

Electrical Science & Engineering

Volume 2 | Issue 1 | April 2020 | ISSN 2661-3247 (Online)



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Volume 2 Issue 1 • April 2020 • ISSN 2661-3247 (Online)

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Contents

Article

- 1 **A Petroleum Leakage Detection System**
Salami S.O Green O.O Akinrinlola Ibitoye
- 4 **An Approach to Carbon Emissions Prediction Using Generalized Regression Neural Network Improved by Genetic Algorithm**
Zhida Guo Jingyuan Fu
- 26 **Technological Analysis on Motor Stall and Its Perspective**
Run Xu Zhiqiang Chen

Review

- 11 **Terahertz (THz) Generator and Detection**
Jitao Li Jie Li

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ARTICLE**A Petroleum Leakage Detection System****Salami S.O Green O.O* Akinrinlola Ibitoye**

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ARTICLE INFO*Article history*

Received: 11 December 2019

Accepted: 9 January 2020

Published Online: 30 April 2020

Keywords:

Pipeline

Sensor

Microcontroller

Detection

Alarm

ABSTRACT

This paper presents report of a design work on petroleum leakage detection system. It is a system that is designed to monitor seepage of petroleum products across pipeline installations. The design work which was simulated on a PROTEUS software, consists of a gas detecting sensor (GH-312), an 8-bit (AT89C51) Microcontroller, an alarm system and a remote PC. It was implemented as a laboratory prototype to sense seepages, generate an alarm and also send an alert message to a PC at remote location. Testing of the prototype was carried out in the laboratory using methane gas which is a component gas contained in petroleum products. Result shows an actuated alarm (upon the release of gas from test tube) and an instant alert message on the PC.

1. Background Study

Leakages from petroleum pipeline have been a subject of major concern to inhabitants of pipeline installations. Emissions from these leakages are hazardous due to the toxicity of the gasses. Seepages can also cause explosion that may lead to immeasurable loss of lives. It can also lead to environmental degradation and ecosystem destruction. Two major causes of leakages are identified; natural cause (e.g ruptures due to ageing) and man-made (through vandalism). Empirical data in the literature (Ogbeni O, 2000), shows that the former accounts for only 2.4% of incidences of leakage while the latter accounts for about 97.5% of incidences.

Pipeline vandalism refers to a deliberate act of damaging petroleum pipelines with criminal financial intent. In Nigerian context, it is termed oil bunkering or sabotage through ethnic militancy. Bunkering is the willful act of

drilling into the pipelines with the intent of stealing petroleum products^[4]. Apart from health hazards and environmental degradation, shortages of petroleum products, drastic drop in electricity generation and avalanche of socio-economic problems are other challenges associated with pipeline vandalism. Consequences of leakages from vandalism are immeasurable and unquantifiable for any nation that aims to attain greatness. One of the ways to get around these challenges is to prevent leakages, and even if it occurs, it must be detected and reported early enough so as to arrest the situation fast enough before it degenerate to a disastrous stage. To actualize this, gas or petroleum detectors can be installed at across pipeline installations and other vulnerable locations. A Number of research works on this have been conducted in the past.

Mahalingam et al.^[3] proposed a cost effective gas leakage detector. Their work was designed to meet UK occupational and health hazard safety standards. In its

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implementation, a MQ-5 gas sensor was used which has the ability to sense multiple gases e.g propane and butane. This sensor was used in conjunction with a PIC 181320 Microcontroller. Their designed work has the ability to monitor gas level. If the gas level increases above normal threshold of 400ppm butane, the system will issue a warning alarm at 100ms interval. In a similar manner, Puran et al.^[5] proposed a gas leakage detection and monitoring system. In their work, a MQ-6 sensor and ARM microcontroller were used to sense and detect leakages. Report of any sensed gas would be sent through a Zigbee receiver to a PC for evaluation. In a bid to get a more robust system, Padmapriya et al. (2014) developed a wireless gas sensing network to detect gas leakage and equally generate an alert. A MQ-6 gas sensor was used in their work to sense seepage of gas in a pipeline. The system was interfaced with a GSM module and LCD to receive alert messages and display report. A little different approach to this challenge was developed by Zhang et al.^[8] called a statistical pipeline system and tagged 'ATMOS PIPE'. This system was developed in Shell and has the ability to detect leakages using flow pattern recognition analysis. In its operation, this statistical method will actuate an alarm system only when there are changes in pressure flow pattern within the pipeline. It was implemented with a remote PC.

This work therefore, has proposed a petroleum leakage detector for use across pipeline installations in Nigeria. The design and implementation of the work comprises both software and hardware aspects. A laboratory prototype was built and tested with a component gas of petroleum product. This can further be adapted and integrated for use with petroleum pipelines. Major comparative advantage of this system is that when likely leakages are detected early, it will stimulate prompt attention by concerned authorities. This will prevent spillage, environmental degradation and loss of lives resulting from imminent explosion. More importantly, if this economic loss is curtailed, the nation will witness sustainable economic growth and development.

2. System Design & Implementation

The system is build on the block diagram as contained in Figure 1.

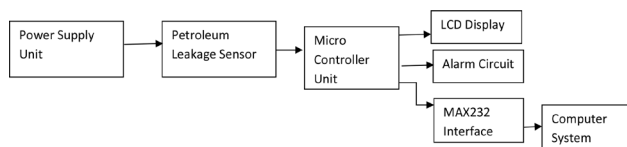


Figure 1. System block diagram

The power supply needed to drive the system is in two folds; a 5v d.c for the microcontroller and a 12vdc to pow-

er the gas sensor and the alarm circuit. Getting a 12vdc was straight forward since the step down transformer used is 12v, which was rectified to generate DC equivalent. However, caution was taken to guarantee a constant DC supply, irrespective of the output voltage from the transformer, hence, an LM7812 I.C regulator was used to achieve this. The 5v needed to power the microcontroller is sourced via LM7805 I.C regulator.

The microcontroller, Atmel AT89C51 is an 8bit component with 4K byte of flash programmable and erasable Read Only Memory (PEROM) with 1000 write/erase cycles for flexible programming and debugging.

The microcontroller is the heart of this system. It serves as a control interface between the gas sensor and the computer system.

The gas sensor is an Arduino gas sensor module which sends an output of 5volts on detection of Methane, butane, propane etc. The data sheet of the sensor shows, it has a high sensitivity of 10m². Though, the practical implementation shows a much less degree in sensitivity, as the sensor only detects a gas within a 100cm² reach.

The alarm unit consists of a 12 volts buzzer. A BC337 NON transistor which acts as a switch, such that, when a microcontroller output a high to the port that connects the buzzer, the transistor is biased, to switch ground to the buzzer whose positive terminal has been connected to a 12vdc supply.

The LCD is a 16x2 portable liquid crystals display which output a caption "Gas found" or "Gas not found" as controlled by the microcontroller. The max232 I.C is an interface unit that connects the microcomputer to a personal computer unit. The I.C has a circuitry, which convert the appropriate machine language suitable for computer process and also transmit the serial signal in parallel form due to the present of a UART circuitry in the chip.

3. Operation Technique

In its mode of operation, the operation relies on the fact that the petroleum is a highly inflammable product, the identified inflammable petroleum gasses are butane and methane. Hence, when the sensor detects any of these gasses, the output impedance of the sensor drops to less than 100ohms, which make it releases its output voltage to the microcontroller. The microcontroller, on getting the signal from the sensor, sends an output high signal to the buzzer, and also send a message to the LCD and to a remote computer system via the max232serial interface unit.

4. Testing and Result

Testing of this system was carried out in two sequence;

before and after construction.

Before construction, a simulation test was carried out using PROTEUS software. To a large extent, it gave a satisfactory result. One of the greatest challenges of the software is however that, it does have component for the gas sensor (GH312). It was not listed the software components library. But knowing that the gas sensor will send some 5v output supply to the microcontroller upon detection of gas, a 5v output switch was used to serve as a sensor.

During the design stage, a variable power supply was used to power the breadboard in order to test the functionality in each stage. Results show that, each of these stages was effectively driven upon supply of required voltage level.

The processor's output low is 0.5, and a high of 3-5volts. Therefore, on receiving a 5volts from the output of the sensor, it switches a high output signal of 5v to the buzzer through a BC337 NPN transistor. The current amplification factor of the transistor (B) is taken as 90 from the transistor's data sheet. The transistor is biased through the base current of 5mA.

i.e

$$I_b = V_{bb} / R_b = 5v / 1 \times 10^3$$

$$I_b = 5mA$$

And;

$$I_c = \beta I_b$$

$$= 90 \times 5 \times 10^3$$

$$I_c = 450mA$$

The input impedance of the buzzer serves as RC, giving the output voltage V_{out} as;

$$V_{out} = V_{cc} - I_c R_c$$

$$V_{out} = 12 - 450 \times 10^3 \times 8$$

$$V_{out} = 12 - 3.6$$

$$V_{out} = 8.4volts$$

Therefore, output current

$$I_{out} = V_{out} / R_c$$

$$= 8.4/8$$

$$= 1.05A.$$

The high current makes the buzzer sound very loudly.

The Max232 output is a signal driven which serves as an interface to the computer system. This is connected to DB-9 serial connector, allowing a serial transmission to computer system. The microcontroller was programmed using assembly language which was assembled using SM-4 assembler and its Hex file is burned to the controller using a universal programmer and a turbo link program.

5. Conclusion

The gas leakage detector cannot be neglected in the effective monitoring of gas leakages and pipeline vandalism. This device could also be used in homes to guide against any domestic gas leakages.

References

- [1] Birnes Williams J. Microcomputer Application handbook, Mc Grahill, 2009.
- [2] Daily Independent Magazine, 2010.
- [3] Mahalingam et al. Design and Implementation of an economic gas leakage detector, 11th international conference on Electrical & Computer Engineering: world scientific and engineering academy & society, 2012: 20-24.
- [4] Okoli et al. Oil pipeline vandalism and Nigeria's national security, Global Journal of Human Social Science, 2013: 67-75.
- [5] Puran Gour et al. Review on Gas leakage detection techniques; International Journal of Scientific Engineering & Technology research, 2014: 3204-3207.
- [6] Ronald Leah. Introduction to software engineering, Mc Grahill, 2007.
- [7] Rui Cabral. Gas detector using GH-312 sensor, Delhi Publisher, 2007.
- [8] Zhang et al. Acoustic leak detection, American Society of Mechanical Engineers, Petroleum division, 1993, 55: 57-61.

ARTICLE

An Approach to Carbon Emissions Prediction Using Generalized Regression Neural Network Improved by Genetic Algorithm

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ARTICLE INFO

Article history

Received: 26 March 2020

Accepted: 3 April 2020

Published Online: 30 April 2020

Keywords:

Carbon emissions

Genetic Algorithm

Generalized Regression Neural Network

Smooth Factor

Prediction

ABSTRACT

The study on scientific analysis and prediction of China's future carbon emissions is conducive to balancing the relationship between economic development and carbon emissions in the new era, and actively responding to climate change policy. Through the analysis of the application of the generalized regression neural network (GRNN) in prediction, this paper improved the prediction method of GRNN. Genetic algorithm (GA) was adopted to search the optimal smooth factor as the only factor of GRNN, which was then used for prediction in GRNN. During the prediction of carbon dioxide emissions using the improved method, the increments of data were taken into account. The target values were obtained after the calculation of the predicted results. Finally, compared with the results of GRNN, the improved method realized higher prediction accuracy. It thus offers a new way of predicting total carbon dioxide emissions, and the prediction results can provide macroscopic guidance and decision-making reference for China's environmental protection and trading of carbon emissions.

1. Introduction

With the continuous development of economic globalization and the implementation of strategies of "Introduce In" and "Go out", China is fully integrated into the world in both depth and breadth. Nevertheless, any major domestic challenge is likely to evolve into an international one, such as carbon emissions and energy shortages^[1]. Ecological environment and sustainable development are arousing more concerns in the party-government and social sectors, where the work arrangement of carbon emissions and carbon sequestration is much obvious. In the meantime, climate change and relevant environmental events have exerted serious impacts on the sustainable development of human society, thereby becoming a common challenge facing the international community today^[2]. Under this context, China can neither do well alone nor undertake international responsibility. In the new era, regardless of the future challenges resulted from carbon emissions, to what extent China can realize accurate predictions require comprehensive research and timely response. The study on accurate prediction of China's future carbon emissions by scientific methods will lay a theoretic basis for relevant policy-making on China's carbon emissions and carbon sequestration.

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So far, the prediction of carbon emissions has been researched by a large number of scholars at home and abroad. Pan Jinghu et al.^[3] accurately identified the spatial characteristics of carbon emissions by building a spatial regression model to simulate the spatial distribution of regional carbon emissions. Wang Yong et al.^[4] made scenario predictions of China's industrial carbon emission peaks and assessed their potential mitigation. Tulson Maimaiti et al.^[5] established a carbon-emission prediction model based on the generalized neural network targeting agricultural production in Xinjiang; they also carried out a quantified analysis of the factors influencing carbon emissions using the average impact value method. China's carbon emissions in 2010-2050 were predicted by Du Qiang et al.^[6] based on an improved Kaya identity model, and by Blanford et al.^[7] through MERGE model. STIRPAT models were constructed by Chinese scholars such as Qu Shenning^[8], Song Jiekun^[9], Zhang Leqing^[10], Wang Yanpeng^[11], Wang Xianen^[12] respectively to predict the carbon emissions of provinces and municipalities in the whole country. Many domestic scholars took the relationship between carbon emissions and energy consumption factors into account. Through the prediction and estimation of the energy consumption structure, a carbon emissions prediction method was constructed^[13-16]. Zhao Aiwen et al.^[17] performed the prediction of the national carbon emissions by the grey correlation method. Artificial neural network (ANN) and genetic algorithm (GA) have shown great advantages in solving complex and highly nonlinear problems, which hence get widely applied in the fields of control, prediction, and optimization. The generalized regression neural network (GRNN) is a form of neural network with good non-linear approximation performance and robustness. It can also achieve an excellent prediction effect even with unstable or insufficient data. GRNN provides a suitable solution to curve fitting^[18-19]. The parameters that GRNN needs to adjust have only one smooth factor, leading to great computing advantages^[20]. For GRNN, the network structure and the connection weights between the neurons are determined by the input learning samples. The training of the network is to determine the only parameter smooth factor σ . Specht proposed a method of multiple experiments to determine the range of the smooth factor ($\sigma_{\min}$, $\sigma_{\max}$), to change it progressively in the range. Then these values of equidifferent σ are used in GRNN prediction, and the mean square error between the predicted value and the actual value is taken as the evaluation index. The value of the minimum error is the optimal smooth factor. This is the most popular way of prediction by GRNN in practice, which however fails to obtain satisfactory results in the prediction of carbon emissions. The

smooth factor can also be selected by an appropriate objective function and obtained by the optimization method. In this study, a genetic algorithm was used to optimize the smooth factor of GRNN. The shortcomings of traditional prediction theory and methods were overcome by the advantages of the above two methods. The improved algorithm was then applied to the process of carbon emissions prediction for accuracy improvement.

2. Methods and Data

2.1 Improvement of GRNN Model Based on GA Improved Method of Prediction Process

The improved method of the prediction process can be divided into the following two steps: (1) The optimal value of GRNN's unique parameter smooth factor is obtained by genetic algorithms, in which values of each parameter are input, and smooth factor of the population is randomly generated; finally, the optimum values of the smooth factor are output; (2) The optimal values of the smooth factor is transmitted to GRNN which is the main body. The index system data and the optimal smooth factor for carbon emissions prediction are input, and the prediction result of carbon emissions is output^[21]. The first step is to achieve an improvement in the genetic algorithm on GRNN. It is designed based on the genetic progress generalized regression neural network model. The basic procedure of the improved prediction method is shown in Figure 1.

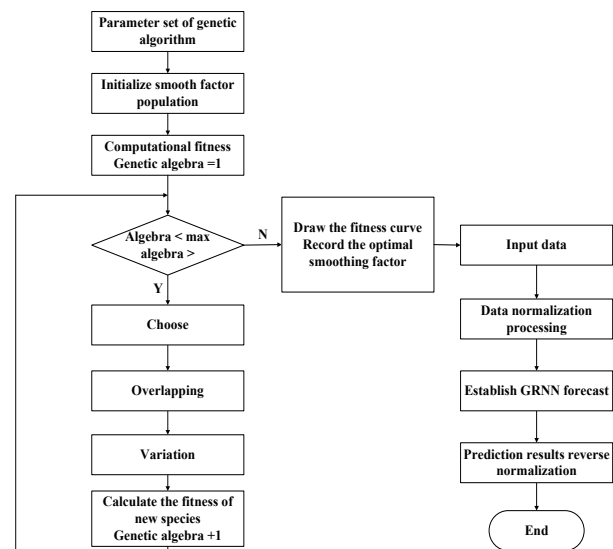


Figure 1. Flow chart of carbon emission prediction method improved based on general regression neural network

2.2 Genetic Improvement of Optimal Smooth Factor

The genetic algorithm of randomly generating indi-

vidual smooth factor of the population is presented in this section. According to the size and genetic selection, individuals with crossover and mutation are screened. The individuals with the best values are kept, and those lacking adaptations are eliminated. The new group inherits the generation of information and performs better than the previous generation. This procedure is repeated until the condition gets satisfactory^[22]. The genetic algorithm is composed of three modules, which are encoding and decoding, individual fitness evaluation and genetic operation, and genetic algorithm (including chromosome selection, crossover, and mutation and so on). Based on the basic genetic algorithm, the following techniques are used for optimization.

2.2.1 Encoding and Decoding

Encoding is the smooth factor of the feasible solution from the solution space to the algorithm that can deal with the search space method. Binary encoding is consistent with the principles of computer processing information, which facilitates the crossover, mutation and other operations of the chromosome^[23]. The binary coding mode is carried out among the randomly generated individuals within the prescribed range; each individual corresponds to a value of the smooth sigma factor. In the crossover and mutation operations, the binary value of the operation and the individual's fitness value are directly calculated. The binary value should be decoded to decimal.

2.2.2 Assessment of Fitness

Fitness is used to measure the excellent degree of the optimal solution that each smooth factor individuals in the population may reach or close to. The function of calculating the individuals' fitness is the guided search option evaluation function based on the genetic algorithm. How to construct a fitness function is one of the key problems of the genetic algorithm. In the adaptation degree function, a GRNN is created based on five samples. The target values of the three samples in the trained network are predicted. The predicted results and the actual values of Euclidean distance are taken as the reciprocal of the fitness function. The smaller the Euclidean distance is, the greater the fitness value is. The fitness function is expressed below:

$$f(x) = \frac{1}{\sqrt{\sum_{i=1}^3 (x_i - X_i)^2}} \quad (1)$$

where x is the predictive value; X is the practical value.

2.2.3 Genetic Operation

(1) Selection

Selection is used to determine the crossover or mutation of the individual operation. In this paper, the selection probability of each chromosome is selected according to the selection probability of each chromosome. The function for calculating the probability of selection is expressed as:

$$P(x_i) = \frac{f(x_i)}{\sum_{j=1}^N f(x_j)} \quad (2)$$

The selection probability of random selected chromosome is obtained through the roulette selection method:

- ① Generate a uniform distribution of random numbers in the $(0,1)$ interval r ;
- ② If $r \leq q_1$, then the chromosome x_1 is selected;
- ③ If $q_{k-1} < r < q_k$ ($2 \leq k \leq N$), then the chromosome x_k is selected.

The following function is obtained:

$$q_i = \sum_{j=1}^i P(x_j) \quad (i=1,2,\dots,N) \quad (3)$$

where q_i is the cumulative probability of chromosome x_i ($i=1,2,\dots,N$).

(2) Crossover

Crossover refers to the exchange of two genes that are selected from some of the genes on the chromosome so that new individuals are generated by combining information from their parents. The crossover operation is determined by the setting of the crossover probability. In crossover operation, the crossover is randomly generated, and then part of the genes on two chromosomes exchange. Afterward, a new individual is generated. If it is not a crossover operation, then a new individual is the choice of two individuals.

(3) Mutation

Mutation means that the position of one gene on a chromosome gets changed, such as from 0 to 1 or 1 to 0; in fact, it is the change of the offspring gene according to the small probability. Similar to crossover, mutation operation is also determined by the setting of the mutation probability. If so, the mutation is randomly generated, and two new individuals corresponding mutation are formulated after crossover, following update for two individuals; if not, then do not do the operation.

3. Application of Carbon emissions Prediction Algorithm

3.1 Basic Permits

To verify the effectiveness of the algorithm in the theoretical research, the algorithm was programmed under the MATLAB environment, and the MATLAB neural network toolbox was used to build generalized regression neural network prediction model with genetic improvement and the improved generalized regression neural network prediction algorithm. Then carbon emissions were predicted according to the improved prediction model and algorithm^[24]. The predicted results were compared with the practical ones, thereby laying a basis for theoretical research in this field.

3.2 Index System

Based on the data collected from 2001 to 2011, the carbon emissions of China from 2019 to 2029 were predicted in this study. Many factors were influencing carbon emissions^[25]. Through the gray correlation degree model, those influential factors with the correlation degree above 0.6 were selected to constitute the index system. A total of eight elements, including the proportion of the total respectively, the factors that affect these total population (10,000 people), the proportion of urban residents (%), GDP per capita (yuan), the ratio of GDP to industrial output (%), total energy consumption (million tons of standard coal), the consumption proportion of coal (%), the consumption proportion of oil (%), are taken into ac-

count, respectively representing by I_1 , I_2 , I_3 , I_4 , I_5 , I_6 , I_7 and I_8 . China's carbon emissions data can be found from the Energy Information Agency (EIA), Carbon Dioxide Information Analysis Centre (CDIAC), International Energy Agency (IEA), World Resources Institute (WRI) and many other international energy agencies, which has no significant difference. In summary, the most authoritative, updated and timely EIA and IEA were selected as sources of carbon emissions data, expressed as V_1 and V_2 respectively. This will make the study more objective, universal and scientific. The arithmetic average value of EIA and IEA carbon emissions was taken as the target value of prediction. The average value of carbon emissions (10000 tons) is expressed as $\bar{V}$. Table 1 lists the detailed information.

3.3 Data Processing

During the prediction process, in most cases, the prediction of the data increment is better than that of the data directly. The incremental data were input and predicted. Those for 8 consecutive years were classified into as a group. The incremental data of each group seven years ago were taken for seeking smooth sigma factor and GRNN training. The 8-year incremental data were used for prediction. In this way, the incremental data were divided into 3 groups, respectively, to predict the carbon emissions during 2019~2029.

To prevent an increase in network training time caused by outlier sample data, normalization processing should be conducted on various data. It aims at converting data to numerical values between 0 and 1.

Table 1. Carbon emissions and the influencing factors during 2019~2029

Serial Number	Year	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	V_1	V_2	$\bar{V}$
1	2019	127627	37.66	8622	39.7	40.5	150406	68.3	21.8	3226.52225	3396.15	3311.336125
2	2020	128453	39.09	9398	39.4	41.5	159431	68	22.3	3422.08573	3605.39	3513.737865
3	2021	129227	40.53	10542	40.5	41.2	183792	69.8	21.2	3959.96585	4176.63	4068.297925
4	2022	129988	41.76	12336	40.8	40.4	213456	69.5	21.3	4596.97027	4837.28	4717.125135
5	2023	130756	42.99	14185	41.8	40.5	235997	70.8	19.8	5116.34858	5403.09	5259.71929
6	2024	131448	44.34	16500	42.2	40.9	258676	71.1	19.3	5575.198	5913.49	5744.344
7	2025	132129	45.89	20169	41.6	41.9	280508	71.1	18.8	5908.42776	6316.44	6112.43388
8	2026	132802	46.99	23708	41.5	41.8	291448	70.3	18.3	6166.56551	6489.98	6328.272755
9	2027	133450	48.34	25608	39.7	43.4	306647	70.4	17.9	6816.09505	6792.94	6804.517525
10	2028	134091	49.95	30015	40.0	43.2	324939	68	19	7446.51986	7252.77	7349.64493
11	2029	134735	51.27	35198	39.8	43.4	348002	68.4	18.6	8126.69441	7954.79	8040.742205

$$x' = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \quad (4)$$

$$y' = y_{\min} + y(y_{\max} - y_{\min}) \quad (5)$$

In equation (4), normalized value x' as the original value x_i , and affect the same element x_i in the minimum value $x_{\min}$, and affect the same element value x_i of maximum value $x_{\max}$. The predictive value obtained ranged from 0 to 1. Therefore, the predicted value y' should be reduced to the actual value by the formula (5). For the normalized value, the minimum value $y_{\min}$ of the network is the direct output value; the maximum value $y_{\max}$ of the network output value.

3.4 Prediction Process

In the use of GA optimizing smooth factor, operating parameters were set as below: smooth sigma factor ranging 0.05-1, precision arithmetic of 0.0001, the population size of 50, the biggest genetic algebra of 12, crossover probability of 0.9 and mutation probability of 0.09. In terms of the fitness function, the 8-year the incremental data of each group were divided into two parts: that of the first 5 years, and that of the last 3 years. The first part was used to train GRNN, and the second part was to predict increment values of the carbon emissions.

3.5 Result Analysis

It was observed that all the maximum values of genetic algorithms in the fitness curves and average fitness degree curves did not appear large-scale shocks, and the convergence of the algorithm was relatively smooth. The population in the evolutionary process of the two curves showed mutual convergence; successive generations of the individuals with the maximum adaptation did not evolve. It suggested that populations reached mature, as shown in Figure 2 and Figure 3.

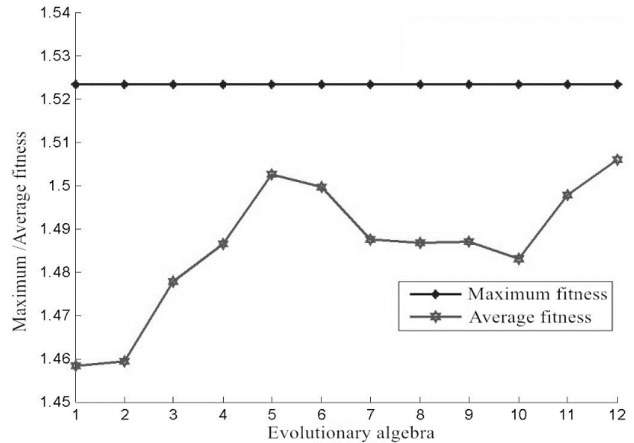


Figure 2. The smooth factor fitness curve of the carbon emission increment in 2019

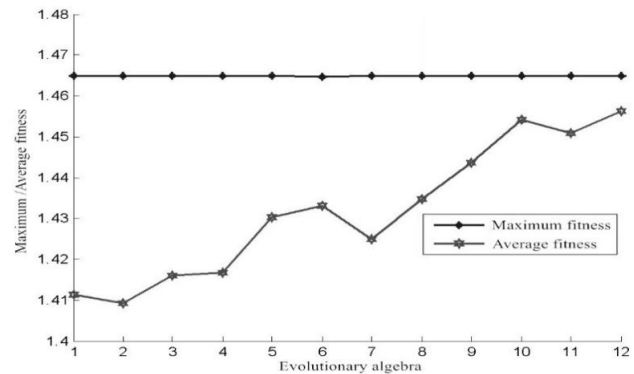


Figure 3 The smooth factor fitness curve of the carbon emission increment in 2029

According to the genetic algorithm, GRNN's smooth factor for predicting carbon emission increment in 2019 and 2029 was 0.084212 and 0.94416. The carbon emissions before the increment from 2019 to 2029 were predicted, as shown in table 2.

The general GRNN was used to fit training samples and determine smooth factor sigma. As a result, the test value of a general GRNN smooth factor sigma was obtained to be 0.1 in the range of 0.1 ~ 0.5. As a result, the predicted

Table 2. prediction results of GRNN and genetic improvement in GRNN

Year	Carbon emissions reference value	Smooth factor σ		Prediction results		Absolute relative error	
		General GRNN	Genetic improvement GRNN	General GRNN	Genetic improvement GRNN	General GRNN	Genetic improvement GRNN
2019	7349.64493	0.1	0.084212	6804.5	7172.60753	7.42%	2.41%
2029	8040.742205	0.1	0.94416	7349.6	7792.18493	8.60%	3.09%
Average						8.01%	2.75%

and actual values of carbon emissions had no remarkable difference, indicating higher prediction accuracy. In the two years of carbon emissions prediction, the relative error of the genetic improved generalized regression neural network was less than 3%. This proved that the accuracy of carbon emission prediction was greatly improved.

4. Discussion and Conclusions

Accurate prediction of carbon emissions is of great significance for environmental control and the policymaking related to carbon emissions. This study proposed a new method of genetic improvement based on the generalized regression neural network, so as to enhance the accuracy of carbon emission prediction. By directly compiling the MATLAB program code, the genetic improvement based on generalized regression neural network algorithm model was constructed to predict carbon emissions from 2019 to 2029. The comparison clearly demonstrated that the choice of the only parameter smooth factor exerted a significant impact on the prediction accuracy of carbon emissions when the generalized regression neural network was employed. Based on the prediction of data increment, the desired target value was obtained, making the prediction of carbon emissions more sensitive. Hence the prediction results closer to the actual ones were obtained. The algorithm was improved to adapt to the function setting and innovative “5 + 3” pattern was adopted to build a generalized regression neural network (GRNN). A row of five samples was trained, among which the three samples adjacent to the target value were predicted. The predicted result and the actual value were applied in Euclidean distance as the reciprocal of the fitness function. The smooth factor was optimized on the basis of the changing trend of the target data. The predicted results showed that the use of the sample was equal to the number of training. In terms of prediction for the same target value, the GRNN model with genetic improvement outperformed the unimproved ones. The improved method was able to effectively reduce the prediction error of carbon emissions.

References

- [1] A. Hu, & W Zhang. Major Challenges and Active Responses in the New Era of China. *Journal of Beijing Jiaotong University (Social Science Edition)*, 2018, 17: 1-8.
- [2] J. Wu, J. Qu, H. Li, H. Zhang, L. Xu. Practical Research on Multidisciplinary Cooperative Mechanism of Climate Change, *Ecological Economy*. 2018, 34: 128-133.
- [3] J. Pan, X. Zhao. Spatial Difference Modeling of Carbon emissions in China Based on Spatial Regression Model, *Journal of Environmental Science*. 2018, 27: 131-140.
- [4] Y. Wang, Y. Bi, E. Wang. Scenario Prediction and Emission Reduction Potential Assessment of Industrial Carbon emissions Peak in China, *China Population, Resources and Environment*. 2017, 27: 131-140.
- [5] Tulson M., W. Ding, J. Xie. Carbon emissions Prediction and Influencing Factors Analysis Based on Neural Network. *Environmental Engineering*, 2017, 35: 156-160.
- [6] Du Q., Chen Q., & Lu N. (2012) China's Future Carbon emissions Forecast Based on Improved IPAT Model. *Journal of Environmental Science*, 32, 2294-2302.
- [7] Geoffrey J. B., Richard G. R. Thomas F. Rutherford. Revised Emissions Growth Projections for China: Why Post Kyoto Climate Policy Must Look East. *Project on International Climate Agreements*, 2008, 3: 1-26.
- [8] S. Qu, Z. Guo. Prediction of China's Peak Carbon emissions Based on STIRPAT Model[J]. *China Population, Resources and Environment*, 2010, 20: 10-14.
- [9] J. Song. Carbon emissions Prediction Model Based on STIRPAT and Partial Least Square Regression[J]. *Statistics and Decision-making*, 2011, 24: 19-23.
- [10] L. Zhang, S. Chen, W. Wang. Measurement and Trend Prediction of Carbon emissions Effect of Construction Land Change in Anhui Province in Recent 15 Years Based on STIRPAT Model[J]. *Journal of Environmental Science*, 2013, 33: 950-958.
- [11] Y. Wang. Evolution and Forecast of Energy Consumption Carbon emissions in Henan Province. *Enterprise Economy*, 2013, 6: 26-32.
- [12] X. Wang, Y. Wang, H. Duan. Prediction and Controllability of Peak Emissions of Regional Energy Consumption. *China Population, Resources and Environment*, 2014, 24: 9-16.
- [13] B. Wei. Scenario Analysis of Energy Demand and Carbon Dioxide Emission in China. Beijing: China Environmental Science Press, 2007: 75-78.
- [14] Yongbin Zhu, Zhen Wang, Li. Pang. Peak Forecast of Energy Consumption and Carbon emissions in China Based on Economic Simulation. *Geography Journal*, 2009, 8: 935-944.
- [15] Sen Bao, Lixin Tian, Junshuai Wang. Prediction of Energy Production and Consumption Trends and Carbon emissions in China. *Journal of Natural Resources*, 2010, 25: 1248-1253.
- [16] Xiaoming Li, Anjian Wang, Wenjia Ding. Global CO2 Emission Trend Analysis Based on Energy Demand Theory. *Journal of Earth Science*, 2010, 31:

- 741-748.
- [17] Aiwen Zhao, Dong Li. Grey Prediction of Carbon emissions in China. *Mathematics in Practice and Theory*, 2012, 42: 61-69.
- [18] Teo Lian Seng, M Khalid, R. Yusof. Adaptive GRNN for the Modeling of Dynamic Plants. *Proceedings of the 2002 IEEE International Symposium on Intelligent Control*, 2002, 11: 27-30.
- [19] Donald F Specht. A General Regression Neural Network. *IEEE Transactions on Neural Networks*, 1991, 2: 568-576.
- [20] Specht D F. The general regression neural network-Rediscovered. *Sustainable Livestock Production & Human Welfare*, 1993, 6: 1033-1034.
- [21] Wiener, J.B. Climate change policy and policy change in China. *UCLA Law Review*, 2008, 55: 1805-1826.
- [22] Baareh, A. K. Evolutionary design of a carbon dioxide emission prediction model using genetic programming. *CARBON*, 2018, 9: 298-303.
- [23] Aziz, B., Arina, N., & Yee, C. J. Inventory Routing Problem with Carbon Emission Consideration. *Matematika*, 2019, 35: 39-49.
- [24] Cariou, P., Cheaitou, A., Larbi, R., & Hamdan, S.. Liner shipping network design with emission control areas: A genetic algorithm-based approach, *Transportation Research Part D: Transport and Environment*, 2018, 63: 604-621.
- [25] Nagapurkar, P., & Smith, J. D.. Techno-economic optimization and social costs assessment of microgrid-conventional grid integration using genetic algorithm and Artificial Neural Networks: A case study for two US cities. *Journal of Cleaner Production*, 2019, 229: 552-569.

REVIEW**Terahertz (THz) Generator and Detection****Jitao Li^{*,*} Jie Li[#]**

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ARTICLE INFO*Article history*

Received: 26 March 2020

Accepted: 30 March 2020

Published Online: 30 April 2020

Keywords:

Terahertz

Generation

Detection

ABSTRACT

In the whole research process of electromagnetic wave, the research of terahertz wave belongs to a blank for a long time, which is the least known and least developed by far. But now, people are trying to make up the blank and develop terahertz better and better. The charm of terahertz wave originates from its multiple attributes, including electromagnetic field attribute, photon attribute and thermal attribute, which also attracts the attention of researchers in different fields and different countries, and also terahertz technology have been rated as one of the top ten technologies to change the future world by the United States. The multiple attributes of terahertz make it have broad application prospects in military and civil fields, such as medical imaging, astronomical observation, 6G communication, environmental monitoring and material analysis. It is no exaggeration to say that mastering terahertz technology means mastering the future. However, it is because of the multiple attributes of terahertz that the terahertz wave is difficult to be mastered. Although terahertz has been applied in some fields, controlling terahertz (such as generation and detection) is still an important issue. Nowadays, a variety of terahertz generation and detection technologies have been developed and continuously improved. In this paper, the main terahertz generation and detection technologies (including already practical and developing) are reviewed in terms of scientific and engineering principles, in order to provide a systematic and up-to-date reference for researchers in terahertz field.

1. Introduction of Terahertz (THz) Wave

In the electromagnetic spectrum, a band between microwave and infrared is called terahertz (THz), as shown in Figure 1. In fact, the definition for standard range of terahertz wave is still controversial. Now most researchers accept the definition of 0.1-10 THz, which corresponds to the electromagnetic wave with the wavelength range of 3 mm-30 μm (1 THz = 10^{12} Hz, corresponding to the wavelength of 300 μm)^[1]. The photon

energy of THz wave is small, and the photon energy of 1 THz is 4.14 meV. Due to the lack of effective technical means to generate and detect terahertz wave, this band is called “terahertz gap” for a long time. Terahertz radiation exists everywhere in nature, but the absorption of terahertz wave by the atmosphere of the earth (especially polar molecules in atmosphere such as water) is also very strong, resulting in the weak terahertz signal intensity in nature^[2]. Terahertz waves have a wide range of applications, and the schematic summary as shown in Figure 2.

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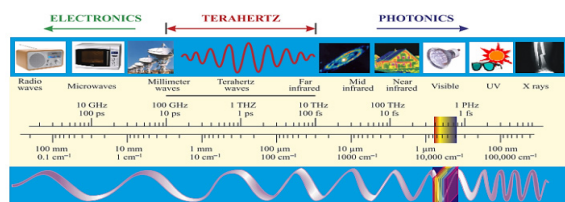


Fig. 1. The electromagnetic spectrum.

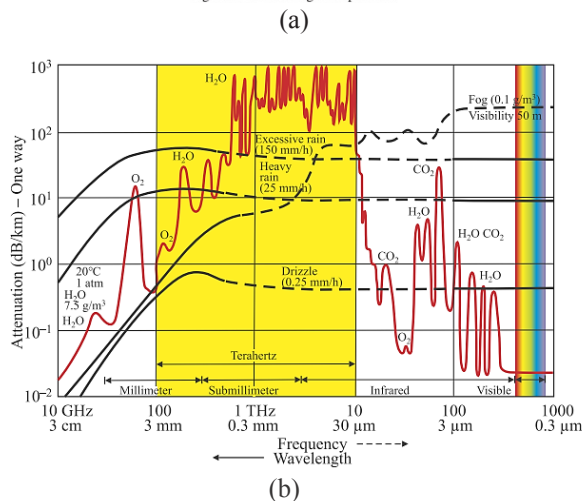


Figure 1. (a) The position of THz in electromagnetic spectrum, and (b) the atmosphere induced attenuation from visible to radio frequency range [2]. Copyright © 2011 SEP, Warsaw

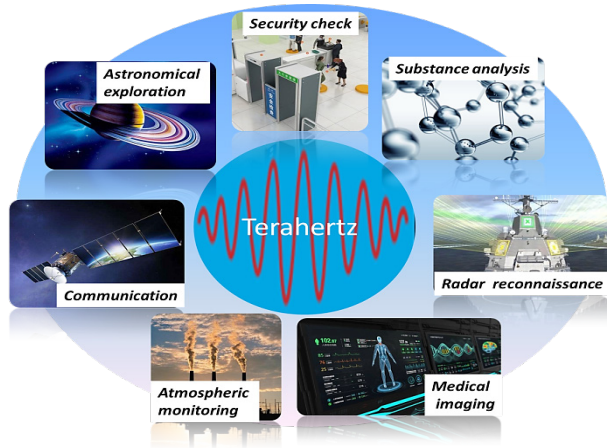


Figure 2. The wide application range of THz

Substance detection and analysis [3-5]: the vibrational and rotational energy levels of many molecules, lattice vibrational phonons of some crystals, and the oscillatory motion of biomolecules are in terahertz band. According to the analysis of terahertz spectrum of these substances, we can obtain the complex structure inside these substances.

Atmospheric environment monitoring [6-8]: terahertz

remote sensing technology can be used to detect the information of atmospheric environment, including water vapor, cloud layer, ozone content and temperature in the atmosphere. In addition, chlorine, sulfur, nitrogen and other elemental compounds have independent characteristic absorption spectrum in terahertz band. Hence, using this special sensitivity, we can monitor the atmospheric environment through terahertz remote sensing, and timely understand the development of environmental problems such as pollution gases, ozone holes and other harmful human survival. Terahertz remote sensing also has the unique advantage of all-weather observation, and has an important application prospect in the research fields of atmospheric composition detection and environmental monitoring.

Security check [9-11]: the photon energy of terahertz wave is very low (1 THz is about equivalent to 4.14 meV), which will not cause ionizing radiation and is safe for human body. Compared with microwave, the wavelength of terahertz wave is smaller and the imaging spatial resolution can be higher. Furthermore, many toxic and harmful substances or dangerous explosives have unique "terahertz fingerprint spectrum" characteristics in terahertz band, so terahertz technology also has great potential in the field of public security, which can be applied to the active and passive detection and identification of concealed drugs, pistols, knives, explosives and other contraband in airports, stations, subways and other occasions. Figure 3 shows the practical application of THz security check, and some dangerous things such as pistol and knife, can be seen.

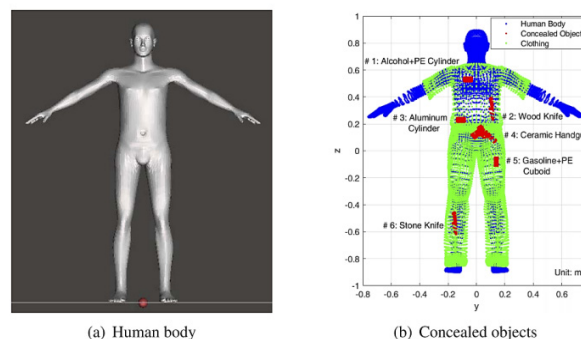


Figure 3. The THz security check images [9]. © 2020 Optical Society of America

Medical imaging [12-14]: terahertz wave does not interact with nonpolar molecules so that terahertz has a good penetrability for nonpolar molecules. However, the absorption of terahertz wave by water molecules is very strong. Different water content of biological organs with different characteristics leads to their different absorption and reflection efficiency of terahertz wave. Meanwhile, a variety of biological components such as protein and fat

possess different radiation-absorbing. Hence, it can take advantage of these characteristics to do terahertz imaging, and biological organs can be easily judged with high sensitivity. Figure 4 shows the THz image of brain cancer, it can be seen that the results of terahertz imaging directly reflect the severity of brain cancer.

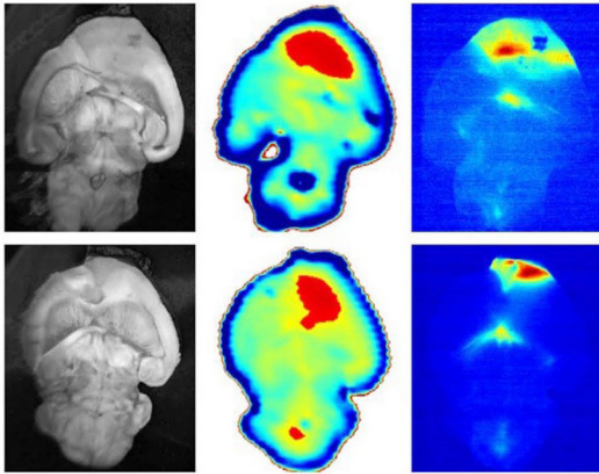


Figure 4. THz images (middle part) show brain cancer ^[14].

Terahertz communication ^[15-18]: according to Shannon formula, the channel capacity of electromagnetic wave is directly proportional to its bandwidth. Compared with the existing wireless communication technology, terahertz band has a higher frequency, so it can obtain a larger signal transmission bandwidth. The absorption of THz wave in the atmosphere is very strong, but there are still several small absorption windows in the low-frequency THz band, including 0.15 THz, 0.23 THz, 0.34 THz, 0.67 THz and 0.85 THz, which makes THz can be applied to the atmospheric short-range secure communication. In 2019, the World Radiocommunication Conferences (WRC-19) clearly points out that the total 137 THz bandwidth resources of 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz bands can be used for fixed and land mobile service applications without restrictions. In the future, terahertz technology is expected greatly in those fields such as the internet of things, 6G communication, and space communication.

Astronomical exploration ^[19-21]: according to statistics, about half of the photon energy and 98% of the photon number in the universe fall in the terahertz band. Terahertz is an important band for cosmic observation, especially for understanding the early evolution of the universe. Compared with infrared and visible bands, terahertz wave has a stronger ability to penetrate interstellar dust, which is of great significance for astronomical observation and research. At present, many countries have launched or are launching astronomical exploration plans in terahertz

band. Among them, the Atacama Large Millimeter/Sub-millimeter Array (ALMA), and the European Herschel and Planck Space Telescopes, etc., are more successful and useful for observing the background radiation of the universe, and have been successfully used, as shown in Figure 5.

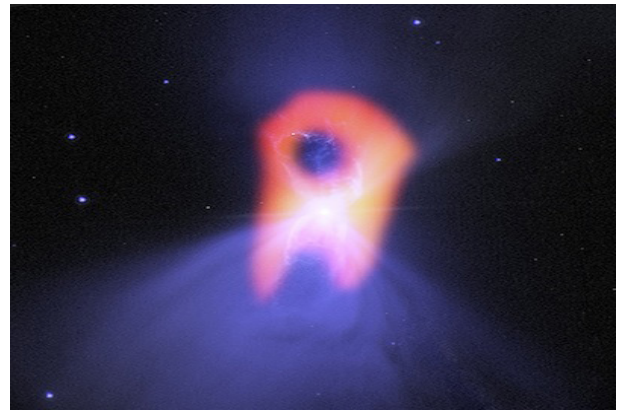


Figure 5. ALMA detects “Boomerang Nebula” that has only 1 K temperature, using THz wave. Copyright ©2013 ALMA

Terahertz radar ^[22-24]: still, it is difficult for microwave radar to directly obtain the full-scale measurement data of large-scale targets. At present, it is a feasible scheme to use the scaled model of the target (the small-scale target model) to derive the full-scale results of the target from the high-frequency measurement results. However, for super large targets such as aircraft carrier and large aircraft, it is still difficult to measure their scaled model size in microwave frequency band. Thus, we need a larger scaling and a higher measurement frequency band. Terahertz has a high measurement frequency band and can meet the measurement requirements of large-scale target and large-scale scaled model. Nowadays, terahertz radar is the high technology that every country wants to seize. Radar cross section area (RCS) in terahertz radar technology plays an important role in target recognition and imaging, and means the physical quantity of the echo intensity produced by the target under the radar wave irradiation, as shown in Figure 6.

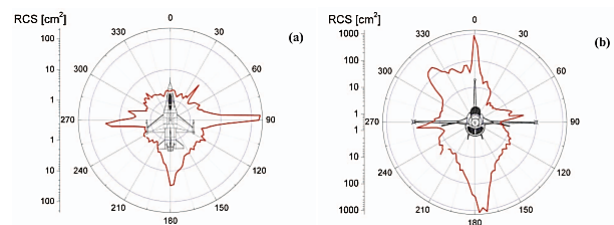


Figure 6. Terahertz radar obtains (a) polar and (b) azimuthal RCS information of the aircraft fighter F-16 model ^[24]. Copyright ©2010 Optical Society of America

2. THz generation Technology

Table 1. The THz generation technologies and some features

Technology	Duration	Coherence	Section
Femtosecond pulse laser excited photoconductive antenna	Pulse	Incoherent	2.1.1
Femtosecond pulse inducing the optical rectification of nonlinear optical crystal	Pulse	Incoherent	2.1.2
Electron accelerator (bremsstrahlung and synchrotron radiation)	Pulse	Coherent	2.1.3
Optical mixing based on semiconductor materials	Continuous	Incoherent	2.2.1
Difference frequency and optical parametric amplification based on nonlinear crystal	Continuous	Incoherent	2.2.2
Laser (P-type Ge laser, free electron laser, far-IR gas laser, quantum cascade laser)	Continuous	Coherent	2.2.3
Backward wave oscillator	Continuous	Incoherent	2.2.4
Microwave frequency multiplication	Continuous	Incoherent	2.2.5

In order to control terahertz, terahertz radiation generation is an important issue. The generation of terahertz radiation benefits from the development of ultrafast optics, nonlinear optical crystal material technology and micro-nano processing technology. According to the duration of THz radiation, they can be divided into THz pulse radiation and THz continuous radiation. Due to the feature of frequency and time, they can be divided into time-domain THz radiation and frequency-domain THz radiation. Further, relying to the coherence, the radiation generator also can be divided into coherent THz or incoherent THz. In this review, we discuss them from the perspective of duration of THz radiation. The technology for generating terahertz radiation is summarized in Table 1.

2.1 Generation of Pulsed THz Radiation

2.1.1 Femtosecond Pulse Laser Excited Photoconductive Antenna

The most common way to generate terahertz radiation is to use photoconductive antenna^[25-26], as shown in the Figure 7. Coplanar two electrodes are evaporated on one side of semiconductor materials (such as GaAs), and two electrodes are connected to DC bias voltage. Because of the difference of electrode gap size, the electrode gap which is far less than THz wavelength is called small aperture photoconductive antenna (SAPA), and the electrode gap which is far greater than THz wavelength is called large aperture photoconductive antenna (LAPA). A femtosecond laser pulse (with a wavelength of 800 nm) is used to

excite the semiconductor materials between the electrodes to obtain photo-generated carriers (mainly electrons) that will accelerate and attenuate under bias voltage to radiate electromagnetic pulses. Because the carrier lifetime of the semiconductor material used is sub-picosecond, the electromagnetic pulse radiated is also sub-picosecond, which just falls in the terahertz wavelength range. Shorter femtosecond pulse can obtain higher frequency THz wave.

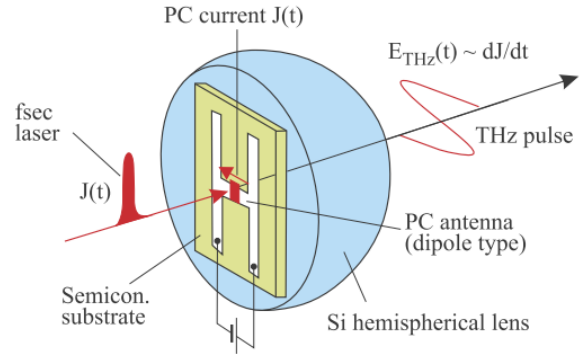


Figure 7. The schematic process of femtosecond pulse laser excited photoconductive antenna inducing THz^[2].

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The radiation and propagation mechanisms of THz pulse to free space are in accordance with the electric dipole radiation model. The space THz radiation field of small aperture photoconductive antenna E_{THz} can be expressed as follows:

$$E_{THz} = \frac{\mu w}{4\pi} \frac{\sin\theta}{r} \frac{d}{dt_r} [I_{PC}(t_r)] \hat{\theta} \quad (1)$$

Where μ is the vacuum magnetic permeability, w is the spot size of femtosecond laser beam, θ is the angle between the terahertz radiation direction and the plane of the material irradiated by the femtosecond laser, r is the radiation distance, t_r is the time delay from terahertz radiation to a certain point in the space with distance r , and I_{PC} is the photocurrent. In addition, because the THz wavelength is larger than the aperture size, the THz radiation direction is seriously scattered, hence the collimating lens (high resistance silicon material) is generally integrated on the back of the device. The terahertz signal generated by the small aperture photoconductive antenna is low in intensity, but low in heating, and can work stably for a long time. For high power terahertz pulse generation, large aperture photoconductive antenna is needed. The large aperture photoconductive antenna has a large stimulated area, also needs high DC bias voltage and amplified femtosecond laser pulse. The spatial radiation field E_{THz} of large aperture photoconductive antenna can be expressed as:

$$E_{THz} = -\frac{\mu A}{4\pi} \frac{E_b}{z} \frac{\frac{d\delta(t)}{dt}}{\left[\frac{\delta(t)Z_0}{1+\sqrt{\varepsilon}} + 1\right]^2} \quad (2)$$

Where A is the photoexcited area, E_b is the bias electric field, z is the THz radiation distance, $\delta(t)$ is the surface conductivity at the time of t , $Z_0 = 377 \Omega$ means the impedance in the free space, and ε is the dielectric constant of the material. Although the large aperture photoconductive antenna has high terahertz output power, it is not easy to work stably for a long time due to its high heating.

2.1.2 Femtosecond Pulse Inducing the Optical Rectification of Nonlinear Optical Crystal

The interaction of optical field and nonlinear optical crystal (such as ZnTe) makes the electric polarization of nonlinear optical crystal. When the light intensity is weak, the electric polarization intensity P is directly proportional to the optical field, which is a linear optical effect. However, when the light intensity is too high, the nonlinear optical effect will be excited. At this time, the electric polarization intensity and the optical field intensity are not in direct proportion. The optical rectification belongs to the second-order nonlinear optical effect^[27]. The total polarization $P^{(2)}$ caused by the optical rectification is proportional to the applied light intensity I , which is expressed as:

$$P^{(2)} = 2\varepsilon_0 \chi^{(2)} |E_0|^2 \propto I \quad (3)$$

Where $\chi^{(2)}$ is the second-order nonlinear optical susceptibility corresponding to the optical rectification process. E_0 is the amplitude of incident light field. Considering the rectification polarization caused by femtosecond optical pulse, the incident optical field pulse $E(t)$ is set as:

$$E(t) = E_0(t)e^{-i\omega t} \quad (4)$$

Where ω is the light angle frequency. As shown in Figure 8, the nonlinear polarization $P(t)$ of the optical rectification will reappear the envelope of the optical pulse, and the final THz field E_T can be obtained by resolving the relationship of E_T and $P(t)$ the spectral bandwidth radiated is about the reciprocal of the optical pulse time. Because the optical pulse time is in the category of 10-100 fs, that is to say, the radiation spectral bandwidth is sub-picosecond, thus the femtosecond pulse optical rectification can generate THz pulse. Ideally, the propagation speed v_T of terahertz pulse is the same as that of optical pulse v_o . At this time, the terahertz radiation field E_T propagating along the z -axis is expressed as:

$$E_T = Cl \left[1 - 4a \left(t - \frac{z}{v_o} \right)^2 \exp \left[-2a \left(t - \frac{z}{v_o} \right)^2 \right] \right] \quad (5)$$

Where C is a constant, l is the transmission length of terahertz in the crystal, and a is the angle between the light field and terahertz field. It should be pointed out that the expression of terahertz radiation field is different for different nonlinear optical crystals and different polarizing crystal planes of the same optical crystal. Furthermore, the propagation speed of terahertz and optical pulse is difficult to be the same in fact. Coupled with the linear absorption of crystal, the real representation of terahertz radiation field is very complex.

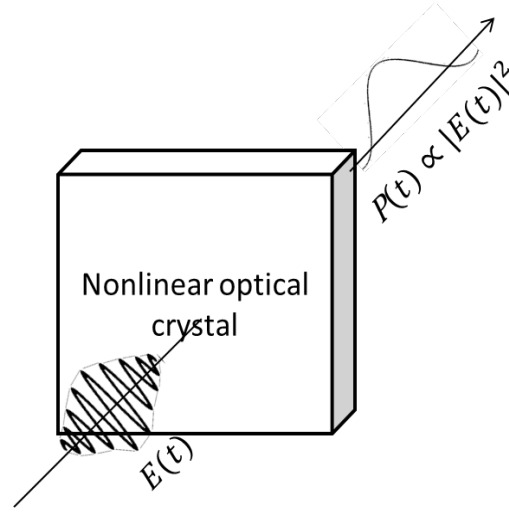


Figure 8. The schematic for femtosecond pulse excited nonlinear optical crystal inducing the optical rectification

2.1.3 Electron Accelerator (Bremsstrahlung and Synchrotron Radiation)

The THz radiation produced by photoconductive antenna and nonlinear crystal is incoherent. The electron accelerator provides a solution for the generation of coherent terahertz radiation. The principle is as shown in the Figure 9. When femtosecond pulse light is incident to semiconductor material surface (such as GaAs) or photocathode electron cavity, it will generate sub-picosecond electron beam that will be further accelerated to 10-100 meV (become relativistic electron) through linear particle accelerator. If the electron beam bombards the metal target at this time, the coherent terahertz radiation will be produced when the electron decelerates rapidly, which is called bremsstrahlung (Figure 9a)^[28]. On the other hand, if the electron beam deflects through the magnetic field to make a circular motion, then the radiation coherent terahertz wave is called synchrotron radiation (Figure 9b)^[29], and the terahertz radiation power generated by synchrotron

radiation can be as high as 20 W. After the electron beam is accelerated, its size is close to radiation wavelength. The emission of a single electron is superimposed in the same phase, so the total THz radiation power is greatly improved.

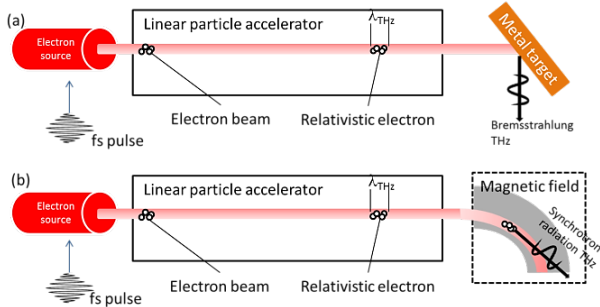


Figure 9. The schematic (a) bremsstrahlung and (b) synchrotron radiation

2.2 Continuous THz Radiation Generation

2.2.1 Optical Mixing based on Semiconductor Materials

As shown in Figure 10, the structure of optical mixing device is similar to that of photoconductive antenna in Section 2.1.1. The main materials in optical mixers are low temperature growth GaAs (LT-GaAs) with high electron mobility and short lifetime^[30]. The metal electrode is generally made into interdigital electrode, with the logarithmic antenna structure of outward spiral, and can also be made into dipole photoconductive antenna structure. The excitation source uses two different frequencies (w_1 , w_2) in the wavelength range of 800-850 nm. Beat frequency light is received by the metal antenna and mixed in an optical mixer. The frequency after mixing is located in the terahertz band, which is the two-photon frequency difference $w_T = w_1 - w_2$. This method is also called optical heterodyne down conversion. By enlarging the excitation area and irradiating the area continuously with high power laser, the THz radiation power can be increased. In addition, the THz radiation power of the device can also be increased by using semiconductor heterojunction instead of LT-GaAs.

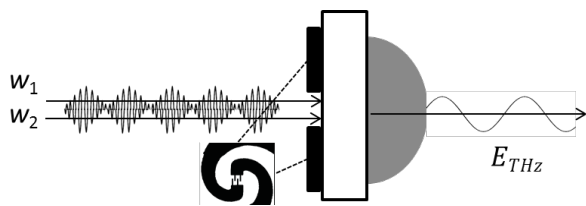


Figure 10. The schematic structure of optical mixing device.

2.2.2 Difference Frequency and Optical Parametric Amplification based on Nonlinear Crystal

As shown in Figure 11, when two beat frequencies (w_1 , w_2) of different frequencies are incident into a nonlinear crystal, the difference frequency $w_T = w_1 - w_2$ located in the terahertz band is produced, which is caused by the second-order nonlinear optical effect of the crystal^[31]. The optical rectification effect enables the generated difference frequency continuous wave (nonlinear polarization reappear the envelope of two difference frequencies), similar to that in 2.1.2 Section. In most nonlinear crystals, GaSe has the best effect, and other crystals such as quartz, LiNbO₃, gap and DAST have also been proved to be available. If a pumping photon w_p is transformed into two photons (w_i , w_T) with lower energy, and the sum of the two photons is the same as the energy of w_p photon (that is, $w_p = w_i + w_T$), which involves the case of optical parametric amplification^[32]. As shown in Figure 12, the w_i is called idle frequency photon, and w_T is in terahertz band. When the wave vector of photon meets $k_p = k_i + k_T$, both idle frequency light and terahertz light can be amplified. LiNbO₃ is the core material of optical parametric process, and the wavelength of pump light is generally 1.064 μm . By changing the angle between the pump light and the idle light, the terahertz frequency can be continuously adjustable.

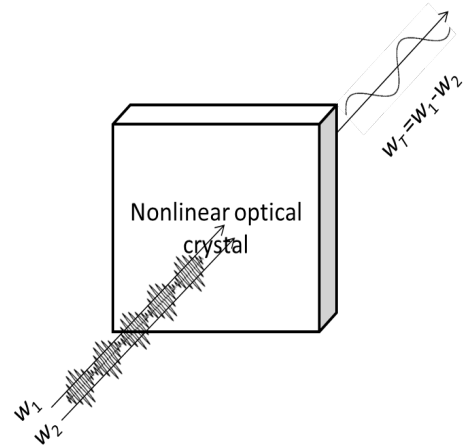


Figure 11. The schematic THz generation based on difference frequency through nonlinear crystal

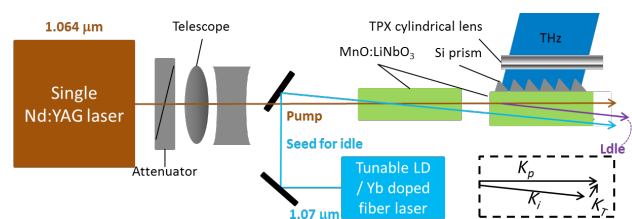


Figure 12. The schematic THz optical parameter generator

2.2.3 Laser (P-type Germanium Laser, Free Electron Laser, Far Infrared Gas Laser, Quantum Cascade Laser)

One of the most important characteristics of laser is to obtain large output gain through resonant cavity. **P-type germanium laser**^[33]: P-type germanium (Ge) is generally realized by doping beryllium. When an orthogonal magnetic field is applied, a four level system will form in P-type germanium, as shown in the Figure 13(a). At low temperature ($< 40\text{K}$), the applied electric field is strong enough to complete a particle number inversion between the light hole (LH) state and the heavy hole (HH) state. At this time, the hole in the high energy state will emit an optical phonon w_{op} and complete the transition to the low energy state. The THz wave occurs when the hole accumulated in the stable Landau level transits to the lower LH state. **Free electron laser**^[34]: similar to synchrotron radiation, free electron laser also use electron accelerator. As shown in the Figure 13(b), the electrons are accelerated to near the speed of light (i.e. become relativistic electrons), and then enter the resonant cavity. The resonance is in the magnetic field array with alternating magnetic poles, which is called Wiggler magnetic array. The electrons do sinusoidal oscillation to emit coherent terahertz radiation in the magnetic field, and the terahertz laser beam produced is amplified in the resonant cavity for many times. The biggest disadvantage of free electron laser is that it takes up a lot of space and costs a lot. **Far infrared gas laser**^[35]: the gain material in the resonant cavity can be some gas molecules, such as CH_3F , CH_3OH and CH_2F_2 . The pump source uses generally CO_2 gas laser. If electrons transition among the rotational energy levels of these gas molecules, they can radiate terahertz waves. **Quantum cascade laser**^[36]: the core of quantum cascade laser is to construct periodic structure alternation superlattice, which is different from the conventional semiconductor in which the mission of electron is terminated after only one transition from high energy level to low energy level. The cascade structure makes the electron enter the next cycle after one transition, and each transition can produce the same frequency THz radiation, as shown in the Figure 13(c). A typical quantum cascade laser belongs to a three-level system. The terahertz radiation transition occurs between the third and the second levels. Then, by adjusting the applied bias electric field, the first level of the previous period is consistent with the third level of the next period. At this time, the first level electrons of the previous period will be injected into the third level of the next period for reuse.

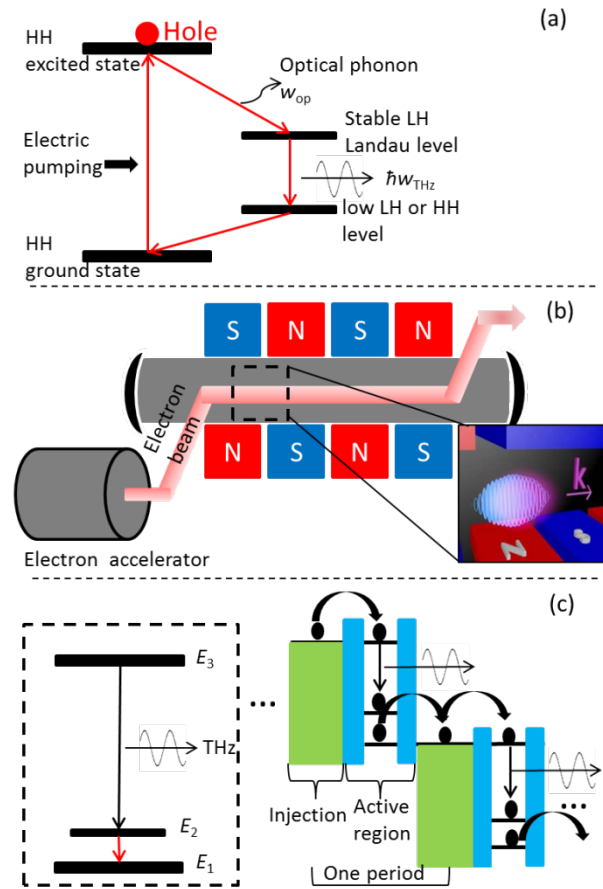


Figure 13. (a) A four level system in P-type Ge under an orthogonal magnetic field, (b) the schematic free electron laser, and (c) the schematic principle of quantum cascade laser

2.2.4 Backward Wave Oscillator

The backward wave oscillator consists of an electron vacuum tube, a group of calibration magnet, and a metal gate, as shown in the Figure 14. Under high voltage, the cathode emits electrons to move towards the anode. The two magnets with different polarity are located at the two ends of the vacuum tube, respectively, which provides a strong magnetic field. The function of the magnetic field is to bunch the electrons and avoid the loss of energy caused by the electrons hitting the tube wall. The metal gate has a comb like structure, and its function is to slow down the electron in the process of moving. The change of electron velocity radiates terahertz electromagnetic wave^[37]. The move direction of electromagnetic wave is opposite to the move direction of electron beam, and electromagnetic wave increases in intensity, so it is called backward wave oscillation. Finally, terahertz radiation is longitudinally output to free space. Backward wave oscillation structure requires the equipment to be precise enough. Its magnet

takes up most of volume. The terahertz output wavelength is determined by the electronic speed, so by changing the electronic speed under applied voltage conditions, it can be adjusted at 0.5-1.5 THz, and the continuous wave output power can reach 1 mW.

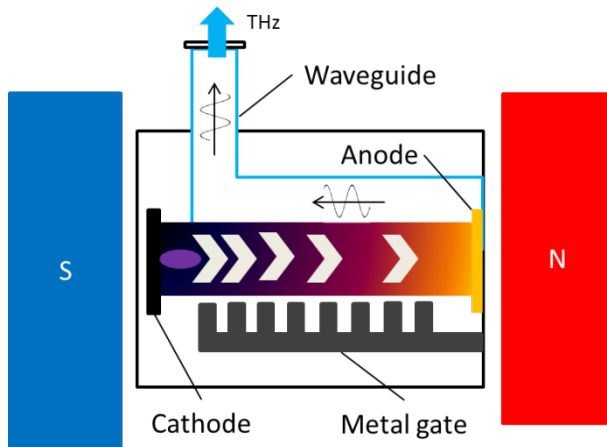


Figure 14. The schematic principle of backward wave oscillator.

2.2.5 Microwave Frequency Multiplication

Microwave frequency multiplication technology is the product of pure electronics technology^[38]. The microwave source includes Gunn oscillator and tunnel diode. When it is connected with the resonator, the DC electric signal can be converted into AC microwave signal. Then, the microwave signal is input into the frequency multiplier to generate THz wave. The core of the frequency multiplier is the Schottky barrier diode (mainly composed of Au and GaAs), as shown in the Figure 15. Microwave frequency doubling is similar to the generation of light wave harmonics in nonlinear crystals. Microwave frequency multiplier can be cascaded, so a microwave can be multiplied many times to form a higher frequency terahertz wave, but the wavelength cannot be adjusted continuously, and the higher the frequency has the faster the output power decays.

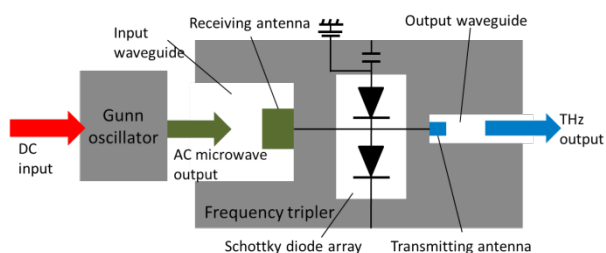


Figure 15. A schematic principle for THz generation by triple frequency of microwave

3. THz Detection Technology

Nowadays, the development of terahertz detectors with high response, easy to use, easy to integrate and low cost has become a research hotspot and focus in this field. Terahertz wave is between microwave and infrared, and it has the particularity of electricity and optics, so there are abundant ways to detect terahertz in as summary in Table 2.

Table 2. The THz detection technologies and some features

Technology	Attribute based	Detection coherence	Section
Photoconductive antenna detector	Electromagnetic field	Incoherent	3.2.1
Electro optical sampling and optical rectification	Electromagnetic field	Coherent	3.2.2
Nonlinear mixing and difference frequency detector	Electromagnetic field	Incoherent/coherent	3.2.3
Glow discharge detector	Electromagnetic field	Incoherent	3.2.4
Surface plasmon detector	Electromagnetic field	Incoherent	3.2.5
Golay detector	Thermal effect	Incoherent	3.2.6
Bolometer	Thermal effect	Incoherent	3.2.7
Thermoelectric detector	Thermal effect	Incoherent	3.2.8
Pyroelectric detector	Thermal effect	Incoherent	3.2.9
Barrier detector	Photonic property	Incoherent	3.2.10
Electron bound state transition detector (quantum well detector)	Photonic property	Incoherent	3.2.11

Considering the characteristics of terahertz as electromagnetic field, terahertz detection can be realized. Terahertz electric fields cause electronic motion, such as photoconductive antenna detectors. Terahertz electric field induces polarization of materials, and produces a series of changes, such as electro-optical sampling and optical rectification. In addition, the interaction between THz electric field and some substances can excite the surface plasma of substances, which will cause the change of electrical signal, so as to realize THz detection, such as surface plasma detector.

Considering the thermal effect of terahertz, many detection techniques have been created. When some materials are irradiated by electromagnetic wave, they will produce thermal effect, that is, the increase of temperature after absorbing the energy of incident electromagnetic wave will cause the change of physical characteristics such as resistivity, volume or spontaneous polarization intensity. Through the measurement of these changes, the terahertz thermal detector can detect the terahertz wave. Because the detection process is only related to the thermal energy of the incident electromagnetic wave, the terahertz

thermal detector has a wide range of response frequency, which can generally cover all terahertz bands. Common THz thermal detectors include Golay detector, bolometer, pyroelectric detector and thermoelectric detector.

The optical properties of terahertz are also used. Among the photodetectors, semiconductor based intrinsic photodetectors are usually used to detect ultraviolet to infrared light. However, because the terahertz photon energy is far less than the intrinsic forbidden band width, it is difficult to detect via the transition of electrons between the intrinsic bands. Photodetectors working in terahertz band usually use the non-intrinsic transition, in-band transition and sub-band transition effects of materials. Due to the interference of thermal radiation from any object in background, these detectors need to work in deep and low temperature environment, such as some barrier detectors and quantum well detector.

3.1 Detector Performance Evaluation Index

Frequency range: that is, the effective frequency range that the terahertz detector can detect. No matter what the THz detector is a narrow-band or a wide-band, users need to know whether the THz detector is effective or invalid for a certain frequency range. **Noise:** THz detectors are used in most environments with a variety of inherent current signals. These effects come from temperature, vibration, humidity, ambient light and other electromagnetic radiation, etc., and itself factors of detector materials such as impurities, lattice vibration, electronic motion, etc. All these current signals can be called noise. Ideally, the detector does not have any noise, which makes the detected THz signal very satisfactory. But in fact, noise is inevitable. If the noise is not handled well, it will seriously affect the terahertz detection. The main indicators related to noise are signal-to-noise ratio (SNR) and normalized detectivity (D^*). The signal-to-noise ratio (SNR) represents a proportional relationship between the noise and the THz signal. The normalized detectivity is expressed as: $D^* = \sqrt{A \times \Delta f} / NEP$, where A is the effective detection area of the device, Δf is the amplifier bandwidth, and NEP is the noise equivalent power which is defined as the incident light power at the unit signal-to-noise ratio. The higher the D^* means the better the detectability. **Responsivity:** the responsivity is divided into voltage responsivity and current responsivity, which are the voltage (V) and current (I) signal under unit THz radiation power P and expressed as dV/dP and dI/dP respectively. At the same time, there is also a frequency response, which is expressed as $R(f) = R_0 / [1 + (2\pi f\tau)^2]^{1/2}$. $R(f)$ is the response at the frequency f , R_0 is the response at the frequency 0, τ is the response time of the detector which is determined by the material and ex-

ternal circuit. Other indicators include polarizability and coherence.

3.2 The Main Types of THz Detectors

3.2.1 Photoconductive Antenna Detector

The photoconductive antenna described in Section 2.1.1 can not only generate terahertz radiation, but also be used to detect terahertz radiation^[2]. The detection principle is opposite to the production principle, as shown in the Figure 16(a). When the photoconductive antenna detects terahertz, the electrode does not need to be biased, but it needs to connect an ammeter to detect the current. Terahertz wave is incident to semiconductor material through one side of silicon lens of photoconductive antenna, and carriers are produced when femtosecond laser irradiates to one side of electrode of semiconductor material. Terahertz can be detected when the carriers are drove by terahertz electric field and generates a current signal. However, it should be pointed out that the detected photocurrent signal is not a copy of the terahertz waveform, but is determined by the incident terahertz field and the surface conductivity together. Therefore, to obtain the final terahertz amplitude signal, a complex mathematical deconvolution operation is necessary. The most typical application of generation and detection based on photoconductive antenna is to construct terahertz time domain system (THz-TDS), as shown in the Figure 16(b).

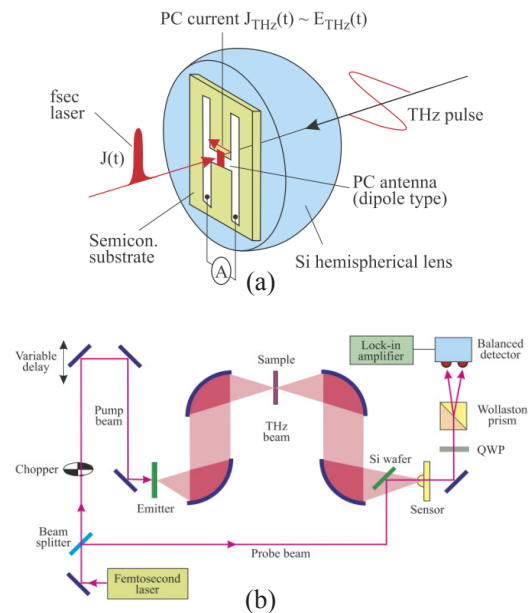


Figure 16. (a) The schematic photoconductive antenna detector, and (b) the schematic picture of THz-TDS^[2].

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3.2.2 Electro Optical Sampling and Optical Rectification

The terahertz signal detected by the photoconductive antenna is still the intensity signal, but the electric field phase and other information cannot be determined. A good solution based on free space electro-optic sampling is proposed^[39]. The basic mechanism of electro-optical sampling is the Pockels effect, which is closely related to the optical rectification. In practical application, the process is as follows. As shown in Figure 17, terahertz wave and optical pulse (here optical pulse as a probe pulse) pass through the electro-optic (EO) crystal together. When there is no terahertz pulse, the polarization direction of the linearly polarized optical pulse does not change. After passing through a $\lambda/4$ wavelength plate, probe pulse turns into a circularly polarized light. The Wollaston prism decomposes subsequently the circularly polarized light into two vertical components with the same light intensity. The balance photodetector will eventually fail to detect the radiation intensity. However, if a terahertz pulse is incident on the EO crystal, the field induced birefringence will cause the probe pulse to produce elliptical polarization, which will be further converted into an elliptical polarization similar to circular polarization after passing through a quarter wavelength plate. Then, the elliptically polarized light is decomposed into two vertical components with different intensities by the Wollaston prism, which eventually causes the balance photodetector to detect the intensity difference. The intensity difference is proportional to the amplitude of terahertz field and also can reflect the phase information.

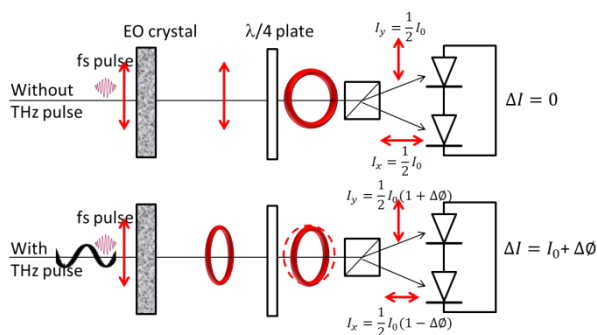


Figure 17. The typically schematic principle of EO sampling in free space

3.2.3 Nonlinear Mixing, Heterodyne and Difference Frequency Detector

As shown in Figure 18, THz radiation with frequency w_s is combined with reference frequency w_o (the reference frequency is generated by a local oscillator (LO) with

definite frequency and power)^[40]. THz radiation and reference radiation are combined in a nonlinear mixer, which induces a frequency sum ($w_s + w_o$) and a frequency difference ($w_s - w_o$). The latter means the down-conversion of THz signal, which usually falls in the microwave range. Subsequently, it can be detected indirectly by a mature detector (such as the microwave detector based on Schottky barrier diode). The difference frequency detection method can also be used for coherent detection of THz radiation of continuous wave, and can also determine the phase. Scanning the local oscillator signal can reappear the THz wave.

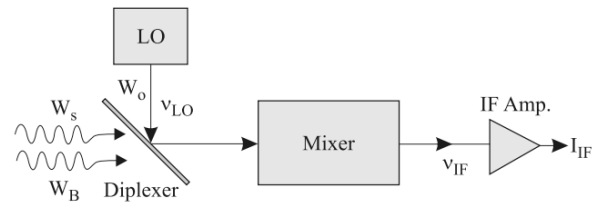


Figure 18. The schematic principle of nonlinear mixing and difference frequency detector (w_B is background radiation)^[2]. Copyright © 2011 SEP, Warsaw

3.2.4 Glow Discharge Detector

Terahertz radiation hits the gas plasma (i.e. that in the commercial neon tube) that thus is heated by the inverse bremsstrahlung effect in the negative glow region, resulting in the increase in the ionization of the gas plasma^[41]. At this time, the current flowing and the brightness in the tube will increase at the same time, and these phenomena can be monitored. On the one hand, the current in the neon tube is operated in the "normal" or "abnormal" range, and then, the current change is tested to determine the terahertz radiation. On the other hand, due to different brightness, optical technology is also utilized to monitor the brightness of the tube to determine terahertz radiation.

3.2.5 Surface Plasmon Detector

When the matching conditions of the incident terahertz wave vector and the materials' surface plasma wave vector are satisfied, and the matching conditions of the terahertz frequency and the materials' surface plasma frequency are satisfied, terahertz field can interact with the surface plasmon of materials to excite the surface plasma wave of materials. This interaction can be detected by designing appropriate device structures, such as field effect transistors (FET), as shown in Figure 19(a)^[42]. In recent years, with the development of new materials and micro-nano technology, the surface plasmon detection method has been brought into full play and has a bright future. The surface

plasmon detector has the advantages of fast response, high detection, high sensitivity and gate voltage control.

A variety of material systems have been used to prepare THz detection devices based on the principle of plasmon resonance, such as high electron mobility transistors based on III-V family materials and graphene two-dimensional materials. Compared with many other types of room temperature terahertz detectors, these devices achieve higher detection sensitivity and faster response speed. At the same time, their preparation process is compatible with the current common semiconductor production process, which is conducive to the practical and commercial development of the devices.

Meanwhile, the artificial metamaterials (metasurfaces) structures are one of the emerging research hotspots in recent years^[43], which are usually composed of periodic arrangements of meta-atoms that size is less than or equal to a specific wavelength. By studying the structure design of metamaterials, the terahertz wave can be modulated or absorbed. As shown in Figure 19(b), metamaterials are expected to use in various kinds of surface plasmon detectors, further improving the detection efficiency of THz^[44].

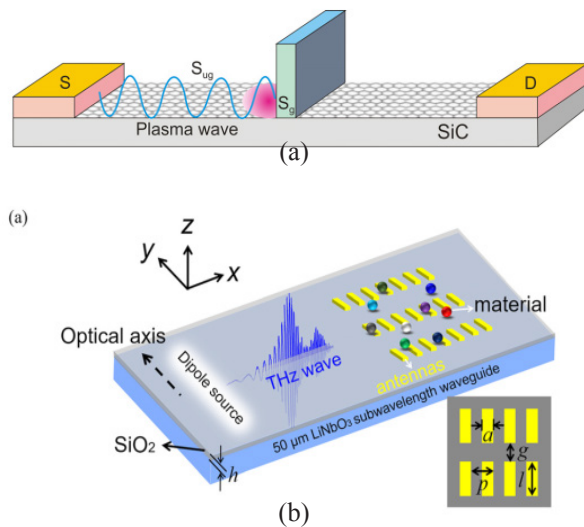


Figure 19. (a) The FET surface plasmon detector^[42], and (b) the use of metamaterials in THz sensing^[44]

3.2.6 Golay Detector

Golay detector is one of the most common terahertz gas detectors, which is often used for astronomical detection and infrared band detection. As shown in the Figure 20, the core part of Golay detector is a closed gas chamber. The one wall of the chamber is equipped with a radiation absorber, and the other wall of the chamber is a flexible mirror. When terahertz irradiates, the radiator absorbs

the heat of the terahertz wave. As heat builds up, the gas expands. This makes the flexible mirror deform, and then the probe beam deflect and terahertz is detected indirectly. The device can work at room temperature with low cost, low energy consumption, no wavelength selection, but it has a slow response and is easy to be interfered by its own thermal fluctuation, external radiation and vibration.

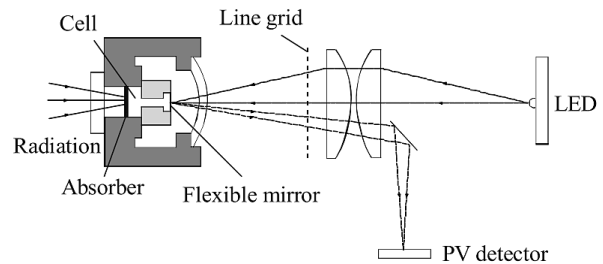


Figure 20. The schematic principle of Golay detector^[2]. Copyright © 2011 SEP, Warsaw

3.2.7 Bolometer

Bolometer is another common terahertz thermal detector^[1], including semiconductor bolometer, hot electron bolometer (HEB) and transition-edge sensor (TES) bolometer based on superconducting phase transition. The working principle of bolometer can be summarized as follows: when the device absorbs the energy of electromagnetic radiation, the lattice temperature or electron gas temperature of the photosensitive element in the device changes, resulting in the change of the conductivity or the electrochemical property of the photosensitive element, and then the electrical signal that can be detected is generated. The detectivity of this device is high, but it needs to work at very low temperature.

3.2.8 Thermoelectric (photo-thermoelectric) Detector

As shown in Figure 21, thermoelectric detector uses Seebeck effect to realize terahertz detection, which is generally made of two different materials as electrodes or the same material but different diameters. Further, photo-thermoelectric detector based on photo-thermoelectric effect emphasizes the thermal radiation characteristics of light^[45]. Because of the difference of Seebeck coefficient, the temperature difference between two different electrode materials or the ends of different diameters of the same material will produce the potential difference. The medium receiving thermal radiation are various (such as graphene we are familiar with). Thermoelectric detector has the advantages of small size, durability and low price,

but generally it has slow response, high noise and poor sensitivity.

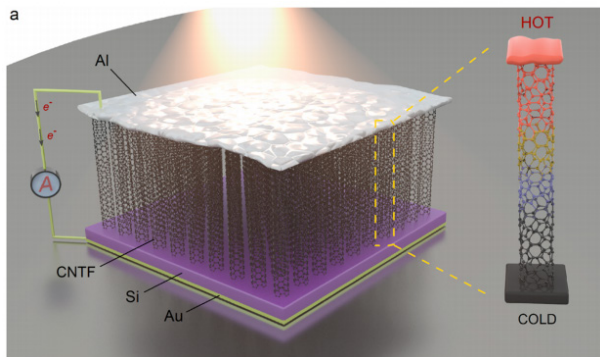


Figure 21. The THz thermoelectric detector based on Al-carbon nanotube-Au system^[45]. Copyright © 2019 American Chemical Society

3.2.9 Pyroelectric Detector

Pyroelectric detector is based on pyroelectric material^[46]. Pyroelectric materials can show spontaneous polarization, and the degree of polarization is usually related to temperature. When the heat of THz wave is absorbed by the pyroelectric material, the temperature of the material increases, which will change the electric field on the upper and lower surfaces of the material. Usually, the pyroelectric material is usually inserted into the capacitor as a medium. As a results, the THz can be monitored by test the change in electrical performance of capacitor. Pyroelectric materials can work at room temperature and have compact and simple structure. But the noise is strong, the response is slow, and the sensitivity is still low.

3.2.10 Barrier Detector

By constructing devices with electronic barriers, the most common ones are Schottky diodes^[1], and other ones are tunnel diodes, superconductor-insulator-superconductor or superconductor tunnel junctions. As shown in Figure 22, the terahertz field acts on one side of the barrier, and the electron gains energy across the barrier, which makes the device obtain current signal. Because the diode can operate under zero bias voltage, it can effectively reduce the device noise, and the response speed is faster when detecting terahertz at room temperature. However, because the potential barrier is a certain value, the electron must obtain the corresponding energy in order to effectively transition, which makes the device often work in the narrow band and cannot realize the wide-band detection.

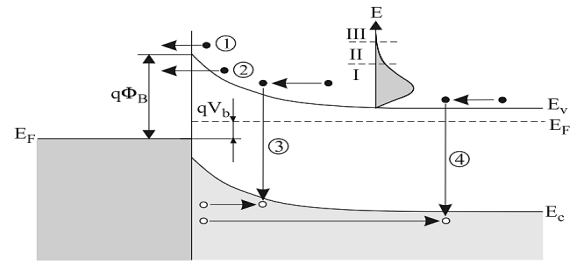


Fig. 28. Four basic transport processes in forward-biased Schottky barrier on an n-type semiconductor: 1 – thermionic emission, 2 – tunnelling current, and generation-recombination current inside (3) and outside (4) the depletion region.

Figure 22. The schematic principle of Schottky barrier THz detection^[2]. Copyright © 2011 SEP, Warsaw

3.2.11 Electron Bound State Transition Detector

At low temperature, electrons combine with atoms that supply electrons, and electrons in certain bound states can absorb terahertz photons and transition to high energy states. The device can be realized by doping the intrinsic semiconductor to building a quantum well^[47,48], as shown in Figure 23. Terahertz light makes the electrons on the impurity bound state transition to the unbound state. Affected by the well parameters, the quantum well detector belongs to a narrow band, but by adjusting the transition energy between sub-bands, the detection frequency range can be widened. These devices have fast detection response, but low quantum efficiency and need low temperature environment.

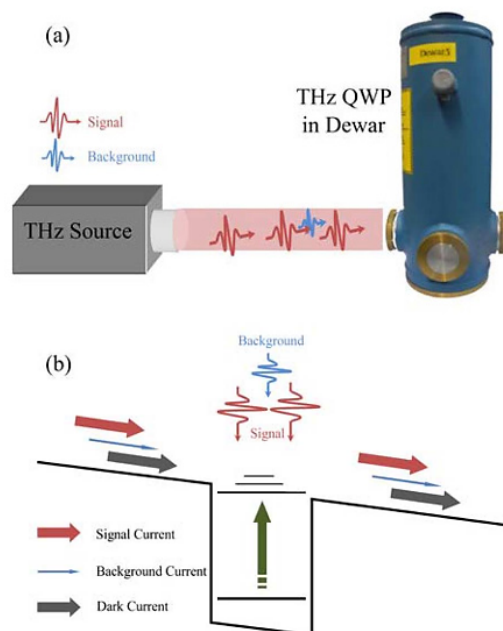


Figure 23. The schematic THz quantum well detector^[47]. Copyright © 2015 IEEE

4. Forward

Today, terahertz generation and detection technologies have achieved a prosperous development, but there are still many problems. Traditional terahertz generation technologies, such as those based on photoconductive antenna and electro-optic crystal, are difficult to achieve high output power. Although electron accelerator, laser and backward wave oscillator have been applied to the terahertz generation field and obtained improved output power, these devices are precise and huge, which lead to the high cost of terahertz generation. On the other hand, many kinds of detection technologies have been developed, but these methods have their own limitations. Traditional detection technology based on terahertz thermal effect is always difficult to detect terahertz efficiently and accurately. With the development of new material technology and micro-nano technology, the technologies of detecting terahertz by means of electromagnetics and photonics seems to be more and more popular, especially the surface plasmon detection technology that is completely based on the new material and advanced micro-nano machining technology, has a broad development space. In general, although the development of terahertz generation and detection technology still has a long way to go, with the progress of industry and science, it is believed that the engineering and theoretical bottlenecks restricting terahertz generation and detection will be solved.

References

- [1] R A Lewis. A review of terahertz detectors. *Journal of Physics D: Applied Physics*, 2019, 52: 433001. DOI: 10.1088/1361-6463/ab31d5
- [2] A. Rogalski, F. Sizov. Terahertz detectors and focal plane arrays. *Opto-Electronics Review*, 2011, 19: 46-404. DOI: 10.2478/s11772-011-0033-3
- [3] Rong Zhao, Bin Zou, Guling Zhang, Dongqian Xu, Yuping Yang. High-sensitivity identification of aflatoxin B1 and B2 using terahertz time-domain spectroscopy and metamaterial-based terahertz biosensor. *J Journal of Physics D: Applied Physics*, 2020, 53: 195401. DOI: 10.1088/1361-6463/ab6f90
- [4] Fang Wang, Ling Jiang, Jun Song, Lin Huang, Yunwei Ju, Yunfei Liu. Sub-THz spectroscopic characterization identification for pine wood nematode ribosomal DNA. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 2020, 232: 118152. DOI: 10.1016/j.saa.2020.118152
- [5] Liudmila Alyabyeva, Samvel Yeghyan, Victor Torgashev, Anatoly S. Prokhorov, Denis Vinnik, Svetlana Gudkova, Dmitry Zhrebtssov, Martin Dressel, Boris Gorshunov. Terahertz-infrared spectroscopy of Ti4+-doped M-type barium hexaferrite. *Journal of Alloys and Compounds*, 2020, 820: 153398. DOI: 10.1016/j.jallcom.2019.153398
- [6] Peter M Solyankin, Irina A Nikolaeva, Andrey A Angeluts, Daniil E Shipilo, Nikita V Minaev, Nikolay A Panov, Alexei V Balakin, Yiming Zhu, Olga G Kosareva, Alexander P Shkurinov. THz generation from laser-induced breakdown in pressurized molecular gases: on the way to terahertz remote sensing of the atmospheres of Mars and Venus. *New Journal of Physics*, 2020, 22: 013039. DOI: 10.1088/1367-2630/ab60f3
- [7] Gyeong-Ryul Kim, Kiwon Moon, Kyung Hyun Park, John F. O'Hara, D. Grischkowsky, Tae-In Jeon. Remote N2O gas sensing by enhanced 910-m propagation of THz pulses. *Optics Express*, 2019, 27: 27514-27522. DOI: 10.1364/OE.27.027514
- [8] Chensi Weng, Lei Liu, Taichang Gao, Shuai Hu, Shulei Li, Fangli Dou, Jian Shang. Multi-Channel Regression Inversion Method for Passive Remote Sensing of Ice Water Path in the Terahertz Band. *Atmosphere*, 2019, 10: 437. DOI: 10.3390/atmos10080437
- [9] Yayun Cheng, Yingxin Wang, Yingying Niu, Ziran Zhao. Concealed object enhancement using multi-polarization information for passive millimeter and terahertz wave security screening. *Optics Express*, 2020, 28: 6350-6366. DOI: 10.1364/OE.384029
- [10] Liu Zhaoyang, Liu Liyuan, Wu Nanjian. Imaging system based on CMOS terahertz detector. *Infrared and Laser engineering*, 2017, 46: 0125001. DOI: 10.3788/IRLA201746.0125001
- [11] Ryota Ito, Michinori Honma, Toshiaki Nose. Electrically Tunable Hydrogen-Bonded Liquid Crystal Phase Control Device. *Applied Science*, 2018, 8: 2478. DOI: 10.3390/app8122478
- [12] A. J. Fitzgerald, X. Tie, M. J. Hackmann, B. Cense, A. P. Gibson, and V. P. Wallace. Co-registered combined OCT and THz imaging to extract depth and refractive index of a tissue-equivalent test object. *Biomedical Optics Express*, 2020, 11: 1417-143. DOI: 10.1364/BOE.378506
- [13] Minah Seo, Hyeong-Ryeol Park. Terahertz Biochemical Molecule-Specific Sensors. *Advanced Optical Materials*, 2019, 8: 1900662. DOI: 10.1002/adom.201900662

- [14] Joo-Hiuk Son, Seung Jae Oh, Hwayeong Cheon. Potential clinical applications of terahertz Radiation. *Journal of Applied Physics*, 2019, 125: 190901. DOI: 10.1063/1.5080205
- [15] A. I. Hernandez-Serrano, Daniel M. Mittleman, Emma Pickwell-MacPherson. Broadband amplitude, frequency, and polarization splitter for terahertz frequencies using parallel-plate waveguide technology. *Optics Letters*, 2020, 45: 1208-1211. DOI: 10.1364/OL.45.001208
- [16] Daniel Headland, Masayuki Fujita, Tadao Nagatsuma. Bragg-Mirror Suppression for Enhanced Bandwidth in Terahertz Photonic Crystal Waveguides. *IEEE Journal of Selected Topics in Quantum Electronics*, 2020, 26: 4900109. DOI: 10.1109/JSTQE.2019.2932025
- [17] High-speed modulation of a terahertz quantum cascade laser by coherent acoustic phonon pulses. *Nature Communications*, 2020, 11: 835. DOI: 10.1038/s41467-020-14662-w
- [18] MehdiTaherkhani, Zahra Ghattan Kashani, Ramazan AliSadeghzadeh. On the performance of THz wireless LOS links through random turbulence channels. *Nano Communication Networks*, 2020, 23: 100282. DOI: 10.1016/j.nancom.2020.100282
- [19] Liang Meiyan, Ren Zhuyun, Zhang Cunlin. Progress of Terahertz Space Exploration Technology. *Laser & Optoelectronics Progress*, 2019, 56: 1006-4125. DOI: 10.3788/LOP56.180004
- [20] S. Lara-Avila, A. Danilov, D. Golubev, H. He, K. H. Kim, R. Yakimova, F. Lombardi, T. Bauch, S. Cherednichenko, S. Kubatkin. Towards quantum-limited coherent detection of terahertz waves in charge-neutral grapheme. *Nature Astronomy*, 2019, 3: 983-988. DOI: 10.1038/s41550-019-0843-7
- [21] Geoffrey C. Bower, Jason Dexter, Keiichi Asada, Christiaan D. Brinkerink, Heino Falcke, Paul Ho, Makoto Inoue, Sera Markoff, Daniel P. Marrone, Satoki Matsushita, Monika Moscibrodzka, Masanori Nakamura, Alison Peck, and Ramprasad Rao. ALMA Observations of the Terahertz Spectrum of Sagittarius A*. *The Astrophysical Journal Letters*, 2019, 881: L2. DOI: 10.3847/2041-8213/ab3397
- [22] Hironori Matsumoto, Issei Watanabe, Akifumi Kasamatsu, Yasuaki Monnai. Integrated terahertz radar based on leaky-wave coherence tomography. *Nature Electronics*, 2020, 3: 122-129. DOI: 10.1038/s41928-019-0357-4
- [23] Bin Tang, Qi Yang, Ye Zhang, Bin Deng, Hongqiang Wang. Three-Dimensional Micro-Motion Feature Extraction of the Vibrating Target Based on Multi-Channel Radar in the Terahertz Band. *Sensors*, 2020, 20: 8. DOI: 10.3390/s20010008
- [24] Krzysztof Iwaszczuk, Henning Heiselberg, Peter Uhd Jepsen. Terahertz radar cross section measurements. *Optical Express, Optics Express*, 2010, 18: 26399-26408. DOI: 10.1364/OE.18.026399
- [25] Abhishek Singh, Alexej Pashkin, Stephan Winner, Malte Welsch, Cornelius Beckh, Philipp Sulzer, Alfred Leitenstorfer, Manfred Helm, Harald Schneide. Up to 70 THz bandwidth from an implanted Ge photoconductive antenna excited by a femtosecond Er:fibre laser. *Light: Science & Applications*, 2020, 9: 30. DOI: 10.1038/s41377-020-0265-4
- [26] G. Jemima Nissiyah, M. Ganesh Madhan. A Narrow Spectrum Terahertz Emitter Based on Graphene Photoconductive Antenna. *Plasmonics*, 2019, 14: 2003-2011. DOI: 10.1007/s11468-019-00998-7
- [27] B. N. Carnio, P. G. Schunemann, K. T. Zawilski, and A. Y. Elezzabi. Generation of broadband terahertz pulses via optical rectification in a chalcopyrite Cd-SiP2 crystal. *Optics Letter*, 2017, 42: 3920-3923. DOI: 10.1364/OL.42.003920
- [28] J. Snyder, L. L. Ji, K. M. George, C. Willis, G. E. Cochran. Schumacher Relativistic laser driven electron accelerator using micro-channel plasma targets. *Physics of Plasmas*, 2019, 26: 033110. DOI: 10.1063/1.5087409
- [29] Di Mitri S., Perucchi A., Adhlakha N. Coherent THz Emission Enhanced by Coherent Synchrotron Radiation Wakefield. *Scientific Reports*, 2018, 8: 11661. DOI: 10.1038/s41598-018-30125-1
- [30] Maria Herminia Balgos, Rafael Jaculbia, Elizabeth Ann Prieto, Valynn Katrine Mag-usara, Masahiko Tani, Arnel Salvador, Elmer Estacio, Armando Somintac. Surface effect of n-GaAs cap on the THz emission in LT-GaAs. *Journal of Materials Science: Materials in Electronics*, 2018, 29: 12436-12442.
- [31] Cyril Bernerd, Patricia Segonds, Jérôme Debray, Jean-François Roux, Emilie Hérault, Jean-Louis Coutaz, Ichiro Shoji, Hiroaki Minamide, Hiro-masa Ito, Dominique Lupinski, Kevin Zawilski, Peter Schunemann, Xinyuan Zhang, Jiyang Wang, Zhanggui Hu, Benoît Boulanger. Evaluation of eight nonlinear crystals for phase-matched Terahertz second-order difference-frequency generation at room temperature. *Optical Materials Express*, 2020, 10: 561-576.

- DOI: 10.1364/OME.383548
- [32] Peng Wang, Xingyu Zhang, Zhenhua Cong, Zhaojun Liu, Xiaohan Chen, Zengguang Qin, Feilong Gao, Jinjin Xu, Zecheng Wang, Na Ming. Modeling of intracavity-pumped Q-switched terahertz parametric oscillators based on stimulated polariton scattering. *Optics Express*, 2020, 28: 6966-6980.
DOI: 10.1364/OE.385493
- [33] A Urbanowicz, R Adomavičius, A Krotkus, V L Malovich. Electron dynamics in Ge crystals studied by terahertz emission from photoexcited surfaces. *Semiconductor Science and Technology*, 2005, 20: 1010-1015.
DOI: 10.1088/0268-1242/20/10/005
- [34] L Shi, SL Johnson, S Reiche, Compact and powerful THz source investigation on laser plasma wakefield injector and dielectric lined structure. *Physical Review Accelerators and Beams*, 2020, 23: 014701.
DOI: 10.1103/PhysRevAccelBeams.23.014701
- [35] J. Déchard, X. Davoine, L. Bergé. THz Generation from Relativistic Plasmas Driven by Near- to Far-Infrared Laser Pulses. *Physical Review Letters*, 2019, 123: 264801.
DOI: 10.1103/PhysRevLett.123.264801
- [36] Kazuue Fujita, Shohei Hayashi, Akio Ito, Masahiro Hitaka, Tatsuo Dougakiuchi. Sub-terahertz and terahertz generation in long-wavelength quantum cascade lasers. *Nanophotonics*, 2019, 8: 2235-2241.
DOI: 10.1515/nanoph-2019-0238
- [37] Linlin Hu, Rui Song, Guowu Ma, Yi Jiang, Wenqiang Lei, Fanbao Meng, Hongbin Chen Experimental Demonstration of a 0.34-THz Backward-Wave Oscillator With a Sinusoidally Corrugated Slow-Wave Structure. *IEEE Transactions on Electron Devices*, 2018, 65: 2149-2155.
DOI: 10.1109/TED.2018.2805699
- [38] Alina C. Bunea, Dan Neculoiu, Antonis Stavriniadis, George Stavriniadis, Athanasios Kost. Monolithic Integrated Antenna and Schottky Diode Multiplier for Free Space Millimeter-Wave Power Generation. *IEEE Microwave and Wireless Components Letters*, 2020, 30: 74 – 77.
DOI: 10.1109/LMWC.2019.2954208
- [39] Philipp Krauspe, Natalie Banerji, Julien Réhault. Effective detection of weak terahertz pulses in electro-optic sampling at kilohertz repetition rate. *Journal of the Optical Society of America B*, 2020, 37: 127-132.
DOI: 10.1364/JOSAB.37.000127
- [40] F. Joint, G. Gay, P.-B. Vigneron, T. Vacelet, S. Pirotta, R. Lefevre, Y. Jin, L. H. Li, A. G. Davies, E. H. Linfield, Y. Delorme, R. Colombelli. Compact and sensitive heterodyne receiver at 2.7 THz exploiting a quasi-optical HEB-QCL coupling scheme. *Applied Physics Letters*, 2019, 115: 231104.
DOI: 10.1063/1.5116351
- [41] Jingle Liu, Xi-Cheng Zhang. Terahertz radiation enhanced emission of fluorescence. *Frontiers of Optoelectronics*, 2014, 7: 156-198.
DOI: 10.1007/s12200-014-0396-4
- [42] A. Rogalski, M. Kopytko, P. Martyniuk. Two-dimensional infrared and terahertz detectors: Outlook and status. *Applied Physics Review*, 2019, 6: 021316.
DOI: 10.1063/1.5088578
- [43] Jie Li, Jitao Li, Yue Yang, Jining Li, Yating Zhang, Liang Wu, Zhang Zhang, Maosheng Yang, Chenglong Zheng, Jiahui Li, Jin Huang, Fuyu Li, Tingting Tang, Haitao Dai, Jianquan Yao. Metal-graphene hybrid active chiral metasurfaces for dynamic terahertz wavefront modulation and near field imaging. *Carbon*, 2020, 163: 34-42.
DOI: 10.1016/j.carbon.2020.03.019
- [44] Ride Wang, Qiang Wu , Yaqing Zhang, Xitan Xu, Qi Zhang, Wenjuan Zhao, Bin Zhang, Wei Cai , Jianghong Yao, Jingjun Xu. Enhanced on-chip terahertz sensing with hybrid metasurface/lithium niobate structures. *Applied Physics Letters*, 2019, 114: 121102.
DOI: 10.1063/1.5087609
- [45] Mingyu Zhang, Dayan Ban, Chao Xu, John T. W. Yeow. Large-Area and Broadband Thermoelectric Infrared Detection in a Carbon Nanotube Black-Body Absorber. *ACS Nano*, 2019, 13, 13285-13292.
DOI: 10.1021/acsnano.9b06332
- [46] Weizhi Li, Jun Wang, Jun Gou, Zehua Huang, Yadong Jiang. *Journal of Infrared, Millimeter, and Terahertz Waves*, 2015, 36: 42-48.
DOI: 10.1007/s10762-014-0115-7
- [47] J. Y. Jia, T. M. Wang, Y. H. Zhang, W. Z. Shen, H. Schneider. High-Temperature Photon-Noise-Limited Performance Terahertz Quantum-Well Photodetectors. *IEEE Transactions on Terahertz Science and Technology*, 2015, 5: 715-724.
DOI: 10.1109/TTHZ.2015.2453632
- [48] Alireza Mobini, M. Solaimani. A quantum rings based on multiple quantum wells for 1.2-2.8 THz detection. *Physica E: Low-dimensional Systems and Nanostructures*, 2018, 101: 162-166.
DOI: 10.1016/j.physe.2018.04.012

ARTICLE**Technological Analysis on Motor Stall and Its Perspective****Run Xu* Zhiqiang Chen**

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ARTICLE INFO*Article history*

Received: 27 March 2020

Accepted: 9 April 2020

Published Online: 30 April 2020

Keywords:

Motor stall

Assembly line

Quality inspection

Unloaded rotary

Pseudo soldering

EMI

Experiment method

Motor use on cars in future

Reverse voltage

ABSTRACT

The brush lock is due to assembly tightly during assembling three gripper so that it curls after some time in motor and bare motors. The motor happen to have current decreasing and cause rotary too slowly is an important technique problem. At last the motor hasn't worked due to disconnection. It give company to bring assembly issue for customers. So the motor stall is main issue in motor working. We shall pay more attention to it necessarily and shall be strict quality inspection and we shall monitor the flow line for the sake of decreasing it. We shall solve the problem as soon as possible and communicate with the customer engineers. Unloaded rotation is radical in the base inspection. The engineer need to negotiate with supplying engineers for the qualified material of brush. Increasing inspection into more times is a method to decrease unqualified brushes. Some experiment method is explained to analyze for customer engineers. Two kinds of motors ie. stepping and asynchronous motor and motors used in future in car is explained to further knowledge to motor's application. Such as the experiment with torque, voice and electric voltage converter. The pseudo soldering results the slow rotary. The reverse voltage is a reason for a motor to slow rotary even stall.

1. Introduction

The motor is a mechanism can rotate to work in a certain load with rotary under the electricity. It is usually used in tool, auto, DVD, Printer and personal care etc.^[1,2] It sold to customers often happen to voice, stall and low rotary etc quality & technique problem. Many of them happen in load after assembling with machine, so that the technique issues bring about serious complaint. Because they are sold to customers the motor technique issue will be substituted into new products. If the test in company is small problem they are feasible to connect with factory for substitution. Some of methods to motor will be known by technique staffs in customer com-

panies for them to proceed a certain adoption to solve.^[3,4] unloaded rotation is important in detail it refers to construction and coil that will affect the rotation. This is necessary inspection to look for the causes the motor has stall or slow rotation. Unload one is too high since it wastes energy becoming high cost too low it causes low working efficiency. The motor reverse rotation is one problem. If DC (direct current) motor meets the reverse connection the brush will reversely rotate. That is harmful to motor use even makes a pair of brush to tangle to motor install due to the reverse rotation. So we shall pay an attention to the color of connection. The red one is anode and yellow id cathode. This is assembly turn.

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2. Analysis and Discussion

2.1 Motor Process

The process of producing motors has assembly including shaft assembly, magnet, assembling shell etc, inspection, after sale & technique support. The reasons of quality is below. (1) brush lock; (2) rotary slowly due to over load; (3) disconnection; (4) life fatigue. The brush lock is due to assembly tightly during three gripper so that it curls after some time in motor. The motor happen to current increasing and cause rotary too slow is a technique issue. As last the motor hasn't worked due to disconnection. If in the situation the load is big that the motor rotates slowly. In the situation the one who is deliberate to increase load to trial the motor. So we shall investigate to be responsible to the one who does practical joke. The flow line is a big and complicated so the cost control is necessary to devices and workers. Due to the several hundreds meter flow line with several hundreds workers in the unit the cost control must be considered and calculated to scientific management and profits. Unloaded rotation can investigate the motor's technological properties, for example the manufacture technical force is qualified or not because it is design core. Engineers will design the property firstly they may evaluate the motor behavior goodly. This is a long distance auto flow line to assemble 50 workers with several very expensive machinery. The first is flow line machine. It completes three coil wire in turns automatically and at last joint three points to output currency to two metal polarities in motor plastic cover. The second is very delicate auto work to insert brushes to plasticity cover with the magnified monitor to check the delicate brush to assemble completely. Only if it is live monitored the fault can be found happen or not immediately. This work need delicate insert because the thickness of brush foil is very thin about 0.1mm. Next one is riveting brush in plastic cover with sophisticated machinery in assembly heat box. And then the fourth is the permanent magnet the rubber which is inserted into motor housing with electricity and last one the sixth is automatically assembling motor house and plastic cover with machine.

2.2 Motor Stall or Rotate Slowly

There are video magnified system to inspect the qualified rush assembly in work line. If there is no problem it will pass the products. If there is slight strain eg twist they will limit and exclude those unqualified. If the elastic and hardness has issue they will cause rush shaft twist and abandon due to the contact over big between rush and shaft knot with some contact metal ring. It may be formed scratch in assembly course and cause rush strain. So the worker in

assembly need to find the unqualified early and also purchase division to inspect the figure and elasticity strictly. The sample shop need to find the unqualified and inform to engineering division and quality division to adapt method to decrease the unqualified. Former is easy to find and latter is difficult to find. Step in first is key otherwise it will reproduce and abandon material. Person effects the firm efficiency and benefit due to reproduce and form complaint. So that that complaint effect staffs emotion and produce. The unloaded rotation needs check with device to find the important values then loaded one is to be known eg slight loaded rotation etc and at last the current is to be known to find its maximum life. The train to staffs is necessary of speciality and quality. Let them know the operation skill to promote their quality so as to produce high quality products. Sony etc Japanese company propose cost decreasing project to obtain high efficiency. In order to high efficiency they increasing high quality to product line. The aim of project is high quality and efficiency to increase competition. The efficiency is high then the quality is high too due to reasonable management. if the unloaded rotation is normal the motor cause internal problem. For example coil has some problem or internal construction has problem. Due to decreasing harmful and unhealthy radiation from Smart Phone or i-pad the EMI is applied to inspecting the eletro magnetic interference situation. EMI is mean of electro magnetic interference which is used to inspect the motor to prevent from radiation of electro magnetic field. It happens to in electro circuit usually and in higher energy state like big informative output from transformation. Engineer checks the number according to connecting with circuit through this device. The number is high when interference is big so that we regulate the parameters to fit to low radiation for customer usage healthily. The first method is to distribute copper etc. to electric brushes through changing composition to cut down the big interference radiation. The second method adds the voltage dependent resist in some frequencies. pseudo soldering is the one reason for slow rotary. This is a important factor to slow rotary and stall as well. many faults will happen in manufacture so that it is inspected carefully to ensure its finish. Regulating machine is necessary process that will guarantee the solder to cover two poles correctly. It increases current to benefit rotation.

2.3 Experiment Method

Don't let voltage is bigger than maximum voltage in order to burn the current plate. As for the designer they control the voltage. If it is small precise need to be big, and it let the motor small. It is easy to produce precise problem. If it is neglected the plate is burned and stall. In the flow line the worker inspect the currency to be mag-

nified to check the normal motor. Moreover the quality staff check the complaint motor with voltage or flow line device which is highly magnified through regulating the size of currency with oscilloscope etc. So to resolve the motor stall etc. non-technological exquisitely property many experimental methods to be used to have searched for as rapidly as possible when a quality issue occurs. The unloaded rotation need to be investigated to find essential factor and designer correctness or not. If there is certain deviation the responsibility will be checked and resign responsible persons evenly. So the monitor technique engineer is necessary duty in factory. They have lot number written the date, line etc. So issue is known through lot number by the direct and secondhand, then the responsibility is asked and give penalty seriously.

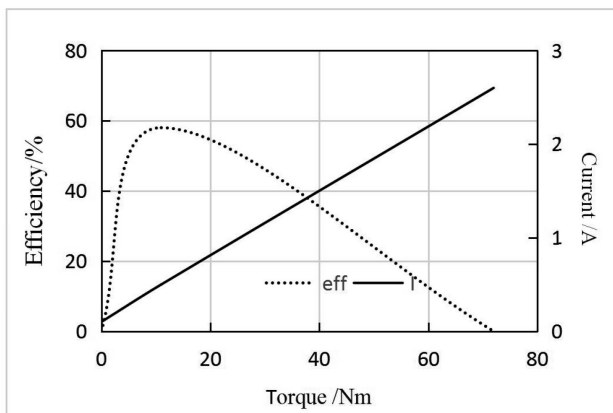


Figure 1. Performance curves for Fuel pump motors

2.3.1 Motor Torque & Current

In terms of load motor is measured to decide it. As for the samples and complaint we adopt the working load and maximum one to inspect where to be issue. If load is low and voltage is over low we judge the structure and coil winding problem. If structure is small the motor isn't issue. Coil winding is over big and winding small it need to negotiate with sample shop to look for the over high and load small. The load test use a strip attaching to motor and then switch on power in order to rotate it. In terms of load size motor is confirmed through rotary. This experiment is sophisticated so it is used necessarily. eg new kind design and customer complaint to inspect torque situation. Another simple method is to use a tool limit motor shaft then in terms of current judge the motor life. This time the current become high until the motor is failure. Latter see the value of current to judge the coil winding etc inner problem. Due to oversize load or formed motor structure the stall or slow rotary will occur too. It will prove the unloaded rotation additionally. As shown in Figure 1 the fuel pump motor's current and ef-

ficiency are shown with the torque. Efficiency is the highest at 11 Nm of torque. It will increase steeply from zero before the value and then decrease sluggishly after this value. So this is the rate torque. If the torque is higher than it the efficiency will become low. The current increases generally as the torque becomes high. If big torque even stall happens the current will increase continuously. At last the current will ascend until the open circuit takes place.

2.3.2 Fatigue Experiment

To apply to the fatigue experiment is wanted to do. The metal plate is joined to motor and put it into slotted magnetic device then power on the motor will rotate. Regulate the depth of metal plate can change the motor's load. Generally several weeks even several months are wanted to this test for the property. Every type uses several ten. Technique look the rotary state in this period. When there is stall or slow rotary pick off to inspect additionally. Cause analysis is needed and regulates to test again till the qualification even stop this type products severely. If the qualification is gained the lot product will write out specification to delivery together. To investigate unloaded rotation and fatigue ability is the important aim. We may model and measure additionally.

2.3.3 Voice

The voice of motor is main specification of valuing the qualification. So the voice Inspection is very important. We put several ten small motors to a room and close their doors and in other room to inspect their dB. According to the GB10069.2-88 5dB is rotary motor minimum value in terms of discrete frequency composition. Due to the voice produced in load the lowest motor voice is needed according to new situation and standard. It makes the shaft scratch stalls seriously due to over size burr. We went to customer to deal with the voice complaint and recall the lot motors to investigate. This issue has generally occurred

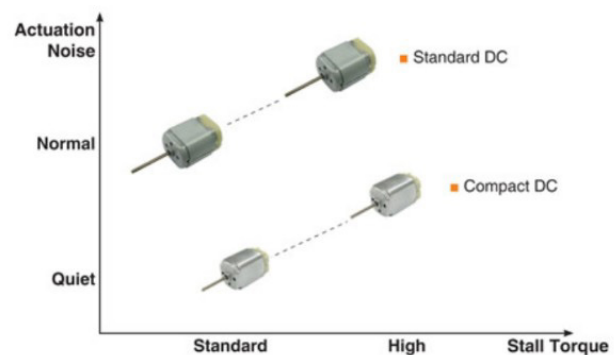


Figure 2. Advantages of new compact motor in electric steering column lock product line for good unloaded rotation

in the customer assembly and experiment, so we shall pay attention to it. To review the unloaded rotation voice is the most foundation condition.

2.4 As for Unloaded Precise New Stepping Motor & Asynchronous Motor and Use in Future

The stepping motor is a kind of one of precious controlling speed and torque distance according to unloaded precise. It usually divides two groups, three groups and five groups. It is used in automatic toll switching system firstly and no need alternating current ship later etc. It is promise and vision one in the future. It is depended on the pulse signal frequency and amount. It is called as Pulse motor. It isn't depended on load. That single chip micryoco controls it is necessary in the future and fits digital tendency of time too. synchronous motor is a simple structure & easy to make motor, the disadvantage is poor power factor which is $\cos \phi$, Here the phase difference in voltage and currenxy is used with ϕ , ratio of active power and apparent power P/S . It has rotary magnetic field and rotary rotor which uses alternate current power. The induction motor is generally called asynchronous motor in some countries. All the motors have the same problem of stall etc. To promote unloaded rotation the lamination voltage and currenxy and graphite rush force etc will be the possible reason for.

As shown in Figure 2 the new compact motor is good at some properties. In future for unloaded rotation, low weight and high torque motor will be prospective applications such as electric steering lock and window in car etc vehicle. There is market in future for advanced reflectors to use for five degrees of freedom. They can regulate the reflector with motor to see better and clear for running off accident. One is forwards and backwards, one is up and down and another is along vertical and two horizontal axes. They are highlight to be used in luxury personal cars widely in future. As shown in Figure 3 the reflective mirror has five freedoms which promote the flexible function to the most exhibiting multiplied regulation through motors.

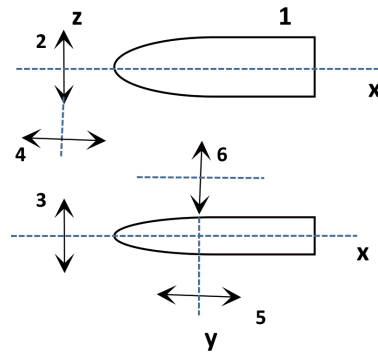


Figure 3. The five freedoms in reflective mirror. 1 is the mirror; 2~6 is the freedoms; 4~6 is rotational ones; z is vertical axis, x and y is horizontal axis

3. Conclusion

Motor stall produced by flow line and inspection isn't strict. So increasing the flow line quality and inspect carefully can control it. Technique and quality division shall monitor producing tightly. Meantime the material inspection do more times to find the issue. Some experimental methods and device is introduced besides new high technology stepping motor and asynchronous motor & use on cars in future. eg. Motor torque and device & voice for the stall or slow rotation. The unloaded rotation is radical.

The pseudo soldering results the slow rotary due to the small current. This is a factor to slow rotary and stall as well. The reverse voltage is a reason for a motor to slow rotary even stall due to brush's reverse rotary. So it is paid attention to and grasped anode and cathode to guarantee the forward set of DC motor because of its correct use and decreasing unqualified of slow rotary even stall.

References

- [1] Qin Zenghuang. *Electrics*. Advanced Education Publisher, 2015: 261.
- [2] Qiu Guanyuan. *Electric Current*. Advanced Education Publisher, 2013: 301.
- [3] A. E. Fitzgerald. *Electric Machinery*. 2003. 100.
- [4] Ge Baojunetc. *Electric Machinery (Third Edi.)*. Chinese Electricity, Publisher. 2016: 2-3.

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