Design and Manufacturing of Q-Switched Pulsed Nd:YAG Laser System For Spectroscopic Measurements

A THESIS

SUBMITTED BY

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B.Sc. In Electrical Engineering

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For the partial fulfillment of the requirement of the M.Sc. Degree in laser sciences from the Department of Laser Sciences and interaction

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Contents

Chapter III:Pulsed Nd:YAG laser system design and characterization

Chapter IV: Application of the laser system in laser induced breakdown spectroscopy (LIBS)

Abstract

In this thesis we designed and built a passive Q-switched pulsed Nd: YAG laser system that can be used in various applications. This system can provide a potential compact robust laser source for portable laser induced Breakdown Spectroscopy system. This is an advantage since most other analytical technique can not be used in field.

In LIBS experiment the breakdown threshold for solid targets ranges from 10^7 to 10^8 W/cm^2. The whole laser system including, power supply, optical pump cavity, and laser resonator was designed and built to meet this power density.

The passive Q-switching technique was chosen while designing the system for more compact, robust and lessen the complexity of the system. The present Nd:YAG laser system operates at 1064-nm single shot pulsed. The maximum output energy of the present passive Q-switched laser pulse is about 170mJ with slope efficiency of 0.34%. The number of pulses was found to be in the range of 1 – 6. This depends on the pump energy. By increasing the pump energy, the number of pulses per laser shot increases. The six laser pulses are obtained at the maximum pump energy of 50J. The pulse width of each pulse ranges from 20 to30 ns. All laser pulses in each shot have different intensities. The variation of the laser pulse energy in each shot is within 36% relative standard deviation. The minimum energy per pulse within train of pulses is 10-mJ while the maximum is 60-mJ. The average energy per pulse is 28 mJ. The maximum total energy of the 6-pulses laser shot was about 167 mJ with 16% relative standard deviation.

The pulses are found to be approximately evenly distributed in time. The time distribution of the pulses show that the average duration of inter-pulse time gaps decreased when the number of pulses increased. The total duration of the output pulse series is within 300 µs. The inter-pulse time gap at the maximum pump energy is 60µs. At any given pump energy level, the laser output pulse structure was seen to be reasonably stable; only one out of 10–20 shots gave rise to a pulse number one higher or lower . The jitter on the time gaps between pulses was found to be 3–5 µs. The inter-pulse time gap between the last two pulses was about 25% shorter than all former gaps.

The system can provide an adequate source of laser energy to run many spectroscopic experiments as compared to commercial laser source. The size and the performance of the present system are suitable for robust LIBS technique to be used in field. In addition the present laser system can also be applied in more spectroscopic techniques such as Raman spectroscopy.

List of Figures

List of Tables

Nomenclatures:

Absorption coefficient	**α**
Absorption efficiency	**η_a**
Average absorption cross-section	**σ_{ij}**
Beam diameter-(m) meter	D, D_0
Boltzmann's constant	**k_B**
Capacitance-(F)farad	**C**
Current-(A)amp	**i**
Degeneracy factors of the state E_j	**g_j**
Efficiency	**η**
Electron charge	**e**
Electrical resistance- **(Ω)** ohm	**R**
Energy difference	**E**
Flashlamp explosion energy -(J) joul	**E_{exp}**
Focal length-(m) meter	**f**
Gain coefficient	**g**
Incident pump power-(W) watt	**P_p**

Input-, output-, optical energy-(J) joul	$\mathbf{E_{in},E_{out},E_{opt}}$
Lamp impedance parameter- Ω (A) 1/2	$\mathbf{K_0}$
Length element	**dz**
Life time of the flashlamp (number of shots)	**N**
Number of atoms in exited state	$\mathbf{N_j}$
Normalized spatial distribution	$\mathbf{r_p}$
Operating energy-(J) joul	$\mathbf{E_0}$
Photon density	$\mathbf{\Phi}$
Population densities of the laser levels	$\mathbf{N_1}$, $\mathbf{N_2}$
Power supply efficiency	η_p
Power density of laser beam -watt/cm^2	**I**
Power-(W) watt	**P**
Propagation factor	$\mathbf{M^2}$
Pulse width at one third of the peak amplitude-(s)second	**t**
Pulse width of the flashlamp(pumping puls) -(s)second	$\mathbf{t_p}$
Quantum efficiency of the pumping process	η_p