Researchers find material ultra-sensitive to light for use in optical computers

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ITMO researchers have discovered a material that is ultra-sensitive to light. Moreover, they were able to identify a parameter that will help find other structures with high refractive coefficients. This discovery will bring us a step closer to developing compact and efficient elements for optical computers—lasers, chips, and sensors. The research is published in *Nanophotonics*.

Each year, there is a growing demand for more powerful and advanced computers. The problem with conventional ones, though, lies in the electrons that play a major role in them. In any structure with an electric current running through it, there is a risk of overheating, which creates fundamental limitations on the minimum size of computational elements. A solution to this problem lies in optical computers that will process information transmitted by the movement of photons that don't heat up, as opposed to electrons.

"We will soon reach the limit when any further modernization of electron-based machines will not allow for the necessary increase in efficiency. To start using optical computers, we have to create chips and lasers of comparable size. We need materials with high refractive coefficients to develop optical elements at a nanoscale. The refractive coefficient tells us how well a structure reacts to light. If its interaction with light is poor, then the device will work accordingly," expounds Anton Shubnic, a student at ITMO's Faculty of Physics and Engineering.

There are not many materials highly sensitive to light. One of them is silicon (Si), with a refractive coefficient of 4. There are no known materials with a higher refractive coefficient in the visible range. Moreover, the researchers admit, it is not completely clear, where one could look for them. After extensive mathematical calculations, ITMO University physicists were able to identify a parameter that could point at how quickly the light would pass through a semiconductor before physical experiments or complex calculational modeling. This parameter depends on the electronic properties of a material: its band gap and the effective mass of an electron.

"We focused our attention on semiconductors. These materials have band gaps, known for most of them and frequently used. In optics, the band gap determines the maximum wavelength at which a material stays transparent. The second parameter is the electron's effective mass. When interacting with other particles in a material, electrons would act as particles with a different mass to the one they originally have," explains Ivan Iorsh, head of ITMO University's International Laboratory of Photoprocesses in Mesoscopic Systems.

The band gap is an energy range which electrons can't have in a certain material. If a photon's energy is less than the band gap, then the light can spread in the material, and if the energy is more—then the light will be absorbed. In optics, the band gap determines the maximum wavelength at which a material stays transparent. This parameter is known for many materials and is actively used. The second parameter is the electron's effective mass. When interacting with other particles in a material, electrons would act as though they have a different mass to the one they originally have. And this new mass is known as effective mass.

The theoretical model demonstrated that the higher the ratio is between these two parameters, the higher the refractive coefficient should be. First, the researchers tested their hypothesis on known materials such as silicon and then turned to the ones less studied. As a result, they discovered rhenium diselenide ($ReSe_2$), a highly promising material for optic elements. It turned out that $ReSe_2$ has a refractive coefficient of 6.5 to 7 in the visible range, which is significantly higher than that of silicon.

Now, the researchers are planning to launch a global search through open databases of materials' electronic properties to find other high-refractive-coefficient substances, previously disregarded by optics specialists.

More information: Anton A. Shubnic et al. High refractive index and

extreme biaxial optical anisotropy of rhenium diselenide for applications in all-dielectric nanophotonics, *Nanophotonics* (2020). DOI: 10.1515/nanoph-2020-0416

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