Novel Superlens Offers a Simplified Subwavelength Imaging Technique

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(PhysOrg.com) -- Since the first demonstrations of subwavelength imaging just a few years ago, scientists have been making great improvements, developing a variety of new methods for realizing high-resolution imaging. Recently, a new superlens for subwavelength imaging has been developed that offers a simplified and wide broadband operation. The superlens could potentially shrink the size of features on computer chips to make faster transistors, as well as increase the storage capacity of computer memory.

Cesar Monzon of Enig Associates, Inc., in Bethesda, Maryland, has presented this new technique in a recent issue of *Physical Review Letters*. As Monzon explains, many (but not all) subwavelength imaging mechanisms involve a complicated implementation and offer narrowband operation, such as lenses using metamaterials. He hopes that his technique could overcome these challenges with purely resistive means, simply by using a thin electrically conducting sheet to counteract the effects of space's filtration properties.

"An important advantage of the present method is that the resolution of the image so produced is not limited by the extent of a wavelength as in a common lens, but by the separation from the image to the conducting thin sheet," Monzon told *PhysOrg.com*. "In fact, the analysis presented in the paper indicates that we can easily form images 10 times sharper than a conventional lens (or 5% of a wavelength of operation). Actually, depending on the frequency of operation, achieving images that are over 20 times higher resolution than possible with diffraction limited optics seems feasible. Hence the proposed technique is that of a 'superlens,' because it beats the diffraction limit."

Basically, space acts like a low pass filter for highly evanescent components, and makes evanescent waves very short-lived; these waves usually decay exponentially with the distance from their light source. Monzon found that, when he placed a thin sheet of conducting material close to the light source, the sheet could restore the evanescent components of the light that had been diminished by the air in between.

"Saving" these evanescent wave components results in near-field subwavelength imaging right behind the resistive sheet. The "spot size" (imaging area) depends on the separation between the light source and the sheet, meaning that extremely high resolution is possible for very small separations. As an additional benefit, the effect is found to be broadband.

"An evanescent wave is essentially a near field wave component that is not propagating away from a radiator, but remains standing in its neighborhood," Monzon explained. "Evanescent fields are responsible for the reactive energy around a radiator, and generally decay quickly with distance. Just like radiating waves, evanescent waves are a general property of wave equations, and since they basically form the near field of a radiator, they are needed for its proper reconstruction (via focusing or imaging). Now suppose we have a point radiator; if evanescent waves are not used in the reconstruction, such as done by a typical lens (which operate in the far field), then we get a diffraction limited image where the minimum spot size is commensurate with the wavelength. If on the other hand we utilize the evanescent fields, as done here, then we are not bound by a diffraction limited spot size, as the evanescent field spectrum has the ability to form the very near field. For a point radiator this means, in principle, extreme resolution, with a minimum spot size clearly a very small fraction of the wavelength, hence enabling very high resolution imaging."

Unlike in previous subwavelength imaging techniques that use surface plasmons (electron density fluctuations) and that are plagued by losses, the new technique has a different physical cause based on harnessing the spectrum of evanescent fields. As Monzon explained, the smaller wave impedance of the conducting sheet enables researchers to trade definition for amplitude.

"What is shown here is that a simple conducting thin sheet acts like a special type of 'lens' for evanescent fields, allowing the details of a nearby image to be transferred to the other side of the sheet faithfully (this happens because accurate reconstruction of the evanescent fields of the original image takes place there)," Monzon explained. "Now, it happens that the more conducting the sheet is, the more faithful the reconstruction. However, as we know, the more conducting the sheet is, the more reflective it becomes, resulting in smaller transmitted fields, and a lower amplitude image being formed. Thus better definition can be obtained at the expense of sacrificing amplitude, and vice versa."

This technique could have useful applications, showing that micrometer or nanometer layers of resistive materials can be used to achieve subwavelength imaging in the optical and elusive infrared regions. The method could also be applied to other areas of physics where wave motion exists.

"The sharper images, the simplicity of the scheme, and the broadband operation are definite advantages for applications," Monzon said. "A superlens such as this, capable of creating images of objects or features much smaller than the wavelength of light, could be use in novel types of microscopes, of the super-resolution type. The method can also be used to shrink the size of features on computer chips, so to make smaller transistors that will result in faster computer chips. There is also potential to use this technique in computer memory technology such as read and write devices, so as to be able to access even smaller bits, which can definitely increase general storage capacity/density, and the corresponding data transfer capability."

More information: Cesar Monzon. "Subwavelength Imaging Using Conducting Sheets." *Physical Review Letters*, 102, 173901 (2009).