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APPLICATION NOTES

(Terasense® THz-imaging technology)

TeraFAST-256-HS
High Speed Terahertz Line scanner
(http://terasense.com/products/thz-scanner/)
was designed specifically to fill the needs in non-destructive testing (NDT) and quality control for various INDUSTRIAL APPLICATIONS. *TeraFAST-256-HS* is now our flagship product and the most enhanced THz imaging system.

Below are our APPLICATION NOTES with regard to *TeraFAST-256-HS High Speed THz Line scanner* listed in priority sequence (i.e. with the most promising applications topping the list)

It should help you better zero in on the target groups/customers.

VIDEO showing Terahertz High Speed Line Scanner performance on conveyor belt:
https://www.youtube.com/watch?v=iHOt7Quyduk

1. SECURITY screening

Screening envelopes and small-size mail packages to detect hidden objects (e.g. knives, guns, cut and thrust weapons concealed in inside). It may also include security screening of small baggage at the airports or any other check-points.
Please watch our main video at: https://www.youtube.com/watch?v=iHOt7Quyduk

2. FOOD Industry – NDT, QC, process control

2.1. Detecting forging objects (including plastic, metal, stones etc) in dry food products food of food packaging to avoid any debris inside the food at the end of the production line (this may happen if the plastic debris are too big for the particle aspirator to absorb it).

2.2. Detection of insects in dry food products (or in food packaging). Reports of insects and other foreign objects found in food are a cause of concern for food manufacturers retailers and consumers alike. Unwrapping a chocolate bar might reveal an unpleasant surprise like insects and pieces of metal or glass.
Please see our NEWS for additional information on the subject.
(http://terasense.com/news/terahertz-imaging-technology-infiltrates-food-and-agricultural-industries/)
(http://terasense.com/news/mars-founds-plastic-in-chocolate-bars-in-55-countries/)

2.3. It is a common knowledge that quality control for detection-through surfaces in agricultural and food industries is crucial to avoid using ionizing radiation. So, another simple example is a non-invasive technique used for monitoring the availability/number of hazel nuts inside of chocolate candy (already wrapped and packaged in a box). For instance, one of our distributors in Europe wanted to

use (instead of X-ray machine) our THz imaging technology where our THz imaging sensor arrays were meant to handle the task of checking '*if Pick-n-Place Machine has actually put 5x 29g candy Bars into a cardboard carton'*. Seeing through cardboard, paper or polyethylene package poses no problem to our THz imagers.

3.PHARMACEUTICAL & COSMETICS Industries– NDT, QC

3.1. Another application associated with quality control in production environment is running NDT of baby's diapers (nappies) on conveyors to determine presence of moisture inside a material or wet areas or foreign bodies and any other inhomogeneous areas inside.
Please see our NEWS for additional information on the subject.
(http://terasense.com/news/determination-of-water-content-in-diapers-with-terasense-thz-imaging-system/)

3.2. Checking for availability of tables in the blister pack (to make certain that the all tablets have been placed in the pouch inside.) The packing material should be a paper or plastic (but should not contain metal foil).

4. WOODWORKING & LUMBERING Industries – NDT, QC

4.1 Wood analysis: Checking wood for moister or wet areas inside)
The application is intended to see if there is water in the wood (or depending from the "grey scale" how much water there is into the wood).

4.2.Lumbering (checking wood for knots, hollows, nails including pest control (insects inside) or any internal detects and even measuring knots)
Detection of defects that are difficult to detect using other current technology (color vision). One of these defects is the knots (some knots don't have color contrast, but the density of the knot is much higher than the wood surrounding it, which makes them visible in THz waves.
Please see our NEWS section for additional information on the subject.
(http://terasense.com/news/terahertz-wood-industry/)

5. PEST CONTROL / insects control services – detection of pests

Detecting termites and other insects (warms, bugs, larvae, maggots, slugs etc) inside the wood.

6. CERAMICS INDUSTRY - NDT in production

Defectoscopy of ceramic tiles or other ceramic products on production line.
Detection of internal defects, hollows, cracks and inhomogeneous impurities
(http://terasense.com/news/terahertz-screening-as-a-safe-and-cost-saving-alternative-to-x-rays-in-ceramic-tiles-industry/)

7. RECYCLING INDUSTRY - paper sorting / classification

Recycling industry may require sorting paper into certain categories (e.g. writing paper, hard paper board and some other kinds). Our THz images can do it based by measuring transmission/absorption of each type of paper .

8. CIGARETTE INDUSTRY – NDT inspection of carton fullness

THz rays cannot penetrate metal, accordingly, we cannot see though metal foil wrapper, which is used inside of most cigarette packs (to count cigarettes) . However, since metal leaves perfect contracts in THz imaging, we can easily count cigarettes packs inside of a cigarette carton without disturbing package integrity.

9. PETROCHEMICAL & CHEMICAL INDUSTRY - NDT & QC

Some customers involved in the petrochemical industry are looking for a way to see if products they load in tank trucks are of good quality and not contaminated with water. The liquids to be checked that are in the focus of attention are diesel, benzene, petroleum, kerosene, alcohol – all perfectly transparent in THz rays.

Many of these substances are (like alcohol) are absolutely transparent for T-rays. As opposed to alcohol, water remains impervious for Terahertz rays, and therefore will be perfectly visible by contrast with other transparent substances, like kerosene, gasoline, etc.

Using the unique properties of the Terahertz wave, we can identify impurities and contaminants in various liquids, and differentiate between them.

10. WIND TURBINE production lines – NDT of composites

Inspecting composite materials related to Wind Turbine blade fabrication. Detecting concealed defects or extraneous objects inside the turbine blade materials, sometimes as small as 3mm in size. Many composites (except for high carbon materials) are fairly transparent in THz light,

11. AUTOMOTIVE INDUSTRY - NDT

11.1- We have completed small-scale R&D meant to demonstrate capabilities of our THz imaging systems to indentify the presence (or absence) of steel objects (steel wires etc) inside of rubber tyres and rust on them (in both *Reflection* and *transmission* imaging modes).
In all of the cases our THz cameras proved to be perfectly usable (especially in transmission mode), while these test allowed us to establish certain dependence between the thickness of rubber material and our THz capabilities.

11.2.- We had one inquiry from automotive industry aimed at using terahertz imaging to see if run-flat tire have some kind of special nylon inserts attached to the alloy wheels (and therefore concealed under the rubber tire precluding visual inspection). Without our THz imaging capabilities at hand, when a vehicle arrives to have tire fitted, they had to take the tire off all the wheels, just to check whether nylon inserts on run-flat sections had been installed or not (and check the model of nylon inserts required) and then put the tire back on.

12.OIL & GAS - QC & NDT for Petroleum products

The clients inquired into our capabilities with respect to identifying the presence of iron and sand particles (small-size fraction) in gas flow supplied under certain pressure. Iron particles are absolutely non-transparent in THz radiation, therefore 100% detectable by contrast in this media. Sand particles in the flow inevitably cause certain scattering of Terahertz radiation, but are detectable as well. The quality of the resultant image will largely depend on the speed of flow.

13. CONSTRUCTION MATERIALS & BUILDING TRADES - NDT, QC

Using THz imaging camera in building trades to find out moisture in concrete, floor screed, plaster, wall paint and so forth.

Successful application depends on many factors:
Type and thickness of material (up to 5 cm) // internal configuration // Distance to the target // Frequency of the THz generating source, and water content. Tests are yet to be held.

ADDITIONAL INFORMATION & LIMITATIONS OF THz IMAGING TECHNOLOGY

1) MAXIMUM PENETRATION DEPTH

Each material has its own *transmission* ratio and behaves differently in THz light (i.e. has its unique absorption index). We cannot speak about some average figure for all materials.

In determination transparency of a particular material for THz rays, the general rule of thumb is like this : Conductive materials are likely to be non-transparent in our THz spectrum (except for thin films). Water and water-containing materials are not transparent. High-carbon materials (like high-carbon plastics or composites) are usually not-transparent either.

Metal and metal-containing materials heavily attenuate and absorb THz radiation and therefore are not transparent. With metal-containing material penetration index is very low (this is why we can perfectly detect metal knife hidden in a box due to the high contrast its creates in THz image.

Non-conductive materials, on the contrary, are likely to be fairly transparent. Many types of plastic and rubber, PVC, synthetic foam (polyfoam) some composite materials, wood have fairly low absorption and therefore are transparent in THz light. With some of these materials max thickness (or penetration depth) can reach 10-15 cm. Penetration depth in Teflon, PTFE, Silicon can be higher by an order of magnitude because of their extremely high transmission ratio.

Each material transparent for THz waves has is own refraction index. Silicon, TPX, Teflon and PTFE are great for THz optics because they have very high refraction index and very low absorption.

All in all the maximum penetration depth a particular material can be effectively scanned depends on a number of factors (apart from the type of material proper), not the least of which are a) the power output of THz generating source; b) the mode (reflection vs transmission*); configuration and shape of target material (i.e. rectangular cross section vs variably configured shapes; Internal structures).

*Note: *Tera-FAST-256-HS* employees transmission mode because it is more effective.

DIFFERENTIATION / DISTINGUISHING CAPACITY

Our detectors and sensor arrays are of ***broad-band*** type and, accordingly, are not *frequency-selective*. It follows that our technology does not allow obtaining spectroscopic data/images. That is why *we can only differentiate substances based on their absorption / transmission* data (rather than their spectroscopic data).

Our THz imaging systems can distinguish only ***inhomogeneous*** materials (i.e. different from surrounding substance in one or more critical parameter) and show the contrast in image.
As you see , there may be a number of factors that come to play in the matter, for instance density and thickness of target material; power output of THz generating source; presence of hollow parts inside materials etc .

For instance, if a powdered drug is placed next to a wheat flour, our camera is unlikely to distinguish one from the other, because both materials are ***homogeneous*** in nature (have the same absorption capacity and fraction size).

SPATIAL DISTRIBUTION of material

Spatial distribution of materials under inspection on conveyor belt can also affect penetration capacity of THz light (i.e. if pieces of materials are piled up they can form very thick layer beyond penetrating capability of our equipment. Spatial distribution of materials on a surface being scanned can also affect our THz camera ability to distinguish between uniform (homogenous materials). Non-uniform (inhomogeneous materials i.e. different from the surrounding materials should be easily distinguished (be detectable) by contrast in THz image.

RESOLUTION and DETECTING SMALL OBJECTS

Our technology can easily detect inhomogeneous areas (defects or foreign bodies) in a number of materials transparent in THz spectrum). One key limitation of our technology is that the size of internal defects /objects to be detected should not be less than 2 mm – 3mm. In other words should defects/objects should commensurate in size with the wavelength employed by our THz imagers (around 1mm – 3mm depending on frequency specs preferred). This limitation is imposed by the physical principle employed (wavelength), as well as the size of our pixel (1.5 x 1.5mm – for standard 2D cameras and 1.5 x 3mm – for high speed line scanner). Again, the primary objective of our THz technology is detecting concealed defects, rather than obtaining their sharp images.