Experimental Demonstration of Second Harmonic Generation of Ultrashort Laser Pulses of Various Wavelengths using a Single Sample of ZnO Nanorods

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Abstract

In this work the SHG study of ZnO nanorods was done by using a Ti:sapphire femtosecond (fs) laser pumped optical parametric amplifier (TOPAS-prime of light conversion). The wavelength range variation was done in the range 800 nm-1300 nm. The seed assisted ZnO nanorod sample grown by us by using seed assisted chemical bath technique was used for this study. The typical length and diameter of these nanorods were 300 nm and 60 nm respectively. The obtained result indicate that ZnO nanorods can be used for wavelength independent SHG generation. This result indicates that one can develop a wavelength independent ultrashort laser pulse diagnostics system using the SHG of ZnO nanorods.

1. Introduction

In industry and medical ultrashort laser pulses are extensively used for various applications like nonlinear optical (NLO) frequency conversion, high resolution microscopy, material processing, microsurgery, frequency metrology, THz generation, detection, imaging etc. These laser pulses are also extensively used for probing or monitoring various ultrafast physical, chemical and biological processes. For reproducibility and precise control of these applications; continuous, real time and accurate diagnostic or characterization of ultrashort pulses is highly essential. The second harmonic generation (SHG) is a NLO process which is commonly used in development of ultrafast laser pulse diagnostic system. Nanocrystalline zinc oxide ZnO films belong to the most promising materials for SHG application because of specific advantages such as ease and cost-effective manufacturing, structurally-enhanced frequency conversion by grain boundaries,[5] high transmittance in visible-near infrared range, large damage threshold, and chemical stability.[3-6]. It has applications in different fields of science and technology as pulse characterization, pump/probe spectroscopy or carrier envelope offset phase measurements (7). There are many more examples of ZnO nanostructures grown for different applications. However only the nanorod geometries warrants the generation of arrays having well controlled uniformity, shape and size distribution. So, various efforts have been made to study the SHG behaviour of the ZnO nanorods. Theoretically as well as experimentally it has been demonstrated that due to localization of field and surface polarization effect, the nonlinearity of the ZnO nanorods can enhance drastically [8]. Earlier we have demonstrated that the $d_{\text{eff}}$ value of ZnO nanorods can be as high as 15 pm/V. This is 7.5 times higher than the $d_{\text{eff}}$ of Beta Barium Borate (BBO). [9]Das et al. 2008 APL]. We also demonstrated that the generated signal can easily be detected by low cost (~$5000) /portable spectrometer like Ocean optics HR 4000 and the spectral behaviour of SHG can easily be predicted by the theoretical model [9-11]. Also SHG in ZnO nanorods can be generated with both low energetic (few nano-Joule) unamplified and high energetic (few mili-Joule) amplified laser pulses [9-11]. The SHG in ZnO nanorods generally takes place through non-phase matching process. So unlike the NLO crystals, SHG of fs laser pulses of various wavelengths can be generally done through a single sample of it. This concept is experimentally demonstrated in the present work. Discussion is given on the potential application of this observation and its significance.

2. Experimental Details

We did the SHG study of ZnO nanorods using a Ti:sapphire femtosecond (fs) laser pumped optical parametric amplifier (TOPAS-prime of light conversion). The duration of the fs pulses is ~100 fs. The wavelength range variation was done in the range 800 nm-1300 nm. The seed assisted ZnO nanorod sample grown by us by using seed assisted chemical bath technique was used for this study. The typical length and diameter of these nanorods were 300 nm and 60 nm respectively.

3. Results and Discussion

The result of this study is shown in figure 1. Here we had taken into consideration of the fundamental pulses having two extreme wavelengths viz. 800 nm and 1300 nm. Their SHG signal were shown in Figure 1a and Figure 1b respectively. As can be seen from these figures the peak of these SHG signal were found to be at wavelength close to 400 nm and 650 nm respectively.
From this figure it is clear that ZnO nanorods can be used for wavelength independent SHG generation. It is to be mentioned here that generation of such wavelength independent SHG is not at all possible in commercial NLO crystal due to their phase matching restriction. This result indicates that one can develop a wavelength independent ultrashort laser pulse diagnostics system using the SHG of ZnO nanorods.

4. Conclusion

In this work the SHG study of ZnO nanorods was done by using a Ti:sapphire femtosecond (fs) laser pumped optical parametric amplifier. The obtained result clearly indicates the SHG can be generation for ultrashort laser pulses of various wavelength by using a single sample of ZnO nanorods.

5. References


