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IMPROVED SPECTRAL CHARACTERISTICS OF A SINGLE-MODE SEMICONDUCTOR LASER USING A FIBRE GRATING AND A REDUCED LASER DIODE LENGTH

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ABSTRACT

Use of a reduced laser diode length with a fibre Bragg reflector leads to decreased mode-hopping and a factor of 3 improvement in temperature stability of the lasing wavelength over ΔT=22°C. Single frequency output power of 1.7 mW in the fibre with 45 dB side mode suppression was obtained.

DBase Submitted to OFC '95

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SUMMARY

Densely spaced (sub-nanometer) wavelength-routed optical transport and access networks require stable single frequency lasers operating on exactly specified wavelengths to reduce four wave mixing and crosstalk penalty[1]. Semiconductor lasers using external cavity fibre Bragg reflectors can fulfill these requirements and devices with impressive characteristics have been reported[2,3]. These lasers can be directly modulated, using standard Fabry-Perot (FP) laser diodes, with the exact output wavelength selected by the fibre Bragg grating.

Although more stable compared with DFB/DBR lasers due to lower temperature dependence of the Bragg wavelength in silica, the carrier induced refractive index change with current and temperature in standard length (500 μm) FP devices leads to nonlinearities in the device Light-Current characteristic, mode-

hopping and the increase in the output linewidth[3]. We show that decreasing the laser diode length increases the FP mode separation relative to the Bragg reflection band and significantly improves the longitudinal mode discrimination, leading to a kink-free Light-Current characteristic, reduced mode-hopping and an improvement in the spectral stability with temperature.

The experimental set up (fig 1a) consists of a single facet AR coated (< 1%) BH semiconductor laser, coupled to the fibre grating with an efficiency of > 45% using an AR coated GRIN rod lens. The fibre grating was fabricated by holographic exposure of Ge-doped fibre. The grating length is 2 cm (estimated 0.1 nm chirp), with reflectivity of 65% and FWHM bandwidth of 0.35 nm. The Light-Current characteristics, together with the spectral output obtained for the 600 μm and 150 μm devices, measured through the grating (P_1) and the rear facet of the device (P_2), are shown in fig 2. Nonlinear kinks can clearly be observed for the 600 μm device corresponding to mode hops, leading to dual-frequency operation when two semiconductor laser mode fall within the Bragg reflector bandwidth. For the 150μm device the Light-Current characteristic is linear, no mode-hopping was detected. This is expected since the inter-mode spacing is increased by a factor of 4, and the next FP mode falls outside the Bragg reflection band (fig 1b). Stable single frequency operation with sidemode suppression of better than 45 dB was obtained. The output power of 1.7 mW in the fibre was measured for a current value of 90 mA ($3xI_{th}$).

The average variation of the lasing mode wavelengh with temperature was measured as 0.07Å/K for the 150 μm device (T=13°C-35°C) compared with 0.26 Å/K (T=13°C-28°C). Such improvement is in agreement with the results reported for monolithically integrated diode laser with a Ta_2O_5 DBR[4] which has a similar temperature stability to silica.

In conclusion, these results show that the reduction of the laser diode length leads to linear Light-Current characteristics, reduced mode-hopping and improved temperature stability of the lasing wavelength in this type of laser. By proper design of the laser diode length and the Bragg reflector wavelength, bandwidth and reflectivity together with the overall cavity length, further improvements can be obtained.

1. F.Forghieri et al, Photon. Tech. Lett. **6**, 754 (1994)
2. D.M. Bird, et al, Electron. Lett. **27**, 1115 (1991)
3. P.M. Morton et al, OFC'94 Technical Digest, paper WG4, pp102-103
4. Zh.I. Alferov et al, IEEE J. Quantum Electron. **QE-23**, 874 (1987)

FIGURE CAPTIONS

Figure 1. Schematic diagram of (a) the experimental set up
(b) the relationship between the laser diode Fabry-Perot modes with diode length relative to the Bragg reflection bandwidth

Figure 2. Light vs Current characteristics for (i) L= 600 μm and (ii) L=150 μm. Inset are the measured optical spectra corresponding to the various points on the curve, indicating mode-hopping corresponding to the kinks in the curve for L= 600 μm and stable single mode operation for L=150 μm. Centre wavelength is 1.553 μm

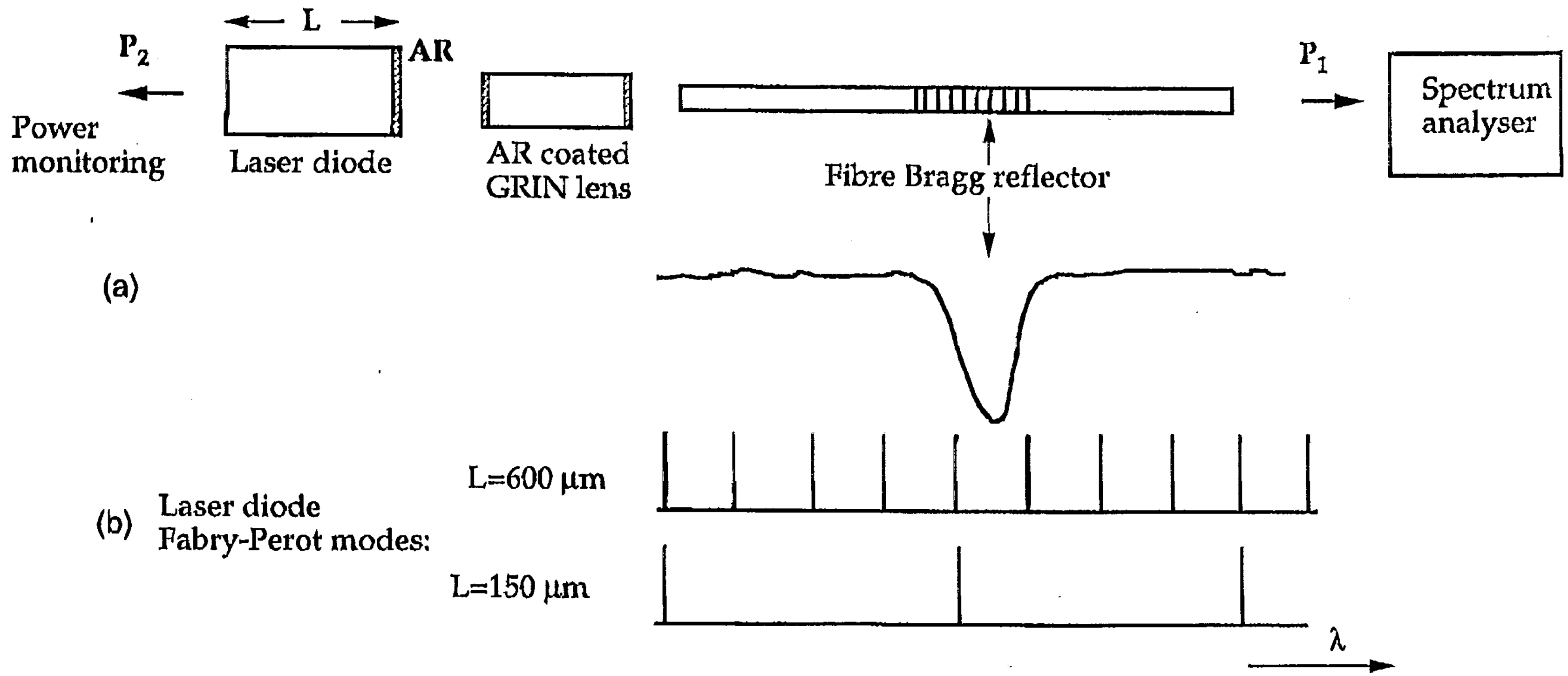
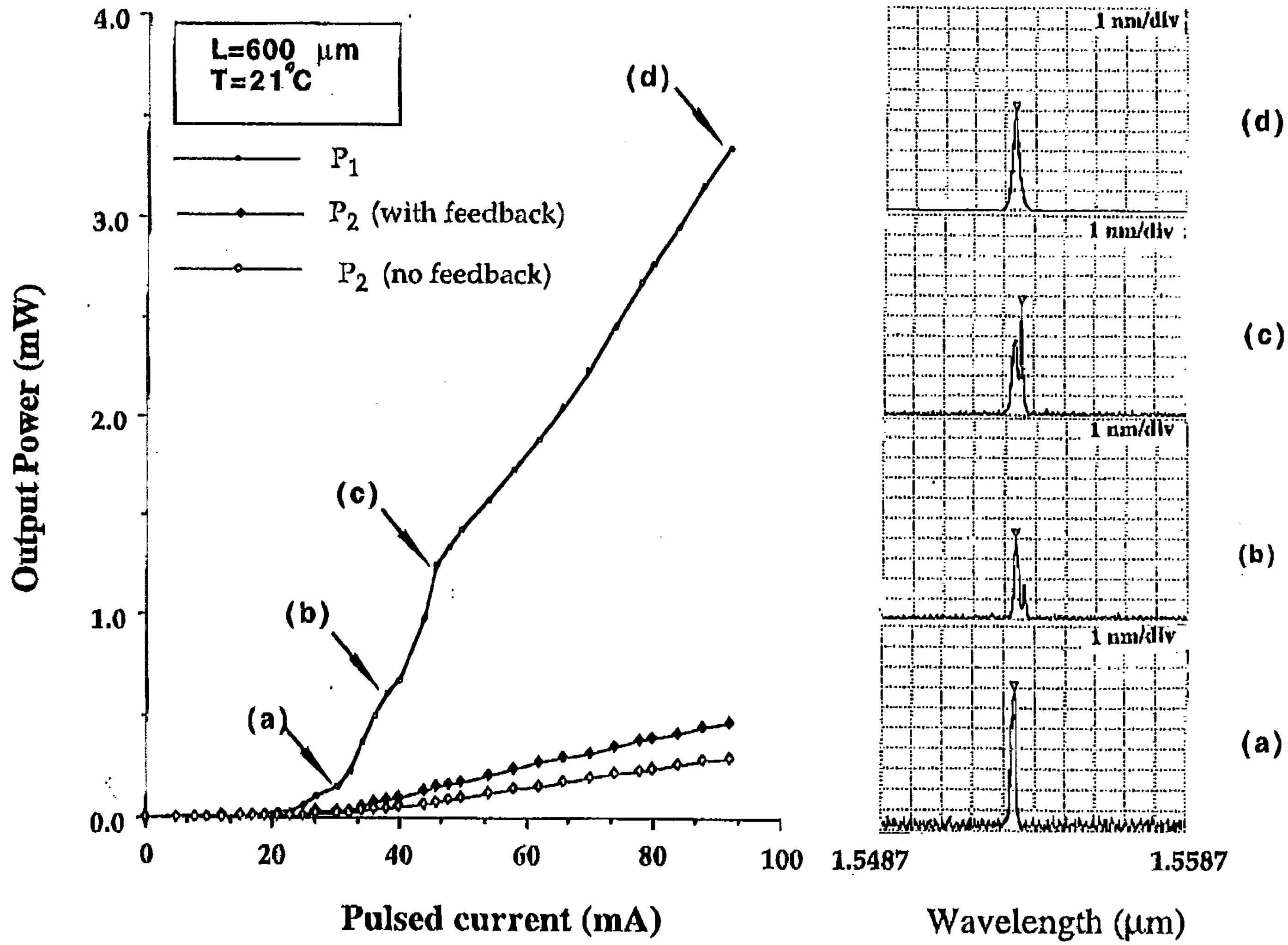

L
AR
P_2
Power monitoring
Laser diode
AR coated GRIN lens
Fibre Bragg reflector
P_1
Spectrum analyser
(a)
(b) Laser diode Fabry-Perot modes:
L=600 µm
L=150 µm
λ

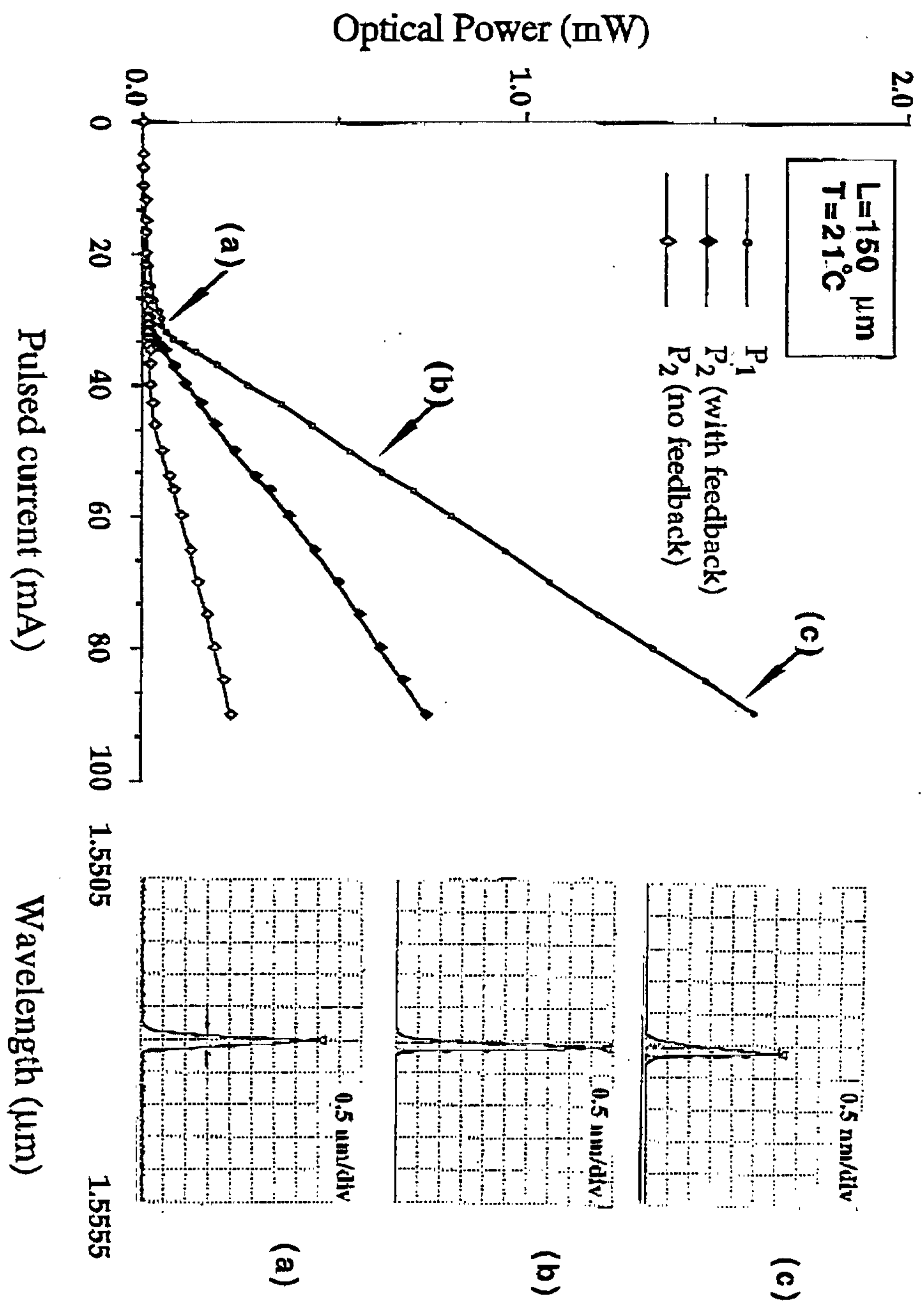
Fig 1.



Output Power (mW)
4.0
3.0
2.0
1.0
0.0
L=600 µm
T=21°C
P_1
P_2 (with feedback)
P_2 (no feedback)
(a)
(b)
(c)
(d)
0
20
40
60
80
100
Pulsed current (mA)
1 nm/div
1 nm/div
1 nm/div
1 nm/div
1.5487
1.5587
Wavelength (µm)
(d)
(c)
(b)
(a)

Fig 2(i)

Fig 2(ii)


Optical Power (mW)
0.0
1.0
2.0
0
20
40
60
80
100
Pulsed current (mA)
L=150 µm
T=21°C
P_1
P_2 (with feedback)
P_2 (no feedback)
(a)
(b)
(c)
0.5 nm/div
0.5 nm/div
0.5 nm/div
1.5505
1.5555
Wavelength (µm)
(a)
(b)
(c)