SERVICE CLINIC

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Laser Pointers and Diode Laser Modules

This month I am inaugurating a somewhat new direction for "Service Clinic." Over the past several years, this series has covered many areas of consumer-electronics repair—most of which I can discuss above the level of an informed carrot. While some areas like television sets haven't been dealt with, computer monitors have—and these share about 90 percent of the same problems and solutions. Rather than repeating topics, which seems wasteful of space, or treating TVs or other major topics in depth (which puts people to sleep), this series will now cover a variety of mostly shorter topics, some involving repair, some involving general electronics, and some involving lasers and related areas. In other words, although the name of the series is still "Service Clinic," it may actually deal with almost anything. I may still cover a few other major areas of repair, but the era of the never-ending repair saga is over!

Laser Pointers

Even if you haven't used one or don't own one, it's hard to avoid having seen them. How do they get an entire laser inside a gadget that fits in your pocket? What's the real story on the safety of these things? Why is the green variety so much more costly than red ones? For that matter, how can the red ones be so inexpensive? Can the output power of a laser pointer be increased safely (to you and the pointer)? What other modifications are possible? In this and the next "Service Clinic," we'll cover these fascinating topics and more.

Even if you don't do presentations and don't own a cat, a red laser pointer represents by far the least expensive real laser readily available and can have all sorts of other applications—so the following material may still be of interest.

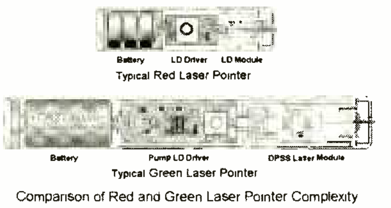


Fig. 1. In comparison, a red laser contains less parts than a green laser. The green laser requires a separate optics-module, called a DPSS, to produce the proper wavelength.

History

In the old days, before CD players, and before the laser was invented, you used a stick to point out something on a screen or blackboard (this was even before whiteboards!). The earliest optical pointers used tiny incandescent bulbs, a lens, and mask or transparency to project a dot or arrow. Such devices were about as big as a full-size (D-cell) flashlight, required a separate power pack attached by wires, and probably plugged into the wall. Performance was not all that great since the beam could not be collimated as well as a laser, but, nonetheless was a major advance over the stick. However, since they used an incandescent lamp, any color was possible using optical filters. Given the brightness or lack thereof, white was most common.

The first laser-based laser pointers used helium-neon (HeNe) lasers with their high-voltage power supplies packaged as compactly as possible. They still required a separate power pack or bulky case, which included heavy batteries.

Being true lasers, the beam was very clean and well collimated. Both red and green HeNe laser pointers were produced (yes, HeNe lasers come in green). The real laser pointer revolution came about as a result of the development of inexpensive visible laser diodes. Laser diodes are only slightly larger than a grain of sand and run on low-voltage low current. They can also be mass-produced—originally driven by the CD player/CDROM revolution, barcode scanners, and other applications where a compact low-cost laser source is needed. Now manufactured by the millions, these laser diodes cost well under $1.

Safety

There have been some recent articles (mainly in the UK) about eye injuries resulting from careless or malicious use of common laser pointers. In the U.S., there have been numerous news reports that would lead the average person to believe that the absolute end of civilization as we know it will result from the proliferation of these devices. Although the potential for eye injury is typically what comes to mind when one thinks of a laser, the possible side effects—or collateral damage—that may result from aiming one at somebody is at least as likely a cause for the current wave of hysteria.

Keep in mind that what gets reported in the popular press is not exactly rigorously reviewed for scientific accuracy. If it turns out that the outcome wasn't quite as originally reported, any correction for a front-page story is usually to be found in fine print buried on page 17!

Actual substantiated instances of long-term or permanent effects on vision resulting from momentary or unintentional exposure to a laser pointer's beam—or even from prolonged intentional misuse—appear to be all but non-existent. Flash blindness IS possible, but this is temporary and will clear up on its own.

The above applies where the laser pointer has been manufactured and tested to meet CDRH (Center for Devices

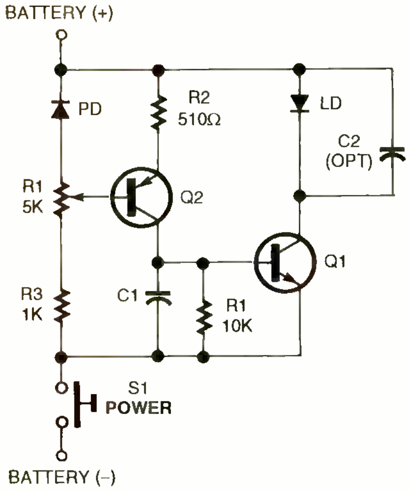


Fig. 2. This schematic shows a simple driver for a laser. People have successfully modulated this module at a reasonable frequency (upper limit not determined) by removing or greatly reducing the value of the filter capacitor, C1. However, do this at your own risk!

and *R*adiological *H*ealth, part of the FDA) Class IIIa safety limits or below. Note possible eye damage increases where these devices originate from countries with less rigorous quality control, where an internal current adjust pot can be twiddled, where laser-diode output power is greater, or where there is intentional abuse.

With respect to direct personal danger, potential damage to vision is the only real consideration—there is no risk from radiation, and there isn't enough power in a beam of less than 5mW to burn anything. However, from a public policy and regulatory perspective, there are actually three areas of concern:

1. Flash blindness from momentary exposure or permanent damage to vision from prolonged intentional misuse. Laser pointers are usually rated Class IIIa or less, which means that the power is low enough that the eye should be protected from permanent damage by natural pupil contraction, blink, and aversion reflexes.

Here's what you get when you crack open one of those bargain laser pointers. As you can see, the parts are minimal—power source, driver, laser.

2. Distraction and collateral damage—you wreck your car because someone directed a laser pointer at you while you were driving.

3. Misinterpretation of intent—you get blown away by someone with a BIG gun who thinks you are targeting them with a laser sight. Or, you are arrested and thrown in the slammer for aiming a laser pointer at a cop (this happened recently).

I am in favor of tough laws to make (2) and (3) crimes with appropriate punishments. Such behavior should not be tolerated. However, in the remainder of this section, I only really want to address the vision issues (1).

While I absolutely agree that intentionally aiming a laser of any kind into someone's eye is basically stupid (unless you are having laser eye surgery), one must be careful in interpreting the meaning of press reports that describe momentary exposure to the beam from a laser pointer waved around an auditorium resulting in instant total loss of vision in all three eyes! One would have to direct the beam into the pupil of the eye from a close distance for a few seconds or more without either the eye or pointer moving, twitching, or blinking. Distance is significant for two reasons. Laser pointer beams diverge (especially cheap ones), so less energy is able to enter the pupil of the eye as the source moves further away; and it is harder/less likely for it to remain stationary and centered on such a target a few millimeters across.

In fact, despite the great amount of press coverage lately—and such reports resulting in the passage of laws in some places banning laser pointer sales to minors (or to anyone), there are very few if any confirmed reports of permanent vision damage attributable to these things. The irresponsible aiming of a laser pointer at a person that might result in tragic consequences, whether from distraction or misinterpretation of intent, is far more likely to be a problem in today's world—and justifiably so.

Specifications

Here are some of the things that manufacturers use to rate and promote both red and green laser pointers (see Table 1). However, given the quality control (or lack thereof) and constant shifting suppliers, none of this can be taken too seriously.

- **Wavelength**—This may be specified but don't trust it too much. Usually, lower (e.g., 640 nm versus 660 nm) is better since visibility is a strong function of wavelength.

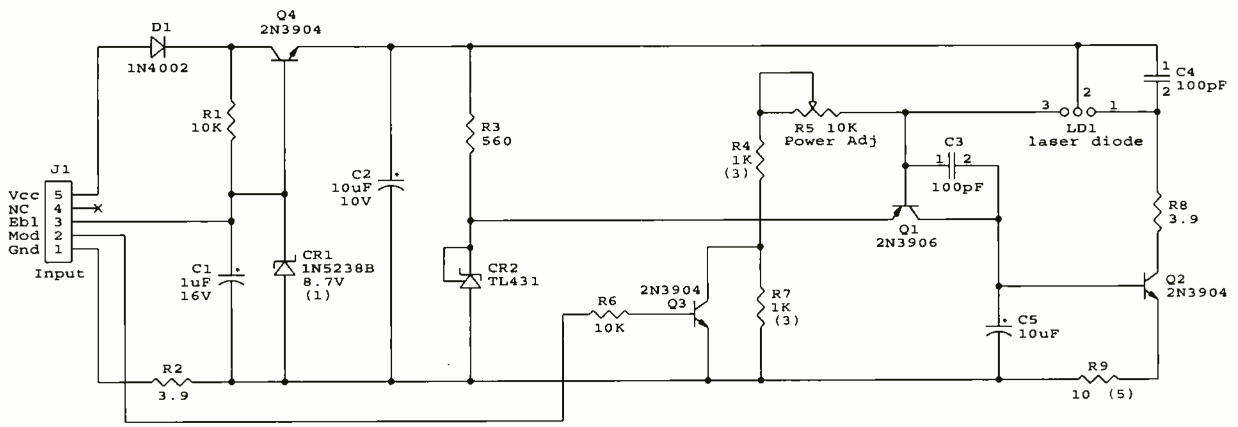
- **Relative and Factor**—The term "relative" refers to the visibility compared to the 555nm peak of human vision; while the "factor" compares the brightness to that of an older 670 nm pointer. Note that visual perception of brightness is not linear. Thus, a 1 mW 532 nm green laser pointer isn't actually going to appear 28 times brighter than a 1 mW 670 nm red model. What it means is that a 1 mW green pointer will appear similar in brightness to a 28 mW 670 nm red one (if such a thing existed, but anything above 5 mW true power isn't legal).

- **Output power**—Power ratings are often made deliberately confusing like "<5 mW," which could mean almost anything! Even among identical models, there can be significant variation, especially for green laser pointers.

- **Distance/range**—By itself, this is basically a totally useless number. Do they mean on a moonless night under smog-free conditions? Light doesn't travel a specific distance and stop or suddenly become too dim to be seen.

- **Beam shape/quality**—Without significant effort, the output of a red diode laser pointer is not a nice round spot like that of a HeNe laser. More expensive pointers may have the necessary optics to do a decent job of beam shaping but most do not. Sometimes, the beam shape will be shown in the catalog or Web site listing, probably to convince you to upgrade to the model with the rounder spot.

- **CW or pulsed**—As far as I know, all red laser pointers produce a continuous (CW) beam. However, due to the way modern green laser pointers work, there are significant advantages in terms of efficiency and thus battery to use a pulsed system. As a practical matter, it doesn't much matter to the user unless the pointer is moved rapidly in which case the pulsed beam will show up as discrete



Notes:

1. Preregulator zener value is not critical.
2. TL431 set for 2.5 V - a zener diode may also be used.
3. R6 and R7 should be selected for the desired power levels.
4. C5 uF value must be reduced for high speed modulation.
5. Laser diode current may be monitored as 100 mA/V across R9.
6. Circuit san be debugged and tweaked safely by substituting 3 or 4 LEDs in parallel for the laser diode and using a discrete photodiode instead of the one built into the laser assembly.

   Once the circuit is working, replace with the laser diode assembly.

Laser diode connector (LD1):

Pin 1: Laser diode cathode
Pin 2: Common
Pin 3: Photodiode anode

Input Connector (J1):

Pin 1: Gnd
Pin 2: Power Select (Modulation)
Pin 3: Enable (high)
Pin 4: NC
Pin 5: Vcc (+6 to +12 V)

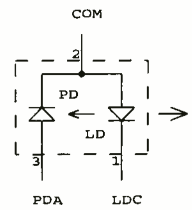


Fig. 3. While basically similar to the one in Fig. 2, this circuit includes soft start circuitry, reverse polarity protection, a reference to maintain output power constant regardless of power supply input voltage, and a modulation input.

spots rather than a continuous line.

- **Adjustable focusing lens**—While this may at first appear to be highly desirable, in the end it may turn out to be a nuisance—going out of focus on its own and prone to constant fiddling. (Of course, a piece of adhesive tape or dab of glue can cure this malady.) However, make sure that the pointer you acquire has had its focus properly set at the factory!

- **Multiple pattern-generating optics**—This type of thing appears really neat and cute. In my opinion, it has limited value, at most. Pattern generating reduces the overall brightness of the projected spot and, except for a basic arrow, just detracts from a presentation.

- **Battery**—The amount of time claimed for a set of batteries may tend to be optimistic. Some/many/most may assume something about the usage pattern in a pointing application (as opposed to cat teasing) like "25 percent on, 75 percent off." The brightness of some pointers decreases significantly as the batteries are drained while others remain exactly the same and then poop out without warning.

- **Life expectancy and warranty**—Sometimes there will be a spec like "2000 hour lifetime." This is probably mostly relevant for the expensive green DPSS laser pointers and may be reasonable. Certainly, anything over 1000 hours is adequate for a pointer used as a pointer within one's (human) lifetime (or until it becomes obsolete). However, any lifetime claim isn't of much value unless there is an enforceable warranty!

By now, you're probably totally confused. My advice: Use the specs for guidance, but if you really care about the quality of your laser pointer, try a few out which come with money back no-questions-asked warranties and keep the one you like. If, on the other hand, you just want to use the pointer for presentations (what a concept!) and not to stroke your ego, the cheapest red one will probably be just fine.

What's Inside a Laser Pointer?

The description below applies to most red laser pointers sold today (pen or key-chain type). We'll discuss green laser pointers next time. A common red laser pointer contains the following components (see Fig. 1):

- **Laser diode**—This will have a 3- to 5- mW maximum output. Better or older ones will be in a can package like that in the diagram; newer cheaper ones will just be a bare chip mounted on a heatsink. See the photos for some typical packaged laser diodes, as well as a laser diode without the cover. The actual laser is the chip mounted on the fat vertical post.

- **Power source**—These are typical AAA Alkaline cells or watch-style button cells. Depending on design, the battery must produce 1.5 V to 4.5 V or more.

- **Power regulator**—Many of the visible laser diodes used in laser pointers have very precise current requirements. Too little and they don't last; too much and they turn into poor imitations of Leeds or die entirely. The cheapest pointers today apparently use laser diodes that have a somewhat wider tolerance and just

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have a resistor to limit current.

- **Collimating/correcting optics**—At the very least, there must be a lens to convert the highly divergent beam from the bare laser diode to one that is roughly parallel.

- **Some means of generating multiple patterns (optional)**—These permit the projected shape to be selected to be something other than a formless spot either by a built-in thumb-wheel type thingie or by replacing end-caps.

Power Regulators in Laser Pointers

Figure 2 shows an example of a discrete driver from a cheap laser pointer. (Laser diode driver ICs may also be found in better units; but since these still cost more than discrete parts, they are probably still less common.)

Since there is no absolute reference, output power depends somewhat on battery voltage. People have successfully modulated this module at a reasonable frequency (upper limit not determined) by removing or greatly reducing the value of the filter capacitor, C1. However, do this at your own risk!

Difference Between Diode Laser Modules and Laser Pointers

Collimated diode-laser modules and pocket-laser pointers both produce a spot of light. So why the typical huge difference in price? There can be variability in any type of product. While the desired output of a laser pointer and collimated diode-laser module is similar, how fussy the end-user is and how one gets there may not be.

Laser pointers are mass-produced, so this helps reduce costs. They generally have less complex and less robust drive electronics since the power source is supposedly well defined—a set of batteries. There may be no corrective optics for the astigmatism and elliptical aberrations of the typical laser diode—at a distance, your spot isn't a nice round Gaussian profile. There is probably just a single cheap plastic lens glued in place, though some models do have adjustable focus.

Diode laser modules are more of a specialty item used inside other equipment and for optics research and development. Production volumes are not as high. They usually (but not always) have high quality driver circuits designed to protect the sensitive laser diode from moderate abuse—noisy power, for example. Many have high quality optics including additional elements for correction of the laser diode aberrations. They usually have adjustable focus.

Figure 3 shows the typical circuit that might be used in a high-quality diode-laser module. While basically similar to the one in Fig. 2, it includes soft-start circuitry, reverse-polarity protection, a reference to maintain output power constant regardless of power supply input voltage, and a modulation input.

In the end, it is probably the mass production that is the most significant factor in keeping costs down. There is also another difference between the two that relates to output power.

For a laser pointer, the power rating is the maximum you might see with fresh batteries, under the right conditions, on a very good day, or possibly just the 5 mW maximum for Class IIIa (which is the most that is legal in the U.S.A. for a laser pointer). Obviously, the seller wants to impress you with the specs for their product and not all are being entirely honest or forthcoming. The actual power could be much less and may decrease rapidly as the batteries are drained.

For a diode laser module (from a reputable manufacturer at least), the power rating is likely to either be what they actually measured for that sample or a guaranteed minimum value, and the actual output power could be greater. The CDRH safety sticker will still list an upper boundary, but it will likely be much higher than the module's power rating.

Can I Boost the Power Output of a Laser Pointer or Diode Laser Module?

The quick answer is probably not, or at least, not by much. I know that in your fantasies, you have dreamed about the possibility of creating a burning laser or Star Wars style light saber from a laser pointer. Unfortunately, neither of these is even possible theoretically. The best you could ever hope for would be to obtain 5 mW from a device currently outputting 2 or 3 mW.

While it might be feasible to increase the current to the laser diode, unless you know its specifications AND have an accurate laser power meter (mucho $$$), there is no way of knowing when to quit. Above their rated maximum optical power, laser diodes turn into DELDs (*D*ark *E*mitting *L*aser *D*iodes) or expensive LEDs. Exceed this rating for even a microsecond and your wimpy 3 mW output may be boosted to precisely 0.0 mW. This is called *C*atastrophic *O*ptical *D*amage (COD) to the microscopic end-facets of the laser diode. There can also be thermal runaway problems or a combination of both of these depending on design—or lack thereof. However, if you have a bag of these gadgets and are willing to blow a few, feel free to experiment.

Wrap-up

Next time, we'll continue with some of the more technical aspects of red laser pointers, as well as the much more complex green ones. There is much more information on laser pointers and almost anything else laser related on my Web site *www.repairfaq.org* under "Sam's Laser FAQ."

TABLE 1

Wavelength	Relative	Factor	Color	Type
555 nm	1.000	33	Green	Reference peak
543.5 nm	.974	30	Green	HeNe laser
532 nm	.885	28	Green	DPSS laser
632.8 nm	.237	8	Orange-red	Red HeNe laser
635 nm	.217	7	Orange-red	Red diode laser
640 nm	.175	5	Orange-red	Red diode laser
650 nm	.107	3	Red	Red diode laser
660 nm	.061	2	Red	Red diode laser
670 nm	.032	1	Red	Red diode laser