http://www.imperial.ac.uk/electrical-engineering/research/optical-and-semiconductor-devices/research/terahertz/

FURTHER READING

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'3-D printed 1.1 THz waveguides',
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3D printing allows for record-breaking, low-cost waveguides operating at 1.1 THz

printing: the future of THz

Researchers from Imperial College London, the UK's National Physical Laboratory (NPL), and the University of Tokyo, have demonstrated a 3D-printed metal-pipe rectangular waveguide operating at a record-breaking frequency of 1.1 THz.

3D printing has found uses in a huge number of industries and applications, and its strengths over traditional manufacturing techniques were quickly exploited by the communications community. William Otter and Stepan Lucyszyn, two of the researchers on the THz project, told us that at Imperial College London, 'the initial research into 3D printing of radio frequency metal-pipe rectangular waveguides was for the microwave frequency range of 8 to 12 GHz (X-band), and the success of this work gave our team the confidence to move up into the millimetre-wave frequency band, of 75–110 GHz (W-band), where the small dimensions require a tighter manufacturing tolerance.'

Simplifying complexity

3D printing, also known as additive manufacturing, is the layer-by-layer addition of material to create a structure. It dramatically reduces the time and the cost of producing components, while allowing more design freedom. In comparison with traditional manufacturing, ever more complex geometries can be realised with 3-D printing as fewer mechanical constraints are imposed on the process. With large complex structures, this means reducing the number of individual components needed to create a subsystem, thereby reducing the number of tests required during the manufacturing process.

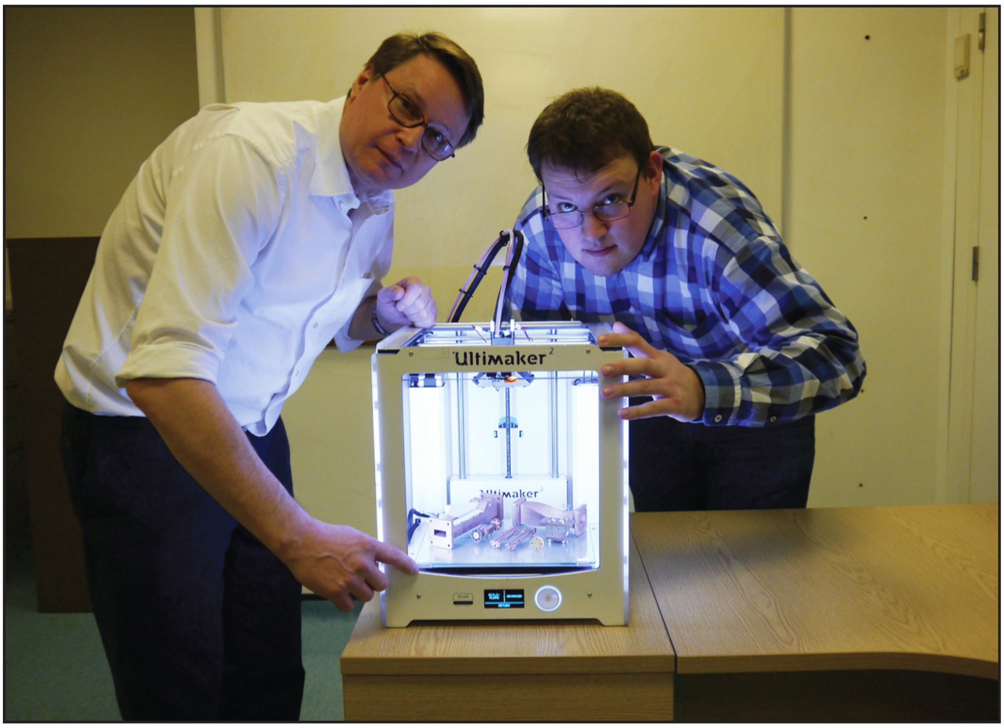
This design freedom helped produce excellent initial results in the W-band, comparable with off-the-shelf commercial waveguides. However, as Otter and Lucyszyn explained, they did not stop there, 'This high level of performance was also demonstrated at W-band with a 6th-order Chebyshev filter, which are notoriously sensitive to manufacturing tolerances.' The next challenge was to demonstrate a mechanically tuneable component that was fully 3D-printed. This was achieved using an X-band dielectric-flap phase shifter.

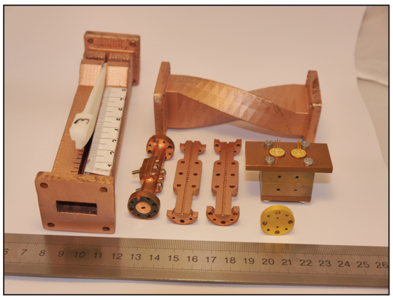
Onwards to THz

After these early successes the team kept increasing the frequencies of their components. 'We were pushing the mechanical limits of all 3D printing processes, but, we set our sights specifically on breaking the record for metal-pipe rectangular waveguides,' said Otter and Lucyszyn, 'and this was achieved with an I-Q vector modulator operating up to 500 GHz.'

Overcoming the limitations of 3D printing, specifically in regards to THz technology, to achieve record frequencies is where the collaboration between the UK and Japanese began: 'The main limitation for THz waveguides is the ability to 3D print with relatively large structures, having small feature sizes and high-quality surface finishes.' For this reason, the prototype for a new class of 3D-printers called RECILS, and developed at the University of Tokyo was used. The new RECILS technology, through its innovative method of controlling the photocurable resin level and detachment of cured resin, provides the required finish without further post-processing.'

Now that the team have achieved inexpensive THz technology, what doors do they hope to have opened?





TOP: Stepan Lucyszyn and William Otter, two of the researchers behind the record-breaking waveguides.
LEFT: From left to right: X-Band phase shifter, W-Band thru line, W-Band 6th-order Chebyshev filter, 500 GHz I-Q vector modulator. In the background is an X-band twist and the foreground shows the 1.1 THz waveguide.

Limitless possibilities

The work is expected to find future applications in high-performance imaging systems for security monitoring, satellite payloads and medical diagnostic equipment. Thanks to the team's techniques, according to Otter and Lucyszyn, 'these systems can be developed in a shorter time and at a significantly lower cost, and, as such, [the method] represents a paradigm shift in the manufacture of precision components using mass marketable 3D printers.'

To move ever closer to such a reality, the group have been developing minimal-part subsystems that break conventional design rules by exploiting the multiple degrees-of-freedom offered by additive manufacturing.

And this is, as Otter and Lucyszyn explained, the really exciting thing about the technology. 'Within a decade, ultra-high resolution low-cost 3D printing will be ubiquitous. It will become the norm to replace parts by downloading CAD files and printing and spray coating metal onsite.' This is particularly important for remote and inaccessible locations. Moreover, a printer offering multiple materials, perhaps even having exotic properties, will be capable of printing whole systems, the only limit being our imaginations.'