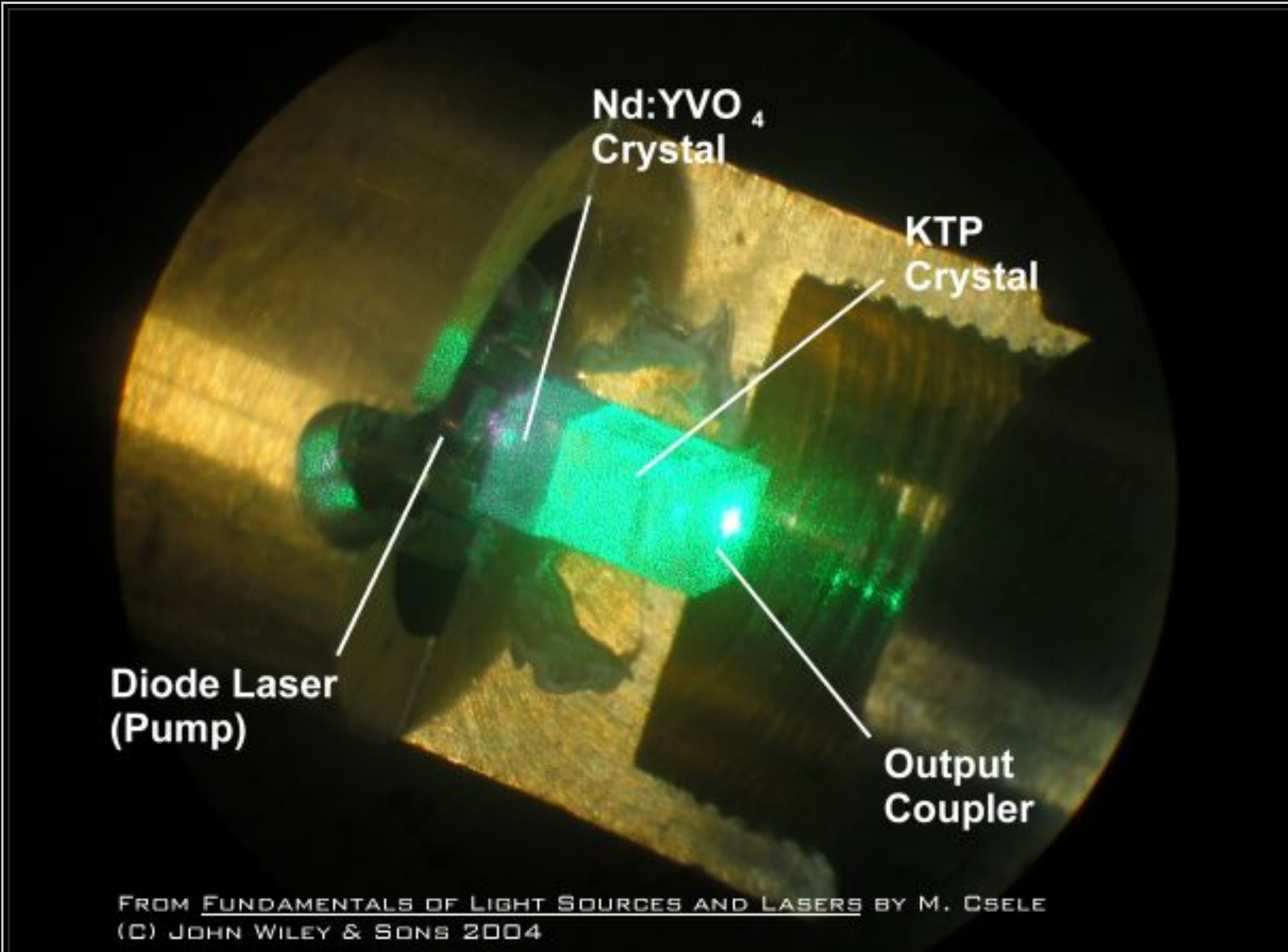
DPSS Lasers

While a DPSS appears to be a relatively simple device, building one that is truly stable requires a bit of engineering. This page describes the conversion of a simple, inexpensive green laser pointer into a lab-grade laser.

Abstract

The heart of this DPSS laser is an inexpensive green laser pointer. Such pointers are actually diode-pumped solid-state (DPSS) lasers consisting of a small vanadate ($Nd{:}YVO_4$) laser (operating at 1064nm) pumped by an 808nm diode laser and frequency doubled to produce 532nm output. The actual vanadate crystal and KTP frequency doubling crystal, along with the HR and OC mirrors, are built as a small one-piece composite unit under 5mm in length. Radiation from the pump diode (at 808nm) passes through the HR to pump the vanadate (the HR is a wavelength-selective coating which transmits 808nm while reflecting 1064nm). [1]



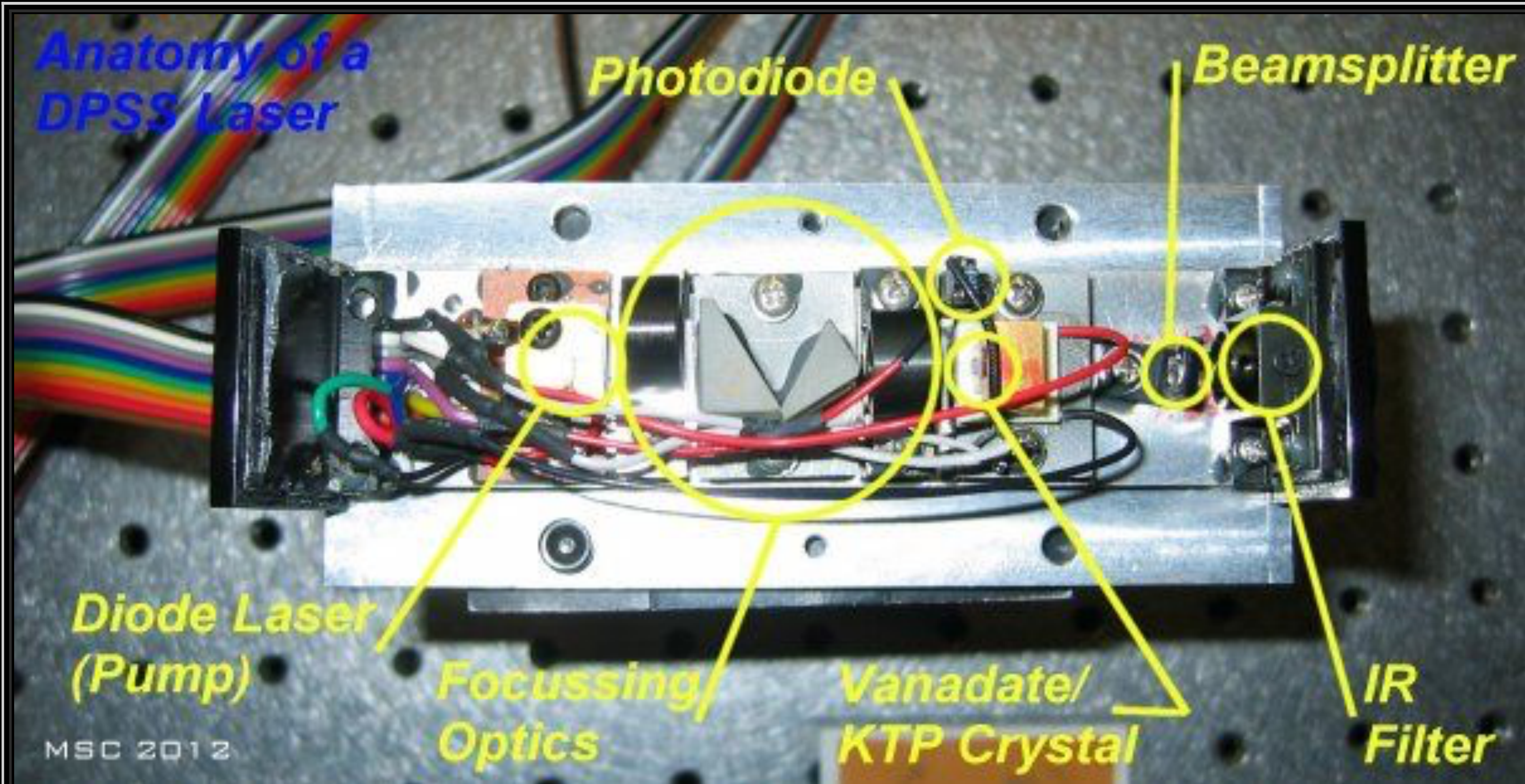
A close-up of a green laser pointer DPSS as seen through a microscope. The vanadate and KTP crystals are constructed as a single unit with the HR and OC reflectors deposited directly on the surfaces of the optical components. The assembly is pumped directly from a diode (usually around 200mW output at 808nm) *which passes through the HR.*

Introduction

There are two basic problems with a simple laser such as this: the wavelength of the pump diode varies with temperature, and the phase-matching characteristics of the KTP doubling crystal also varies with temperature. In the case of the pump diode, all diodes behave in a similar manner with wavelength shifting towards longer IR wavelengths as temperature increases (of course, as drive current increases, temperature does as well). Unfortunately, vanadate (as well as YAG, and other neodymium laser host glasses) has sharp absorption peaks as so allowing the pump wavelength to vary over a span of a few nanometers can move the wavelength from one of great absorption to one of less absorption resulting in a decrease in output power. In decent commercial lasers, diodes are provided with a separate Pelltier thermolelectric cooler (TC) and temperature sensor (usually a thermistor) to keep temperature constant regardless of drive current or ambient temperature.

Phase-matching of frequency-doubling crystals is, similarly, temperature sensitive. Again, high-quality commercial lasers use a separate thermoelectric cooler to stabilize the temperature of the crystal since a variation of only 0.2C can result in a decrease in efficiency of over 60% (at an anomaly point ... normally variations with temperature are not quite this large).

A commercial DPSS laser, a Crystal Laser, is seen here with the cover removed to reveal key elements. The pump diode is mounted directly on a TC with a thermistor attached. Pump radiation then passes through lenses and prisms to shape the beam and pumps a vanadate/KTP laser mounted in a copper block with a separate TC. The output beam is then sampled by reflecting a small portion from a piece of glass onto a photodiode. Ultimately, output power controls pump diode current resulting in stable optical output power. TC's ensure diode wavelength is stable and the KTP material remains phase-matched for efficient second-harmonic production.



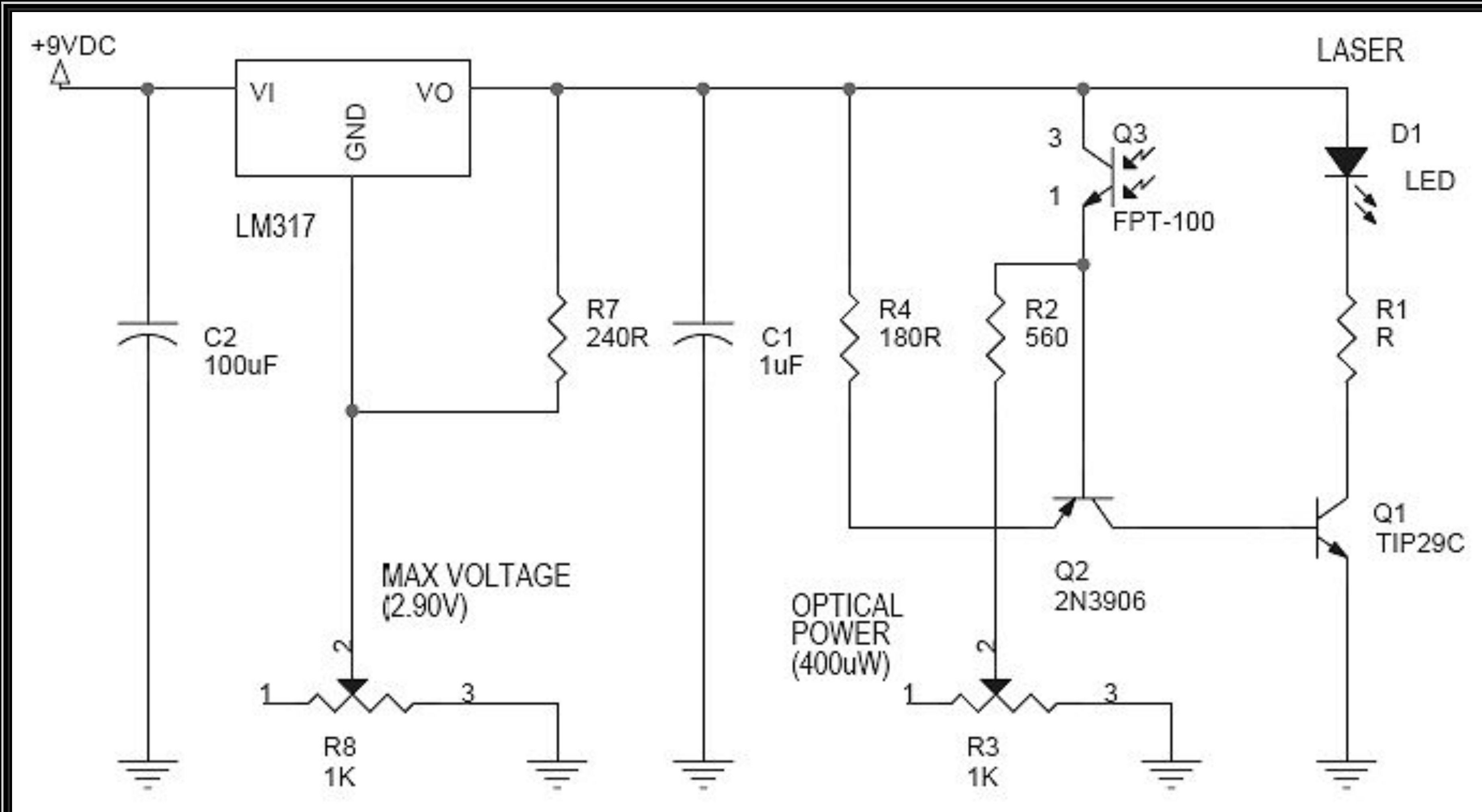
Components of a typical commercial DPSS system (as explained in the text).

Building The Device

Lacking the ability to add two TC's to the unit, the easiest solution is to use electronic feedback such that diode current is adjusted to maintain constant output. To allow this scheme to work (a) the entire laser must be heatsunk quite well to prevent heat buildup and

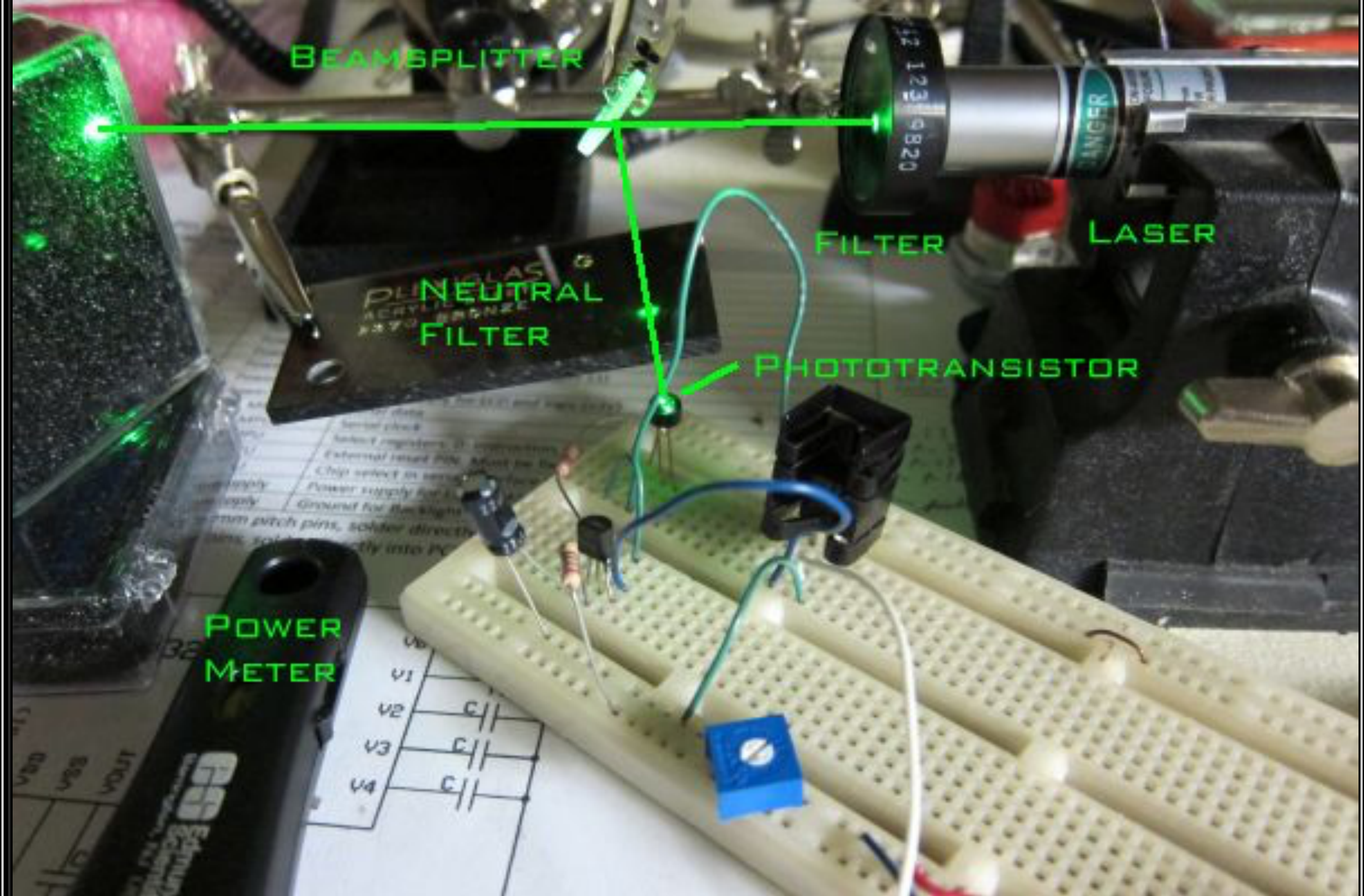
(b) the laser must be run at well below the maximum power output allowing suitable range for adjustment. With respect to heatsinking, one prototype laser literally cooked when operated at rated current for over five minutes (the casing was only about 45C at the time). The new laser was mounted into a large, solid, block of aluminum. The aluminum was drilled to a diameter of 9/16" allowing the brass cylinder containing the laser (stripped of the black housing), to fit snugly with thin shimstock metal and thermally conductive grease inserted to fill the remaining gap. A set screw was tapped at right angles to secure the laser into the block.

As for output control, a basic feedback circuit was employed almost identical to that used with basic laser diodes however with the feedback taken from the output beam itself. The circuit itself is seen in the figure below:



Schematic diagram of the DPSS driver. It is almost identical to the simple driver used with a laser diode alone, in which the laser diode and photodiode are mounted in the same package (the photodiode receives a small amoung of radiation emitted from the HR of the diode). In this case, feedback is obtained from the actual output beam and so represents actual laser output (i.e. after frequency doubling in the KTP crystal).

The incoming supply is regulated to 2.90V which sets the maximum output (as well as maximum current for the laser diode) - the laser assembly itself contains an integral driver designed for maximum output (of about 4mW of 532nm green radiation) at at voltage of 3.00V (and a curresponding current of 375mA) ... the chosen value of 2.90V results in a maximu current of about 350mA. Light from the laser assembly is first filtered to remove residual 808nm and 1064nm IR (of which there was over 12mW measured) using a narrow-band dielectric filter. The resulting beam then passes through a piece of quartz with the small reflection incident on an FPT-100 phototransistor. The prototypical optics are seen here:

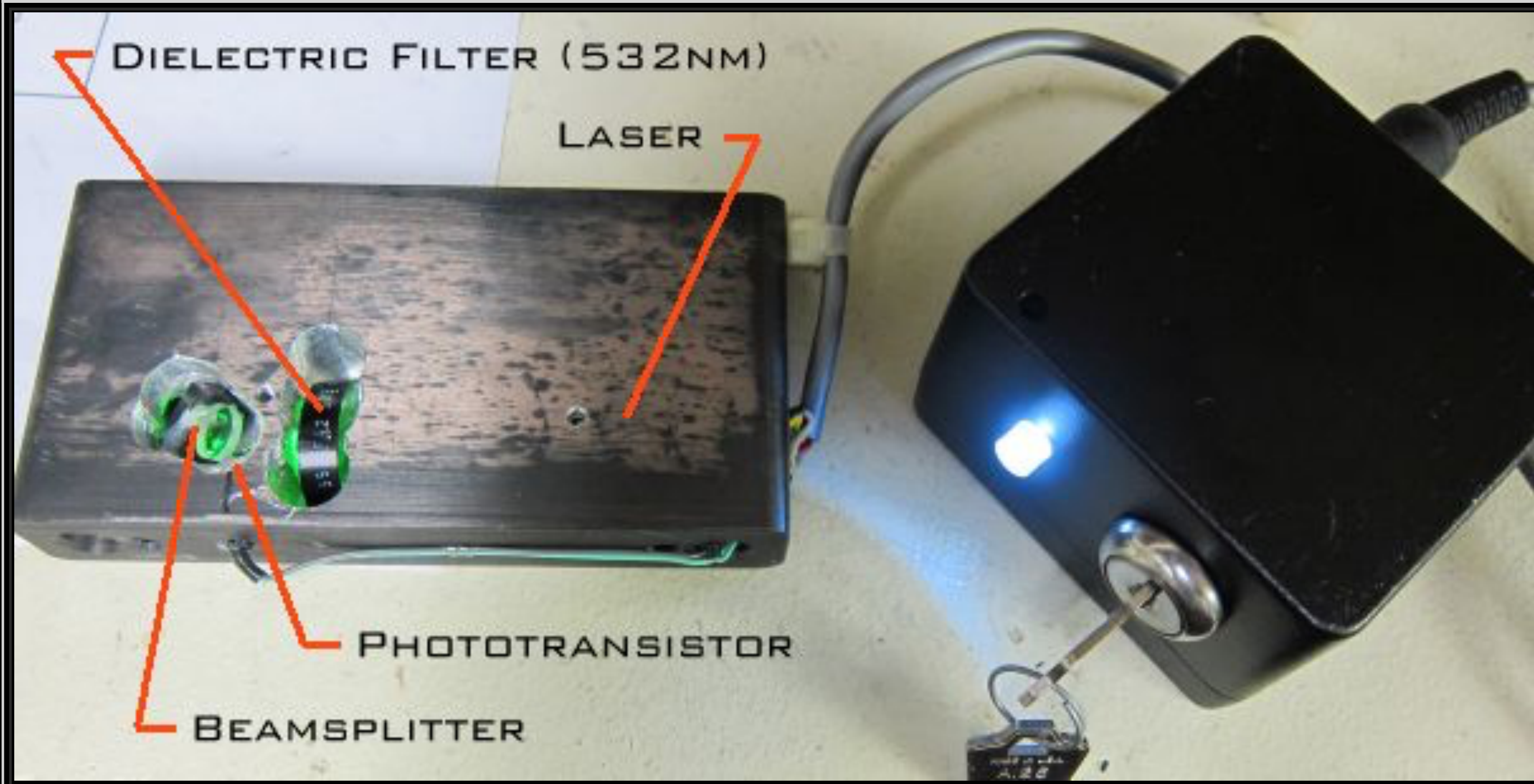


The prototype of the DPSS system. The laser was mounted in a portable vice, and optical components on "third hand" alligator clips normally used while soldering. The beam path is outlined in green showing how a portion of the beam is split off for sampling by the phototransistor which is mounted on the breadboard along with components for the driver circuit. A commercial power meter is seen in the left corner, used when calibrating the circuit.

When first turned on, Q3 is not conducting (since no light is produced yet) and so current flows through R2 & R3 causing Q2 to conduct. Collector current from Q2 flows into the base of Q1 causing it to conduct turning on laser diode D1. As the laser operates, light is produced and falls on Q3 causing it to conduct. Base current through Q2 is hence reduced (since it now flows through Q3) hence reducing base current through Q1 as well. In this manner, the system reaches an equilibrium value of optical output power. It must be set to a relatively low value to allow a decent control range and so R3 is set for an optical output power of 400μW. If a higher power is chosen, current will increase until the maximum value of 350mA resulting in a decrease of optical output power below the set value.

As with any system, a transfer function exists and gain may be set, crudely, by setting the amount of light from the laser which is fed-back to the phototransistor. On the prototype, it was found that insertion of a neutral filter between the quartz plate and the phototransistor reduces the overall feedback of the system. The values given were found to be adequate for small optical output powers however at large powers the system tends to oscillate and so a filter must be inserted immediately before the phototransistor as per in the prototype. The finished version was designed for power levels of under 1mW - underrating the laser this much allows for a large operating range (ambient temperatures may reach up to 30C and still allow operation).

The finished DPSS is seen here mounted in the aluminum block. The beam path was drilled through the block first and a large hole in one end for the laser. In the middle of the block two areas were milled to hold the green filter (first) and the quartz beam pick-off (with FPT-100 phototransistor). Two holes on the bottom were tapped to hold the laser to an optical bench.



The completed DPSS system. The laser is entirely enclosed in the large aluminum block used as a heatsink with only the set screw visible on top. Machined portals hold the dielectric filter, beamsplitter, and phototransistor. Normally, a cover conceals these elements. The entire laser is normally mounted vertically via two tapped holed on the bottom.

References:

[1] Fundamentals of Light Sources and Lasers
Mark Csele
John Wiley and Sons, 2004 (ISBN 0-471-47660-9)

[2] Crystal Lasers 532nm DPSS laser
