Unique modulator could change mid-infrared photonic systems for the better

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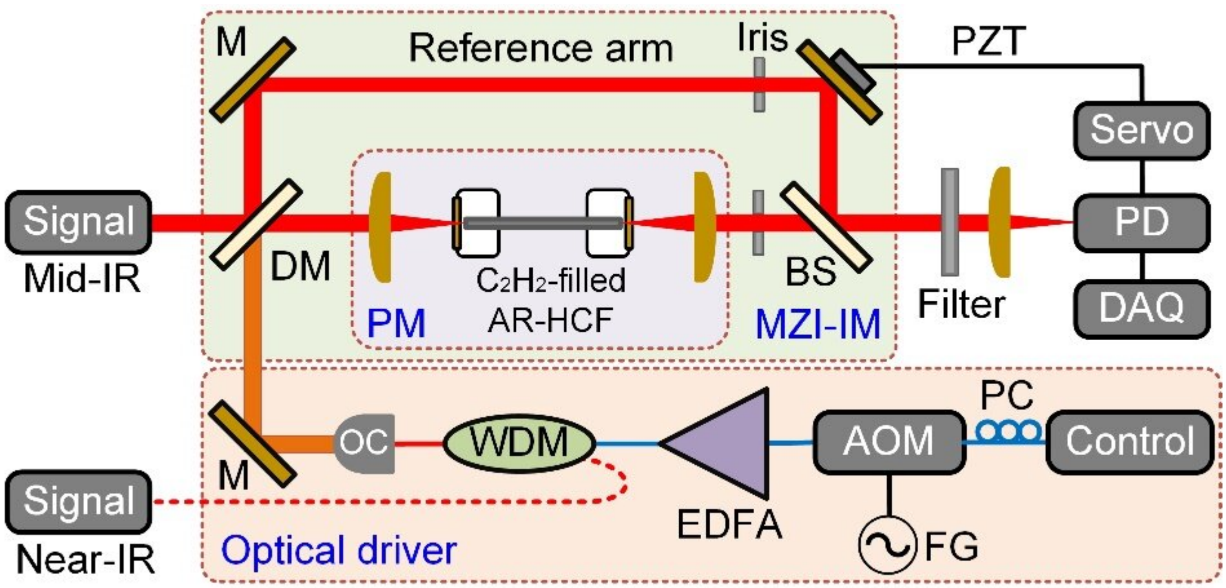

Credit: Kaiyuan Zheng, Shoulin Jiang, Feifan Chen, Yan Zhao, Shoufei Gao, Yingying Wang, Hoi Lut Ho and Wei Jin

There has been significant interest in photonics over the last decade due to their prospects in creating functional devices both for near-infrared (NIR) and mid-infrared (MIR) wavelengths. Optical modulators are crucial photonic circuits that enable signal switching and routing, data encoding, phase-sensitive detection, and spectroscopic interrogation. For NIR modulators, various types of materials have spurred a large number of research projects.

In a new paper published in *Light: Advanced Manufacturing*, a team of scientists led by Professor Wei Jin from The Hong Kong Polytechnic University have developed a new MIR all-optical modulator based on an acetylene-filled hollow-core fiber.

The motivation for investigating modulator wavelengths further into MIR comes from the possible applications for photonics and sensing in this range. MIR modulators have a wealth of applications, including actively Q-switched laser generation, environmental pollution monitoring, chemical and biosensing, industrial processes control, multispectral thermal imaging, and medical diagnostics of early disease.

Most of the MIR modulators are established on waveguide-integrated or free-space platforms. On-chip integrated devices have attracted significant attention due to their flexible waveguide geometry and complementary metal oxide semiconductor compatibility.

Various waveguide-integrated modulators have been demonstrated, including those based on electrooptic, thermo-optic, free carrier plasma dispersion, and electro-absorption effects. Most waveguide-integrated modulators are based on the silicon-on-insulator or silicon-on-lithium-niobate platform, mainly used in the NIR region due to stronger material absorption at longer wavelengths.

For free-space modulators, metamaterial, hybrid and pattern structures are commonly used to enhance light-matter interaction to achieve higher modulation efficiency. Most MIR modulators are electrically driven with external electronics applied directly on the modulation devices.

The researchers have shown a novel method to achieve MIR phase modulation by exploiting the photo-thermal (PT) effect in acetylene (C_2H_2)-filled anti-resonant hollow-core fiber (AR-HCF). The PT effect in gas-filled HCFs has been exploited for ultra-sensitive gas detection.

The long interaction distance and near-perfect overlap of the HCF's pump and probe fields with gas material significantly enhance light-gas interaction, enabling larger phase modulation and hence better gas sensitivity over free-space systems. The researchers further extended the application scope of PT effect in the gas-filled HCFs to all-optical MIR modulators.

Different from the voltage-driven waveguide and free-space modulators, the PT MIR phase modulators are driven optically by a cost-effective control laser in the NIR telecom band. By placing the phase modulator (PM) in one arm of a Mach-Zehnder interferometer (MZI), MIR intensity modulation (IM) is further demonstrated. The AR-HCFs intrinsically have broadband transmission which, coupled with the narrow absorption lines of gas materials, makes it possible to develop ultra-broadband all-optical modulation devices from NIR to MIR.

More information: Kaiyuan Zheng et al, Mid-infrared all-optical modulators based on an acetylene-filled hollow-core fiber, *Light: Advanced Manufacturing* (2022). DOI: 10.37188/lam.2022.050

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