High-efficiency and ultra-wideband reflective beam splitter for visible light based on metasurface of all-dielectric layer

Yu Lin & Chunping Jiang*

（Key Laboratory of Nanodevices and Applications, Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Science, Suzhou 215123, China）

***cpjiang2008@sinano.ac.cn**

INTRODUCTION

Currently, the realization of metasurfaces offers potential for developing virtually flat optics, thin-film optics and diffractive optics. For instance, metasurfaces are being explored for their potential in super-resolution imagin high precisionlithography and invisibility cloaks as well as being used to construct planar optical. To meet the demand of more efficient and integrated optic devices, the dielectric material gradually enters the field of view due to its extremely low optical loss.

A few reports show that the dielectric metasurfaces have the ability to overcome these challenges. A few reports show that the dielectric metasurfaces have the ability to overcome these challenges. More importantly, they are also compatible with standard semiconductor integration techniques and easy-to-fabricate. Thus, it can be tailored to flat chromatically-corrected imaging lenses, polarizers, lightweight flat lenses and beam shaping.

METHODS

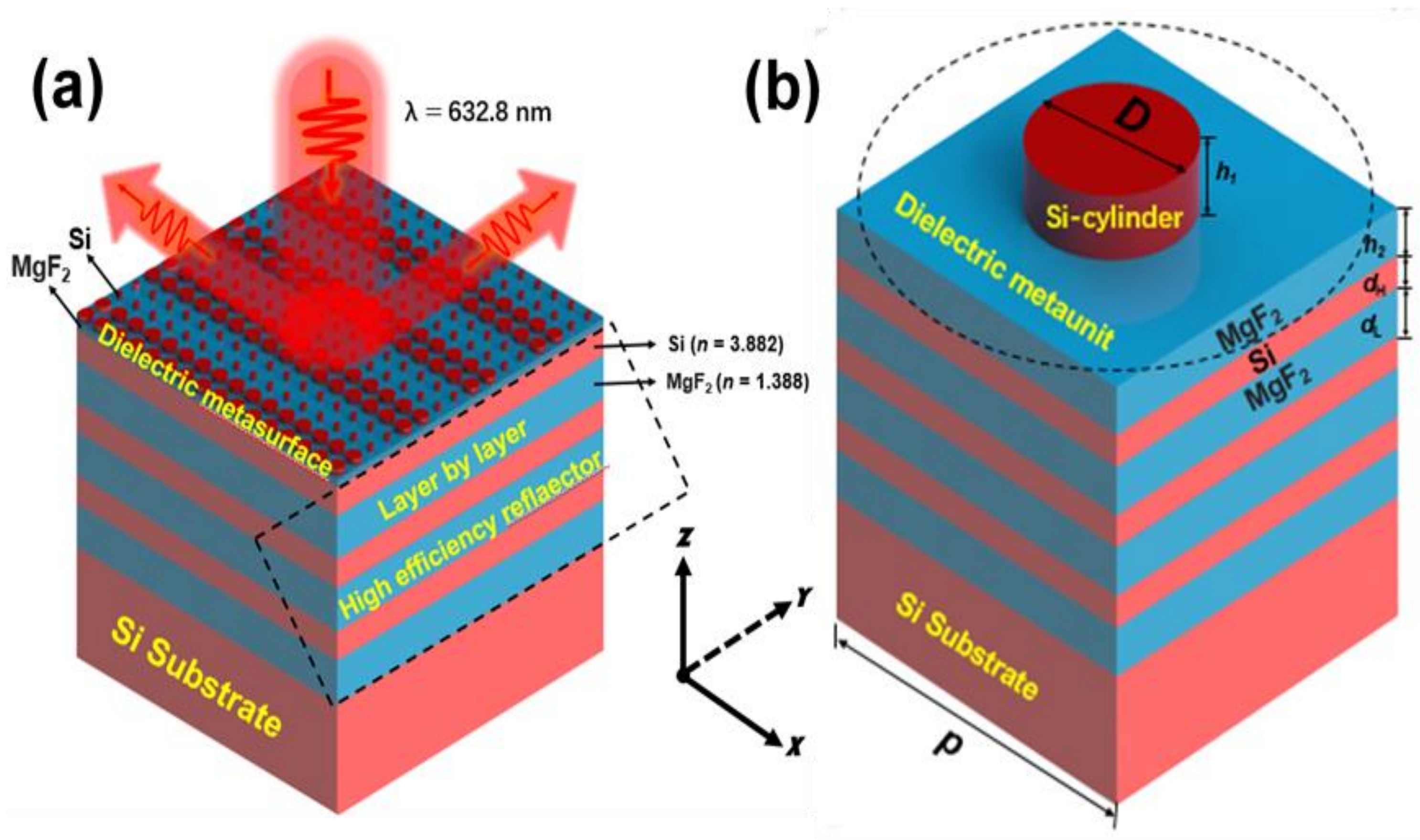


Figure 1. (a) Schematic of the metasurface-based all-dielectric beam splitter. (b) Schematic of the unit cell.

•Proposed dielectric metamaterials consist of periodical array of sub-wavelength dielectric particles.

• Highly refractive dielectrics with low losses at focused frequencies, such as silicon and germanium, are employed;

•Arrangement of Si-cylinders and formation of beam splitting according to the generalized Snell‘s law：

$$\theta_r = \sin^{-1}(\lambda_0/\Gamma) = \sin^{-1}(\lambda_0/(np))$$

Equation . Generalized Snell's law

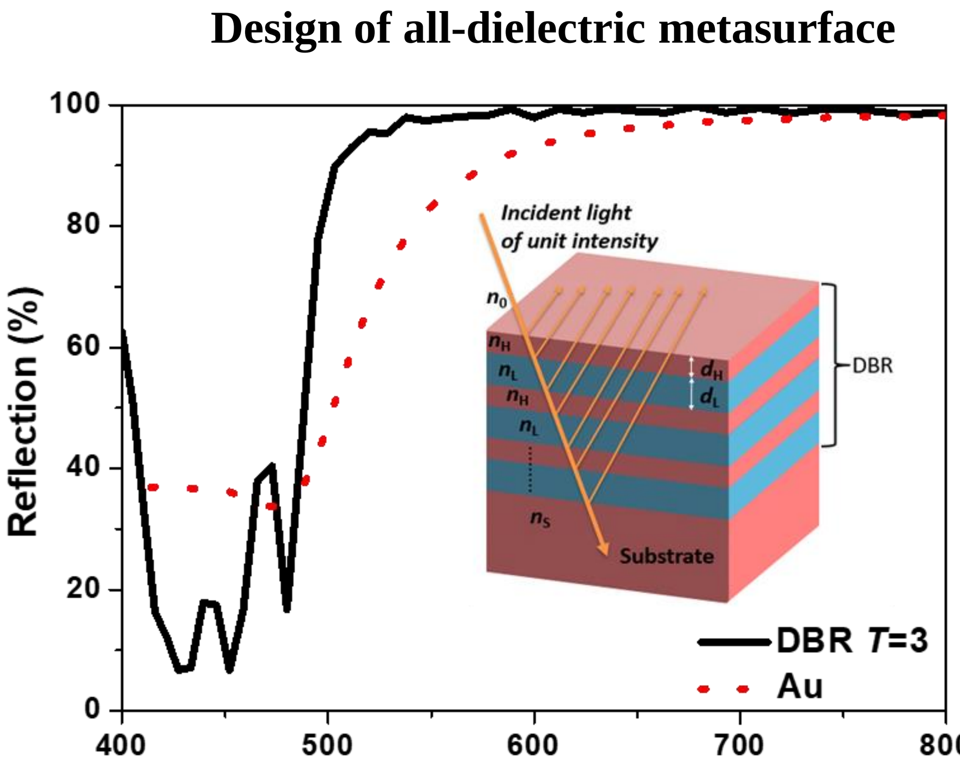
Numerical simulations:

Full-wave electromagnetic numerical simulations are performed using finite-difference-timedomain (FDTD).

RESULTS

In this letter, a state-of-the-art high efficiently and ultra-wideband reflective beam splitter based on all-dielectric metasurface for the visible light is demonstrated. The proposed all-dielectric layer consists of Si nano-cylinders array and a layer by layer (LBL) high efficiency reflector separated by the MgF2 spacer. Using the finite-difference-time domain (FDTD) simulations, the reflective beam splitting with a high conversion efficiency about 95% has been realized and the operation bandwidth is larger than 150 nm. We expect that our approach has the potential to fundamentally change the performance and economics of the compact photonic devices.

Design of all-dielectric metasurface



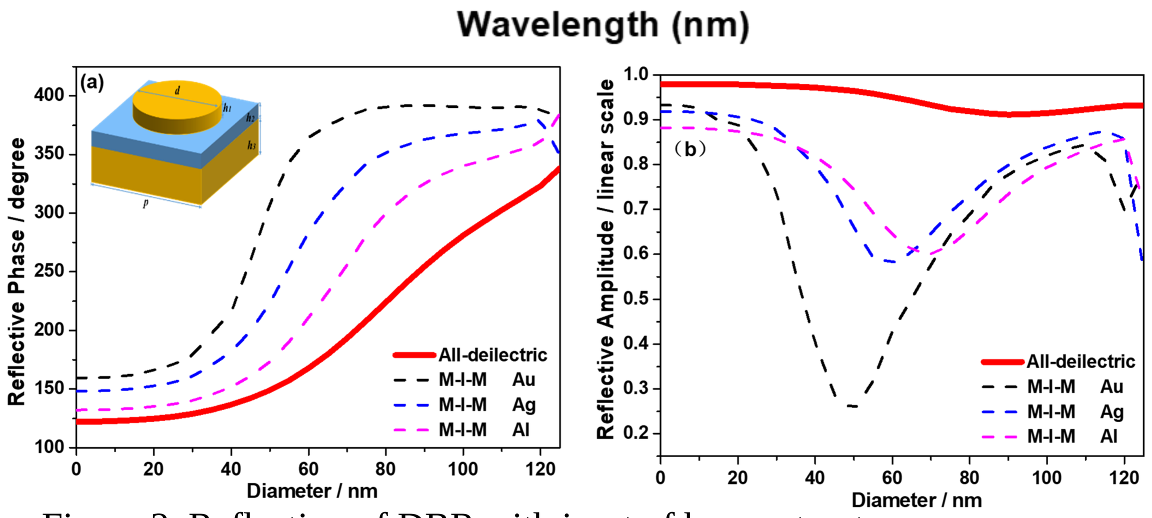
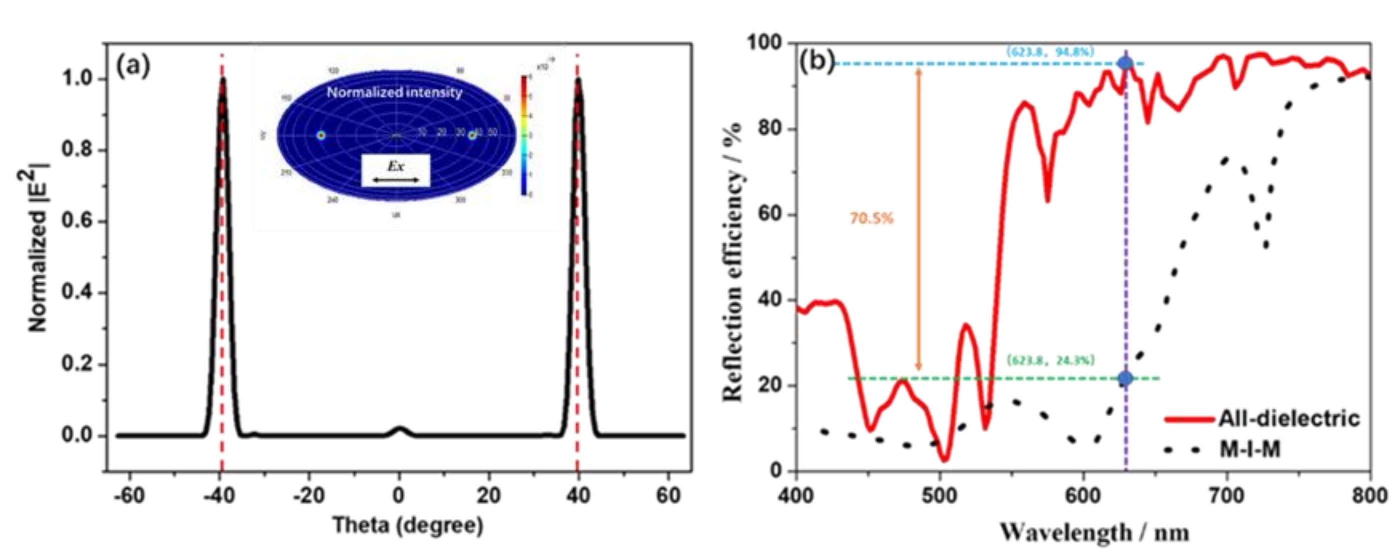


Figure 2. Reflection of DBR with inset of bragg structure.

Figure.3 Comparison of the performance between the proposed all-dielectric multilayer and the metal-insulator-metal (M-I-M) structures

Comparison of the efficiency between all-dielectric metasurface and the metal metasurface



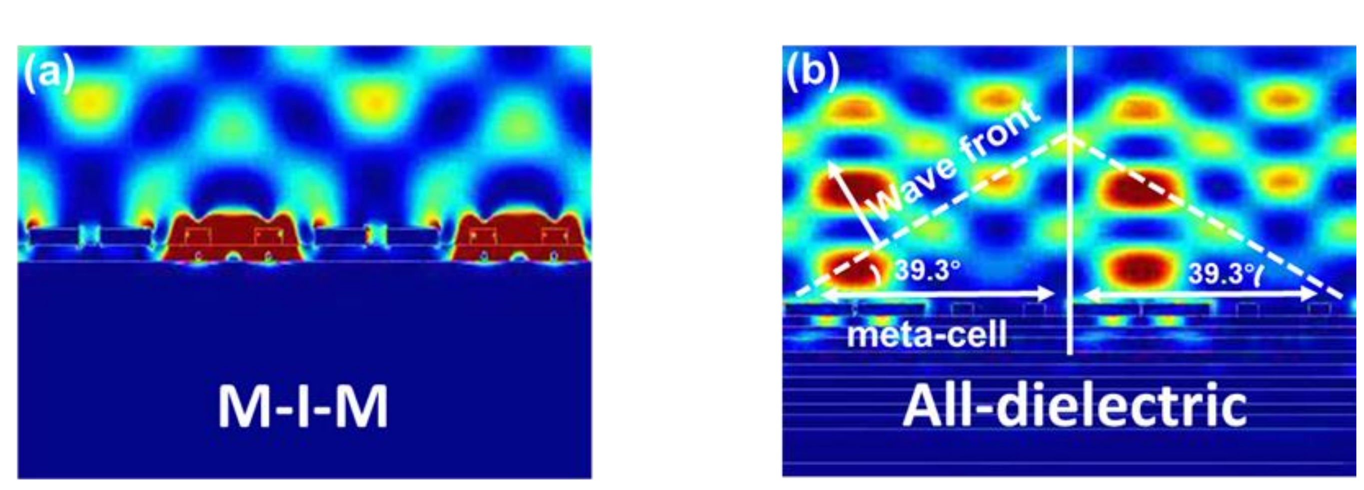
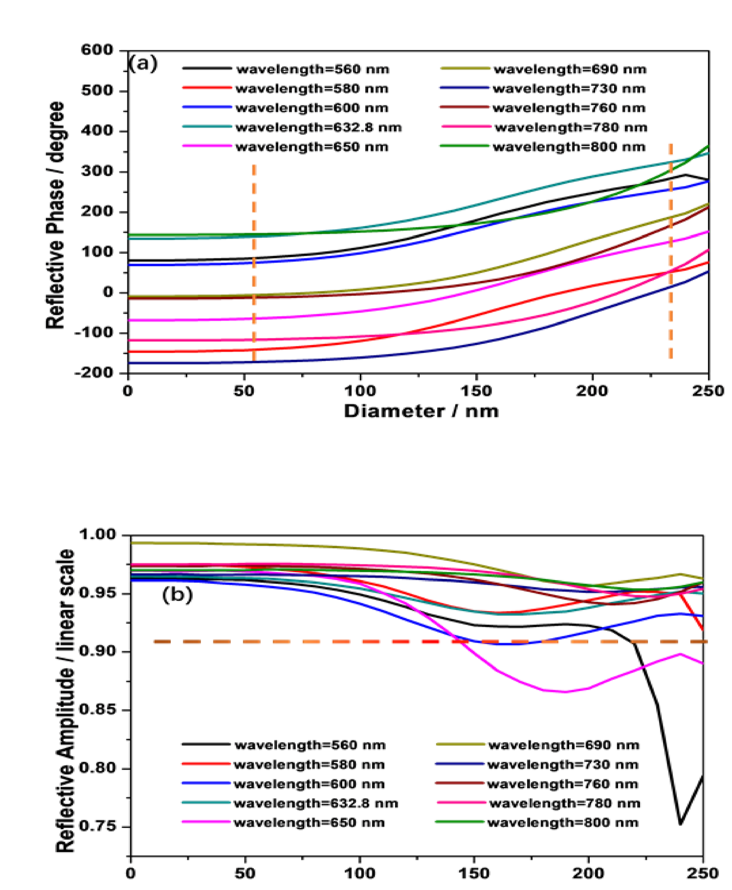


Figure 4. FDTD simulated (a) Normalized far-field radiation pattern of the reflected beam for x- polarized illuminations with λ = 632.8 nm and the inset polar diagram of normalized intensity show the beam is reflected to two deviation angles of ±39.3° with respect to the z-axis. (b) Reflection of the whole system under the illumination of a normally incident x- polarized light through the whole visible spectrum, with the blue point indicate the reflection with λ = 632.8 nm.

Figure 5. Scattered Ex field patterns of (a) M-I-M metal meta-surface and (b) all-dielectric meta-surface under the illumination of a normally incident x- polarized light with λ = 632.8 nm, phase profile obtained by the metasurface with the dashed line defining the wavefront.

The formation of ultra-wideband characteristics



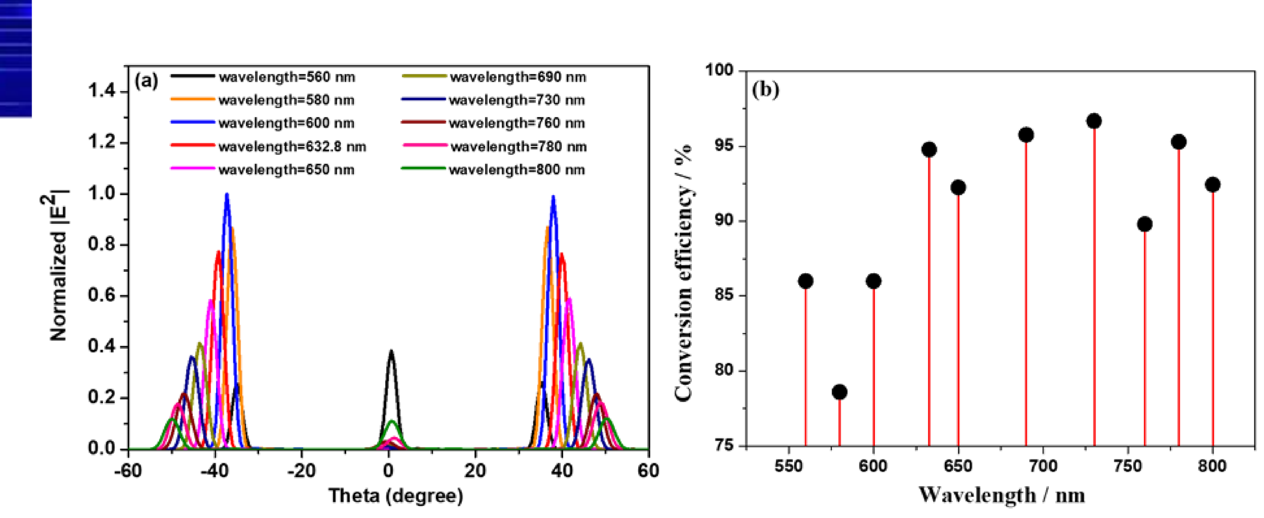


Figure 6. (a) Reflective phase and (b) Reflective amplitude with different wavelength of the incident light.

Figure 7. FDTD simulated (a) Normalized far-field radiation pattern and (b) conversion efficiency of the reflected beam for x- polarized illuminations with λ =560 nm, 580 nm, 600 nm, 632.8 nm, 650 nm, 690 nm, 730 nm, 760 nm, 780 nm and 800 nm, respectively.

References:

(1) Mohammadreza Khorasaninejad & Federico Capasso. Metalenses: Versatile multifunctional photonic components. Science. 358, 1146 (2017)

(2) Longqing Cong, Tze Chien Sum, & Ranjan Singh. Perovskite as a Platform for Active Flexible Metaphotonic Devices. ACS Photonics, 4, 1595−1601 (2017)

(3) Hyunmin Kim & Jong-Hyun Ahn. Graphene for flexible and wearable device applications. Carbon 120, 244−257 (2017)

(4) N. Yu et al. Light propagation with phase discontinuities: Generalized laws of reflection and refraction. Science 334, 333–337 (2011).

(5) A. V. Kildishev, A. Boltasseva & V. M. Shalaev. Planar photonics with metasurfaces. Science 339, 1232009 (2013)

(6) 6N. Yu, F. & Federico Capasso. Flat optics with designer metasurfaces. Nat. Mater. 13, 139–150 (2014).

CONCLUTION

In summary, we have proposed an all-dielectric optical metasurface to be used as high efficient beam splitter applied in visible light spectrum and the functionality of the beam splitter has been theoretically and numerical simulation demonstrated. Furthermore, the proposed metasurface based all-dielectric device not only has a minimized spatial size and ultrathin planar structure but also has advantages such as low cost, integratable and high efficiency, thus having great potentials in large scale photonic integrated circuits applications in future.

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