第26卷 第2期 半 导 体 学 报 Vol.26 No.2
2005年2月 CHINESE JOURNAL OF SEMICONDUCTORS Feb.,2005

Passively Mode Locked Diode-End-Pumped Yb:YAB Laser with High Reflectivity Type Semiconductor Saturable Absorption Mirror

Wang Yonggang[1,2], Ma Xiaoyu[1], Xue Yinghong[2], Sun Hong[2],
Zhang Zhigang[2], and Wang Qingyue[2]

(1 Institute of Semiconductors, Chinese Academy of Sciences, Beijing 100083, China)
(2 Ultrafast Laser Laboratory, School of Precision Instrument and Optoelectronics Engineering,
Tianjin University, Tianjin 300072, China)

Abstract: A novel high reflectivity type of semiconductor saturable absorption mirror grown by metal organic chemical vapor deposition is presented. Using the mirror as well as an end mirror, passively mode locked Yb:YAB laser is realized, which produces a pulse as short as 3.05ps at 1.044μm. The pulse frequency is 375MHz; the output power is 45mW.

Key words: Yd:YAB; high reflectivity; SESAM
EEACC: 4330B **PACC:** 4260; 4260D
CLC number: TN365 **Document code:** A **Article ID:** 0253-4177(2005)02-0250-04

1 Introduction

Since 1990s there has been increasing interest in the development of picosecond diode-pumped solid state lasers, which have numerous applications in medicine, material processing, free electron lasers, pulse laser for distance measurement, and so on. Passive mode-locking techniques for CW solid-state lasers based on saturable absorbers especially semiconductor saturable absorber mirror (SESAM) seem to be favorable because of its typically shorter pulse durations and the simpler setup than those of actively mode-locked lasers. Such structures consist of multiple quantum wells grown by molecular beam epitaxy or metal organic chemical vapor deposition. Mode locking with such a device is performed by a nonlinear bleaching process of interband absorption. The absorbers can also be used to initiate Kerr-lens mode locking and to stabilize the mode-locking operation. Mode locking with SESAMs[1~7] is based on a resonant saturation of interband absorption, and consequently the bandgap of the material has to be adjusted to the emission wavelength of laser.

However, mass production for passive modelocking picosecond laser with SESAMs faces with many difficulties, which is due to the short lifetime of SESAMs. The absorber of SESAMs is grown at low temperature, which leads to much nonsaturable loss that shortens the lifetime of SESAMs. In this article, we grow high reflectivity film upon the SESAMs to decrease the intensity of laser into the device. By this way, we prolong the lifetime of SESAMs from several days to several months.

Now, SESAMs are used widely to produce infrared ultrashort laser pulse. However, being limited to the characteristics of SESAMs, blue and green ultrashort laser pulses are hard to produce directly from passive modelocking lasers with SESAMs. Recently, Shangdong University in China invents a novel crys-

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Wang Yonggang male, was born in 1973. He works in absorbers (semiconductor saturable absorption mirrors and GaAs) for the modelocking and Q-switching of solid-state lasers. Email: wygxjwchina@vip.sina.com

Received 7 June 2004, revised manuscript received 3 September 2004

tal, Yb:YAB. In our experiment, we obtain ultrashort pulse at wavelength of 1044nm.

2 Theory and manufacture of high reflectivity type SESAM

One key to SESAM is its absorption layer, which acts as an absorber that adsorbs special wavelength light, at the same time provides a fast saturable absorption recovery time owing to the fast trapping of the electrons in the As_{Ga} generated after the growth at low temperature. The two mechanisms make SESAM a nonlinear absorber against the intensity of light so that it can suppress the side lobes of a pulse and enhance the center of the pulse. For a fast recovery time, the absorption layer is usually grown at low temperature by MBE or MOCVD. At higher growth temperature, large lattice mismatch of InGaAs on GaAs can cause surface striations that scatter the incident light. InGaAs/GaAs MQW bandgap is not a very critical parameter, which is adjusted approximately to the lasing wavelength. As antisites or As_{Ga} will generate when As fluence is excessive relative to Ga fluence after the low temperature (LT) growth of InGaAs by MBE or MOCVD.

However, growth rate of MBE is much lower than that of MOCVD, therefore MOCVD is more suitable for mass production in industry than MBE is. We made SESAM by low temperature MOCVD. we tried to grow $In_{0.25}Ga_{0.75}As$ at substrate temperature of 400, 500, and 550 ℃, respectively. The n^+ dope of the substrate plays little role since the reflectivity of SESAM with DBR is as high as 99 %. The number of quantum well absorption layer ranges from 1 to 3. The thickness of every quantum well is from 12 to 15nm respectively. We found that the SESAM grown at 400 ℃ or the ones with three quantum wells are easier to be destroyed than others. While the SESAM with single quantum well grown at 500 ℃ performs the best characteristics in the latter applications. Figure 1 shows the structure of the SESAM. In this structure, DBR is 22 pairs of GaAs/AlAs alternative layers. The absorber layer is 10nm $In_{0.25}Ga_{0.75}As$ grown at 500 ℃. Figure 2 shows the reflectivity as a function of wavelength of the saturable absorber (the vertical coordinate does not indicate absolute value).

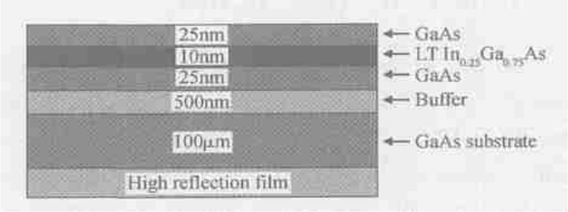

Fig. 1 $In_{0.25}Ga_{0.75}As$ absorber grown by MOCVD

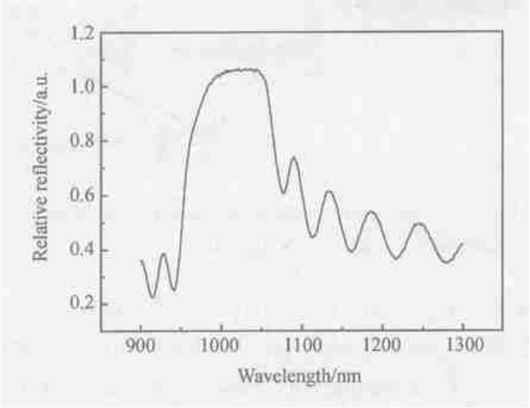

Fig. 2 Relative reflectivity of SESAM measured

When the thickness of $In_{0.25}Ga_{0.75}As$ is above the critical one, the large lattice mismatch of $In_{0.25}Ga_{0.75}As$ on GaAs can cause degradations such as surface striations, which can lead to much nonsaturable loss. Therefore, we choose $In_{0.25}Ga_{0.75}As$/GaAs quantum well (QW) structure other than bulk $In_{0.25}Ga_{0.75}As$. The bandgap of InGaAs/GaAs QW is not a very critical parameter, which is adjusted approximately to the lasing wavelength. Figure 1 shows the structure of growth recipe.

In order to lessen nonsaturable loss in the SESAM, we make SESAM coated with high-reflection film which is composed of $Al_2O_3/Si/SiO_2/Si$ multiple layers structure in order to obtain as high as 90 % reflectivity. To choose Al_2O_3 is in order to form good contact between semiconductors and dielectric materials. We incorporate H in the Si layer in order to lessen the absorption of infrared light for Si material.

3 Passive mode locking of diode-end-pumped Yb∶YAB laser with high reflectivity type SESAM

In our experiment (as shown in Fig. 3), we choose flat-concave cavity for simplicity. Pump source is F15-940-1 from Apollo company whose center wavelength is 940nm with the output power as great as 15W. The Yb∶YAB crystal is 3mm ×3mm ×3mm cube with 10at % dose, both sides of which are coated with 940～1070nm anti-reflection film. L is a focusing lens whose curvature radius is 50cm. M1 is an end mirror as well as an input mirror. The curvature radius of M2 and M3 are 100mm and 30mm correspondingly. The latter focuses laser upon the SESAM so that the optical intensity on the surface of absorber is large enough to reach modelocking threshold. The cavity length is about 40cm. We obtained continuous wave mode locking at the repetition rate of 375MHz (Fig. 4). In order to measure the pulse duration, we insert a flat glass of 2mm-thick between M2 and M3 to lead the laser out. The pulse duration is measured to be 3.05ps by the method of autocorrelation (Fig. 5), which is the best result in picosecond level mode-locking in China till now.

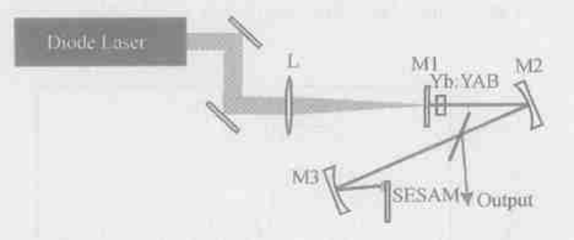

Fig. 3 Experiment scheme of passive mode locking diode-end-pumped Yb∶YAB laser

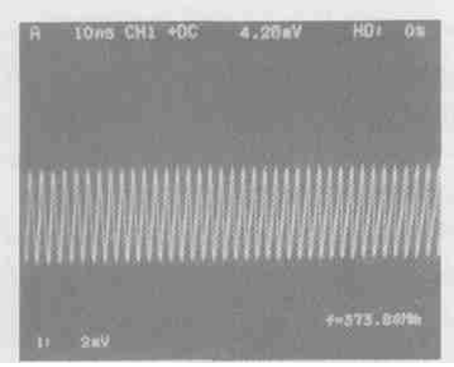

Fig. 4 Continuous wave passive mode locking trace

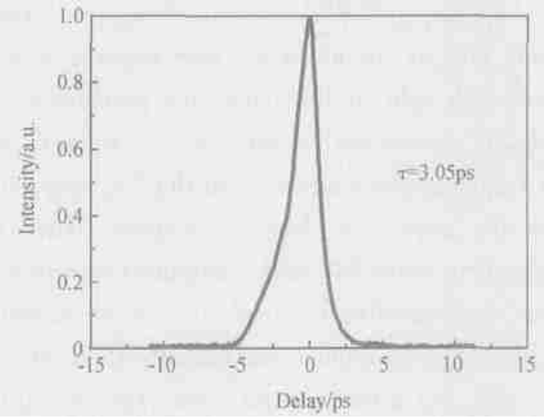

Fig. 5 Autocorrelation trace of the resulting pulses

4 Conclusion

A novel high reflection SESAM as an end mirror is reported, with which we obtain CW mode locking in a diode-end-pumped Yb∶YAB laser. The pulse width is about 3ps. The repetition rate is 375MHz.

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用高反射率型半导体可饱和吸收镜实现半导体端面泵浦 Yb∶YAB 激光器被动锁模

王勇刚[1,2]　马骁宇[1]　薛迎红[2]　孙　虹[2]　张志刚[2]　王清月[2]

(1 中国科学院半导体研究所, 北京　100083)
(2 天津大学精密仪器与光电子工程学院 超快激光实验室, 天津　300072)

摘要: 利用金属有机气相淀积方法生长了一种新型吸收体:高反射率半导体可饱和吸收镜. 用这种吸收体兼作端镜, 实现了 1.044μm 半导体端面泵浦 Yb∶YAB 激光器被动锁模, 脉冲宽度为 3.05ps, 重复率为 375MHz, 输出功率为 45mW.

关键词: Yb∶YAB; 高反射率; 半导体饱和吸收镜

EEACC: 4330B　　**PACC:** 4260; 4260D

中图分类号: TN365　　**文献标识码**: A　　**文章编号**: 0253-4177(2005)02-0250-04

王勇刚　男, 1973 年出生, 主要研究方向是用于固态激光器锁模和 Q 开关的半导体可饱和吸收镜和 GaAs 吸收镜. Email: wygxjwchina@vip.sina.com

2004-06-07 收到, 2004-09-03 定稿