Room-temperature bow-tie terahertz detectors integrated with focusing optics

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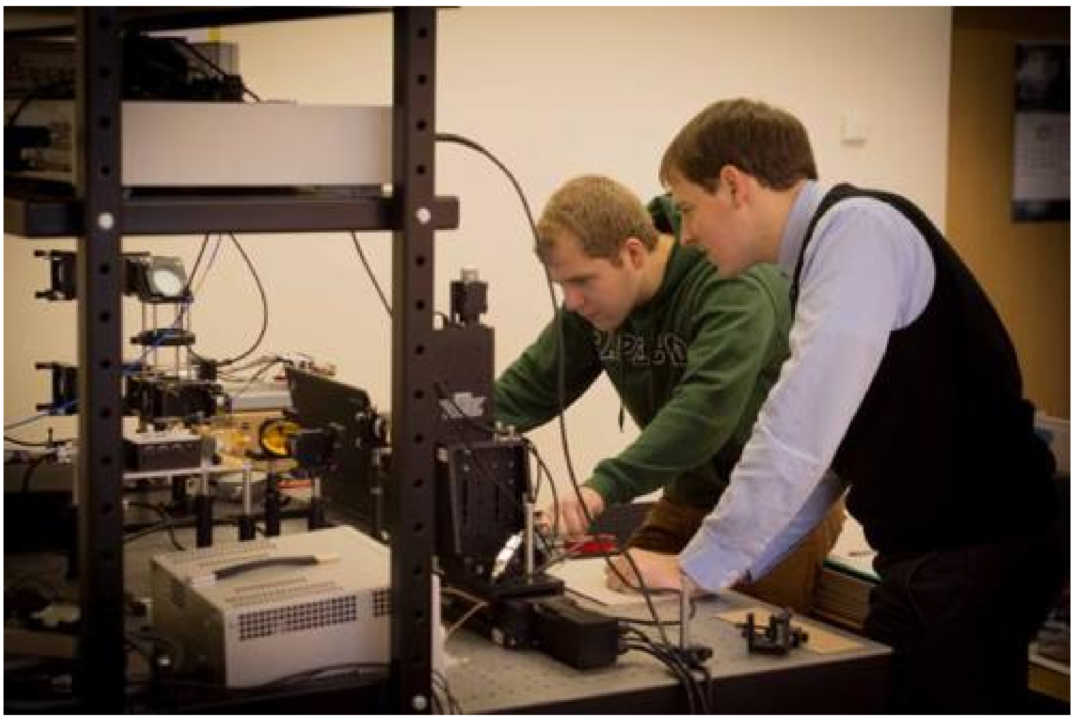


Linas Minkevičius (R) and Karolis Madeikis (L) investigating the THz detector with compact diffractive optics

Room-temperature bow-tie terahertz detectors have been successfully integrated with focusing optics for the first time. This achievement, from researchers at the Center for Physical Sciences and Technology in Lithuania, not only makes the detector much more compact and reliable, but the use of zone plates also enables an order of magnitude increase in the detection capability, making this system very attractive for use in terahertz imaging applications.

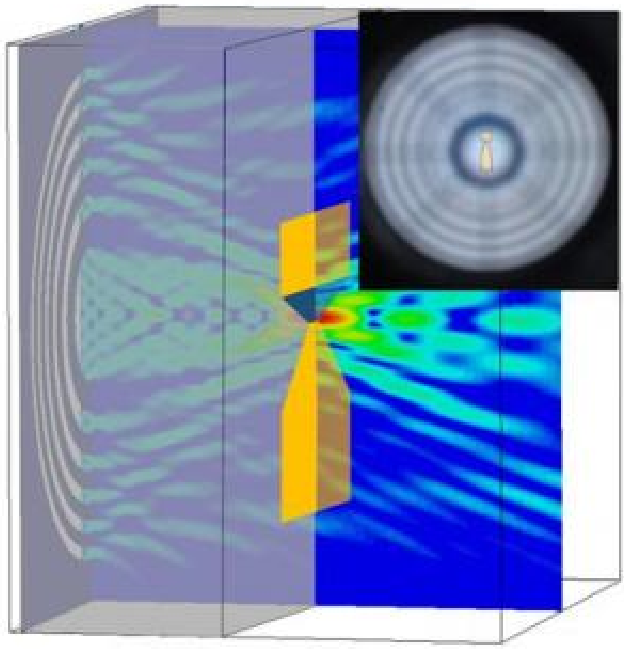
Smaller solutions

Terahertz (THz) imaging is a powerful tool in many applications such as security systems, materials testing and their identification and medical diagnostics. One of the limitations of these imaging systems at the moment is their physical size. Reducing the size is not only key to integrating the focusing optics and active components on to one chip, but also to making the system cheaper, more reliable and comfortable to use.

There are two 'elements' to the system that are being actively studied worldwide in order to reduce the size: more compact THz emission sources are being developed using quantum cascade lasers; and broadband and sensitive THz sensors are being developed using compact technology such as nanometric field effect transistors, Schottky diodes, microbolometers and bow-tie diodes. Less commonly studied are solutions to replace the bulky passive optical components such as parabolic or spherical mirrors from conventional imaging systems.

All in one

The team from Lithuania is focused on finding solutions to the challenges of THz imaging and spectroscopy, and one of their topics is the development of compact room-temperature operating sensors for real-time THz imaging cameras and sensor arrays for spectroscopic THz imaging.



The focusing features of the compact optics placed on the same chip with the THz sensor.

In their earlier research, they concentrated on the development of compact diffractive optics components for THz imaging systems.

"The first in this direction was the fabrication of free-standing zone plates and cross shape filter arrays, made from thin metal film used for focusing and frequency selection purposes," said Linas Minkevičius, lead author in this work. "The second step – filter array integration into the free standing zone plate – aimed to reduce the number of components and make the system more compact."

In the latest step, presented in this issue of *Electronics Letters*, the team show how they have further advanced the miniaturisation of THz imaging systems by integrating a room temperature InGaAs-based bow-tie THz diode, that has broadband operation up to 2.5 THz, with the secondary diffractive optics in a single chip.

"We have managed to attach the detector and the diffractive optics on separate sides of the semi-insulating semiconductor substrate," said Minkevičius. "This allowed us to simultaneously make the system more reliable and more compact while improving the sensing properties of InGaAs THz detector."

The measurements made with the detector at different angles of incidence showed an enhancement in the detected signal of an order of magnitude, which agreed with the team's numerical simulations, proving the effectiveness of the focusing performance of the zone plates.

Combined experience

Minkevičius believes that the key factors leading to the success of this work were collaboration, experience and technology.

"There are three important matters: first, the zone plate and detector design were selected by simulating the properties of the electric field distribution via the zone plate and substrate to the detector's apex using the 3D finite difference time domain method; secondly, fruitful collaboration with Prof. H. G. Roskos' group from Goethe University, Germany, and their experience in processing technology, let us overcome difficulties in the detector's manufacturing process; and finally, the most challenging issue was to arrange the zone plate focal spot and the detector active part at one geometrical point from both sides of substrate – this was achieved by employing advantages from our laser direct writing technique."

This solution is not only more compact, but also removes the problems arising from the need for precise optical alignment, as this strongly affects image quality and resolution. Another advantage is that this solution is not restricted to THz sensors of this type; it can be extended to other types of planar technology-based detectors as well.

More information: "On-chip integration of laser-ablated zone plates for detection enhancement of InGaAs bow-tie terahertz detectors" L. Minkevičius, et al. *Electronics Letters*, Volume 50, Issue 19, 11 September 2014, p. 1367 – 1369 DOI: 10.1049/el.2014.1893

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