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Building and Characterization of Q-Switched Pulsed Nd:YAG Laser Range Finder Transmitter

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Abstract: A passive Q-switched pulsed Nd:YAG laser system was built for TOF (time-of-flight) laser range finder. The main goal is to build a TOF laser rangefinder transmitter operating at 1064 nm with 25 mJ output energy, 22 mm beam diameter, 15 ns pulse width, 0.5 mrad beam divergence. Construction and characterization of the laser cavity components including the function of the component for the laser transmitter and factor affect the performance are presented. In our design it is possible to use the transmitter in other applications using its compact dimension and power supply mobility by using batteries and also exploiting the narrow angle of the output transmitter with power reaches distance up to 15 km.

Keywords: Q-switched pulsed, Nd:YAG laser, laser range finder.

1. Introduction

The majority of laser rangefinders being manufactured use an optically-pumped solid-state laser source as a pumping source. The commonly used laser materials are ruby-O.6943µ, Nd:phosphate glass-l.054µ, Nd:YAG-l.064µ, these laser materials are pumped by xenon flash lamp. Laser material is in the form of a rod, the optical energy of the flash lamp is coupled to the laser material using elliptical gold-plated, silver or dielectrically-coated glass elliptical reflectors, with laser rod and flash lamp are placed at foci. The laser resonators are formed by a partially reflecting dielectric mirror, or resonant reflector at one end and prism, corner cube prism or total reflecting dielectric mirror at the other end. As population inversion is reached, the part of flash lamp energy that is transferred into laser material is released in a single giant pulse. This technique is called Q-switching technique, for solid-state lasers this technique can be done by mainly rotating prism, electro optics, and passive Q-switching. In rotating prism Q-switching techniques a prism is used as total reflector of laser, where resonator is mounted on a shaft of permanent magnet DC high speed or 400 Hz hysteresis synchronous motor. The prism position and flashing of lamp are synchronized in such a way that when all the energy from the flash lamp is absorbed by the1aser material, the prism gets aligned to a partial mirror at the instant of optimum population inversion to generate a single giant pulse whose duration is 30 to 50 ns, depending on laser material gain, motor speed and resonator length. The advantage of this type of Q-switching is that the alignment is not very critical, only prism edge has to be placed exactly at resonator, 70 to 80 % of the stored energy is released in a well collimated beam with divergence between 2 to 3 mrads. Electro optics Q-switching uses lithium neobate or lithium neobate polarizer and

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quarter wave plate in a laser resonator forming an electro optics shutter. This electro optics shutter is kept closed till the flash lamp energy is absorbed and optimum population inversion in the laser material is achieved. In this type of Q-switching, the laser output is available either from partial reflector or from polarizing beam splitter. If the prisms form both ends of the resonator, a quarter wave plate is used. In this type of Q-switching, 5 to 20ns pulses are obtained depending on the mode of operation, i.e., cavity dumping mode or pulse reflection mode. Although this type of Q-switching is complex and costly, the precise time-control for the generation of pulse is easily achieved. Passive Q-switching is mainly used in compact or hand-held laser rangefinders where the material contains an organic reverse bleachable infrared dye dissolved in organic solvent or dispersed in acetate sheet. In this paper, construction and characterization of flash pumped passive Q-switching Nd:YAG laser system are presented. We design and build a passive Q-switched pulsed Nd:YAG for laser rangefinder operating at 1064 nm single shot, and the laser peak power should be high enough to range targets up to 15 km.

2. Laser Cavity Resonator

Nd:YAG resonant cavity consists of two 4 mm diameter flat mirrors, M1 and M2, on both sides of the gain medium. The selection of the cavity configuration depends on diffraction loss, mode volume, and ease of alignment. The plane parallel cavity configuration is very useful for pulsed solid-state lasers because of its large mode volume, which is the volume inside the laser cavity occupied by the laser beam. The plane parallel cavity has high diffraction losses but this loss can be easily overcome in pulsed laser by high laser medium gain. Another advantage is that there is no focusing inside the laser cavity which can damage the laser rod or any other optical components. The disadvantage of the plane parallel cavity is the difficulty of alignment.

2.1 Optical Pumping Cavity Assembly

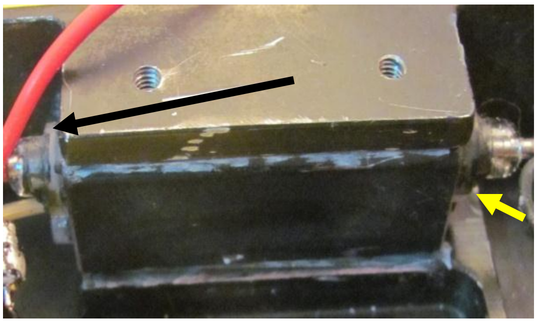
We start collecting the entire laser transmitter in the transmitter housing using the adhesives 088 and cleaning the laser housing before cement the parts in the pumping cavity as shown in Figure 1 which describes the steps for collecting the parts of the laser transmitter.

2.2 Laser Housing Alignment

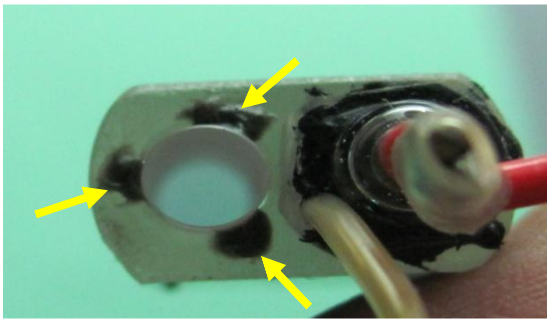
We mount the housing on an optical bench using collimator with cross slide attached and roughly align until laser rod is in front of He Ne laser and place a cube in front of laser housing and push it up against mounting face and do not hold in position. We fired a He Ne laser at the cube and adjust until reflected beam is at its source, then removed the cube and insure the laser strikes the center of the laser rod, align until reflected beam is at its source as in Figure 2.

Mount housing on optical bench place a cube in front of laser housing and push it up against mounting face and view cube using a NIKON telescope and adjust the telescope and laser housing until aligned. Remove cube, view on to the front face of laser rod and adjust until the laser rod and telescope are parallel as in Figure 3.

Using He Ne laser to align the cavity after assembled with the flash tube to be sure the laser beam is toward the middle of the end mirror and fire the He-Ne laser at a cube that we put it in front of laser housing and push it up against the mounting face and do not hold in position. Adjust the reflected beam is at the source then remove the cube, ensure the laser strikes the center of laser rod and alignment the beam is at its source as in Figure 4.

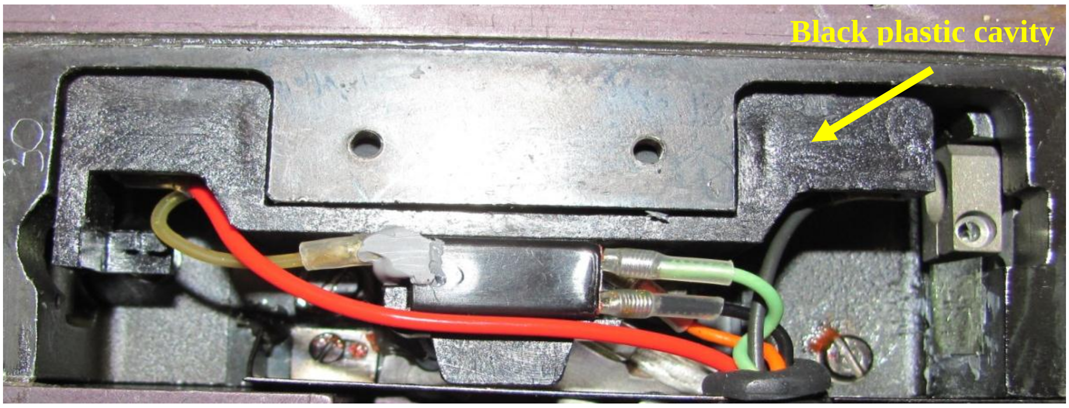


Cement pumping cavity with transmitter body



Cement pumping cavity

Welding high voltage wires to pumping cavity with transmitter body



Assembly of pumping cavity with body and cover transmitter body

Figure 1. laser pumping cavity assembly

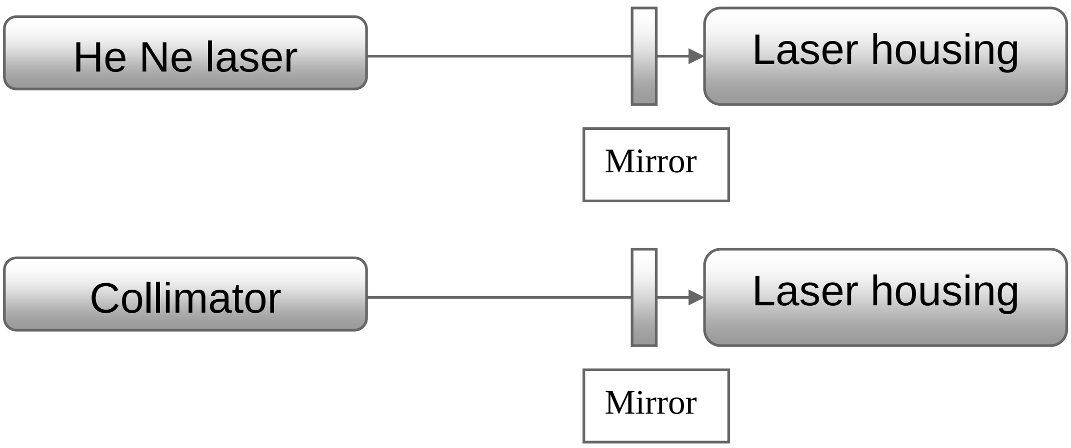


Figure 2. Laser rod alignments procedures

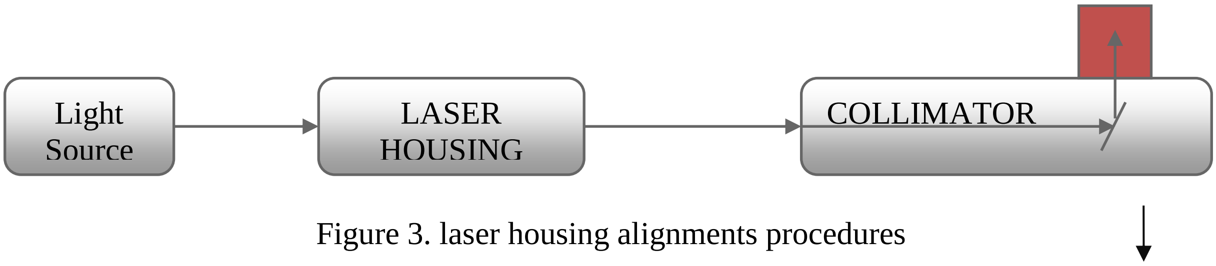


Figure 3. laser housing alignments procedures

Figure 4. laser pump cavity alignments setup

Connect the power supply to the transmitter and fire the laser and record the reading in the energy meter and with the movement of the polarizer to right and left to get 25 mJ and put the q-switch, and by using the polarizer get the best profile of the pulse and get the reading to 16 mJ and check the pulse on the oscilloscope as in Figure 5.

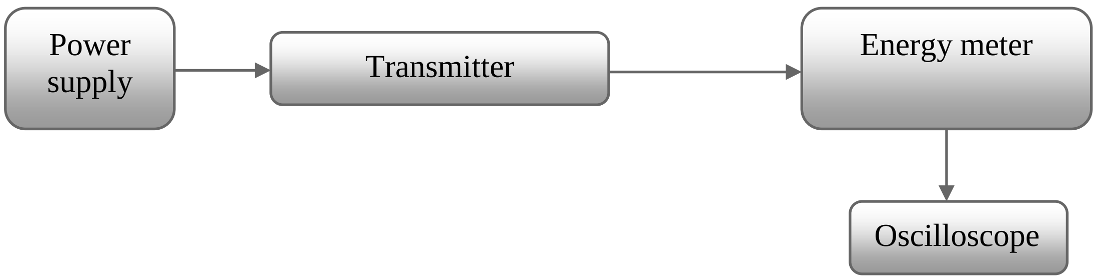


Figure 5. laser housing alignments procedures

2.3 Laser Transmitter Layout

The laser beam is produced within the laser housing from the pulse supplied by the PFN. The pulse fires flash lamp to stimulate the laser rod to an output between (0.7–1.5 MW) at this level the dye Q-switch ceases to absorb the light and transmits it at 1064 nm wavelength so that the output pulse passed through the q-switch to complete the optical pumping cycle. The two dielectric polarizing plates deflect the pulse through two angles to displace the transmitted beam so that it leaves through the optical wedges. The KG3 glass plate bonded to the housing wall absorbs any laser light not reflected by the polarizers. The reflected beam passes through the outer polarizer plate to be filtered then focused by the filter and collecting lens to fall on the photo diode hole to stop the range counter. Figure 6 shows laser transmitter layout.

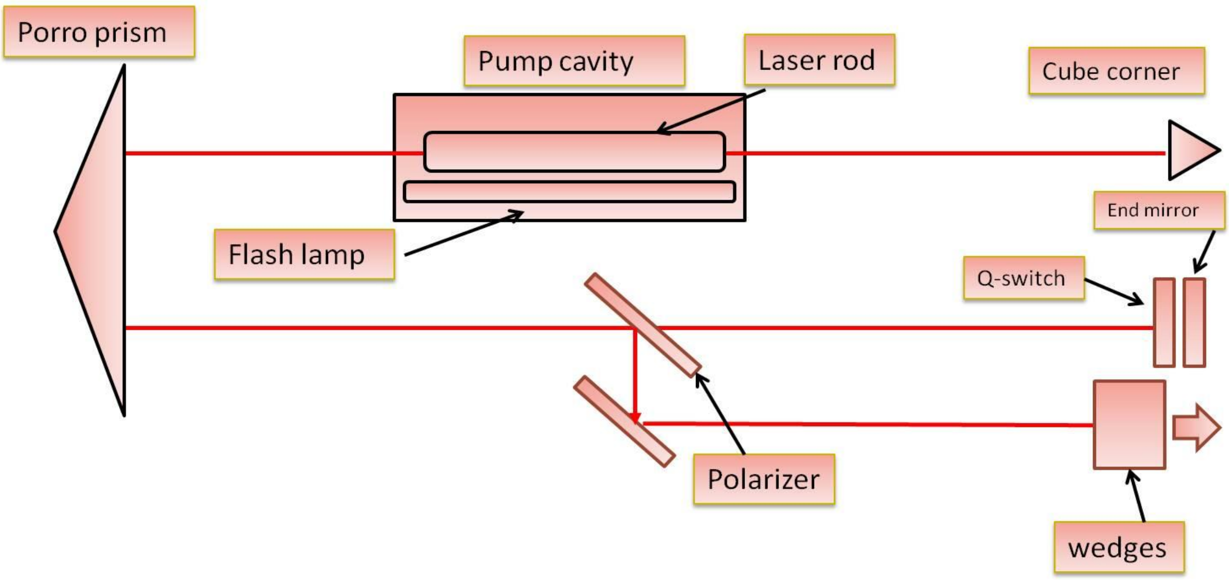
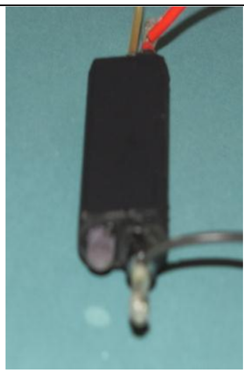
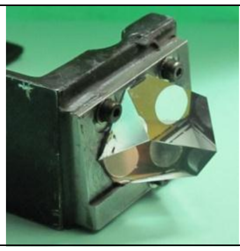
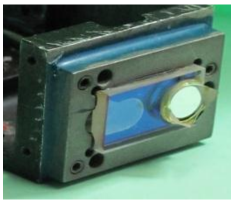
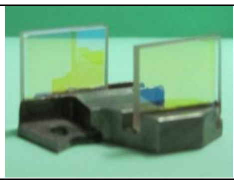
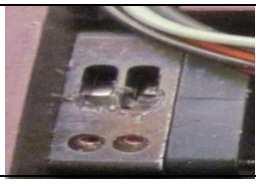


Figure 6. Laser Transmitter Layout

2.4 Transmitter Layout Component

The function of each component of the laser transmitter is listed in Table 1.

Table 1 Transmitter components

Rod	Nd:YAG crystal 20 end faces, antireflection coated roughened surface (not clad or polished)	
Flash lamp	Xenon flash lamp, 450 torr, matched with Nd:YAG absorption 10 J typical cerium doped fuse quartz	
Pump cavity	Close coupled reflection, cerium doped, silver and gold blackened	
Porro prism	Was originally conceived to circularly polarize the reflected beam provided stability in one axis reduces and for given 3-axis q-switching using a cube corner.	
Cube corner	Folds beam back in parallel which longer cavity gives lower beam divergence and improve the cavity stability by means of acting as beam de-polarizer.	
Polarizer	1st polarizer provides laser output, polarizer beam. 2nd polarizer provides sharing with receiver channel	
End mirror	100% at 1.06 µm	
Q-switching	Optical density selected to provide amount of q-switching and the angle of the sheet selected by test to compensate for remaining error in axis.	
Wedge	Was required to compensate for prism bonding errors and it is no longer required due to improved manufacturing tolerances	
Electrical component operation	The flash lamp initial arc formation that streamer at 10 ns per cm which get unstable arc until high power and the bore diameter controls the discharge, the ionization voltage about 850 vdc	
Trigger transformer	It gives 12 KVdc on the cavity to give core saturation in 50 ns.	

3. Factors Affecting Performance

During the workout to generate the output, many factors affected the performance of the design and gave an error for the system characteristics, Table 2 summarizes these factors.

Table 2 Factors affecting laser performance

Internal angular tolerances	total of the errors increase thresholds modes changing near field beam form
Positional tolerance	aperture of beam
Q-switch	selection critical to operation and affects errors which we expect porro axis
Dirt	centers for laser damage causing blocking laser beam and reduce the output power
Accidental damage	scratches and digs as dirt
Laser damage	long use coating may become damage
Contamination	not easy to watch and can reduce coating damage threshold get the output reduced
Flash lamp failure	make explosion and poor triggering and reduce the output beam

4. Laser Transmitter Measurements

After finishing the transmitter connection and securing in the housing without any error or bad alignment, any problem can be adjusted using the wedges until getting the error free. Many measurements can be performed to ensure the design is correct and to eliminate any recent problem, also can redesign the system if needed.

4.1 Laser Threshold Measurements

Temporal profile of the laser beam is examined to guarantee that the laser works with only a single pulse output to be suitable to the TOF operation. Using the energy meter (laser Mate-P energy meter with pyroelectric sensor- coherent) we measured the output energy and its parameter such as the threshold voltage as follows and shown in Figure 7:

1. Mount the transmitter on test fixture and alignment with the energy meter.
2. Apply high voltage to the flash lamp terminal and increase the voltage until the flash lamp fires.
3. Record V1(single pulse threshold)=700 v , the maximum measured voltage is 850 v
4. Record V2 (double pulse threshold) =870 v.
5. High tension calibration voltage =(V1+V2)/2 to get 785 v
6. Optimum energy by increasing voltage on flash lamp until max laser energy is obtained

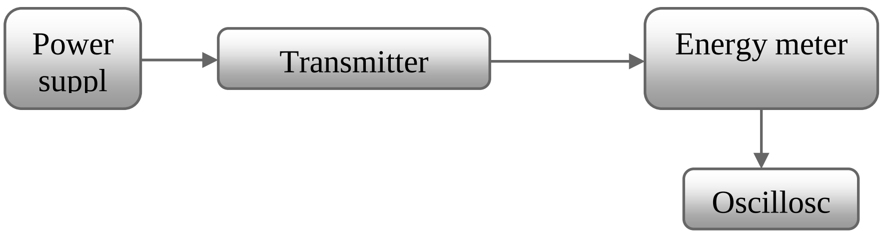


Figure 7. Laser thresholds and temporal profile measurements

4.2 Laser Beam Measurement and Beam Divergence

Laser beam divergence was measured using a lens and CCD camera from SPIRICON LBA-100A and 4x beam expander with the transmitter. Setup is shown in Figure 8 and the procedures for the measurement are summarized as follows:

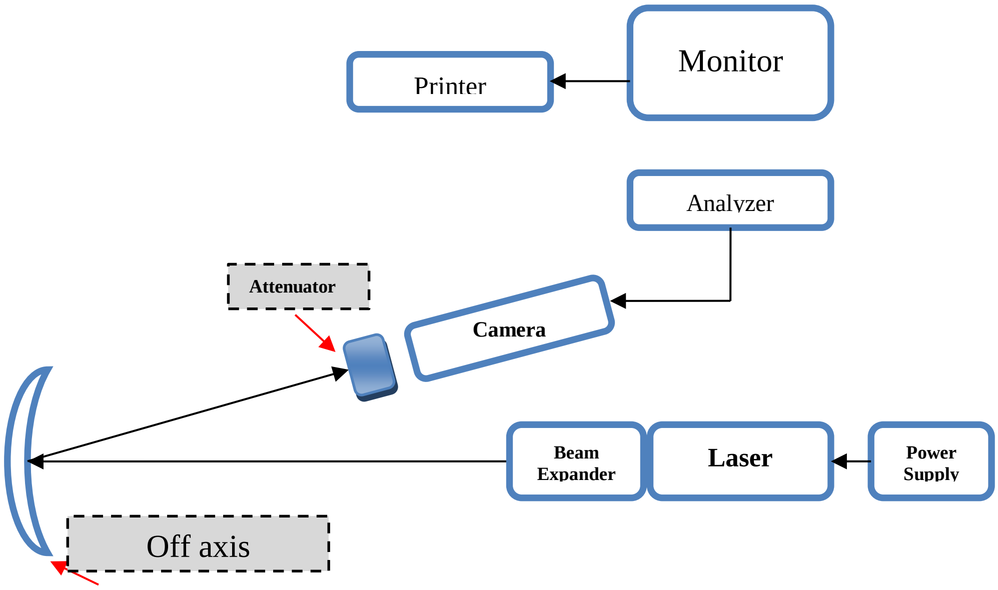


Figure 8. Setup for laboratory measurement of beam quality

The equipment used in the setup are: laser beam analyser, camera, attenuator, off-axis mirror, and monitor and printer.

1. Locate and measure the beam focus by move the CCD array along the axis and estimate the smallest spot size found (measure only the x- diameter now, y will be done later) and find the positions on either side of the estimated focus where spot size is twice the estimated waist size, locate the position of the actual focus, which lies exactly halfway between these two points, move the position of the camera to the actual focus position. Record the focus diameter and scale position as Dm and Z1.
2. Fire laser and display the result.
3. Loss the back screw of the lens and move the lens until we have the suitable reading by the software of the system, Make 10 reading until having the average reading less than 0.6 mrad ,and Calculate the imbedded Gaussian beam diameter using the relationship by Do= $(Z_R\lambda/\pi)^{1/2}$
4. M^2 using the relationship $(M2=Dm/Do)^2$
5. If the beam divergence has been previously measured, the diameter of the spot at the laser output can be calculated. If λ is the laser wavelength in microns and θ is the full-angle beam divergence in milliradians, the output diameter is given by the relation $(D=\pi M2/4\lambda\theta)$. We can measure the laser irradiance output by calculating the output area $A=\pi r^2$ and r=10 mm, giving A=3.14 cm^2 and I_r = laser output/area= 6 mJ/cm^2 and the result is 0.482 mrad and the result is close to the radial beam divergence.

Figure 9. shows laser beam and Figure 10. shows the setup used to determine the laser beam divergence using two energy meters as alternative method to insure our reading and result of the laser transmitter before finishing the assembly and after collecting its parts together and finish alignments.

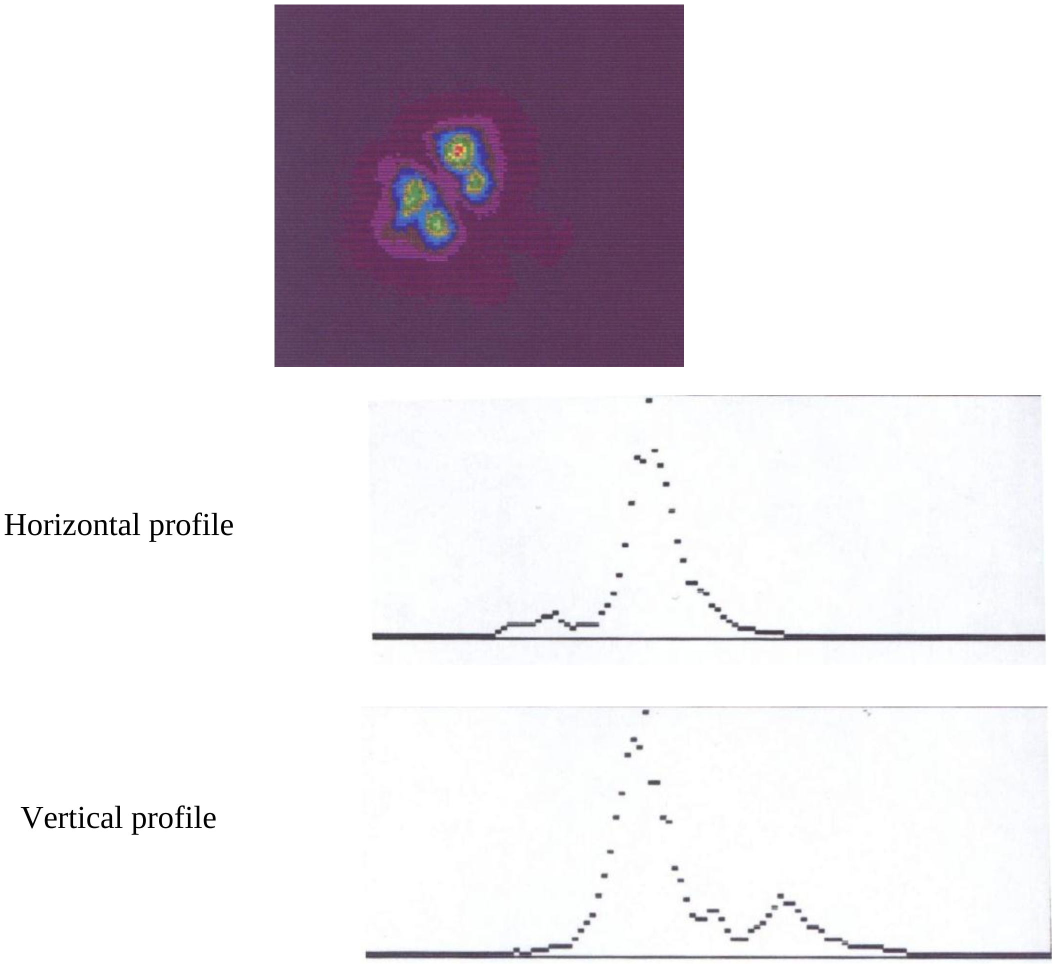


Figure 9 laser beam

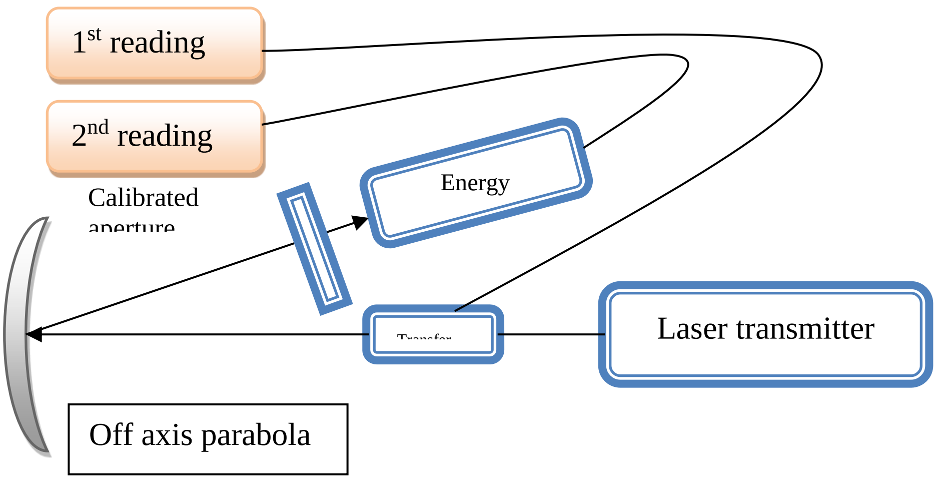


Figure 10. laser power beam divergence measurements

Alignment of the pin hole (0.6 mrad) with the laser source using energy meter and film on the hole to adjust the beam coming from transmitter onto pinhole to energy meter. Based on the measurements; Average= 2^{nd} /1^{st} = 92.62 % At 0.6 mrad beam divergence, the beam quality is greater than 90%.

Laser Energy and Pulse Width Stability Measurement

We mount the transmitter in the test station to determine the energy and the pulse width after applying the high voltage to flash lamp terminals and increasing this voltage until flash lamp fires, we tested the laser threshold before and we recorded the reading of the output energy and high voltage and pulse width and repeat the test after one day to make ensure the adhesive is fixed well in all optical parts after alignment all the laser path. Figure 11 shows the Result for measuring optimum energy.

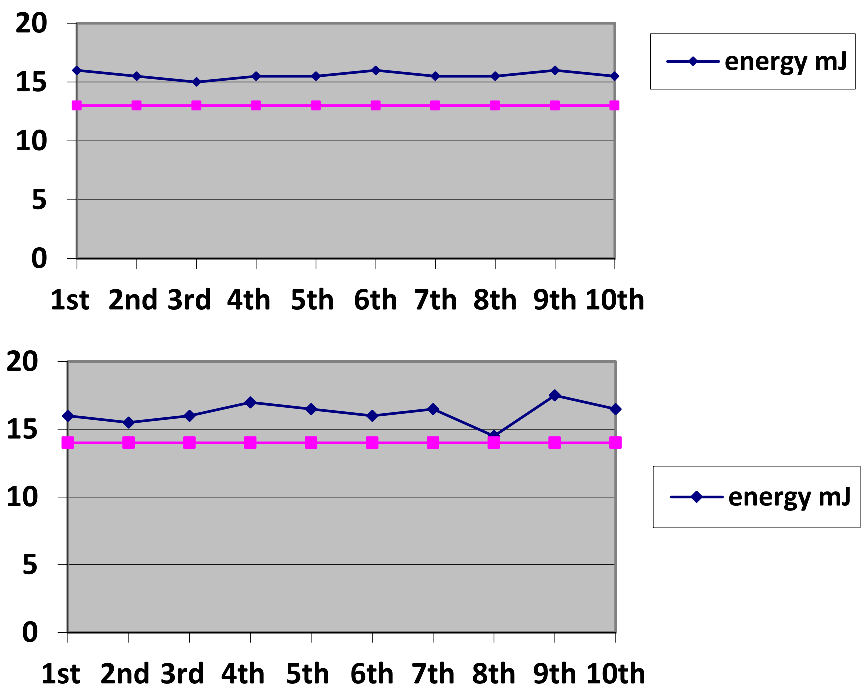


Figure 11. Result for measuring optimum energy

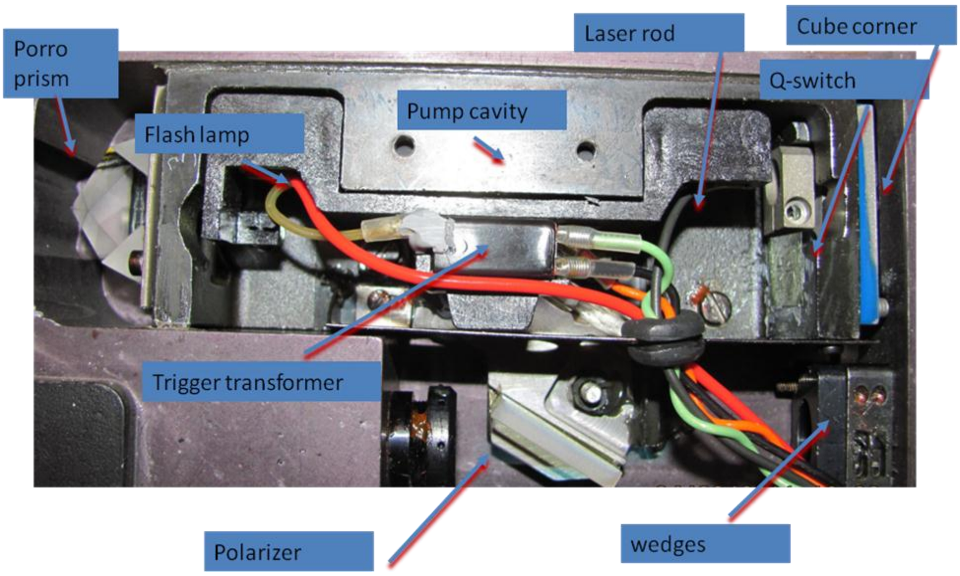


Figure 12 laser transmitter after final assembly

Conclusions

We present the building and measurements of a passive Q-switched pulsed Nd:YAG laser for rangefinder operating at 1064 nm with 25 mJ output energy, 22 mm beam diameter, 15 ns pulse width, 0.5 mrad beam divergence. Construction and characterization of The Nd:YAG resonant cavity components including the function of the component for the laser transmitter and factor affect the performance are presented. Also laser threshold, beam divergence, and laser energy was measured.

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