A photonic crystal fibre generates light from the ultraviolet to the mid-infrared

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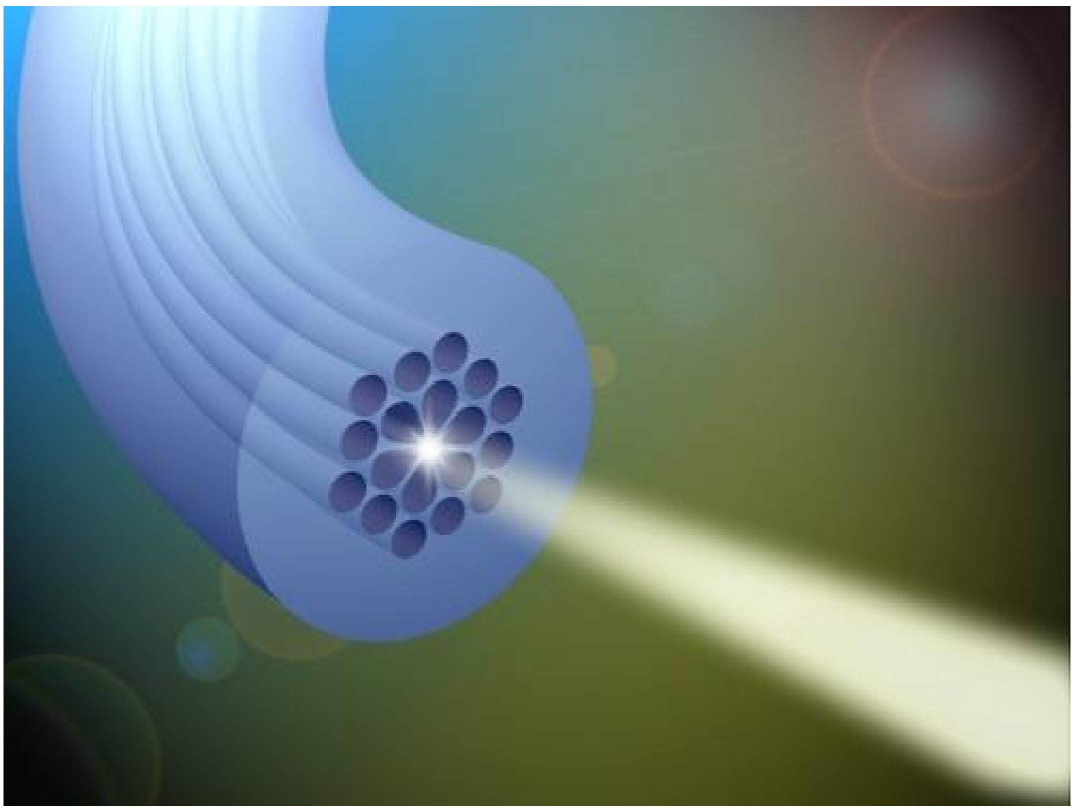


Bright source of white light: Max Planck researchers from Erlangen generate ultra-broadband light from a tailor-made photonic crystal fibre carrying infrared laser pulses. The crucial factor here is how the hollow channels, which run along the entire length of the glass fibre, are arranged around the fibre core. Credit: Xin Jiang

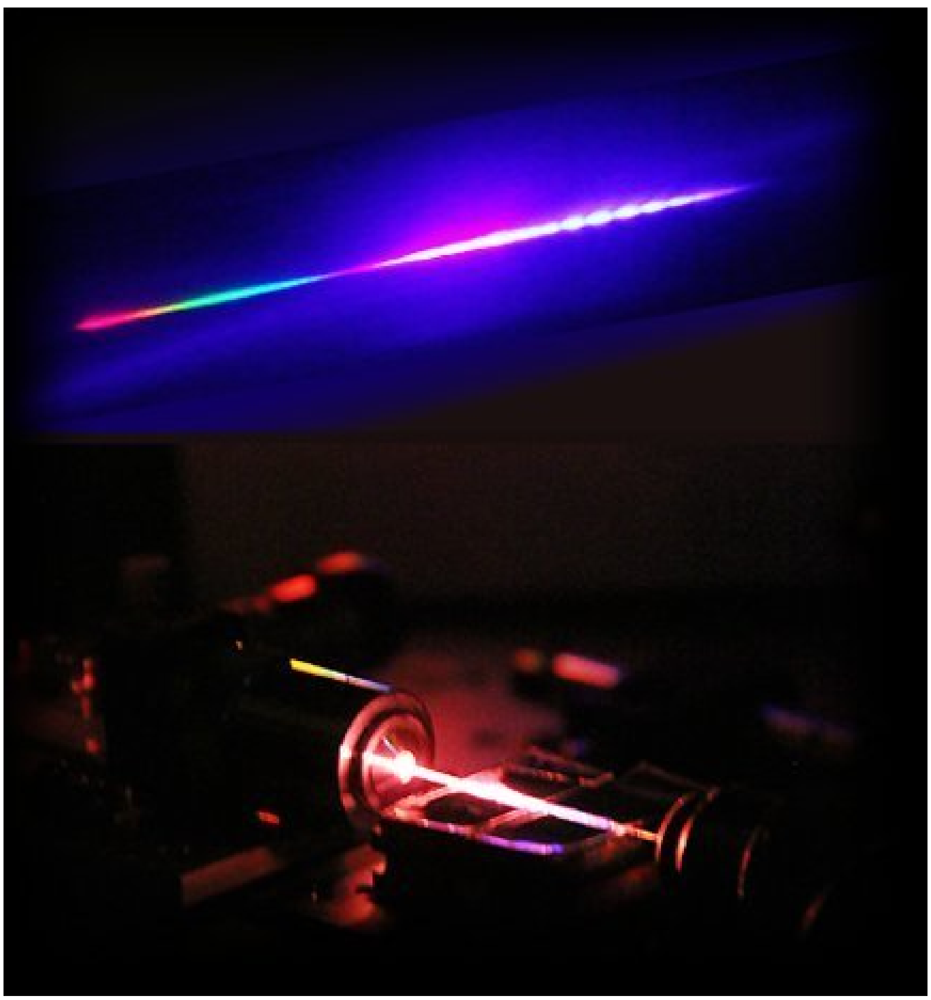
The light generated by researchers from the Max Planck Institute for the

Science of Light in Erlangen is more colourful than a rainbow. The scientists couple a low-energy, infrared laser pulse into a photonic crystal fibre (PCF) which is tailor-made so that the spectrum of the pulse broadens significantly to become white light: the generated spectrum spans from the deep-ultraviolet region to the mid-infrared region – a world record at such low input energy. The researchers from MPL in Erlangen are the first to produce microstructured glass fibres from a material that is particularly resistant to ultraviolet light, unlike conventional quartz glass. This material (ZBLAN) is actually extremely difficult to draw fibres from, and up until now it was regarded as impossible to draw photonic crystal fibres from it. In such fibres, a 2D periodic structure of hollow channels surrounds the fibre core, and runs along the entire length the fibre. The light produced with the world-record spectrum, could facilitate many investigations in biomedical research, in physics and chemistry, or even make new ones possible in the first place.

Light is one of the most important scientific tools nowadays. If researchers want to study biochemical processes in cancer cells, for example, they irradiate the cell with light of different colours and search for ways to stop tumours with the aid of fluorescent proteins. Chemical reactions can be observed or even controlled with the aid of light. And nothing much happens in physics without light, as for example with spectroscopic methods it coaxes out of atoms, molecules and crystals a great deal of information about their structure and properties. A lamp with a very broad spectrum should therefore find many applications, especially if it can provide light source qualities (e.g. spatial coherence, high brightness…) similar as those presented by a team of researchers in Erlangen, headed by Philip Russell, Director at the Max Planck Institute for the Science of Light.

White light, which contains all wavelengths, i.e. colours of visible light, can be generated in many ways. However, in Russell's team, scientists do it in a special way. They launch very short, infrared pulses with relatively low energy through a photonic crystal fibre, from which white light with record properties is generated: "What excites me most is the fact that our light covers such a large part of the ultraviolet range in the spectrum," says Philip Russell. "There have not yet been comparable light sources, especially in this wavelength range."

The brightness of the light remains the same across the whole spectrum

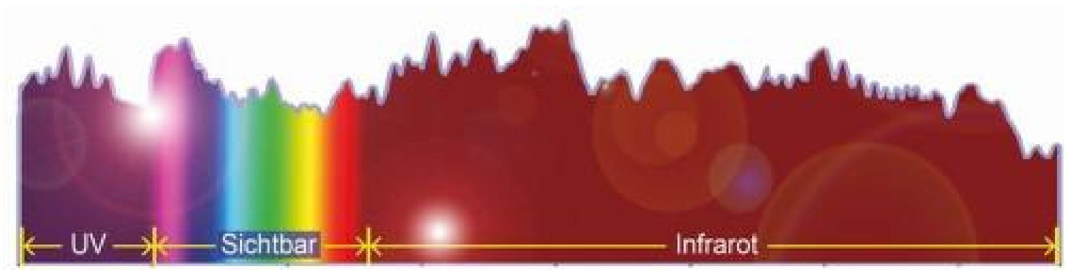


Light with a UV component: The Erlangen-based researchers disperse the light generated in the photonic crystal fibre with a prism, similar to the way in which water drops refract sunlight to create a rainbow. The dispersed spectrum (top part of the picture) shows the very broad ultraviolet part of the radiation (right-hand part of the spectrum). The normally invisible UV radiation becomes visible through high intensity UV-induced photoluminescence. The invisible, very large portion of generated infrared spectrum comes after the visible range (left-hand part of the spectrum after the visible rainbow bar). Credit: Xin Jiang

"In addition, the light generated from the PCF is very bright, and it retains more or less the same brightness over the whole spectrum," says Russell. "This is particularly important for applications." For example, biological/chemical scientists need light sources with a broad span of colours for many experiments. Normally they scan their experimental objects with different wavelengths. To do this, they filter the broadband light source with narrow bandwidth optical filters. The filtered light loses much of its brightness due to this process; in order to keep enough intensity, it is better to have a light source with reasonable brightness from the beginning.

In order to generate broadband white light with high brightness, Russell's team focus more on the possibilities with a special optical fibre: photonic crystal fibre. The hollow channels, which are arranged in a 2D periodic structure in the fibre end face, act as barriers for the light waves, restricting light to the fibre core. On the other hand, the chromatic dispersion of the photonic crystal fibre can be manipulated by the fibre microstructure. The Erlangen-based researchers can masterfully control the interaction of light and photonic crystal through the design of the PCF. "We obtain a particularly broad spectrum from the infrared pulses by essentially exploiting two properties of the glass and the photonic crystals," explains Russell: "On the one hand, the refractive index changes depending on the intensity of the light. On the other, the speed of the light waves varies with their colour."

A fluoride glass makes the fibre resistant against UV light



Similar brightness from ultraviolet to infrared: The intensity of the broad bandwidth light that can be generated with a photonic crystal fibre remains more or less the same level across the entire wavelength range – a very advantageous property for many applications. Credit: Xin Jiang

The work undertaken by the scientists in Erlangen not only sets standards in the manipulation of light, but also in materials science. They were the first to draw a photonic crystal fibre from a material called ZBLAN, which consists of five fluoride salts, instead of from quartz glass. "This was deemed impossible before, because the temperature of the glass has to be so precisely controlled that it had been previously regarded as impossible," says Xin Jiang, who manufactured the fibres at the Max Planck Institute in Erlangen. While PCF can be produced from quartz glass over a temperature range of 300 degrees, the temperature range for production of PCF from ZBLAN glass can span only a few degrees. "We have succeeded in adjusting the temperature of the glass so precisely that we can draw fibres."

The scientists used the difficult material for a reason: quartz glass, which was previously chosen as the ideal material for PCF, is quickly degraded by UV light – a fibre of this glass would therefore only generate ultraviolet light for only a short time. "We have not found any damage to the fibre made of ZBLAN, in contrast, although we have done experiments with this new material fibre over several months for several hours per day, or continuous operation for longer than 24 hours" says Xin Jiang. So it is no longer the endurance of the PCF, but only the endurance of the researchers that will determine whether they can undertake all the experiments which become possible with a brilliant new white light source.

More information: "Deep-Ultraviolet to mid-infrared supercontinuum generated in solid-core ZBLAN photonic crystal fibre." *Nature Photonics*, 19 January 2015; DOI: 10.1038/nphoton.2014.320

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