Backward Terahertz-wave parametric oscillator and its application in nondestructive testing

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Abstract

We demonstrated backward terahertz-wave parametric oscillation and generated terahertz-wave pulses with a high peak intensity of about 200 W at 0.3 THz. And Terahertz-wave imaging was performed using the source for nondestructive testing applications. Due to the long-time stability of terahertz-wave oscillation, transmission images with good visibility and inside information were obtained by point scanning imaging. As a result of measuring various materials, we found that the system is applicable to versatile nondestructive inspection applications.

With the maturity of modern society, various new materials and structures have been invented and developed. In production, new and old materials are efficiently utilized and provided to us as familiar manufactured products. On the other hand, quality inspections of manufactured and ready-made products are extremely important in a social environment that demands safety and security and the demand for inspection targets is expanding in accordance with the times. Until now, nondestructive testing has solved many problems using conventional technologies such as X-rays and ultrasonic waves. However, in the evolving environment of material development and inspection, there are many demands for multimodal measurement and the introduction of new technologies.

Terahertz waves (THz waves) are electromagnetic waves that exist between radio waves and light waves, and have the property of penetrating plastics, ceramics, clothing, paper, wood, and mortar. Since various materials have unique fingerprint spectra in the THz wave region, THz wave technology has attracted much attention as a non-destructive inspection tool, and researchers around the world have been vigorously engaged in research and development for about 30 years. Currently, development of equipment has progressed, and some of it has been introduced to the market. Meanwhile, light-wave technologies such as LiDAR and hyperspectral cameras are also advancing, and expectations for nondestructive inspection using THz waves are growing more sophisticated. Very recently, THz-wave imaging research has evolved from conventional two-dimensional transmission imaging to three-dimensional measurement, and artificial intelligence (AI) technology has been introduced to improve the degree of object determination and inspection accuracy, among other technological developments.

Thus, the performance requirements for THz-wave light sources are increasing more than ever in response to increasingly sophisticated THz-wave technology. We have been studying the generation of high-power THz waves from light waves by wavelength conversion using nonlinear optical effects. Recently, optical injection-type terahertz-wave parametric generation using bulk lithium niobate crystals has achieved peak intensities of up to approximately 100 kW. On the other hand, there has been insufficient development of light sources that simultaneously satisfy the requirements of miniaturization, wide wavelength tunability necessary for 3D measurement, and high-power generation of sub-THz waves with high transparency into materials. In this paper, we describe a new backward THz-wave parametric oscillator discovered using periodically polarized inverted lithium niobate crystals as a light source that satisfies all of the above requirements and discuss its attractiveness and application to nondestructive inspection applications.

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