The development of mid-infrared and far-infrared nonlinear ZGP crystals

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The mid-infrared (MIR) and far-infrared (FIR) lasers in the range of 3-20 μm, especially the atmospheric windows at 3-5 μm and 8-12 μm, play an important role in the application of remote sensing, telecommunication, photoelectric countermeasure, etc. As the key component of solid-state laser frequency conversion system, nonlinear optical crystals have made great progress in the growth and application. Among which, $ZnGeP_2$ (ZGP) crystal are regarded as the best infrared nonlinear optical crystal with excellent comprehensive performance, due to the superior characteristics of large nonlinear coefficient, high damage threshold, and good thermal conductivity, etc. Normally, to achieve the high-power/high-energy middle infrared laser output, the ZGP based solid-state laser requires the ZGP component to have a large size, high damage threshold, high conversion efficiency, and low absorption coefficient. Herein, a high-quality ZGP single crystal with a diameter of 60 mm was grown through Vertical Bridgman technique, and then large aperture OPO device with a typically dimension of 25×25× 40 mm was obtained based on the forementioned ZGP crystal. Specially, the cracking issue was solved by precise control of crystal defects, and the absorption coefficient at ~ 2.0 μm was significantly reduced to ~0.05cm^{-1} with the treatment of thermal annealing and electron irradiation. Finally, the key parameters, such as the average dislocation density (N_d), FWHM of X-ray rocking curve, and the optical heterogeneity were measured with a value of ~ 2.5×10^2 cm^2, 11-22'' and $\leq2.57\times10^{-5}$ respectively, which all confirmed the high quality of these crystals. Furthermore, a ZGP master-oscillator power-amplifier (MOPA) system was demonstrated using a Ho:YAG MOPA as the pumping source. It was shown that with the increase of ZGP OPO length, the threshold become much lower and the optical-to-optical conversion efficiency see a significant increase. The threshold of 40 mm ZGP OPO device was as low as 14.06W (0.469 mJ, 0.318 mJ/mm^2, 0.42MW/cm^2). And the output power is 51.7W with the highest slope efficiency of 61.4% and optical-to-optical conversion efficiency of 53.6% under the pump power of 96.45W. Thus, high-energy of joule-level or med-wave laser of hundred-watt-level output could be achieved by using the 25mm×25mm×(30~40) mm ZGP devices based MOPA system.