Chapter 5

Conclusions

5.1 Summary for the Dissertation

In previous chapters, the applications of fiber laser in communication systems and sensor networks have been explored. The wavelength-tunable pulses generation using a linear-cavity fiber laser, the actively mode-locked fiber ring laser with a wavelength-tunable range over 46 nm, and the WDM light source using an EDFA and a FPLD have been investigated and studied. In addition, the self-healing ring architecture, the hybrid star-ring architecture, and the star-bus-ring architecture for fiber-laser-based sensor networks also have been proposed and demonstrated. Moreover, the IWDM sensor system using a tunable multiport fiber ring laser, a long-distance sensor system using a linear-cavity fiber Raman laser scheme, and a remote sensor system using a hybrid amplifier have been analyzed and presented. These investigations and demonstrations will be useful in the fields of communication systems and sensor networks. The important results and contributions achieved in this dissertation are briefly summarized blew.

5.1.1 Wavelength Tunable Laser using FPLD

We experimentally investigate and demonstrate the wavelength tunable lasers using FPLDs. The contributions and results include:

(a) A wavelength-tunable mode-locked linear-cavity fiber laser is demonstrated using a FPLD. By adding a tunable bandpass filter within the linear cavity, the wavelength-tunable fiber laser is easy to be tuned dynamically. This linear-cavity fiber laser output exhibit a good performance having the optical SMSR over 30 dB and the wavelength-tuning range up to 27 nm. Furthermore, this fiber laser generates pulses with pulsewidth between 53.2 ps and 80.4 ps at a repetition frequency of 908.39 MHz.

(b) An actively mode-locked fiber ring laser is demonstrated. An EDWA is used as an optical amplifier, and a FPLD is used as a modulator in the fiber laser. Moreover, we add a variable optical delay line to control the cavity length for maintaining a constant repetition frequency and pulsewidth at different wavelengths. The optical side-mode-suppression-ratio is better than 33.5 dB over the wavelength-tunable range of 46 nm.

(c) We propose and experimentally demonstrate a system for the generation of wavelength-tunable pulses using a gain-switched FPLD and an EDFA. The EDFA is used as both an external-injection light source and an amplifier for the FPLD. The wavelength tuning is achieved by a tunable filter. The optical side-mode-suppression-ratio of this system is better than 32 dB over the wavelength-tunable range of 34.5 nm. Moreover, the repetition frequency is 2000 MHz, and the pulsewidth is between 49.3 ps and 65.3 ps. The whole system is simple and can be easily constructed.

5.1.2 Fiber-laser-based Sensor Network with Self-Healing Function

We propose and experimentally demonstrate the fiber-laser-based sensor networks with self-healing functions. The contributions and results include:

(a) We present a fiber-laser-based sensor network with self-healing function and demonstrate its effectiveness. The network survivability and capacity for a multipoint sensor system are enhanced by adding switches in a self-healing ring architecture. The fiber laser adopted in this system is a linear-cavity FBG laser leading to the signal-to-noise ratio over 52 dB for the sensor network. The network survivability of a 10 point FBG sensor is experimentally examined. The experimental results show that the proposed system can facilitate reliable sensing network for a large-scale and multipoint smart structure.

(b) We present a hybrid star-ring architecture for a highly reliable FBG sensor system and demonstrate its effectiveness. The main trunk of the proposed sensor network is star topology and the sensing branches comprise a series of concatenated ring subnets. The weakness in reliability of the star network is overcome by the ring subnets with a self-healing function based on the reconfigurable optical switches between each subnet. To enhance the signal-to-noise ratio of the sensor system, we adopt a linear-cavity FBG laser scheme to construct our proposed hybrid star-ring architecture. The network survivability of a 10 point FBG sensor is experimentally examined. It is shown that the proposed FBG sensor system can increase the reliability of a sensing network.

(c) A star-bus-ring architecture for FBG sensors is proposed and demonstrated. The FBG survivability and capacity of a multipoint sensor system are enhanced by adding remote nodes and 2x2 optical switches to the star-bus-ring architecture. Moreover, to enhance the signal-to-noise ratio of the sensor system, we adopt a FBG laser scheme in constructing our proposed star-bus-ring architecture. Finally, the network survivability is experimentally verified.

5.1.3 Large-Scale Sensor Network using Fiber laser Scheme

We propose and experimentally demonstrate the large-scale sensor networks using fiber laser schemes. The contributions and results include:

(a) We propose an IWDM-FBG sensor system using a tunable multiport fiber ring laser. The different output powers of a multiport fiber laser are used to address the information reflected from the sensing FBGs, even if the Bragg wavelengths of the FBGs connected at different laser output ports are identical. We describe the operation principle and experimentally demonstrate a three-port fiber sensor. For the IWDM technique, our proposed fiber grating sensor system can enhance the sensing capacity, signal-to-noise ratio, and sensing resolution.

(b) We propose a novel FBG sensor system using a linear-cavity fiber laser scheme with a distributed Raman amplifier as a gain medium. The inhomogeneous broadening property of the distributed Raman amplifier is used for multiwavelength operation. The experiment shows that such a linear-cavity fiber Raman laser can provide a stable output with an optical signal-to-noise ratio over 50 dB even if the FBG is located at a 25 km remote sensing position. The feature of our proposed fiber laser can facilitate a long-distant or a large-scale fiber sensor system and can be easily extended for multipoint sensing applications.

(c) A novel FBG sensor system using a fiber ring laser with a hybrid amplifier is proposed and demonstrated. The hybrid amplifier comprises an EDWA and a SOA. Experimental results demonstrate that the hybrid amplifier has a high amplifier spontaneous emission power and gain spectrum. Moreover, this novel fiber ring laser provides a stable multiwavelength output with an optical signal-to-noise ratio over 50 dB. The primary feature of the proposed fiber laser is that it facilitates a long-distance or a large-scale sensor system.

5.2 Suggestions for Future Work

Further researches that could be useful for fiber laser applications in communication systems and sensor networks are described in the following:

(a) In recent years, OCDMA has raised a lot of interest for the development of access networks. Multiwavelength and wavelength-tunable pulse lasers are very important for OCDMA systems. In the future, it is needed to investigate multiwavelength mode-locked fiber lasers for OCDMA systems.

(b) There have been several approaches to provide a low-cost light source for WDM passive optical networks. In Section 2.3, we also proposed a low-cost WDM source using an EDFA and a FPLD. We can study the performance of low-cost WDM source in the WDM passive optical networks.

(c) Three self-healing architectures for fiber-laser-based sensor networks are proposed in Chapter 3. The design of self-healing functions is must considered in future large-scale sensor networks. However, the network reliability is proportional to the cost of protected devices. The low-cost and high reliable sensor networks are needed to study.

(d) The multiplexing capability is one of the features of a FBG sensor system. To improve the capacity of sensor network is the import research topic in sensor systems. We can combine the IWDM with other multiplexing techniques to increase the capacity of sensor network in the future.