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DOCTOR DISSERTATION OUTLINE

**博士　論文要約**

# Slow-light Bragg Reflector Waveguide-based Functional Devices for Use in Next-generation Optical Networks

by

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This study focuses on the design, fabrication, and characterization of novel photonic functional devices using a slow-light Bragg reflector waveguide. Although a Bragg reflector waveguide was firstly proposed in 1970s', the slow-light effect was a recent research topic. Slow-light mode can be excited and propagates inside the Bragg reflector waveguide with a low group velocity. As a result, the interaction between the light and material is largely enhanced. Also, the slow-light shows large waveguide dispersion. Utilizing these special properties, it is possible to make breakthroughs over the bottlenecks of current photonic technologies. Especially, the author paid attentions on designing devices which are capable for use in next-generation optical communication networks and interconnection systems. The device sizes, operating performances, and power consumptions are key evaluating criterions. Main achievements of this study are summarized in the following paragraphs:

Firstly, the author deeply analyzed the basic working principles of a slow-light inside the Bragg reflector waveguide, and pointed out the possibilities in realizing some typically desired functionalities during photonic technology development. It is found that the low group velocity (or large group index) and large dispersion are especially of interest and significance.

The first outcome is a small-size electro-absorption optical modulator. Due to the slow light propagation, stronger modulation is possible at a very short distance. The modulator can be made small hence the device parasitic capacitance is largely reduced. The author carried out numerical simulations and succeeded in fabricating such a device. A 20 μm-long modulator showed a modulation bandwidth over 20 GHz, which can be further increased by continuously downsizing or other techniques such as impedance matching. The device provides a large extinction ratio over 10 dB even with a low driving voltage below 1 V. As a result, extremely low power consumption is achievable, which is estimated to be even lower than 10 fJ/bit for dynamic dissipation. The outstanding properties reveal the proposed device's capabilities for use as an ultra-fast and low-power consumption external modulator in optical interconnection systems.

Secondly, the author proposed and demonstrated a revolutionary non-mechanical beam deflector based on the slow-light waveguide structure. This design is of high novelty and breaks the bottlenecks in other approaches that limit the application developments. To summarize the highlighting characteristics of this technology, it provides large steering range over 60° and an ultra-narrow beam divergence angle in the order of 0.01°. Experimentally, a number of resolution-points, which is the key of merits for those beam-steering technologies, exceeds 1,000 on a millimeter-order long device. It is the highest number for any non-mechanical steering technologies reported ever. It is noted that the technology is flexible for any wavelengths-band thus various applications are expected. Preliminary experiments were also carried and revealed the possibilities in polarization-independent steering, in electro-thermal steering, and on-chip electrical steering.

Inspired by the excellent property of the Bragg reflector waveguide beam deflector, the author designed a novel wavelength selective switch (WSS) for use in reconfigurable optical add/drop multiplexing (ROADM) systems. The WSS setup is simple in the optical configuration and very compact comparing with other approaches. It can provide large numbers of switching ports and wavelength channels at the same time. A prototype device, which gives out 182 output-ports and supports 60 wavelength-channels, was demonstrated in fabrication and functioning. After improvements and optimizations, this WSS can be soon adapted in current optical networks and keep playing an important role in the future.

Last but not least, the author suggested the future prospects of the slow-light Bragg reflector waveguide-based technologies. There are strong desires for making faster optical modulators, for realizing higher quality beam-steering, for making more intelligent optical switches in ROADM node, etc. Some theoretical analysis and designs were given, which all show the great potentials and significances in the future of this study. The author wishes and believes that the outcomes of this study will become key building blocks in the next-generation optical communication networks and interconnection systems.