

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

Communications Department

Military Technical College

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

***NATIONAL INSTITUTE OF LASER ENHANCED SCIENCES,
CAIRO UNIVERSITY
EGYPT.***

2008

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Acknowledgements

I'm deeply grateful to all the people who have supported and helped me towards the successful completion of this dissertation.

I wish to express my profound gratitude and sincere appreciation to **Professor Dr. Mohy Saad Mansour** (Dean of the National Institute of Laser Enhanced Sciences) and **Professor Dr. Moayad Aziz**, a visiting Professor of laser engineering at National Institute of Laser Enhanced Sciences (NILES), Cairo University, who both have been most generous with their supervision, guidance, advice, and encouragement throughout the preparation of this thesis.

I would like to express my gratitude to **Dr. Khaled Abdelsabour**, Assistant Professor of laser physics at Faculty of Science, Cairo University for his guidance, advice, generous help and scientific support.

Many thanks to Mr. M. Atef Reda for his support and fruitful discussions, as well as Dr. Hisham Imam, Assistant Professor of laser physics at Niles for his kind help and scientific support in setting and analyzing the results of LIBS experiment.

Thanks to Eng. Mohamed Zaki and his co-worker at Arabian-British co. for helping in manufacturing the opto-mechanical systems.

Thanks to Dr. Fatma, Assistant Professor of Conservation department, Faculty of Fine Arts for providing the samples and helping in interpreting the data of LIBS experiment.

Last but not least, I wish to convey my deepest appreciation and utmost gratitude to my family for their meticulous encouragement and support.

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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/cm². 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 to 30 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 μ s. The inter-pulse time gap at the maximum pump energy is 60 μ s. 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 μ s. 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.

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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) joule	E _{exp}
Focal length-(m) meter	f
Gain coefficient	g
Incident pump power-(W) watt	P _p

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