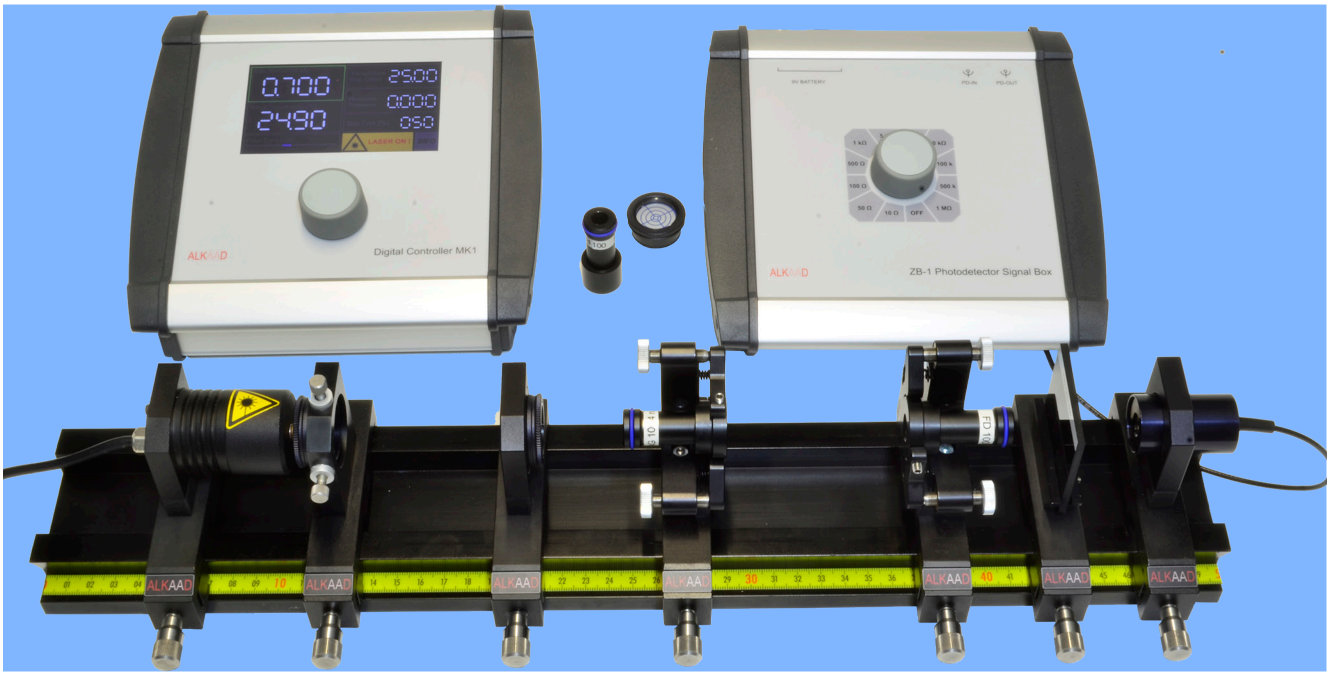
LE-0600 Diode pumped Nd:YAG Laser



Keywords

Properties of Diode laser
Static and dynamic behaviour
Resonator Stability Criterion
Hemispherical Resonator
Optical Pumping
Output Power
Transversal Modes
Spherical Resonator
Rate Equation Model
Optical Resonator
Spiking
Laser Line Tuning

Optical pumping in conjunction with Nd:YAG lasers is of particular interest, because these have become widely accepted for industrial use, along with the CO_2 laser. The laser-active material which, in the case of the Nd:YAG laser, is excited by optical pumping, consists of Neodymium atoms that are accommodated in a transparent YAG host crystal (Yttrium Aluminium Garnet).
Whereas up to a few years ago Nd:YAG lasers were always excited using discharge lamps, optical pumping with laser diodes is becoming more and more significant. This is because laser diodes are available economically and they emit narrow band light at high optical powers, which matches the energy levels of the Nd:YAG crystal. The advantage over the discharge lamp is that the emission of laser diodes is nearly completely absorbed by the Nd:YAG, whereas the very wide spectral emission of discharge lamps is absorbed to only a small extent.
The four level system is explained, a theoretical analysis of the Nd:YAG laser is performed, and a rate equation model derived. The steady state solution is presented, and the dynamic situation considered to investigate spiking.
The experiments contains all components necessary to assemble a diode pumped Nd:YAG laser - a 1W diode with driver and Peltier controller, collimating and focusing optics, Nd:YAG crystal, laser mirrors, a photodiode detector and all necessary mounts etc.
The stability criterion of the resonator are verified experimentally. The dependence of the pump wavelength on diode temperature and drive current are proven, and the absorption spectrum of Nd:YAG derived. By using a few additional modules, this basic set-up can be upgraded to LE-0700 „Frequency Doubling with KTP“ or LE-0800 „Generation of short pulses“. Furthermore the components for the oscillation at 1.3 µm including frequency doubling to “red” or an active or passive Q-switch are available as options.

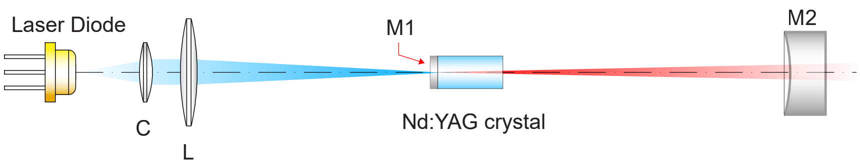


Fig. 2.36: Hemispherical Nd:YAG laser cavity

One side of the Nd:YAG crystal is coated and forms the first mirror (M1) for the laser cavity. The second mirror (M2) is a curved mirror resulting in a hemispherical cavity. The Nd:YAG crystal is pumped by the radiation of 808 nm emitted from the laser diode. The divergent radiation is collimated (C) to an almost parallel beam and afterwards focused (L) in such a way that the focus lies within the Nd:YAG crystal.

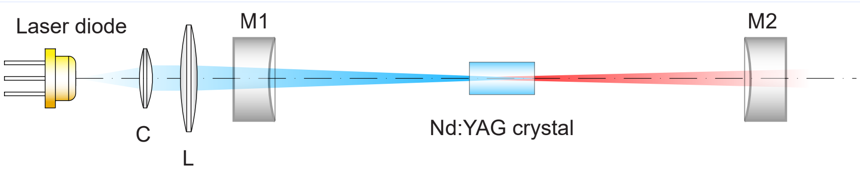


Fig. 2.37: Concentric Nd:YAG laser cavity

Another concept is to use a Nd:YAG rod which has no mirror coating. With such a rod other cavity configurations can be realized. One of it is the concentric cavity which uses two curved mirror (M1 and M2) of same radii of curvature. This concept allows a much better mode matching and gives more intracavity space for more experimental freedom

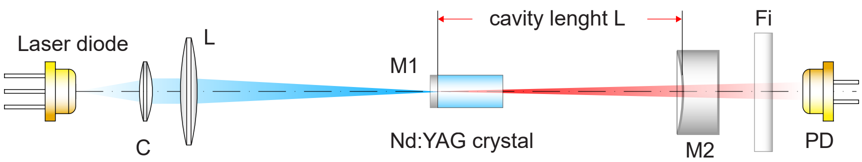
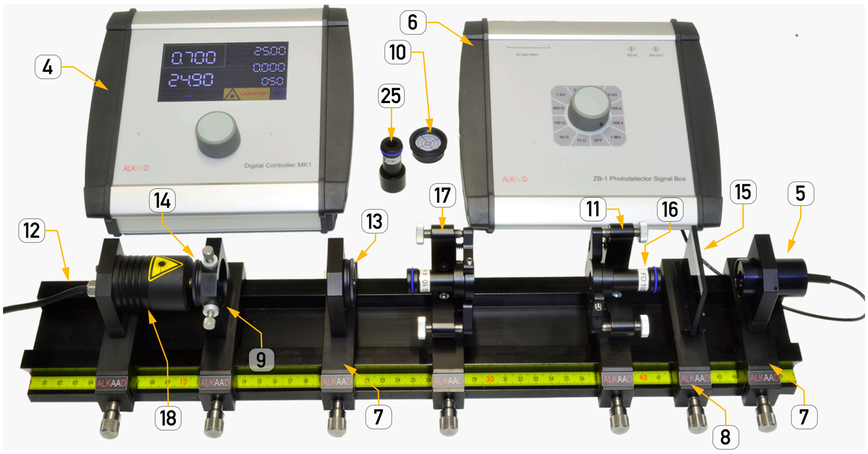


Fig. 2.38: Measurement setup

Independent of the choice of the cavity, a photodetector and a NIR long pass filter is used to measure either the power of the Nd:YAG laser or without the NIR filter the absorption of the pump laser. With the removal of the Nd:YAG crystal and NIR filter the radiation of the pump laser is measured for various values of the temperature or injection current.

Description of the components



The Nd:YAG rod is mounted to a M16 mirror mount and screwed into the mirror adjustment holder of (17). The rod is optically pumped by the diode laser (18) which is mounted to a Peltier cooler inside the housing of (18). The laser emits a power of 1 W at a wavelength of 808 ± nm at 25°C. The divergent light is collimated by a precision aspheric lens (14) to an almost parallel beam. The XY- adjuster (9) is used to align the beam with respect to the mechanical axis of the rail which is given by the target screen (10) when plugged in to the mounting plate (7) at the end of the rail (12). The lens (13) focuses the beam into the Nd:YAG rod (17). The Nd:YAG laser cavity is formed by the coated back side of the Nd:YAG rod and the mirror (16) which is screwed into the adjustment mount (11). The optical signals are detected by the photodiode of (15) which is connected to the junction box (6) where the photo current is converted into a voltage.

Measurements

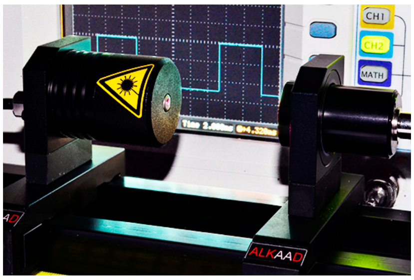


Fig. 2.39: Characterising the laser diode

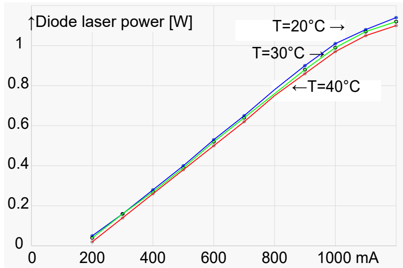


Fig. 2.40: Diode laser power versus injection current

One of the first measurement may be the characterization of the pump laser diode concerning the power and spectral properties. The Fig. 2.40 shows the diode laser power versus the injection current with the temperature as parameter. The power has been measured using an optional power meter (20, 21). The measurement can also be done by using the provided photodetector (5) in connection with the junction box (6). In this case the power values are given in relative units. In a next step the spectral property is measured. That means the dependence of the wavelength on the temperature and injection current.

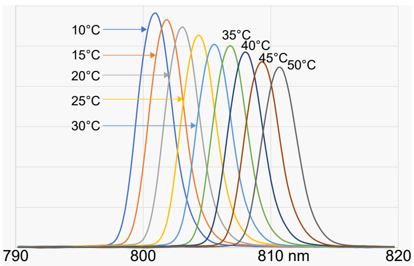


Fig. 2.41: Wavelength versus temperature

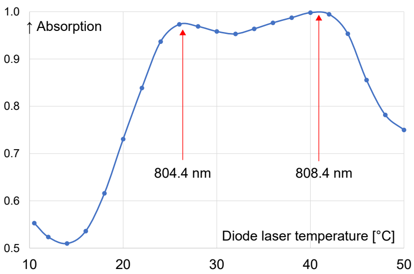


Fig. 2.42: Absorption spectrum

These experiments are related to the spectral property of the pump laser diode, which means the wavelength as function of the injection current or temperature. The Fig. 2.41 shows the emission spectrum taken with the fibre coupled optional spectrometer (22) at constant injection current for different temperatures from 10 to 50°C in steps of 5 °C. The Fig. 2.42 shows the absorption spectrum of the Nd:YAG rod for different temperatures of the pump laser diode. From literature it is known that the maximum absorption occurs at 808.4 nm.

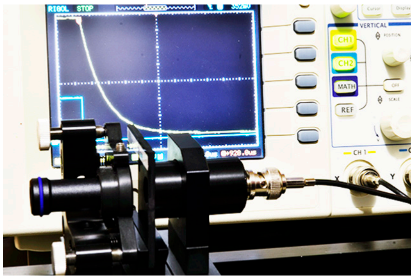


Fig. 2.43: Fluorescence decay

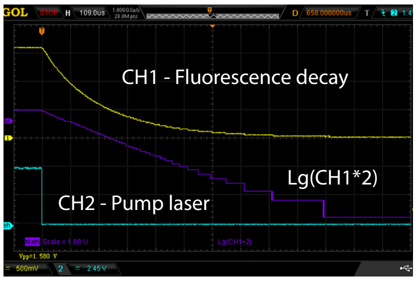


Fig. 2.44: Determination of the lifetime of the excited state

This experiment is addressed to the optical pumping of the Nd:YAG rod. The Fig. 2.43 shows the arrangement, the Nd:YAG rod is excited by the pump laser in pulse mode and the photodetector (5) senses the created fluorescence intensity. To block the residual pump power, a filter (15) is used. The photodetector is connected to the junction box (6) where the photo current is converted into a voltage, which is displayed on an oscilloscope. The Fig. 2.44 shows the screen dump of the oscilloscope (28) with an extra math track which linearises in real time the fluorescence decay to evaluate the lifetime of the excited state as its slope.

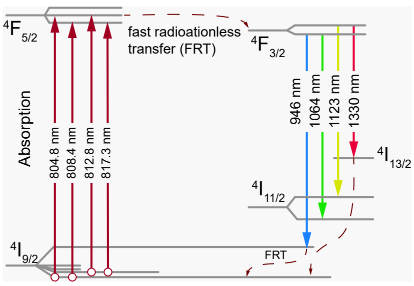


Fig. 2.45: Relevant Nd:YAG energy level diagram

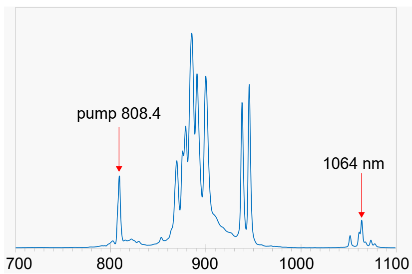


Fig. 2.46: Fluorescence spectrum taken in the range from 700 - 1100 nm

With the fibre coupled spectrometer (22) the fluorescence spectrum is easily obtained (see Fig. 2.46). The peak at 808.4 nm stems from the pump laser which is tuned to this wavelength. The absorption around 808 nm belongs to the $^4I_{9/2} \rightarrow ^4F_{5/2}$ manifold and the fluorescence manifold in the range of 850-950 nm to the $^4F_{3/2} \rightarrow ^4I_{9/2}$ transitions. The fluorescence intensity is quite high, laser oscillation is hardly possible, since the laser transition would end in populated ground state levels. The main wavelength is the 1064 nm, the fluorescence intensity appears to be low, also due to the spectrometer sensitivity

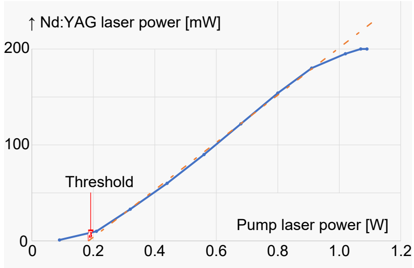


Fig. 2.47: Output versus pump power measured with power meter

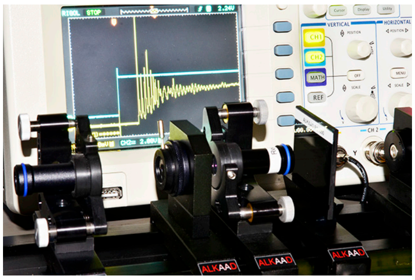
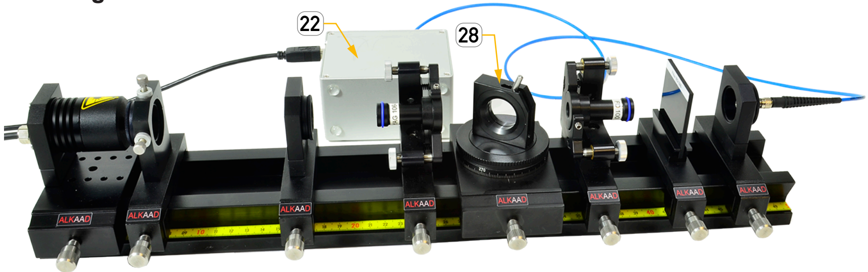


Fig. 2.48: Laser spiking (yellow curve) as a result of modulated pump power (blue)

After performing the characterization of the laser diode, absorption and fluorescence spectra, the laser cavity is setup and its properties studied. By using for the mirror M2 the output coupler with 2% transmission for 1064 nm the laser output power is measured as function of the pump power. From this, the laser threshold and efficiency is determined. Enabling the modulator of the controller MK1 (4) allows the study of the dynamic behaviour of the Nd:YAG laser like the so called spiking (Fig. 2.48). Extending the length of the cavity by moving the mirror M2 allows the study of the optical stability criterion.

Birefringent tuner extension



The fluorescence spectrum of Fig. 2.46 and Fig. 2.49 shows next to the traditional 1064 nm line a couple of some more lines which are candidates for laser operation. However, they can only oscillate if the strong 1064 nm is suppressed significantly which is obtained by using the birefringent tuner (28) inside the laser cavity. By means of the fibre coupled spectrometer (22) the laser lines are identified. For almost each fluorescence line laser operation can be achieved.

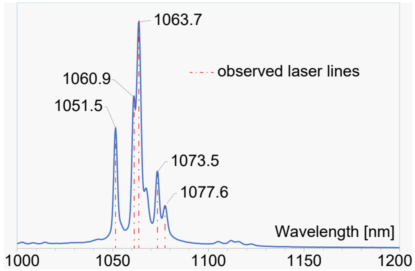
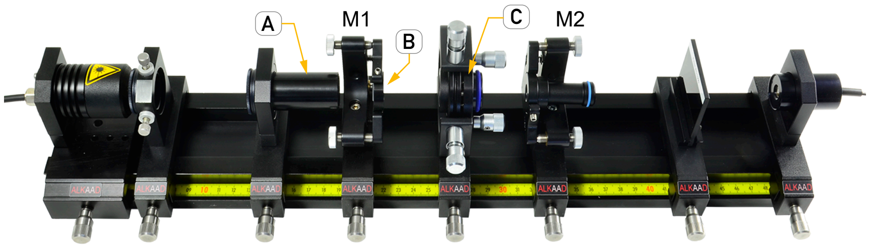


Fig. 2.49: Fluorescence spectrum and laser lines in the range from 1000 to 1200 nm

The concentric cavity extension



Within this exciting experiment the hitherto hemispherical setup is interchanged against a concentric or confocal one. For this purpose the Nd:YAG rod (17) is exchanged against a spherical mirror (B). The Nd:YAG rod used (C) has no (except antireflection) coatings and is positioned in the centre between M1 and M2. For best performance the rod can be adjusted in all directions. Instead of the focusing lens (13) a lens in an extended housing is used to create the focus in the centre of the cavity. This design enhances the study of optical cavities as well as the respective stability ranges. The arrangement of the mirrors M1 and M2 can be concentric (mirror distance L=100 mm) or confocal can with L=50 mm.

LE-0600 Diode pumped Nd:YAG Laser consisting of:

Item	*Code*	*Qty.*	*Description*	*Details page*
1	CA-0060	1	Infrared display card 0.8 -1.4 µm	127 (10)
2	CA-0080	1	Optics cleaning set	127 (12)
3	CA-0450	2	BNC connection cable 1 m	130 (28)
4	DC-0040	1	Diode laser controller MK1	121 (4)
5	DC-0120	1	Si-PIN Photodetector, BPX61 with connection leads	123 (14)
6	DC-0380	1	Photodetector Junction Box ZB1	125 (30)
7	MM-0020	2	Mounting plate C25 on carrier MG20	93 (1)
8	MM-0060	1	Filter plate holder on MG20	94 (7)
9	MM-0090	1	XY adjuster on MG20	94 (8)
10	MM-0100	1	Target Cross in C25 Mount	94 (9)
11	MM-0462	1	Kinematic mirror mount M16, right	97 (29)
12	MP-0150	1	Optical Bench MG-65, 500 mm	93 (8)
13	OC-0060	1	Biconvex lens f=60 mm in C25 mount	99 (5)
14	OC-0170	1	Collimator 808 nm in C25 mount	99 (13)
15	OC-0950	1	Filter RG1000 50x50x3 mm	104 (54)
16	OC-1070	1	Laser mirror M16, ROC 100 mm, HR @ 1064 nm	105 (65)
17	OM-0624	1	Nd:YAG rod in 2 axes kinematic mount	115 (32)
18	OM-L500	1	Diode laser module 808 nm on C20	118 (55)
19	UM-LE06	1	Manual for Nd:YAG Laser	
	Option (order separately)			
20	CA-0260	1	Laser power meter LabMax-TO	129 (22)
21	CA-0266	1	Power sensor PM3 0.5 mW to 2W	129 (25)
22	CA-0270	1	Fibre coupled spectrometer 200 - 1200 nm, USB	129 (26)
23	LE-0620	1	Concentric Cavity Extension	132 (2)
24	LE-0710	1	“Green” 532 nm SHG extension	20
25	LE-0720	1	“Red 660 nm” SHG Extension	20
26	LE-0810	1	Passive Q-Switch Extension	132 (3)
27	LE-0820	1	Active Q-switch Extension	132 (4)
28	OC-1060	1	Laser mirror M16, ROC 100 mm, T 2% @ 1064 nm	105 (64)
29	OM-0580	1	Birefringent Tuner	114 (27)
30	CA-0200	1	Oscilloscope 100 MHz digital, two channel	128 (19)

Highlights

Basic, advanced and top level ★★★ experiment

★★★	Classical Nd:YAG laser
★★★	Laser spectroscopy
★★★	Hemispherical cavity
★★★	Concentric and confocal cavity
★★★	Lifetime and Einstein coefficients
★★★	Optical Stability Criteria
★★★	BFT Line tuning

Intended institutions and users:

Physics Laboratory
Engineering department
Electronic department
Biophotonics department
Physics education in Medicine