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Time to Bridge the Terahertz Gap



Researchers at IMRA turn to THz-capable components in pursuit of a molecular clock that can more accurately measure time, down to the second.

The scientific community is striving to bring life to the so-called “dead zone”, a region of the electromagnetic (EM) spectrum between electronics and optics. This band, often referred to as the “terahertz gap”, resides between 100 GHz and 30 THz. Below it lies the microwave bands that are increasingly being consumed by numerous commercial and scientific applications. Above it, infrared devices like thermal imaging, night vision equipment, and fiber-optic transmission and data storage are now common.

Within the terahertz technology gap lies a vast reserve of bandwidth poised for development. However, the development of user-friendly technologies capable of generating, manipulating, and detecting radiation within these frequency bands is not only technically challenging but has also been hindered by the limitations of available THz-capable components.

IMRA, a creative research and innovation organization that develops essential technologies for industrial use, was able to overcome many of the issues associated with the THz regime recently when working at frequencies above 300 GHz. Researchers at the Colorado-based laboratory were looking to use mol-

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ecules as stable frequency references that could potentially be used as clocks.

"Let me be clear, we are not redefining the definition of a second," explains Research Scientist James Greenberg, a program manager at IMRA. "The definition of the second is always going to be a laboratory experiment that's very complex, but there are many reasons why you do need a practical implementation to more accurately measure a second."

While it may seem esoteric to be concerned about the accuracy of a second, several future industries stand to benefit from this functional research; a noteworthy one includes space travel.

Motivating the move

"Future space navigation will benefit from this type of research," adds Greenberg. "You can't use GPS in space because there is no "G" in your global positioning system. So, if you want to know where you are, you need extremely good inertial sensors and timekeeping."

While space travel is provocative and exciting, the urgency to bridge this terahertz gap is currently being driven by numerous other, more terrestrial, applications. For example, the development of 6G wireless communication and beyond. Higher frequencies between microwave radiation and infrared light are essential for achieving wider bandwidths which will enable faster data rates and reduce overcrowding.

"The carrier frequency of 300 GHz is 150 times larger than two gigahertz where the current cellular network is today," explains Greenberg. "So, take the number of devices we currently have and imagine multiplying that by a factor of 150. That's the biggest driver in going into a higher frequency."

Other industries that stand to benefit from better utilization of the THz band include radio astronomy, GPS navigation systems, navigating in areas where GPS is unavailable like underwater, caves,

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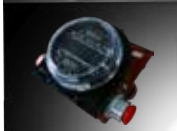


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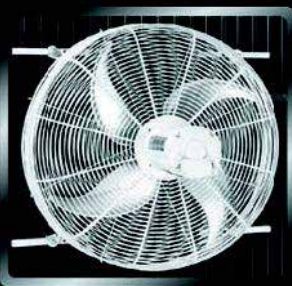
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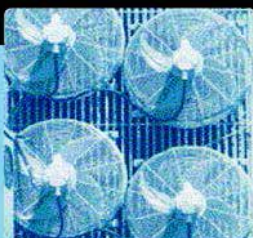
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Another breakthrough will include terahertz radar which will provide the missing link between traditional radar and lidar - Light Detection and Ranging. For example, lidar can see objects much smaller than radar, but cannot see through clouds. Terahertz radar can perform better than lidar in inclement weather while improving the angular resolution of traditional radar. It is also complimentary to both radar and lidar in that some materials exhibit different opacities in the different spectral ranges.

IMRA research

During their research of alternatives to the current state-of-the-art optical atomic clocks operating at several hundreds of terahertz, IMRA researchers encountered the common issue of standing waves, also referred to as signal reflections or mismatches. These undesirable waves, or ripples, can attenuate power output, distort the information on the carrier and, in extreme cases, damage internal components.

To alleviate the problem of standing waves at lower microwave frequencies, engineers rely on Faraday rotation isolators – more commonly referred to simply as isolators. At their very basic level, an isolator is a two-port, input and output, component that allows EM signals to pass in one direction but absorbs them in the opposite direction. The problem is that traditional isolators fail to deliver at higher frequencies within the THz regime.

IMRA was working at hundreds of gigahertz to interrogate molecules – which naturally rotate at a very specific frequency. A molecule will only absorb radiation when it is identical to the frequency at which it is rotating. The challenge for researchers is to efficiently reach frequencies within the terahertz band, where the majority of small molecules rotate.

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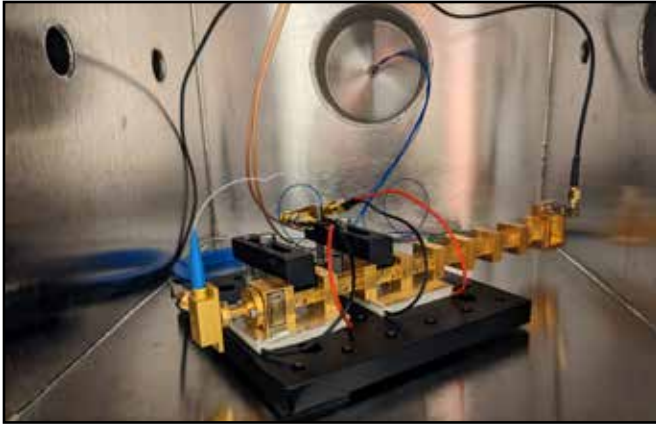


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Instead of multiplying microwaves up, which is most common, IMRA researchers used a photonic oscillator to divide lasers down using dissipative Kerr soliton (DKS) microcombs.

By generating a 301.442 gigahertz wave the researchers were able to talk to nitrous oxide (N₂O) molecules in a vacuum chamber where they were isolated. However, reflected waves would have interfered with the signal, delivering sub-optimal results. Therefore, Greenberg and his team decided to insert an MMW isolator that worked within the WR 3.4 band (220 GHz - 325 GHz) into the waveguide.

"We actually had a WR 3.4 band isolator from Micro Harmonics on the shelf from past research projects," explains Greenberg. "We plugged it in and got fantastic results."

Under a NASA awarded contract, Micro Harmonics Corporation designed an advanced line of MMW isolators capable of optimal operation between WR-28 and WR-2.8 (26.5 GHz to 400 GHz). The commercial off-the-shelf (COTS) components offered IMRA the high isolation, low insertion loss and small footprint it was looking for.

THz Components

"High isolation was extremely important, and we were getting 30 dB of isolation with the isolators," adds Greenberg. "We were also starved for power because our transmitter was weak, and we were

really pleased with the low insertion loss the isolator provided which allowed us to get the maximum signal to noise."

For molecular spectroscopists and people who work with clocks, tiny effects have huge implications, namely for GPS. For example, the difference between parts per million and parts per billion is the difference between having GPS and not.

"If you can't do better than a part per billion, you can't have GPS," adds Greenberg. "It just doesn't work."

Since the initial experiment, IMRA has moved on to study other molecules in its research.

"The Micro Harmonics isolators also have a really wide band which allows us to look at a range of molecules at different frequencies using the same spectrometer as previous experiment with the exact same isolator," says Greenberg.

The pursuit of a molecular clock

Atomic clocks all work the same way. There is an oscillator operating at a specific frequency and the key is to stabilize that frequency to an atomic reference, something that will not change no matter where or when you look at it. An atom, for example, is going to react the exact same way anywhere on Earth as well as in space.

While the cesium atom remains the industry standard, the world's first atomic clock actually used a molecule (Ammonia NH₃).

"I love that what is old is new again," concludes Greenberg. "The scientific community is now producing portable atomic clocks that use molecules. Some can outperform commercial cesium microwave clocks that most of the world relies on for their time standard. This is just the tip of the iceberg for what we are going to find by bridging the terahertz gap."



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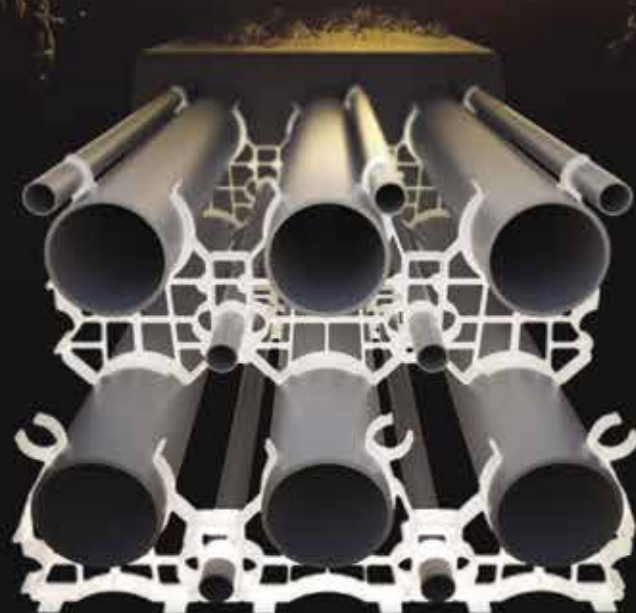
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Most of this HMI/SCADA software runs on a dedicated computer system. “Today, sophisticated web server technology facilitates access to HMI screens and the viewing of SCADA systems. Newer PLCs and RTUs frequently incorporate web servers that allow diagnostics and monitoring via browsers as well,” says Paul Shu of ARISTA Corporation, a leading provider of computing platforms and visualization display products for manufacturing environments across all industrial sectors.

Facilitating Implementation of Web-Based HMIs

Historically, HMI/SCADA client software has run on a dedicated computer with a compatible Operating System installed that exhibited slow loading times during startup and restart procedures. This reduced productivity on a routine basis, cutting into valuable production time. Updating and maintaining software on individual PCs resulted in higher cost of ownership and even more downtime.

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Fortunately, web-based applications have revolutionized accessibility by enabling connectivity from any location using a web browser. Still, for manufacturers, the integration of the HMI presented several challenges.

When standard web browsers are used, operators must open a browser and type a long website address to be routed to a specific program. Users have the liberty to explore various unrelated websites as well, but

this only exposes the system to potential risks inherent in online browsing activities.

Now manufacturers can optimize operations by utilizing software-enabled web clients to streamline web-based HMI implementation. The best solutions involve touchscreen displays that can serve up HMI pages on multiple monitors, in multiple split screen configurations, or at cloned workstations to streamline the management of equipment across the production line.



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ARISTA, for example, has introduced a web client computer called Q8 Edge that is designed to serve as the display or control panel for web-enabled PLCs, HMI systems, and IP cameras.

In the case of the Q8 Edge web client, ARISTA designed the interface to automatically connect with the assigned web pages without opening a browser and entering an address.

"After initial setup, the browser automatically launches with the assigned web link after turning on the PC's power or restarting the system, so the operator gets to needed information much faster," says Shu.

Hybrid remote desktop services (RDS) and web-based applications can also be launched simultaneously, when needed. The web client supports clones, duplicate screens, and multi-screen. Touch Screen is supported as well. The applications can be displayed one by one by toggling a hot key, or all applications can be displayed by split screen. For data security, the USB drive function is disabled automatically after the system boot up. No external USB drive can be used to download or



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upload data.

In addition, ARISTA prevents access to other sites or browser features. "The operator can only see what is displayed on the screen and cannot change anything beyond the intended HMI pages," says Shu.

When troubleshooting is necessary, the Q8 Edge can be securely accessed using interactive remote mirroring by an administrator.

The approach facilitates installation of a wide range of pharmaceutical cleanroom grade computers, panel PCs, monitors, and KVM. To promote efficient use in space constrained areas, various types of mounts are available, including pendant arm, wall, pedestal, ceiling, and VESA.

When web client computers, Panel PCs, or Mobile Workstations must be customized to the manufacturer's process, this can be accommodated as well.

"If there are unique requirements such as space constraints, we can meet with the manufacturer to fully understand the situation and design a solution," says Shu. "In six to eight months, we can deliver the first articles for approval, and begin production of the equipment."

As manufacturing facilities continue to actively explore new avenues to enhance productivity, the utilization of web-based HMIs on industrial-grade computers can significantly boost efficiency. This innovative solution, characterized by streamlined and adaptable display features as well as improved security measures, promises to enhance the profitability and productivity of plant operations in the years ahead.

For more information, contact ARISTA Corporation at (510) 226-1800, e-mail sales@goARISTA.com, or write to 48460 Lakeview Blvd., Fremont, CA 94538.

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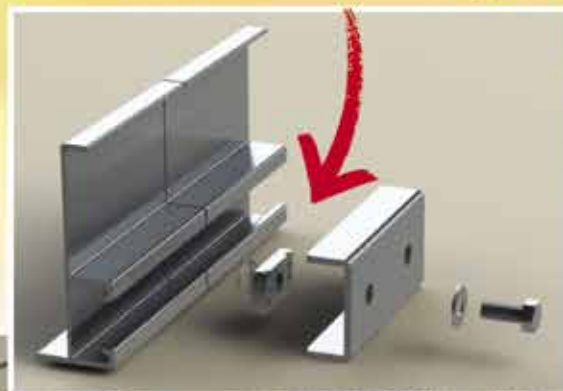
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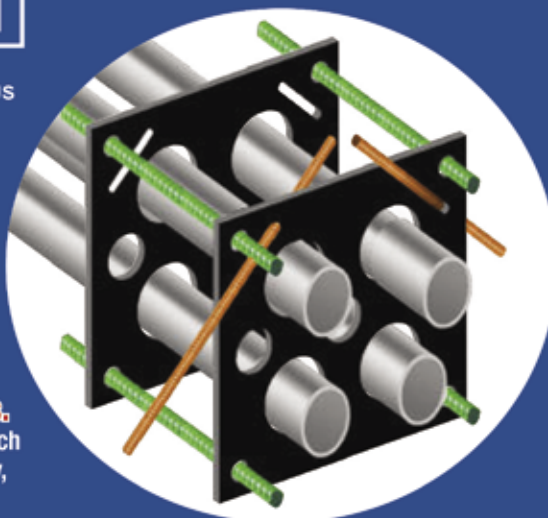
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