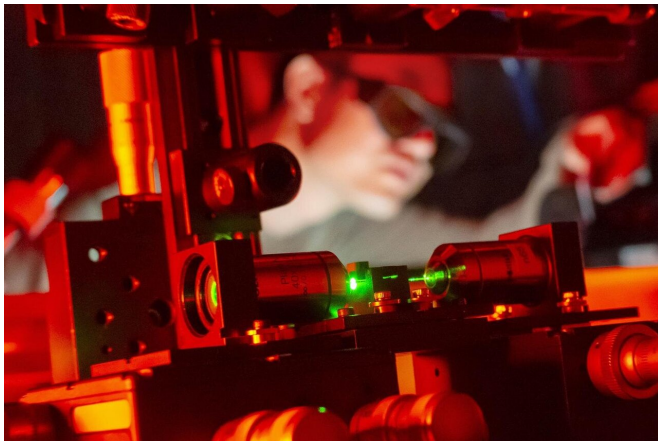


# Intelligent nanomaterials for photonics

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PhD student Quyet Ngo studies optical fibers functionalised by 2D materials. Credit: Jens Meyer/University of Jena

Since the Nobel Prize in Physics was awarded for research on graphene in 2010, 2-D materials—nanosheets with atomic thickness—have been a hot topic in science. This significant interest is due to their outstanding properties, which have enormous potential for a wide variety of applications. For instance, combined with optical fibers, 2-D materials can enable novel applications in the areas of sensors, non-linear optics, and quantum technologies.

However, combining these two components has so far been very laborious. Typically, the atomically thin layers had to be produced separately before being transferred by hand onto the optical fiber. Together with Australian colleagues, Jena researchers have now succeeded for the first time in growing 2-D materials directly on optical fibers. This approach significantly facilitates manufacturing of such hybrids. The results of the study were reported recently in the renowned journal on [materials science](#) *Advanced Materials*.

## Growth through a technologically relevant procedure

"We integrated [transition metal dichalcogenides](#)—a 2-D material with excellent optical and photonic properties, which, for example, interacts strongly with [light](#)—into specially developed glass fibers," explains Dr. Falk Eilenberger of the University of Jena and the Fraunhofer Institute for Applied Optics and Precision Engineering (IOF) in Germany. "Unlike in the past, we did not apply the half-nanometre-thick sheet manually, but grew it directly on the fiber," says Eilenberger, a specialist in the field of nanophotonics. "This improvement means that the 2-D material can be integrated into the fiber more easily and on a large scale. We were also able to show that the light in the glass fiber strongly interacts with its coating." The step to a practical application for the intelligent nanomaterial thus created is no longer very far away.

The success has been achieved thanks to a growth process developed at the Institute of Physical Chemistry of the University of Jena, which overcomes previous hurdles. "By analyzing and controlling the growth parameters, we identified the conditions at which the 2-D material can directly grow in the fibers," says Jena 2-D materials expert Prof. Andrey Turchanin, explaining the method based on chemical vapor deposition (CVD) techniques. Among other things, a temperature of over 700 degrees Celsius is necessary for the 2-D material growth.

## Hybrid material platform

Despite this high temperature, the optical fibers can be used for the direct CVD growth: "The pure quartz glass that serves as the substrate withstands the high temperatures extremely well. It is heat-resistant up to 2,000 degrees Celsius," says Prof. Markus A. Schmidt of the Leibniz Institute of Photonic Technology, who developed the fibers. "Their small diameter and flexibility enable a variety of applications," adds Schmidt, who also holds an endowed professorship for fiber optics at the University of Jena.

The combination of 2-D material and glass fiber has

thus created an intelligent material platform that combines the best of both worlds. "Due to the functionalisation of the glass fiber with the 2-D material, the interaction length between light and material has now been significantly increased," says Dr. Antony George, who is developing the manufacturing method for the novel 2-D materials together with Turchanin.

### **Sensors and non-linear light converters**

The team envisages potential applications for the newly developed materials system in two particular areas. Firstly, the materials combination is very promising for sensor technology. It could be used, for example, to detect low concentrations of gasses. To this end, a green light sent through the fiber picks up information from the environment at the fiber areas functionalised with the 2-D material. As external influences change the fluorescent properties of the 2-D material, the light changes color and returns to a measuring device as red light. Since the fibers are very fine, sensors based on this technology might also be suitable for applications in biotechnology or medicine.

Secondly, such a system could also be used as a non-linear light converter. Due to its non-linear properties, the hybrid optical fiber can be employed to convert a monochromatic laser light into white light for spectroscopy applications in biology and chemistry. The Jena researchers also envisage applications in the areas of quantum electronics and quantum communication.

### **Exceptional interdisciplinary cooperation**

The scientists involved in this development emphasize that the success of the project was primarily due to the exceptional interdisciplinary cooperation between various research institutes in Jena. Based on the Thuringian research group "2-D-Sens" and the Collaborative Research Centre "Nonlinear Optics down to Atomic Scales" of Friedrich Schiller University, experts from the Institute of Applied Physics and Institute of Physical Chemistry of the University of Jena; the University's Abbe Center of Photonics; the Fraunhofer Institute for Applied Optics and Precision Engineering IOF; and the Leibniz Institute of Photonic Technology

are collaborating on this research, together with colleagues in Australia.

"We have brought diverse expertise to this project and we are delighted with the results achieved," says Eilenberger. "We are convinced that the technology we have developed will further strengthen the state of Thuringia as an industrial center with its focus on photonics and optoelectronics," adds Turchanin. A patent application for the interdisciplinary team's invention has recently been filed.

**More information:** Gia Quyet Ngo et al, Scalable Functionalization of Optical Fibers Using Atomically Thin Semiconductors, *Advanced Materials* (2020). [DOI: 10.1002/adma.202003826](https://doi.org/10.1002/adma.202003826)

Provided by Friedrich Schiller University of Jena

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