Study of tunable infrared light beat generator by laser frequency splitting method

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Abstract: In this paper, the experimental study on 1150nm tunable infrared light beat generator by He-Ne laser longitudinal mode splitting is reported. The results show that the range of beat frequency of the generator is from 40MHz to hundreds of megahertz. Meanwhile some other characters, for example the mode competition, are studied.

Key words: laser frequency split infrared light beat method

利用激光频率分裂技术研制可调谐的红外光拍发生器

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摘要: 本文叙述了利用氦氖激光频率分裂技术研制波长为 1150nm 的可调谐的红外光拍发生器的实验及其结果, 结果表明这种红外光拍发生器拍频的大小可以从 40MHz 到几百兆赫兹。同时, 我们也对其它特性, 如模竞争等进行了研究。

关键词: 激光频率分裂 红外光拍发生器

ⅳ. Introduction

In some fields, such as the semiconductor device studying and manufacturing, optical fiber communication and etc., a continuous infrared light beat generator is needed to check the frequency response of the opto-electrical detectors and amplifiers whose acceptable wave-length is near to 1μm. At the present time, the sine electric signal is used to modulate the lasers supply current to get a modulated light signal, by this method it's very diffcult to produce high frequency light beat signal with no-distortion, such as tens of megahertz to hundreds of megahertz. In this paper we present a new method to produce a sine infrared light beat signal and the beat frequency can get up to hundreds of megahertz.

Ref. [1] [2] have studied the frequency split of 632.8nm He-Ne laser, the method is to rotate an intracavity crystal quartz plate around the axis which is perpendicular to the incident surface of the laser beam in the cavity of a He-Ne laser.

But no literature reports the work on 1150nm laser frequency split and the tunable infrared light generator. Although the birefringent effect of the quartz exists, whatever the wavelength is, we don't know the magnitude of the birefringence corresponding the any angle between the crystalline axis and the laser beam in the 1150nm wavelength. In order to make the infrared light beat generator, the principal experiments on the laser mode split phenomenon which is caused by the crystal quartz in 1150nm wavelength laser have to be done.

㈦. Experiments and results

The experimental device is shown in Fig. 1. T is a He-Ne laser discharge tube. The left end of the tube is the anti-reflecting window, M_2 is a fully reflective cancave mirror. Q is the quartz plate, its thickness is 2.55mm. The right end of the tube is sealed by M_1 which is the output mirror. D is a scanning interferometer connected with the oscilloscope S. The variance of the mode split is detected, displayed and measured by D and S.

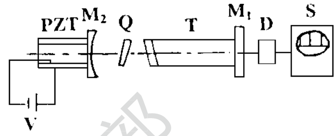

Fig. 1 The experimental setup

1. Observation of mode splitting

In this experiment the cavity length is 290mm, then the longitudinal mode spacing is about 517MHz. The lasing bandwidth of the laser with 1150nm wavelength is about 700MHz, so there shoud be two modes in operation. It is easy to understand that the longitudinal mode spacing is the largest frequency splitting magnitude.

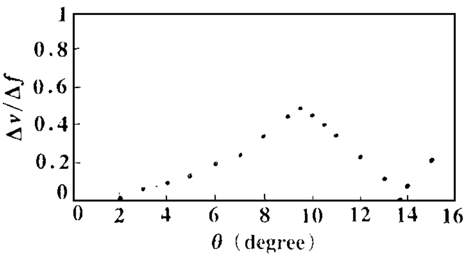

Fig. 2 The curve for $\Delta\nu$ versus θ

The curve of results is shown in Fig. 2 (Δf is the magnitude of the longitudinal mode spacing, $\Delta\nu$ is the magnitude of the splitting), it indicates: From $\theta = 0°$ to $\theta = 3°$, no mode splitting is observed. The minimum splitting is about 40MHz. From 3° to 9.5°, the splitting increases with θ. But from 9.5° to 13.8°, the splitting decreases with θ until $\Delta\nu$ is zero. From 13.8°, the splitting increases with θ, and when θ is 16°, the output of the laser dies out, we can't go on observing the phenomenon. Because the transmissivity of the crystal quartz palte is the most when the incident angle is zero, if when the incident angle is 9° to 10°, the transmissivity is the most, we can continue the experiment until θ up to 25°.

Because the cavity length is 290mm, there are two modes working even in the case of no mode split. When making the beat generator, the cavity length must be less than 180mm, the maximal beat frequency can get up to 800MHz.

2. Observation of mode competition

When the mode split is less than 40MHz or less, because of the competition of the two split mode, the beat frequency isn't stable. In this experiment, we focus our attention on one mode and its two split mode frequencies. When the magnitude of the mode split is about 40MHz, the DC voltage applied on the PZT (piezoelectric ceramic) is varied for moving the mirror M_1 to vary the cavity length, the pattern of mode competition is observed on S.

The result is shown in Fig. 3. The pattern of mode competition for the tube of He∶Ne= 7∶1 and Ne20∶Ne22= 1∶0. The band of light is the range of no mode split. The band of shadow is the range of mode split. With increasing the voltage on PZT, the two mode split frequencies move from left side to right side on the screen of the oscilloscope so that the ranges of two modes working and one mode can be seen. The curve is the approximate intensity of one mode.

From Fig. 3, we see:

(1) There are two frequencies from ν_1 to ν_2. As the two frequencies moving towards the right, the intensity of the left mode decreases and finally disppears at ν_2, at the same time, the intensity of the right one increases quickly. The bandwidth in which the two frequencies exist together is about 100MHz.

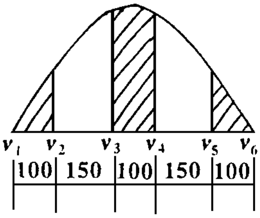

Fig. 3

(2) Within the following bandwidth of 150MHz, ν_2 to ν_3, only one frequency works. That means no mode split happens within this range.

(3) After the one mode crossing 150MHz towards the right side at ν_3, a new frequency appears at the left side of the mode which exists from ν_2 to ν_3, which means that mode split begins. As the two frequencies continue to move toward the right side, the intensity of both frequencies begins to increase. But that of the left one increases quicker than that of the right one. As soon as the two frequencies have almost the same intensity, the intensity of the right frequency will become smaller and then finally disppears at ν_4, at the same time the intensity of the left frequency continues to increase. The bandwidth in which the two frequencies exist together is about 100MHz.

(4) Within the following bandwidth of 150MHz, ν_4 to ν_5, only one frequency works. In other words, no mode split happens again.

(5) Hence, there is a range of 100MHz in which the right frequency comes again. It means that the mode split happens again.

(6) Finally, at ν_6 the two frequencies get to the right edge of lasing bandwidth. They disappear one after another.

3. Conclusions

(1) The 1150nm wavelength tunnable infrared light beat generator has been achieved. The frequency of light beat can be contralled by tuning the angle between the crystalline axis and the laser beam. By this method the infrared light beat generator can output the beat frequency of 40MHz to hundreds of megahertz.

(2) The generator can't output the beat signal which is less than 40MHz, because the strong mode competition arises. At the range of 100MHz distributed symmetrically about the central frequency of lasing bandwidth, the two frequencies with 40MHz frequency difference can work at the same time, but at the range of 150MHz near the edge of lasing bandwidth, the strong mode competition exists, one of the two frequencies dies out. This fact proved that the generator can output sine light beat signal of more than 40MHz.

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脉冲钛宝石激光器动力学特性的理论及实验研究

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摘要: 本文采用速率方程理论, 比较全面详细地分析计算了脉冲钛宝石激光器的动力学特性。在实用参数范围内, 给出了输出参数与泵浦参数的关系。采用这些结果可以统一解释以往文献报道的结果并与我们自己的实验数据相一致, 证明了该方法的正确性和参数选择及近似处理的合理性。

关键词: 脉冲钛宝石激光器　动力学特性　激光速率方程

Theoretical and experimental investigation of characteristics of pulsed Ti∶sapphire laser

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Abstract: According laser rate equations, the dynamic characteristics of pulsed Ti∶sapphire laser has been comprehensively studied. The theoretical study and experimental results prove, if duration of pumping pulse is much less the life of up-energy-level, (1) the width and waveform of the output pulse is independent of the pumping pulse, (2) the only factor of determining the output pulsewidth is the ratio of pumping energy to threshold pumping energy, (3) the time delay of output pulse is dependent of the pumping pulsewidth and the ratio of pumping energy to threshold pumping energy.

Key words: pulsed Ti∶sapphire laser　dynamic characteristics　laser rate equations

一、引　　言

动力学特性是脉冲钛宝石激光器研究的一个重要内容。通过分析振荡脉冲发生、发展直至输出的过程, 可以得到对研究和设计实用化激光器件十分重要的激光输出参数, 如输出脉宽、延迟时间等, 及其与泵浦参数的关系。

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