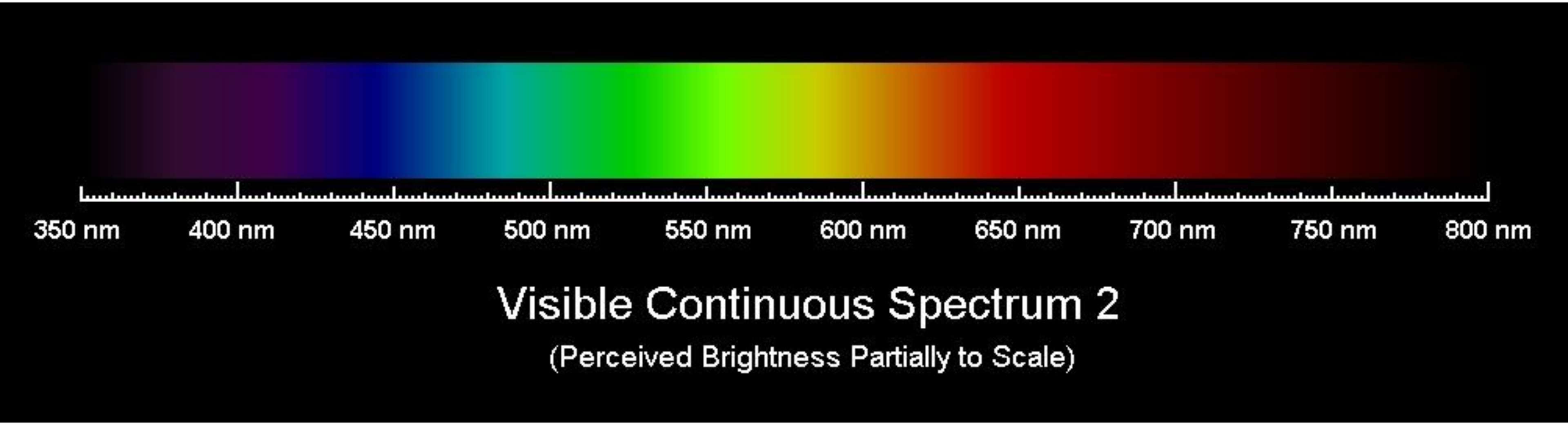
Cardiff RT 2019

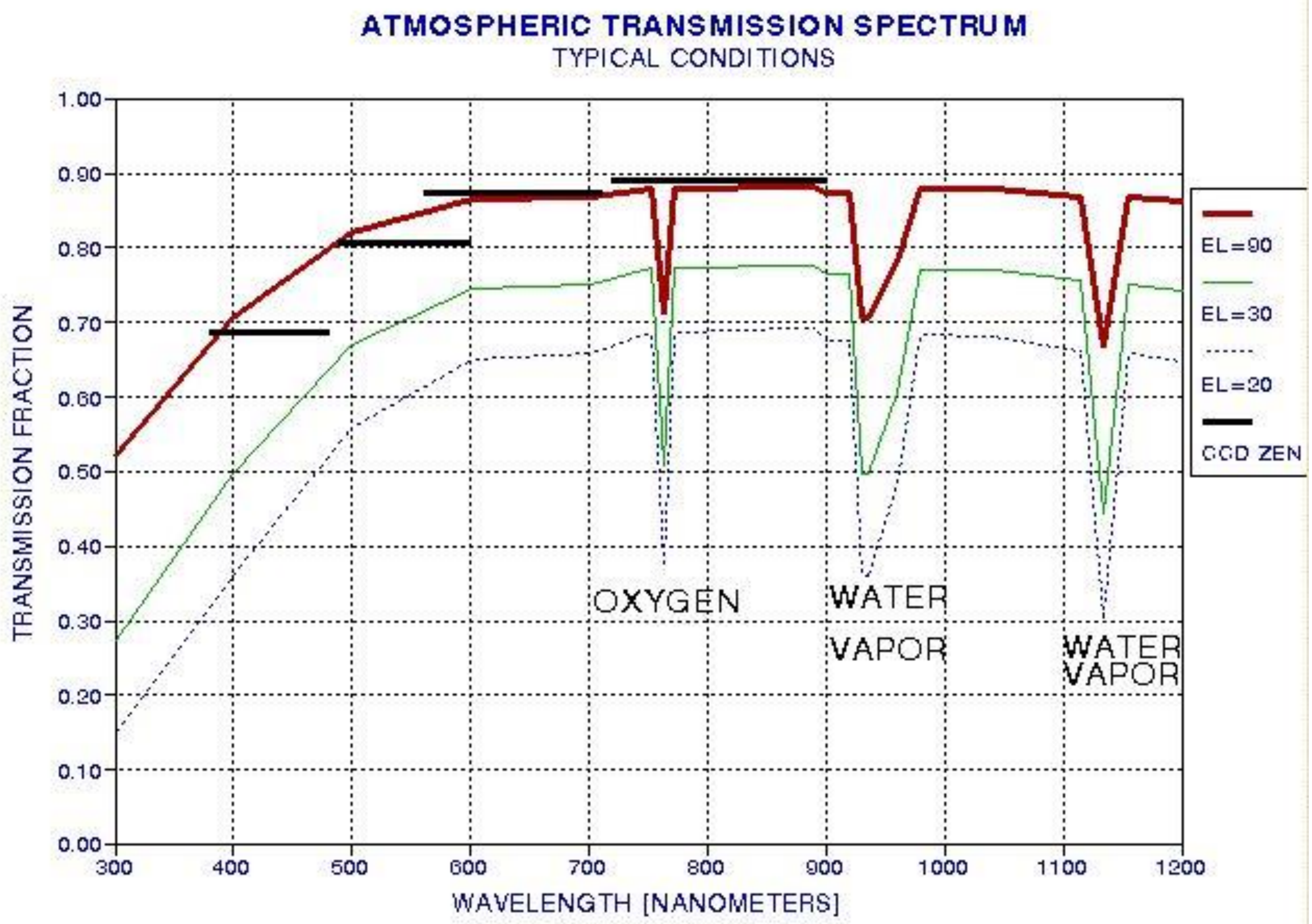
Communicating with Light

Barry Chambers G8AGN

The Visible Spectrum



- Red LEDs and lasers emit at wavelengths between 620-670 nm
- The eye is most sensitive to wavelengths around 550 nm
- Atmospheric transparency depends on wavelength

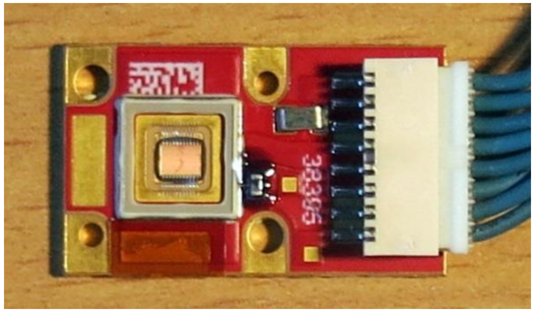


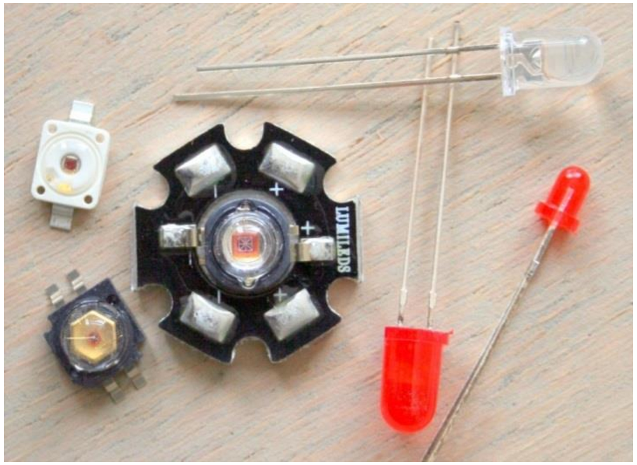
Source: B.L. GARY, 1990

Red optical sources

Luminus PhlatLight
2.5A/mm^2

8A standing current
>16A peak current





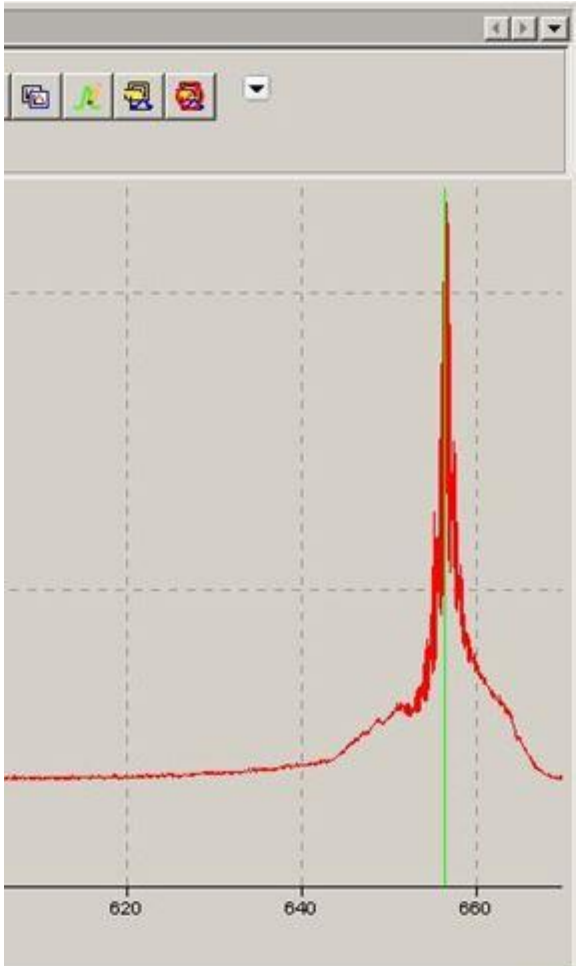
LEDs

High outputs available (watts!)
Easily modulated
Wide beam (collimation)

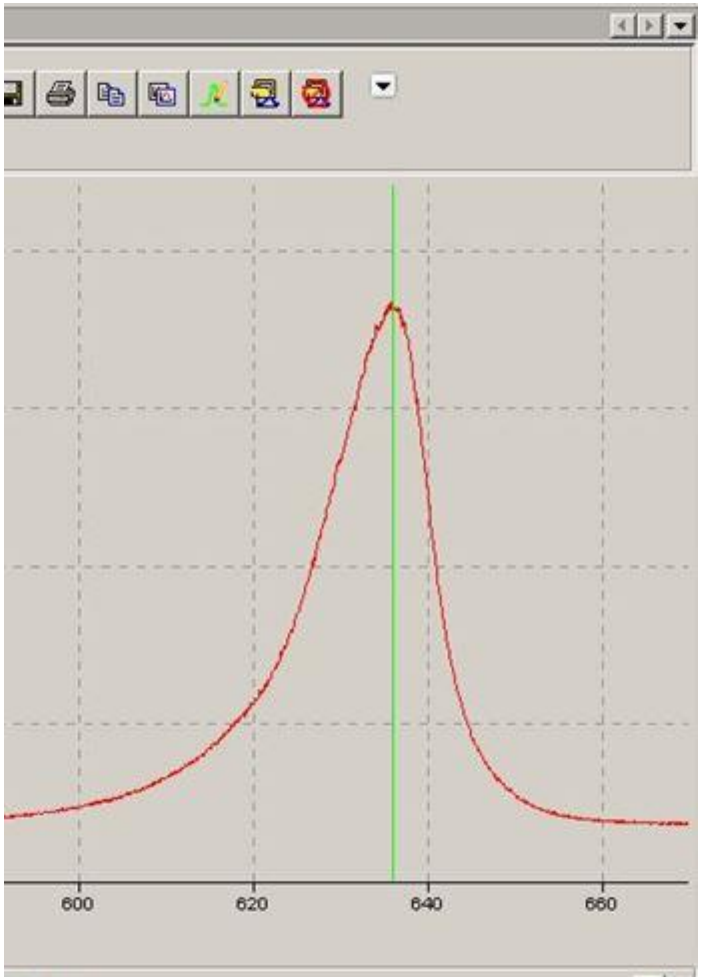
Lasers

Very narrow beam
Eye safety issues

Measured spectra of red optical sources



Laser pointer



3 watt Luxeon Star

Measured with Ocean Optics HR-2000 spectrometer

Optical Detectors

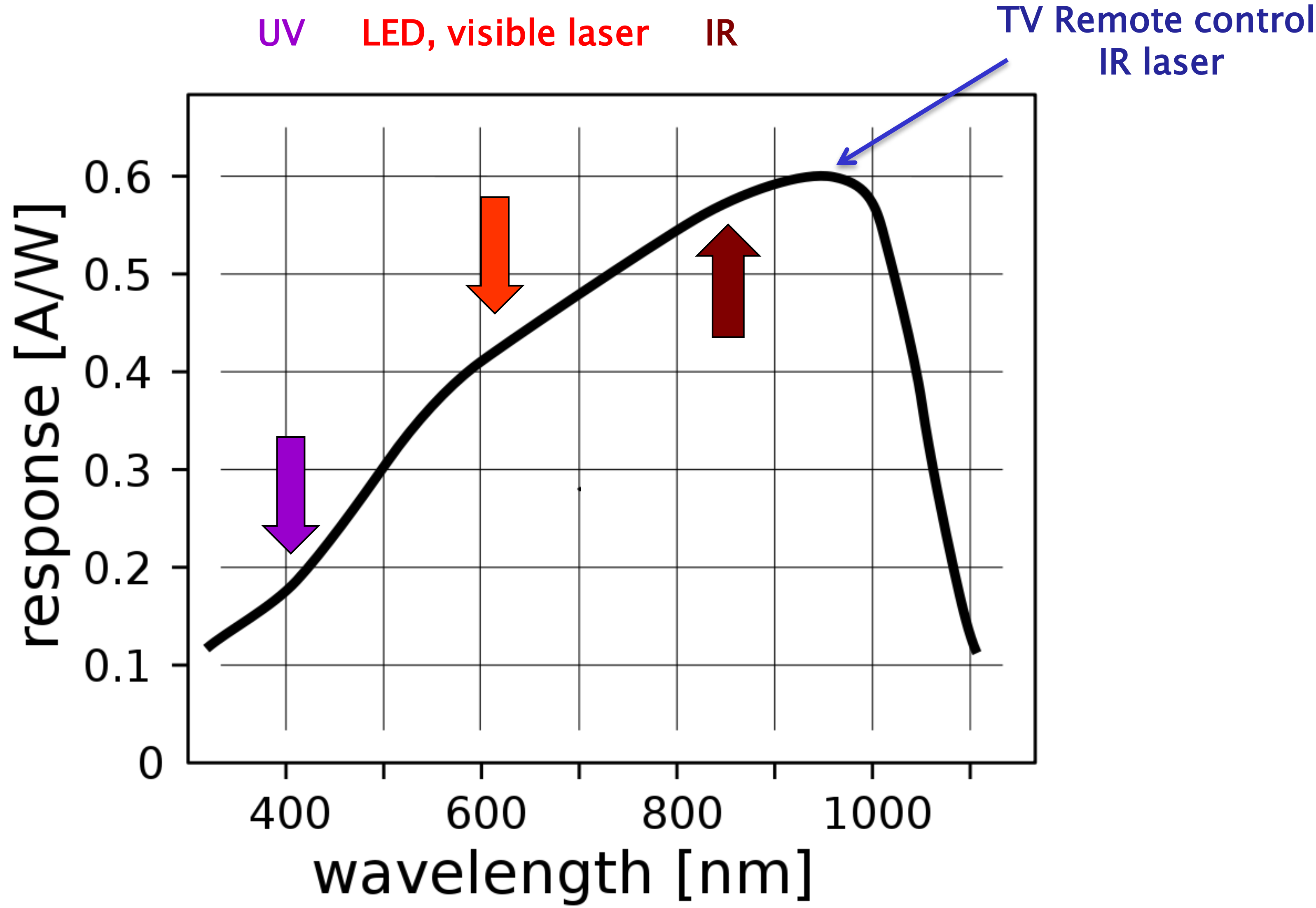
- Photo transistor
  Low MHz bandwidth
  Sensitive but slow & noisy

- PIN diode
  Fast but lower output
  Low noise - GHz bandwidth possible

- LED
  High efficiency LEDS look similar to PIN diodes in sensitivity
  Relative speed & noise unknown

- Avalanche photo diode
  High gain, low noise, very expensive.
  Need high applied reverse bias voltage

Response of Silicon photo diodes and transistors

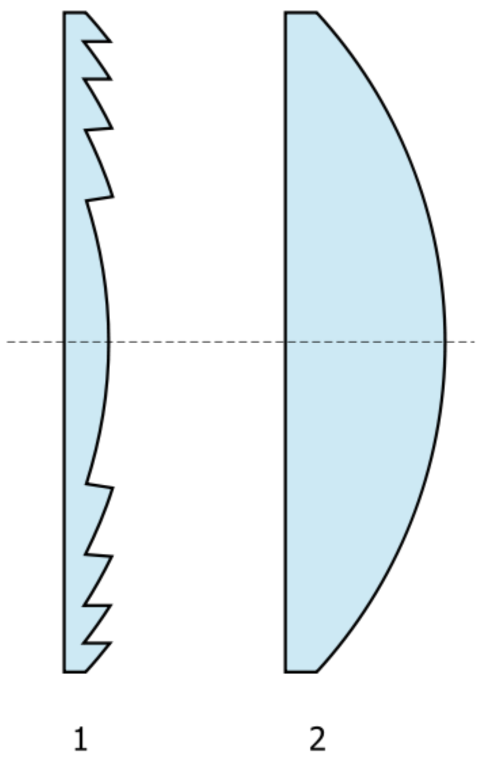


Lenses

- Act like antennas - larger aperture means higher gain with narrower beam-width

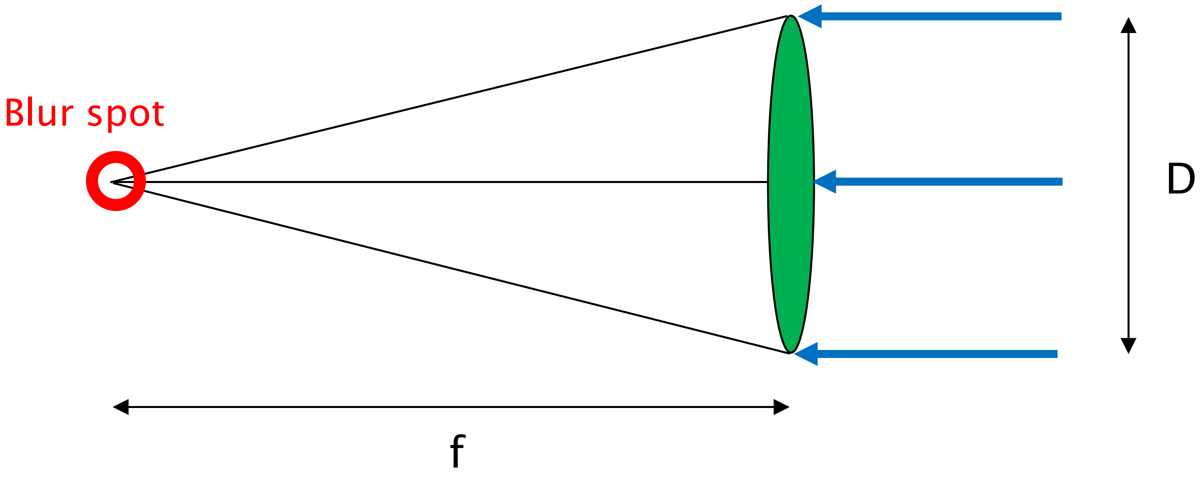
- Typical gain is approximately the ratio of lens diameter to the photo-detector area Photodiodes are typically 1- 3mm square

- Glass lenses are best but heavy and expensive. Plastic A4 size Fresnel lenses are OK and only 99p



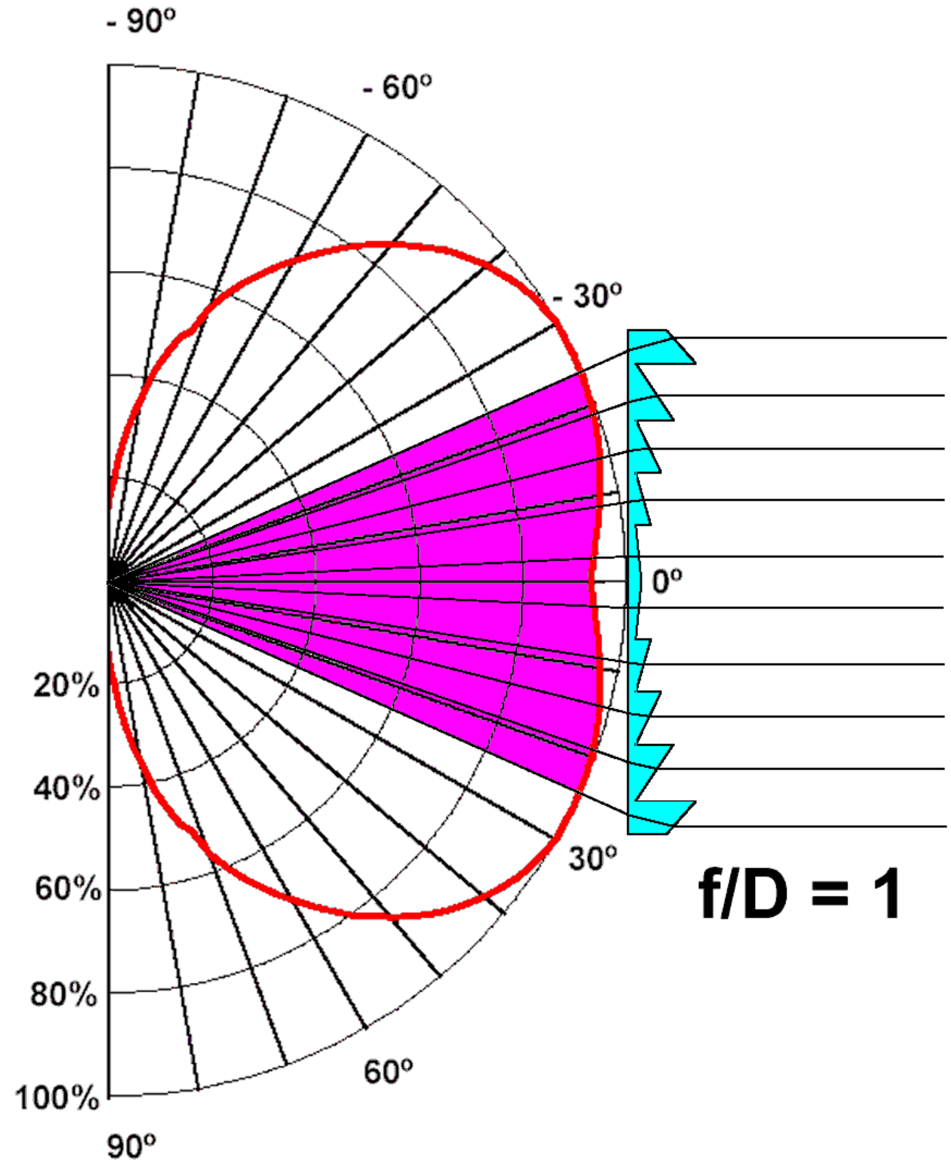
1. Fresnel lens
2. Plano convex lens

Receiver optics

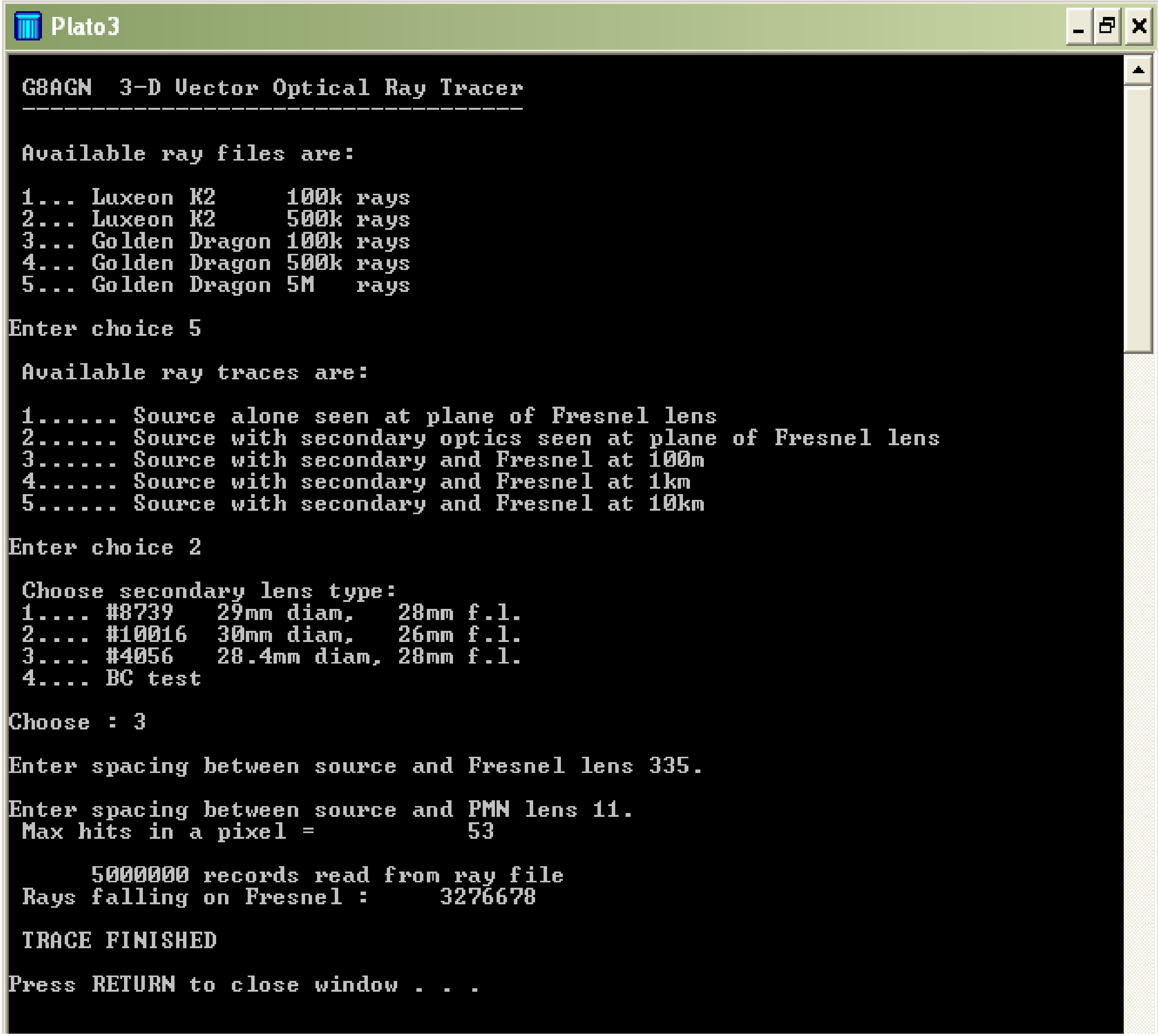


Blur spot diameter ~ D / 1000 for Fresnel lenses

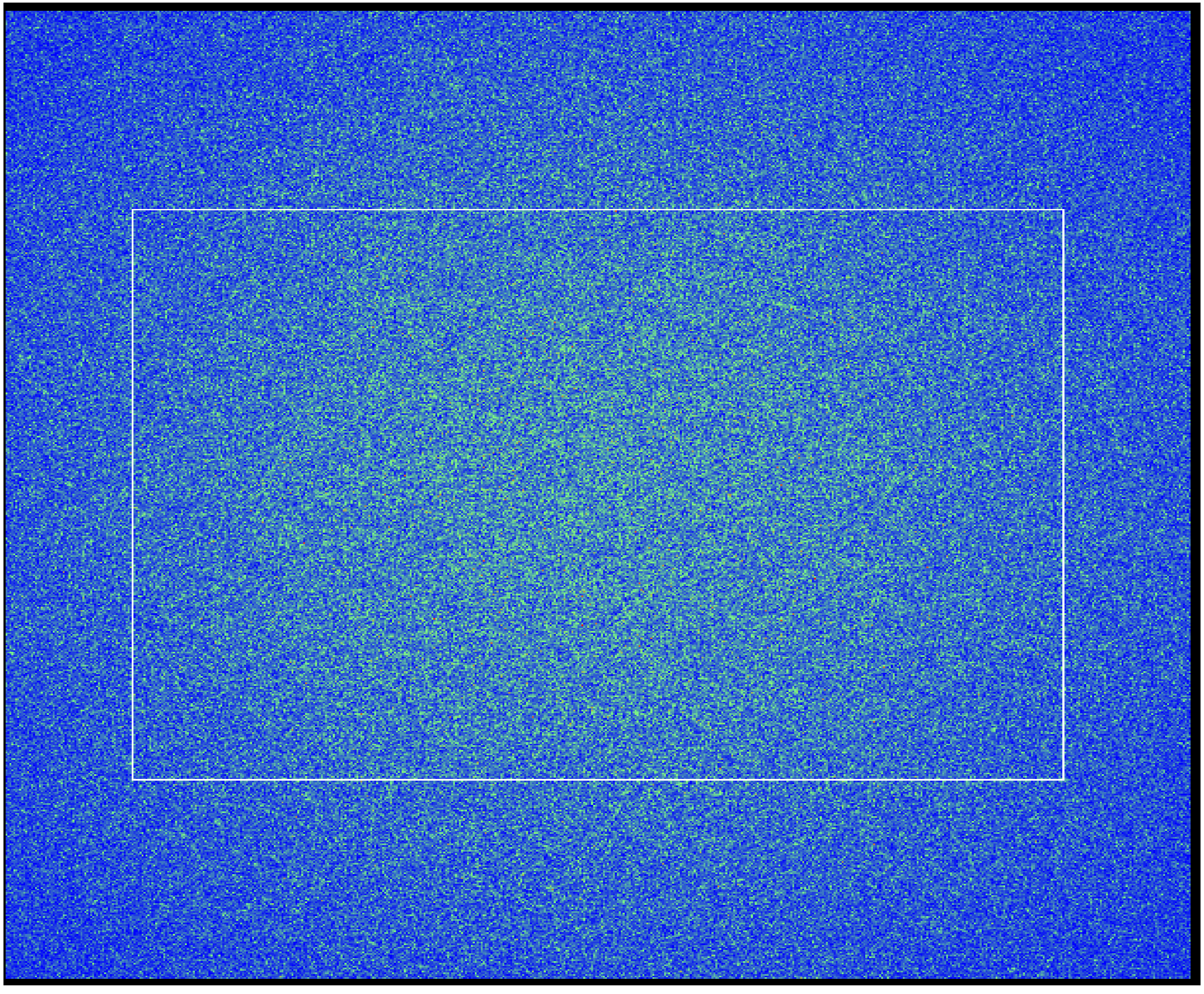
LED illuminating a Fresnel Lens



Much of the emitted light does not illuminate the Fresnel lens and is wasted.


Plato3
G8AGN 3-D Vector Optical Ray Tracer
Available ray files are:
1... Luxeon K2 100k rays
2... Luxeon K2 500k rays
3... Golden Dragon 100k rays
4... Golden Dragon 500k rays
5... Golden Dragon 5M rays
Enter choice 5
Available ray traces are:
1...... Source alone seen at plane of Fresnel lens
2...... Source with secondary optics seen at plane of Fresnel lens
3...... Source with secondary and Fresnel at 100m
4...... Source with secondary and Fresnel at 1km
5...... Source with secondary and Fresnel at 10km
Enter choice 2
Choose secondary lens type:
1.... #8739 29mm diam, 28mm f.l.
2.... #10016 30mm diam, 26mm f.l.
3.... #4056 28.4mm diam, 28mm f.l.
4.... BC test
Choose : 3
Enter spacing between source and Fresnel lens 335.
Enter spacing between source and PMN lens 11.
Max hits in a pixel = 53
5000000 records read from ray file
Rays falling on Fresnel : 3276678
TRACE FINISHED
Press RETURN to close window . . .

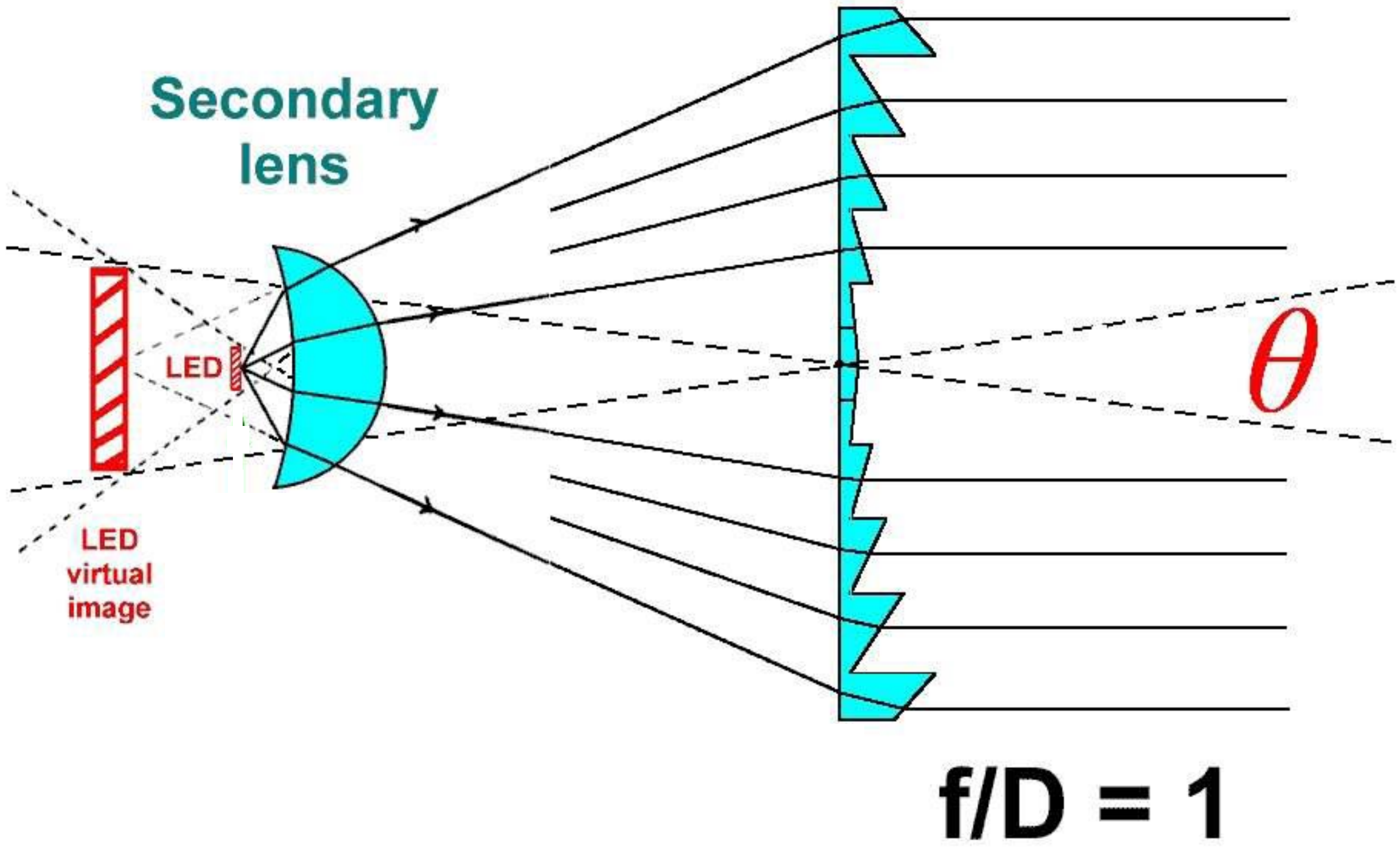
Golden Dragon 5M rays, Fresnel at 335mm, No PMN, 686618 rays hit Fresnel (13.7%)



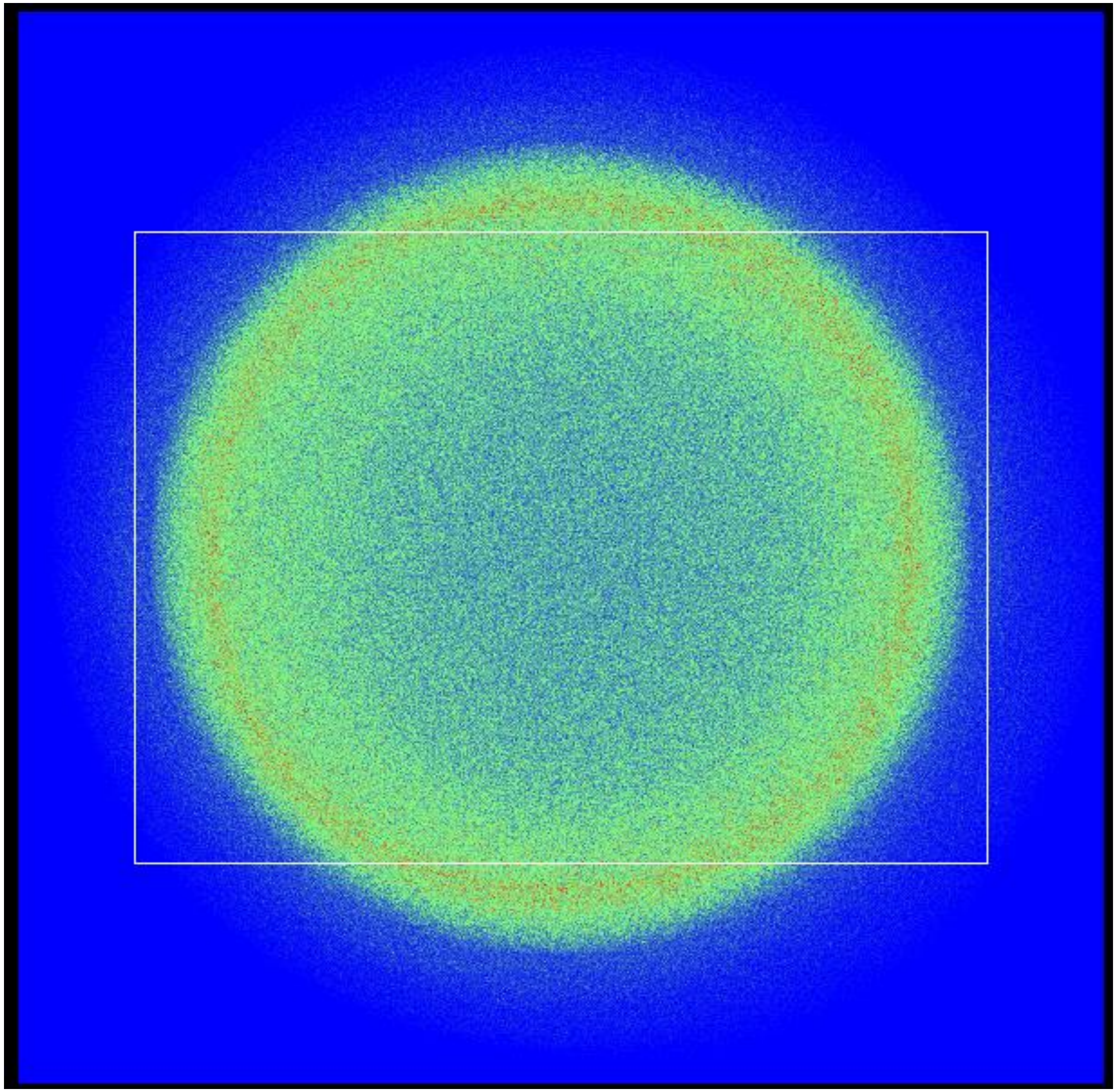
0.4 m

Using a secondary lens

Better lens illumination but greater beam divergence

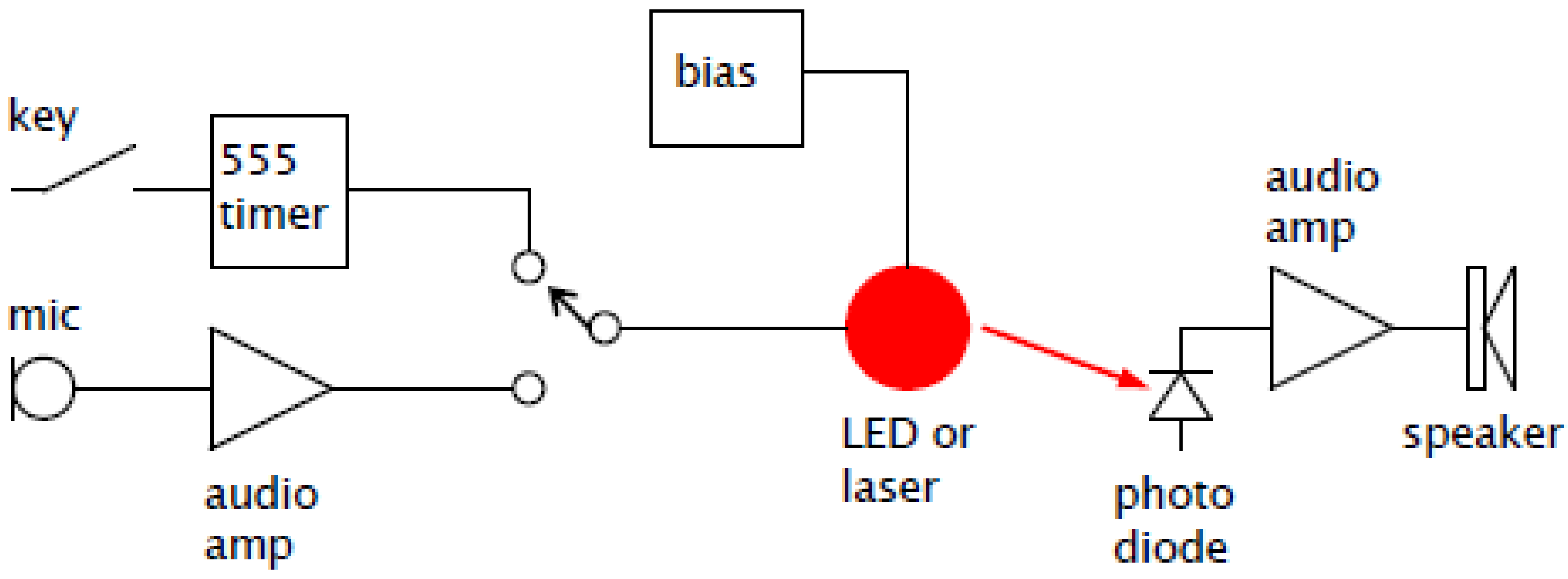


Golden Dragon 5M rays. #4056 lens at 11 mm, Fresnel at 335 mm
3108555 rays hit Fresnel (65.5%)



0.4m

Basic optical Tx and Rx for MCW or AM



G8AGN's optical transmitter and receiver

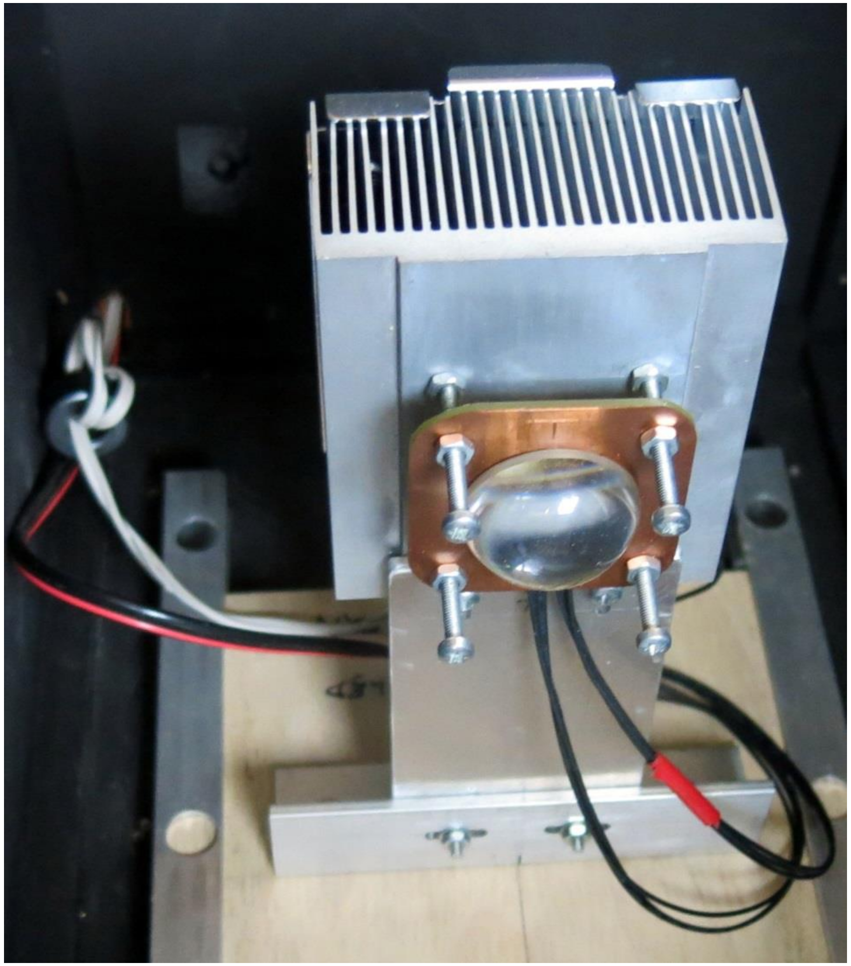
- Based on circuits developed by Clint, KA7OEI
- Tx uses Luminus *PhlatLight* LED 5 watt optical output, AM, MCW or data modulation
- Rx uses BPW34 photodiode and AF amplifier
- Separate Tx and Rx lenses (A4 page magnifiers)
- Solid construction and heavy duty tripod
- Telescopic sight for alignment

General view of G8AGN's optical transceiver

This photo was taken near Harpswell, Lincs
24 Nov 2010

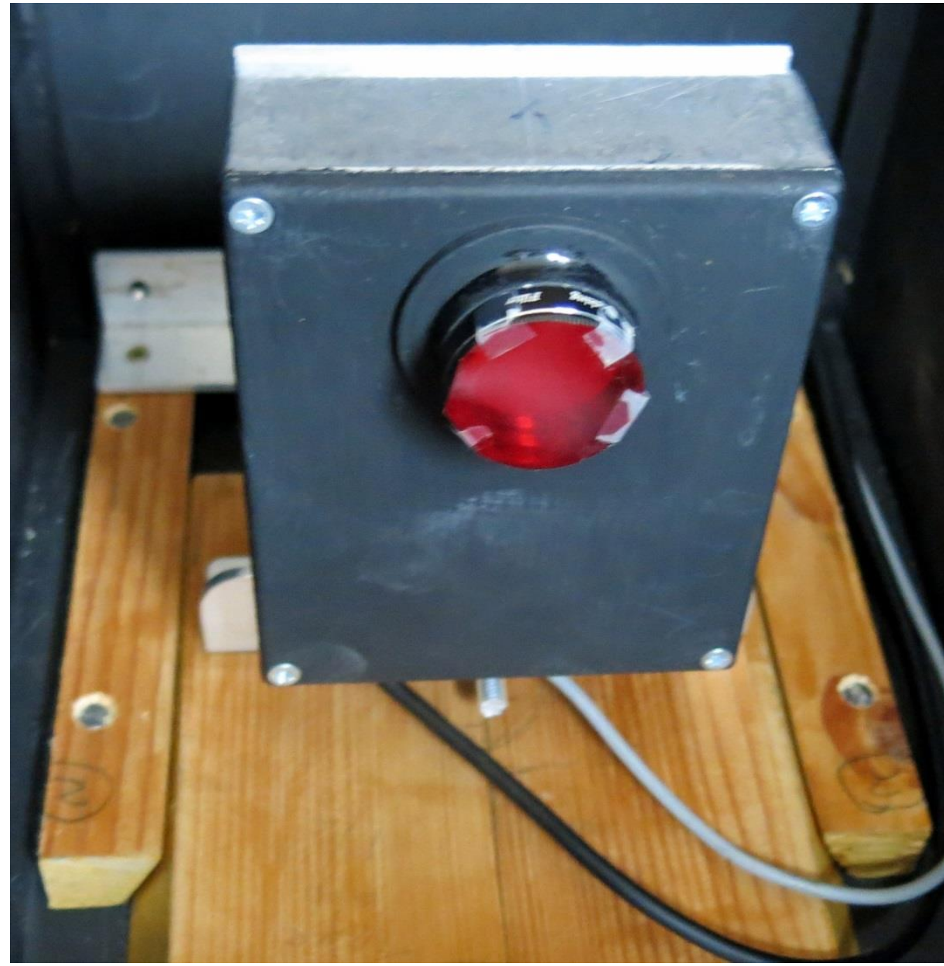
G8AGN's optical transceiver – front view showing Fresnel lenses

G8AGN optical transceiver – mounting of LED Tx and Rx front-end



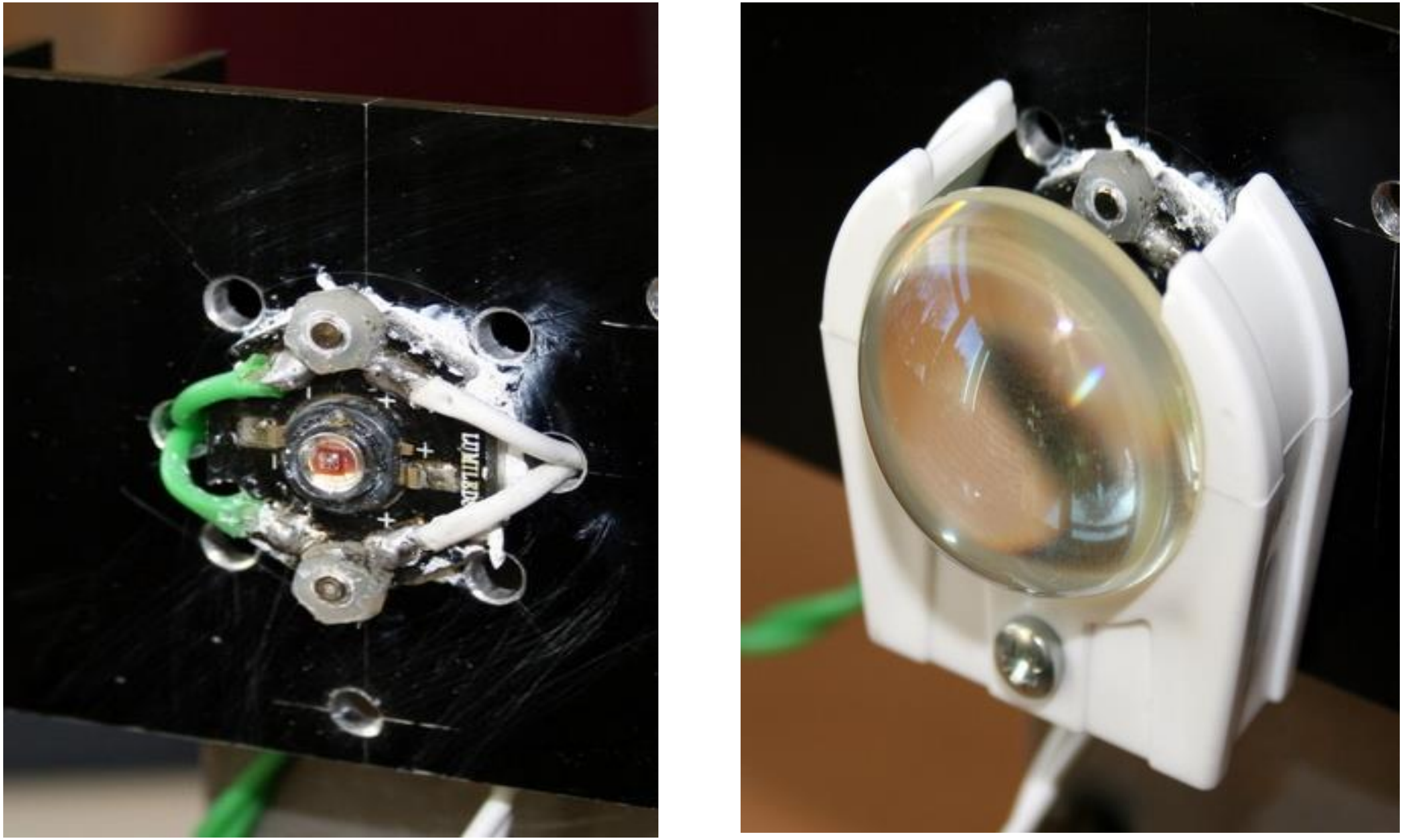
Tx

Fan-assisted cooling of LED



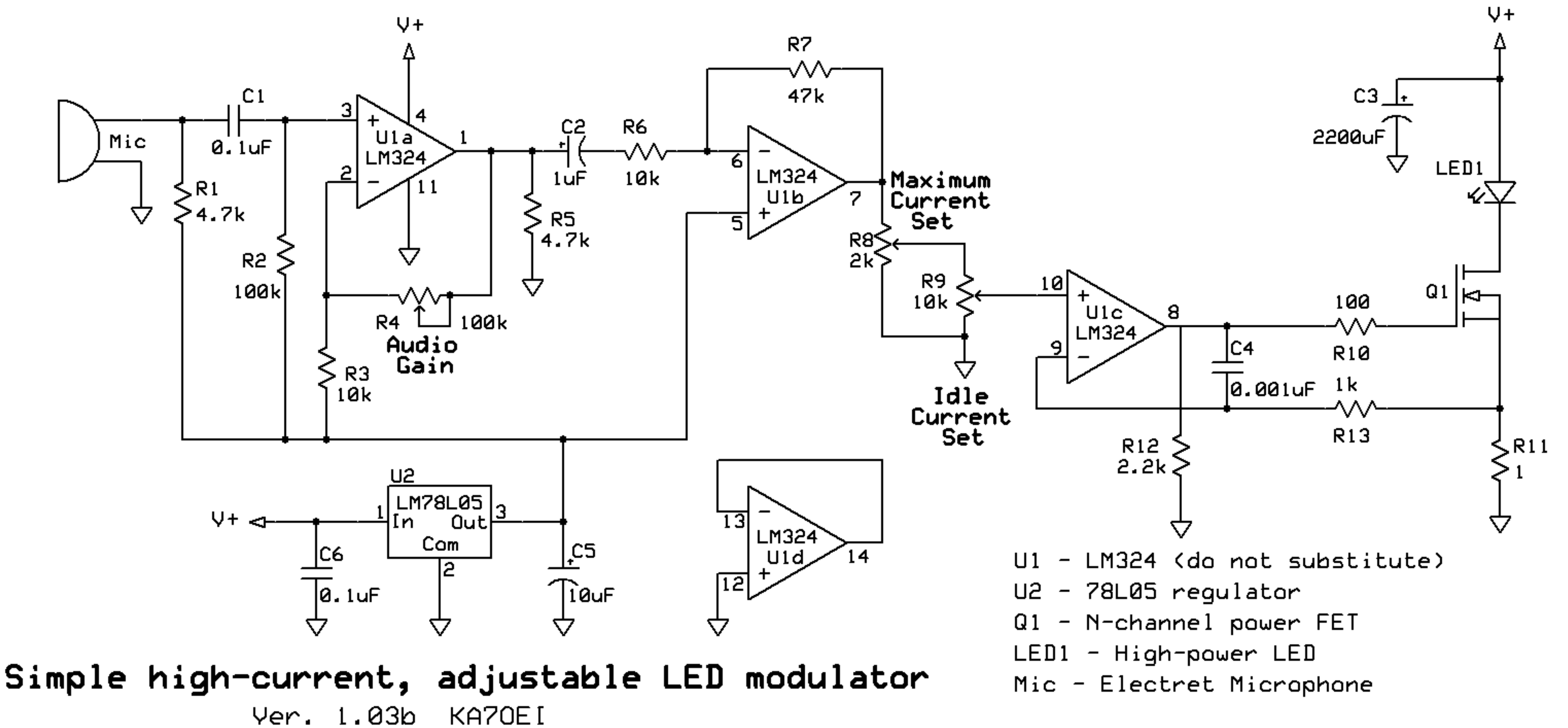
Rx

Red filter over photo-diode



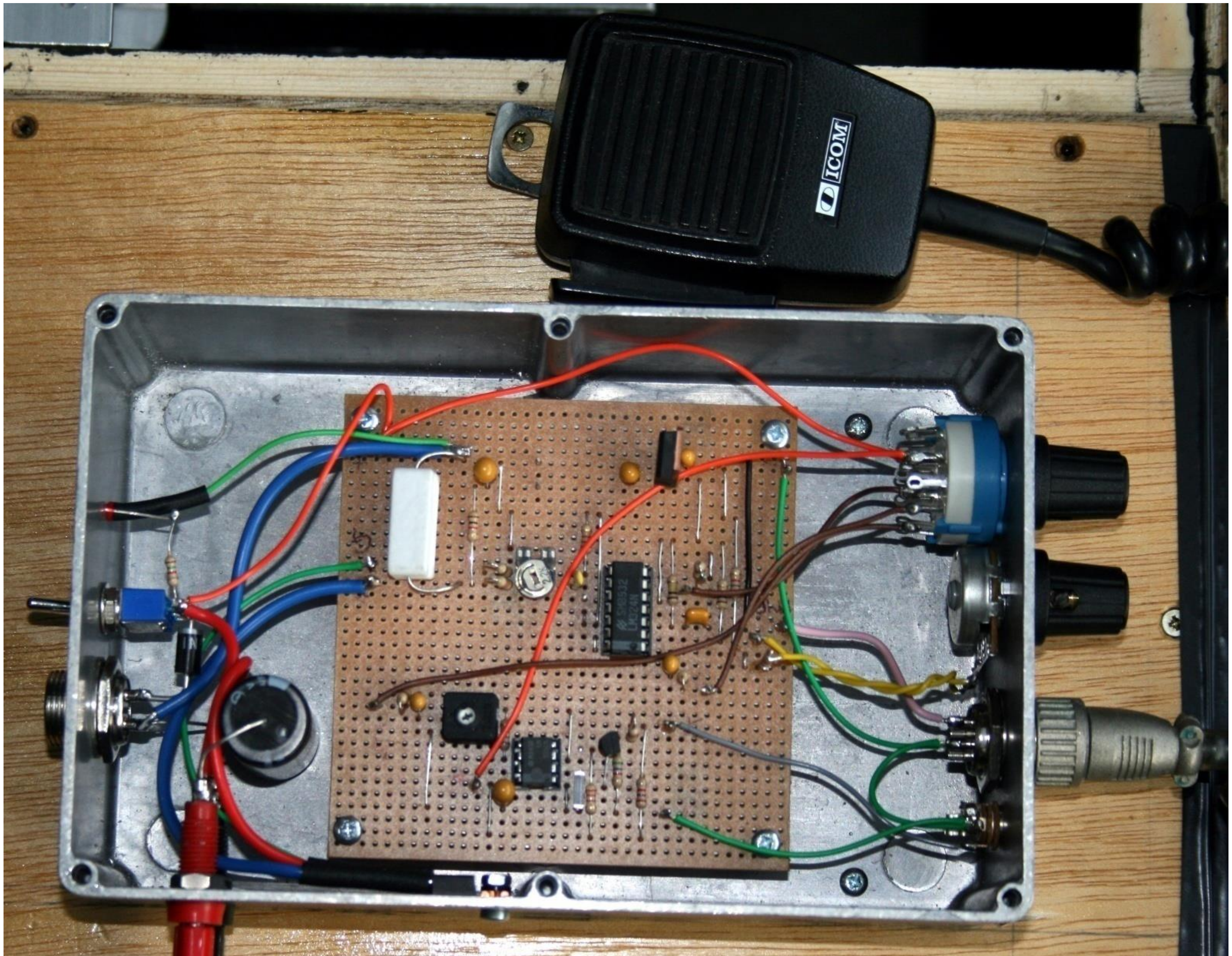
<u>Luxeon III mounted on heat-sink and fitted with PMN secondary lens</u>

KA7OEI current-sink modulator for high power LED



Light output of a LED is proportional to current, not voltage.

KA7OEI linear modulator for high power LED



KA7OEI optical receiver front-end

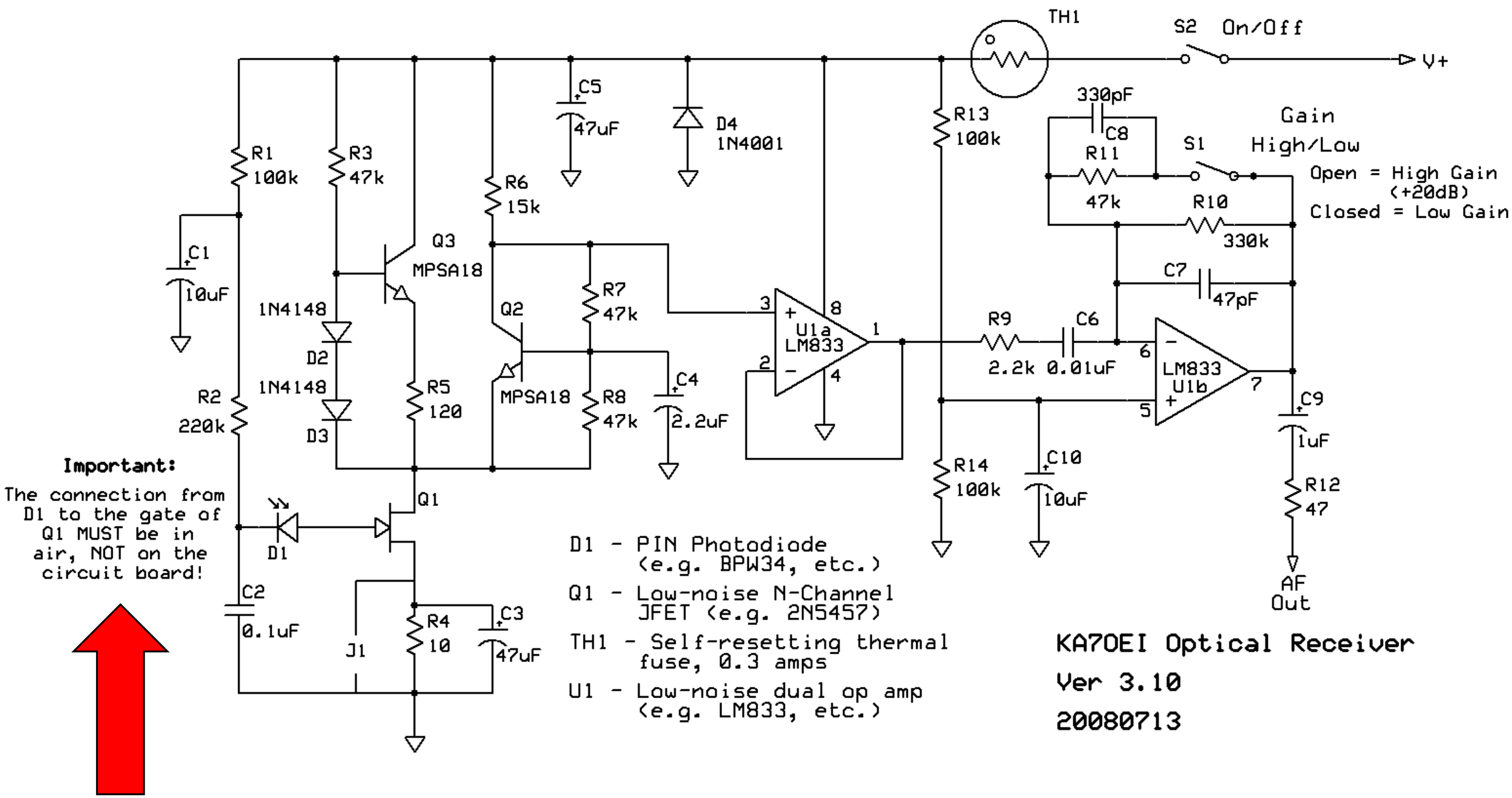


Photo-diode reverse-biased to reduce capacitance and improve bandwidth

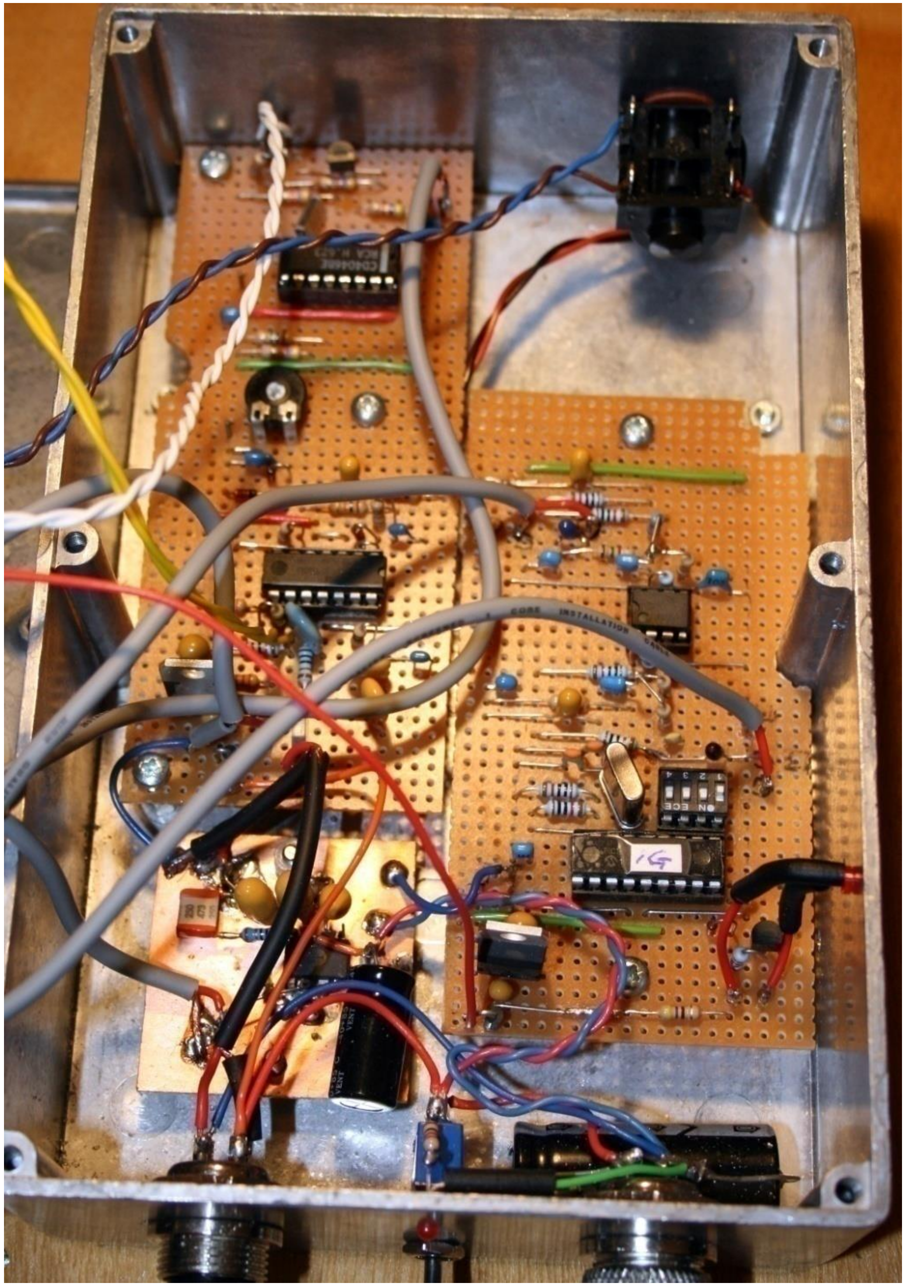
G8AGN optical Rx

This box is fed from a front-end comprising a photodiode and a low-noise pre-amplifier.

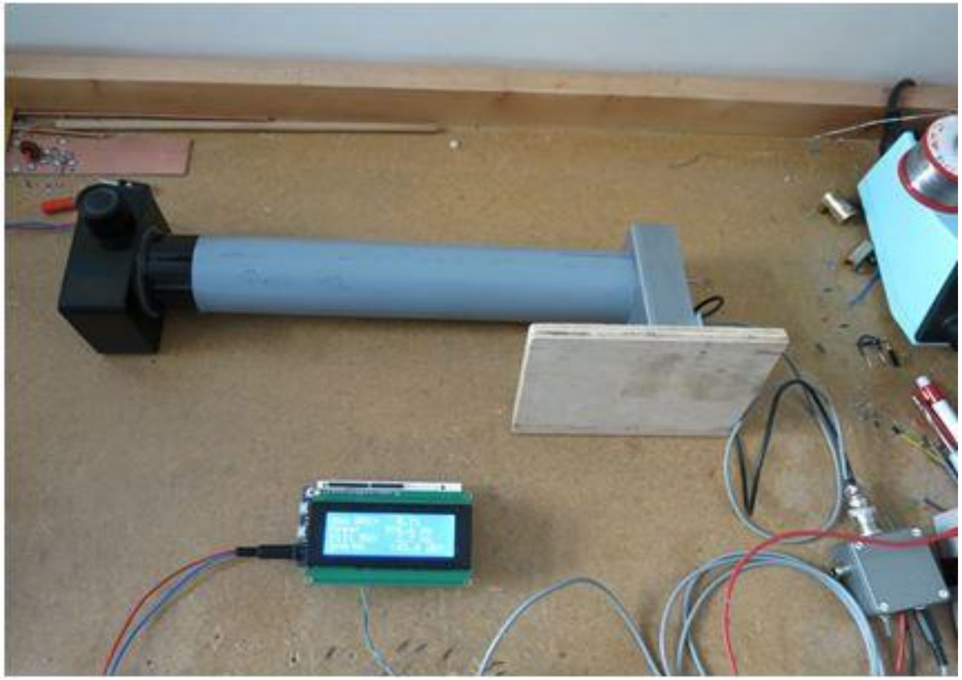
Shown are

- Audible S meter
- PIC comb filter for removing 50 Hz and harmonics
- Audio amplifier

All circuits due to KA7OEI



Optical receiver testing using a photon tube



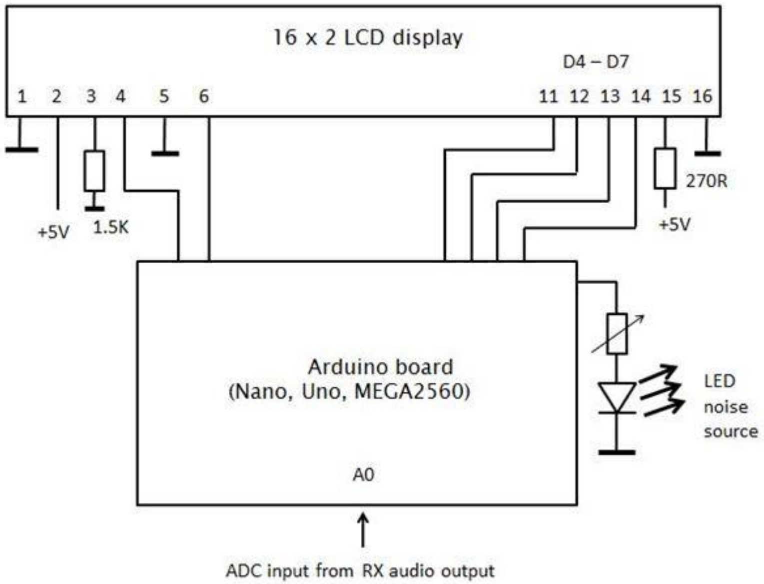
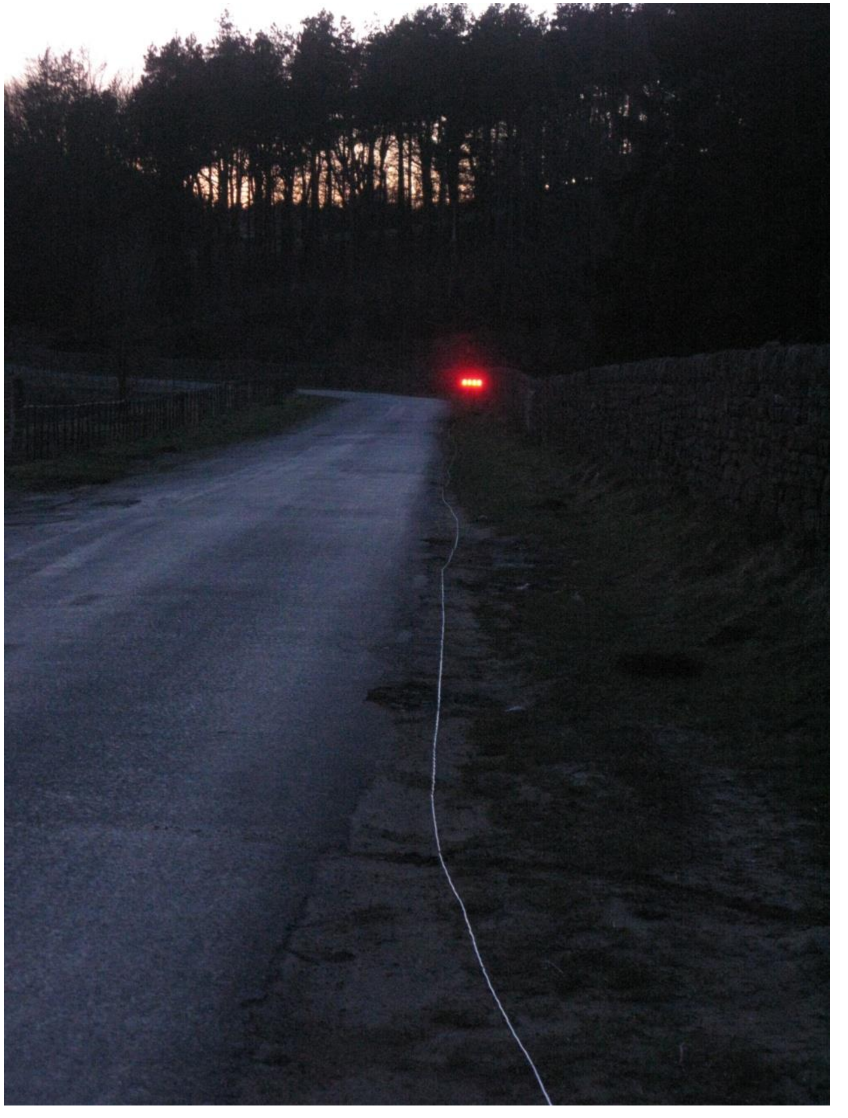


FIGURE 1: Hardware for Arduino S/N meter

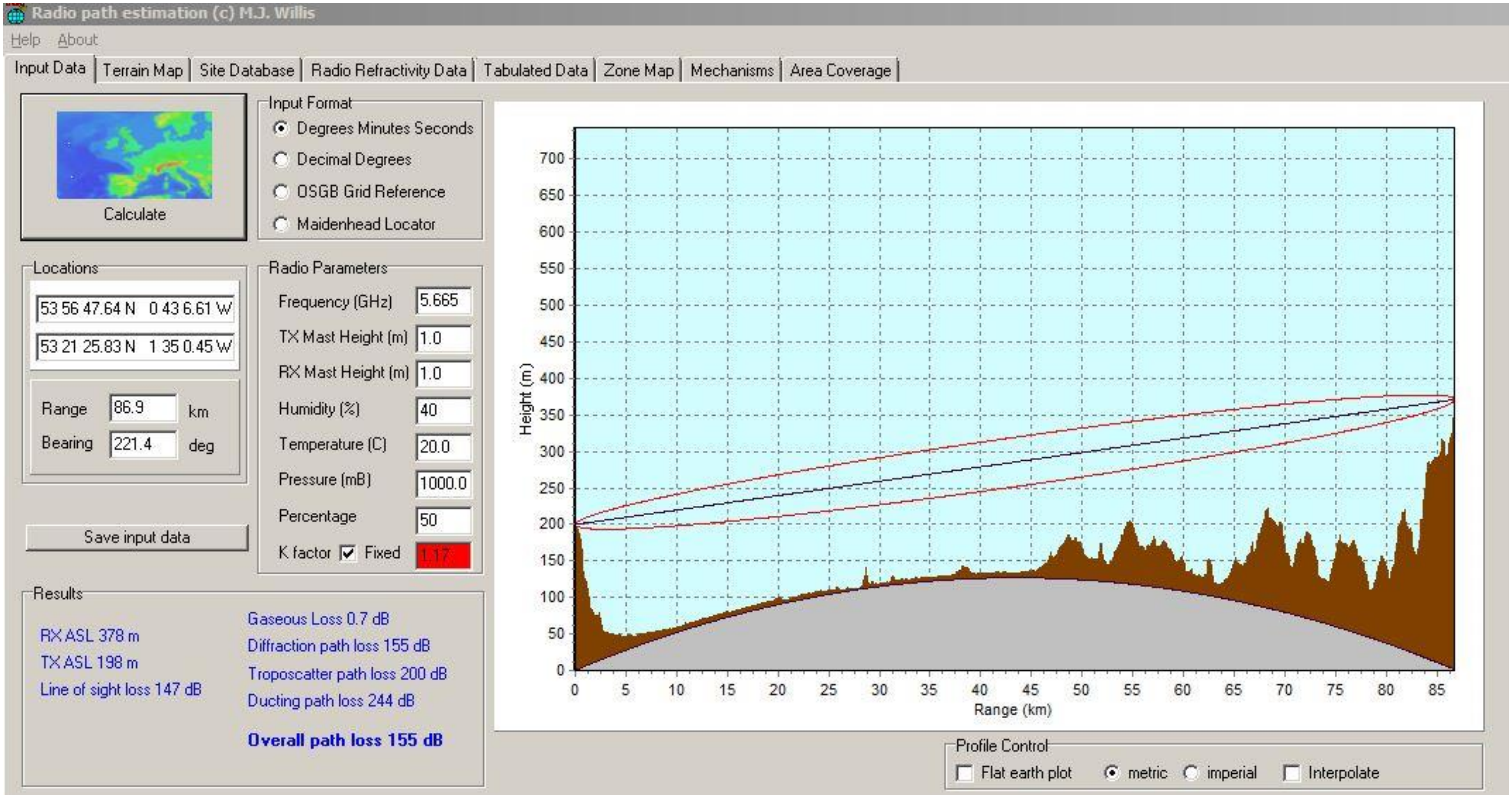
In practice the photon tube is at least 2m long and lined with black flock paper to eliminate wall reflections

Optical target with light sensor

Optical target when illuminated by G8AGN's Tx situated 100m away



Path planning Pocklington to Roper Hill – 87km



Making an optical contact

- Pointing requires good Az/El control
  LEDs much easier due to wide beam

- Aligned rifle scope or viewing through
  receiver optics

- Target must be visible unless precise Az/El
  calibration and data is available

- Liaison radio link for coordination
  and audio pointing feedback

- Atmospheric scintillation can be a problem

G8AGN/P's 0.5W Tx as seen by G0EWN/P over an 87km path

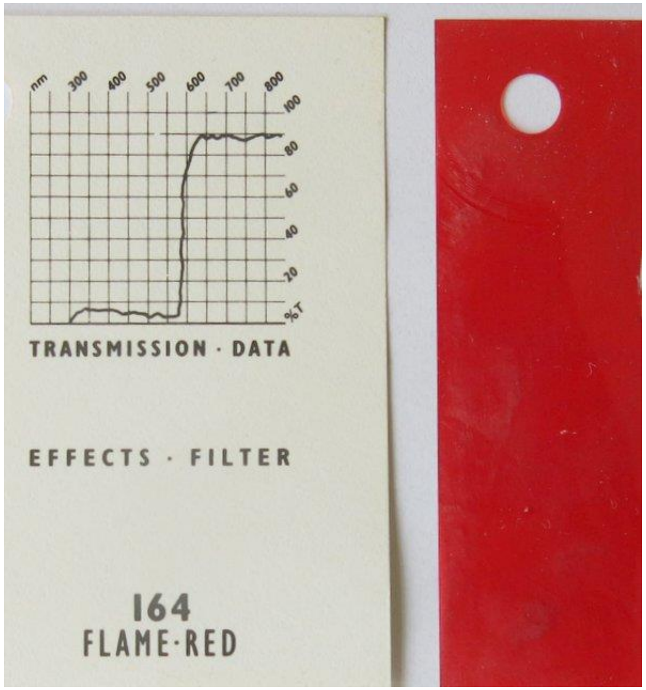
Note the QRM

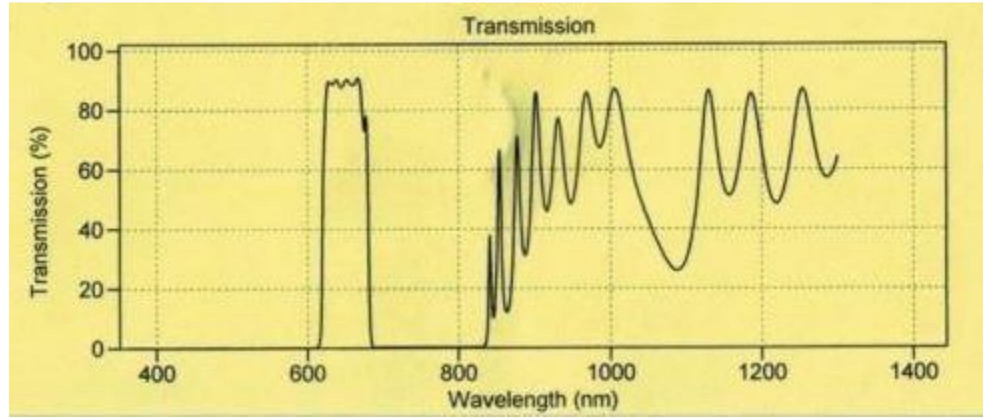
Contact made on 8 Jan 2011

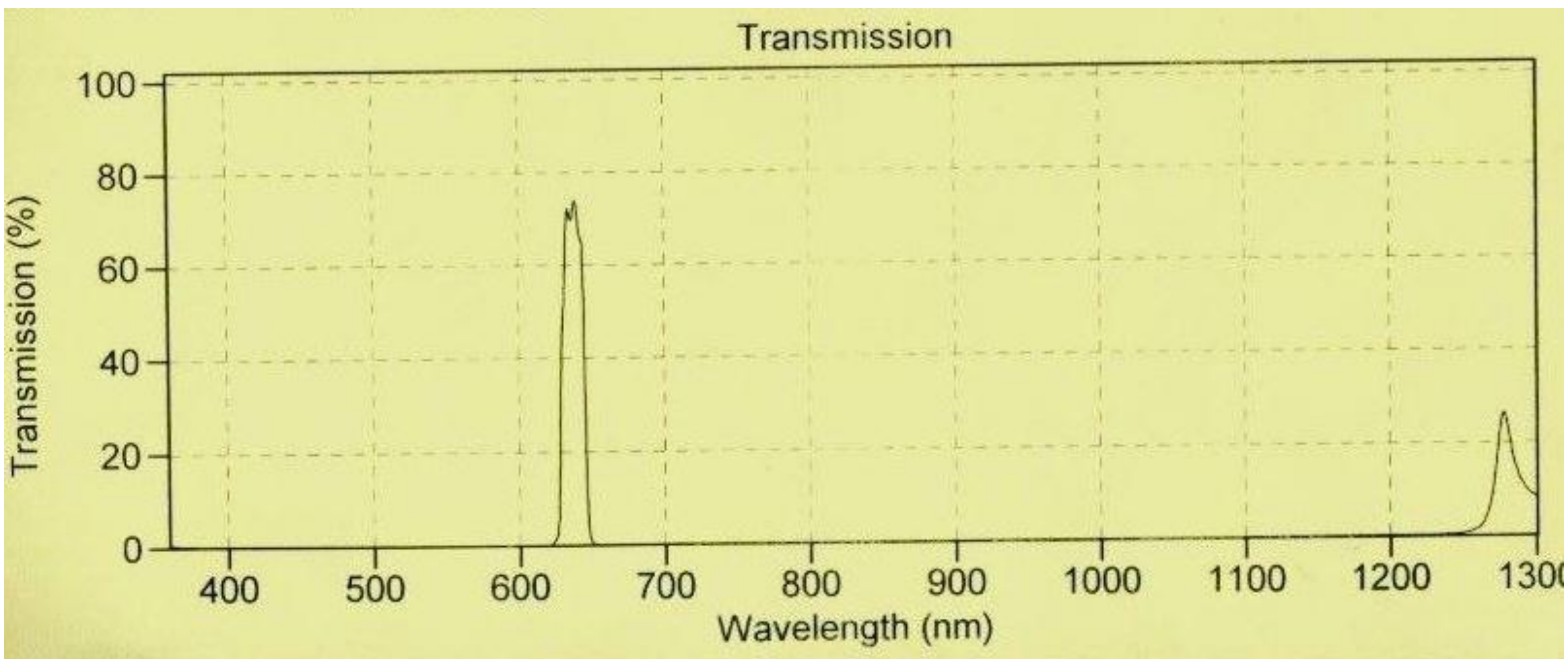
Optical DX records

Heliograph	293km	US Army	1894
Line of sight (laser)	189km	W6QYY, W6OP	1963
Line of sight (LED)	278km	KA7OEI group	2007
Cloud Bounce (LED)	288km (1 way)	VK7MO group	2009
UK (LED)	129km	G8AGN, G0EWN	2012
Daylight (LED)	83km	G8AGN, G0RPH	2013

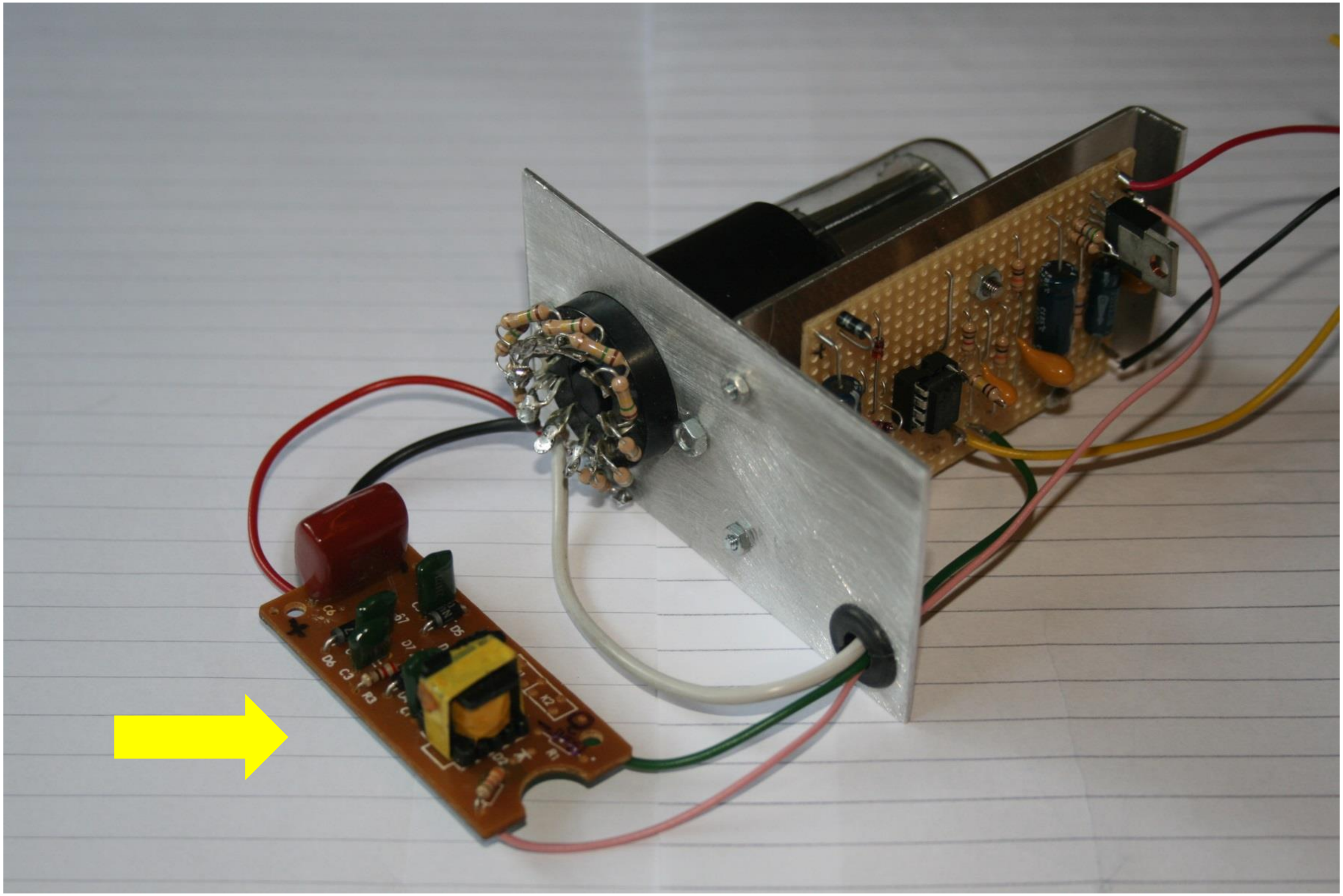
Optical Filters





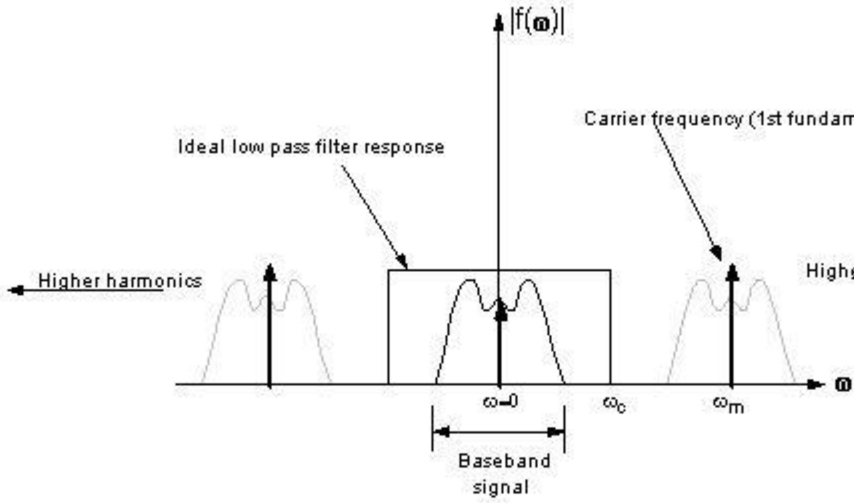


UV receiver using 931A photo-multiplier tube

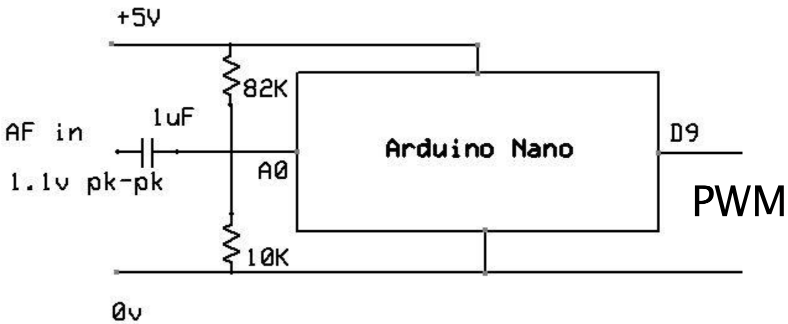


High voltage PSU for 931A taken from low-cost “bug zapper”

LED pulse width modulation



Default PWM frequency = 490 Hz
Reconfigure Timer 1 to increase this



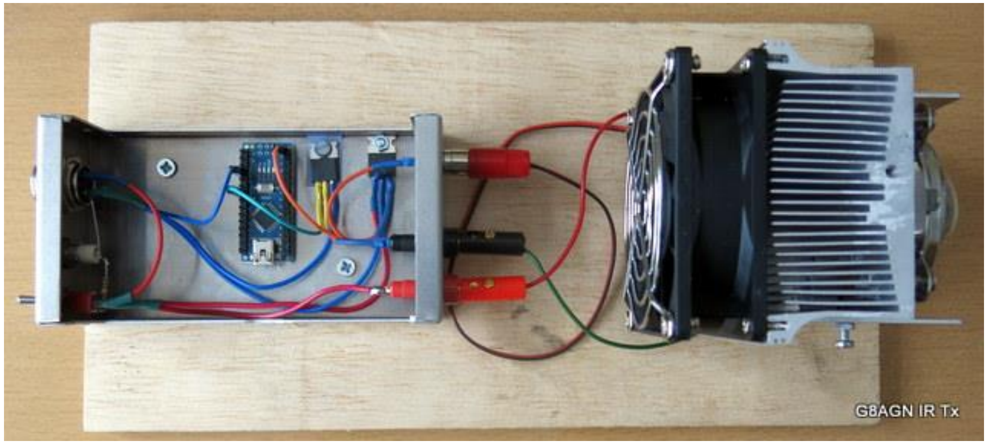
Clock frequency = 16 MHz
Number of bits = 10 = 1024 levels
Sampling frequency = 16000/1.024
=15.625 kHz

wiki.openmusiclabs.com/wiki/PWMDAC

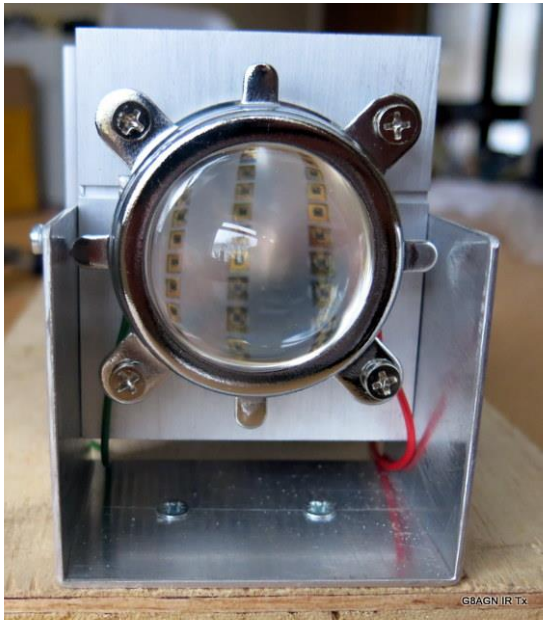
.

Use Arduino internal 1.1 V voltage reference

SMT-Hell modulator for LED



Arduino Nano version (G8AGN)



A more versatile approach is the PIC based

SCRIBER module developed by G8HAJ

Details in Scatterpoint Feb 2019

Where to Find More Information

www.ka7oei.com

www.k3pgp.org/
www.barry-chambers.staff.shef.ac.uk/LED_files/led.html
www.pageperso.aol.fr/YvesF1AVY/UKINDEX.html
www.ham-radio/sbms/sd
http://g8haj.uk/

Yahoo Group on UKNanowaves
Yahoo Group on Optical DX

www.surplusshed.com (for lenses)
www.ebaystores.co.uk/BJOMEJAG-EBUYER-STORE (for optical filters)

"An Arduino-based receiver noise figure alignment aid", Barry Chambers G8AGN, RadCom, 2014
"Exploits in lightwave communications", Stuart Wisher G8CYW, Practical Wireless, 2013

Thank you for listening.

Any questions ?