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Modes competition in a dual modes HeNe laser with optical feedback

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Abstract

The optical feedback characteristics in a short cavity dual modes HeNe laser are studied under different modes strength condition. Modes competition can be obviously observed during optical feedback. The whole laser intensity curve has intensity branches and its leaning direction is related to the moving direction of the external feedback mirror. There are two cross points at different voltage levels between the two orthogonally polarized lights in a period of the optical feedback fringe and the order that the cross points come out is different when the feedback mirror moves at different direction which can be used for direction discrimination. Sometimes there are two peaks of the same size in a period of the optical feedback curve which can be used to improve the resolution of an optical feedback system.

Keywords: HeNe laser; Optical feedback; Modes competition

1. Introduction

The laser intensity can be modulated when its output lights are reflected back into its original laser cavity by an external reflector and this phenomenon is called an optical feedback or self-mixing interference. The optical feedback characteristics have been studied in different kinds of lasers such as the gas lasers [1–6], the microchip solid lasers [7–9], and the semiconductor lasers [10–13]. Some applications for velocimeter [1–3,7,9,12], ranging, displacement [4–6,10,11], or imaging [14] have been developed based on the optical feedback characteristics. Theory models have also been created to explain the optical feedback phenomena [4,5,10,15–18].

Recently, some attention has been paid to the optical feedback in dual frequency lasers such as the birefringence dual frequency lasers [19,20] and birefringence-Zeeman dual frequency lasers [21]. These researches focus on the optical feedback characteristics of the two orthogonally polarized lights. Little attention has been paid to the relationship between the whole light's intensity and the intensities of the two orthogonally polarized lights at the presence of an optical feedback.

In this paper, we observe the intensity variations of a dual longitudinal modes HeNe laser at the presence of an optical feedback. Both modes' intensities and the whole light's intensity are detected at the laser tail emission direction. Modes competition can be obviously observed during optical feedback and one mode's intensity is minimum when the other's is maximum. The whole light's intensity curves have intensity branches at the presence of optical feedback. The size of the intensity branch is determined by the average intensity relationship of the two modes. When the optical feedback fringe is not symmetrical, the leaning direction of the fringe can be used to discriminate the moving direction of the external feedback mirror. Sometimes there are two peaks that are of the same size in a period of the optical feedback curve which can be used to improve the resolution of an optical feedback system.

2. Experimental setup

The experimental setup is shown in Fig. 1. The 632.8 nm HeNe laser used has a half-intracavity. The laser cavity is

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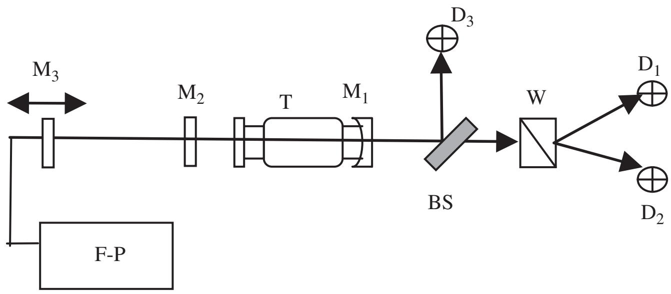

Fig. 1. Optical feedback experimental setup using a short cavity HeNe laser.

126 mm long and composed of mirrors M_1 and M_2. T is the laser tube. Mirror M_3 is the external feedback mirror whose reflectivity is 40%. The external cavity length is 290 mm. BS is a beam splitter which is used to separate the laser tail lights into two parts. One part is separated by a Wollaston prism W into two orthogonally polarized modes (we call them ⊥-light and //-light, respectively) whose intensities are detected by the photo detectors D_1 and D_2, respectively. The other part is detected by the photo detector D_3. F–P is a Fabry–Perot scanning interferometer which is used to observe the oscillating modes.

3. Experimental results

First, we take off the feedback mirror and carry out an experiment to examine the power tuning curve of the short cavity laser. When mirror M_2 moves a displacement of $\lambda/2$, a period of the power tuning curve can be obtained as shown in Fig. 2. λ is the wavelength of the laser. In Fig. 2 and the following figures, the vertical axis represents the laser intensity and the horizontal axis represents the time. We take the circle point curve as ⊥-light's intensity variation curve and the dot point curve as //-light's one. The star point curve is the whole light's intensity variation curve. The power tuning curves have three different regions: region A where only ⊥-light oscillates, region B where both lights can oscillate, and region C where only //-light oscillates. The laser is a single mode laser in region A and C but a dual modes laser in region B. In the following experiments, we put much attention on the optical feedback characteristics when the laser can run as a dual modes laser.

We fix mirror M_3 on and drive mirror M_3 with a triangle wave. We can observe from the Fabry–Perot scanning interferometer that there are two longitudinal modes jumps: up and down. One jumps up while the other jumps down because of the modes competition. We tune the laser cavity by driving mirror M_2 to make the average intensities of these two jumping longitudinal modes equal to each other and the experimental results are shown in Fig. 3. In Fig. 3 and the following figures, the square point curve is the ⊥-light's intensity variation curve plus //-light's intensity variation curve and the triangle wave is the signal with which the feedback mirror is driven. ⊥-light's

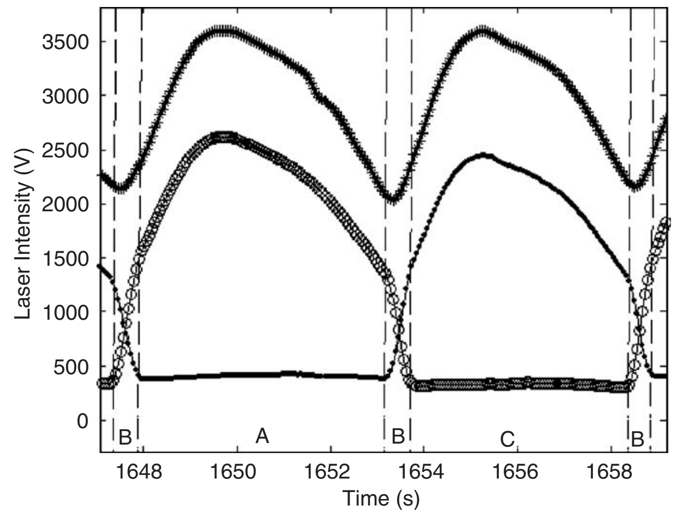

Fig. 2. Power tuning curve of the short cavity laser.

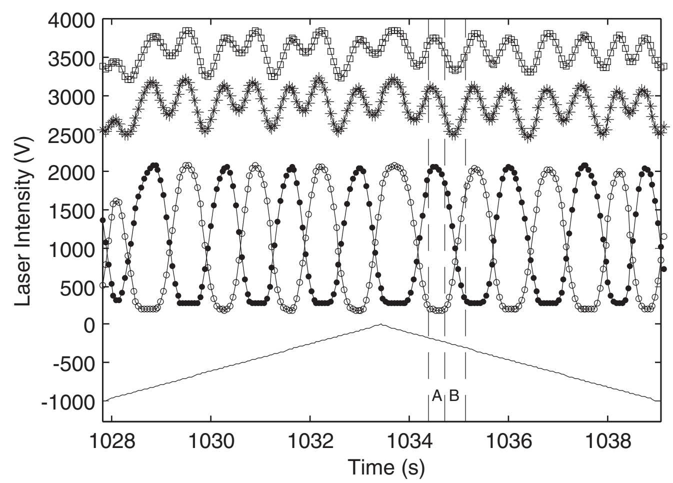

Fig. 3. An observation of both modes' intensities and the whole light's intensity when both modes' average intensities are comparable.

intensity variation curve is inverted with //-light's intensity variation curve. When one mode's intensity is near its maximal intensity, the other one is zero intensity. The whole light's intensity curve detected has intensity branch. There are two peaks that are of the same size in a period of the optical feedback curve. The square point curve is the dot point curve plus the circle point curve and it is the same as the star point curve. This means that the whole light's intensity is just the summary of ⊥-light's intensity and //-light's intensity. The modulation depth of either mode's intensity is much deeper than the whole light's intensity modulation depth.

Then, we drive mirror M_2 to tune the laser cavity to make the ⊥-light's maximal intensity little lower than the //-light's maximal intensity at the presence of optical feedback. The experimental results are shown in Fig. 4(a). ⊥-light's intensity variation curve is like a pulse waveform while the //-light's intensity variation curve is like a cosine waveform. When //-light's intensity is its maximum, the ⊥-light is zero intensity. When ⊥-light's intensity is its