VolB5, No. 6 CHINESE JOURNAL OF LASERS December, 1996

A New Laser Frequency-stabilizing and Frequency-locking System

CHEN Changmin

(Department of Electronic and Information Technology,
Shanxi University, Taiyuan 030006 *China)*

Miao Dejia, HUANG Maoquan, GAO Jiangrui,
WANG Hai, ZHENG Jinling

(Institute of Opto-Electronics, Shanxi University, Taiyuan 030006, *China)*

Received Feb. 15 1996; Revised manuscript received June 27 1996

ABSTRACT The principle of a new kind of laser frequency-stabilizing and frequency-locking systems is introduced, emphasising on its design ideas of center-ring frequency-locking unit and auto-search locking unit. It can be used for the frequency stabilizations such as pulsed lasers, cavity frequency-doubling and OPO cavity locking techniques. The frequency-drift of the stabilized pulsed-laser is less than 1 MHz.

KEY WORDS frequency-stabilizing, frequency-locking, concentric ring bi-detector, auto-search locking.

The new laser frequency-stabilizing and frequency-locking system consists of three parts: a reference Fabry-Perot confocal cavity, a specially designed center ring frequency-locking unit and an auto-search locking unit. We will emphasize on the design ideas of the latter two parts.

1. Center-ring frequency-locking unit

A single frequency laser light transmitting through a F-P confocal cavity will form an interference pattern, a series of concentrie rings on a screen. When the frequency of the incident laser-light is monotonously sweeping, the interference rings will shrink towards their center or expand outward. This phenomenon is taken to be the basis of designing and manufacturing the concentric-ring bi-detector shown in Fig. 1. The bi-detector is composed of two parts: the inner part *A* is a round photo-cell with a diameter of 2mm, the outer part *B* is a ring-type photo-cell with an inner diameter slightly larger than 2 mm and an outer diameter of 4mm. The out puts of the two photo-cells are connected in series with their polarities reversed. The bi-detector is placed on the screen with its central circle coinciding with the central spot of the interference pattern. When the laser operates at the resonance frequency of the F-P cavity ν_0, the voltages induced on the two parts of the bi-detector will balance to each other. However, if the laser frequency deviates away from ν_0, the balance will be breaken and an error signal $U_{ab} = U_a - U_b$, caused by the detuning, will appear. If the frequency of the laser light is made to sweep, the discrimination signals will be obtained from the bi-detector as shown in Fig. 2. The design details of the bi-detector, are described in Ref. [1].

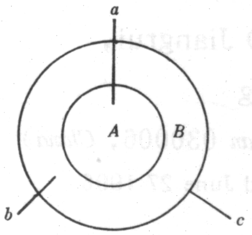


Fig. 1 Diagram of concentric bi-detector

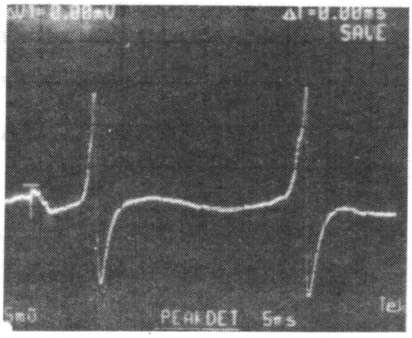


Fig. 2 Curve of frequency-discrimination

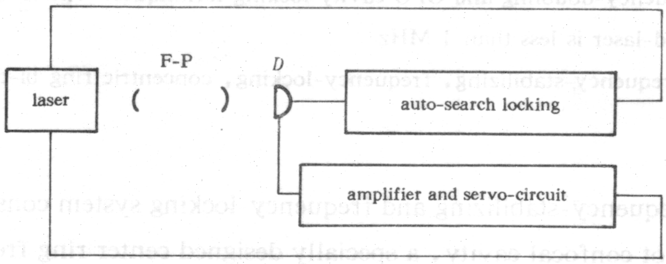


Fig. 3 Diagram of laser frequency-stabilizing and locking unit

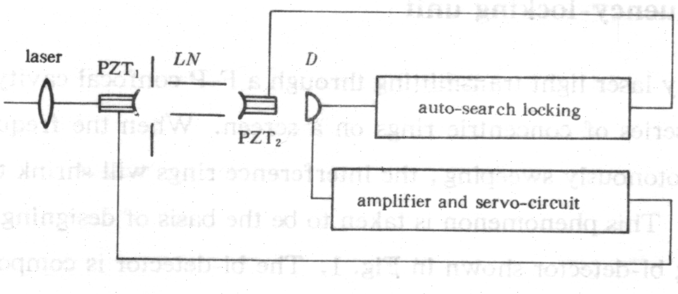
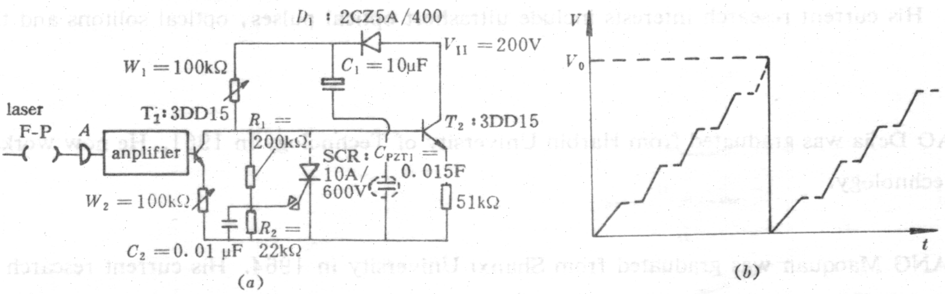


Fig. 4 Diagram of locking an OPO cavity

Fig. 3 is a diagram of the laser frequency-stabilizing and locking unit. The F-P is a confocal reference cavity with length $l=102$mm and fineness $F=40$. The error-signal of detuning taken from the bi-detector D is amplified and feedback through a servo-circuit to the piezoelectric element attached to the cavity mirror of the laser cavity or fed to the optical index modulation crystal inside the laser cavity to compensate the change of the optical length of the laser cavity and the laser frequency is locked to the resonance frequency ν_0 of the reference F-P cavity. The way to lock a frequency-doubling or an optical parametric oscillation (OPO) cavity is similar to this, the only difference is that instead of sending the feedback to the laser cavity, it is sent to PZT to control the change of the length of OPO cavity in this way to make the central resonance frequency ν_0 of the confocal cavity tracing and being locked to the frequency ν_0 of the input laser light. The process is shown in Fig. 4, where the lens L is used for mode-matching. The focal length of lens L is determined by the beam parameters of the laser light and the F-P confocal cavity parameters. In our experiment, it is taken to be $f=200$mm.

2. Auto-search locking unit

Fig. 5 is the schematic diagram of the auto-search locking unit. A in Fig. 5 (a) is the inner-circle detector of the bi-detector D , C_{PZT1} is the equivalent capacitance of the piezoelectric element attached to the cavity to be controled. C_{PZT_1} , together with T_2 and SCR, forms a bootstrap sawtooth voltage searching circuit. When the laser frequency is out-of-locking, there will be no signal, and T_1 is cut-off. The source V_{II} will charge C_{PZT_1} with a current I_{charge} and thus a monotonously increasing voltage is generated across C_{PZT_1}. Therefore a frequency searching process begins with the increasing Vc_{PZT_1} until to a point. At this point A receives light signal again be cause the constant-current source T_1 begins to work and discharges through C_{PZT_1} with a current I_{disc}. Evidently Vc_{PZT_1} will keep constant when $I_{\mathrm{disc}}=I_{\mathrm{charge}}$ and thus locking is achieved. If out-of-locking occurs once more, the above-mentioned process will repeat once again and the frequency is locked anew. In this searching process there comes the point that $Vc_{\mathrm{PZT}_1}\geqslant V_0$ then SCR is triggered. Then the whole procedure begins once again with Vc_{PZT_1} starting from value zero as shown in Fig. 5 (b).



(a) (b)

Fig. 5 Schematic diagram of the auto-search locking unit

When the system is used in the case of pulsed laser frequency stabilization, the light signal from the xenon lamp or from the laser light is used to trigger the sawtooth wave generator to carry on the aynchronous frequency sweeping. Thus, the frequency of laser light is quickly searched and brought to the resonance frequency ν_0 of the F-P confocal reference cavity (the inner part of the bi-detector lies in the central light spot of the interference fringe) and then is locked there through a close-loop servo-locking system. The transmission curve of the F-P confocal cavity as detected by the inner part of the bi-detector is shown in Fig. 6. As the F-P confocal cavity has very high dispersion in its confocal interference spot, high sensitivity is ensured. With the aid of a quick and accurate auto-search system and of a precisely adjusted servo-feedback system a frequency-stabilized laser output can be obtained. Numerical processing of the results shows that, in the duration of a light pulse, the drift of laser frequency ν relative to the F-P resonance frequency ν_0 is less than 1 MHz, i. e. $|\nu - \nu_0| \leqslant 1$ MHz. The pulsed laser frequency-stabilization equipment and its data processing is depicted in Ref. [2].

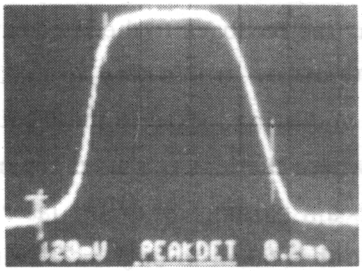


Fig. 6 Transimission curve of a confocal cavity with frequency locked

References

1. Huang Maoquan *et al.* . Design of concentric ring bi-detectors to directly obtain the curve of frequency-discrimination. *Optics & Laser Technology*, 1995, **27**(59): 327—330
2. Huang Maoquan *et al.*. Pulsed frequency-stabilized ring Nd:YAG laser. *Chinese Journal of Laser*, 1993, **20**A(1): 6—9

Biography

CHEN Changmin was born in November 1938, and was graduated from Beijing University in 1960. In 1988-1989 he was a visiting scholar on applied mathematics and physics, University of South Carolina, U. S. A.. His current research interests include ultrashort optical pulses, optical solitons and their applications.

MIAO Dejia was graduated from Harbin University of Technology in 1961. He now works in the field of laser technology.

HUANG Maoquan was graduated from Shanxi University in 1964. His current research interests include novel solid state lasers, frequency stabilizing and frequency locking systems, laser physics and their applications.