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碩 士 論 文

同調控制雙色光激發各向同性介質中的非線性頻率轉換現象

Nonlinear Frequency Conversion by Coherently Controlled Two-Color Excitation of Isotropic Materials

研究生：101022541 蔡淳意(Chun-Yi Tsai)

指導教授：潘犀靈 教授（Prof. Ci-Ling Pan）

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國立清華大學物理所碩士學位論文

學生:蔡淳意

指導教授:潘犀靈 教授

中文摘要

合成同調多色光雷射達到電場波形控制是正積極發展中的同調控制技術，已有相關的理論與實驗研究在探討以雙色光的波形合成對於提高高階諧波產生的轉換效率以及提高截止頻率的作用。相對於在 XUV 波段的高階諧波，在紫外光到近真空紫外光波段的同調光源，對於光譜學、光化學及雷射加工等應用也是十分重要的。本論文內容即在於運用同調雙色光的波形控制與各向同性的原子氣體及固體介質中非線性光學中產生諧波轉換控制的研究。

我們使用 Nd:YAG 雷射的基頻光(1064 nm)及其倍頻光(532 nm)作為同調雙色光源。運用強度及相位控制器來控制這兩道光之間的相對強度及相對相位，就可控制雙色合成光的波形。我們研究了波形控制在與各向同性介質的作用中對於三階諧波產生的影響。

因為在雙色光的三階諧波產生中同時有直接三倍頻($\omega_3=\omega_1+\omega_1+\omega_1$)及四波混頻($\omega_3=\omega_2+\omega_2-\omega_1$)這兩種作用，而此兩種非線性過程產生的三階諧波彼此之間的強度與相位都與驅動作用的雙色光的相對強度及相位有關。我們以這兩種作用下強聚焦的雙色光高斯光束在各向同性介質中的理論架構並進行數值模擬，並比較了以氬氣、氪氣、氙氣與氪氣的混合氣體以及固態的高純度熔融石英玻璃作為非線性介質時諧波產生的轉換效率發現其受同調控制影響。

在實驗方面，我們使用氬氣作為非線性介質，測量了在不同氣體壓力下，雙色光波形控制與三階諧波產生的轉換變化。同調控制實驗結果與模擬結果大致吻合。此表明了我們能以理論及實驗研究雙色光控制諧波的產生，也指出了進一步以多色光產生較高階諧波，並控制其合成的波形的可行性。

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Student: Chun-Yi Tsai Advisor: Prof. Ci-Ling Pan

Master of Science

Department of Physics, National Tsing Hua University, Hsin-chu City, Taiwan

Abstract

Synthesizing coherent multi-color laser field is an emerging technique for coherent control of optical field. Waveform control of two or three color fields can enhance the conversion efficiency and cutoff frequency of high harmonic generation. Comparing to the high harmonic generation in XUV region, the low-order harmonic generation in the ultraviolet to near vacuum ultraviolet region is also important for many applications like spectroscopy, photochemistry, and laser processing. In this thesis, we investigate the effect of waveform control of two-color laser field to the nonlinear frequency conversion process in an isotropic medium

We use the fundamental (1064 nm) and second-harmonic beams (532 nm) of a narrow-band Q-switched Nd:YAG laser for excitation. By using amplitude and phase modulators, we can tune the amplitude and relative phase of incident two-color beams, and synthesize the waveform of incident two-color laser beam. We investigate the coherent control to the generated third harmonic signal by the effect of waveform control.

According to the four-wave mixing process ($\omega_3=\omega_2+\omega_2-\omega_1$) and direct third harmonic generation ($\omega_3=\omega_1+\omega_1+\omega_1$) in the third order nonlinear effect, the relative phase and amplitude of generated third harmonic signal is related to the relative phase and amplitude of two color incident beams. In the theoretical part of this thesis, we perform the simulation of third harmonic generating by using the tight focused two-color Gaussian beam in Argon, Krypton, fused silica, and mixing gas of Krypton and Argon.

In the experimental part, we present the case of pressure-dependent two-color third harmonic generation in Argon. The simulation result is in good agreement with experiments. This result also illustrates the higher harmonic generated by waveform controlling the multi-color laser field is possible.