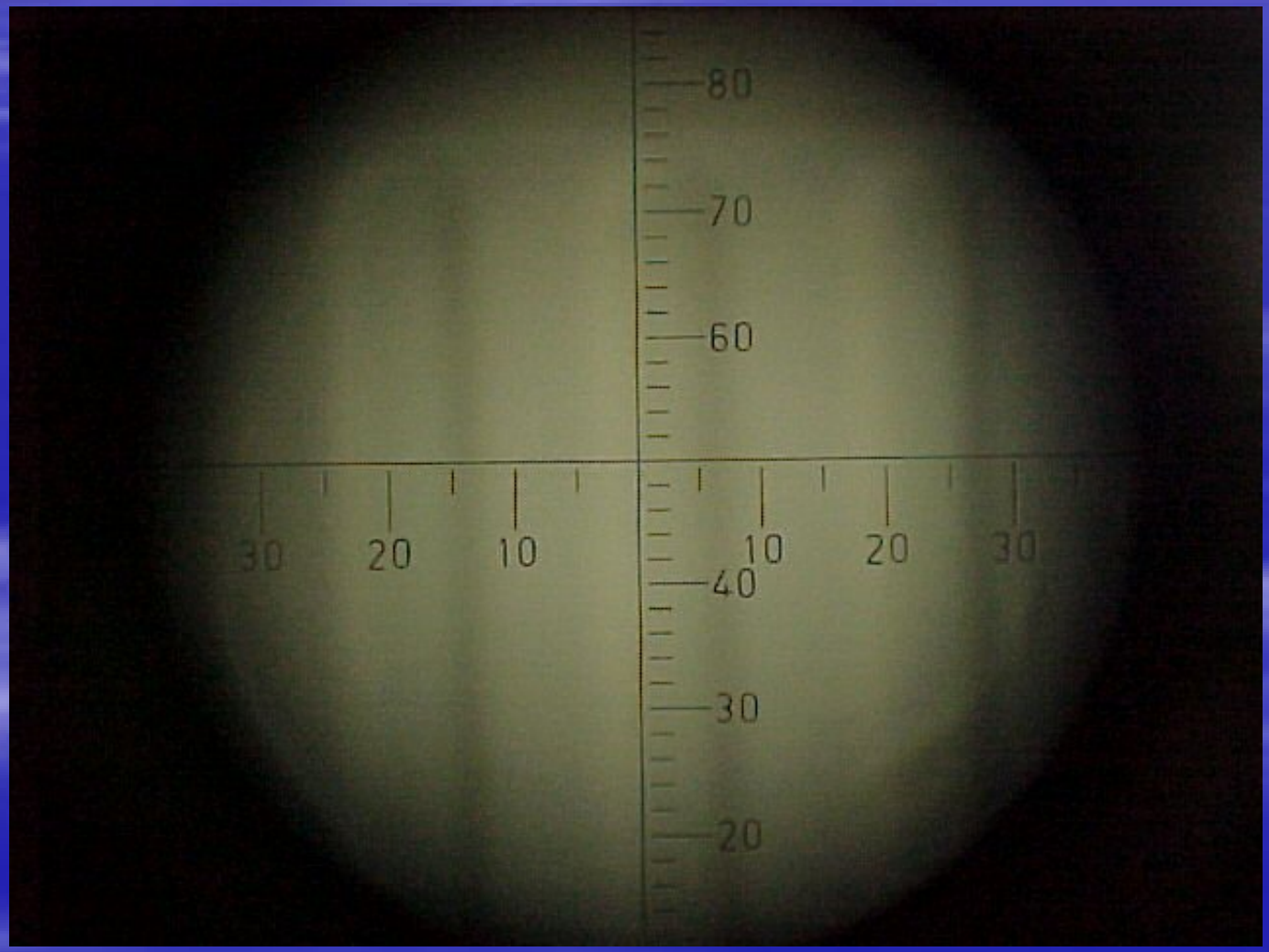
Under £15 at Lidl, Netto and Aldi

Telescopic sights ... under £20 at local gun shops or Ebay



Laser level tripods make a good beginning

Telescopic sight must have cross hairs … the scale is a bonus!



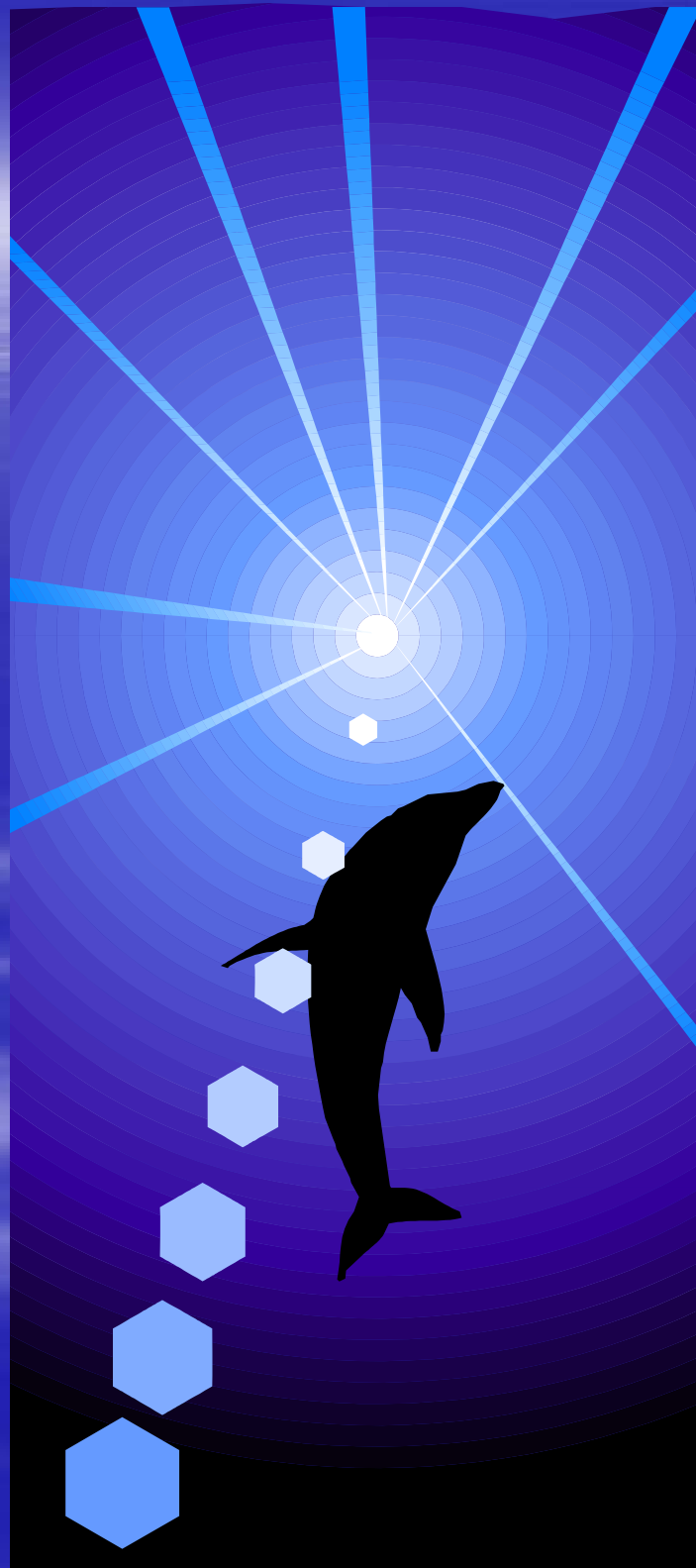
Laser pointers are cheap and plentiful

Sources of information

- Internet ..just Google for amateur lightwaves or laser communications..you'll be amazed!
- Yahoo Laser group and reflector
- G8AGN, G3PHO and G0EWN will be delighted to assist anyone wishing to make a start

So…have you seen the light yet?

Come and join us on the real
“top band” !

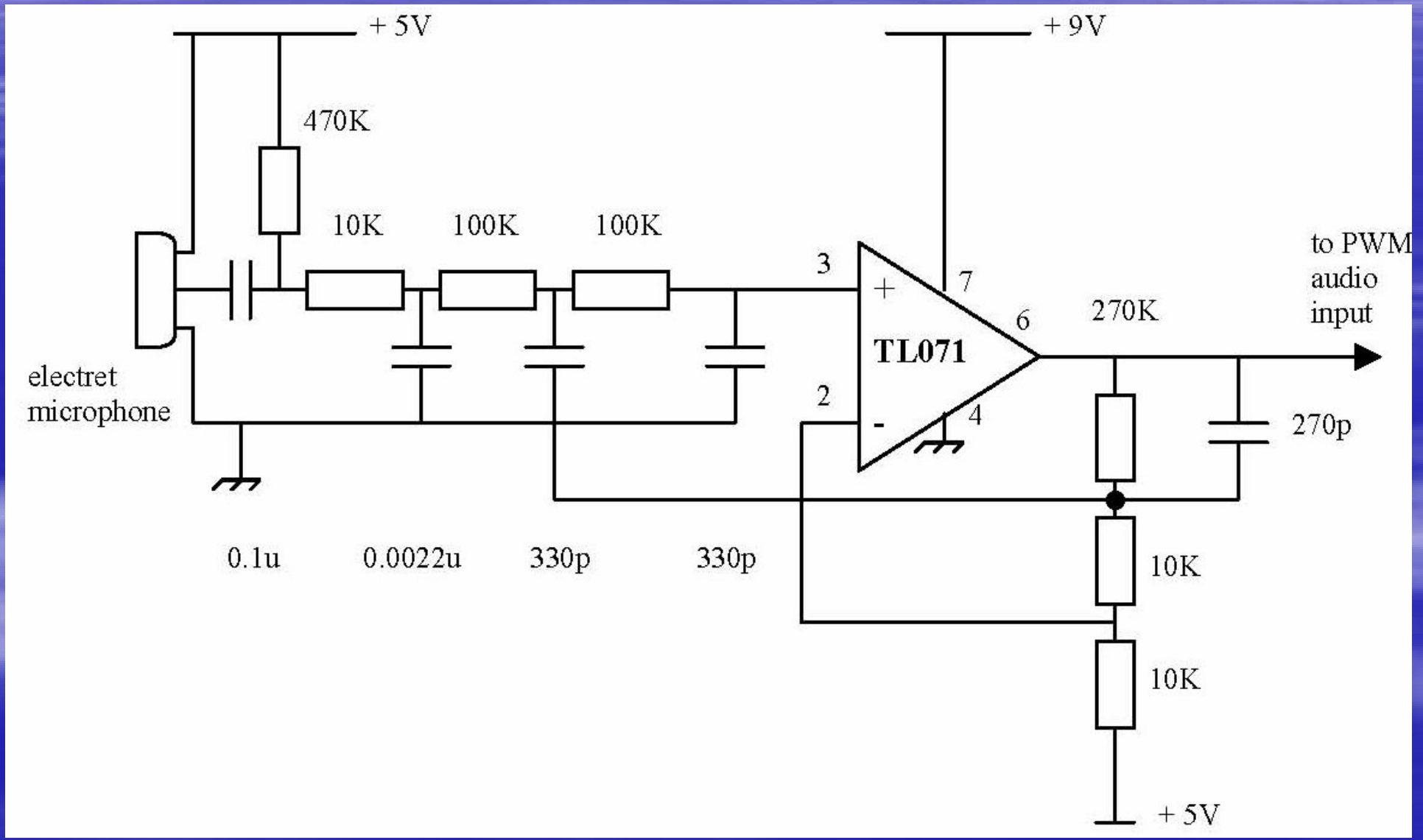


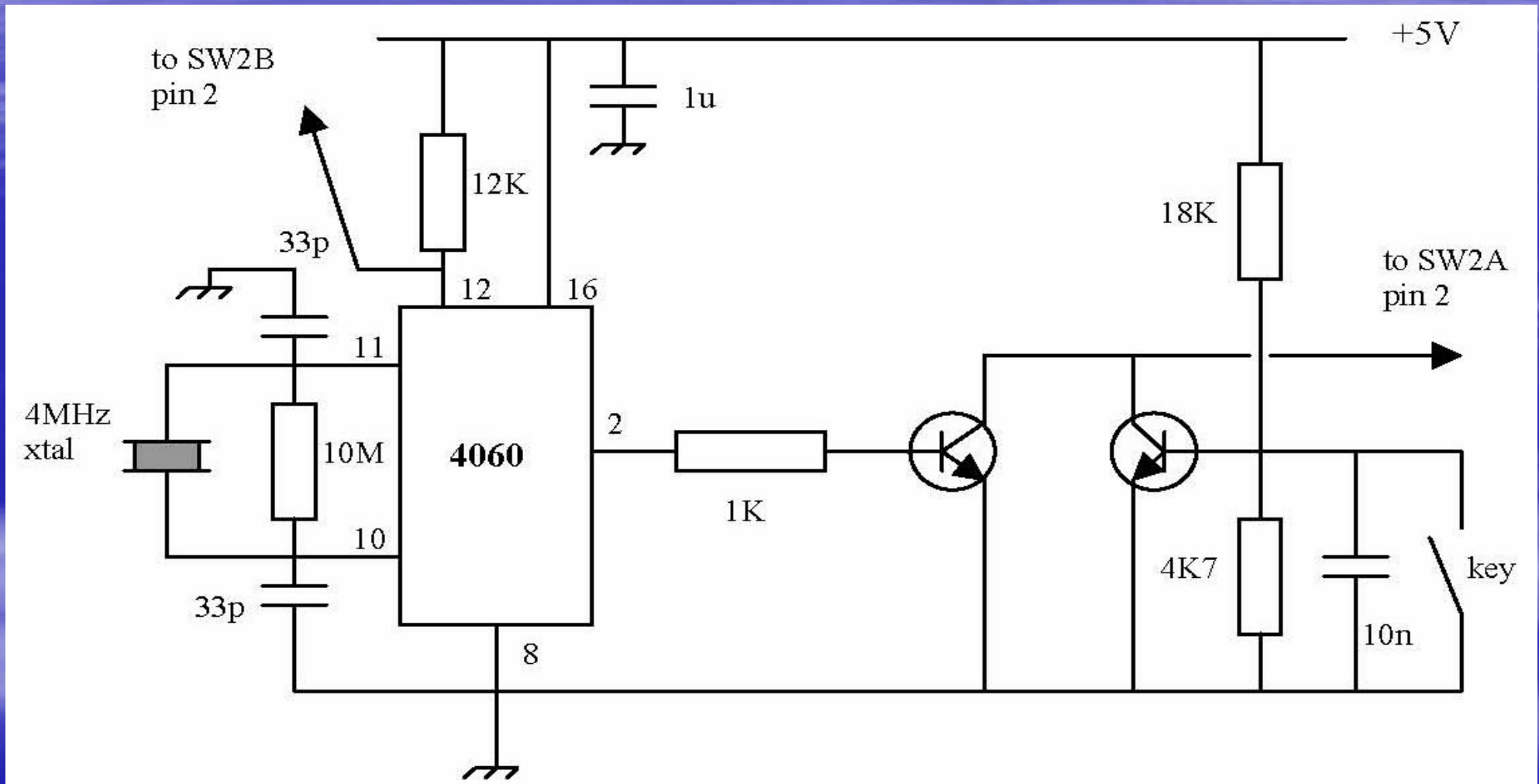
LIGHTS OUT

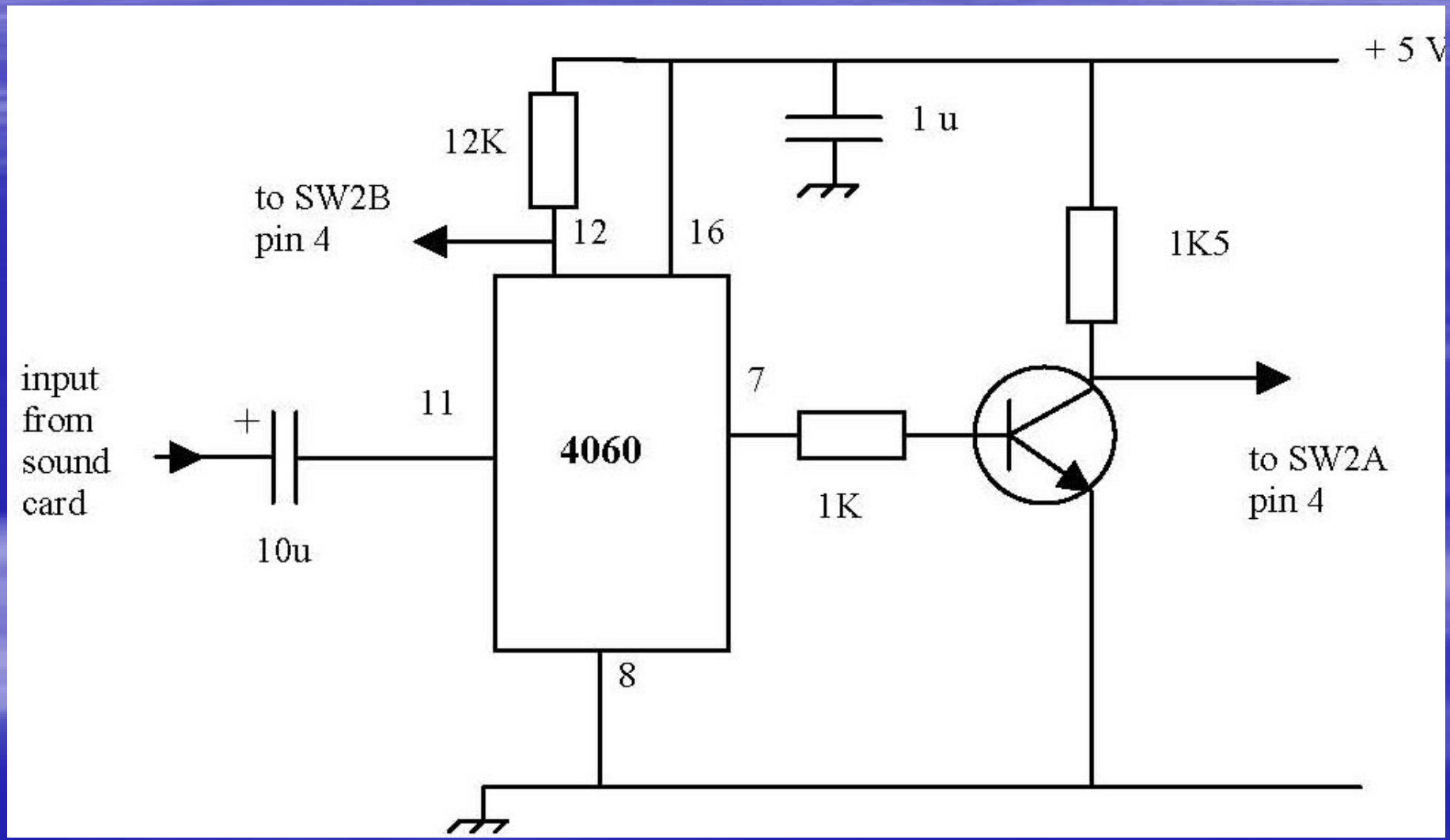
The End

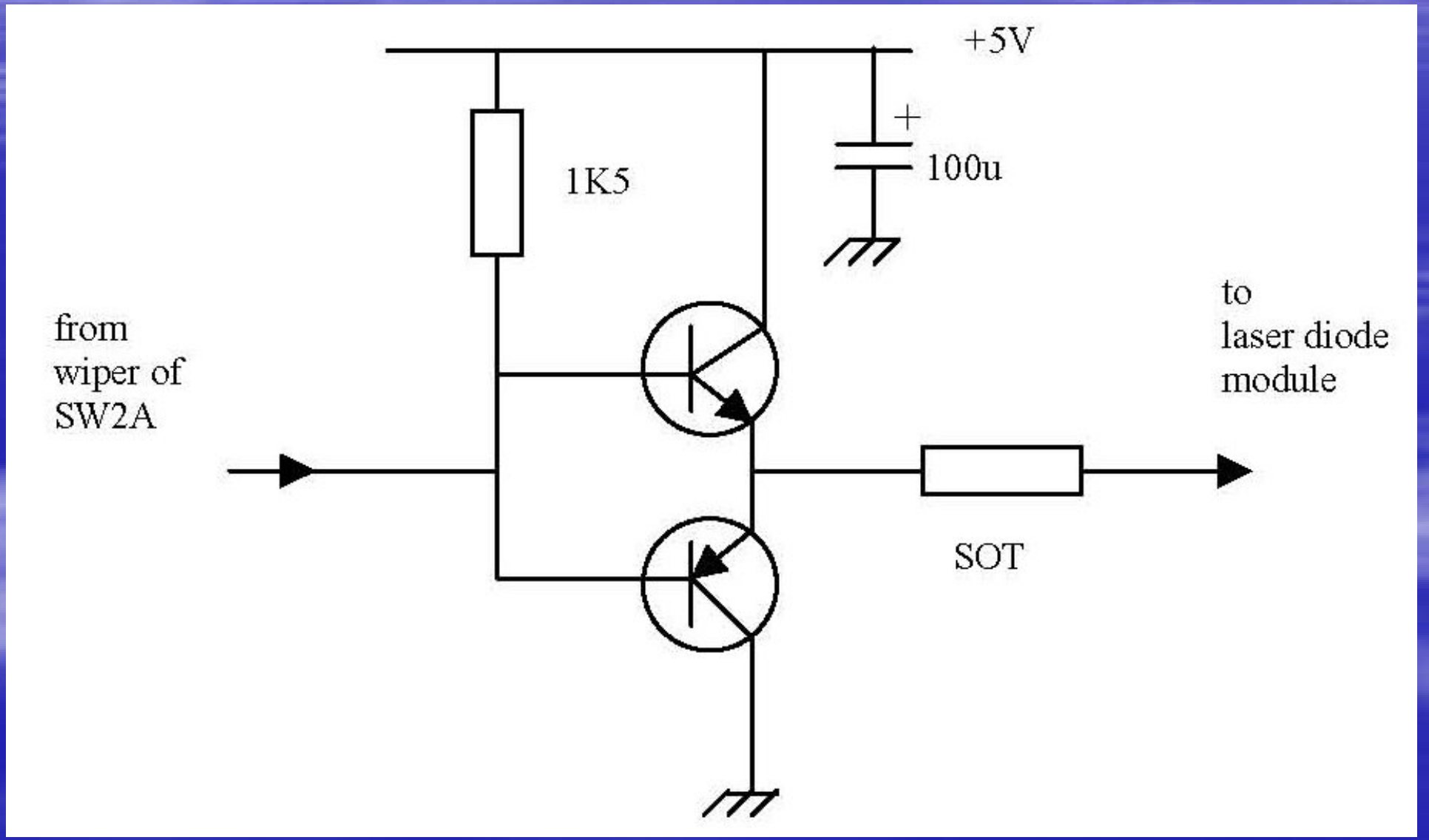
MULTIMODE LASER TRANSMITTER ~ G8AGN

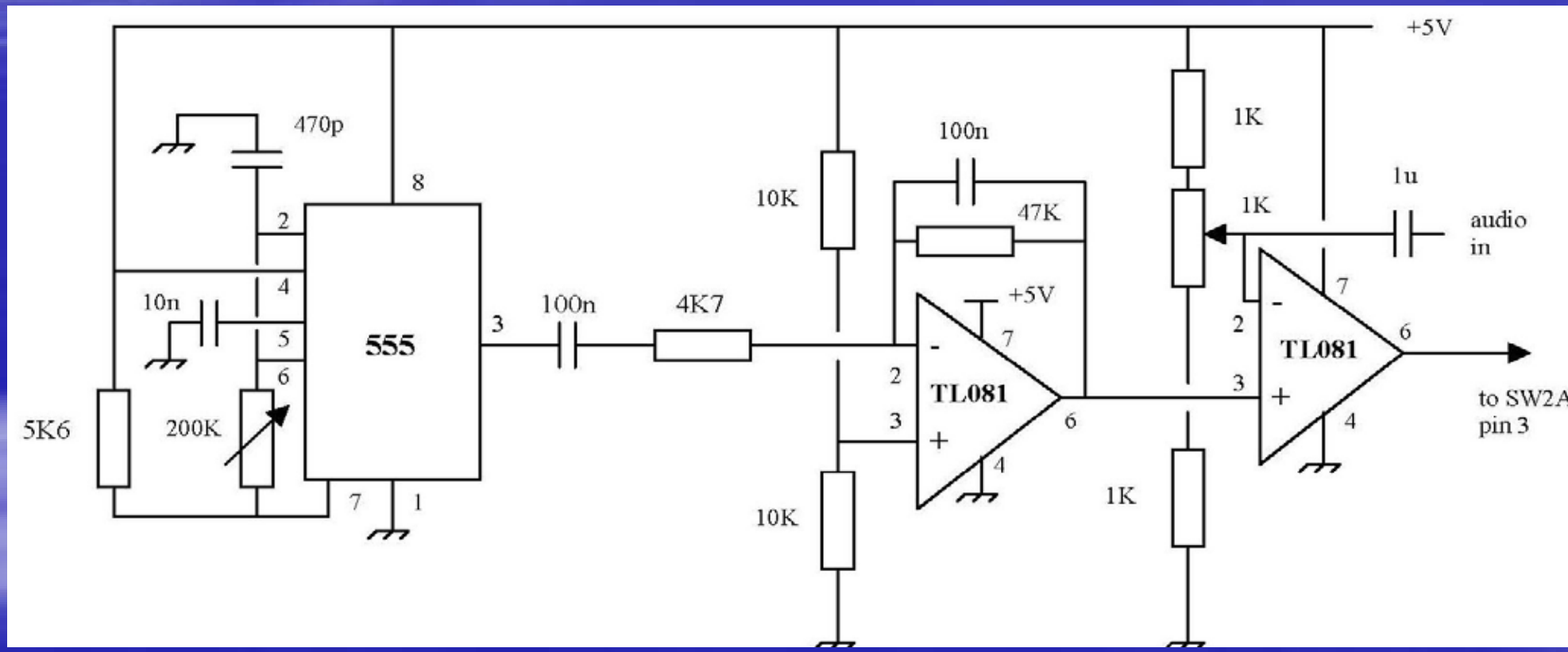
- Uses circuits by G0MRF, G7JTT and David Johnson
- Inexpensive (£2 to £3) laser pointer provides the diode
- Choice of op amps and transistors is not critical
- Simple +12VDC input power supply
- Layout not critical …can be built on Veroboard

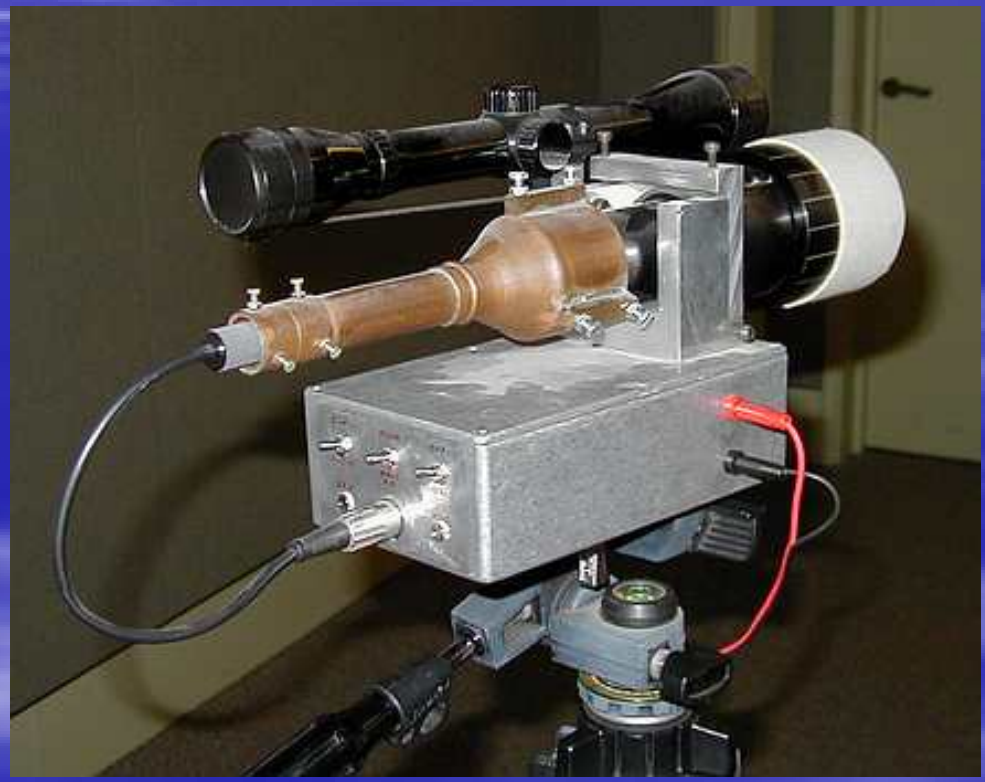

+ 5V
+ 9V
470K
10K
100K
100K
3
7
6
2
4
TL071
270K
to PWM
audio
input
electret
microphone
270p
0.1u
0.0022u
330p
330p
10K
10K
+ 5V

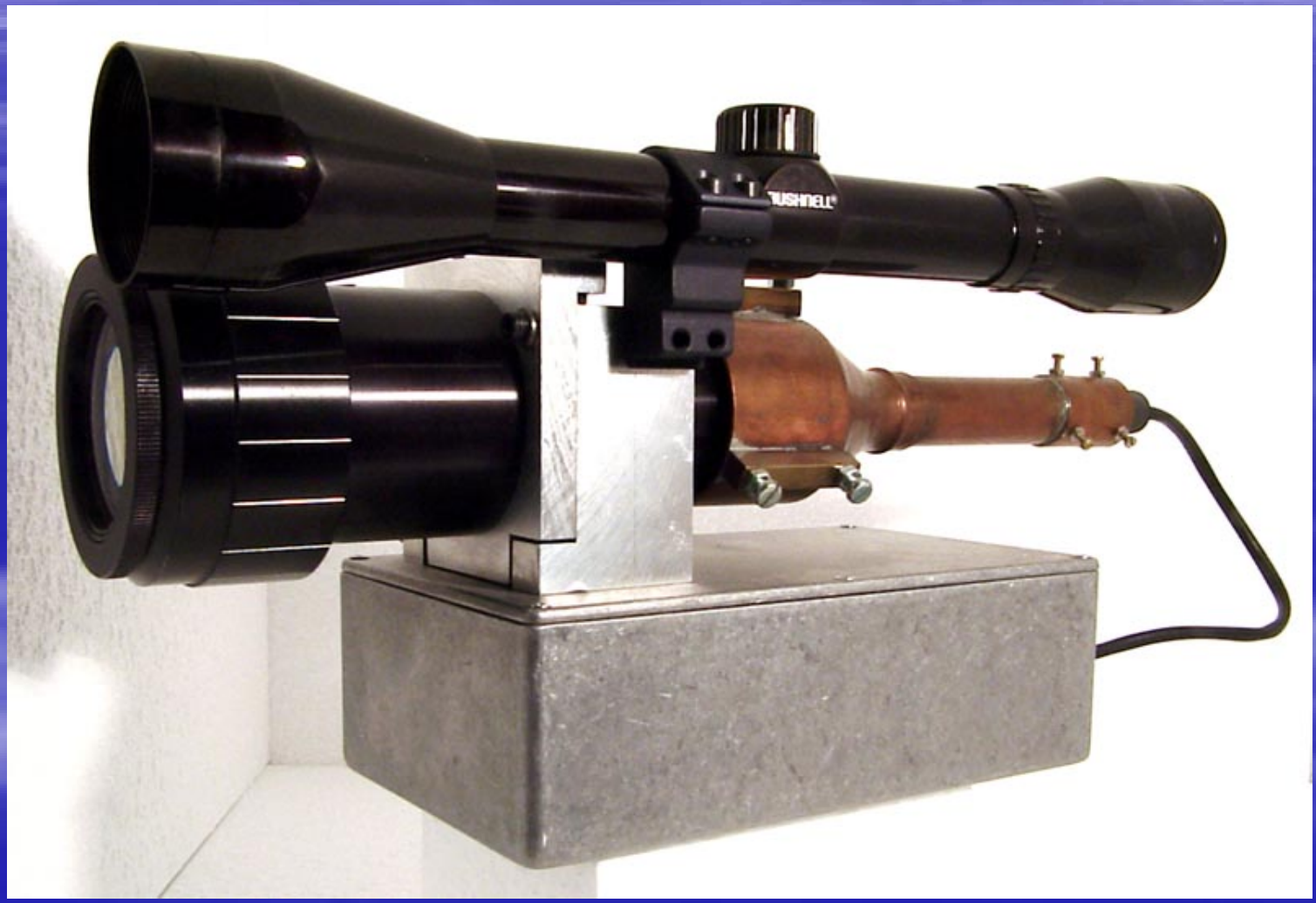

+5V
to SW2B
pin 2
1u
12K
18K
33p
to SW2A
pin 2
12
16
11
4MHz
xtal
10M
4060
2
1K
10
4K7
key
33p
10n
8


+ 5 V
12K
1 u
to SW2B
pin 4
12
16
1K5
input
from
sound
card
11
7
+
4060
1K
to SW2A
pin 4
10u
8


+5V
+
1K5
100u
from
wiper of
SW2A
to
laser diode
module
SOT


+5V
470p
8
2
4
10n
5
555
6
5K6
200K
7
1
3
100n
4K7
10K
100n
47K
+5V
7
2
TL081
3
6
4
10K
1K
1K
1u
audio
in
7
2
TL081
3
6
4
to SW2A
pin 3




BUSHNELL


SONY