Due to the discrete nature of the density of states, quantum dot (QD) mode-locked lasers based on such material are great candidates as next generation of compact ultrashort pulses sources [1]. Furthermore, currently-available QD growth technology enables a high degree of control over the emission spectrum of QD devices, which can be tailored for different applications, such as a broadly-tunable laser [2-5]. For example, monolithic multi-section lasers incorporating 5 QD layers have shown the wavelength tunability from 1004.3 nm to 1029.1 nm, controlled by different injection currents to the multiple sections [2]. In this context, the chirped multiple QD based mode-locked monolithic lasers have recently demonstrated electronically-controlled 45 nm wavelength sweep range [6]. Alternatively, external-cavity diode lasers incorporating multiple chirped QD layers and bent waveguide have also been demonstrated impressive tunability ranges (up to 202 nm) with nearly 500 mW maximum output power in continuous-wave mode [3]. In this paper, we present about 100 nm wavelength tunability between 1192.9 nm and 1287.4 nm in a mode-locked regime from multi-section QD laser. The maximum peak power of 532 mW was achieved at 1226 nm wavelength while the maximum average power of 86.7 mW at 1262 nm wavelength. The presented work demonstrates significant improvement in mode-locked devices by offering a broad spectral tuning.

The investigated two-section laser has a total length of 4 mm and a ridge waveguide width of 6 µm with 7º tilting from the normal direction of the cleaved facet. A reverse bias is applied to the section placed nearer the back facet, thus forming a distributed saturable absorber with a total length of 800 µm while the gain section is forward biased. The chosen external cavity length of 36.6 cm results in a fundamental mode-locking at 410 MHz. AR coatings for the rear and front facets are ~10^-3 (angled facet) and 10^-2, respectively. Large wavelength tuning range is achieved due to the multi chirped QD structure grown on a GaAs substrate by molecular beam epitaxy. The active region of the laser consists of 10 InAs QD layers covered by non-identical InGaAs capping layers as fully explained in [3]. The laser was kept at 20ºC by a Peltier cooler. The gain section was pumped with a low-noise current source, while a reverse bias was applied to the absorber section. The pulse duration was measured by a non-collinear autocorrelator based on second-harmonic generation. The mode-locking performance was further investigated with an RF spectrum analyzer in combination with a high-speed 29 GHz photodiode. The spectral characteristics were measured with an optical spectrum analyser.

We observed stable fundamental mode-locking or harmonic mode-locking corresponding up to 15th order harmonic of ~410 MHz fundamental frequency for gain currents from 500 mA to 1 A and reverse bias between 0 V and 5 V with wavelength tuning for about 100 nm. Optical spectra tuning with suppression ratio higher than 40 dB for gain current of 900 mA and reverse bias of -3 V was demonstrated (Fig. 1a). The pulse duration and power dynamics were characterized as well (will be shown at conference), the pulse duration varies from 12.8 ps to 39 ps while average power up to 86.7 mW (at 1262 nm wavelength) was observed. The highest peak power of 532 mW was achieved at 1226 nm for reverse bias -3 V and gain current 900 mA (Fig 1b). Corresponding autocorrelation trace is shown in Fig. 1c.

![Fig.1](image)

Fig.1 (a) Wavelength tunability in mode-locked regime from 1192.9 nm to 1287.4 nm and (b) peak power dynamics with the emission wavelength and (c) autocorrelation trace at 1226 nm for gain current of 900 mA and reverse bias of -3V.

Pulse duration of 15.3 ps in the highest peak power regime was achieved (using a Gaussian fit with full width half maximum). From the corresponding optical spectra an effective spectral width of ~1 nm is determined and demonstrates a resulting time-bandwidth product of 3, suggesting that the pulses are still highly chirped.

Tunable lasers generating picosecond pulses can be effectively used for varieties of applications including optical coherent tomography and generation of tunable visible light by second harmonic generation [7].

We demonstrated a broad (almost 100nm) wavelength tunability in a mode-locked regime from a multi-section QD laser in external cavity configuration. The pulse duration varies from 12.8 ps to 39 ps while the maximum peak power up to 532 mW and average power up to 86.7 mW were observed at 1226 nm and 1262 nm wavelengths respectively.

References