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CONTENTS

PASSIVE MODE-LOCKING IN SINGLE TAPERED DIODE LASER

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ABSTRACT

Passive mode-locking was demonstrated in a monolithic single contact tapered diode laser without a separate saturable absorber section. Pulsewidths of 0.86 ps have been achieved at a repetition rate of 116 GHz, with average power of about 8 mW. It is believed that physical mechanisms of the laser, which is due to the nature of the taper, are the cause of the mode-locking operation. Thus, mode-locked pulses are conveniently obtained in a much simpler technique compared to multi-section lasers. Moreover the laser can also be mounted as p-side down for effective heat-sinking.

Keywords: mode-locking, semiconductor laser, ultra-short pulse, tapered waveguide, multiple quantum well (MQW)

1. INTRODUCTION

Mode-locking of diode lasers has been found to be a very successful method of generating high energy, picosecond pulses suitable for a number of applications such as spectroscopy, free space communications and the pumping of nonlinear optical materials. Among the key effect of self-modelocking is the process of self-focusing and Kerr effect in the optical medium[1,2]. Both external cavity and monolithic devices have been used to achieve mode-locking, although monolithic devices have been of particular interest as they offer a significantly more robust pulse generation technique than that achieved using an external cavity.

It was reported that the passive mode-locking of a monolithic double tapered "bow-tie" laser, in which the integrated tapered gain sections act so as to reduce the effects of gain saturation and catastrophic optical damage[3]. Peak mode-locked powers of about 300 mW have

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been obtained for multiple quantum well monolithic lasers at repetition rates of about 100 GHz. In this paper, a novel type of monolithic passive mode-locking is demonstrated, in which it is not necessary to use separated electrical contacts to form a saturable absorber.

2. MATERIALS AND METHODS

Figure 1 shows the schematic of a single tapered laser with 5 μm narrow facet expanding to a broad 45 μm output facet over a length of 335 μm. The diode laser was mounted n-side down and pumped at the p-side, and the light outputs from the uncoated broad facet active region. The material structure of the single contact tapered diode laser consisted of three 7.0 nm $In_{0.25}Ga_{0.75}As$ undoped quantum wells in a $GaAs/Al_{0.6}Ga_{0.4}As$ waveguide[4] is shown in Fig. 2.

The experimental set up for the optical spectra measurement is shown in Figure 3. Data of the spectrum were captured and stored in the SRS lock-in amplifier.

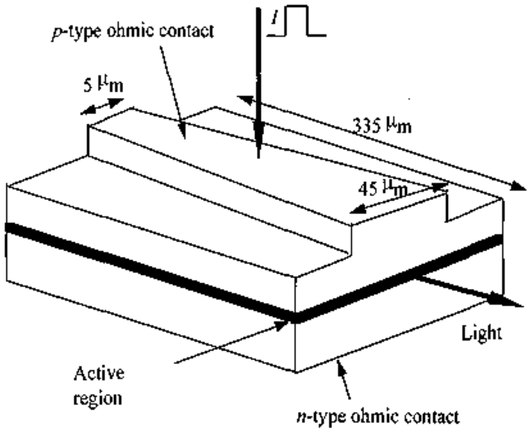

Figure 1: Schematic diagram of a single contact 3-QWs uncoated tapered laser.

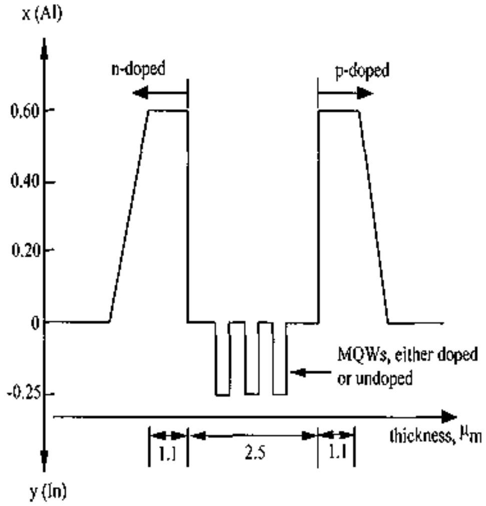

Figure 2: Layer structure of the MQW laser.

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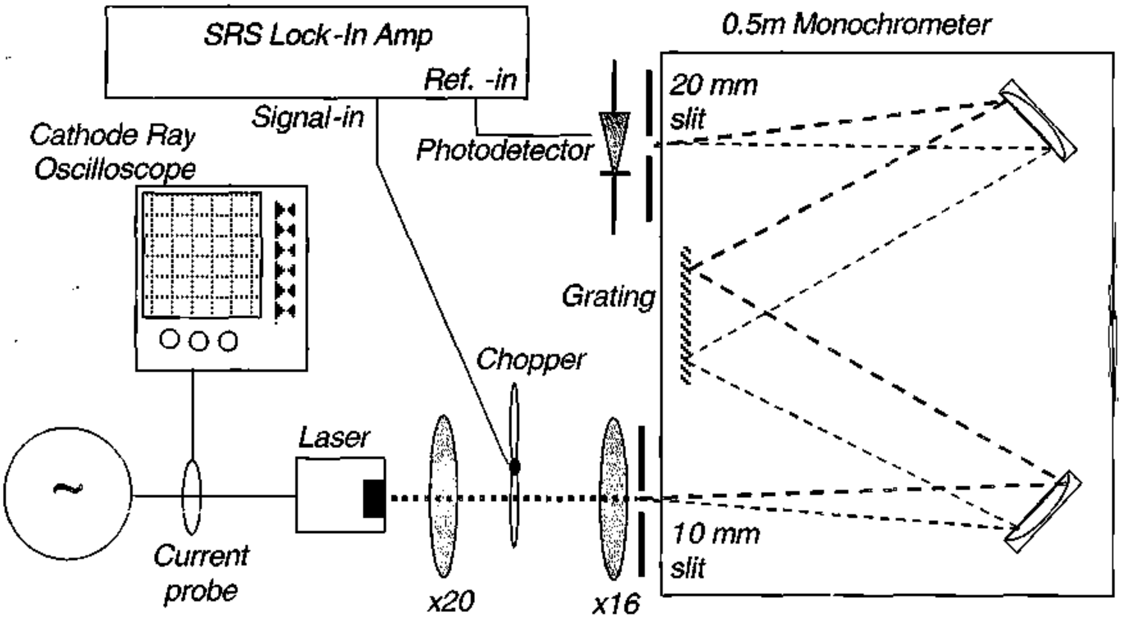

Figure 3: Experimental setup of optical spectra measurement.

3. RESULTS AND DISCUSSION

The measured threshold current of the laser was 45 mA with a differential quantum efficiency of 17 % per facet and the lasing wavelength is about 1022 nm. This monolithic device exhibits passive mode-locking operation for currents between 64 mA and 110 mA. This was achieved without separate electrical contact to form a saturable absorber, as there would normally be for a monolithic passively mode-locked laser[3].

The development of the optical spectra with increased drive current is shown in Figure 4. Mode-locking is clearly observed at around 100 mA drive current where the spectrum broadens and the pulse width narrows to less than 1.0 ps. The laser was driven at 1% duty cycle and the temperature was maintained at around 18 °C.

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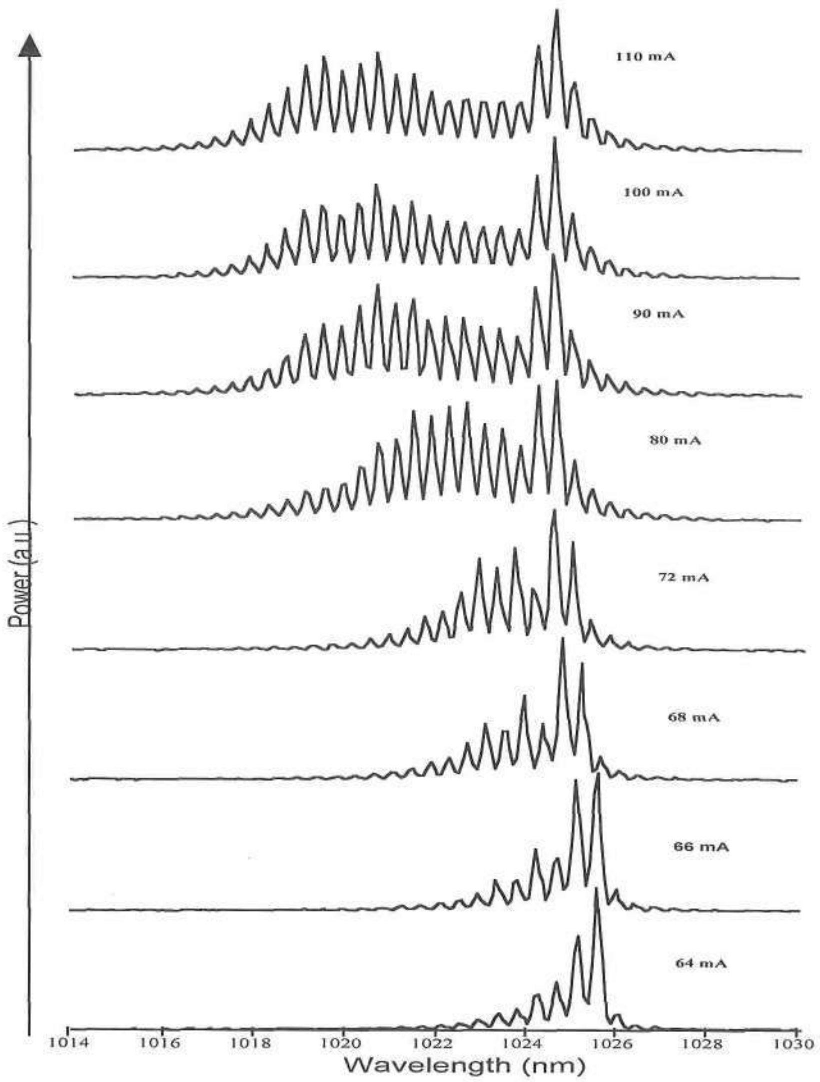

Figure 4: Development of mode-locking in the laser, which is illustrated by the broad, stable and Gaussian-like optical spectra.

A little indication of mode-locking at around 64 mA drive current is observed, where the spectrum is the narrowest and centred at about 1026 nm. As the current was increased further, a strong indication of mode-locking is observed clearly from 90 mA to 110 mA drive current with wide, stable and Gaussian-like spectrum.

Figure 5 shows an SHG autocorrelation trace for a 100 mA current pulse of width 10 μs at 1% duty cycle. Indication of partial mode-locking are observed by the

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traces of a mode-locked pulses with a contrast ratio of about 2.4. The pulse width is 0.86 ps at the repetition rate of 116GHz. The partial mode-locking operation of the laser is further confirmed by direct observation of the pulses on an oscilloscope, when continues wave (CW) background is observed, which could associate with a residual CW lasing mode at 1025 nm. Average power of 8 mW is measured, corresponding to maximum peak powers of at about 60 mW, assuming complete mode-locking.

Several factors peculiar to the tapered laser are crucial in understanding the origin of the mode-locking. To explain the phenomenon of mode-locking occurring in the laser, near-field profiles indicate that as the beam propagates from the narrow to the wide facet, the optical mode does not generally expand at the same rate as the lasing stripe. Thus, the mode does not completely fill the stripe at the wide facet, where the carrier profile is therefore broader than the optical profile.

At the narrow end of the tapered laser stripe, conversely, the effects of carrier spreading and current diffusion are much greater than the wide end; hence the effective injection current density is smaller. This results in absorption at the narrow end of the taper and furthermore, the optical mode profile is broader than the carrier profile. The effective confinement factor is lower at the narrow end than at the wide end. Together, these factors contribute to give an effective distributed saturable absorber at the narrow end of the tapered laser[5]. A traveling wave model incorporating these features has therefore been developed, and confirms that a distributed loss within the laser cavity is sufficient to produce mode-locking.

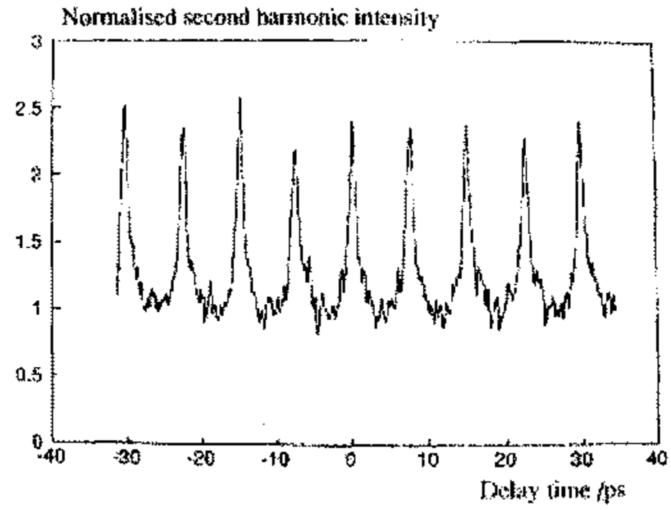

Figure 5: SHG autocorrelation trace for the single contact tapered laser at drive current of 100mA.

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4. CONCLUSIONS

A passive mode-locking in a monolithic single contact tapered diode laser without a separate saturable absorber section has been demonstrated. The coincidental occurrence of passive mode-locking in the single tapered laser bring to light the possibility of gaining high output power from a rather simple operating CW condition. Simplicity in the fabrication of the single contact laser provides an advantage of driving it *p*-side down for an efficient heat sinking.

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