

Lab Report of Laser Spectroscopy

Demonstration of ns-Laser Flash photolysis Setup

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1 Questions Before Demonstration

1. Repeat the principle of Q-switching. What are the gain and the Q-factor?

Q-switching is used to generate ns pulse. In principle, the low intense laser cannot exit the cavity, and after it multiple passes the cavity to get an intensive pulse, the filter switches that allows pulse out.

Gain is a measure of the ability of medium that transfers part of its energy to light by population inversion. Loop gain is defined as a ratio of intensity of light in the resonator, after and before completing a full round loop in the resonator. Q-factor is a measure of oscillation loss in resonator. High Q-factor means low energy loss. Quantitatively, $Q = \frac{\nu}{\delta\nu}$, where ν represents the frequency and $\delta\nu$ means FWHM bandwidth.

2. Is Nd:YAG laser a 2,3,4 or 5-level system? What is the lasing wavelength?

Nd:YAG laser is a 4-level system. The lasing wavelength is 1064nm.

3. Calculate the output power during the pulse for the laser in simplicity, given the data above.

$$W = \frac{Q}{\Delta t} = \frac{2.5J}{10ns} = 2.5 \times 10^8 W$$

in Q-switch mode using the data above. Similarly, $W = 12500W$ for long pulse mode.

4. What is the Second/Third harmonic generation? Repeat the working principle.

SHG happens when 2 input laser with the same frequency ω mix with phase matching condition in a non-linear optical device, which generates a doubling frequency laser beam 3ω . Third harmonic generation is similar to SHG, which generates a tripling frequency laser beam 3ω . from fundamental frequency laser and doubling frequency laser.

2 Questions After Demonstration

1. The OPO is seeded with the 3rd harmonic of the fundamental laser light. Describe the different ways how this 3rd harmonic can be generated from the fundamental and which nonlinear coefficients are involved in these?

The first way involves 2 steps that is to generate doubling frequency first and then generate tripling frequency with frequency mixing process. Both of the 2 steps involves $\chi^{(2)}$.

$$\omega \xRightarrow[\text{SHG}]{\quad} 2\omega + \omega \xRightarrow[\text{Mixing}]{\quad} 3\omega$$

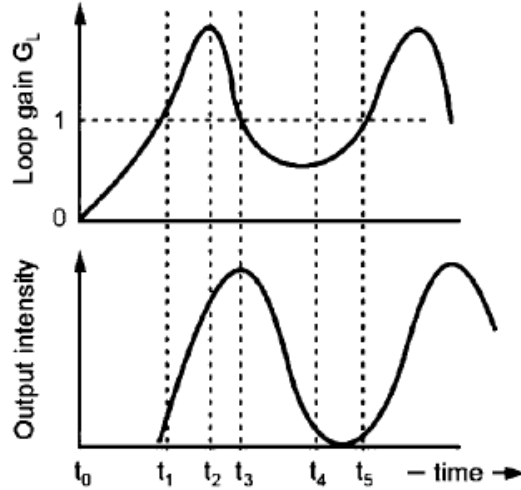
Another way is to generate 3rd harmonic in only 1 step with nonlinear polarization process, which involves $\chi^{(3)}$.

$$\omega \xRightarrow[\text{THG}]{\quad} 3\omega$$

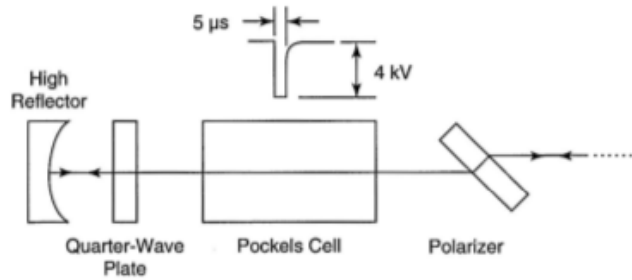
2. Describe the difference between Long Pulse(LP) mode and Q-switch mode and how LP mode works?

The most obvious difference between LP and Q-switch mode is the time duration of each pulse. LP has a duration of $0.1\text{--}100\mu\text{s}$ while that of Q-switch is $1\text{--}50\text{ns}$. The work mechanism of them are also different.

LP mode works with the variation of loop gain G_L . When the system starts to work, G_L increases from 0 to 1, at which time that the laser begins to output. When G_L falls down from 1 to minimum, output laser decreases to 0. Thus a relative long time pulse forms. Then G_L repeats to increase to over 1 and decrease to below 1 and another pulse is generated.



3. How Q-Switch mode of our Nd:YAG laser is implemented with the help of scheme below?



As shown in the figure above, when 0 voltage of Pockel Cell and laser comes from left to Quarter-wave plate, the linear polarization light changes from horizontal to vertical by passing the Quarter-wave plate twice. So the beam can not transmit polarizer slit and keep accumulating in the resonator. When the Pockel Cell is charged to certain voltage that exactly compensates the polarization of Quarter-wave plate, the beam then travel passes the polarizer slit, and an intense pulse outputs.

4. How is mode-selection performed in this laser?

In this laser, longitudinal mode was selected by nonlinear crystal with Kerr effect. Kerr effect only helps to focus high intense light and eventually a single giant pulse outputs after many times' travel in the resonator.

5. Why are the pump chambers of the amplifier outside the oscillator resonator? What would happen if they were inside the oscillator?

It helps to generate short time and uniform pulse. In the resonator, the incident beam travel back and forth for many times. If pump chambers were put inside the resonator, when beam travel across the crystal,

different frequencies go with different time duration, thus it would stretch the width of beam and eventually elongate the time duration of laser. And polarization dispersion would happen as well.

3 Brief Report

In this demonstration, we first go through each component of this ns-Laser Flash Photolysis system. In general, this system is made up of laser system, signal detector of sample and PC control system. In the laser system, the Nd:YAG laser generates 1064 nm laser pulse initially by Q-switch of a Pockels Cell, then the fundamental frequency is doubled by SHG mechanism. Then the output green laser beam goes through the shutter and filters to the sample chamber (Here without the OPA system). In the sample chamber that is perpendicular to laser beam is the detector system, where CCD camera is used to count the number of photon emitted. The computer is connected to laser system and detector system that could control the duration of laser and receive the counting result.

After a brief introduction of all components and the mechanism of them, some experiments are shown with this system. When the laser beam hits the liquid sample, fluorescence photons are emitted and received by the perpendicular CCD camera, where the number of photons are counted. After about 100 ns after the laser, we received phosphorescence photons that are generated by $T_1 \rightarrow S_0$ transfer and have a relatively long lifetime. When we shorten the time gap between laser input and detector counting time, the fluorescence photons dominates the counting curve which are generated by $S_1 \rightarrow S_0$ transfer and has a short lifetime. From this experiment, we could observe the change of long wavelength fluorescence peak to a shorter wavelength phosphorescence peak with times goes within 1 μs on the counting curve.