Ultra-fast Tuneable DBR Laser using Quantum Confined Stark Effect Tuning

C. C. Renaud¹, M. Pantouvaki¹, C. P. Liu¹, S. Cole², M. Robertson², R. Gwilliam³, A. J. Seeds¹

¹ Dept. of Electronic & Electrical Eng., University College London, Torrington Place, WC1E 7JE, London, United Kingdom.
Tel: +44 (0)20 7679 7928, Fax: +44(0)20 7388 9325, email:a.seeds@ee.ucl.ac.uk
² Centre for Integrated photonics, Aduastral Park, Martlesham Heath, Ipswich, Suffolk, IP5 3RE, United Kingdom.
³ Surrey Ion Beam Centre, Advanced Technology Institute, University of Surrey, Guildford, Surrey, GU2 7XH, United Kingdom.

Abstract: A record (<2 ns wavelength switching speed, electronics limited, and 10 GHz 3dB FM bandwidth) tuning speed tuneable DBR laser using quantum confined Stark effect tuning is demonstrated.

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Optical packet switched networks and frequency modulated (FM) analogue links require sources having ultra-fast tuning response. These sources will ideally be semiconductor based and monolithic. Until now, most tuneable semiconductor lasers have used Carrier Injection Effect (CIE) tuning with Distributed Bragg Reflector (DBR) designs achieving tuning ranges up to 16 nm [1]. This approach has several draw-backs. First, the interaction, between red-shifting thermal effects and blue-shifting carrier density effects induces a non-uniform tuning response, secondly, the tuning transition time is limited by the carrier transport time (ns timescales).

Using Quantum Confined Stark Effect (QCSE) induced refractive index change [2-4] as the tuning mechanism eliminates these issues as it gives an uniform and reproducible tuning response and the transition time is only limited by the RC constant of the device and photon lifetime delay, hence much faster devices can be built and high speed modulation can be used for comb generation. So far the use of QCSE as the tuning mechanism has been demonstrated in the GaAs/AlGaAs materials system, which emits at 850 nm wavelength [5,6] and recently in the InP/InGaAsP system with DBR structure at 1,550 nm yielding a tuning range of 7 nm [7].

In this paper we present the fast tuning results obtained with the laser described in [7]. The laser was able to switch between two specified wavelength in less than 2 ns (bias source switching time limited) and when the tuning section was driven with a sinusoidal signal the device achieved a tuning frequency response 3dB bandwidth of > 10 GHz.

Figure 1: [7], Schematic cross-section of the QCSE-tuned laser and micrograph of fabricated device.

The design chosen for the ultra-fast tuneable laser is shown in Figure 1. This is a multi-section laser comprising a DBR tuning section, a phase section and a gain section. The tuning and phase section bandgaps were blue-shifted by 35 nm using quantum well intermixing in order to reduce absorption in the emission wavelength range. Tuning is obtained using QCSE-induced refractive index change, and, for short photon lifetime, tuning speed is limited by the RC time-constant of the device. In order to reduce the capacitance of the tuning section oxide-bridged contacts and a semi-insulating substrate were used. The resulting measured capacitance was 380 fF, giving an RC limited bandwidth of 8.4 GHz (50 Ω source).
Figure 2: Measurement system

Figure 2 shows the experimental systems used to measure the fast tuning response of the laser. The laser tuning section was driven through a coplanar probe with a 65 GHz bandwidth which was fed by either a voltage source giving 1V steps or by a sinusoidal frequency generator giving 1 V peak to peak at frequencies up to 40 GHz. The resulting optical signal was passed through a tuneable optical filter and was measured on a sampling oscilloscope. The filter bandwidth for the wavelength switching experiment was 0.5 nm in order to select precisely the resulting wavelength. For the frequency response measurement a 2 nm bandwidth filter was used to give FM slope detection and the laser was used in the middle of a continuous tuning zone [7].

Figure 3: (Left) wavelength switching measurement, (right) FM frequency response

Figure 3 (left) shows the measured wavelength switching speed for the DBR laser. This was measured to be 2.1 ns, with the pulse source reaching a voltage stable enough to have a resulting wavelength within the filter bandwidth after 1.9 ns. The source had an initial rise time of 780 ps followed by a 250mV overshoot (1.2 ns long) before stabilising, the overshoot is sufficient to be out of the filter bandwidth, thus it was effectively limiting the laser wavelength switching speed. To assess the ultra-fast tuning response of the tuneable DBR laser the tuning section was driven by a sinusoidal signal generator at frequencies up to 40 GHz. The response is shown in Figure 3 (right) and the tuning section of the laser shows a 3dB bandwidth of the order of 10 GHz, which is in agreement with the fast switching time, allowing for pulse source overshoot, measured in the previous experiment.

We have demonstrated ultra-fast tuning in a DBR InP/InGaAsP multiple quantum well semiconductor laser emitting at 1.5 µm using QCSE as the tuning mechanism. The laser was fabricated in a single epitaxial step, and used techniques such as QWI and oxide-bridge contacting to achieve the desired ultra-fast tuneability. It was able to switch between two given wavelength in less than 2 ns (pulse source limited) and achieved a record frequency modulation 3dB bandwidth for QCSE tuning of > 10 GHz.