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# Monolithic AWG-based discretely tunable laser with nanosecond switching speed

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## *Introduction*

Tunable lasers operating at wavelengths around 1.55 μm are widely used in wavelength-division multiplexed systems as a flexible back-up for fixed-wavelength lasers [1]. New applications of these tunable lasers, such as in optical switching and routing, require fast wavelength switching in the nanosecond regime [2,3]. Wavelength tuning is often achieved by relatively large changes in driving currents. As a result, thermal transients occur when wavelengths are switched and these limit the tuning speed of the device [3]. Another drawback of most tunable lasers is that they have to be optically isolated from the network during switching, so called "dark tuning", to avoid polluting the network with unwanted wavelengths [1].

In this paper we present a tunable laser based on an arrayed-waveguide grating (AWG), which is monolithically integrated in InP/InGaAsP and aims to overcome the above-mentioned limitations. The concept and realization of this device are shown in Fig. 1. The configuration utilizes a single 1-mm length SOA in the laser cavity. Wavelength selection is then achieved by biasing small, 40-μm long amplifier sections, which act as a gate for that particular channel (S1 to S8 in Fig. 1).

## *Fabrication*

The chip is realized using an active-passive integration technology. The active regions consist of 4 strained quantum-wells, embedded in a 500-nm InGaAsP (Q1.25) waveguiding layer. The passive regions are butt-joint coupled to the active regions and also have a 500-nm Q1.25 waveguiding layer. These active and passive layers are sandwiched between an n-doped InP substrate and a p-doped 1500-nm thick InP cladding with a 300-nm contact layer.

The device is etched using a $CH_4/H_2$ three-step reactive-ion dry etch process to create high and low contrast ridge waveguides and amplifiers [4]. The structures are planarized using polyimide. Evaporated and plated Ti/Pt/Au metal pads provide the SOA and the gate contacts. The metallized backside of the n-InP substrate provides the ground contact. The structures are cleaved to create the mirrors for the Fabry-Pérot-cavity (Fig. 1).

## *Characterization*

Needle probes are used to bias the SOA and gates individually. A lensed fiber-tip is used to collect the light. Passive waveguide propagation losses are in the order of 4 – 5 dB/cm. The SOA gain is 35 – 40 $cm^{-1}$ for wavelengths between 1560 – 1570 nm at an injection current density of 2.5 $kA/cm^2$. The AWG has 8 channels, spaced at 0.8 nm, with a free spectral range (FSR) of 8 times the channel spacing.

Without biasing S1 – S8 the device has a lasing threshold at an SOA injection current of 60 mA and output power at 100 mA is around 1 mW. With all gates closed, lasing starts at residual reflections from the end of the AWG free-propagation region. Biasing S1 – S8 respectively then switches the lasing wavelength to the corresponding channels. In Fig. 2 the peak positions in the optical spectrum are plotted for 1-mA bias currents of S1 – S8 respectively. Simultaneous lasing and switching between wavelengths separated by (a multiple of) the AWG-FSR takes place due to the relatively small FSR and broad gain bandwidth of the SOA. In Fig. 3 the optical spectra are shown. The side-mode suppression ratio is around 35 – 40 dB, with the exception of channel S5, and the linewidth of the laser peak is around 30 MHz, as measured with a 20-MHz resolution optical spectrum analyzer.

We can measure switching between the 'closed-gates' lasing wavelength and the wavelength corresponding to S7 by applying a pulsed injection current. The laser output is filtered using a 2-nm optical bandpass filter and recorded using a 1-GHz photodiode connected to a 1-GHz oscilloscope. Fig. 4

shows the switching obtained by selecting either the unbiased-case signal, which switches off, or the signal corresponding to channel S7, which switches on when the pulse is applied. The measured switch-on time is (3 ± 2) ns and the switch-off time (4 ± 2) ns.

## *Conclusion*

We have presented a novel concept for a discretely tunable laser. Wavelength switching speed is in the order of a few nanoseconds. Switching is achieved by a 1 mA SOA bias current, thereby minimizing thermal re-stabilization effects. Since the switching between AWG channels is discrete, no laser operation takes place at wavelengths corresponding to other channels.

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## *References*

1. J. Buus and E.J. Murphy, IEEE Journ. of Lightw. Techn., vol. 24, no. 1, pp. 5-11, Jan. 2006
2. R. Phelan et al., IEEE Journal of Quantum Electronics, vol. 44, no. 4, pp. 331-337, April 2008
3. J.-O. Wesström et al., in Proc. OFC 2005, TuE2
4. J.H. den Besten et al., IEEE PTL, vol. 14, no. 6, pp. 753-755, June 2002

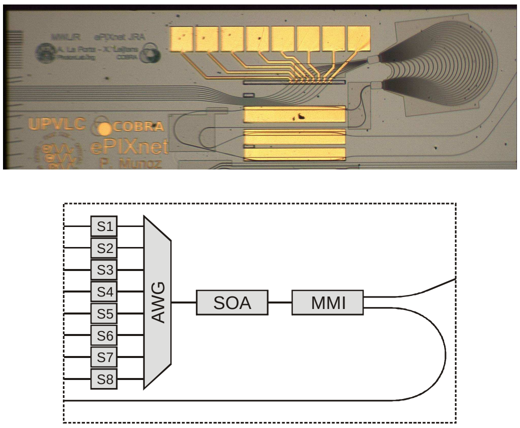

Fig. 1 (top) Photograph of the realized device and (bottom) schematic of the device. The coupler (MMI) directs part of the light to the output waveguide.

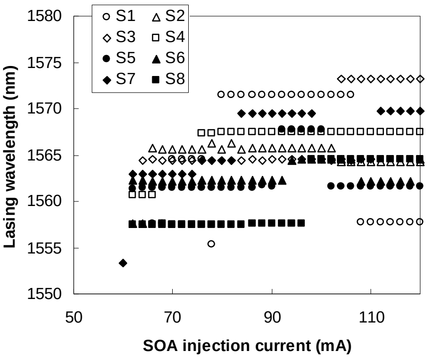

Fig. 2 Spectral positions of the main laser peaks, showing wavelength switching. The gates are biased one by one at 1 mA.

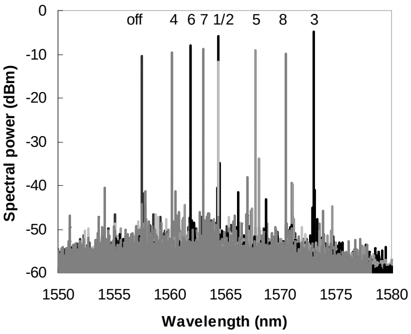

Fig. 3 Optical spectra obtained by biasing each gate, as indicated by the numbers. The optical bandwidth used to obtain the spectra is 0.8 pm.

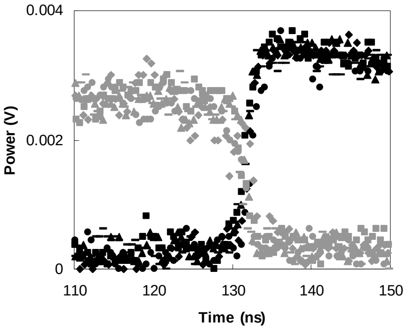

Fig. 4 Oscilloscope traces (2 GS/s, 5 traces overlaid) obtained after filtering by a bandpass filter at 1557.5 nm (grey) and 1563.1 nm (black). SOA injection current is 90 mA. Pulsed injection current is applied to S7.