T-Rays

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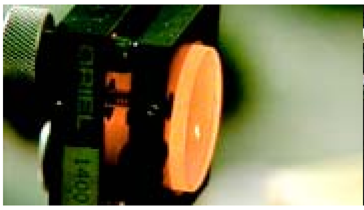
Bernadette looks at the world of T-rays. They're safer than X-rays and they can reveal the contents of packaging in a way X-rays can't, so they could be the way of the future for security screening.

Bernadette Nunn: You can't see it but these laser light pulses are manufacturing something called terahertz radiation - or T-rays.




Prof Derek Abbott: (Founder of the National T-ray Facility at the University of Adelaide) T-rays are basically a form of light. It's just that simply they're at a frequency that's between infra-red and microwave frequencies so it's stuck between the optical world and the electronics world. The terahertz is the frequency.

Bernadette Nunn: Astronomers use the terahertz frequency region to look at stars because a lot of space radiation is in the T-ray region.

Prof Derek Abbott: But the problem has been that scientists didn't know a way to make T-rays in the lab so we were able to detect them but not generate them. And this ability has really only emerged in the last ten years so that's why they're new and people haven't really heard of them.

Bernadette Nunn: Yet terahertz radiation was discovered in 1896.

Prof Derek Abbott: The reason why T-rays are so hard to generate in the lab is that they're kind of in no man's land, stuck between the world of optics and the world of electronics. This shows you the spectrum of light. SO this shows you the frequency spectrum and as you can see T-rays or the terahertz region is here and one side you've got visible light and on the other side you've got microwaves and basically this is in the domain of electronics whereas on this side it's optics and photonics so terahertz is bang in the middle.

T-rays are bang in the middle of those two regions and that's what makes it such a challenging area.

Dr Sam Mickan: (Director of the National T-ray Facility) There have been established techniques for over 50 years for generating optical light but as you scale those down to longer and longer wave lengths which is where you get to terahertz, those techniques don't work anymore. The same occurs when you use electronic techniques which you use to generate radar for example as you make them smaller and smaller going to higher frequencies, to reach that terahertz gap, those techniques tend to fall over as well. So it was necessary to develop completely new techniques to generate radiation in this gap.

Bernadette Nunn: One way to make terahertz radiation is based on an ultra fast laser.

Dr Sam Mickan: An ultra fast laser is a laser that can generate pulses of light that are in the order of 100 femtoseconds long. Now a femtosecond is ten to the minus fifteen seconds so it's an extremely short period of time, it's an extremely short pulse of light. That pulse of light is used in conjunction with a terahertz emitter - which can be either an optical crystal or radar. If you shine your ultra fast, your femtosecond pulse on to one of these terahertz emitters, a burst of terahertz radiation comes out the other side.

Bernadette Nunn: Measuring how an object absorbs the terahertz radiation reveals clues about the properties of the material.

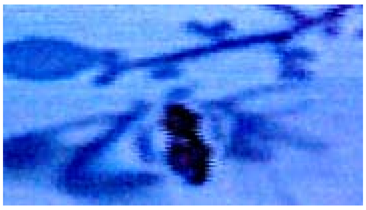
Gretel Png: (PhD student) If you shine T-rays on this leaf, you expect the T-rays that are transmitted through the leaf to be altered in some way or another. One obvious things that happens with any kind of electromagnetic ray, for instance light, is that the light on the other side of the leaf will be dimmer. We also expect that the T-ray to be delayed because this material here is a lot denser than the air that surrounds it and as a result of that any ray that passes through it will be delayed by a certain degree.

We look at what happens to the terahertz over time, (refers to screen) ….you can see that the terahertz data gives quite a good picture of what the sample was: the shape of the leaf, the veins and some kind of bug on the leaf.

Prof Derek Abbott: Basically the way we do this with T-rays is we blast the molecule with many T-rays all at once and we see which frequencies got absorbed by the molecule and which didn't. Each molecule has its own characteristic vibrational resonances and by measuring these vibrations we can identify one molecule from another. So it's like the molecule's fingerprint. So it's a bit like if you make a wine glass sing by making the wine glass resonate with your hand different wine glass shapes will have different notes and it's the same with molecules.

Dr Sam Mickan: If the radiation passes through a vacuum, we know the radiation hasn't been changed at all. If it's passed through some kind of object, say a piece of bone, then we can determine, because the pulse we detect is slightly changed, the amplitude is slightly reduced, the wave form may be slightly different shape, it may be delayed in time so the pulse different shape so from that shape we can go back and determine some of the properties of the object we're looking at.

Prof Derek Abbott: What you're seeing here is a picture of a butterfly with a little twig just above it and we blasted the butterfly with many different terahertz frequencies all at once, from .01 terahertz all the way to 1 terahertz.



Different details in the butterfly's wings emerge for different frequencies so the darker the patches of the image means it's absorbed those terahertz frequencies more than others. What that tells you is that the different regions of the butterfly's wings are composed of different molecules that absorbing different terahertz frequencies so that tells us something about the molecular composition. This is the basis of that detection method, that molecular fingerprinting.

Bernadette Nunn: T-rays can effectively see through packaging - as paper, plastic, clothing, even wood appear transparent under terahertz radiation which distinguishes between properties that are broadly defined as wet and dry.

Dr Sam Mickan: We had a dry envelope which provides very little change to the pulse as opposed to the Australian $100 note where the ink that's been used to draw that note has some degree of dampness depending on the bonding of the molecules that make up that plastic note, and that is then visible because that changes the shape of the terahertz pulse as it passes through it. Seeing through the envelope just means that the pulse doesn't change much in the same way that optical light passing through clear plastic doesn't change much. Professor Abbott says T-rays have enormous potential for security screening - complementing rather than replacing X-ray technology.

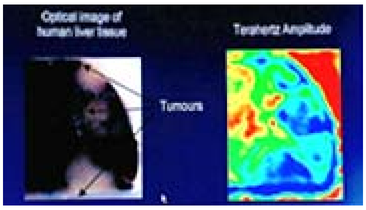
Prof Derek Abbott: The X-ray scan only tells you the shape of the object in there so if it's the shape of a gun, you'll see a gun. Whereas the T-rays …won't just give you the shape of the image, it will give you that molecular fingerprint. So I will be able to detect maybe if there's plastic explosives in there and things like that that you wouldn't normally detect with the X-ray. T-rays can discriminate for example between anthrax and salt in an envelope because the anthrax molecule will have different vibrational frequencies to the salt molecule. So by blasting the envelope with many different T-ray frequencies all at once and seeing which frequencies get absorbed and which don't gives us a unique fingerprint of anthrax.

Bernadette Nunn: Unlike X-rays, T-rays are safe for human application because they're non-ionising radiation.

Prof Derek Abbott: Because X-ray photons are such high energy they blast right through soft tissue in the human body so you don't get much contrast in the skin an in the soft tissue when you're detecting cancer in the surface X-rays are not that good whereas T-rays are more gentle and will give you more contrast in detecting cancers near the surface. It turns out that somewhere between 50 and 80 % of cancers tend to be surface cancers and so this is the niche where T-rays will win over X-rays.

Bernadette Nunn: The Adelaide University team is researching use of terahertz to safely distinguish between cancerous or healthy cells - without surgery.

Dr Sam Mickan: Most cancer tests involve taking away some of the cells that seem suspect, testing them in a laboratory somewhere else and coming back with an answer later on and so removing those cells of interest involves some kind of surgery. On a small scale that's OK but on a larger scale that can be quite traumatic to the patient. In this slide we can see some exciting results about the possible results of terahertz radiation because we can see healthy tissue and diseased tissue and the areas of diseased tissue show up very differently in the terahertz image to the healthy tissue.



The healthy cells tend to be green and red, the tumours, the dangerous cells tend to be a darker blue colour and that means we can use the terahertz radiation to detect the differences between the healthy and the dangerous tissue. What we see here is dead cells. When cells are living they're not static, they're changing every day. We want to monitor healthy cells and unhealthy or cancerous cells and see what terahertz sees in terms of the difference between the two cells and also how that signal changes over the growth cycle of the cell and then pull out that actually show the presence of cancer and the absence of cancer as opposed to other signals that appear in the picture you've got there. The next step is to look at cancerous growths in living tissue and we're going to be doing that with mice. So we'll have mice with some kind of skin cancer and then areas of healthy tissue and we're going to compare them and see how the terahertz images are different.

Bernadette Nunn: The Adelaide Uni team predicts that T-rays will play a bigger role in the future than X-rays do now.

Dr Sam Mickan: It's a portable machine in terms of the size of a photocopier and it's affordable in terms of medical instrumentation. It's a lot cheaper than X-ray machines and MRI machines… and surgery as well.

Prof Derek Abbott: At the moment X-rays are huge big machines, they're dangerous, so you don't see x-rays in the home - it's always in hospitals. Whereas with T-rays because it's safe and because it has the potential of becoming very compact, you could envisage a future T-ray machine being the size of a shoe box or smaller. I could see these things being in everybody's home one day for doing regular health check ups yourself.