DIY LED dimmer for the microscopist

Lum-i-pas light is too bright to my eyes and the diode / resistor dimmer is too coarse, so I made a pwm-dimmer. This story has:

- compulsory don't try this in home warnings
- how to burn LED & LED variations
- very simple undimmed blue-usb/ocular light
- pwm dimmer
- another experimental light
- shopping list to non-electrician
- some technical points of components

The story is written for a person who has done some soldering, but if your hobby is electronics: please skip the whole story.

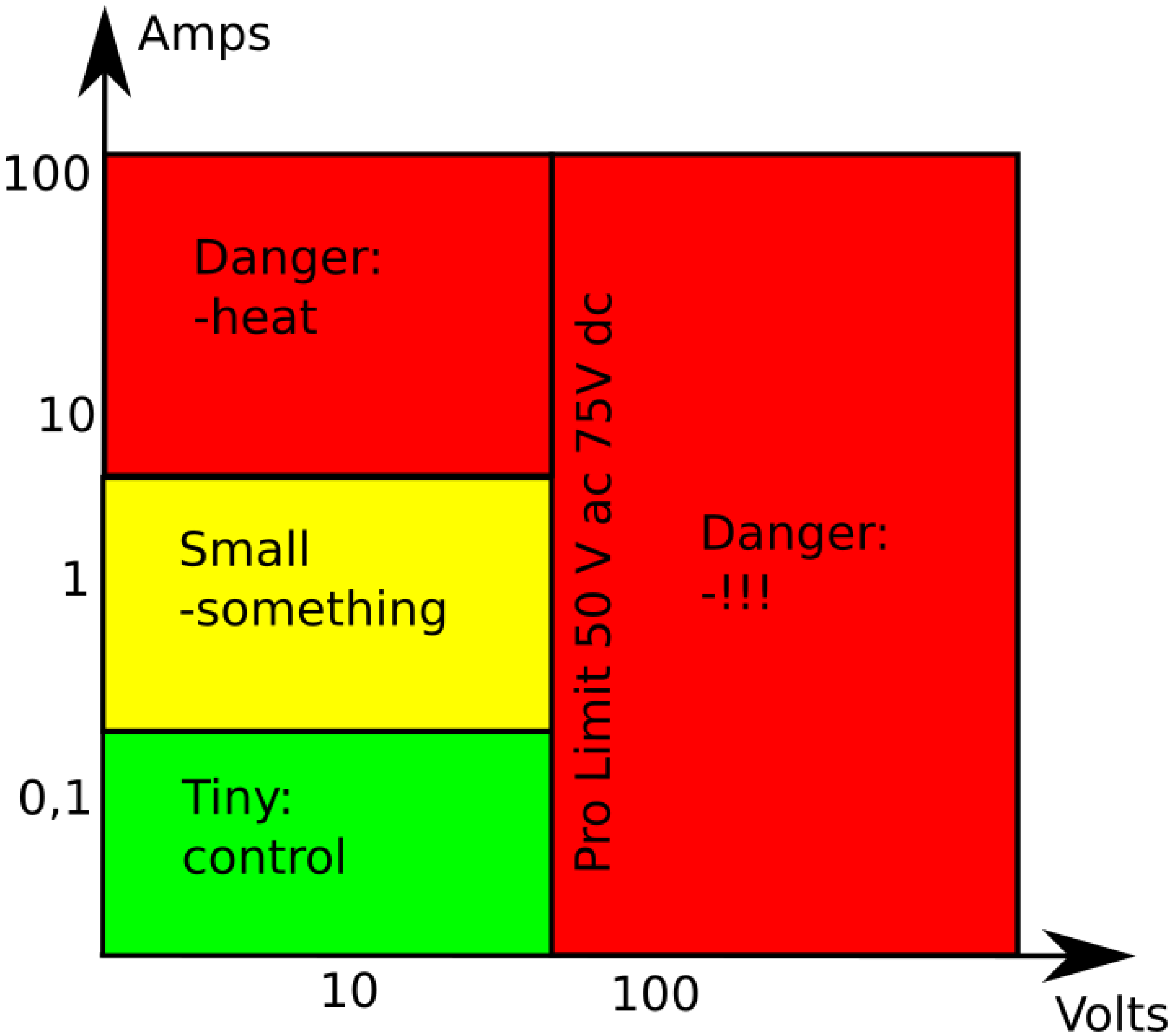
In the picture from up: pwm dimmed Jansjö, undimmed USB-Blue and pwm dimmed 1W

Warnings

We make no representation or warranty of any kind, express or implied, regarding the accuracy, adequacy, validity, reliability, availability, or completeness of any information.

For me there are 3 types of electricity

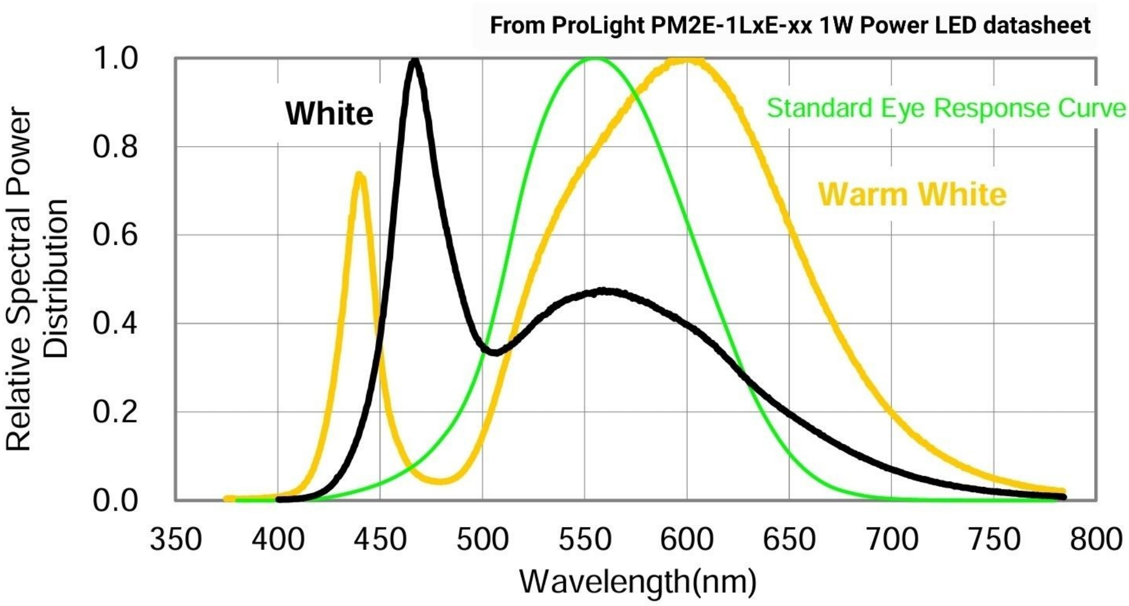
- tiny logic / green
- small / yellow
- big & danger / red



Limits to work allowed only to certified ELECTRIC (I am pro too, but not with electricity) profs vary, EU limits are 50V ac and 75V dc. If you leave ac transformer intact, we stay in the green & yellow sectors. Please note the dangerous but "allowed for amateurs" sector: risk of burning yourself, your car, etc.
In the green zone you can burn components, but damages to 'other world' are very limited or consequential.

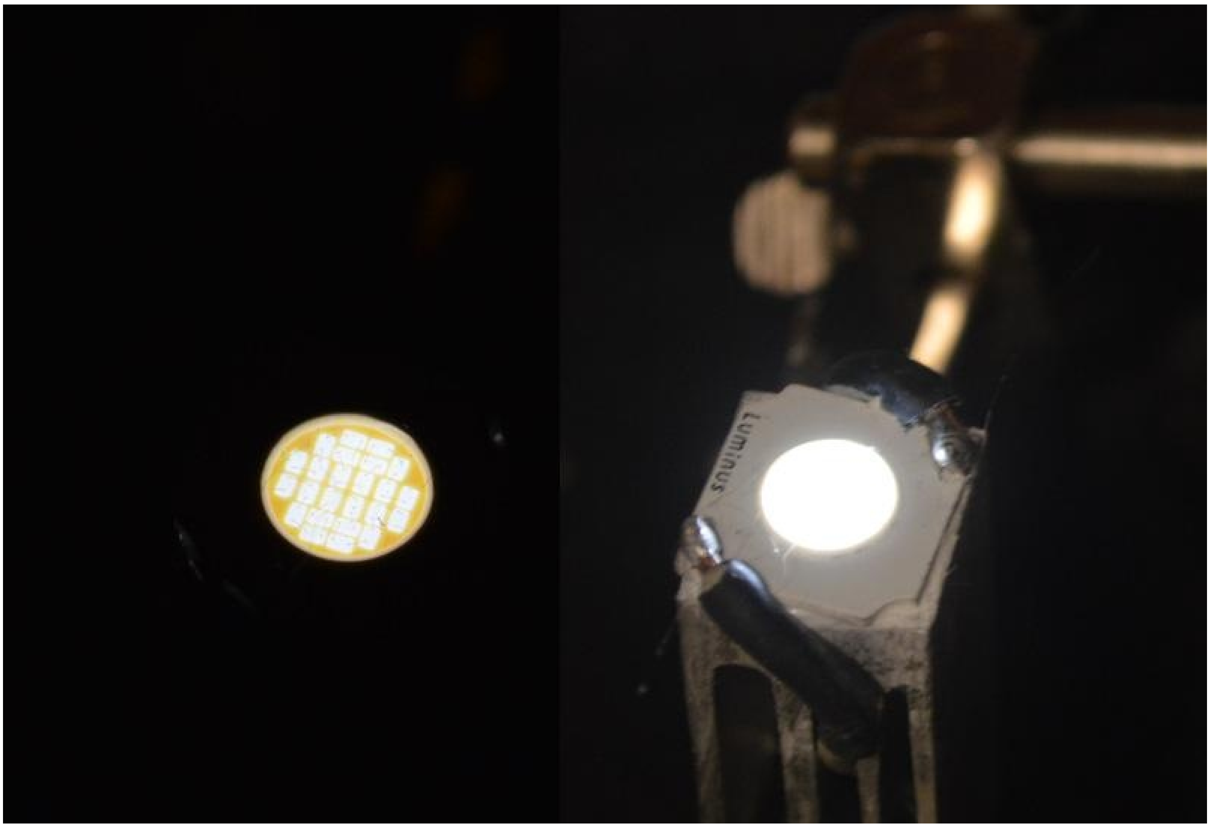
From LEDs

Only blue and white LEDs are discussed (white & blue are colors of the flag of Finland). In this century development has been fast.



Traditional LED emits narrow one color spike. Big invention of Dr Nakamura was the invention of blue LED and adding a phosphorus layer which absorbs blue light and emits a wider spectrum. ‘Blue’ is about 450 nm. Jansjö (smooth) spectrum can be found: https://www.baertierchen.de/wb_dez19.html

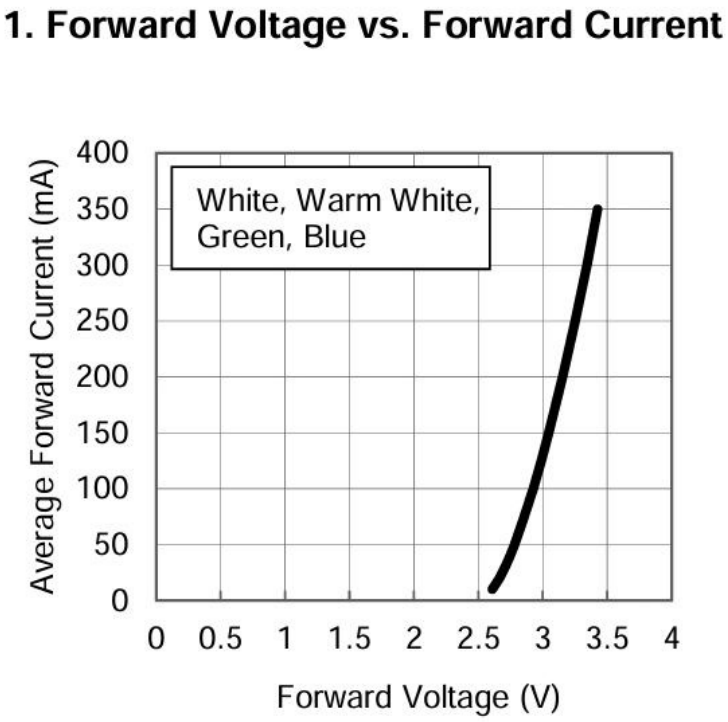
Very powerful LED systems are series of LEDs: if ten LEDs with 3.6V forward voltage are connected to series, there is a LED for 36V voltage. This 7 mm diameter 36V LED has 24 elements:



Single LED is easier to power, but two problem persists:

- a LED is easy to burn
- a LED is difficult to dimm: commercial dimmers are for series of LEDs and voltage limiter is not optimal

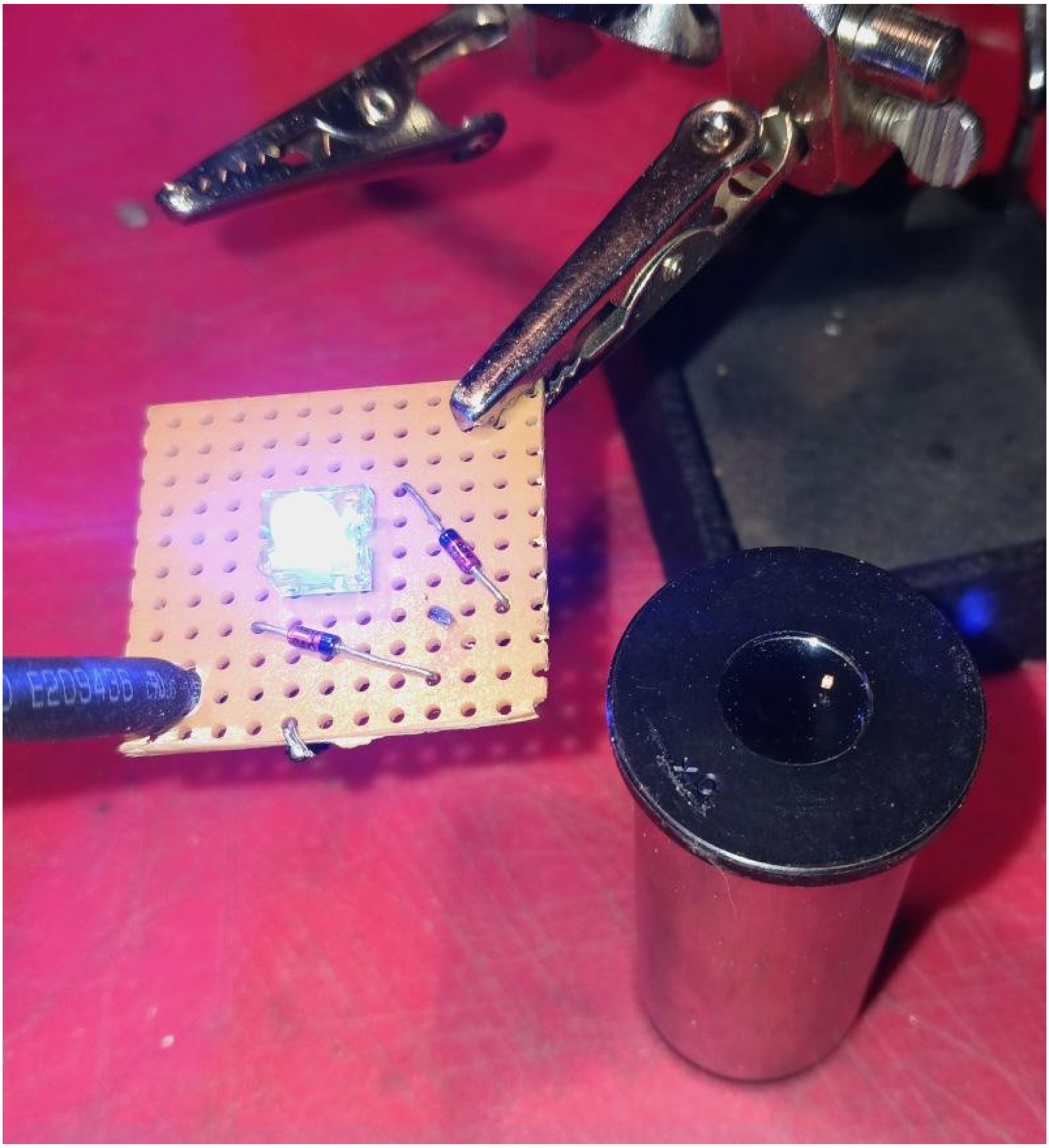
A LED is a greedy invention: it tries to ‘eat’ more than it can stand (in the Finnish folklore wolverine acts similarly).



Suitable maximum voltage for long term use may vary for different LEDs (even between production lots) typically 3.1 - 3.6 V for blue and white LED. When building a LED system you must monitor after every modification temperature and voltage of LED (actually current is only really relevant parameter, but current measuring is more error prone (I have blown so many overcurrent fuses that in the multimeter A is for ALARM)).

Usb blue with ocular

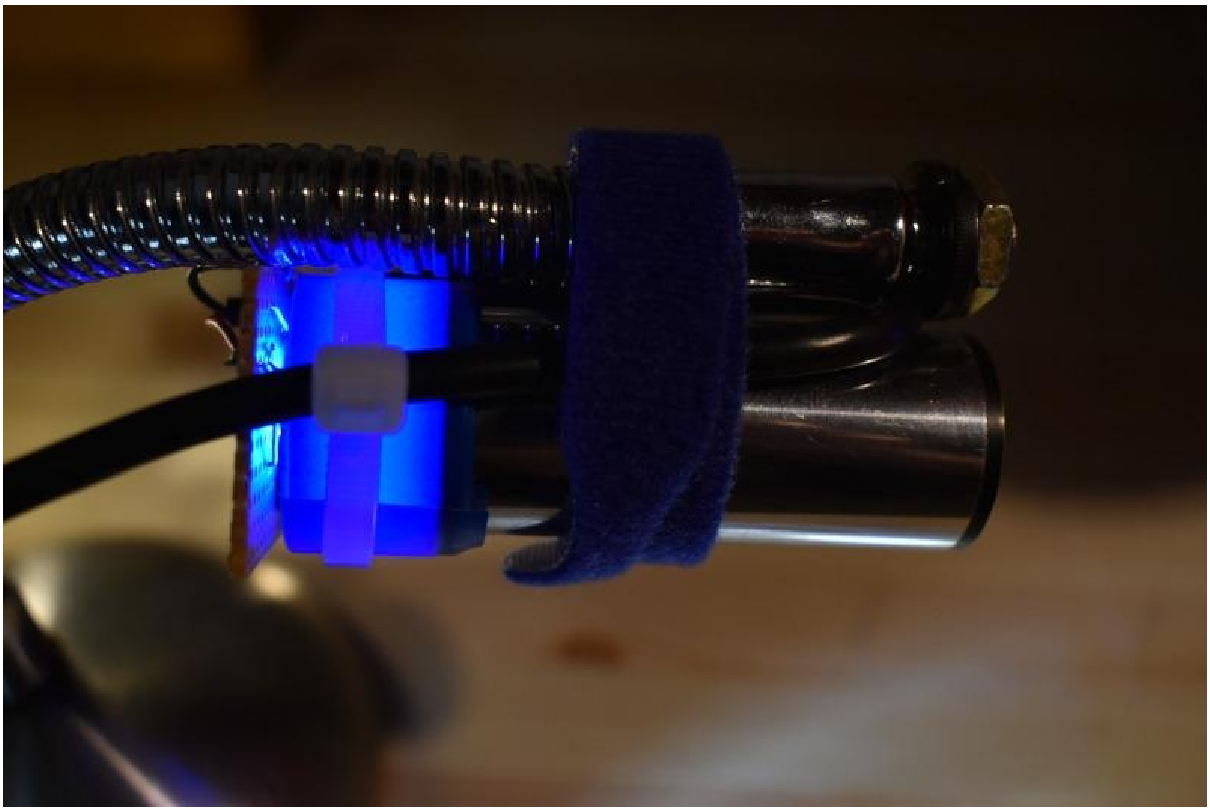
When I shopped for parts for the pwm-dimmer, there were LEDs on sale (UV LED may be interesting, but I haven’t found suitable: 50 mA may be enough).



OSB56LZE31D is a 50 mW blue LED.

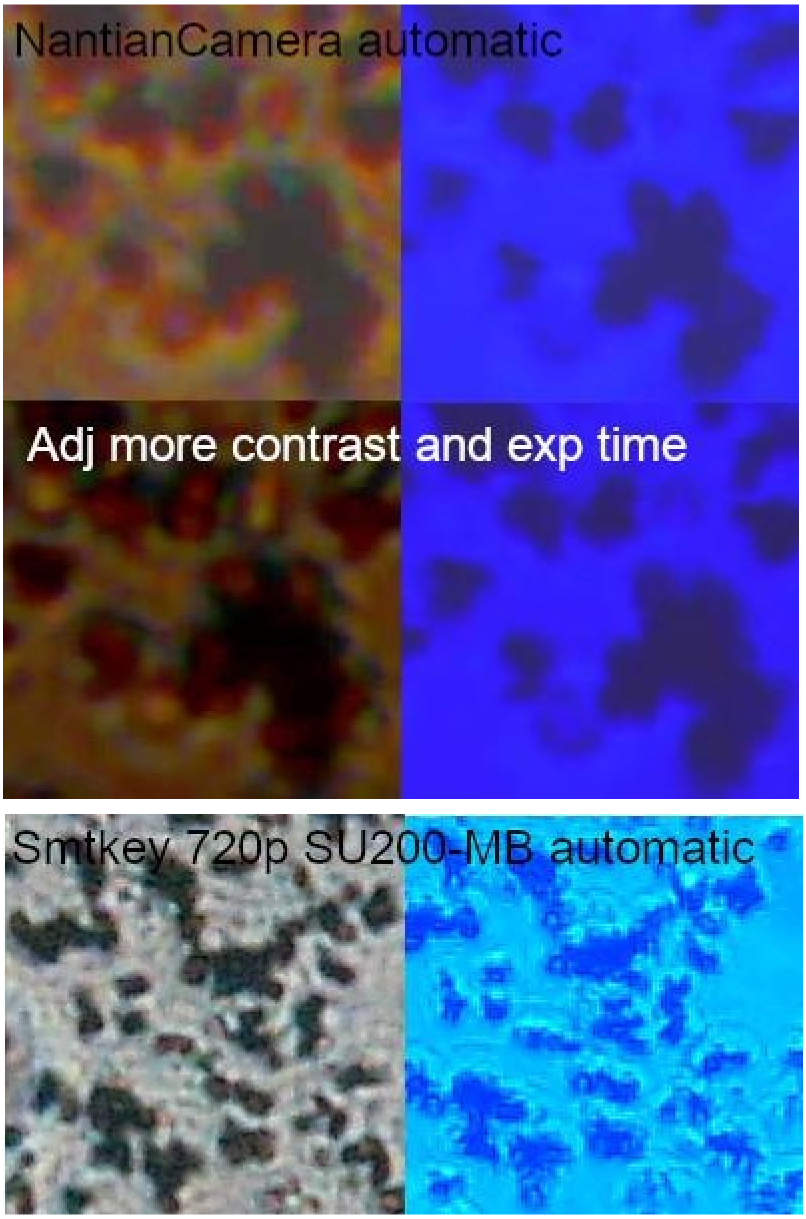
- can power from usb port
- single color suits for achromat objectives
- blue color / shorter wavelength produces better max resolution
- luminous flux is ok for my eyes as undimmed
- transverse ramsden eyepiece can used as collector lens
- one of my camera cell seems to love the wavelength (others not so much)
- really eco & economical

Usb voltage is 5V, so we need to get rid of at least 1.4V. A (silicon) diode drops usually 0.7V so we need one per both legs of the LED. If another type of a LED can't be handled by two (forward) diodes in series, maybe one 1.8 V zener diode as reverse can handle voltage drop (diode with 0.5W power dissipation and 50 mA & 5 V (only 0.25 W)).



Here are plastic 14 mm stud + tape has been used to fit the board to 6X ramsden type eyepiece. Do not block airflow, but insulate components electrically.

Setup is experimental and there is no adjustment in the light system: you must do adjustments with distance of set. May be useful to use a sheet of paper on the sample area to adjust the nice spot with condenser height and distance on the usb-blue.



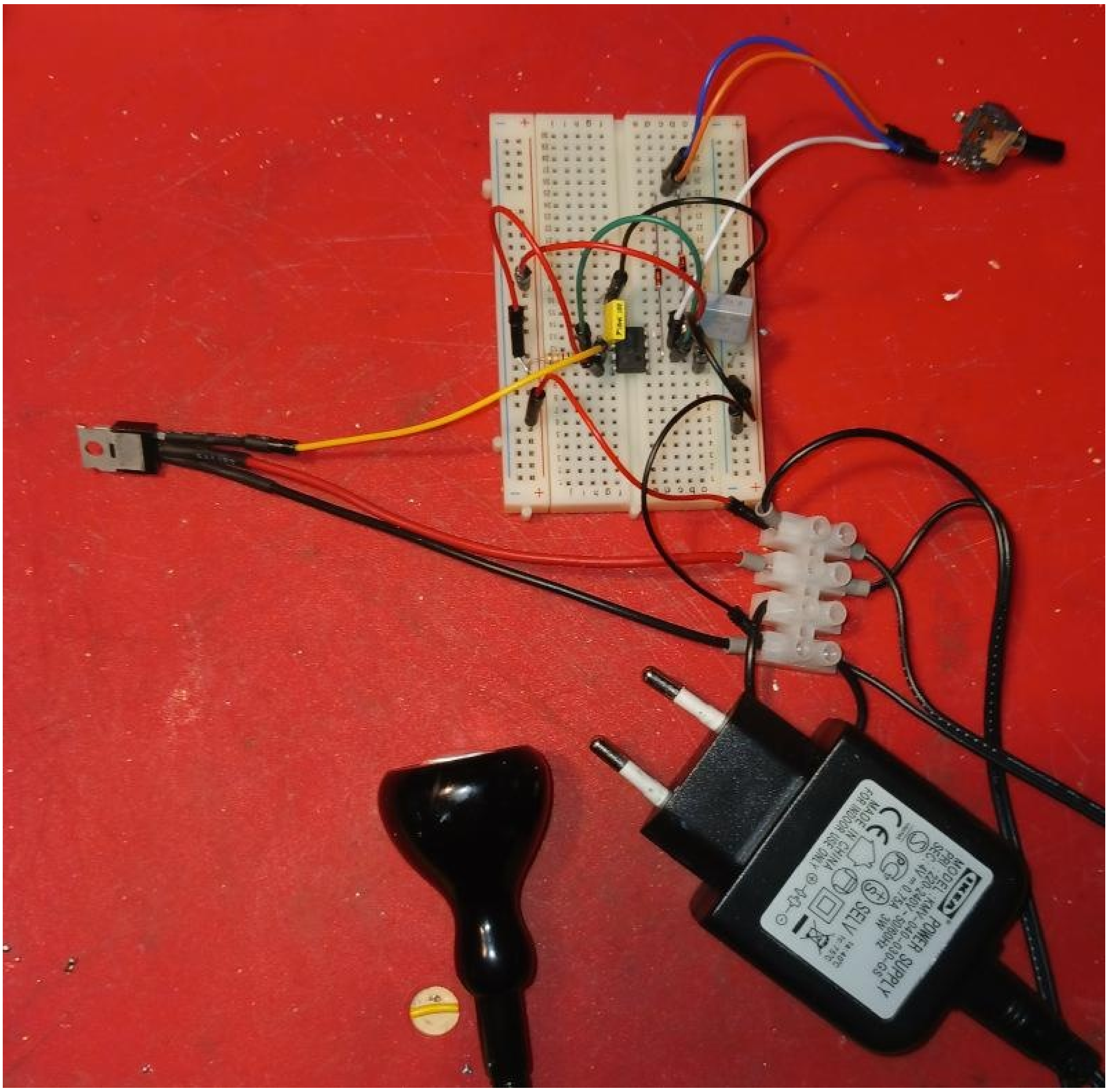
About the same area photographed with 3264x2448 (Nantian) and 1280x720 (Smtkey) sensors with white & blue light from Zeiss LgO (cell / sensor about 100mm above object plane).

There seems to be a ‘compatible’ blue filter in a 24€ Smtkey CS-mount camera sensor with USB-blue light (note dark areas in blue picture: they are blue instead of black).

I can’t explain the poor picture quality of the 4 times bigger image sensor of Nantian: it is poor with white and blue light. Webcamoid software can make decent pictures with CS-lens and Nantian cell.

Images are heavily zoomed: diameter of smallest grains in the picture is a couple um.

Pulse Width Modulation



For pulse width modulation a 555 timer (controls duty cycle), switching transistor(s) and power source is needed.

Power

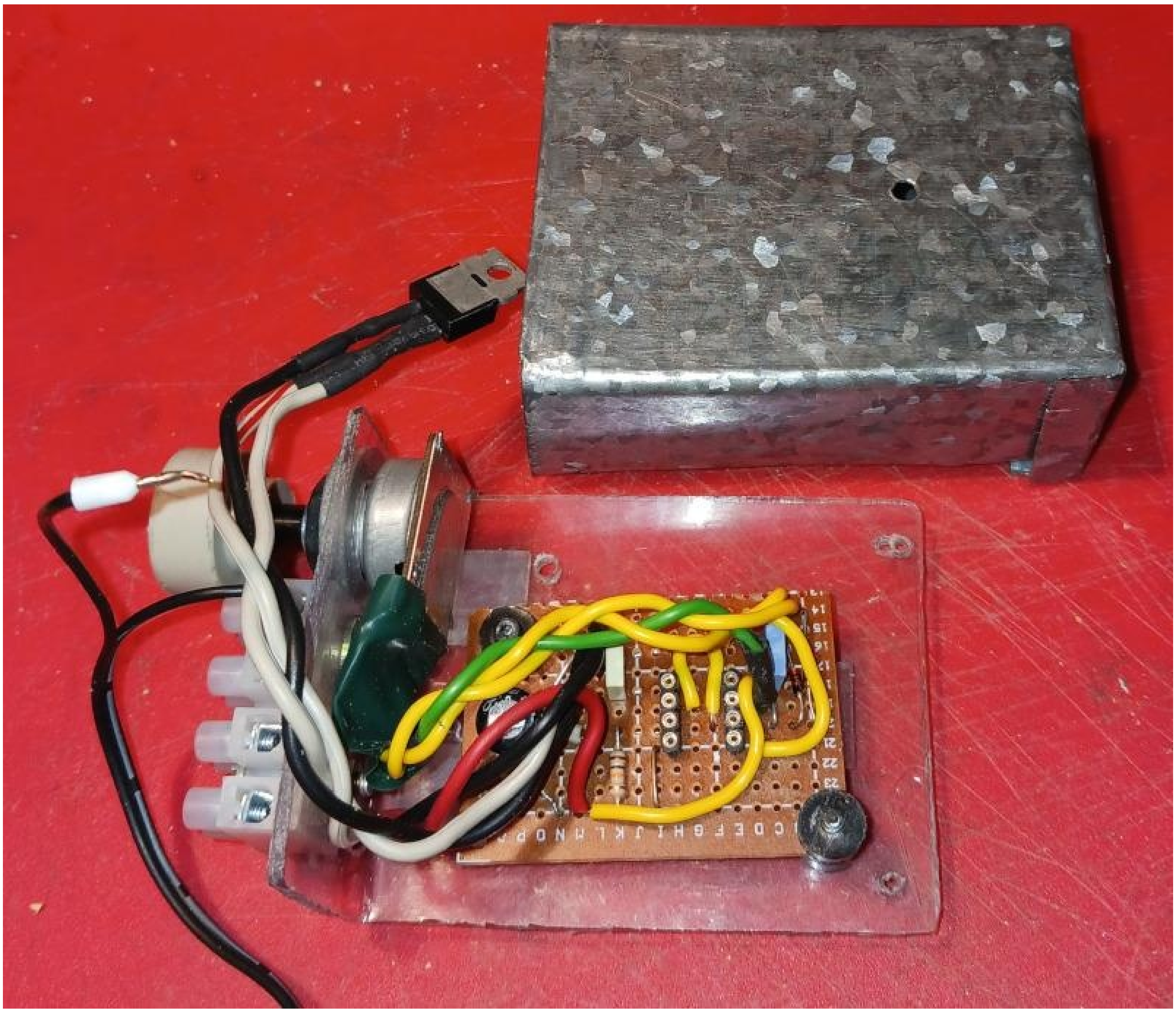
Ikea Jansjö power output is 4V, which can ‘almost’ power bipolar NE555 but generates odd malfunctions. Cmos TLC555 is happy with 4V and 4V is a little safer with misconnection. I have used recycled 5V power with a big internal capacitor with NE555, Jansjö 4V with TLC555 and a usb charger (can usually power up to 2A, instead 500 mA or 900 mA from the computer). Suitable voltage range to 555 itself is up to 15V.

I cut -cable shorter than +one: this convention equals to LEDs (shorter leg is cathode / -). Uneven wires of power may short circuit less.

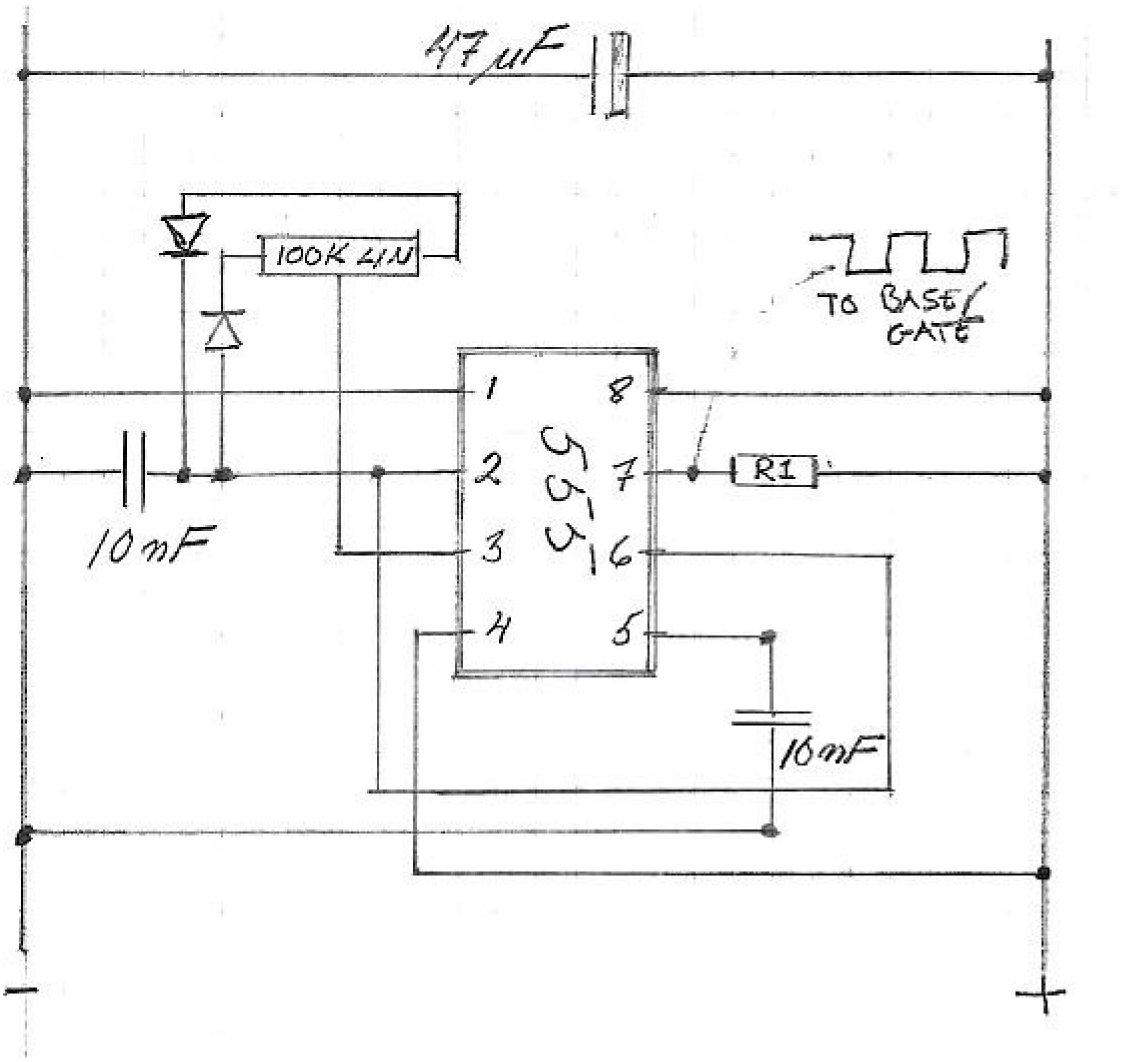
Timer / oscillator

Circuit I have found from the web, details are discussed later. The 555 generates an on/off signal from an analog Resistor-Capacitor (RC) oscillator.
Some hints for construction:

- make prototype with breadboard
- potentiometer may be critical for enclosure (https://www.partco.fi/en/mechanics/housing/plastic-enclosures/4166-kot-proto-1.html or similar may be easiest?)
- cooling & heat sink paste are necessary for longtime run with full pwr (at least over 1W power)
- small diam solid wire for fixed and 0.5 - 0.75 mm2 cable for 'moving' parts
- if you make soldered board, use dil8 ic-socket for 555 (less stressful to solder and much easier to replace)
- use datasheets of component to find correct pins and leads
- value of resistor R1 depends from transistor type: 10 kohm for mosfet or not at all for PNP bipolar
- values are tuned for single led powered from 4 - 5V



Layout chema is designed for breadboard and can easily be used with ‘pre-drilled’ soldering boards (you should not read this far, if you have capability to make your own PCB). With decent power, 47 uF capacitor can be omitted, it is for 555.



Switching transistor

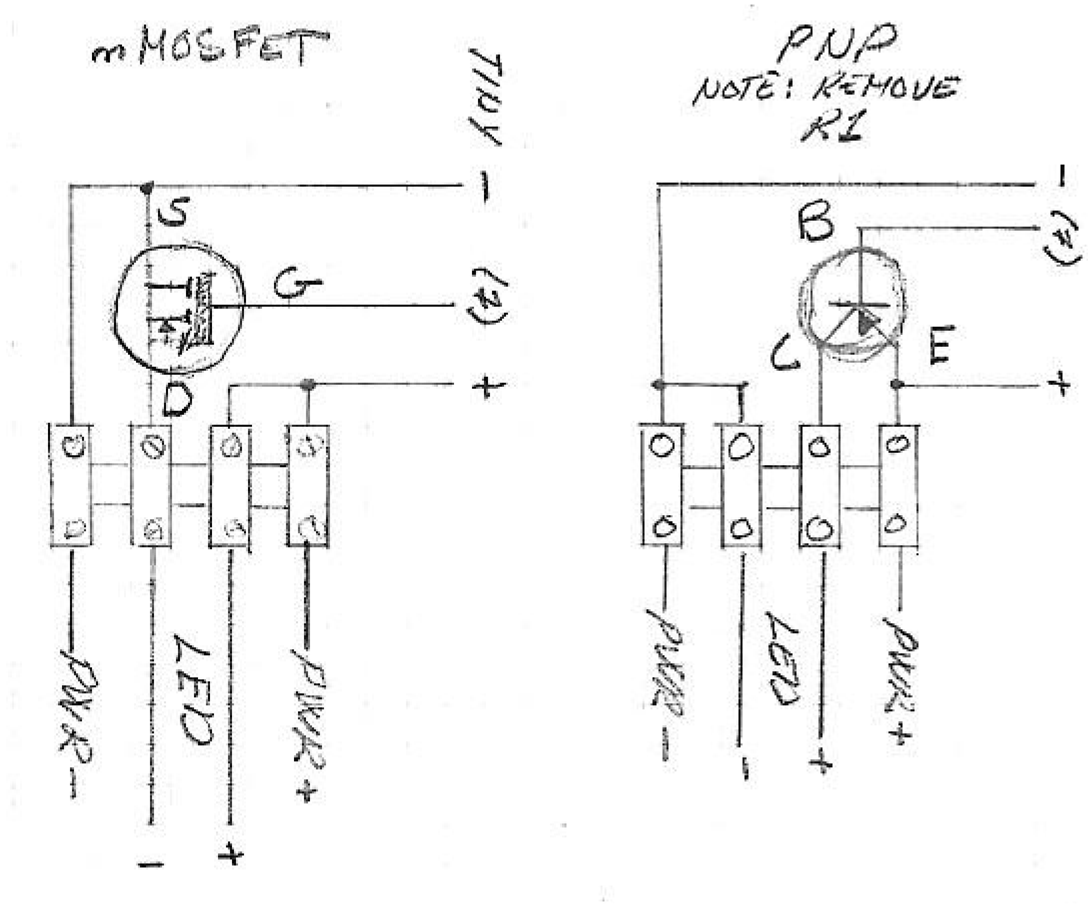
Original 12V circuit is done with mosfet, but I have problems with low voltage and ‘high’ power. Switching can be done with NPN / nMosFET or PNP / pMosFET transistors (‘digital’ duty cycle inverts between them, this may be useful for fine tuning).
https://www.build-electronic-circuits.com/transistor-as-a-switch/
If you don’t have enough current for bipolar or enough voltage for mosfet transistor: you don’t have an on/off switch, but some kind of limiter (check luminosity and/or voltage (actually current!) compared to undimmed LED). Power transistors tend to have low Hfe (amplification) and there is a limit for max draining (and output) of 555 IC (even smaller for tlc / cmos).

We can’t use a pull up system designed for voltage driven FET with bipolar: current via R1 has alternate routes thru 555 discharge port and transistor base; it is hard to get enough base current for an NPN transistor.

Luckily PNP bipolar suits here: changing switching transistor to between plus and LED, base current can drain directly via 555 discharge AND without R1 (this flips duty cycle also, but you can reverse 'direction' of potentiometer by changing wires connected to diodes).

From the LED point of view bipolar transistors look like diodes: generate about 0.1 - 0.6V drop depeding transistor, degree of saturation and current (Saturation Vce in datasheet). MosFET look like small resistors, if operated with enough voltage.

Switching transistor can connect in two different ways. NPN bipolar isn't practical with 555 discharge port, so nMosFET and PNP are drawn here:



1W white power LED

Warm white LEDs tend to be too yellow for my taste. ProLigth white PM2B-1LWE seems nice and 1W power needs dimming at visual observation when bundled with a lens.

Tube has Whitworth (BSW) ¼ inch thread (common in cameras) and old table stative. If you like tools, special tools are available from
https://www.tracytools.com/product-category/taps-and-dies/bsw-taps-dies/
You may buy both taps and die. If you optics hobby include theodolite or other surveying instrument, don't forgot ⅜ BSW used in large tripods.

Lens in the tube is from a slide projector with f about 40 mm. If you have a cheap condenser, it may be interesting to test the inverted condenser front lens with led. Longer focal length seems to produce more diffused light, despite the larger diameter lens.

Shopping list

There is redundancy for cheap and ‘sensitive’ parts: shipping costs are high compared to component price. There are necessary and not so necessary tools:

you need

- small soldering dev
- multimeter
- tongs or scissors

2 piece TLC555 ic
3 piece 10nF capacitor
1 piece 47 uF capacitor
6 piece 1.8V zener diode (can used in reverse to reduce usb voltage)
2 piece 10 kohm resistor
2 piece BD233 PNP transistor
1 piece IRF510 MosFET
1 piece 100k lin potentiometer
breadboard
box and solder board
wires
wire protector terminal
heat shrink tube
ic socket 8-pins (dip8 / dil8)

Power source assumed to be found.
If you don’t have Jansjö LED, 1w power LED PM2B-1LWE and small 50 mA OSB56LZE31D are decent.
I believe that Jansjö like ‘planar element’ LED with ‘classic cone’ as white or cold white shall be best: focused image of ‘radiator’ doesn't have picture of wire or other discrete hotspot.

If you planned an undimmed prole/eco usb light, it may be useful to alternate around luminosity 7000 mcd (maybe 3500, 7000 and 10000?)

Notes:

Datasheets

There is a huge amount of data and usually only after some solved problem - I can pinpoint the correct value. Pin layout is easy to find and only half of maximum power values are reasonable (in our power range components are cheap and we don’t have design skills to understand all conditions).

Is it gigant or small

Electricity has huge range in order of magnitude:

- Farad is ‘big’:nano must used
- Ohm is ‘small’: mega shall used

Semiconductors are not ‘linear’ components (usually you can’t use ohm’s law) and have many kinds of interdependence.
When modifying circuits calculations are needed, but it is easy to make several decades of error. If you are tired of calculation for component value, trial and error strategy may work with a step of decade (or don’t).

LED speed vs switching frequency

Traditional LEDs are very fast, switching time is some nanoseconds. Phosphorus LEDs are much slower, I have seen values as high as 100 microseconds. So if we take 1000 Hz switching frequency, we still have a ten times difference (LED doesn't reduce the system).

Failsafe design / building principle

I do not know enough from electricity to make real failsafe design, but some more or less obvious points:

- do not leave potential short circuit points
- make cable screen clamp
- fix components reliably
- try find out detailed power consumptions (here 555 internally uses some mW, BD233 base may drain 10 times more via 555 (but not exceed 100 mA))

- try avoid ‘digital / analog hybrid’ system (here idea is to run transistor fully on / fully off state, hybrid action may be useful in some cases, but definitely confusing and ‘analog area’ may be narrow (or totally in a different place))
- try foresee malfunctions

Potential malfunction is a dead oscillator. This situation can lead to fully open switching transistor: depending on the type of transistor either missing minus or plus power turns the transistor open. This (and building time bugs) is the reason why I want to reduce the potential max voltage possible to feed a LED.
Cmos 555 + bipolar transistor is nice to Jansjö: no risk for overvoltage and possibility to use original power (my first prototype uses 5V power + series diode to reduce max voltage).

The timer

The timer ic 555 is over 50 years old: https://en.m.wikipedia.org/wiki/555_timer_IC
Our circuit uses 555 little upside down; output is the pin normally used to discharge RC-timing components and normal output pin drains the capacitor via potentiometer and diodes.
Problem with the traditional way is the duty cycle: you can’t get a duty cycle for dim / long off periods. Original circuit:
https://hackaday.com/2013/09/15/the-easy-or-hard-way-to-build-a-pwm-dimmer/
also has an RC capacitor of 100 nF, but I believe it blinks at dimmest settings. Changing it to 10 nF increases frequency to 1kHz and we still have a decent capacitor (old thumb rule for designers: choose values from middle of tables - in wiki article ‘common values table’ 10 nF isn’t smallest).
Circuit is sensitive to change of values in capasitor-diodes-potentiometer part: not sure if it is change of resistance or capacitance which blinks output when touching in the potentiometer. Also bigger current drain via R1 seems to reduce ‘touching blinking’.

Too low voltage

Why with the 555 timer cmos version can be powered with low voltage down to 2V (compared bipolar 4.5V), but mosfet can’t drive 2W load with 4V?
You can get rid of IRF510 mosfet about 100 mA with 4 V, bigger current needs higher voltage due field effect (see datasheet Typical Output Characteristics figure).

In PWM 1 + 1 is not 2

Digital multimeter may show fancy readings with PWM: there may ‘appear’ bigger voltage readings than actually in use. At normal DC usage values are constant or ‘smooth’, but with PWM values are alternating (from max to 0, not to ‘opposite’ min/max) and some kind of average appears.
If you have fancy DC readings, try:

- smallest suitable AC range in your multimeter
- bigger AC range

And you may have 3 different readings from the same points.
Oscilloscope is nice, but quite difficult to operate.

Anode & cathode

Electrochemically cathode is a positive electrode, from the components point of view cathode shall connect to negative voltage (to 'work').
Electrons flow in the opposite direction compared to current in a schema, but electricity / current is the flow of electrons.
I can't understand / stand / tolerate that kind of mismatch, …

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Comments to the author Pasi Grönqvist are welcomed,
email – vihervitsa AT gmail DOT com.

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