Harmonic Generation in N_2 and Ar by Wave-Mixing

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Abstract : Harmonic generation in gases has been investigated by mixing of fundamental (1064nm) and second harmonic (532nm) of a 100-mJ 35-ps Nd:YAG laser. Even and odd harmonics of fundamental wavelength are generated by wave-mixing. We have investigated in detail harmonic spectrum in Ar and N_2 , up to the 14th harmonics, versus the gas pressure and laser intensity.

1. INTRODUCTION

The phenomenon of the harmonic generation in gaseous media has been studied extensively by many research groups as an alternative method of producing short-wavelength coherent radiation [1]. Harmonic spectrum generated in noble gases by a 30-ps Nd:YAG laser with a peak power of $5 \times 10^{13} \text{ W/cm}^2$ exhibits a plateau and ends up with a sharp cut-off [2]. Plateau extension increases as the laser wavelength increases according to a semi-empirical relation $E_{\text{max}} \approx I_p + 3.2U_p$ (where E_{max} is the maximum harmonic energy, I_p is the ionization potential and U_p its ponderomotive shift). Attention has been mainly focused on harmonic generation in rare gases by single-frequency excitation. We have analyzed the harmonic spectrum in Ar and N_2 by wave-mixing of parallel polarized fundamental (1064nm) and second harmonics (532nm) of a picosecond Nd:YAG laser in the region from the 3rd to 14th of fundamental, as a function of gas density and laser intensity. The experimental setup is quite common to this kind of experiments. The laser beam is fed into a vacuum chamber which contains a pulsed valve to generate the gas jet, and harmonics are detected along the laser direction by a monochromator in the Seya-Namioka configuration. We have performed a calibration of detection components. More detailed information about experimental setup and calibration are described in Ref. [3].

2. EXPERIMENTAL RESULTS

Shapes of harmonic spectra, recorded in Ar and N_2 , are quite similar, [figs 1 (a) and (b)]. Hence, the structure of bound levels does not affect harmonic generation. Since ionization potential of Ar and N_2 are quite close, the spectra likeness can be understood from the point of view of the plasma model [3] [4]. In addition, we have detected harmonic spectra when the chamber is uniformly filled by gas. In this case, the detectable spectrum is limited by the absorption of gas background. We observed a strong gain of some harmonics as compared with the ones detected in the gas jet. Conversion efficiency enhancement in the uniform density mode can be explained in terms of an increase of the active length and hence as a sort of spatial amplification along the interaction region. Spectra recorded versus pressure, in both configuration, do not show evidence of Phase-Matching modulation, [fig 2 (a)]. This can be explained

by collective effects in the MPI plasma [4]. At density below $10^{18} \text{ atoms/cm}^3$, accordingly with plasma model, the intensity of q-th harmonic has a cubic dependence on gas density. Data recorded versus laser intensity are not in agreement with the weak-field approximation. Some discrepancies arise especially for $I_{\omega} < 2 \times 10^{13} \text{ W/cm}^2$ for harmonics order higher than the 6th in Ar. To account this behavior and to test applicability of plasma model, we use a simplified version of model under weak-field approximation, including the ionization of the medium, [fig. 2 (b)].

Let us remark that brilliance of source realized in this experiment ($2 \times 10^{16} - 2 \times 10^{18} \frac{\text{photons}}{\text{s} \cdot \text{cm}^2 \cdot \text{sterad}}$) overcomes by at least one order of magnitude that the one measured in commercial sources.

Figure 1: (a) Photon per pulse in Ar at gas density 1.2×10^{18} (Full squares), 2.1×10^{18} (Open diamonds), 4×10^{18} (Open circles) and 6×10^{18} (Full triangles) atoms/cm^3 . (b) Photon per pulse in N_2 at gas density 2.5×10^{17} (Open circles), 5.5×10^{17} (Full triangles), 1×10^{18} (Full squares) and 2×10^{18} (Open squares) molecules/cm^3 .

Figure 2: (a) Photons per pulse vs N_2 gas jet density. Full squares-3rd, Open diamonds-4th, Open circles-5th and Full triangles-6th. (b) Ar-gas jet density $6 \times 10^{18} \text{ atoms/cm}^3$ -wave-mixing. Full squares-11th, Open circles-12th, Full triangles-13th and Open squares-14th. Continuous lines-best fit.

References

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