The future of Wireless communications may change thanks to programmable structured surfaces.

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Abstract

It has been stated that dual-channel data transfers for light-to-microwave signal conversion can be realized using a creative time-varying meta surface. Such a cutting-edge method is a noteworthy advancement in the realization of full-spectrum networks to meet the expanding need for wireless communications. Additionally, this method encourages the development of new information-focused applications while enhancing the functions of tunable met surfaces.

Within the communications business, wireless communication is a rapidly expanding and dynamic sub segment. Because to its strong ability to carry data without utilizing any connections like wires, cables, or other physical medium to guide signal transmission, it is becoming more and more vital in our daily life. Currently, the deployed networks, using radio frequency (RF) communications, are characterized by a shared medium, limited spectrum bandwidth, and a lack of ability to scale with an increasing number of end devices[1]. Therefore, today's technology does not cater to the growing demand for wireless data. To overcome these limitations, there is a quest to employ multi-domain communication systems, so-called hybrid systems, that can exploit other domains, such as terahertz[2], microwave[3], and optical[4] elec- tromagnetic (EM) waves. In order to implement full-spectrum networks for upcoming sixth generation (6G) wireless communications, such hybrid systems appear to be the best option.

Because to its wide license-free spectrum range, high security, high energy efficiency, and lack of electromagnetic interference, the optical spectrum is regarded as a promising communication resource among several communication domains4.Furthermore, it is perfectly suitable for many unique application scenarios, such as indoor communica- tion, underwater communications, and data transfer in some EM-sensitive environments, including medical facilities, hospitals, and underground mines[4]. However, the current

Technological challenge to fully taking the optical domain on board is converting it to the other domains with minimal loss. Traditionally, such a function requires complicated relaying systems where the received optical signals are firstly amplified and converted to baseband before being down- converted to the other domains. Such an approach needs a large number of additional hardware and multiple process steps causing further delays, higher costs, and more energyresources.

Writing in this issue of Light: Science & Applications, Tie Jun Cui and co-workers at Southeast University (China), Purple Mountain Laboratories (China), and the National University of Singapore have developed an innovative transmitter for direct signal conversion from visible lights to microwaves. They have employed the concept of meta-surfaces, i.e. two-dimensional (2D) structured surfaces with precisely engineered elements in subwavelength scales. Their proposed transmitter can directly convert the real-time signal from visible lights to microwaves and facilitate promising hybrid wireless communication[5].

Metasurfaces are artificial arrays of subwavelength unit cells[6–8] that can be used to manipulate EM radiation in unconventional ways to offer exotic applications, such as metalenses, beam shapers, holograms, nonlinear meta-surfaces, and remote quantum control[9–13]. Programmable metasurfaces are an emerging sub-category of meta-surfaces that allow EM manipulation and information

processing dynamically[14–16]. Such metasurfaces, mostly

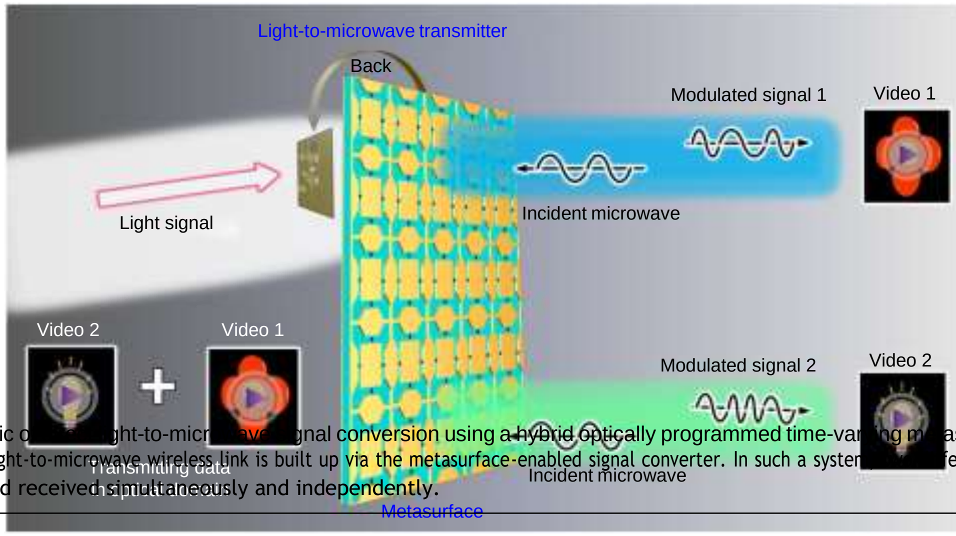

Fig. 1 Schematic of the light-to-microwave signal conversion using a hybrid optically programmed time-varying metasurface platform. A dual-channel light-to-microwave wireless link is built up via the metasurface-enabled signal converter. In such a system, two different videos can be transmitted and received simultaneously and independently.

conversion[18], and information processing[19]. However, the electrical control method limits the programmable metasurfaces to be only considered in a single domain and not applicable to wireless communications.

The authors have designed, fabricated, and demonstrated a metasurface-based transmitter that is low-cost, low-complexity, wireless and multi-domain. Their device consists of a time-varying microwave metasurface and a photoelectric detection circuit sensitive to light. It has been demonstrated that the reflection frequency of the metasurface platform can be controlled by the light intensity waveform in real time. In other words, the programable metasurface can convert a light intensity signal to two microwave binary frequency shift keying signals directly, achieving the dual-channel data transmissions in a light-to-microwave link (see Fig. 1). Such a wireless communication system can transmit two different videos simultaneously using a frequency division multiplexing (FDM) scheme.

The demonstrated light-to-microwave signal conversion process was completed fully on a sole platform, without additional RF devices and optical components. Such a platform offers low-cost and low-complexity hybrid communication systems and opens the promising potential for future multi-domain integrated 6G, a new era of wireless communications. In addition, this technique will enrich the functionalities of metasurfaces, and could also stimulate new information-oriented applications.

References

1. Rahaim, M. B., Vegni, A. M. & Little, T. D. C. A hybrid radio frequency and broadcast visible light communication system. In *Proc. 2011 IEEE GLOBECOMWorkshops* 792–796 (IEEE, Houston, TX, USA, 2011).
2. Nagatsuma, T. et al. Terahertz wireless communications based on photonics technologies. *Opt. Express* 21, 23736–23747 (2013).
3. Chang, K. *RF and Microwave Wireless Systems* (John Wiley & Sons, New York, 2000).
4. Uysal, M. et al. *Optical Wireless Communications: An Emerging Technology* (Springer, Cham, Switzerland, 2016).
5. Zhang, X. G. et al. A metasurface-based light-to-microwave transmitter for hybrid wireless communications. *Light: Sci. Appl.* 11, 126 (2022).
6. Lalanne, P. et al. Blazed binary subwavelength gratings with efficiencies larger than those of conventional échelette gratings. *Opt. Lett.* 23, 1081–1083 (1998).
7. Bomzon, Z., Kleiner, V. & Hasman, E. Pancharatnam–berry phase in space-variant polarization-state manipulations with subwavelength gratings. *Opt. Lett.* 26, 1424–1426 (2001).
8. Yu, N. F. et al. Light propagation with phase discontinuities: generalized laws of reflection and refraction. *Science* 334, 333–337 (2011).
9. Pendry, J. B., Schurig, D. & Smith, D. R. Controlling electromagnetic fields. *Science* 312, 1780–1782 (2006).
10. Neshev, D. & Aharonovich, I. Optical metasurfaces: new generation building blocks for multi-functional optics. *Light: Sci. Appl.* 7, 58 (2018).
11. Wang, K. et al. Quantum metasurface for multiphoton interference and state reconstruction. *Science* 361, 1104–1108 (2018).
12. Rahmani, M. et al. Nonlinear frequency conversion in optical nanoantennas and metasurfaces: materials evolution and fabrication. *Opto-Electron. Adv.* 1, 180021 (2018).
13. Liu, J. et al. Quantum photonics based on metasurfaces. *Opto-Electron. Adv.* 4, 200092 (2021).
14. Shaltout, A., Kildishev, A. & Shalaev, V. Time-varying metasurfaces and Lorentz non-reciprocity. *Opt. Mater. Express* 5, 2459–2467 (2015).
15. Zhang, L. et al. Space–time-coding digital metasurfaces. *Nat. Commun.* 9, 4334 (2018).
16. Li, L. L. et al. Intelligent metasurfaces: control, communication and computing. *eLight* 2, 7 (2022).
17. Zhang, X. G. et al. Smart Doppler cloak operating in broad band and full polarisations. *Adv. Mater.* 33, 2007966 (2021).
18. Wu, Z. N. & Grbic, A. Serrodyne frequency translation using time-modulated metasurfaces. *IEEE Trans. Antennas Propag.* 68, 1599–1606 (2020).
19. Dai, J. Y. et al. Wireless communication based on information metasurfaces. *IEEE Trans. Microw. Theory Tech.* 69, 1493–1510 (2021).