論文の内容の要旨

論文題目　Monolithically Integrated DFB Laser Array by MOVPE Selective Area Growth for Coarse WDM Systems
（選択 MOVPE によるモノリシック集積化低密度波長分割多重 DFB レーザーアレイに関する研究

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Abstract

In long-haul telecommunication systems, Dense Wavelength Division Multiplexing (DWDM) has been deployed in order to increase the amount of information carried over a single fiber. In shorter metro and access networks, single laser/detector transceivers are used to meet cost, size, and performance requirements. Growth of high-bandwidth, integrated services such as Fiber-To-The-Home and Gigabit Ethernet fuels the demand for bandwidth growths in these shorter distance markets. Coarse wavelength division multiplexing (CWDM) systems have been developed to increase fiber bandwidth in the access and metro networks at significantly lower cost compared to metro DWDM systems. In CWDM systems, multiple optical channels separated by a wide spacing of 20nm are aggregated to a single fiber. Due to their wide wavelength tolerance, single CWDM laser transmitters and optical filters have higher manufacturing yield, which drives down the cost of these CWDM systems.

For CWDM systems to be cost effective in the metro and access networks, it is important to reduce the per-wavelength component costs. In a typical CWDM system, four or eight CWDM channels generated from individual DFB lasers are multiplexed into a single fiber. Hybrid integration of these individual laser components requires high-precision optical alignment, which increases system cost/size. Monolithic integration of several DFB lasers on a single InP chip eliminates packaging expenses by removing time-consuming and error-prone processes required to assemble the package. On the other hand, monolithic integration introduces design and processing complexities, which translates into higher cost. A successful integration strategy, however, must strike the right balance between packaging gains and processing losses.

In particular, the optical alignment process alone is one of the top cost drivers in device assembly/packaging. In CWDM systems, it is necessary to combine several optical channels with different wavelengths into a single mode fiber at each transmitter site for signal transmission. In the integrated device fabricated in this study, outputs from four lasers with different wavelengths are combined on a single chip before coupled into a single mode fiber. Such integration scheme, not only simplifies the optical alignment since only a single optical fiber is used, but also reduces the packaging cost per channel since a single optical pigtail including an optical isolator is shared by all the channels.

In a monolithically integrated CWDM laser array, four or eight distributed feedback (DFB) lasers with 20nm channel spacing are integrated on a single InP chip. However, efficient single mode operation of the DFB laser require the wavelength difference (or detuning) between the material gain peak, determined by the composition of the grown active material, and the Bragg wavelength, determined by the grating period, to be within 20nm. In the conventional metal organic vapor phase epitaxy (MOVPE) growth method, only a single material composition is grown on an InP substrate; hence monolithic integration of more than three CWDM DFB lasers is not feasible since at least one of the DFB lasers would have a detuning larger than 20nm. In this study, wide stripe selective area MOVPE is used to form different active material compositions, with material gain peaks separated by 20nm, on different regions of the InP substrate. Furthermore, using the electron-beam lithography system different grating periods can be formed on different selective area grown regions, therefore precise control of the wavelength detuning can be realized. Using the above method, four-channel monolithically integrated CWDM DFB laser arrays with lasing wavelengths around 1530nm, 1550nm, 1570nm, and 1590nm have been realized. In order to combine the laser outputs on a single chip, an integrated optical combiner, in the form of a multi-mode interference (MMI) coupler, is used. To the best of our knowledge, this is the first work on the monolithic integration of a multi-channel CWDM DFB laser array with an optical combiner. In the near future, we believe that the device under study is a promising candidate for high-bandwidth applications in metropolitan networks, such as 100Gbit/s Ethernet systems.