The Stability of Acousto-Optic-Q-Switched YAG Laser

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The main factors, which cause the instability of an acousto-optic-Q-switched YAG laser, include the mechanical vibration of optic elements, change of thermal focal length of active medium, fluctuations of pump rate and repetition rate, and etc. In our thesis, we'll discuss the laser output power affected by these factors.

The expression of the output peak power of a acousto-optic-Q-switched laser can be written as:

$$P_p = T \cdot N_{\text{max}} \cdot C \cdot A \cdot h \nu$$

where, transmission radio of output mirror $T$, light velocity $C$ and photon energy $h \nu$ are all constant, but maximum density of photons $N_{\text{max}}$ within the cavity and output beam cross section area $A$ are changeable. The fluctuations of pump rate and repetition rate will cause the instability of $N_{\text{max}}$, the change of the thermal focal length of active medium and the mechanical vibration of optic elements will cause the instability of $A$. We will discuss them respectively below.

K.B. Chesler has obtained:

$$N_{\text{max}} = \Delta n_s - \Delta n_{th} - \Delta n_{th} \cdot \ln \frac{\Delta n_s}{\Delta n_{th}}$$

$$\Delta n_s = R \tau_t - (R \tau_t - \Delta n_F) e^{-\frac{1}{\tau_t}}$$

$$\Delta n_s = \Delta n_F + \Delta n_{th} \cdot \ln \left(\frac{\Delta n_s}{\Delta n_F}\right)$$

where, $\Delta n_s, \Delta n_{th}$ and $\Delta n_F$ stand for initial, threshold and final inversion density respectively; $\tau$ and $R$ stand for repetition rate and pump rate respectively.

From those three functions, it's obviously that $N_{\text{max}}$ is decided by $\tau$ and $R$, so the fluctuations of $\tau$ and $R$ will cause the instability of $N_{\text{max}}$.

According to Chesler's conclusion and through our theoretical

Fig. 1
deduction, it's found that in a High repetition rate acousto-optic-Q-switched pulse serial, if the initial population inversion density $\Delta n_m$ of the m'th pulse had a declination $\Delta m$ from the stable value $\Delta n_o$, $\Delta n_m=\Delta n_o \cdot \Delta n$ the initial population inversion density $\Delta n_{m+1}$ of the next pulse will also has a declination of $\Delta n_m$. That was content with following function:

$$f = \frac{\Delta m}{\Delta n} = e^{-\frac{1}{T f r}} \cdot \frac{1-\frac{\Delta n_F}{\Delta n_o}}{1-\frac{\Delta n_H}{\Delta n_F}}$$

Through analysis, the conclusion is that:

1. $-1 < f < 0$, it means that if $\Delta n > 0$, $\Delta n_m > 0$ will be; otherwise, if $\Delta n < 0$, $\Delta n_m > 0$ will be set. And still $|\Delta n_m|$ is always smaller than $|\Delta n|$. It means that if a declination was happened in a pulse, latter pulses will be changed up and down the stable value alternately, but the declinations must tend to zero.

2. It's found that the tendation of declinations to zero will be faster when the repetition rate $f$ is slow and the initial inversion density is high. The figures below give out our conclusion.

![Fig. 2](image1)

![Fig. 3](image2)

Through theoretical analyzing, we know that:

$$\frac{d N_{max} \cdot \Delta n_o}{d \Delta n_o \cdot N_{max}} = \left(1 - \frac{\Delta n_H}{\Delta n_o}\right) \frac{\Delta n_F}{N_{max}}$$

The figure in rightside is the corresponding function curve. From the curve, we can know that if $\Delta n_o / \Delta n_{max}$ is high, the change of output power will be small.

Through the theoretical deduction, we have got that:

$$\frac{d \Delta n_o}{d t} = \frac{(\Delta n_o - e^{-\frac{t}{T f r}} \cdot \Delta n_F)}{\Delta n_o}$$

$$\left[1 - e^{-\frac{t}{T f r}} (1 - \frac{\Delta n_H}{\Delta n_o}) / (1 - \frac{\Delta n_H}{\Delta n_F})\right]$$