Cylindrical phononic crystals sense physical, chemical properties of transported liquids

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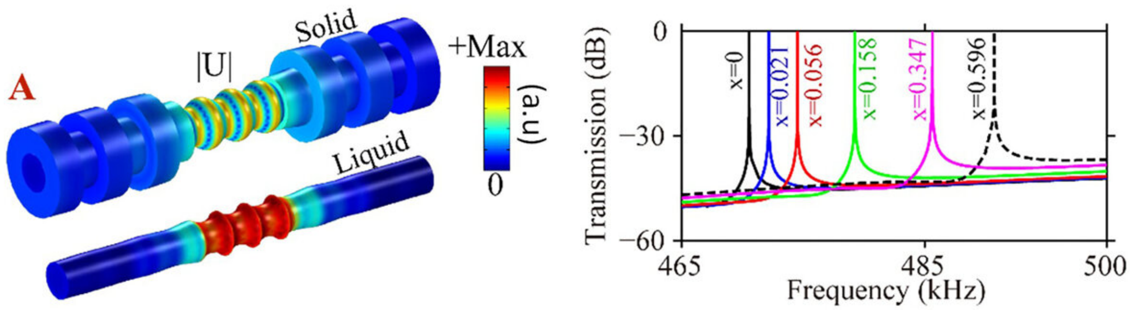

Left panel: Tubular phononic crystal (TPC) with a Fabry-Perot cavity filled with a set of propanol-water mixtures: representation of the acoustic field in the solid (up) and in the liquid (down). Right panel: Application of the sensor for the determination of the propanol-water mixtures with molar ratio x ranging from 0 to 59.6% as a function of the measured frequency (millimeter size). Credit: Yan Pennec

Phononic crystals are an innovative resonant platform for sensing and understanding the volumetric properties of liquids, attracting a growing interest from researchers.

In *The Journal of Applied Physics*, researchers from France and Germany propose the design of a tubular phononic crystal (TPC) for the purpose of sensing the biochemical and physical properties of a liquid filling the hollow part of the tube.

"Depending on its size, the device can be used at low scale, in microfluidic applications, at medium scale, in medicine for syringes, or at a larger scale, in civil engineering for routing of gas in pipelines," said author Yan Pennec.

Phononic crystals are known for their ability to guide, control, and manipulate acoustic and elastic waves. This capacity to control the propagation of elastic waves opened a broad field of applications, depending on the targeted frequency.

The researchers investigated a TPC structured with a periodic arrangement of washers along the tube. They demonstrated how the mixed solid/liquid system can present absolute or polarization dependent band gaps.

By introducing a Fabry-Perot (F-P) cavity inside the periodic structure, the researchers created peaks inside the band gaps and dips inside the passbands in the transmission spectrum.

These peaks and dips have been shown to be sensitive to the density and speed of sound of the fluid flowing inside the pipe, displaying higher sensitivity to the variations of the mass density than the sound velocity. The TPC consequently becomes an innovative platform for sensing applications because of the sufficiently strong coupling of the F-P modes at the fluid/solid interface.

The researchers will conduct an experimental demonstration of the system, using a 3-D printer, and work on all physical parameters to make a full determination of the liquid: density, velocity, viscosity. They will introduce thermo viscous equations and conduct comparisons between sensing gas and liquids.

The findings impact development of acoustic metasurfaces (AMM) in liquid. Until now, AMM were mainly developed in air. There is increased interest in applying the AMM concept for underwater applications.

The article, "Tubular Phononic Crystal Sensor" is authored by Abdellatif Gueddida, Yan Pennec, Victor Zhang, Frieder Lucklum, Michael J. Vellekoop, Nikolay Mukhin, Dr. Ralf Lucklum, Bernard Bonello and Bahram Djafari-Rouhani. The article will appear in *The Journal of Applied Physics* on Sept. 14, 2021.

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