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Characterization of Intensity Distribution in Symmetric and Asymmetric Fiber DFB Lasers

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Abstract:

Measurement of the intensity distribution in a fiber DFB laser is demonstrated by scanning a heat source along the cavity and measuring the induced wavelength shift. Characterization of grating strength and the order of longitudinal mode operation is demonstrated, as well as location of the phaseshift position in an asymmetric phaseshifted DFB-laser with single-sided output.

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Summary:

DFB lasers are complex structures and the understanding of how they operate depends much on simulations. Measurements of intensity distributions in laser cavities can provide information about grating strength, grating uniformity as well as the order of the operating longitudinal mode. Theoretical modells can also be confirmed.Intensity measurements by scanning the side-emission from a 980-pumped DFB Er- fiber laser have been demonstrated previously [1]. In this paper we demonstrate an alternative simple method which can be used also with 1480-pumping. The technique is applied to characterize symmetric and asymmetric DFB-lasers for the first time.

Simulations made of various non-uniform DFB-structures shows that a phase perturbation added to the laser structure will result in laser wavelength shift $\Delta\lambda$ that is proportional to the geometrical mean $\sqrt{(I_r I_l)}$ of the right [I_r] and left [I_l] travelling intensities at the perturbation point. Laser intensity distributions can therefore be determined by scanning a phase perturbation along the cavity and measuring the resulting wavelength shift.

In our experiment the radiation from a halogen lamp was focused onto a small spot on a DFB fiber laser, causing a heat-induced phase-shift. The resulting wavelength shift was read out using a scanning Fabry-Perot interferometer. Er/Yb fiber [2] was used for the lasers, which were operating in the 1550-band and pumped with 100mW at 1480nm from one end.

Figure 1 shows results for one symmetric and one asymmetric 40mm DFB laser, both lasing in their fundamental longitudinal modes. In the asymmetric device the Bragg phase-shift was offset by -5mm from the center. The total output powers from the symmetric and asymmetric devices were 470μW and 30μW, respectively, with left to right output power ratios of 1:1 and 600:1 (±10%). The low output from the asymmetric device can be attributed to a non-optimimum total grating strength [3] and should be straightforward to improve.

It is known that the fundamental mode intensity in a DFB-laser will have a maximum at the phase-shift position. Further, it can be shown that the slopes of the measured sensitivity curves [$\delta\log(\Delta\lambda)/\delta z$] are proportional to the grating strength κ. Therefore, both phase-shift positions and grating strength can be determined from the measurements in Figure 1.

The solid lines in Figure 1 show theoretical values for the wavelength shift [$\Delta\lambda=\delta\lambda/\delta\phi\cdot\Delta\phi$] caused by a locally-induced phase-shift of $\Delta\phi$=0.53rad in the symmetric and asymmetric geometries, assuming uniform DFBs with κ=230m^{-1}. The deviations between the measured and calculated sensitivities at the phase-shift positions can be attributed to the 2mm size of the heating spot used.

Figure 2 shows the measured heating response for a L=60mm DFB. The dip at the center indicates that the laser is not operating in its fundamental mode. This may be due to phase-errors in the grating period, combined with a relatively high κL-value of about 14. For comparison, simulated sensitivities for the first two higher order modes of a uniform DFB-structure, assuming κ=230m^{-1} and $\Delta\phi$=0.28rad, are also shown. The 1st and 2nd order modes can be qualitatively distinguished by the absence and presence, respectively, of a local intensity maximum at the phase-shift position. The characterized laser is therefore shown to operate in its 1st order longitudinal mode.

In conclusion we have presented a simple technique for measurement of power distributions along phase-shifted DFB-lasers. This is used to locate the position of the built-in phase-shift and to determine the grating strength (Figure 1), as well as to determine the order of the operating longitudinal mode (Figures 1 and 2). We have also demonstrated, for the first time to our knowledge, directional fiber laser output by use of a true asymmetric phase-shifted DFB-structure [4].

References:

[1] W. H. Loh, B. N. Samson, J. P. de Sandro, "Intensity profile in a distributed feedback fibre laser characterised by a green fluorescence scanning technique", Appl. Phys, Lett, Vol. 69, pp, 3773-5, 1996.

[2] L. Dong, W. H. Loh, J. E. Caplen, J. D. Minelly and L. Reekie, "Efficient single-frequency fiber-lasers with novel photosensitive Er/Yb optical fibers", Opt. Lett., Vol. 22, pp. 694-6, 1997.

[3] V. C. Lauridsen, T. Søndergaard, P. Varming and J. H. Povlsen, "Design of Distributed Feedback Fibre Lasers", ECOC 97 Proceedings, Vol. 3, paper WE1C, pp. 39-42, 1997.

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Figure captions:

Figure 1. Circular dots and triangles: Heat-induced wavelength shifts measured for two 40mm DFB's with the Bragg phase-shift at the center and at -5mm, respectively. Lines: Theoretical fits to measurements.

Figure 2. Circular dots: Heat-induced wavelength shifts measured for a 60mm DFB. Lines: Theoretical phase-shift sensitivities for the first and second higher order longitudinal modes of a uniform DFB-structure.

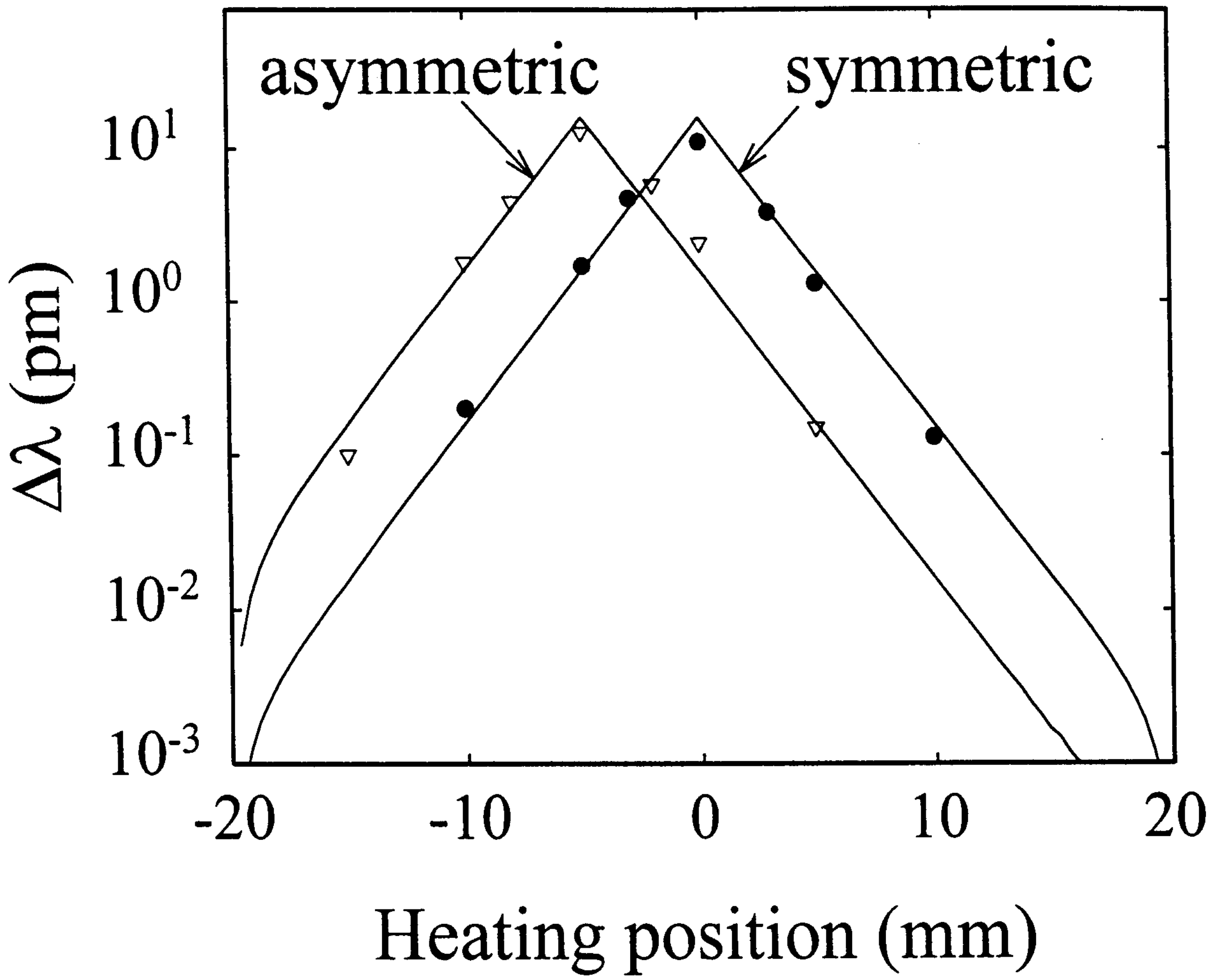

Figure 1. E. Rønnekleiv, "Characterisation of Intensity Distributions ..."

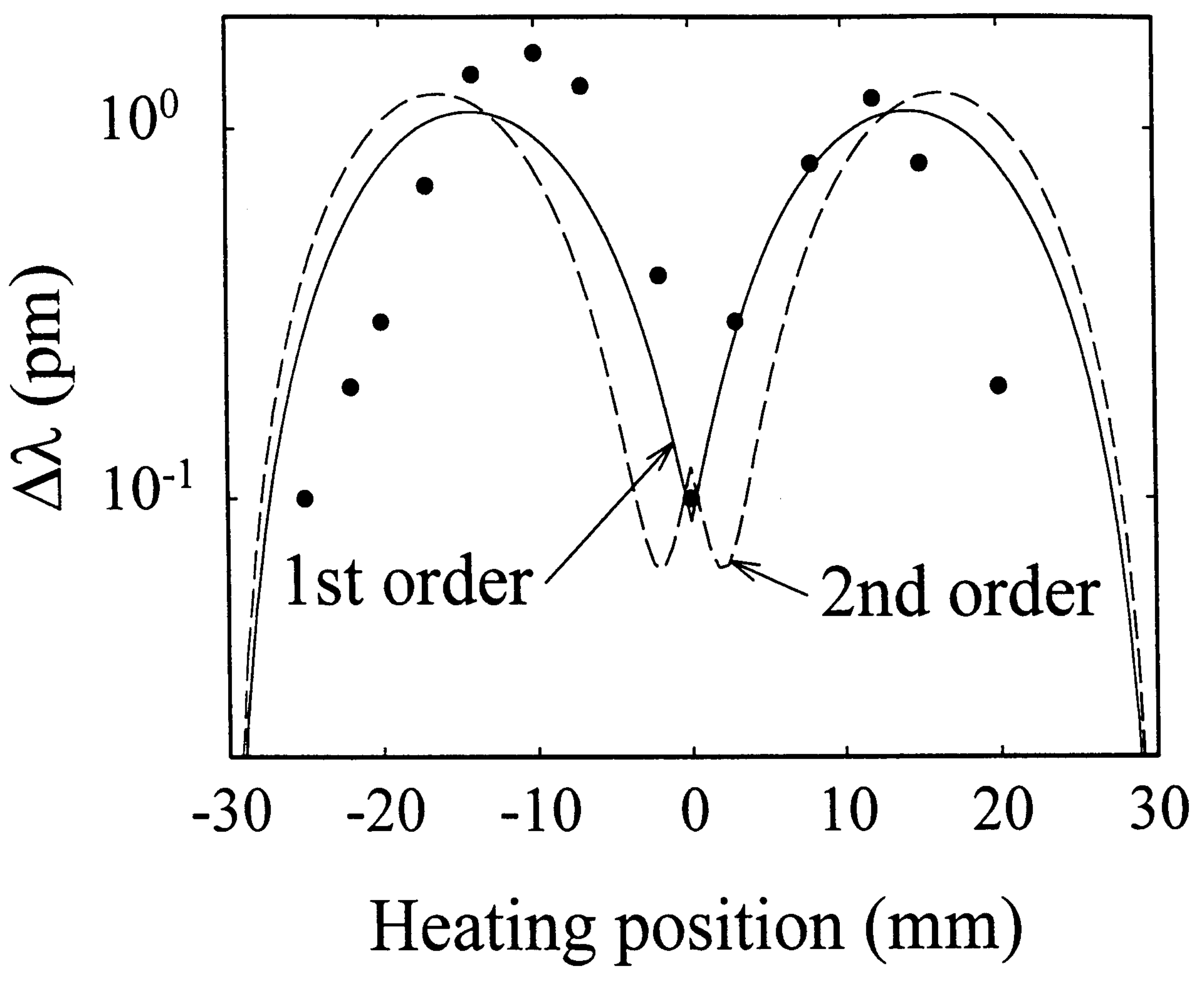

Figure 2. E. Rønneklev, "Characterisation of Intensity Distributions ...".