TERAHERTZ TECHNOLOGY - A RACE BETWEEN PHOTONS AND ELECTRONS

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ABSTRACT

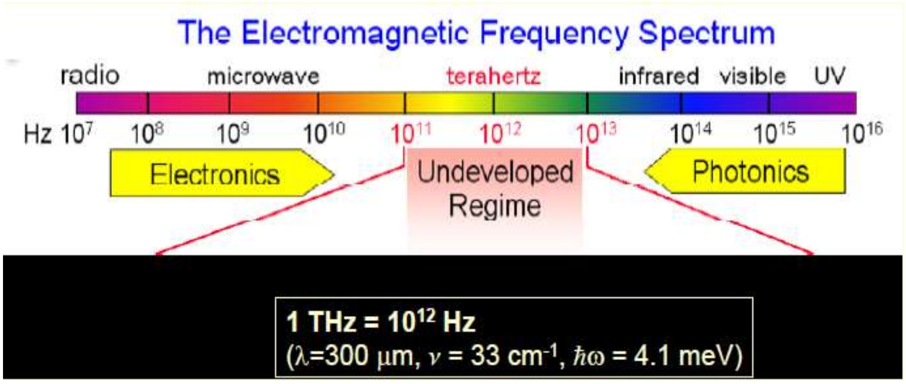
Terahertz technology provides a new era in the extension of electromagnetic spectrum uses. Terahertz waves lies in the region between radio waves and light waves in electromagnetic spectrum. At the lower end of electromagnetic spectrum lies the radio waves have pretty good characteristics and used in electronics side. At the higher end frequency of electromagnetic waves there lies the light waves used in photonics applications. Unfortunately both these radio waves and light waves of our electromagnetic spectrum are not used at its fullest part. Between these two electronic and photonic ends there lies tera waves which has the interesting part that tera waves has the benefits of both radio waves and light waves characteristics. Thus a race between photons and electrons called terawaves can be focused in beneficial applications.

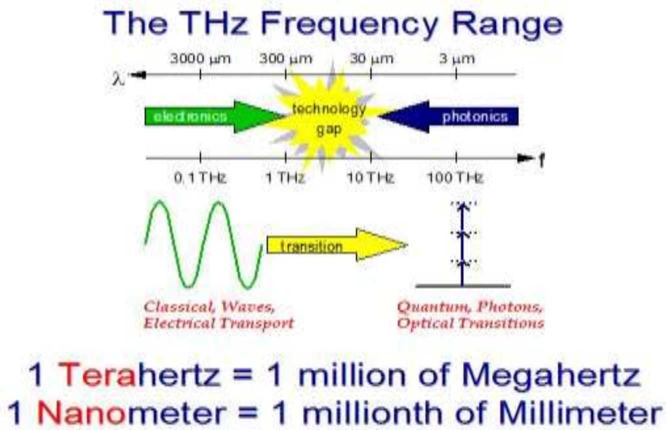
Terahertz (THz) portion of the elec-tromagnetic spectrum (0.1 THz to 35 THz) provides unique features for materials characterization. THz radiation can penetrate most materialsthus, it can interrogate surfaces, sub-surface, and interior layers of a multi-layered material. Unlike X-ray, THz is non-ionizing and does not damage delicate features. It is safe for live imaging on humans. THz radiation is highly sensitive and can detect nanometer-size defects.

The available terahertz devices are big, bulky and expensive and it really limits its applications. It endures the entire evolution in electronic industry. If we look at the driving force of electronics, of half century the development of silicon based circuits is abundant. Silicon circuits improved from micrometre to nanometre, this reduction of size results in continuous increase of speed. Silicon based terahertzdevices with this spectrum can be used in better way.

I. INTRODUCTION

Tera waves transfers huge files quickly, used to detect bombs, poison gas clouds, and concealed weapons. It Peer through walls and senses explosives with T-ray vision. The truth is that this promising technology is not much used widely which lies between the microwave and the optical, corresponding to frequencies of about 300 billion hertz to 10 trillion hertz. This radiation does have some uniquely attractive qualities: For example, it can yield extremely high-resolution images and move vast amounts of data quickly. And yet it is nonionizing, meaning its photons are not energetic enough to knock electrons off atoms and molecules in human tissue, which could trigger harmful chemical reactions. The waves also stimulate molecular and electronic motions in many materials—reflecting off some, propagating through others, and being absorbed by the rest. These features have been exploited in laboratory demonstrations to identify explosives, reveal hidden weapons, check for defects in tiles on the space shuttle, and screen for skin cancer and tooth decay.





1.1 Motivation for the Promising Technology

TeraHertz (THz), the frequencies between electronics and optics, was until recently the last unexploited part of the electro-magnetic spectrum. The harnessing of THz-based technologies

has the potential of impacting globally a vast number of industries, like both electronics in the 70's and optics in the 80's did. THz applications span over a wide array of fields, including: Quality Control and Non-destructive testing, Surface analysis, Security, Chemical and Bio Medical analysis, Telecommunications. Filling the Terahertz "gap" has led to unprecedented creativity in the development and commercialization of TeraHertz sources, transmission components and detectors. This paper provides a unique clue to network with specialists, converge know-how, and scout for innovative applications.

1.2 Objectives

The major objective of this proposed paper is to reveal about the latest TeraHertz technologies and their market potential**, to** discover examples of TeraHertz applications and the corresponding industrial opportunities and to network with specialists in this emerging field.

1.3 Properties of Terahertz Radiation

The terahertz range refers to electromagnetic waves with frequencies between 100 GHz and 10 THz, or wavelengths between 3 mm and 30 µm. Light between radio waves and infrared has some unique properties.

- Frequency range 100 GHz .. 10 THz, wavelengths 3 mm .. 30 µm
- Also known as far-infrared or sub-millimeter waves
- Non-ionizing, but penetrates clothing, paper, cardboard, plastics, …
- Absorbed by water and many organic substances
- High chemical sensitivity

Terahertz waves pass through a variety of amorphous substances – many synthetics and textiles, but also paper and cardboard are transparent to terahertz waves. Many biomolecules, proteins, explosives or narcotics also feature characteristic absorption lines, so-called spectral “fingerprints”, at frequencies between 0.1 and 2 THz. The two main advantages of terahertz radiation are thus the penetration of conventionally opaque materials on one hand, and a high chemical selectivity on the other hand.

One of the strongest absorbers for terahertz radiation is water, which – depending on the application – turns out to be a blessing or a curse: Air moisture limits the propagation of terahertz rays to a few meters, but vice versa, the characteristic fingerprint enables a high precision in humidity-sensitive measurements. Liquid water is an even more dominant absorber than water vapour. Unlike X-rays, terahertz waves do not have any ionizing effects and are generally considered biologically innocuous.

II. THZ NEW OPPORTUNITIES FOR INDUSTRIES

To know about the commercialization of terahertz technology, its source, transmission and detection methodologies have to be understood. THz Sources based on: Solid State, Gyrotron, Extended, Interaction Klystron (EIK), Quantum Cascade Laser (QCL), THz Pulses: Generation, DetectionTHz Transmission: Waveguides, Antennas and other communication Technologies. Terahertz possible industrial applications includeInspection & Security, Non-destructive Testing & Evaluation, Communication, Medical & Analysis, Pharmaceutical, and Time-domain Spectroscopy.

2.1 Terahertz Sources

- Electronic systems: High power, ideal for terahertz imaging
- Optoelectronic systems: High bandwidth, ideal for spectroscopy
- Pulsed lasers: Fast measurements, broad spectrum
- Continuous wave lasers: Precisely tunable, highest spectral resolution

The spectroscopically interesting frequency band of a 0.5 – 3 THz is not easily accessible. Electronic sources like Gunn or Schottky diodes with subsequent frequency multipliers, provide high output levels (mW range) up to some 100 GHz, yet become inefficient in the submillimeter range. Direct optical sources, like quantum cascade lasers, are usually limited to frequencies > 5 THz, even when operated at cryogenic temperatures.

Optoelectronic terahertz generation is an expression for indirect methods, where near-infrared laser light illuminates a metal-semiconductor-metal structure, generating a photocurrent that becomes the source of a terahertz wave. Both pulsedand continuous-wave (cw) techniques have been realized, and both have their advantages and limitations. Pulsed terahertz radiation offers a higher bandwidth (typically 0.1 .. 5 THz) and permits very fast measurements – a spectrum can be acquired within milliseconds. On the other hand, the frequency resolution is limited to several GHz. Vice versa, a cw system features a somewhat lower bandwidth (typ. 0.1 .. 2 THz) and requires longer measurement times – acquiring a spectrum takes several minutes –, yet the frequency can be controlled with extreme precision (down to single MHz).

Many research labs offers ultrafast fiber lasers and a new spectroscopy setup for pulsed terahertz generation, and DFB diode lasers for cw terahertz applications. Our Spectroscopy Extensions provides all required components to get an actual measurement started. Complete “TopSeller” configurations are available for some of the most common frequency-domain terahertz applications.

2.2 Terahertz Components

In this section, we highlight a few of the major componenttechnologies that have been developed for terahertz applications.They broadly fall into two categories: sensors andsources. Space does not permit us to examine other terahertzcomponent building blocks such as guiding structures,quasi-optics, antennas, filters, or submillimeter-wave materials.

III. THE NEED OF HIGH PERFORMANCE TOOLS IN MANY FIELDSIS A GREAT OPPORTUNITY FOR THZ TECHNOLOGIES

After techniques like ultrasound or IR Terahertz is becoming a new competing technology for inspection, control and monitoring.Because of their ability to penetrate through barrier materials (clothes,packaging), to perform non-contactand non-ionizing testing, THz systems are starting to compete with less safe technologies like X-rays or nuclear.THz technologies are also expected toopen new applications, especially inBiomedical and in Telecommunications,that are going to become the drivers of the THz market growth in 5 to 10 years. This report provides a study of THz potential and challenges in more than 25 market segments such as mail scanning, oncology, composites NDT, wireless communications, as well as an application roadmap for the next decade.

3.1 Terahertz Transistors

The terahertz transistor basically has higher speed (in GHz), High power efficiency, and high heat reduction capacity. These transistors have a fast switching rate of more than trillion times per sec. They also have the capability to perform 50 to 100 times faster than normal traditional transistors. The first terahertz transistor was only capable for handling 3GHz. But the latest terahertz transistors is capable of handling more than 800 GHz (scientists at the University of Illinois at Urbana-Campaign have discovered a transistor with a frequency of 845GHz and 300GHz faster than previous discovery).By using this technology, we can create lot of real time functioning and powerful computing techniques such as grid computing, nano-computing and other researches.

Terahertz transistors basically contain three major changes than other conventional transistors. They have thicker source and drain regions and a special ultra thin insulating silicon layer too. These silicon layers integrate below the source drain region. The comparison between terahertz transistor and normal transistor is given below.

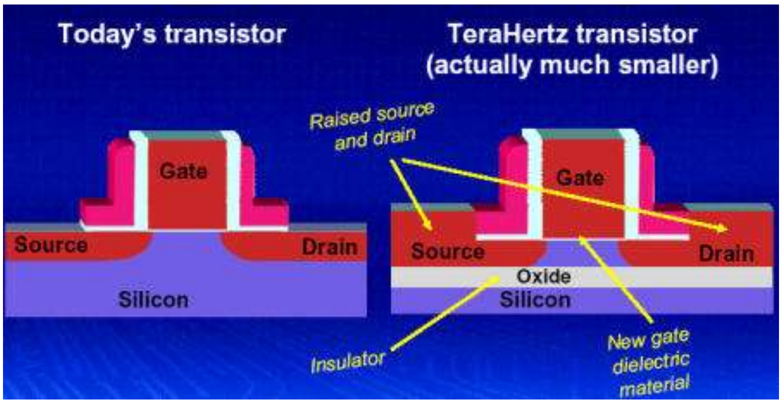


Fig. 3 Comparison Between Terahertz Transistor and Normal Transistor

Terahertz transistors are from made from indium phosphide and indium gallium arsenide that helps to increase its speed and thermal handling efficiency. The grading is an important factor that affects the transistor performance. The compositional grading of these components enhances the electron velocity and also improves its efficiency too. The construction of these transistors is very complex and researchers also refine their fabrication process to produce tinier transistor components as compared to normal transistor. They are designed to be very thin in shape and size (12.5nM approx). Vertical fabrication scaling process is usually used so as to reduce the distance of electron travel and produce a higher speed with better efficiency than before.

IV. APPLICATIONS

The TeraHertz gap is filling up fast, because there are great opportunities for new technological developments in testing, security, analysis, communication etc...

- Dynamic Nuclear Polarization for Nuclear Magnetic Resonance
- Dynamic Nuclear Polarization for targets used in nuclear research
- Time-domain THz spectroscopy

4.1 The Terahertz Market Will Reach Around€350m In 2022 !

THz Applications Industrial NDT Defense & Security Biomedical Other Composition analysis Pharmaceutical products QC Explosives and harmful materials point sensing Bio/Chemical agents detection Oncology Dentistry High-speed outside communication Broadband indoor communication Control of semiconductors Other Applications Mail scanning Baggage & package imaging Biosensors Astrophysics Atmospheric Chemistry Other Applications

V. CONCLUSION AND FUTURISTIC APPROACH

The 0.1 to 10 THz frequency range of the electromagnetic spectrum is where electrical transport and optical transitions merge, thus offering exciting opportunities to study a variety of novel physical phenomena. By combining THz technology and nanotechnology, we can advance our understanding of THz physics while improving and developing THz devices. In developing countries like India terahertz technology has not yet anchored widely. The traces of research in tera science could be deep rooted with this frame sheet. In particular, recent advances in the study of THz dynamics in carbon nanomaterials — carbon nanotubes and graphene — have not only broadened our horizon of THz research but also generated new excitement regarding their exotic AC properties and potential towards novel applications. The new approach terahertz nano science is the advancement can be focused in future. Every technology is focusing towards nanoscience, and it can be extended to terahertz technology also. Futuristic doors can be knocked in the areas of Absorption, emission, and scattering of THz waves in nanostructures, Ultrafast dynamics of carriers, excitons, and phonons in nanostructures, Nonlinear optical spectroscopy using intense THz radiation, THz sources and detectors based on nanostructures, Coherent THz magneto-optical and electro-optical spectroscopy, High-frequency electronic devices, THz sensing and imaging using nanostructures, growth and purification of nanomaterials for THz studies.

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