Passively mode-locked monolithic two-section gain-guided tapered quantum-dot lasers: II. Record 15 Watt peak power generation

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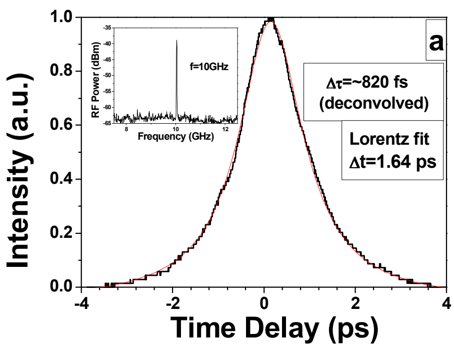
In recent years, quantum-dot (QD) mode-locked semiconductors lasers have shown great potential as ultrashort pulse laser sources [1]. For instance, the generation of ultrashort transform-limited pulses with pulse durations of 360 fs has been previously demonstrated in tapered index-guided mode-locked quantum-dot lasers without any dispersion compensation - however, peak power reached only 2.25 W, for a typical average power of 15.6 mW [2]. In our recent work, we have shown that output average/peak power and pulse energy can be greatly increased using a tapered (or flared) gain-guided structure [3]. In [3], two-section devices incorporating 5 or 10 QD layers with a total length of ~2.78mm were used, resulting in pulse repetition rates of the order of 14.6 GHz. With an absorber-to-gain lengths ratio of 1:7, the highest peak power achieved was 3.6W from both QD structures. On the other hand, a maximum average power of 209 mW corresponding to 14.2 pJ pulse energy with 6-ps pulse duration was achieved for the 5-layer QD laser. The generation of high-peak-power pulses is vital for a variety of applications such as biomedical nonlinear microscopy and imaging, where a combination of high peak power and average power (up to the limit tolerable by the bio-sample) are most effective in enhancing the nonlinear effects required. In this paper, we report the highest peak power (to our knowledge) of 15 W directly from a monolithic quantum-dot tapered laser, with sub-picosecond pulse width.

The gain-guided tapered laser was grown on a GaAs substrate by Molecular Beam Epitaxy, incorporating 10 identical layers of InAs quantum dots. The investigated gain guided tapered laser consists of two sections: a straight one and a tapered one (angle of 2^o), to which reverse bias and forward bias are applied, respectively. The lengths of the straight and tapered sections are 800 µm and 3.2 mm respectively, the total cavity length thus corresponding to a repetition rate of 10 GHz. A longer tapered section and higher absorber-to-gain lengths ratio (1:4) were chosen to boost the power and generate shorter pulses. Anti- and high-reflective coatings were deposited on the front/back facets. By adjustment of the driving conditions, the shortest pulse generated, with a pulse width of 820 fs, was observed for a reverse bias of -4V and an injected current of 1A (Fig.1a). Simultaneously, a high average power of 123 mW was generated, which is made possible due to the increasing width of the tapered section, resulting in a peak power of 15 W. The optical spectrum was centred at 1259.5 nm with a full-width half-maximum of 5.36 nm, resulting in a time-bandwidth product of 0.83. Noise measurements show that timing jitter can be as low as 3 ps. Figure 1b shows the light-current curves at 20°C with -4V on the absorber section. A threshold current of 720 mA with hysteresis loop was observed. Mode-locking was also observed for reverse bias between -2V and -6V. The maximum output average power achieved was 260 mW, for a reverse bias of -4V and current 1.7 A at 20 °C, corresponding to 26 pJ pulse energy with 3 ps pulse duration.



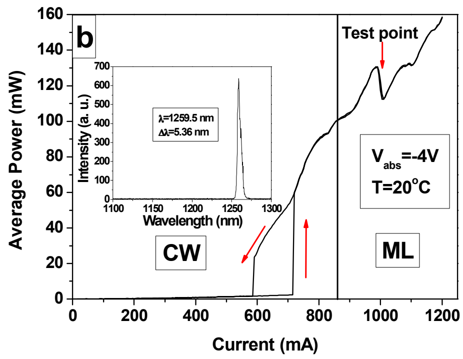


Fig. 1 a) Autocorrelation for an injection current of 1A and reverse bias -4V for sub-ps regime; inset: Corresponding RF spectrum b) Light-current characteristic at 20 °C for reverse bias of -4V inset: Optical spectrum for I=1A and V=-4V.

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