Research article

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Breaking polarisation-bandwidth trade-off in dielectric metasurface for unpolarised white light

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Abstract: Optical metasurfaces have gained attention due to their considerable prospects, which can benefit consumers and industries in terms of virtual reality devices and digital displays in various multimedia and entertainment-related applications. To date, most of the metasurface optimisation strategies involving isotropic or anisotropic nanoantennas encounter a trade-off between polarisation insensitivity and operating bandwidth under unpolarised white light, which is a fundamental requirement for many applications in digital displays. We presented a novel technique to break the trade-off between polarisation insensitivity and bandwidth by engineering the displacement dependent phase delay of the adjacent parallel and perpendicular anisotropic nanoantennas in a dielectric metasurface. As a result, we numerically demonstrate a highly efficient metasurface operating at an almost entire visible domain (wavelength of 450 nm–650 nm) while maintaining a constant phase modulation under all polarisation states, thus enabling the polarisation-insensitive metadevices for unpolarised white light.

Keywords: metahologram; broadband; polarisation insensitive; anisotropic nanorods; dielectric metasurface.

1 Introduction

The planar optical metasurfaces comprising nanoantennas at a subwavelength scale possess unprecedented abilities to manipulate the electromagnetic properties of light, such as the amplitude, polarisation and phase [1–5]. Therefore, optical metasurfaces have gathered an ample amount of attention with the demonstration of various optical phenomena due to their high efficiencies and miniaturised designs, i.e. metalens [6–8], metaholograms [9–13], optical vortexes [14–16] and metapolarisers [17, 18]. These metadevices have great pragmatic prospects at the consumer's end [19] as well as in terms of industrial applications [6, 20]. Amongst all these applications, a broadband polarisation-insensitive metahologram for unpolarised white light can be utilised due to its applicability in the field of display and imaging technology, i.e. multimedia, movie theatres and entertainment. However, most of the broadband plasmonic metasurfaces operating in the infrared domain are sensitive to polarisation [21, 22].

Apart from the polarisation sensitivity issue, plasmonic metasurfaces made up of metallic nanoantennas (i.e. gold, silver and aluminium) showcase meagre efficiency in the visible domain [23–25], and their theoretical efficiency is only limited to 25% in the transmission mode due to the unavoidable Ohmic losses [26]. For many applications in display and imaging, highly efficient metasurfaces are indispensable; therefore, plasmonics metasurfaces appear to circumscribe their pragmatic usage.

Polarisation-insensitive solutions using isotropic dielectric circular nanodisks and square nanopillars have been presented. For example, Khorasaninejad et al. used cuboids to demonstrate an achromatic metalens with the maximum focusing efficiency of 20% at a wavelength of 550 nm. This polarisation-insensitive metasurface has a very narrow bandwidth (60 nm) due to the usage of isotropic meta-atoms [27]. Similarly, Nasir et al. simultaneously demonstrated metalens and helical beam generation

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through low-loss, amorphous silicon circular nanodisks with an average calculated efficiency of 73.5% at a single wavelength of 633 nm [14]. Almost all isotropic designs for the visible domain, as reported in the literature, are designed for a single operational wavelength; hence, they perform inefficiently in the broadband domain. Moreover, the designs comprising of isotropic nanodisks and nanopillars are restricted with no extra degree of freedom i.e. geometric properties.

This challenge can be subjugated by using anisotropic nanoantennas in both the infrared and the visible domains. A metasurface capable of converting incident light into an optical vortex is experimentally demonstrated using V-shaped nanoantennas over a broad waveband in the visible domain [28]. Similarly, broadband L-shaped anisotropic nanoantennas are presented by Chenyang et al. for the polarisation conversion of incident light [29]. In another work, the rectangular nanorods made up of TiO_2 are utilised to achieve a highly efficient metahologram in the entire visible domain [9]. However, all anisotropic nanoantennas discussed above are susceptible to high sensitivity toward the change in the polarisation of the incident light. For example, a geometric metasurface made up of rectangular nanorods can only focus (or diverge) the incident light with left-handed circular polarisation (or right-handed circular polarisation) [25]. For example, Zang and co-workers have demonstrated polarisation-insensitive metalens operating in the terahertz regime at a central frequency of 0.69 THz (wavelength of 434.48 μm) using identical anisotropic micro-pillars with simulation efficiency of 35% and measured efficiency of 26% [30]. However, due to the usage of identical micro-pillars with the geometric phase modulation technique, the design has a practical limitation: the theoretical limit of efficiency of this design is only 50% [30, 31].

Therefore, a metasurface that can accurately control the wavefront of visible light under all states of polarisation with high transmission efficiency over the entire visible domain should be designed. In the present study, we present a novel design strategy to realise a highly efficient metasurface using meticulously optimised meta-cells superimposing a constant phase modulation under any polarisation state in the visible domain. On the basis of a unique concept of a phase delay between two different adjacent parallel and perpendicular nanorods, the reconstruction of identical wavefront shaping is achieved, which is robust against polarisation states and wavelength in the optical regime.

In this work, the polarisation insensitivity of the proposed metahologram is controlled by carefully tuning the phase delay and the dimensions of adjacent non-identical

nanorods, thus enabling the realisation of broadband holographic images under unpolarised white light. The physics and working principle of this design is different as compared to the recent developments of centrosymmetric designs [32, 33] and tri-meta-atoms unit cell structure [6]. Our proposed meta-cell is not limited to the centrosymmetric phase map requirement. Moreover, it does not necessitate the use of multiple meta-atoms within a unit element hence, facilitating a simplistic realisation of the novel design concept with much less computational cost. For example the unit cell presented by Chen et al. consists of three nano-fins with ten structural parameters ($l_1, l_2, l_3, w_1, w_2, w_3, g, P, \theta$ and h) [6]. The design exhibits significantly large number of parameters in the unit cell for the optimisation and is computationally very expensive as it requires multiple nano-fins in a unit cell to achieve desired functionality.

In contrast, our proposed unit cell can achieve polarisation-insensitivity over a broadband spectrum with one nano-fin (within a unit cell) comprising only five parameters (l, w, U, σ and h). In another work, Jisha et al. have presented a polarisation-insensitive functionality using PB-phase modulation by equating the length of the rotated-anisotropic material with the full-wave length (birefringence length). They reported that the phase modulation is proportional to the squared transverse derivative of the angle of the rotated-anisotropic material, which is known as the Kapitza effect [34]. However, they did not demonstrate polarisation-insensitivity at any broadband wavelength range.

To authenticate our strategy, we have designed a metasurface with dimension equal to $40.04 \times 40.04 \mu\text{m}^2$ at a focal length of 20.02 μm . Under the linear horizontal polarisation (LHP), linear vertical polarisation (LVP), left-handed circular polarisation (LCP), right-handed circular polarisation (RCP), elliptical and under unpolarised light source, the metasurface reconstructed the same holographic images with equal efficiency. This desired control is achieved by combining two phase modulation techniques (i.e. propagation phase and geometric phase modulation) after a specific modification.

We have derived a polarisation-insensitive condition for the anisotropic nanorods, which dictates a unique set of geometric phase shifts. Instead of merging complete geometric shifts, only these unique phase shifts are combined with the propagation phase shifts of four distinct nanorods with different lengths and widths. This unique combination is different from previously reported phase merging schemes for asymmetric transmission metasurfaces [31] and continuously shaped metasurfaces [35]. Moreover, the proposed the polarisation-insensitive

metasurface exhibits a broadband response with absolute efficiencies equal to 73%, 90% and 72% for the blue, green and red light, respectively. We believe that the proposed methodology provides a unique and powerful platform to realise the real-time implementation of compact imaging and anti-counterfeiting displays under white light with arbitrary polarisation, especially for multimedia, movie theatres and entertainment industries.

2 Methods and results

2.1 Principle of the polarisation-insensitive metasurface

An array of linearly birefringent nanoantennas maintains distinct optical properties under different states of polarisations. Counterintuitively, this exciting opportunity allows us to tandem well known phase modulation techniques (i.e. propagation phase and geometric phase modulation) after a certain modification in order to achieve a complete and unaltered phase slope and curvature under any polarisation state. From a technological standpoint, neither of these modulation techniques alone are able to address the polarisation insensitivity in case of anisotropic nanoantennas.

We begin by considering the phase delay provided by the two adjacent non-identical nanorods with displacement q between them, as shown in Figure 1A. The electric fields coming out of two non-identical nanorods will carry a phase delay ($\Delta\phi = 2\pi q/U_1 + \alpha$) due to the displacement (q) and the different dimension of the nanorods, where U_1 and α denote the global displacement and propagation phase shift due to distinct parallel nanorods, respectively. The complete derivation of phase delay due to parallel and perpendicular nanorods is covered in the Supplementary Information. Moreover, q_1 and q_2 represent the additional paths traversed by the incident and travelled light rays, respectively. As shown in Figure 1A, the non-identical nanorods have orientations that are perpendicular (90°) or parallel (0°) with each other.

The physical concept presented in this paper can be implemented using anisotropic meta-atoms made of any high-contrast dielectric material. To maintain the near-unity transmission efficiency, we used GaN/Al₂O₃ based dielectric unit cells. Considering the combined effect of parallel and perpendicular nanorods, we can write the expression of the total transmitted electric field under an arbitrary state of polarisation of incident light using Jones calculus (Supplementary Section S1).

$$\begin{pmatrix} E_{tx} \\ E_{ty} \end{pmatrix} = \begin{pmatrix} \cos\sigma & -\sin\sigma \\ \sin\sigma & \cos\sigma \end{pmatrix} e^{i\left(\frac{2\pi q}{U_1} + \alpha + \beta\right)} \begin{pmatrix} 1 & 0 \\ 0 & e^{i\frac{2\pi q}{U_1}} \end{pmatrix} \begin{pmatrix} \cos\sigma & \sin\sigma \\ -\sin\sigma & \cos\sigma \end{pmatrix} \begin{pmatrix} E_{ix} \\ E_{iy} \end{pmatrix}, \quad (1)$$

where σ and β represent the angle between the long-axis of the nanorod and y-axis and the propagation phase shift due to distinct perpendicular nanorods, respectively. The phase and polarisation of the transmitted electric field can be modulated using U_1 , q , σ , α and β . For $\sigma = 0$ and $U_1 = 2q$, the resultant illustrations of nanorods can be seen in Figure 1B and Equation (1) is reduced to

$$\begin{pmatrix} E_{tx} \\ E_{ty} \end{pmatrix} = e^{i(\pi + \alpha + \beta)} \begin{pmatrix} 1 & 0 \\ 0 & e^{i\pi} \end{pmatrix} \begin{pmatrix} E_{ix} \\ E_{iy} \end{pmatrix} = e^{i\gamma} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} E_{ix} \\ E_{iy} \end{pmatrix}, \quad (2)$$

where γ represents the term $(\pi + \alpha + \beta)$. As can be seen, under any state of polarisation, the proposed topology maintains a constant phase modulation. The displacement between two adjacent nanorods is denoted as U and the global displacement is equal to $2*U$. For incident light with LHP, LVP, LCP and RCP, Equation (2) is reduced to the following equations, respectively,

$$\begin{pmatrix} E_{tx} \\ E_{ty} \end{pmatrix} = e^{i\gamma} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \end{pmatrix} = e^{i\gamma} \begin{pmatrix} 1 \\ 0 \end{pmatrix}, \quad (3)$$

$$\begin{pmatrix} E_{tx} \\ E_{ty} \end{pmatrix} = e^{i\gamma} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} 0 \\ 1 \end{pmatrix} = -e^{i\gamma} \begin{pmatrix} 0 \\ 1 \end{pmatrix}, \quad (4)$$

$$\begin{pmatrix} E_{tx} \\ E_{ty} \end{pmatrix} = e^{i\gamma} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} 1 \\ -i \end{pmatrix} = e^{i\gamma} \begin{pmatrix} 1 \\ i \end{pmatrix}, \quad (5)$$

$$\begin{pmatrix} E_{tx} \\ E_{ty} \end{pmatrix} = e^{i\gamma} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} 1 \\ i \end{pmatrix} = e^{i\gamma} \begin{pmatrix} 1 \\ -i \end{pmatrix}. \quad (6)$$

In a more general case, where a nanorod transmits the incident light whose polarisation direction is either along the short axis or along the long-axis of the nanorod, the total transmitted electric field propagating in the z-direction for circularly polarised (CP) light can be written using Jones matrix $J(\sigma)$ and Jones vector of incident light $\hat{E}_{\pm\text{inc}}$

$$\vec{E}_t(z, t) = J(\sigma) \cdot \hat{E}_{\pm\text{inc}} = \frac{t_p + t_s}{2} \begin{pmatrix} 1 \\ \pm i \end{pmatrix} \mp \frac{t_p - t_s}{2} e^{i\gamma} \begin{pmatrix} 1 \\ \mp i \end{pmatrix}, \quad (7)$$

where t_p and t_s correspond to the complex coefficients of transmission in the cases of incident light with polarisation

Figure 1: The principle of phase delay for full phase modulation under arbitrary polarisation.

(A) The transmitted light from two non-identical parallel or perpendicular nanorods leading to holographic constructive or destructive interference. The phase delay is induced by the displacement q , which is the key factor in obtaining constant phase modulation with polarisation insensitivity. The light rays (incident and transmitted) are drawn in the xz plane. The angle between the long axis of the nanorod and the y -axis is represented as σ . The figure illustrates two cases: (1) non-identical nanorods with angle of 90° between each other, (2) non-identical nanorods with angle of 0° between each other. (B) Perspective view of perpendicular nanorods satisfying the condition $\sigma = 0$ and $U_1 = 2q$, where $2*U$ is the global displacement and U is the center to center distance between the adjacent nanorods. Similarly, the parallel nanorods can also be shown that satisfy aforementioned condition (see Figure S2). Therefore, by varying the dimensions of the nanorods with parallel and perpendicular orientations simultaneously, the metasurface modulates polarisation-insensitive wavefront manipulation. (C) The simulated phase of cross-polarised transmitted lights, for example, ϕ_{LR0} and ϕ_{LR90} represent the phase of transmitted RCP light under LCP illumination with the nanorods having rotation angles of 0° and 90° (between the long-axis and x -axis), respectively. The orthogonal nanorods demonstrate a broadband phase difference ($\Delta\phi$) equal to π . The length, width, and height of the nanorod are 220 nm, 70 nm and 600 nm, respectively. (D) The metasurface element containing two different orthogonal nanorods with displacement ($U = 260$ nm) possesses identical cross-polarised phase shifts (ϕ_{LR} and ϕ_{RL}). The yellow and green nanorods have parameters $(l, w, h) = (220, 70, 600)$ and $(l, w, h) = (235, 110, 600)$ in nanometer units, respectively. This metasurface element introduces no phase difference ($\Delta\phi = 0$) under both CP incidences with the same slope and curvature.

along the long-axis and the short-axis, respectively. In addition, γ is responsible for full phase modulation under CP light. The first term in Equation (7) produces undesired scattering and can be minimised by the meticulous optimisation of nanorods. It is evident from the second term that the incident light will impose the same phase profile on the metasurface comprising nanorods satisfying the

$\sigma = 0$ and $U_1 = 2q$ conditions. As the arbitrary state of polarisation can be decomposed into a superposition of RCP and LCP, this condition can be applied to the unpolarised light, which enables the polarisation-insensitive phase modulation in an anisotropic metasurface. The numerical simulations of nanorods fulfilling the polarisation insensitivity condition are shown in the Figure 1C and D, which

prove the results predicted in Equation (7). The legend, for example, ϕ_{LR} , denotes the phase of LCP transmitted light under RCP incidence. A metasurface element produces the same phase ($\Delta\phi=0$) for both CP lights with no difference in the phase slope and curvature (Figure 1D).

2.2 Polarisation-insensitive anti-counterfeiting approach

The polarisation-insensitive condition is encoded in the metasurface using distinct nanorods with desired phase delay and high transmission. The design process begins with a parametric sweep of length and width of anisotropic

GaN nanorod for transmission efficiencies and phase. We have employed a finite difference time domain based full-wave solver at a working wavelength of 532nm with periodic and perfectly-matched layer boundary conditions along x, y and z directions, respectively. The ellipsometry data used in the simulation is presented in Supplementary Section S2. In Figure 2A and B, two quantities of interest are plotted, i.e. cross-polarised transmission and phase (respectively) of each nanorod by the sweeping values of length and width with fixed displacement ($U=260$ nm). Four nanorods are chosen such that they possess high cross-polarised efficiencies and a consecutive phase difference of 45° . The selected nanorods are labelled as white stars in Figure 2A and B. The cross-polarised efficiencies

Figure 2: Numerical optimisation of the GaN nanorods.

Simulated cross-polarised transmission (A) efficiency and (B) phase of the nanorods with varying dimensions at a fixed wavelength of 532nm. The displacement (U) of the unit cell is equal to 260 nm and the height (h) is fixed at 600 nm. White stars indicate the selection of four nanorods based on their high cross-polarised efficiencies and desired phase shifts. (C) Eight unit cells with eight different nanorods that provide full phase coverage ($0-2\pi$) at three common wavelengths (488, 532 and 632 nm). The dimension (length $\times$ width) of nanorods of unit cells 1–4 are N1: 220×70 , N2: 235×80 , N3: 230×100 and N4: 235×110 in the nanometer scale, respectively. Unit cells 5–8 have the same dimension as unit cells 1–4 with the long axis of the nanorods orthogonally oriented with respect to the x-axis. (D) Simulated total transmission (T_1 , T_2 , T_3 and T_4) of unit cells (1–4, respectively) as a function of wavelength from 450 nm to 650 nm. The vertical dashed lines are drawn at 488, 532 and 632 nm. The inset, for example, @532, outlines the values of transmission efficiencies at a wavelength of 532 nm. The simulations are performed here are under normal incident angle. The effect of different incident angles on the transmission curves of unit cells 1–4 are mentioned in Section S4 of Supplementary Information.

and the phase shifts of four unit cells containing four different nanorods (N1: $220\text{ nm} \times 70\text{ nm}$, N2: $235\text{ nm} \times 80\text{ nm}$, N3: $230\text{ nm} \times 100\text{ nm}$ and N4: $235\text{ nm} \times 110\text{ nm}$) are 91.4%, 91.5%, 91% and 90.2%, respectively, and the corresponding degrees are 0, 45, 90 and 135 degrees.

To verify the design principle presented in the Figure 1, these four nanorods are oriented horizontally and shifted vertically (at 90°) to create an array of eight unit cells. By doing so, the additional phase shift equal to π is obtained for full phase coverage, as shown in Figure 2C. The blue, brown and black plots in Figure 2C correspond to the wavelength of 488 nm, 532 nm and 632 nm, respectively. Note that the designed array of eight unit cells maintains a near equivalent slope and curvature of phase. Figure 2D shows the total transmission (T_1 , T_2 , T_3 and T_4) of the designed unit cells. The vertical blue, green and red dashed lines in Figure 2D are drawn at 488, 532 and 632 nm, respectively. At these common wavelengths, the transmission efficiencies remain above 85%, with the greatest drop of 60% for unit cell number 3 at 488 nm.

Despite the drop, the average transmission efficiency is 89.3% at these common wavelengths. Therefore, numerical calculations demonstrate the broadband behaviour with high transmission efficiencies as a function of wavelength between 450 nm and 650 nm. The cross-polarised and co-polarised efficiencies of the transmitted electric fields due to different unit cells are also plotted as a function of incident wavelength (Supplementary Section S3).

In order to authenticate the performance of the optimised array of eight unit cells for broadband and polarisation-insensitive operation, we have designed a $40.04 \times 40.04\text{ }\mu\text{m}^2$ metahologram. The details about the selection of supercell for the metahologram-design is provided in the Supplementary Information (Section S5). The phase map of an image (containing 154×154 elements) is numerically calculated using the inverse Fourier-transform method [36] shown in Figure 3A. The phase map is encoded onto a metasurface using four different GaN nanorods with horizontal and vertical orientations. The phase with values between 0° to 157° and

Figure 3: Demonstration of the polarisation-insensitive metahologram via the reconstruction of a single holographic image.

(A) Desired phase map of the target image (moon and star) with 154×154 pixels. The size of each pixel is 260 nm. Reconstruction of holographic images at a wavelength of 532 nm under (B) LCP (C) RCP (D) LHP (E) LVP and (F) elliptically polarised incidence. The results are obtained using finite difference time domain solver (FDTD Lumerical) with perfect matching layer boundary conditions in the x, y and z directions. The observation plane is kept $20.02\text{ }\mu\text{m}$ away from the metasurface in the z-direction. All results are obtained through the same $40.04 \times 40.04\text{ }\mu\text{m}^2$ metahologram.

338° to 359° is encoded using unit cells 1–4 and the phase with values between 158° and 337° is encoded using unit cells 5–8. This phase map leads to the reconstruction of a holographic image (moon and star) at a focal distance of $20.02\ \mu\text{m}$ in the z -direction. During the calculation of the phase map, the size of the pixel is kept equal to the displacement ($U=260\ \text{nm}$) of the metasurface. The designed metasurface is subjected to different polarisation states at a working wavelength of $532\ \text{nm}$. The optical outputs are demonstrated in Figure 3B–F. The metahologram reconstructs a desired holographic image with an equal intensity profile under LCP, RCP, LHP, LVP and elliptically polarised incidence.

2.3 Broadband analysis under unpolarised illumination

The metahologram is characterised by calculating the total efficiency of metahologram as a function of wavelength under unpolarised light incidence. The efficiency of the metahologram is described as the power of transmitted light divided by the power of incident light through an aperture having the same area as the metahologram ($40.04 \times 40.04\ \mu\text{m}^2$). The efficiencies of metahologram are 73%, 90% and 72% under the illumination of blue ($488\ \text{nm}$), green ($532\ \text{nm}$) and red ($632\ \text{nm}$) light, respectively. The efficiency remains above 66% over the $186\ \text{nm}$

Figure 4: Broadband metahologram under unpolarised light incidence.

(A) The total efficiency of metahologram across the visible domain (from $450\ \text{nm}$ to $650\ \text{nm}$). The colored vertical lines represent the efficiencies at their corresponding wavelengths; for example, the green line is drawn at a wavelength of $532\ \text{nm}$, showing 90% efficiency. (B–D) Intensity profiles of reconstructed holographic images of the same metahologram under the (B) blue ($488\ \text{nm}$) (C) green ($532\ \text{nm}$) and (D) red ($632\ \text{nm}$) unpolarised light illumination. The anisotropic-nanorods are optimised at a central wavelength of $532\ \text{nm}$ and are expected to lose some efficiency far from the central wavelength. If a metasurface is designed via supercell containing optimised nanorods at three different wavelengths (i.e. blue, green and red), the deterioration in image fidelity at a wavelength of $632\ \text{nm}$ can be subjugated. In the small-device-size simulation, the results are affected by the edge effect (radiation from the corner metaatoms) which can be avoided in actual electrically large fabricated metasurface. Moreover, for the same metasurface, the image fidelity can also be improved by simulating a bigger metasurface with more pixels at the expense of more computational expense. Two simulations with orthogonally polarised sources are performed. The results from these simulations are added incoherently to obtain an unpolarised light source.

broadband wavelength range (464 nm–650 nm) with a maximum efficiency of 91% at 530 nm, as depicted in Figure 4A. The corresponding optical outputs under the unpolarised illumination of blue, green and red light are shown in Figure 4B–D, respectively.

The reconstructed holographic images projected at the far-field by the same metahologram for different wavelengths under unpolarised light incidence possess good image fidelities and high efficiencies. Note that, under all conditions discussed above, a substantial portion of the incident light is transmitted and contributed towards the holographic target. The broadband nature of this polarisation-insensitive metahologram is predicted over a long-range in the visible domain. We have strictly followed the fabrication tolerances (of GaN nanorods) presented by Chen et al. [8], to ensure the realisation of the proposed device. This is due to the fact that the minimum feature size of our metasurface is slightly larger than the above-reported metasurface using GaN nanorods (with the same refractive index). Therefore, the realisation of a polarisation-insensitive metasurface of high efficiency and excellent image fidelity in the visible domain is now possible.

3 Conclusion

In conclusion, we demonstrate theoretically and numerically a unique concept for the realisation of broadband and polarisation-insensitive metasurface made of anisotropic nanorods. By using the anisotropic nanorods as building blocks, we are able to harness their geometric properties and gain accurate control over the phase and polarisation state of incident light compared to the isotropic nanorods having no extra degree of freedom. In this work, the principle of phase delay between adjacent parallel and perpendicular nanorods helps in devising a novel technique to simultaneously realise polarisation insensitivity and full phase control over an almost entire visible domain ($\lambda = 450\text{--}650\text{ nm}$). This is achieved by breaking the traditional trade-off between polarisation and bandwidth. For the proof of concept, a metasurface is designed and characterised by different polarisation states and wavelengths. The optical outputs of proposed metasurface show very high efficiency (blue: 73%, green: 90%, red: 72%) and good image fidelity under all polarisation states, i.e. LCP, RCP, LHP, LVP, elliptical and unpolarised incidence. Over a broadband wavelength range of 186 nm, the efficiency of the metahologram remains above 66%. The values of efficiency under unpolarised light and under other polarisation states are equal, thus confirming

polarisation insensitivity. Therefore, our novel approach is valid for all wideband optical metadevices requiring polarisation insensitivity with practical applications in multimedia and entertainment.

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