Nonlinear Frequency Conversion by Coherently Controlled Three-Color Excitation of Inert Gases

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ABSTRACT

In recent year, the coherent control technology is widely used in high-order harmonic generation for many researchers. By controlling two- or three- color waveform synthesis, it will enhance the efficiency of high harmonic generation and cut of frequency. Compared with the high-order harmonic in XUV, the coherent light source in UV and VUV are very important to spectroscopy、photochemistry and laser processing…etc.

In this thesis, we study harmonic generation by three color waveform synthesis in inert gas system. The three-color coherent light are emitted from Nd:YAG laser with fundamental light of 1064 nm (ω_1), second harmonic of 532 nm (ω_2) and third harmonic of 355 nm (ω_3). In order to control the synthesized waveform, we manipulated relative phase and amplitude among these three-color via the amplitude and phase modulator.

In the third-order nonlinear process, the interaction between three-color beam and inert gases can be used to fourth to ninth harmonics of the laser fundamental output. For fourth harmonic generation, there are three kinds of four-wave mixing processes ($\omega_n=\omega_i+\omega_j+\omega_k$、$\omega_n=\omega_i+\omega_j-\omega_k$). For fifth harmonic generation, there are three possible processes: $\omega_5=\omega_1+\omega_2+\omega_2$ 、 $\omega_5=\omega_1+\omega_1+\omega_3$ 、 $\omega_5=\omega_3+\omega_3-\omega_1$. For sixth and seventh harmonic, there are two kinds of four-wave mixing processes. For eighth and ninth harmonic generation, there is one four-wave mixing process possible.

We also assume to simulated Fifth harmonic generation by three-color tightly-focused Gaussian beam. By manipulating the relative phase and amplitude of three-color laser field, we can observe the enhancement of conversion efficiency of fifth harmonic generation in Argon gas. Initial experimental results are in good agreement with theoretical predictions.

We successfully demonstrated coherent control of fifth harmonic generation by controlling three-color laser field. Thus, those results shows the feasibility of high-order harmonic generation by using multi-color coherently waveform controlled.

利用同調控制三色光激發惰性氣體中的非線性頻率轉換現象

國立清華大學物理所碩士學位論文
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中文摘要

合成同調多色光雷射達到電場波形控制是正發展中的同調控制技術,已有相關的理論與實驗在探討以雙色光或三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。相較於在 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亦是十分重要的。本論文即在於運用同調三色光的波形控制與惰性原子氣體之間於非線性光學中諧波轉換控制之研究。

我們使用窄頻 Q-開關 Nd:YAG 雷射的基頻光(1064 nm)、及其共線產生之倍頻光(532 nm)和三倍頻光(355 nm)作為同調三色光源。運用強度及相位控制器來調制這三道光之間的相對強度與相對相位，藉此控制三色合成光的波形。我們研究了控制下的電場波形在與惰性氣體介質的作用中對於較產生高階諧波的影響。在三色光與惰性氣體的三階非線性作用中，可產生第四到第九階的較高階諧波。其中第四與第五階諧波各有三種包含了和頻($\omega_n = \omega_i + \omega_j + \omega_k$)及四波混頻($\omega_n = \omega_i + \omega_j - \omega_k$)的產生過程。第六與第七階諧波各有兩種和頻的產生過程。第八與第九階諧波則各只有一個和頻的產生過程。在模擬部份，我們以強聚焦的三色光高斯光束來模擬產生五階諧波，並深入探討這些不同產生過程彼此之間的強度與相位和驅動作用的三色光的相對強度及相位之間的關係。我們模擬了以氬氣作為非線性介質時各階諧波產生的轉換效率。

在實驗方面，我們使用氬氣作為非線性介質，進行了三色光波形控制對第五階諧波產生的初步研究。實驗結果與模擬結果大致吻合。此結果表明了能以三色光控制較高階諧波的產生，同時驗證了以多色光產生更高階諧波，並控制其合成波形的可行性。