利用摻鐿光纖啁啾放大器架設高功率飛秒雷射系統之研究

High-power Femtosecond Pulse Generation in a Chirped-Pulse Amplified Ytterbium-Doped Fiber Laser System

中文摘要

高功率超快光纖放大器，常伴隨著嚴重的非線性效應，這些非線性效應將會大幅降低光纖放大器輸出光特性。本論文，我們設計及架設一台飛秒級高功率摻鐿光纖放大器之啁啾脈衝放大系統(波長=1064 奈米)。本實驗採用正色散被動鎖模光纖雷射，輸出光源頻寬為 9 奈米，其對應轉換極限脈衝寬度為 185 飛秒，然其輸出光脈衝為 11.7 皮秒，因此其輸出種子雷射為高啁啾脈衝光。託其種子雷射之特性，其輸出光脈衝已展延 60 倍，故在本實驗中無需使用脈衝展延器。其啁啾脈衝經 7 公尺的摻鐿光纖放大後，平均功率可達 1 瓦，脈衝寬度為 20 皮秒(重覆率~15 MHz)。本系統輸出光強受限於光纖放大器之非線效應，特別是受激拉曼輻射最嚴重，將導致訊號光強增益降低。利用光柵將之脈衝壓縮，可產生尖峰功率達 25 千瓦且脈衝寬度約為 900 飛秒，其壓縮損耗約為 50%。最後，我們利用類型一臨界相位匹配三硼酸鋰晶體，產生波長為 532 奈米之二階諧波。當操作在最佳聚焦參數為 1.5 時，其入射壓縮脈衝光在 370 毫瓦平均功率的情形下可得到 88 毫瓦的綠光，同時轉換效率達 23%。此倍頻轉換效率相較先前 10%之皮秒雷射系統尤佳。在未來，本實驗將利用二級纖核直徑為 30 微米的摻鐿光纖放大器亦或於放大器前提升其脈衝展延能力，以達到更進一步的光放大輸出。

Abstract

In this thesis, we demonstrated the chirped pulse amplification (CPA) of a high-power ytterbium-doped fiber amplifier at wavelength of 1064 nm without a stretcher. The all-normal dispersion (ANDi) passively mode-locked fiber laser is used to generate highly chirped seed pulse. Therefore, the pulse stretcher could be optional. The spectrum bandwidth of our ANDi fiber laser is 9 nm which can support 185-fs-width pulses. The actual output pulses width is 11.7 ps. In this case, it is equivalent to -60 times stretching of the seed pulses to reduce the peak power. After amplification, the output signal power can achieve ~1 W with pulse width of 20 picosecond (repetition rate ~ 15 MHz). The output power is basically limited by stimulated Raman scattering (SRS), which reduces the gain of the signal power. After compression by the gratings pair, the output peak power was shown to be 25 kW with a compression ratio ~ 25 (~900 fs). In the meantime, the power loss of the compressor is around 50%. Further, the compressed-pulse was frequency doubled by a type-I critically phase-matched (CPM) Lithium Triborate (LBO) crystal with optimal focal parameter of ξ~ 1.5. With 370 mW of fundamental light, we can generate 88 mW of green output (λ= 532 nm) with conversion efficiency of 23% which is much higher than that achieved with our picosecond laser system (10%). Power scaling is possible but requires introducing second amplification stage with larger mode-field-diameter active fiber or increasing the stretching ratio before the amplification.