中文題目:

利用摻鐿光纖雷射產生似噪音脈衝及其應用在超連續光譜產生和光學同調斷層掃描之研究

英文題目:

Fiber-laser-generated noise-like pulses and their applications to supercontinuum generation and optical coherence tomography

中文摘要:

似噪音脈衝於摻鉺光纖雷射第一次被發現至今，這種特殊之脈衝已吸引眾多研究者的興趣。在本篇論文中，我們報導由摻鐿光纖雷射產生中、高能量似噪音脈衝的研究成果。似噪音脈衝之物理機制及其與一般鎖模脈衝之區別也將予以討論。利用似噪音脈衝雷射作為激發光源可產生超連續光譜。同時，我們利用似噪音脈衝產生之超連續光譜被實際應用於架設一光學同調斷層掃描系統(optical coherence tomography, 簡稱 OCT)。

論文第一部分將從光纖雷射架構本身開始介紹。似噪音脈衝光纖雷射是由非線性極化演化(nonlinear polarization evolution)之環形共振腔產生，本論文將展示並分析兩種雷射之架構：映射色散光纖雷射(dispersion-mapped fiber laser)以及全正色散光纖雷射(all-normal dispersion fiber laser)，兩套雷射系統皆能產生似噪音脈衝(noise-like pulse)及鎖模脈衝(mode-locked pulse)。我們對似噪音脈衝之特性作全面性的探討。理論分析主要是藉由非線性薛丁格方程式模擬光脈衝在光纖內之傳播，結果與實驗量測相當吻合。

在論文的第二部分中，我們探討如何利用似噪音脈衝產生超連續光譜。實驗結果顯示，似噪音脈衝之獨特脈衝性質使其使用一般的單模光纖即可有效地激發產生超連續光譜。我們顯示雷射光源波長(~1 μm)位於正色散區(光纖零色散值為 ~ 1.3 μm)仍能有效地產生超連續光譜。我們同時展示了用多種不同的單模光纖產生超連續光譜與光纖特性之關聯。特殊光纖如光子晶體光纖產生之超連續光譜也將於文中闡述。

最後，我們將光源實際應用於光學同調斷層掃描，其為現今生物學以及醫學上一種非常重要的研究工具。似噪音脈衝之光纖雷射由於其優越的低同調特性，應用於 OCT 極具潛力。我們之光源成功地被應用於自由空間的時域 OCT 中，縱向解析度高達 2.3 μm。高解析度之光纖式頻域 OCT 生物影像的初步結果也呈現在此論文中。實驗結果顯示由似噪脈衝在單模光纖中產生的超連續光做為光學斷層掃描的光源極具優勢。

英文摘要:

Since the first demonstration of noise-like-pulse (NLP) operation in the ring cavity of an Er: doped fiber oscillator, there has been tremendous interests in this special regime of pulsed lasers. In this dissertation, we describe our work on generation and amplification of medium- and high-energy noise-like pulses with Yb-doped fibers. We also demonstrate supercontinuum (SC) generation techniques where

NLPs serve as the pump. Theoretical aspects as well as discussions about physical mechanisms which make NLPs distinguishable from regular mode-locked pulses are also discussed. SC pumped by NLPs has been employed successfully in optical coherence tomography (OCT) systems. The advantages of such approach as well as the promising features of NLPs for such applications are presented.

Beginning with a brief description of the cavity configurations that are typically used in fiber laser oscillators, we then focus our attention on ring-type cavities where nonlinear polarization evolution (NPE) is involved in pulsed operation. We show that both regular Gaussian pulses and noise-like pulses can be achieved in the same cavity by choosing proper cavity components and adjustment. We analyze and compare two popular cavity configurations: dispersion mapped cavity and all-normal-dispersion (ANDi) one. Simulation results based on coupled nonlinear Schrodinger equations are supported by experimental measurements.

Second part of the dissertation is about supercontinuum (SC) generation. Here we analyze the possibilities of efficient SC generation by using standard silica fibers. It is shown that unique features of NLPs make them very useful for such purpose. That is, the central wavelength of the pump and zero-dispersion wavelength (ZDW) of SC generation media is not critical. We show that even if the pump wavelength is deep in the normal dispersion regime (for example, ~1 $\mu$m where ZDW=1.33 $\mu$m), SC can be efficiently generated. Simulations and experimental results of SC generation by NLPs using different single-mode fibers are presented. We discuss the optimal selection of fiber types and other characteristics to generate flat SC in spectral region above 1 $\mu$m. The pros and cons of using specialty fibers such as photonic crystal fibers pumped by NLPs will also be elaborated.

In the third part of the dissertation we consider the application of noise-like pulses for selected applications. The SC spectrum scheme is flat with a bandwidth of 365 nm centered at 1320 nm. The light source is successfully employed in a time-domain OCT, achieving an axial resolution of 2.3 $\mu$m. High resolution fiber-based spectral-domain OCT imaging of bio-tissue (onion skin), comparable to that obtained using a commercial swept source, is also demonstrated.