Gamma ray optics: A viable tool for a new branch of scientific discovery

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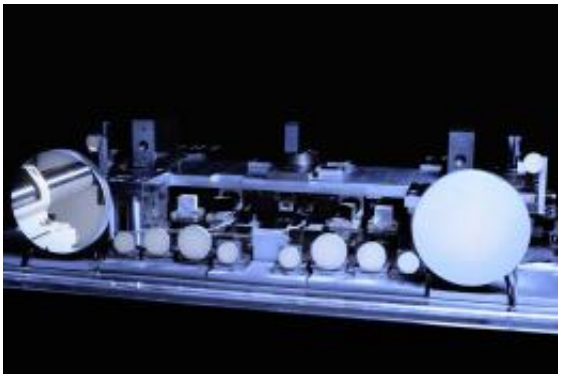

The high resolution gamma ray facility GAMS at ILL. Copyright: ILL/ Bernhard Lehn

Scientists at the Institut Laue-Langevin (ILL) have demonstrated for the first time that gamma rays, a highly energetic form of light produced by radioactive decay of atomic nuclei and amongst other used to kill cancer cells can be bent. In a new paper published in *Physical Review Letters*, the team used a version of the common classroom experiment with glass prisms, similar to the one employed by Newton in 1665, to find bending or 'refraction' at the highest energies ever recorded.

Their discovery overturns decades of theoretical predictions and opens the door to a new field of science called nuclear photonics. By bending and focusing the rays into concentrated beams, gamma ray microscopes could remotely scan for dangerous nuclear material in ships or trucks,

monitor nuclear waste or provide selective, less destructive medical imaging for cancer diagnostics and treatment.

The refraction of light occurs when it passes from one medium to another causing it to change speed. The manipulation of light rays, used by Galileo in 1609 to build his famous telescopes, is also possible for other forms of radiation as long as you can refract them sufficiently. However, as you move up the energy radiation spectrum to x-rays, the amount of refraction decreases. As a result it wasn't until the end of the 20th century when researchers combined hundreds of optical lenses that they were able to build the focusing instruments for x-rays that are used today in facilities such as the Diamond Light Source and the European Synchrotron Radiation Facility to probe materials on the nano-scale.

Whilst x-ray science has proved a major source of scientific insight and discovery, the chances of finding sufficient refraction in gamma rays were thought too small to pursue with significant research. However this assumption was purely theoretical. So scientists from the ILL and the Ludwigs-Maximilians University of Munich decided to test it.

As well as being the flagship centre for neutron science with one of the world's most brilliant neutron beams, ILL also houses one of the most intense gamma ray sources in Europe and a suite of highly sensitive instruments to measure refraction very precisely. The gamma rays produced using ILL's PN-3 facility were analysed through two silicon crystals, the first pre-selecting them as they came out of the reactor and directing them into a very narrow and parallel beam. Further along the instrument, a silicon prism is placed at height where it refracts half of the gamma ray beam. The refraction of this half beam is then detected by a second silicon crystal and compared with the other half of unrefracted gamma rays.

What they found was as the energy of the gamma rays increases the

falling refraction values which had decreased into small minus numbers, suddenly flipped sign and started to increase towards larger positive refraction values similar to that of visible light. These were much higher values than anyone expected. The researchers now believe that by replacing the silicon prisms with higher refracting materials like gold, they can bring refraction up to a level where it can realistically be manipulated for optical techniques. These potential applications are based on gamma rays' ability to easily penetrate material, even thick layers of lead, and the fact they can distinguish between isotopes of the same element.

Dr Michael Jentschel, research scientist at ILL: "20 years ago many people doubted you could do optics with x-rays – no one even considered that it might be possible for gamma-rays too. This is a remarkable and completely unexpected discovery with significant scientific implications and practical applications. These include isotope specific microscopy with benefits across the scientific disciplines, through to direct medical treatment and even tools to address major national security issues."

Potential applications include:

- More selective and less destructive medical imaging techniques achieved by enriching a particular isotope in a cancer and monitoring where it goes
- Improved production and trialling of new, more targeted radioisotopes for cancer treatment
- Remote characterisation of nuclear materials or radioactive waste - gamma rays' high penetration would allow you to scan for nuclear material in ships or trucks, or analyse and monitor nuclear waste in secure containers without ever having to open them up

With this valuable property now demonstrated in gamma rays, the focus

falls on the development of suitable gamma rays sources to develop this technique into working tools. Presently there exists a lack of dedicated sources for gamma rays comparable to the x-ray synchrotrons at ESRF or Diamond.

However, in recent years the announcement that the Extreme Light Infrastructure Nuclear Physics (ELI-NP) facility in Magurele, Romania, outside of Bucharest will contain a new higher photon energy gamma source has re-triggered interest. Dr Jentschel and his colleagues believe that their discovery of the possibility of optical manipulation of gamma ray beams could improve the sensitivity of experiments at ELI by 3-6 orders of magnitude.

More information: D. Habs, M. M. Günther, M. Jentschel, and W. Urban, Refractive Index of Silicon at γ Ray Energies, *Phys. Rev. Lett.* 108, 184802 (2012), 10.1103/PhysRevLett.108.184802

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