Terahertz Generation

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I. Introduction

Terahertz radiation recently draws considerable attention due to its application to security, medical, and other scientific aspects. It is defined, generally as radiation from 0.1THz o 10THz and was originally the part of spectrum missing by laser or other methods of generating radiation. Compared to other methods, using Difference Frequency Generation is more tunable and does not require additional process to get the emission out, as with photoconductive switching. Further more, we could even enhance the efficiency by using Optical Parametric Oscillator.

II. Terahertz Generation and Experiments

2.1 Methods of Terahertz Generation

There are several methods available now for terahertz generation, for example: long wavelength semiconductor lasers, photoconductive switching, and nonlinear optics method (Difference Frequency Generation). By comparison [1], below 1THz the photoconductive method is most efficient, while the nonlinear optics method is best beyond 10THz. Here we'll give an overview of some of the works done with nonlinear optics method.

2.2 Periodically Poled Materials

There have been materials other than $LiNbO_3$ reported to be made periodically poled. GaAs [2], for example, is made by stacking and bonding alternating <110>GaAs or by grown by the molecular beam epitaxy (MBE) method to be orientation-patterned GaAs (OP-GaAs). Figure 2.1 show the plot of efficiency against pump intensity.

Sample	QPM type	Aperture (mm^2)	Length (mm)	QPM period (μm)
DB-77	DB-GaAs	10×10	6	504
A3	OP-GaAs	0.4×3	3	1277
A10	OP-GaAs	0.4×3	10	1277
B5	OP-GaAs	0.4×3	5	759
B10	OP-GaAs	0.4×3	10	759
C5	OP-GaAs	0.4×3	5	564

Table 2.1 Parameters of the QPM GaAs samples.[2]

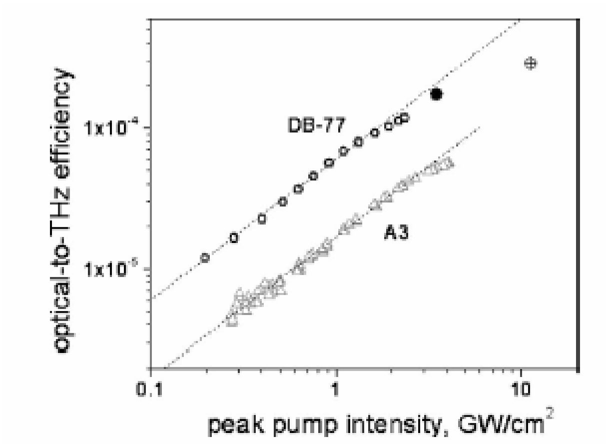

Figure 2.1 Optical-to-terahertz conversion efficiency as a function of peak pump intensity for samples DB-77 (central frequency ~2.2 THz, circles) and A3 (central frequency ~1.5 THz, triangles). The average pump beam sizes were 810 μm (open circles), 520 μm (closed circles), 590 μm (triangles), and 300 μm (crossed circles). The pump wavelengths were 3.5 μm (open circles and triangles) and 4.4 μm (filled and crossed circles). Dashed lines—linear fits. [2]

2.3 Organic Crystal

The use of organic crystals in terahertz generation is potentially beneficial because of higher $\chi^{(2)}$ and also different resonance frequency [3]. For example, the DAST crystal (4-N,N-dimethylamino-40-N0-methyl-stilbazolium tosylate) has large nonlinear coefficient (d_{11}=290 pm/V=692.3・10^{-9}cm/statvolt at 1542nm), compared to -98・10^{-9} cm/statvolt of $LiNbO_3$ (d_{33}). Even with large nonlinearity, DAST isn't wildly used due to difficulties with fabrication.

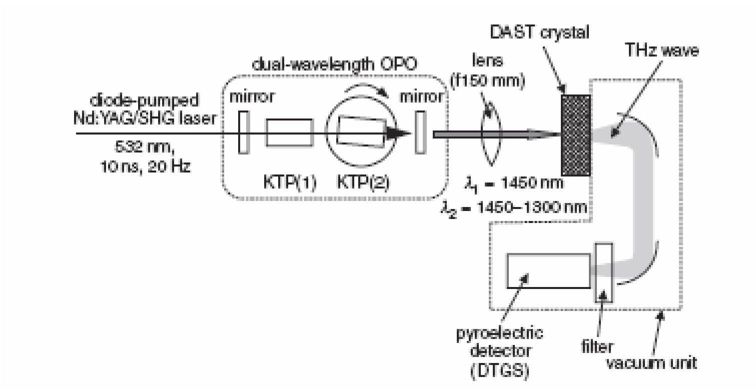

Figure 2.2 Experimental setup for THz-wave generation in DAST crystal [3]

III. Application

Terahertz radiation is non-ionizing, so it is not expected to damage DNA, unlike X-rays. Some frequencies of terahertz radiation can penetrate several centimeters of tissue and reflect back. Thus, terahertz imaging could allow effective detection of epithelial cancer with a safer and less invasive or painful imaging system.

Because of terahertz radiation's ability to penetrate fabrics and plastics it can be used in surveillance, such as security screening, to uncover concealed weapons on a person, remotely. This is of particular interest because many materials of interest, such as plastic explosives, exhibit unique spectral fingerprints in the terahertz range. This offers the possibility of combining spectral identification with imaging. Some controversy surrounds the use of terahertz scanners for routine security checks due to the potential capability to produce detailed images of a subject's body through clothing.

Recently, the THz time-domain spectroscopy (THz TDS) has been shown to be capable of obtaining images of samples that are opaque in the visible and near-infrared regions of the spectrum. Because the absorption characteristics of terahertz radiation vary greatly from material to material, this property can be used to create images. In 1995, Binbin Hu and Martin Nuss [1] at Lucent Technologies' Bell

Laboratories created a terahertz imaging system (Fig 3.1) using TDS and coined the term T-ray for these short, broadband terahertz pulses. The T-ray pulse is measured as it reflects from a sample. Because the pulse is so short, distance can be resolved by looking at the time of flight and then used to create a three-dimensional transparent reconstruction of various objects by measuring the time lapse between pulses reflected from different areas within the object (Figure 3.2) [2].

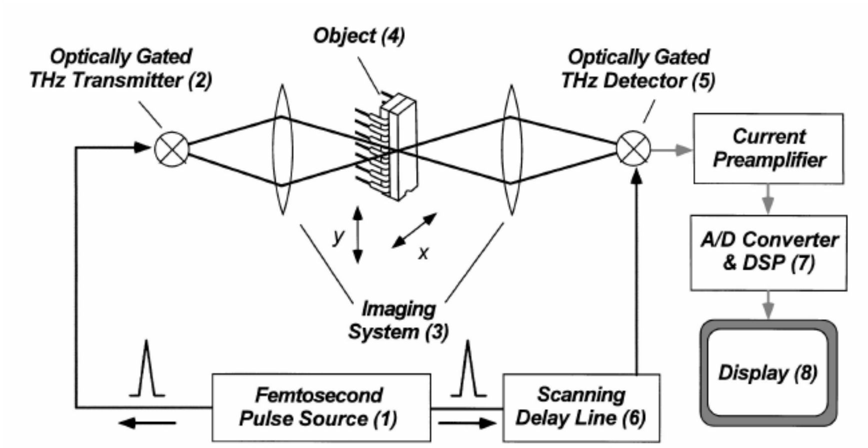

Fig-3.1 Schematic of the THz imaging system [1]

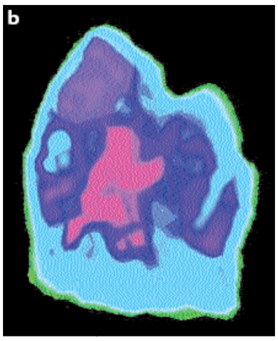

Fig-3.2 The three-dimensional graph of a tooth using THz TDS [2]

The utility of THz-TDS is limited when the sample is very thin, or has a low absorbance, since it is very difficult to distinguish changes in the THz pulse caused by the sample from those caused by long term fluctuations in the driving laser source or experiment. On the other hand, the fact that THz-TDS produces radiation that is both coherent and broadband means that such images can contain far more information than a conventional image formed with a single-frequency source.

IV. Conclusion

The special properties that can penetrate clothing, paper, cardboard and plastic makes terahertz radiation a promising source for medical imaging and security inspection. There are still more work and application to come in terms of terahertz radiation. For instance periodically poled or even aperiodically poled material make further tuning possible [6, 7], also development around the material to improve efficiency would certainly bring more application possible.

V. Reference

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