ANALYSIS OF OPTIMUM CONDITIONS FOR THIRD ORDER HARMONIC GENERATION

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In this article we present an experimental analysis of the third order harmonic generation in neon, with high intensity laser pulses. We determined several laser and gas parameters (i.e. focusing parameters - focus length, power laser, gas pressure) involved in the efficient conversion of a Nd^{3+}:YAG laser radiation to the third frequency. The experimental findings are in good agreement with the experimental results published in literature.

Keywords: third order harmonic generation, conversion efficiency, neon

1. Introduction

In the last years, many theoretical and experimental papers deal with several high-order harmonic generation, which has become a leading research field in nonlinear optics as a way to produce coherent extreme ultraviolet (XUV, 100-10 nm) and soft-X radiation, as well as attosecond pulses [1]-[6].

Several properties of a material change due to the nonlinear effects which occur when the high power laser radiation, characterized by electric field intensities around $10^6 \div 10^7$ V/cm or higher (which are comparable to the atomic electric field), interacts with the material [1]-[3]. The production of vacuum-ultraviolet (VUV, 200-100 nm) and XUV coherent radiation with ultra-short duration through the process of third (THG) and also high harmonic generation (HHG) becomes a current practice [1], [2]. The third harmonic radiation can be used for various applications such as optical lithography and pump-probe experiments.

Third harmonic generation has been developed to characterize the pure electronic third order susceptibility in centro-symmetric materials. No other mechanism but the pure nonresonant electron cloud distortion can respond rapidly enough to produce a nonlinear polarization oscillating at the third harmonic of the incident wave. Therefore even nanosecond laser pulses can be used in the characterization without the problem of competing or interfering mechanisms.

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The third order harmonic pulses are produced by focusing near-infrared laser pulses in different types of materials: gases, liquids, solids, laser-generated plasmas, ablated nanoparticles etc. In isotropic (centro-symmetric) media (e.g. gases), for symmetry reasons only odd harmonics are produced, with efficiencies up to 50%.

The full theory of harmonic generation must include the complete atomic level structure of the target atoms, the nonperturbative interaction of these levels with the intense laser field, the depletion of the neutral atoms due to ionization, the dispersion of the resulting plasma, the geometrical complications resulting from the spatial and the temporal distribution of the field strengths near the focus, and the propagation of the fundamental and the harmonic waves through the perturbed medium. There is no currently available theoretical technique that can handle all of these effects simultaneously. Low-order harmonic generation has usually been described by perturbation theory.

However, the ionization leads to self-induced defocusing of the fundamental laser beam, having a detrimental effect on the HHG process.

Here we present an experimental analysis of third order harmonic generation in neon, determining several laser and gas parameters for the high conversion efficiency, such as focusing parameters: focus length, power laser, gas pressure.

The paper is organized as follows: in Sec. 2 we present the experimental setup and a discussion of the experimental results concerning several parameters in order to obtain the highest conversion efficiency. In Sect. 3 we outline our conclusions concerning the results.

2. Experimental results and discussion

The experimental setup consists of three main parts: the Nd^{3+} : YAG laser operating in the Q-switched regime at $\lambda_p = 1060\,nm$ wavelength, the gas cell containing neon where the third harmonic is generated and the detection system (Fig. 1). Also, we used two filters to select the pump radiation (filter 1, RG 8) and to detect, respectively the third harmonic radiation with $\lambda_3 = 353.3\,nm$ wavelength (filter 2, BG 18).

We used a lens having 10 cm focal length in order to focus the beam into a vacuum cylindrical steel tube having 50 cm length and 3 cm diameter and quartz windows at the edges which is connected to the vacuum pump and the vessel containing neon gas.

The pressure in the vacuum system was in the range of 10^{-3} torr, while the pressure of the neon was of about 4.5 torr in order to obtain the maximum conversion efficiency of THG.

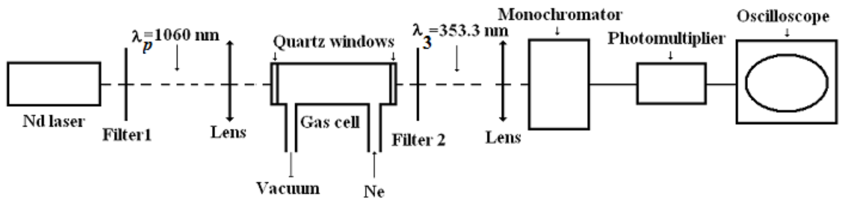

Fig. 1. The experimental setup for THG.

The gas (neon) is released into the chamber with the aid of a jet nozzle, having a diameter of 5 mm and an adjustable length.

We used a monochromator having 0.03 mm entrance slit, a photomultiplier and an oscilloscope (Tectronix 7613) to detect the harmonic emission (Fig. 2).

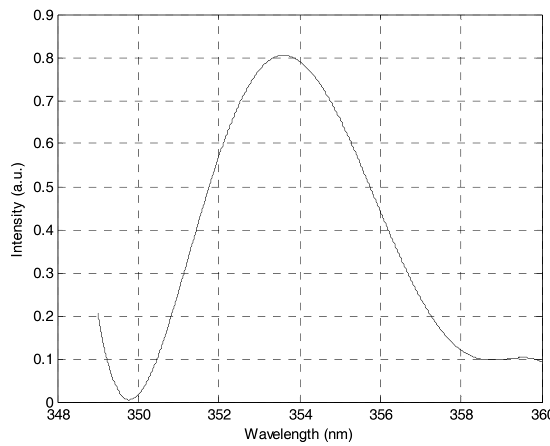

Fig. 2. The spectrum of the third harmonic.

The neon atoms are excited from the fundamental level, $2p^1s$, by absorption of three photons with $\lambda_p = 1060\,nm$, to a virtual energetic level, after which the third harmonic having $\lambda_3 = 353.3\,nm$ wavelength is emitted (Fig. 3).

In the case of 150 kW input pump power of the Nd^{3+}:YAG laser, we obtained about 10^{-6} conversion efficiency of the fundamental radiation into the third harmonic radiation, which is in good agreement with other experimental results published in the literature.

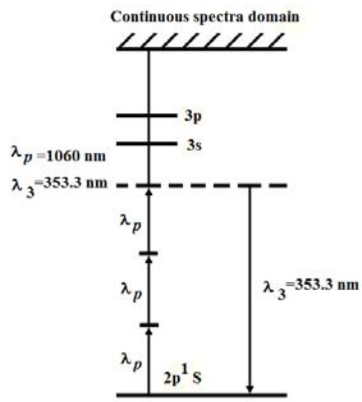

Fig. 3. The scheme of THG.

3. Conclusions

In this article we present an experimental analysis of THG in neon with high intensity laser pulses. We determined several laser and gas parameters (i.e. focusing parameters - focus length, laser power, gas pressure) involved in efficient conversion of a Nd^{3+}:YAG laser radiation to the third harmonic radiation. The experimental results are in good agreement with other experimental results published in the literature.

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R E F E R E N C E S

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