1) Which is the minimal set of elements necessary to obtain a laser oscillation?

4: two mirrors for a laser cavity, a lasing medium, a pump laser/flashlamp/injection current

2) Describe a two-level-system!

Ground energy 0, and energy level 1 separated by energy difference. Absorption, spontaneous emission and stimulated emission can happen. Stimulated emission and absorption are proportional to Planck's law involving the energy density of the required transition energy. Spontaneous emission is proportional to just the amount of electrons in the upper energy level.

3) What are the laser conditions?

Population inversion & the right pumping wavelength to effect stimulated emission

4) What is the wavelength and maximum power of your pump laser diode?

Wavelength: 808 nm
Maximum Power: ~.45 W, corresponding to power output at maximum current of I=564 mA

5) Apart from the pump laser, which are the wavelengths that can be generated in this experiment and at which power?

808 nm up to 450 mW
1064 nm up to 200 mW
532 nm up to 100 mW

6) Taking into account all these information, do you think there are safety concerns related to this experiment?

Yes many. Don't let the laser hit skin or colored paper, as it could burn. **Don't focus laser light onto methanol bottle. This could cause a massive explosion and a fireball.**

7) What precautions do you have to take in order to work safely?

1. Laser safety , avoid direct exposure to eyes, wearing goggles all the time, remove all reflective material, only use a white calibration cardboard.
2. Chemical Safety, don't sniff the chemical for too long, don't focus laser onto methanol cleaning bottle
3. Voltage safety. Just don't touch power supply or associated cabling.

8) Which regulations are available for the laser diode?

Wear laser goggles all the time and operate laser under supervision.

9) To which temperature do you set the laser diode initially?

25 degree C (Page 13) is the starting temperature. To measure the output power as a function of temperature, the starting temperature is 20 degrees Celsius.

10) How do you measure the power of light?

The power is measured using a voltage measurement on a photodiode in a set amount of time. Power is voltage / time period.

11) How do you operate the photodiode?

- When measure temperature over 30 degree, read the value immediately and turn the temperature down below 30 to protect the photodiode.

12) What type of photodiode do you use?

Silicon photodiode.

13) What is the spectral range to which the photodiode is sensitive?

"The detector is sensitive to light with wavelength between 400 and 1100 nm, therefore both wavelengths generated during the experiment (808 nm and 1064 nm) can be detected." Page 22

14) How do you distinguish the various wavelengths generated by the laser while using the photodiode?

The wavelengths are correspond to the amplitude peaks of the voltage.

15) Which filters are available and what is their use?

filters (RG1000 (Fig. 23 left), NG9 (Fig. 23 right), BG39 (Fig. 24)) (Page 12)
RG1000 - longpass filter, cutoff wavelength is 850 nm. Can be used to ensure only 1064 nm is incident on the photodiode.

NG9 - Longpass filter that weakly passes wavelengths > 400 nm. Used to decrease the power of the laser before hitting the photodiode, and avoiding photodiode saturation.
BG39 - bandpass filter, passes light between 310 and 650 nm. Can be used to ensure frequency doubled 532 nm wavelength is the only wavelength reaching the photodiode.

16) What are the goals of your experiment?
Step 1: Characterize the pump laser

a) Build the necessary components to turn on the pump laser
b) Turn it on, then measure the minimum injection current to have lasing from the laser diode
c) Measure the output power of the pump laser as a function of the temperature. From the output power, the emission wavelength can be deduced. The central emission wavelength should scale linearly with the input temperature. The photocurrent on the photodiode is directly proportional to the wavelength hitting it. The voltage across the photodiode should thus go up

Step 2: Measure the focal length of the focusing lens

a) Insert the focusing lens in front of the diode laser and measure the focal distance using a white piece of cardboard

Step 3: Measure the characteristics of the Nd: YAG rod.

a) Find the absorption peaks of the rod by finding the transmission spectrum.
    i) Find it by scanning through emission wavelengths of the laser diode by changing the temperature of the diode. Find the voltage on the photodiode as a function of the temperature of the diode laser. The wells in the transmission correspond to the best pump
b) Measure the spontaneous emission time decay constant of the crystal by sending a square wave to the diode laser, exciting some electrons to higher energy levels and measuring the 1/e voltage (when it is at 37% of the max) of the output on the photodiode using an oscilloscope

Step 4: Characterize the Nd:YAG laser cavity

a) Measure the laser output power as a function of the pump power by changing the injection current. Temperature should be held constant at the optimal wavelength determined in Step 4.
b) Find the intensity of the output as a function of the pump power (wavelength). Through this find the optimal pump wavelength.

Step 5: Achieve and characterize Q-switching process through the use of a Pockels cell

a) Fix the q-switch period and vary the pump power. Measure the pulse power as a function of the pump power. Keep the emission wavelength constant by varying the temperature to offset wavelength shifts due to pump power.
b) Fix the pump power and measure the effect of the q-switch period on the pump power.

Step 6: Achieve and characterize passive Q-switching

a) Insert saturable absorber, observe the frequency of pulses.

b) Change the pump power and observe the effect on the pulses
c) Change the cavity length by changing the position of the saturable absorber

Step 7 (bonus): Achieve frequency doubling to 532 nm

a) Insert the frequency doubling crystal and the bandpass filter RG39 to block all emission wavelengths but 532 nm. Optimize its position to achieve phase matching of the output to the input beam in order to get optimal output intensity.
b) Change the pump power and observe the effect on the intensity of the frequency doubled light. Estimate the threshold power to get lasing.

17) How do you measure the pump output characteristics?

You measure the voltage output on a photodiode and create a curve for the power and the temperature. As the photocurrent is directly proportional to wavelength,
Vary the temperature from 25 degrees starting and the resulting power on the photodiode

18) How do you measure the spectrum of the absorption levels in the YAG crystal?

Scan the temperature of the laser diode between 15 and 35°C with intervals of 1°C. For temperatures between 15 and 30°C wait until the temperature of the laser diode is settled (about 10-20 seconds) and measure the photodiode output. For temperatures above 30°C, make the measurements immediately (don't wait) and after you finished the measurements change the temperature rapidly below 30°C. (At temperatures above 30°C the lifetime of the laser diode drops rapidly!) Calculate the transmission of the Nd:YAG rod using the power/temperature calibration curve of the laser diode you have measured in Step 1. The absorption will be 1-T, with the peaks corresponding to the wells in the transmission curve.

19) How can you accomplish the Q-switching operation (active & passive)?

Active Q-switching can be accomplished with some sort of modulator on one of the mirrors. Possibilities include a mirror wheel, a Kerr cell, or a Pockels cell

Passive Q-switching can be accomplished with a saturable absorber. The buildup of the population inversion and the avalanche emission will be an automatic cycle.