# A compact phased array based multi-wavelength laser

# A COMPACT PHASED ARRAY BASED MULTI-WAVELENGTH LASER

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**Introduction:**
Wavelength Division Multiplexing (WDM) is widely regarded as a promising option to increase the bandwidth and flexibility of broadband optical communication systems. In such systems, multi wavelength laser sources [1], both for selectable single wavelength and simultaneous multiple wavelength operation, will be important components.

Several monolithically integrated solutions of launching multiple wavelengths into a single fibre have been demonstrated. Among these are integration of DBR lasers with a star coupler [2], and an etched grating [3] or a Phased Array wavelength multiplexer [4, 5] in the laser cavity. Previous devices have been fabricated using QW-loaded [4] or Selective Area Epitaxy-grown [5] embedded waveguides. Due to the relatively small index contrast of such waveguides, a rather large device size of $10 \times 4\,\mathrm{mm}^2$ results.

In this paper, devices are presented which employ a simple ridge waveguide structure, enabling a compact Phased Array design due to a high index contrast.

**Design and fabrication:**
As shown schematically in Fig. 1, the passive part of the device consists of an $11 \times 1$ Phased Array wavelength multiplexer having a channel spacing of 400 GHz (3.2 nm), and a free spectral range (FSR) of 38.75 nm. It comprises 50 array waveguides with a minimum bending radius of $500\,\mu$m. The two outer input waveguides are used for testing purposes, while the 9 inner input arms are fit with $500\,\mu$m long gain sections. Total device size is only $3.5 \times 2.5\,\mathrm{mm}^2$.

In addition to a small device size, the ridge waveguide structure in both the active and passive parts of the device leads to a simple fabrication scheme. The complete structure (active + passive) is grown in 3 epitaxy steps. A 120 nm thick InGaAsP laser active layer with $\lambda_{\mathrm{gap}} = 1.55\,\mu$m is grown onto an n-type InP substrate by means of Low-Pressure OMVPE. After defining the active regions using wet chemical etching, 230 nm InGaAsP with $\lambda_{\mathrm{gap}} = 1.30\,\mu$m is grown, butt-jointed to the active layer, and the entire structure is overgrown with a $1.4\,\mu$m thick p-InP cladding layer. Stable TE mode operation [6] is obtained using ridges of $2.5\,\mu$m in width and $1.35\,\mu$m in height, which are etched by means of reactive ion etching. Finally, the laser contact metallisation is fabicated. For characterisation, chips with as-cleaved facets are soldered onto copper carriers providing 8 leads for electrical contacts.

**Experimental results:**
Figure 2 shows the response of a discrete, passive Phased Array. The 11 channels have a spacing of 400 GHz around the central wavelength of 1547 nm, with a crosstalk less than −20 dB. Fibre-to-fibre insertion loss (using two lensed fibres) is 24.7 dB for the best channel, and increases with channel number due to the increasing path length (see Fig. 1). This yields an estimated waveguide loss of 20 dB/cm, which is supported by the results of Fabry-Pérot contrast measurements

on straight waveguides. This relatively high loss is attributed to the p-doped InP cladding layer, which was grown over the entire structure for simplicity of processing.

As shown in Fig. 3, single-mode operation with a side mode suppression of approximately 20 dB is obtained for 6 out of 8 adressable channels. The width of the individual peaks results from the 0.1 nm resolution of the optical spectrum analyser used for the measurements. Threshold current for the devices, operated at 25°C, is 120 mA for channel 2 and increases to 150 mA for channel 7, due to the increasing waveguide loss with increasing length of the passive part of the cavity. Discrete laser arrays (i.e. without passive waveguides; length 500 $\mu$m) uniformly exhibit threshold currents of 38 mA. Finally, for channel 2, at 200 mA approximately 0.15 mW of output power is coupled into a lensed standard single mode fibre.

Stable dual channel operation could be obtained for any combination of lasing channels at a device temperature of 16°C, as shown in Fig. 4 for channel 2 and 3. Device heating resulting from the high operating currents prevented lasing at more than two wavelengths.

**Conclusion:**
A compact multi-wavelength laser has been fabricated in a simple ridge waveguide structure, exhibiting stable single mode operation at 6 out of 9 discrete wavelengths spaced by 400 GHz. Simultaneous operation at two independently lasing wavelengths has been demonstrated.

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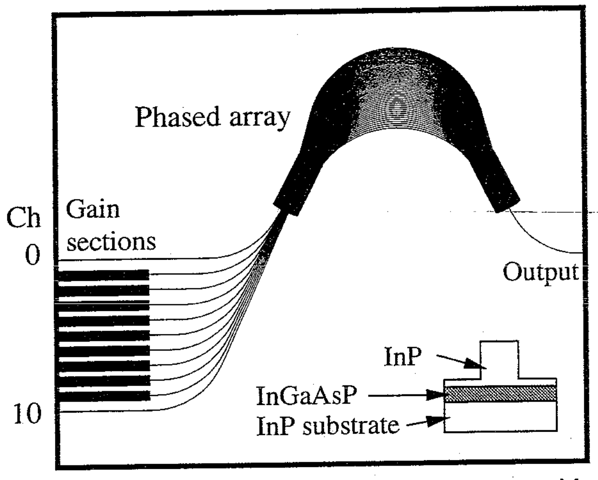


*Figure 1:* Schematic diagram of ridge waveguide multi-wavelength laser.

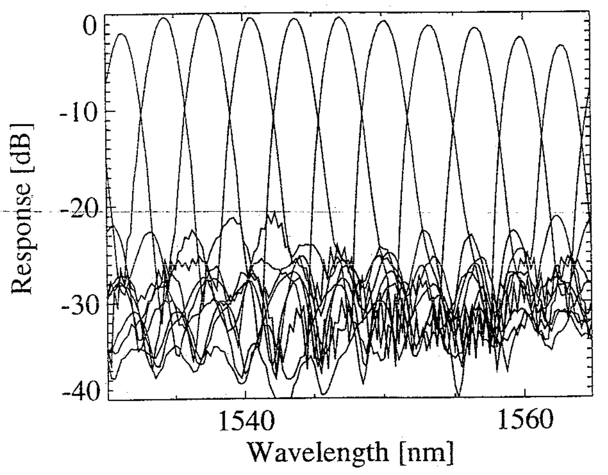


*Figure 2:* Response of a discrete phased array.

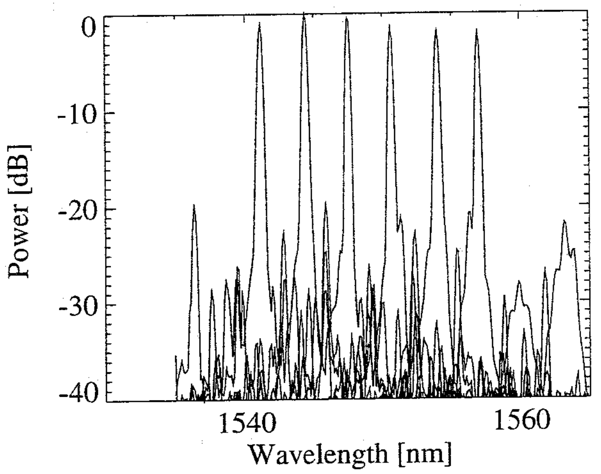


*Figure 3:* Spectra of the individual channels at 175 mA gain current.

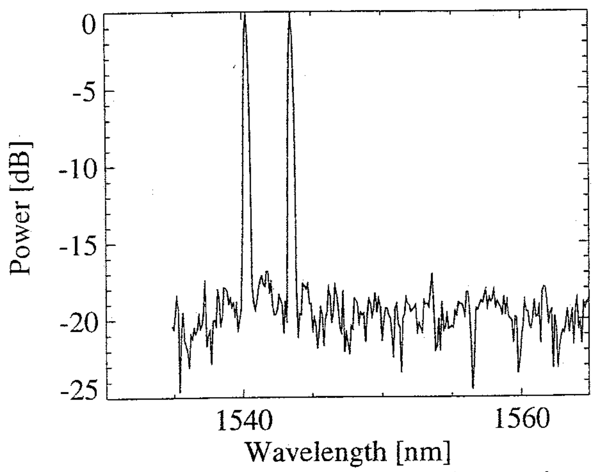


*Figure 4:* Simultaneous dual channel operation; $I_{ch\ 2} = 165\,mA$, $I_{ch\ 3} = 154\,mA$.