Generation of Over 200mW Laser Radiation at 177.3nm in $KBe_2BO_3F_2$ Crystal

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***Abstract* — An average power of 201mW at 177.3nm was obtained through the six harmonic generation of a picosecond Nd:YAG laser in $KBe_2BO_3F_2$ (KBBF) crystal. This is the highest power at 177.3nm ever generated in a nonlinear optical crystal.**

Keywords—KBBF crystal; 177.3nm; Six harmonic generation

I. INTRODUCTION

Deep-ultraviolet (DUV) laser radiations below 200nm are crucial for many important applications in industry and basic research such as ultrafine photolithography in chip manufacturing and high resolution photoemission spectroscopy[1]. The most compact and effective way to generate such radiations is through direct frequency doubling of laser light in UV (300-400nm) in a nonlinear optical (NLO) crystal. $KBe_2BO_3F_2$ (KBBF) is a newly developed NLO crystal allowing directly doubling of the third harmonic (THG) of a Nd:YAG laser at 354.7nm to obtain 177.3nm (six harmonic generation or 6HG) in DUV. Zhang et al.[2] obtained an output power of 120.5mW at 177.3nm in a KBBF prism coupled device (KBBF-PCD). However, the device suffered from interface separation and optical damage after the experiment and the stability test showed a rather low output power. In this paper, we report on generation of a maximum 6HG power of 201mW at 177.3nm from a temperature stabilized diffusion bonded KBBF-PCD.

II. EXPERIMENT AND RESULTS

The schematic of the experimental setup is shown in Fig.1.

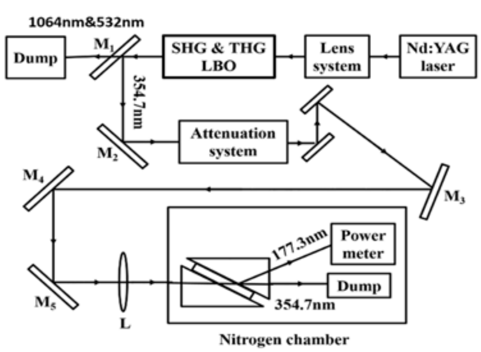

Fig. 1. Experimental setup

The fundamental laser source, a 10ps 1MHz Nd:YAG laser at 1064nm, is frequency tripled to 354.7nm in LBO crystals. After passing through a waveplate-polarizer assembly and a twisted periscope to vary the beam power and the polarization, the THG beam is focused to a KBBF-PCD with a long focal length of 80cm. A motorized rotation stage is used to tune the angle of the KBBF-PCD for the phase matching. The power of the generated 6HG at 177.3nm is measured by a thermal power meter. The KBBF-PCD with the rotation stage and the power meter is enclosed in a nitrogen-filled chamber to prevent the strong absorption of the DUV by oxygen in air.

Previous KBBF-PCDs[2,3] were made of a KBBF crystal and two CaF_2 prisms with direct optical contact and thus suffer from interface separation and optical damage at high laser power due to the weak intermolecular bonding between the two dissimilar materials. In this report we developed for the first time a diffusion bonded KBBF-PCD for high power DUV generation. The polished KBBF (1.58mm thick) and the CaF_2 prisms were coated with SiO_2 layers before optically contacted to make a PCD, which was then brought to ~150°C for the SiO_2 molecules at the interface to diffuse and form a robust chemical bonding. To dispatch heat and stabilize the temperature the KBBF-PCD was further mounted in a copper holder cooled with a water chiller set at 20°C.

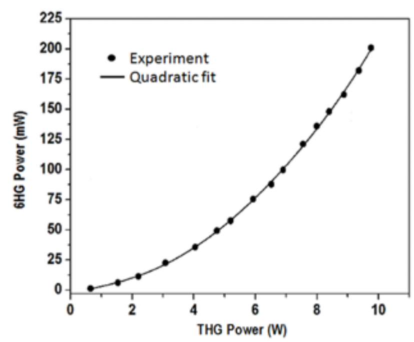

Fig. 2. Output power of 6HG at 177.3nm

The 6HG power versus the THG input is depicted in Fig. 2. The maximum power at 177.3nm was 201mW with the 10W input power corresponding to a conversion efficiency of ~ 2%. The 6HG power increased with the THG input quadratically showing no obvious saturation. The KBBF-PCD was optically intact after the laser exposure, consistent with the strong interface diffusion bonding and indicating a great potential for an even higher 6HG power with the availability of a higher THG power. To our knowledge the maximum power of 201mW at 177.3nm is the highest power achieved in any nonlinear optical crystals to date.

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