A new source for a “safe” and “useful” terahertz wave will be discovered?

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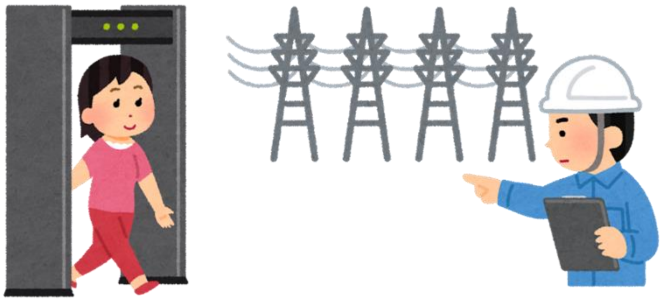

Do you usually recognize the importance of the electromagnetic wave? In our daily life, for example, we always get the latest information on the Internet thanks to telecommunication, heat the lunchbox in the microwave oven, and sometimes have X-ray examinations at the hospital. Such electromagnetic waves are classified by their frequency and applied using the feature of each frequency. Particularly in this paper, I will introduce the terahertz (10^{12} Hz) wave, which falls in between infrared radiation and microwave radiation. This type of electromagnetic wave is attracting attention these days.

Last year, researchers theoretically investigated the material expected as the terahertz wave source [1], which I would like to introduce here. Terahertz waves have many applications, so researchers have studied the efficient generation scheme. Among some suggested methods, this study uses the optical phenomenon called difference frequency generation (DFG). Usually, the light just transmits into the crystal. However, when we input multiple lights into the special crystal, something interesting happens. When you input the appropriate light with two frequencies, for example, *new* light is generated by the interaction between two incident lights. The property of the new light depends on the interaction type, and its frequency corresponds to the difference between the two original light frequencies in the case of DFG. Using the above phenomena, they theoretically investigated the case when they input two beams and obtain the 1 THz light as a *new* light. Then they calculated the efficiency of the terahertz wave generation and discussed the results.

This study's original point is that they consider not the traditional DFG but the *cascaded* DFG. In the *cascaded* DFG, multiple *new* lights are generated sequentially; the difference frequency light, 1 THz light is first generated by two incident lights and then more *new* lights are generated by the interaction between the 1 THz light and the already existing light. This phenomenon continues repeatedly and finally, the 1 THz light is amplified more than the traditional DFG. In general, the propagation in such a crystal can be explained by so-called coupled wave equations. Based on them, they numerically simulated how 1 THz light grows in the crystal and found that the cascaded process is more effective than the non-cascaded one in various kinds of materials. In this study, although they considered about five materials, they found common trends. Therefore, key factors for the high generation efficiency are revealed and it will be helpful to find a new terahertz wave source experimentally in the future.

This research is meaningful because of the following reasons. First, such a theoretical study is important because there are so many material candidates for the terahertz wave source. The strength of the interaction like DFG is characterized by the nonlinear optical coefficient and it depends on the materials. If we use these phenomena for applications, we choose the material with a high optical coefficient. $KTiOPO_4$, called KTP, is one of the typical crystals with a high coefficient and it has been widely used in optical experiments. Hence in the above study, they focused on the high coefficient of the KTP and investigated its so-called isomorphs, which are similar structure materials to KTP. However, the KTP has 118 isomorphs! It is not realistic to try each one experimentally. We need to reduce the number of candidates. It is the reason why this research is essential. Incidentally, although the nonlinear optical coefficients of these isomorphs have not been measured, this study may also create a trigger to start its measurement.

Second, they revealed the important fact that crystal absorption is more important than the phase mismatch in the cascaded DFG. In general, phase matching is a key point for nonlinear optical phenomena. As the incident light propagates in the crystal, the new light occurs at various points. Then they strengthen and weaken each other due to the interference, hence we must consider the so-called phase matching to get the new light effectively. However, in the cascaded DFG, they found that the crystal absorption affects the conversion efficiency more than the phase mismatch. This fact helps to find the efficient structure of the materials.

The terahertz wave has already been applied in our daily life and I would like to show you some examples. First, the terahertz wave is utilized for the maintenance of the infrastructure [2]. The cable for electricity transportation and supporting the bridge are covered with polyethylene so that the inspectors conventionally check them with their eyes or take off these coatings. However, using the terahertz imaging, we can see the internal condition not taking off them. Terahertz wave transmits the polyethylene, while we can obtain the reflected wave from the internal cables, and their conditions are visible. Incidentally, the inspection with the X-ray is also non-destructive to the target. However, the energy of the X-ray is more than the terahertz wave and so more dangerous to humans.

There is another application utilizing not only the merit but also the *demerit* of the terahertz wave. It is a body scanner [3]. Conventionally there is a privacy problem that we can get clear body lines due to the good resolution. However, the resolution of terahertz imaging is worse than X-ray imaging and this demerit can solve the above problem. There are two types of scanning: active method and passive method. The former is a device that emits the terahertz wave to the target, while the latter is a device that distinguishes the terahertz wave from the human body and the objects. Passive imaging is safer for humans and was installed on trial in Kasumigaseki station in 2019 [4].

In summary, the terahertz wave, one of the electromagnetic waves has many applications and its generation scheme has been developed. Recently, the cascaded DFG was theoretically investigated, and it will lead to finding new material for the terahertz wave source in the future.

References

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