Theoretical Modelling of Photon-Photon Resonance on Active Multimode Interferometer Laser Diode

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A lot of attempts have been done to obtain a high modulation speed by utilizing photon-photon resonance (PPR) effect [1, 2]. Recently, PPR on active-MMI LD has been observed [2], however, explanation and modeling of PPR on active-MMI LD was still not sufficient. Asymmetric active-MMI laser diode is a considerable candidate to obtain higher PPR effect on the frequency response [4]. The prerequisite of PPR is to have two closely placed modes simultaneously. On active-MMI LD, different modes excite and interference with each other. Consequently, at the output port the overlap of different modes actually leads to the PPR phenomenon in active-MMI LD. However, traditional analysis of active-MMI LD and small signal transfer function does not include the PPR phenomenon into active-MMI LD quite well. By treating the longitudinal confinement factor as a dynamic variable, a modified rate equation model has been developed to include the PPR peak on active-MMI LD [3, 4]:

$$H(\omega) = \frac{\eta_i}{eV}\frac{\gamma_{PN}}{\Delta} + \frac{1}{I_1}\int_0^T \frac{d\Gamma_z}{dt}\frac{(\gamma_{NN} + j\omega)(N_P v_g g + R'_{sp})\Gamma_{xy}}{\Delta e^{j\omega t}}\,dt$$

The device we designed emits main mode at wavelength of 1555.95 nm. Wavelength difference Δλ of the lasing and PPR mode is 0.12 nm. Inset of Fig. 1 shows the magnified peak near main lasing mode. By using equation (1), calculated small signal frequency response together with the experimental results are shown in Fig. 2. Calculated CPR and PPR peak positions, at about 5.7 GHz and 15 GHz, are close to such positions in experimental data. To obtain a 3 dB modulation bandwidth of more than 40 Gbps, PPR peak should be placed at more than 35 GHz, which corresponds to a wavelength difference of 0.3 nm. To attain this, one possible solution is to design the device as follows: Keep the total length fixed as 425 μm to increase the resonance cavity length difference, while a wider MMI width of 9 μm to enhance photon density in the modulation section.

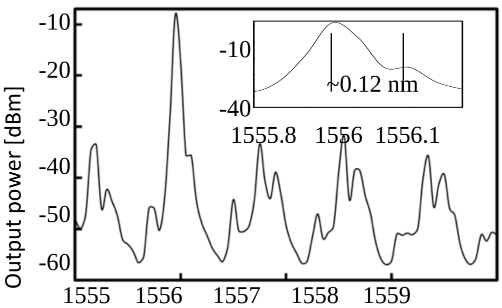

Fig. 1. Optical spectrum

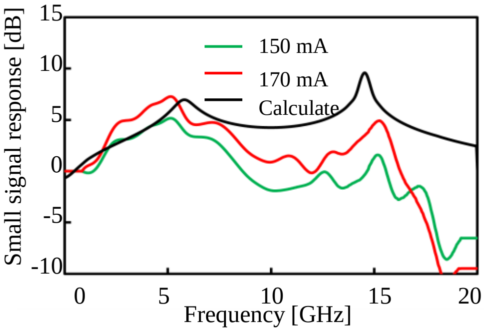

Fig. 2. Small signal frequency response

Reference :

[1] P. Bardella et al., IEEE JSTQE, **19**, 1077, 2013
[2] M. N. Uddin et al., ECIO-MOC, Th4aR7, 2014
[3] A. Laakso et al., Opt Quant Electron, **42**,785, 2011
[4] B. Hong et al., MOC, H66, 2015