20 channels simultaneous oscillation from a semiconductor fibre laser

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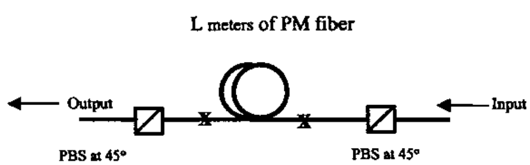
Abstract: *Simultaneous oscillation of 20 wavelength channels is demonstrated using a single SOA in a linear fibre cavity, formed by two nonlinear optical loop mirrors and a polarisation maintaining fiber for comb generation.*

Introduction

In the recent years there has been an intense effort in the development and deployment of very high capacity DWDM systems. The continuous increase of the number of wavelengths used, impose an unprecedented increase in the cost of these systems. With this in mind, a number of alternative techniques of obtaining multi-wavelength operation from cost-effective single laser solutions have been reported up to date. One of the successful techniques is that of spectrum slicing and this has been applied to LED's, superluminescent diodes, EDFAs and fsec pulsed lasers [1-2]. Additionally multi-wavelength operation has been reported using semiconductor optical amplifiers or EDFAs, cooled in liquid nitrogen, combined with intracavity comb like filters, AWG [3], Fabry-Perot filters or birefringent fibres [4-5]. In this paper, we report the demonstration of a stable laser source capable of generating up to 20 wavelengths, with a 100 GHz line spacing and linewidth less than 1,25GHz. In addition the power variation across the most intense oscillating lines was less than 3 dB. The source operates at room temperature and uses an SOA as gain medium, a polarization maintaining fiber based Lyot filter and two nonlinear optical loop mirrors, which form a linear cavity. By using NOLMs as reflectors to form a linear cavity and by using only low loss, fibre components, the end-to-end loss in the cavity is minimised and thus, more channels may oscillate.

The Polarization Maintaining Fibre Lyot Filter

The Lyot filter is formed using L meters of polarisation maintaining fibre and two polarizers with their axes aligned at 45^0 with respect to axes of the PM fiber. Due to the different propagation constants of the two axes of the PM fiber, a squared cosinusoidal filtering function is imposed on the light travelling through it. Figure 1a displays the implemented polarisation maintaining fiber Lyot filter.



$$T=\frac{1}{4}\left|e^{-j\beta_x L}+e^{-j\beta_y L}\right|^2=\cos^2\left[\frac{(\beta_x-\beta_y)\cdot L}{2}\right] \quad (1)$$

$$\delta\lambda_{FSR}=\frac{B\cdot\lambda}{L} \quad (2)$$

Figure 1: (a) The PM fiber Lyot filter and (b) Transmission function (1) and free spectral range of the filter (2)

The single-pass transmission function through the filter is given by equation (1), where β_x and β_y are the propagation constants through the axes of the PM fiber. In addition, from equation (1) the free spectral range of this comb-like filter (eq. 2) can be easily derived. In equation (2) B is the beat length of the PM fiber.

Distinguishing features of the filter that result from its cosine-squared transmission function are the low single pass finesse, the high extinction at the centre of the rejected wavelengths, and the very low insertion loss of it. In addition the filter spacing can be tuned precisely to the ITU specifications since the free spectral range depends on the length of the fibre itself. Therefore using 5.77m of a commercial available PM fibre with 3mm beat length fibre, a 100GHz spacing filter is constructed.

NOLM based Semiconductor Fibre Laser

Figure 2 shows the linear cavity of the multiwavelength source formed by the two nonlinear optical loop mirrors with almost 100% reflectivity. Gain was provided from a commercially available SOA. It is a 500 μm, bulk InGaAsP/InP ridge waveguide device, with facets angled at 10^o and antireflection coated. The device has a small signal gain of 25 dB at 1550 nm when driven with 250 mA dc current. The SOA exhibited 1 dB small signal gain polarization dependence between its TE and TM axes and polarization controllers were used on its ports for polarization control. The wavelength comb generating Lyot filter consisted of 5.77 m of PM fibre, with two Polarization Beam Splitters placed at both its sides. Output from the laser was obtained from a 70:30 fused fibre coupler.

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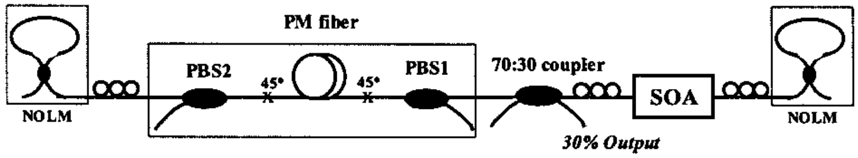

Figure 2: Experimental layout of multi-wavelength linear cavity laser.

Multi-wavelength oscillation is obtained by adjusting the polarisation controllers in order to align the oscillating signal to the high gain axis of the SOA and to achieve maximum transmission through the wavelength comb-generating filter. With this experimental set-up the oscillating light in the cavity is being filtered twice, resulting in the enhancement of the finesse. In addition due the heavy saturation of the SOA the linewidth is improved even more. Figure 3a displays the optical spectrum and shows that 20 of the oscillating lines have less than 3 dB power variation between them and 25 dB extinction. The FWHM of each oscillating wavelength was measured with a high resolution optical spectrum analyser and was found to be less than 1.25GHz, close to the resolution of the instrument. The total power at the output of the source was 412 μW and figure 3b shows the power distribution across the 20 most intense lines.

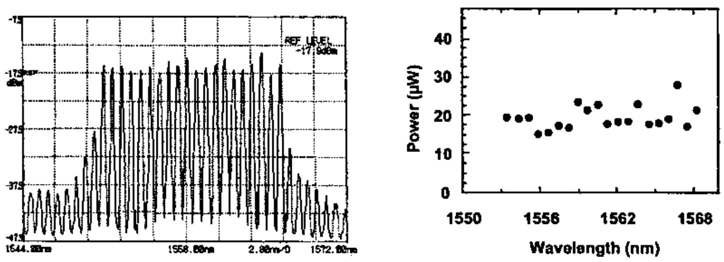

Figure 3: (a) Output optical spectrum of the multi-wavelength (b) Optical power variation versus wavelength.

With the same experimental set-up the PM based Lyot filter was characterized and the normalized transmission functions were measured. Thus, by preventing oscillation in the cavity and using the ASE from the SOA the output spectrum was measured at the free ports of the cavity. Figure 4(a) shows the single pass transmission function of the filter, indicating a finesse of 2, as measured by a leakage at the free port of the left NOLM. The same transmission function corresponds to the second axis of the PM fibre, with the difference that it is shifted by $\Delta\lambda_{FSR}/2$. Finally Figure 4(b) displays the double pass transmission of the filter showing a $\cos^4()$ function and an enhanced finesse of 3.2 as measured at the output port of the 70:30 fused fibre coupler. In that port the optical signal has been filtered twice by the same transmission function, which corresponds to the one (fast or slow) axis of PM fibre.

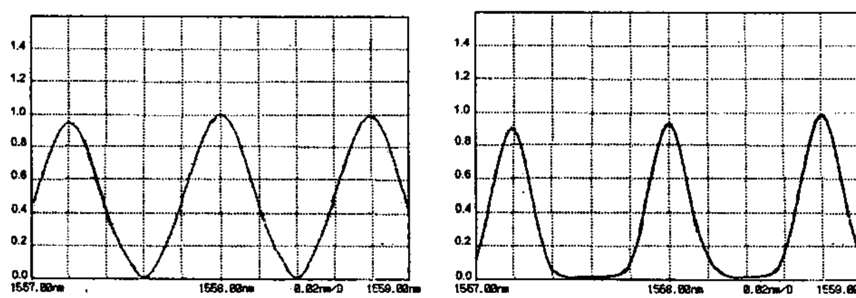

Figure 4: (a) and (b): Single and double pass transmission through the Polarization Maintaining Fibre Lyot Filter.

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