論文の内容の要旨

論文題目　Nano-carbon-based Wavelength Conversion and Fiber Lasers at Novel Mode-Locked Regimes

（ナノカーボンを用いた波長変換および新規モード同期領域光ファイバレー ザ）

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Carbon nanotubes (CNT) and graphene have attracted much attention in recent years; their exceptional mechanical, electronic, chemical and optical properties lead to believe that these materials will be at the cornerstone of scientific research in the upcoming years. Additionally, CNT and graphene behave more promising optical properties, they present a highly nonlinear saturable optical absorption. This property was first successfully applied to noise suppression and is an ideal saturable absorber for the fabrication of mode-locked lasers. Some of the key advantages over competing saturable absorbers are its simple fabrication, fast recovery time, high damage threshold and wide operating bandwidth. In addition to saturable absorption, CNT and graphene presents high third order susceptibility ($\chi 3$). Third order (cubic) susceptibility is responsible for processes such as third harmonic generation, optical Kerr effect, self-focusing and phase conjugation. As a result, third order nonlinear materials can be considered for optical functions such as optical switching, routing and wavelength conversion, and thus have great research and commercial interest. In this thesis, we have been engaged in the research and development of optical devices utilizing optical fibers that can be used in optical networks, the researches being conducted here are as follows: CNT and Graphene based mode-locked fiber laser; the nonlinear photonic properties of graphene and CNT based wavelength conversion photonic devices.

This thesis starts from the introductions of fundamentals, band structures, and linear and nonlinear optical properties, of first graphene and then CNT, and then moves onto their nonlinear photonic applications. The most important thing is how

to apply CNT/graphene to optical fiber system for real applications, therefore different fabrication methods of graphene/CNT based nonlinear devices: optical deposition method for graphene and CNTs, mechanical exfoliation for graphene and CNTs-polymer coated tapered fiber are suggested.

The applications of passively mode locked fiber laser in ring cavity and figure of eight laser configuration are demonstrated using graphene and CNT based nonlinear devices as saturable absorbers. Different laser configurations including ring cavity and figure of eight cavity, and different pulse operating regimes such as soliton and dissipative soliton are conducted. For further applications of commercial products, the polarization maintaining type ring cavity laser and figure of eight fiber laser are also experimentally suggested. In addition, theoretical analysises are proposed for different fiber lasers.

The other applications of graphene and CNT based nonlinear devices are exploited for four wave mixing (FWM) based wavelength conversion. Three demonstrations of generating FWM in different CNT/graphene based nonlinear devices, including the optically deposited graphene/CNT onto fiber ferrules, mechanically exfoliated graphene and CNT-coated tapered fiber are experimentally proposed. Because of longer interaction length, higher nonlinearity and higher damage threshold, the device of CNT-polymer composite coated tapered fiber is regarded as the best candidate for wavelength conversion applications in our cases.

We believe CNT and graphene will continue their roles of cornerstone for scientific research in the upcoming years due to their exceptional mechanical, electronic, chemical and optical properties.