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Closing the terahertz gap could lead to better nanodevices

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(PhysOrg.com) -- "The terahertz regime has become of particular interest simply because it may allow us to look into materials in a completely new way," Diego Kienle tells *PhysOrg.com*. "This regime, which lies between microwave and optical frequencies is known as the terahertz gap. What one would like to have are devices which can operate - simply speaking - within this intermediate regime of conventional electronics and photonics."

Kienle is a researcher at Sandia National Laboratories in Livermore, California. Along with François Léonard, also at Sandia, Kienle developed a theoretical model allowing scientists to simulate the response of carbon nanotube transistors at very high frequencies up into the terahertz (THz) regime. What they found may provide a basis for moving forward on a fundamental level, as well as in the development of new applications. “We wanted to know how carbon nanotubes behave in the terahertz frequency regime,” Kienle explains. He also points out that he and Léonard are interested in discovering whether such a regime could be helpful in “exploiting nanoscale devices.” The results of the exploration can be found in *Physical Review Letters*: “Terahertz Response of Carbon Nanotube Transistors.”

“Our objective was meant to investigate the possibilities for materials such as nanotubes to be useful some day to build practical devices that make use of the terahertz regime,” Kienle says. “You can get an idea of why there is such a growing interest to work on that topic, since it would provide a useful connection between what we have now in conventional electronics and optics thus closing the terahertz gap."

Kienle believes that some of the possible applications of such nanoscale devices include transistors that can operate at faster speeds, improved tools for imaging and diagnosis of tissue in the medical and biological fields, advancements in molecule identification, and security screening. "Being able to study the terahertz regime is certainly interesting from a mere scientific perspective as well, since it would give us further insight into the dynamical aspects how electrons interact with external time-dependent fields on the nanoscale," Kienle continues.

Kienle and Léonard used the computer to solve the quantum transport equations, which allow them to assess the frequency characteristics of different materials. "One important characteristic of such devices is to efficiently interact with externally applied fields.They have to be able to 'respond' — so to say — to 'talk' to signals in the terahertz regime."

After running the model, it appears that carbon nanotubes would make good candidates for building devices capable of operating in the terahertz regime. "So far, from a theoretical viewpoint, it looks good, even though many more aspects, which have not been considered, still have to be investigated," Kienle says. "It appears that using devices of nanoscale size could help us access the terahertz regime more easily." He also points out that the computer modeling method he and Léonard used could also evaluate other materials. "Our approach is quite general and is useful for more than just carbon nanotubes," he insists. "We can apply it to any other material class to identify qualitatively whether other types of materials show promise to be useful in a variety of applications."

The next step is actually experimenting with materials that clear the modeling process. "This is a big practical challenge," Kienle admits. "Building devices with nanometer dimensions and that work in the terahertz regime, specifically at room temperature, is very difficult to realize in practice, and may require further development of experimental techniques to breach into this regime. This may be a few years down the road, but there are few experimental groups that have begun performing terahertz measurements in these nano devices, although still at low temperatures."

Kienle believes that the need for devices with new functionality in the terahertz regime will be in demand in the future, if one succeeds to built such devices. "Our technique would help investigate a number of nanoscale materials in order to make a sound evaluation of whether they would be useful at some point. We still have long ways to go to make it really work, but if one can do it this would be a big advancement and impact for this research field."

More Information: Diego Kienle, François Léonard, "Terahertz Response of Carbon Nanotube Transistors," *Physical Review Letters* (2009). Available online:
link.aps.org/doi/10.1103/PhysRevLett.103.026601 .