Complete control over reflected fields with gap surface plasmons

Sergey I. Bozhevolnyi

Centre for Nano Optics, University of Southern Denmark

Introduction:

Gap surface plasmons (GSPs)

GSP resonators and their arrays

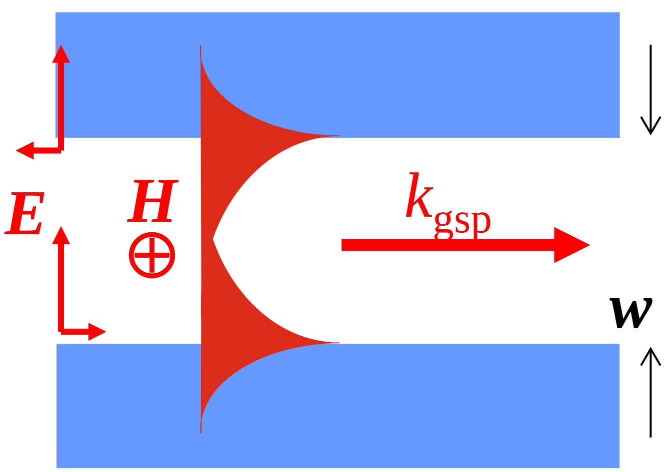
- **Black and coloured metasurfaces**
- **Phase-gradient metasurfaces**
- **Independent polarization control**
- **Analog computing**
- **Polarimetry by metasurfaces**
- **Stealth technologies**
- **Instead of outlook**

5 µm

Intro: gap surface plasmons

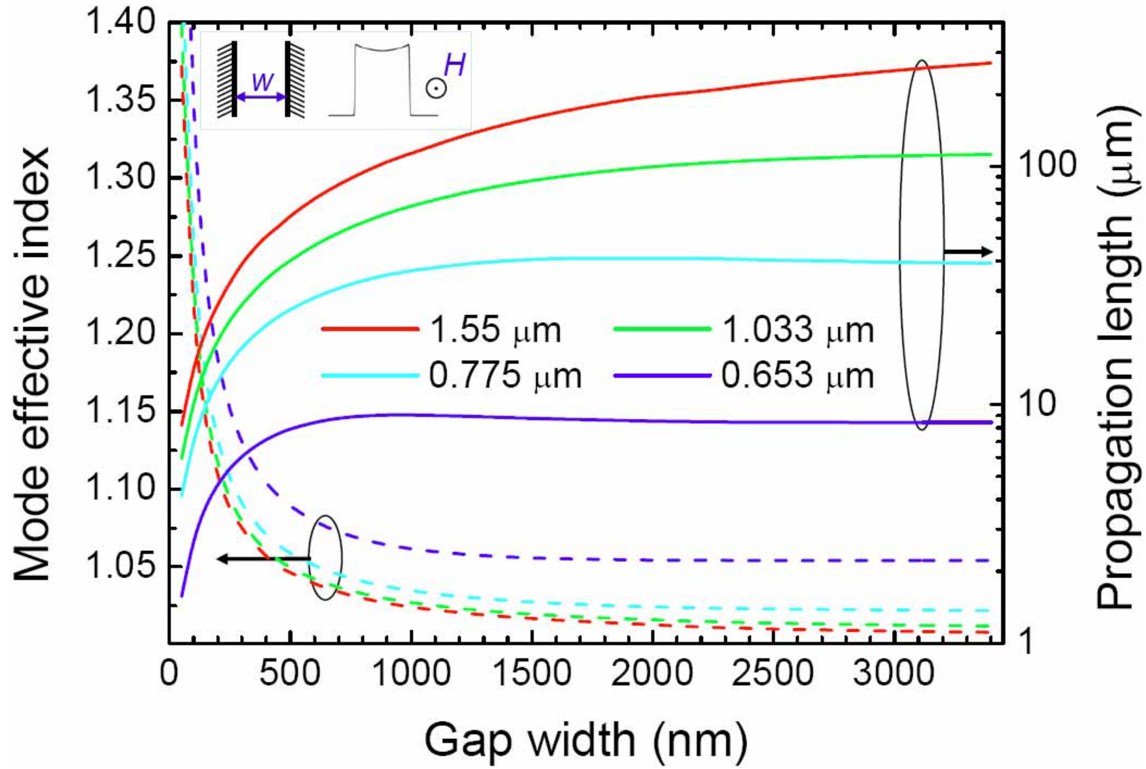
The GSP mode **confinement** and propagation constant **increase** with the decrease in the gap width (no cutoff!), storing field in metal (the propagation loss increases).

MIM geometry:



$$\text{GSP: } k_{gsp}(w) = \frac{\omega}{c} n_{gsp}(w)$$

$$n_{gsp}(w \to 0) \to \infty, \ \lambda_{gsp} \to 0$$



Confined GSP modes should be efficiently reflected by the terminations forming nano-resonators!

Gap plasmon based resonators

General properties of slow-plasmon resonant nanostructures: nano-antennas and resonators

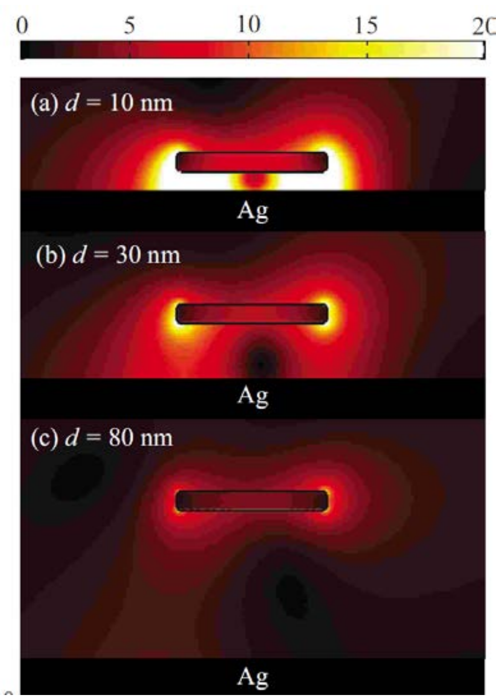
20 August 2007 / Vol. 15, No. 17 / OPTICS EXPRESS 10869

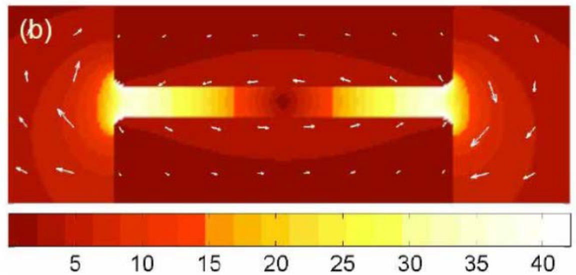
Sergey I. Bozhevolnyi and Thomas Søndergaard

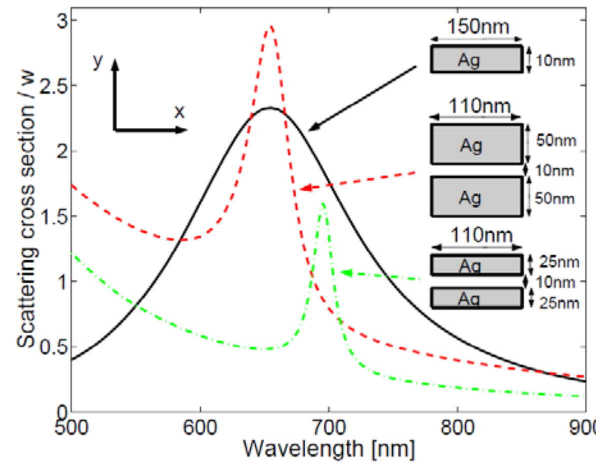
Department of Physics and Nanotechnology, Aalborg University, Skjernvej 4A, DK-9220 Aalborg Øst, Denmark

$$w\frac{2\pi}{\lambda}N_{eff} = m\pi + \varphi$$

Electric-field driven magnetic dipole:







PHYSICAL REVIEW B **79**, 035401 (2009)

Gap plasmon-polariton nanoresonators: Scattering enhancement and launching of surface plasmon polaritons

Jesper Jung* and Thomas Søndergaard

Department of Physics and Nanotechnology, Aalborg University, Skjernvej 4A, DK-9220 Aalborg Øst, Denmark

Sergey I. Bozhevolnyi

Institute of Sensors, Signals and Electrotechnics (SENSE), University of Southern Denmark, Niels Bohrs Allé 1, DK-5230 Odense M, Denmark

Gap plasmon based resonators

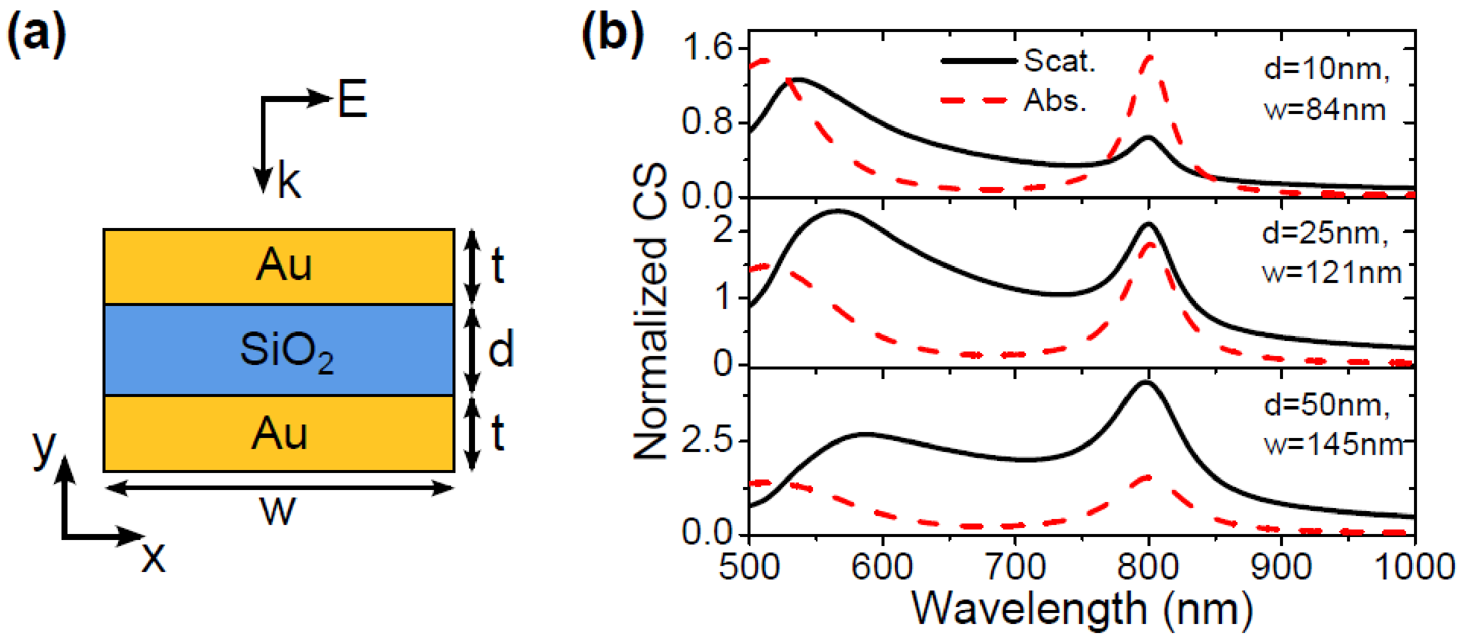


Fig. 1. (a) Sketch of a two-dimensional gold-SiO_2-gold resonator surrounded by air. The incident field is TM-polarized and propagates along the y-axis. (b) Scattering and absorption cross sections (CS) normalized to the width w of the gold strips for three different combinations of w and d. The strip thickness is fixed at $t = 30$ nm.

GSP resonances can be strongly absorbing or strongly scattering, depending on the gap width!

Opt. Express **21**, 27438 (2013).

Gap plasmon based resonators

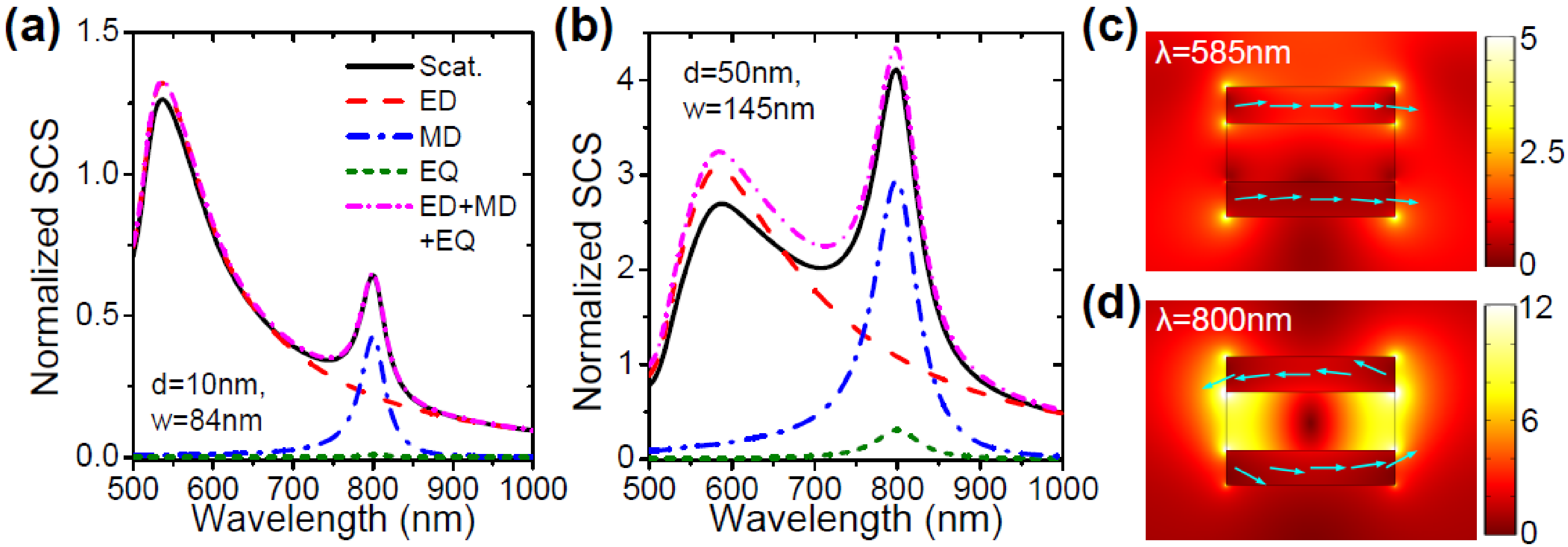


Fig. 2. (a,b) Contribution to the scattering cross section (SCS) from the lowest order multipoles (ED=electric dipole, MD=magnetic dipole, EQ=electric quadrupole). SCS is normalized with the resonator width w, and $t = 30$ nm [see Fig. 1(a)]. Note that in order to compare the relative contributions to the scattering from MD and EQ, we choose the center of mass as the coordinate origin. (c,d) Electric field enhancement at the ED mode ($\lambda = 585$ nm) and GSP mode ($\lambda = 800$ nm). The color bars are chosen as to emphasize the mode profiles rather than the high electrostatic field enhancement at the corners. Arrows indicate the

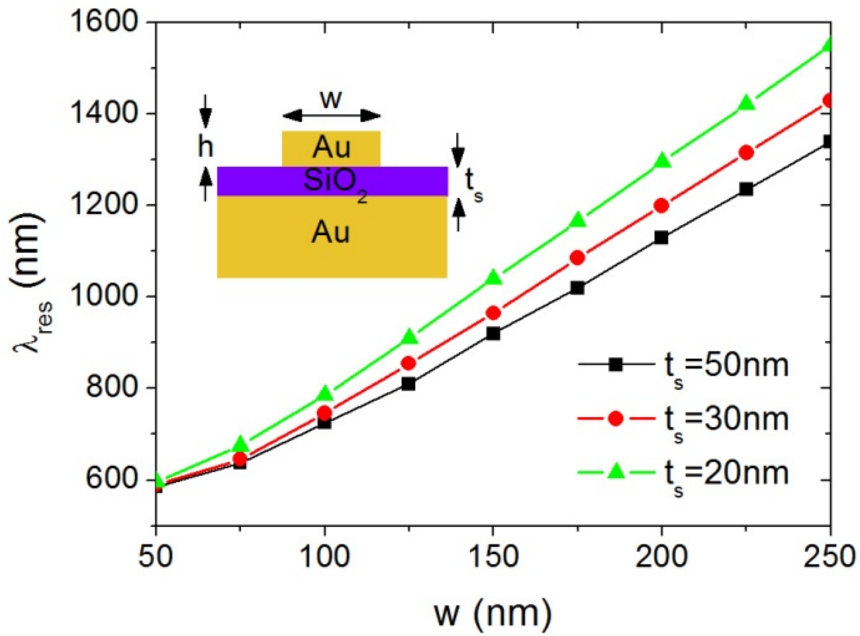
The main contribution to GSP resonances comes from the magnetic dipole resonances!

Opt. Express **21**, 27438 (2013).

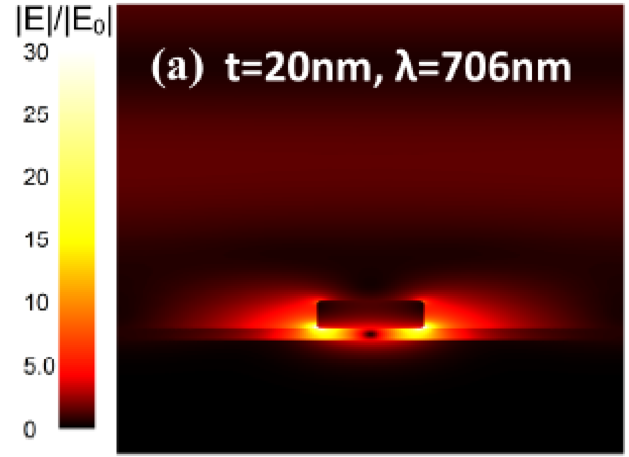
Gap plasmon based resonators

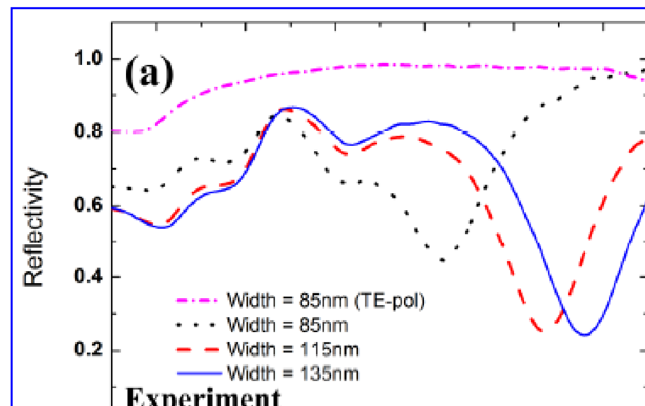
Continuous layer gap plasmon resonators

Michael G. Nielsen,[1,*] Dmitri K. Gramotnev,[1,2] Anders Pors,[3] Ole Albrektsen,[1] and Sergey I. Bozhevolnyi[1]



$$w\frac{2\pi}{\ }n\ = m\pi - \varphi$$





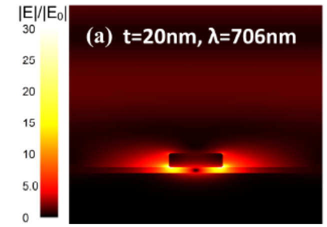
GSP resonators can be designed with continuous bottom metal and dielectric spacer layers!

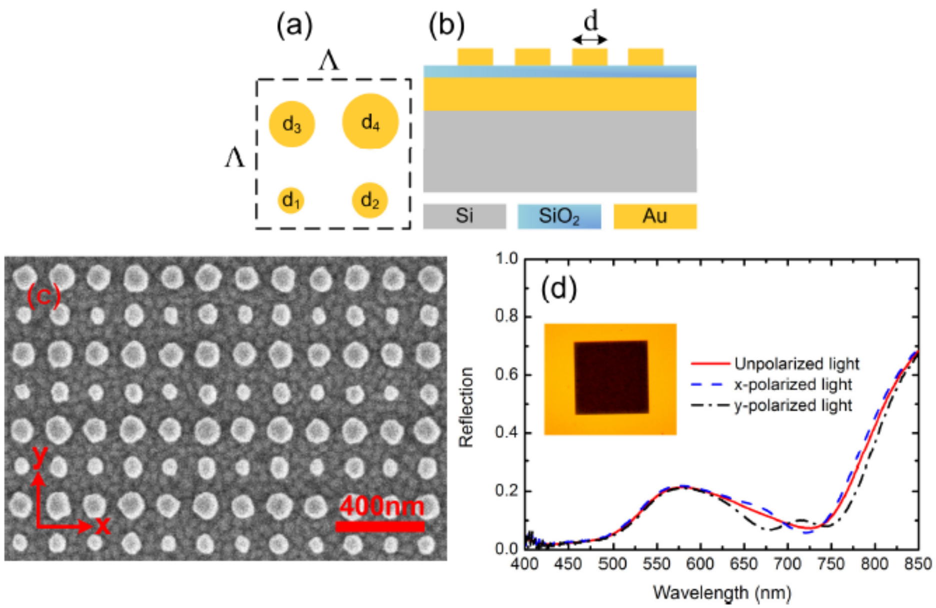
Opt. Express **19**, 19310 (2011).

Plasmonic black metasurfaces

Efficient absorption of visible radiation by gap plasmon resonators

Michael G. Nielsen,[1,*] Anders Pors,[2] Ole Albrektsen,[1] and Sergey I. Bozhevolnyi[1]





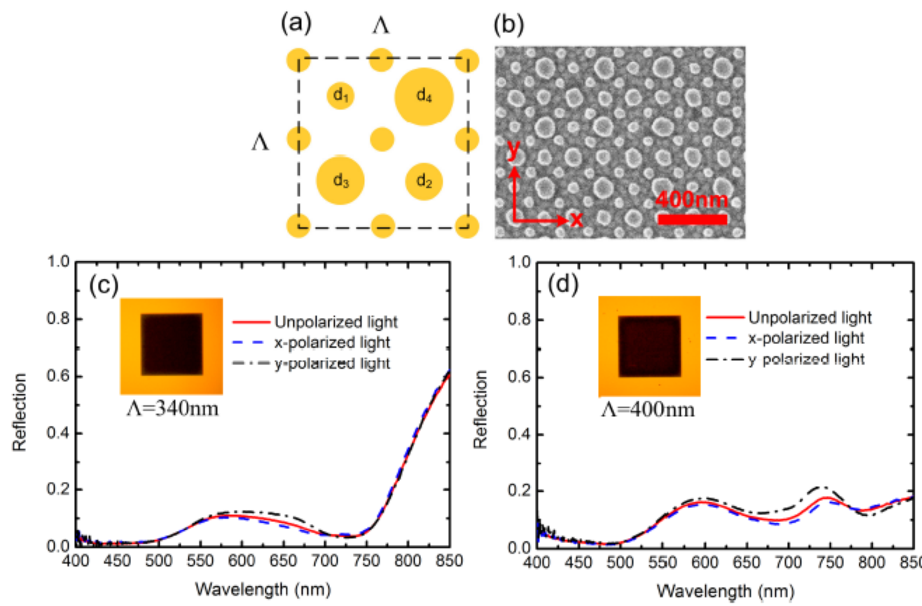


Fig. 1. (a) Schematic representation of the quadratic unit-cell of size Λ, and containing four gold nanoparticles with different diameters d. (b) Schematic representation of the layered sample structure. (c) SEM-image of the fabricated CL-GPRs with particle diameters d_1 =

film coated with ~20nm SiO_2.

Fig. 3. (a) Schematic representation of the unit-cell comprising four gold nanoparticles with different diameters and nine additional small gold nanoparticles with identical diameter. The unit-cell size is Λ = 340nm. (b) SEM-image of the fabricated CL-GPRs with particle diameters

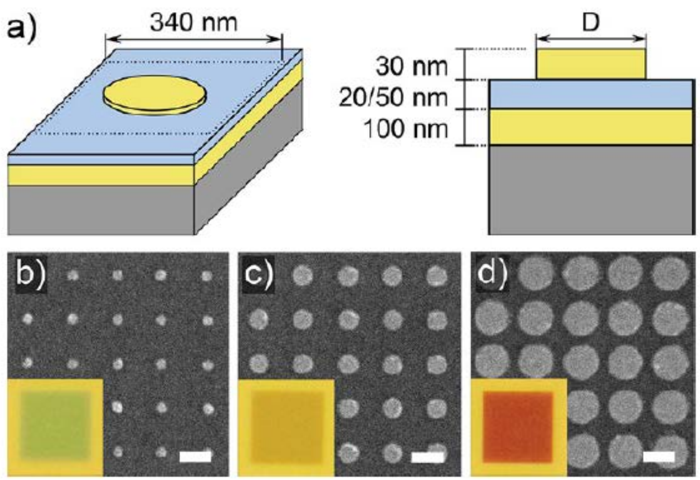
coated with ~20nm SiO_2. (d) Reflection spectra of a similar CL-GPR array, but with unit-cell

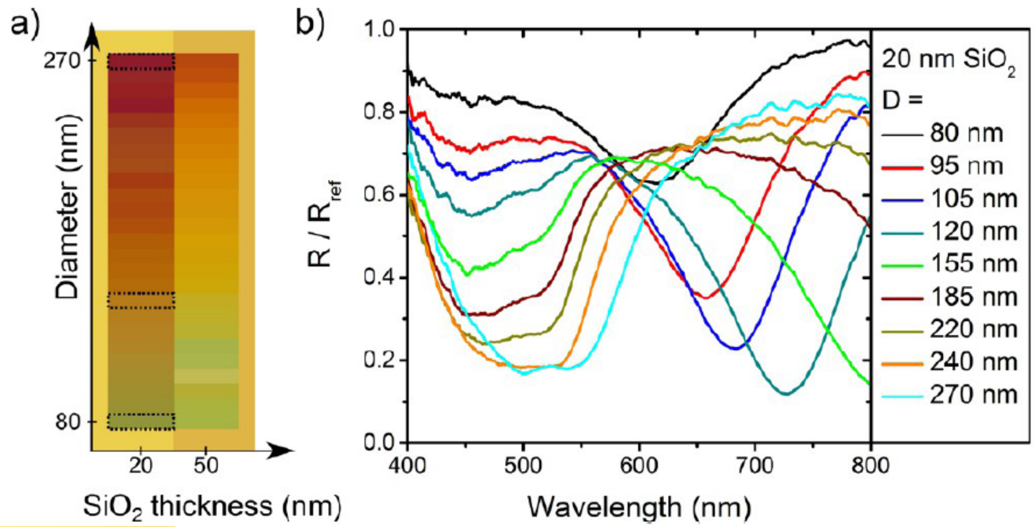
Average absorption: ~ 94% (400 – 750 nm) and ~ 89% (400 – 850 nm)

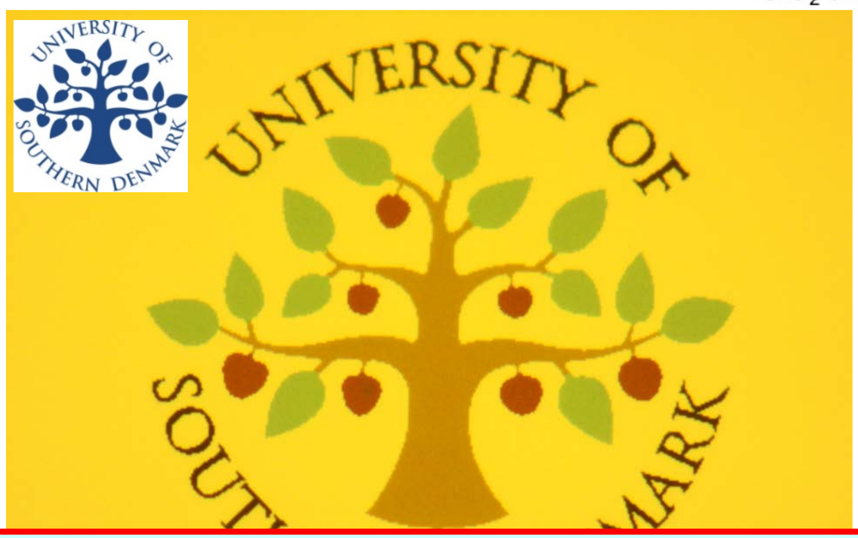
GSP resonances ensure very efficient absorption!

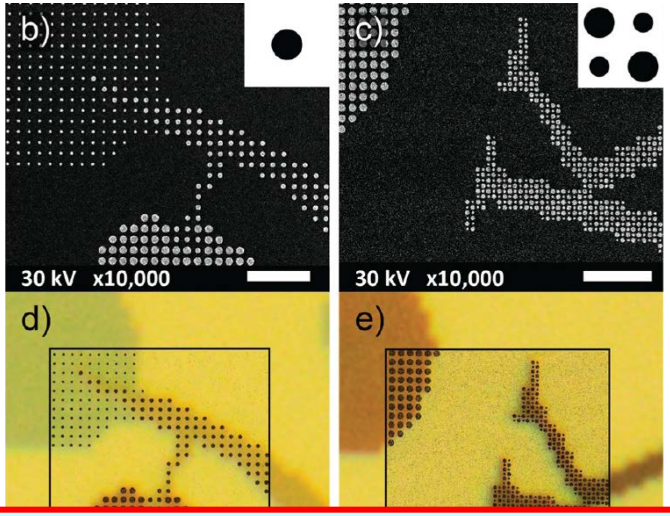
4 June 2012 / Vol. 20, No. 12 / OPTICS EXPRESS 13311

Plasmonic multicolored metasurfaces



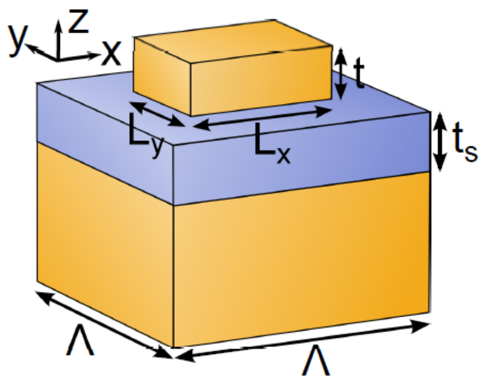






GSP resonances, when properly designed, can be used for sub-diffraction colour printing!

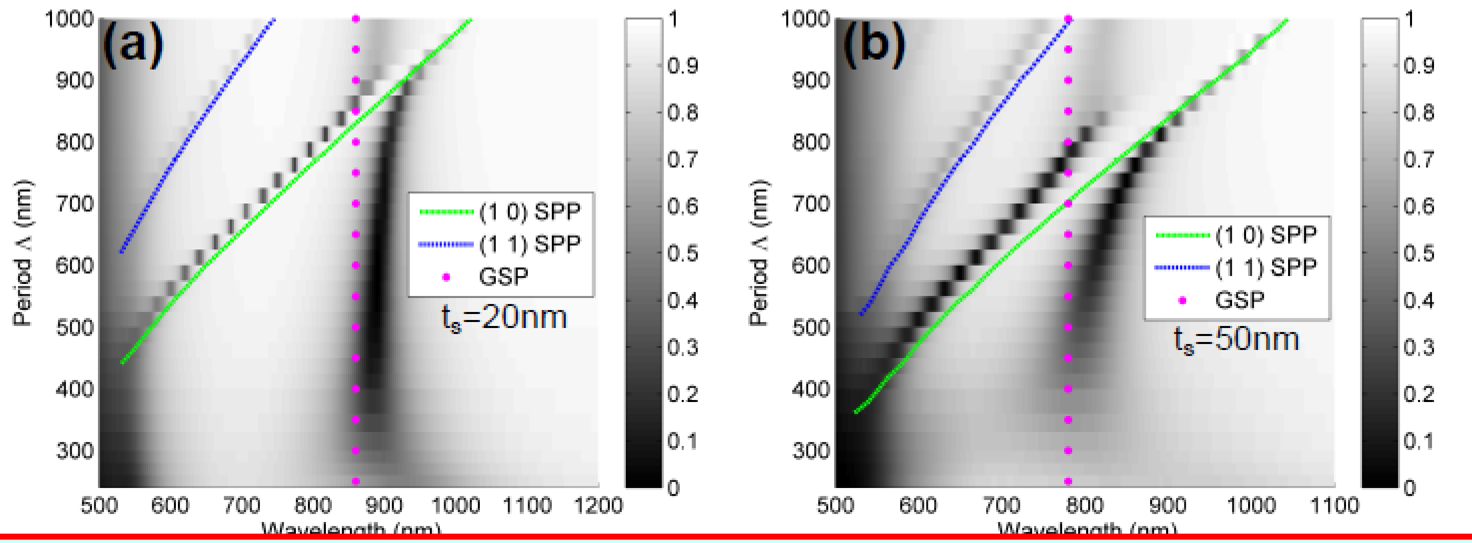
GSP resonator arrays: from amplitude to phase control



Opt. Express **21**, 2942 (2013)

$$t = 50\,\mathrm{nm},\ L_x = 138\,\mathrm{nm},\ L_y = 105\,\mathrm{nm}$$

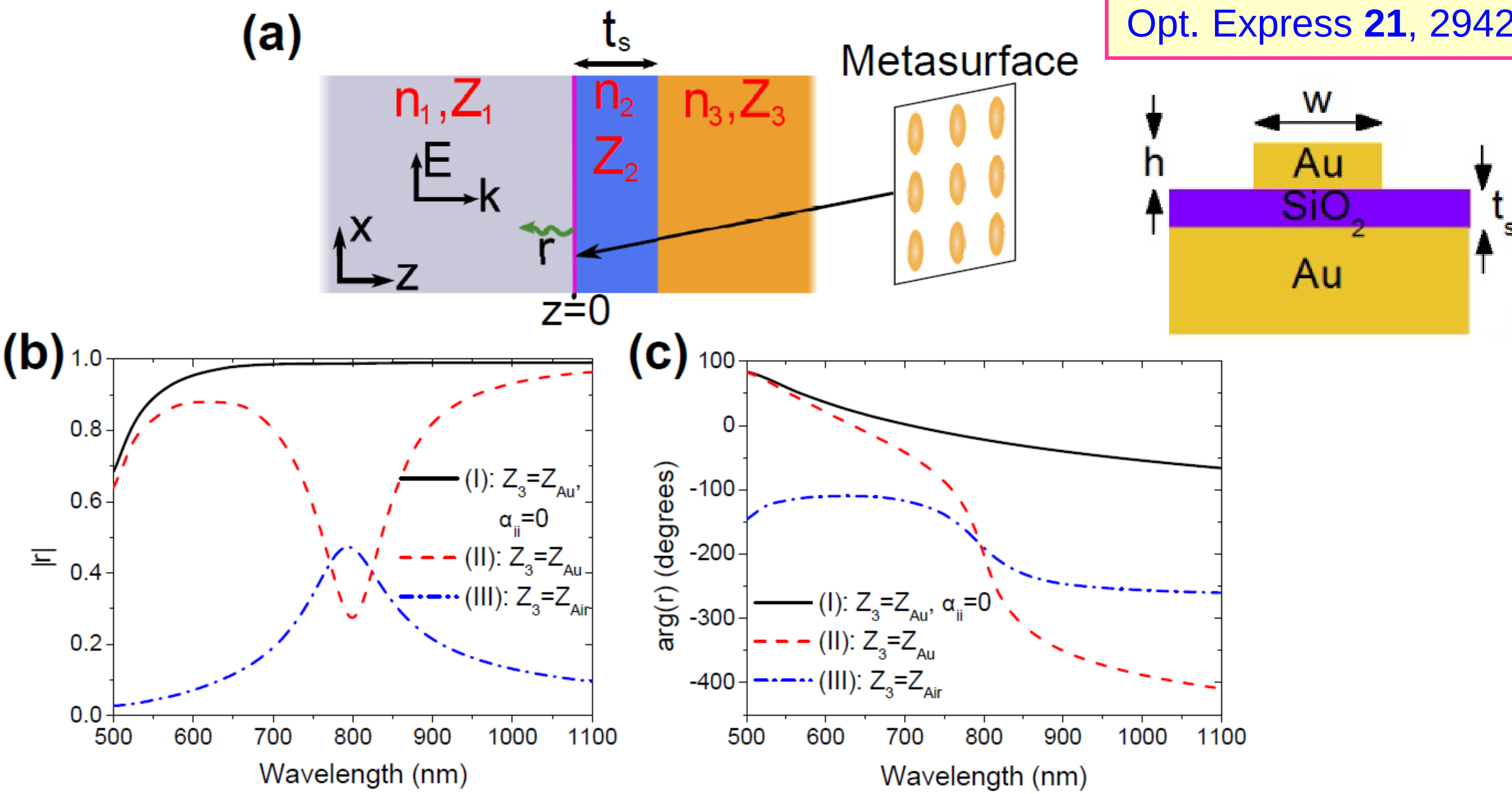
$$E_{in} = (E_x, 0, 0)$$



GSP resonances, when properly designed, can ensure either efficient absorption or reflection!

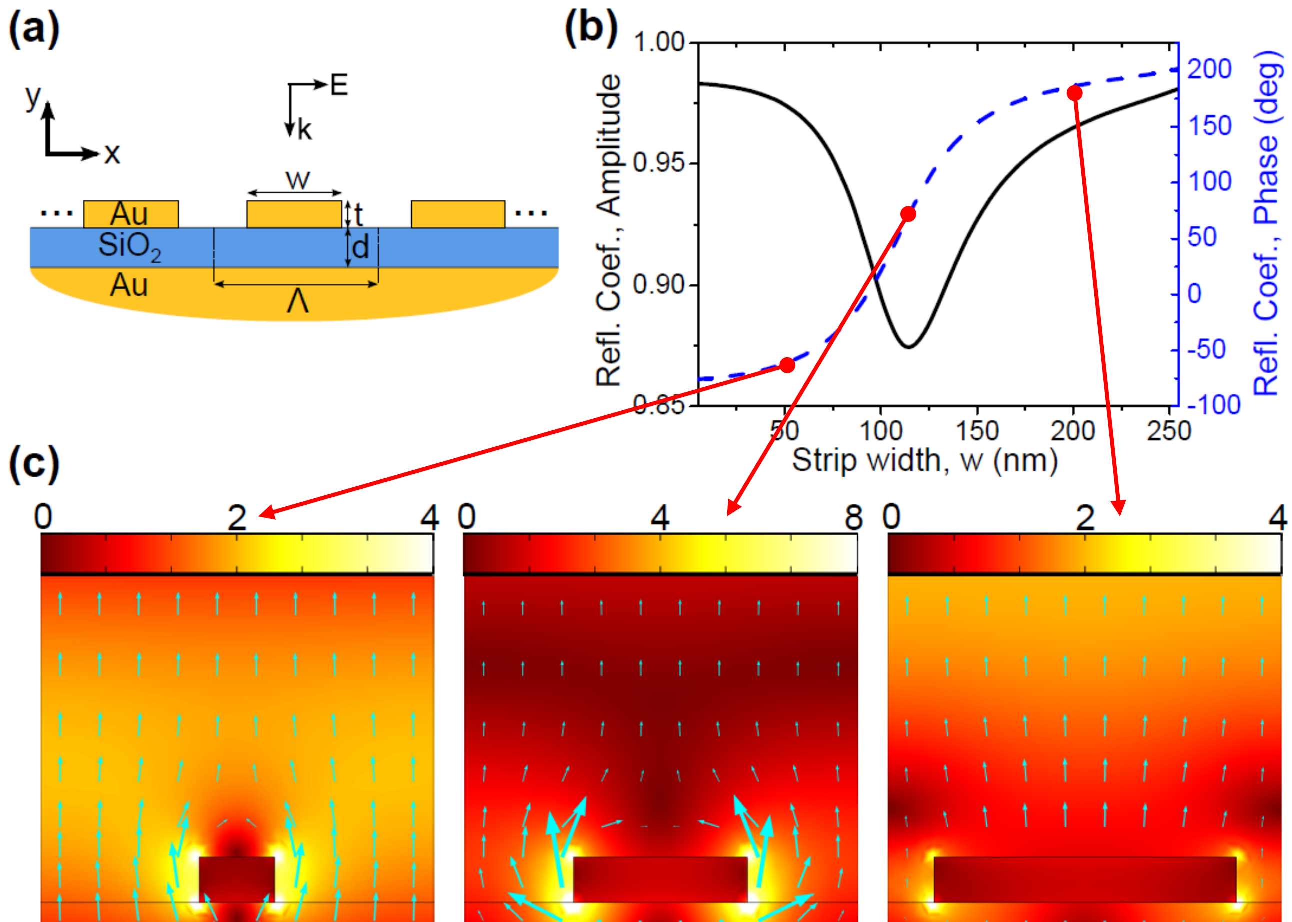
GSP resonator arrays: from amplitude to phase control

Opt. Express **21**, 2942 (2013)



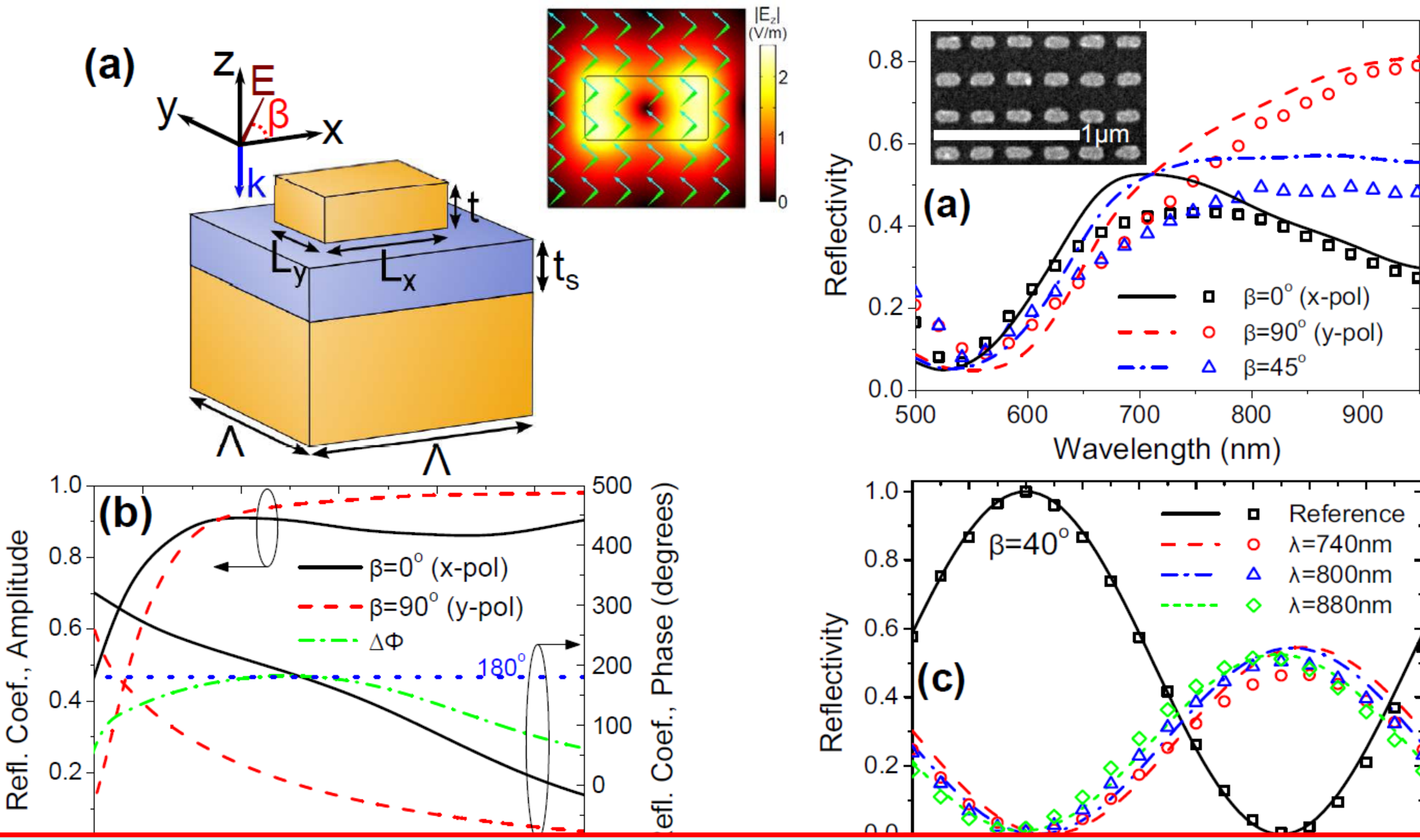
GSP resonances, when carefully designed, result also in strong (reflected light) phase variation!

GSP resonators: from amplitude to phase control



Extra large phase variation is due to drastic changes in path configurations of reflected light!

GSP-based perfectly reflecting half-plates



GSP resonator parameters control the phase difference between different polarizations!

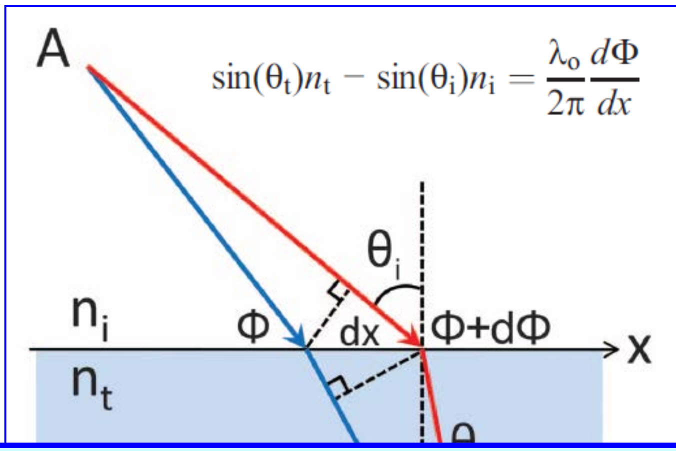
Phase-gradient metasurfaces

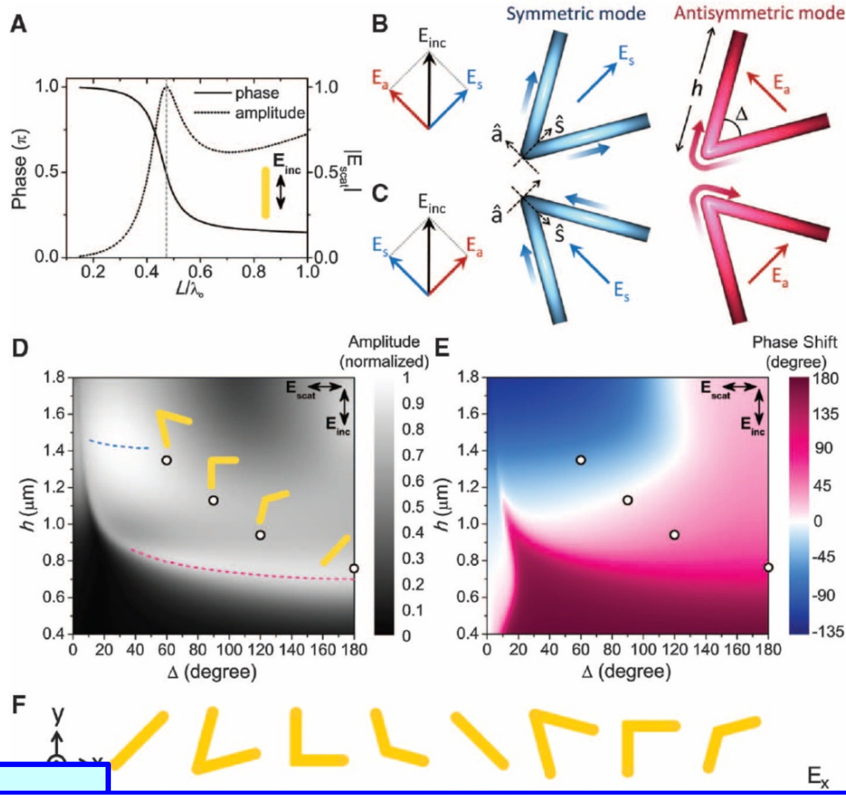
Historical perspective: from blazed gratings to phase-gradient surfaces

Light Propagation with Phase Discontinuities: Generalized Laws of Reflection and Refraction

Nanfang Yu,[1] Patrice Genevet,[1,2] Mikhail A. Kats,[1] Francesco Aieta,[1,3] Jean-Philippe Tetienne,[1,4] Federico Capasso,[1]* Zeno Gaburro[1,5]*

SCIENCE VOL 334 21 OCTOBER 2011





Broadband Light Bending with Plasmonic Nanoanten

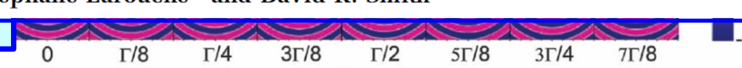
Xingjie Ni, Naresh K. Emani, Alexander V. Kildishev, Alexandra Bolta

SCIENCE VOL 335 27 JANUARY

June 15, 2012 / Vol. 37, No. 12 / OPTICS LETTERS 2391

Reconciliation of generalized refraction with diffraction theory

Stéphane Larouche* and David R. Smith



Prehistoric phase-gradient metasurfaces

1424 OPTICS LETTERS / Vol. 26, No. 18 / September 15, 2001

Pancharatnam–Berry phase in space-variant polarization-state manipulations with subwavelength gratings

Ze'ev Bomzon, Vladimir Kleiner, and Erez Hasman

Optical Engineering Laboratory, Faculty of Mechanical Engineering, Technion—Israel Institute of Technology, Haifa 32000, Israel

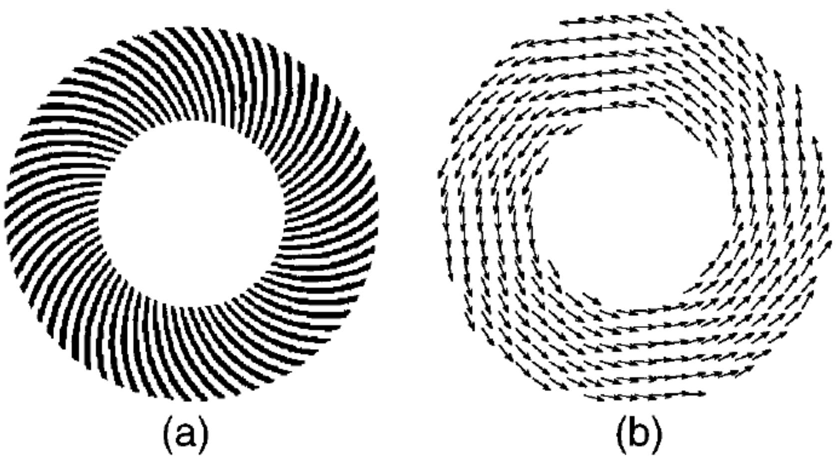


Fig. 3. (a) Magnified geometry of the grating for converting circular polarization into azimuthal polarization and (b) experimental measurement of the local azimuthal angle ψ.

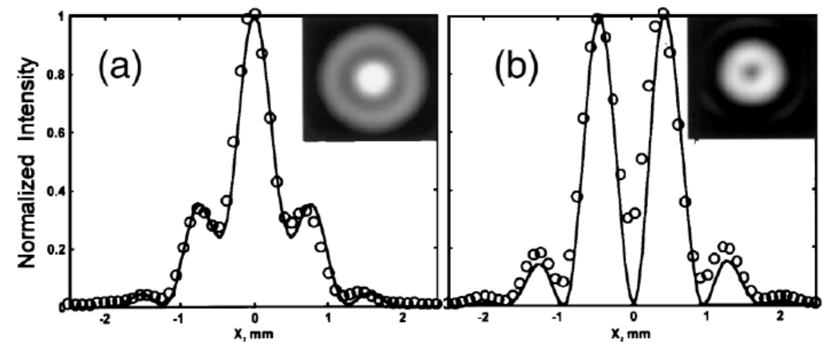


Fig. 4. Measured and calculated cross sections of the far-field images for (a) the in-phase and (b) the antiphase azimuthal polarization. Inset, experimental intensity distributions.

We realized a Lee-type binary grating … The metal stripes consisted of 10 of nm Ti and 60 of nm Au, which were deposited onto 500-mm-thick GaAs wafers by photolithography and a lift-off technique. ..

We illuminated the grating with circularly polarized light at a wavelength of 10.6 μm.

Prehistoric phase-gradient metasurfaces

Metal metasurfaces:

1. "*Pancharatnam-Berry phase in space-variant polarization state manipulations with subwavelength gratings*", Z. Bomzon, V. Kleiner, E. Hasman, Opt. Lett. **26**, 1424-1426 (2001).

2. "*Formation of radially and azimuthally polarized light using space-variant subwavelength metal stripe gratings*", Z. Bomzon, V. Kleiner, E. Hasman, Appl. Phys. Lett. **79**, 1587-1589 (2001).

Dielectric metasurfaces:

3. "*Space-variant Pancharatnam-Berry phase optical elements with computer-generated subwavelength gratings*", Z. Bomzon, G. Biener, V. Kleiner, E. Hasman, Opt. Lett. **27**, 1141-1143 (2002).

4. "*Formation of helical beams by use of Pancharatnam-Berry phase optical elements*", G. Biener, A. Niv, V. Kleiner, and E. Hasman, Opt. Lett. **27**, 1875-1877 (2002).

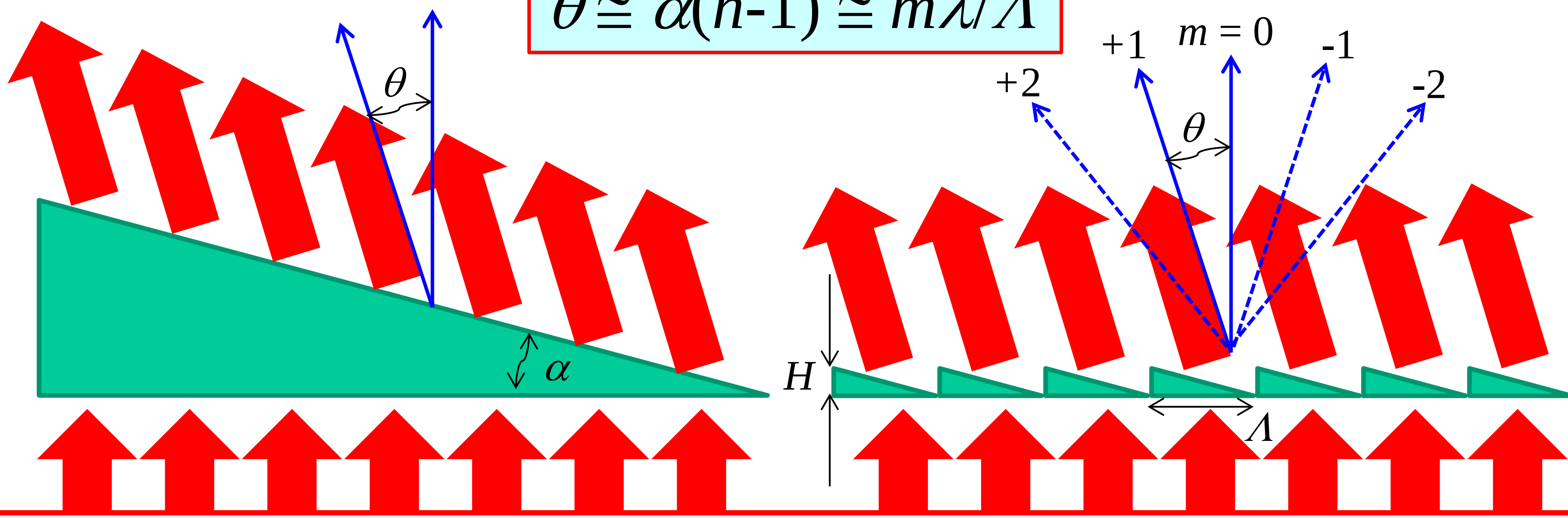
5. "*Polarization dependent focusing lens by use of quantized Pancharatnam-Berry phase diffractive optics*", E. Hasman, V. Kleiner, G. Biener, and A. Niv, Appl. Phys. Lett. **82**, 328-330

There is nothing new under the sun – from Ecclesiastes 1:9

Why phase-gradient metasurfaces?

Historical perspective: from blazed gratings to phase-gradient surfaces

$$\theta \cong \alpha(n\text{-}1) \cong m\lambda/\Lambda$$



Blazed gratings are also strongly bandwidth-limited!

$$H \cong \alpha\Lambda \cong \alpha m\lambda/\theta \cong m\lambda/(n\text{-}1)$$

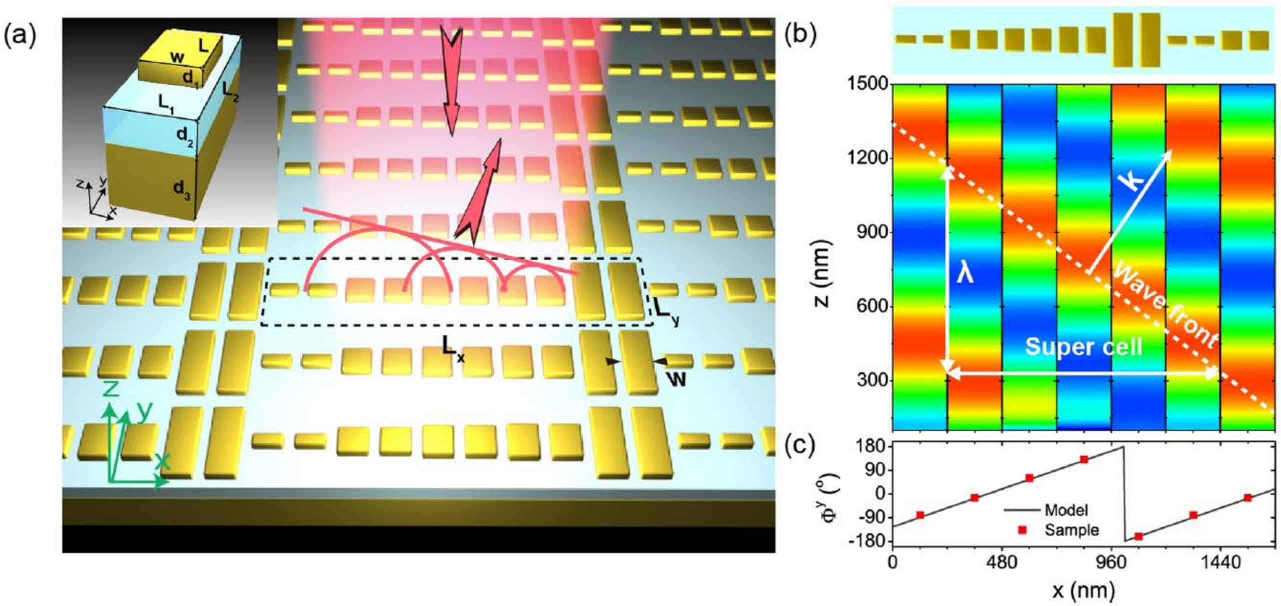
Thickness of blazed gratings is wavelength-limited, whereas thickness of metasurfaces is NOT!

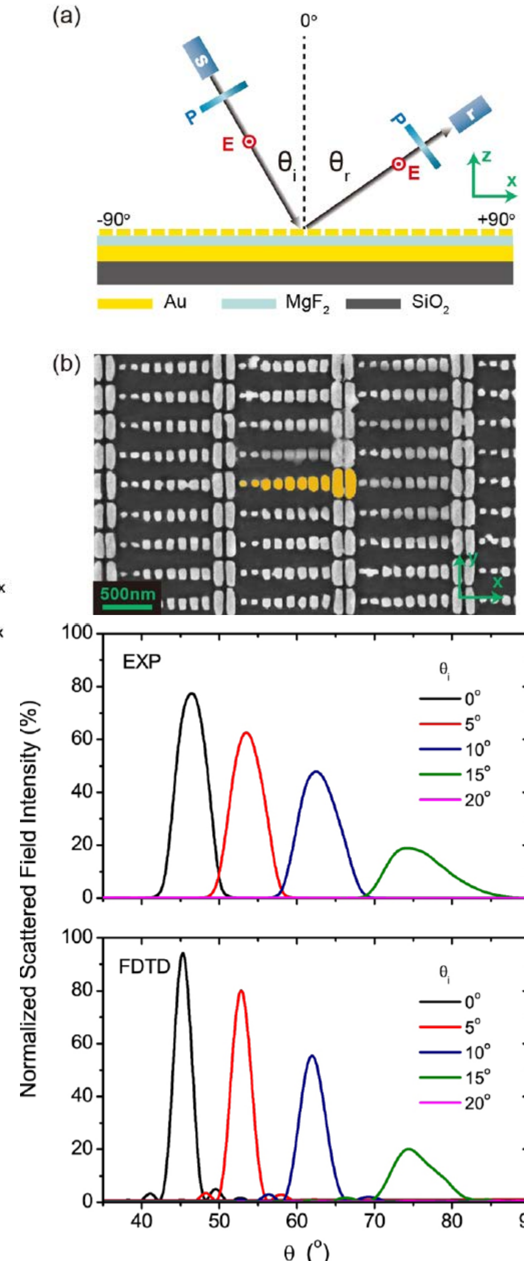
GSP-based phase-gradient metasurfaces

NANO LETTERS
Received: September 2, 2012
Revised: November 24, 2012
Letter
pubs.acs.org/NanoLett

High-Efficiency Broadband Anomalous Reflection by Gradient Meta-Surfaces

Shulin Sun,[†,‡,○] Kuang-Yu Yang,[§,○] Chih-Ming Wang,[∥,○] Ta-Ko Juan,[∥] Wei Ting Chen,[§] Chun Yen Liao,[†] Qiong He,[⊥] Shiyi Xiao,[⊥] Wen-Ting Kung,[∥] Guang-Yu Guo,[†,#] Lei Zhou,[*,⊥] and Din Ping Tsai[*,†,§,∇]





erc European Research Council

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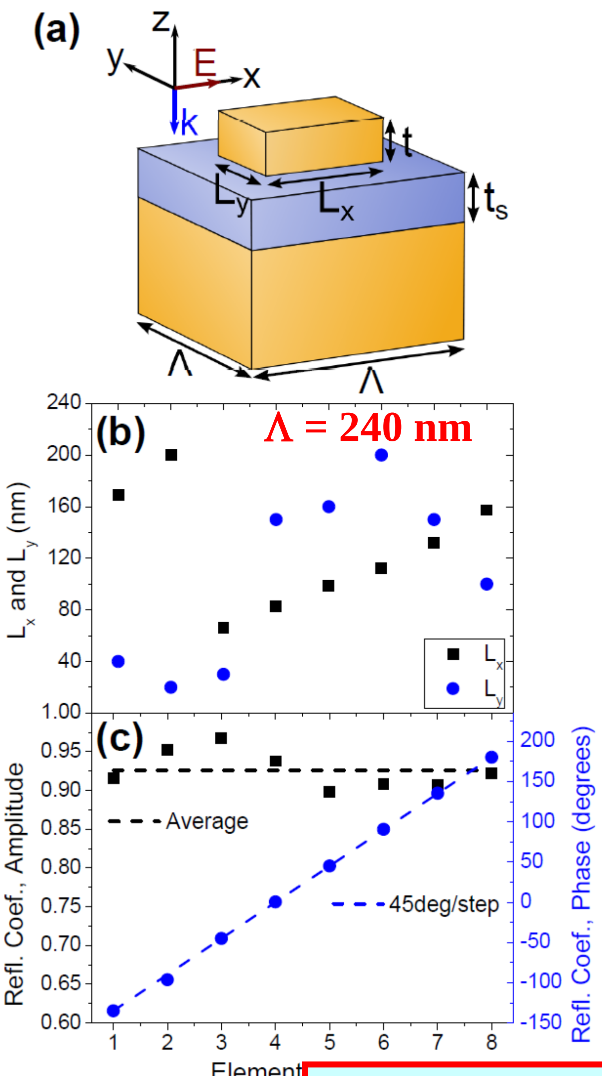
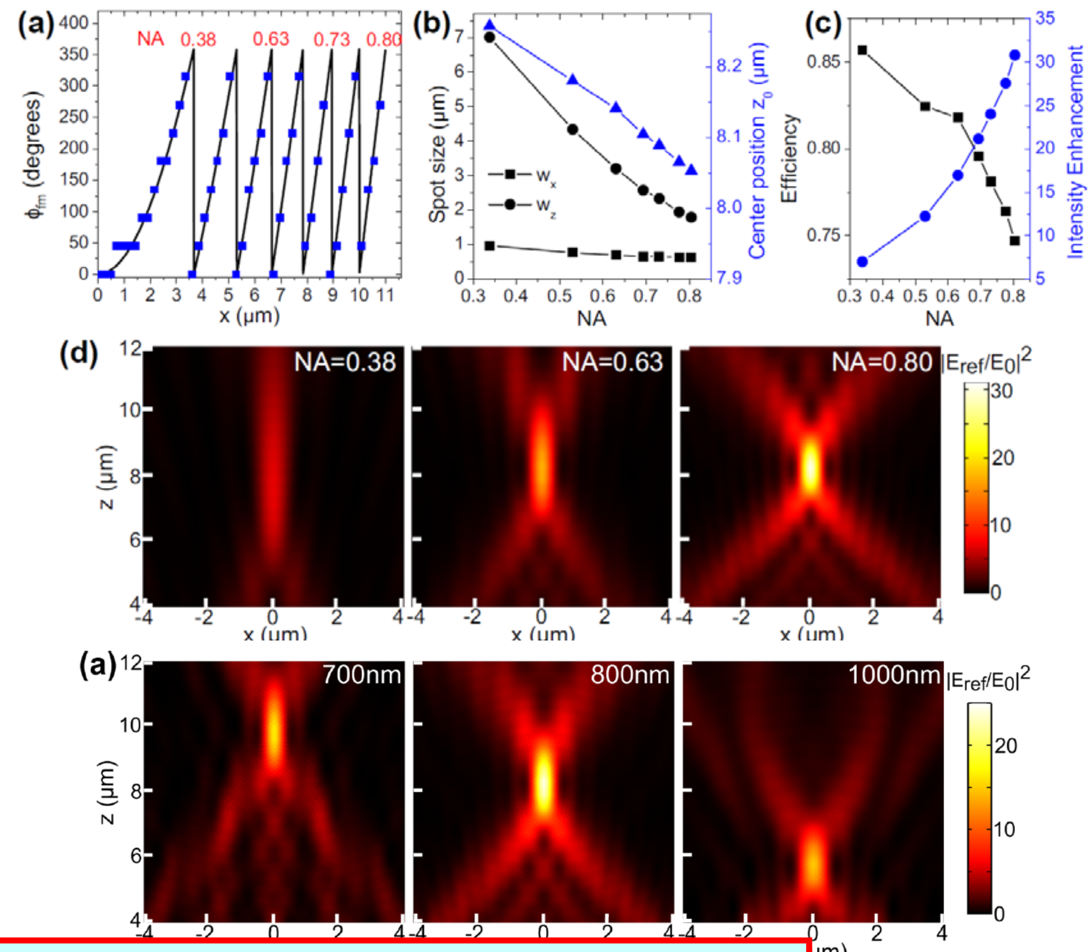
GSP-based phase-gradient metasurfaces



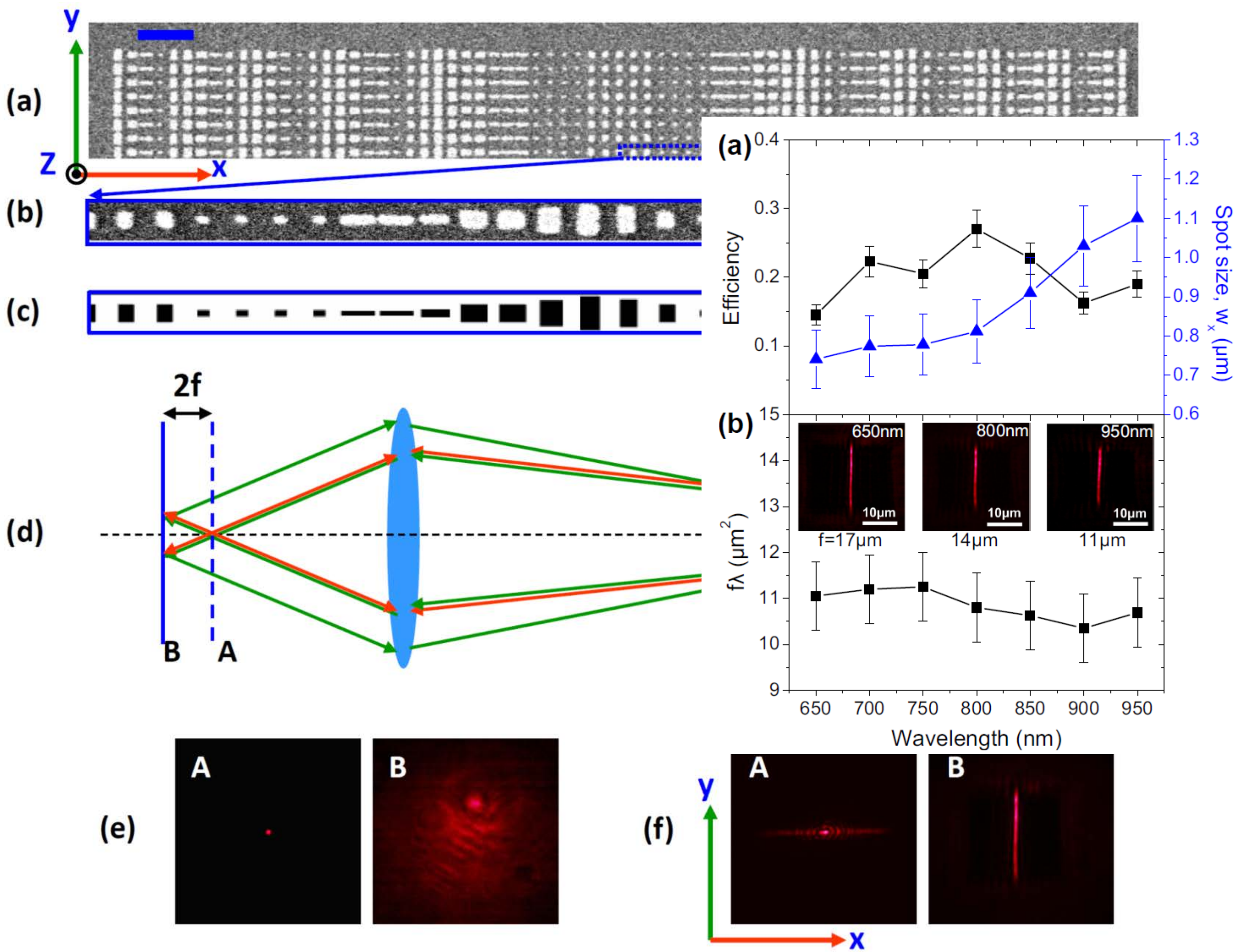
$$\boxed{\phi_{fm}(x) = \frac{2\pi}{\lambda}\left(\sqrt{x^2+f^2}-f\right)}$$



The product $f\lambda \cong$ const, if $\lambda << f$ ($r \cong \sqrt{f\lambda}$) !

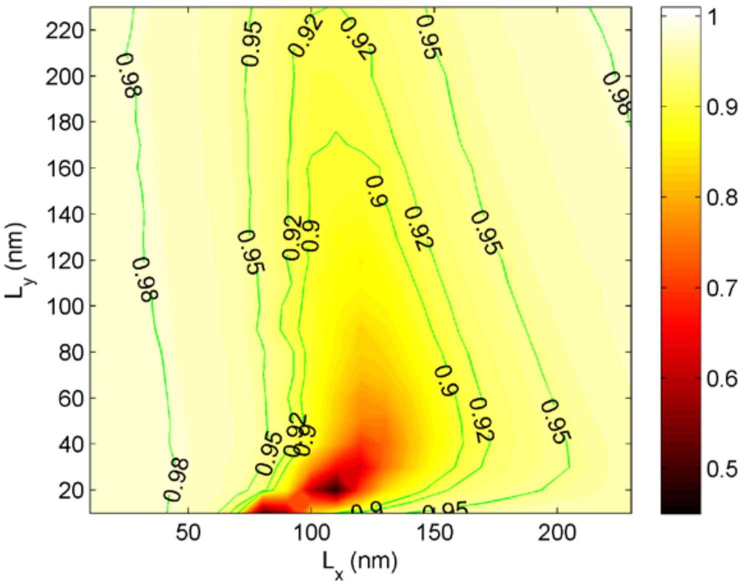
Nano Lett. **13**, 829 (2013).

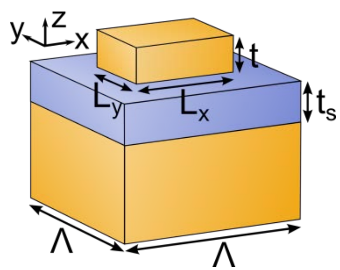
GSP-based phase-gradient metasurfaces



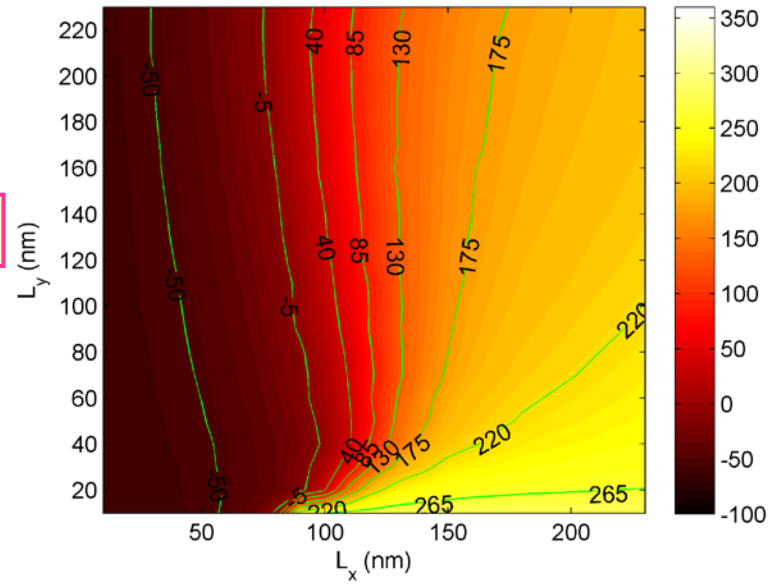
Nano Lett. **13**, 829 (2013).

The crucial features of GSP metasurfaces:





January 2013



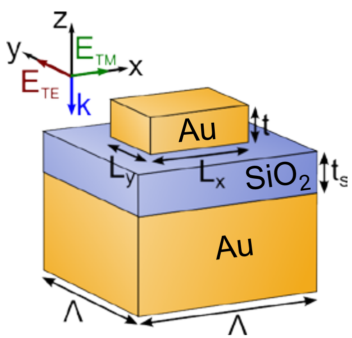
Reflected amplitude and phase for x-polarization

Two polarizations can be controlled independently!

GSP-based phase-gradient metasurfaces: Independent control of two polarizations!

Metasurface properties

Unit cell of metasurface:

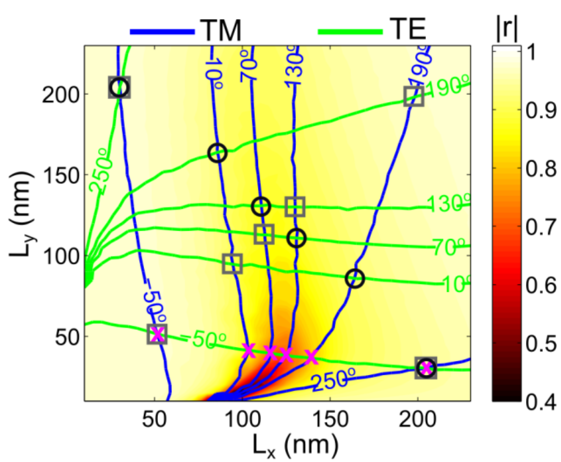


Design wavelength: 800nm

Λ=240nm

Two degrees of freedom (L_x and L_y)

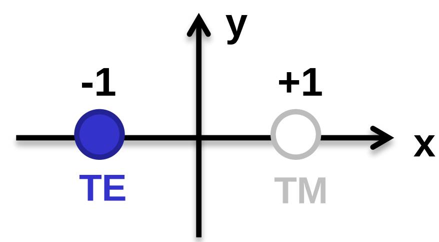
Reflection from metasurface :



Phase is discretized in 6 steps.
Contour line crossings indicate important nanobricks

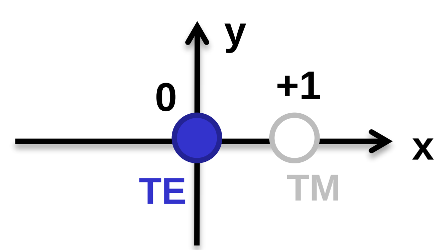
3 examples of independent control

Case 1: Polarization beam splitter



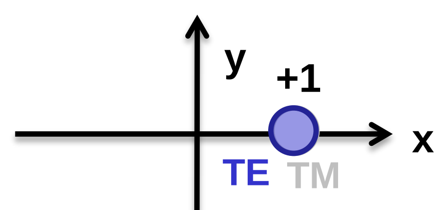
Gradient metasurface consisting of elements marked with circles

Case 2: Polarization beam splitter



Gradient metasurface consisting of elements marked with crosses

Case 3: Polarization-independent BG

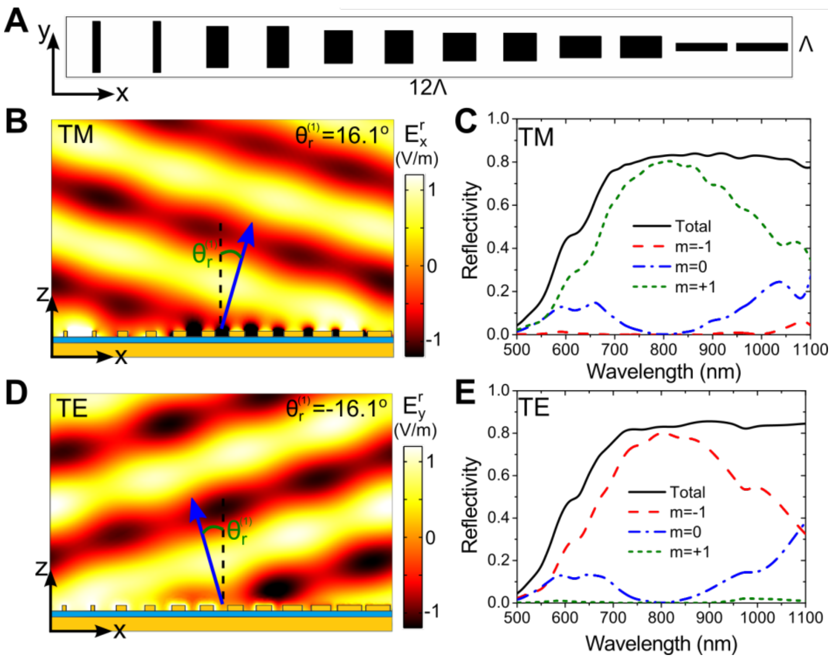


Gradient metasurface consisting of elements marked with squares

Sci. Rep. **3**, 2155 (2013).

GSP-based phase-gradient metasurfaces: Independent control of two polarizations!

Simulations



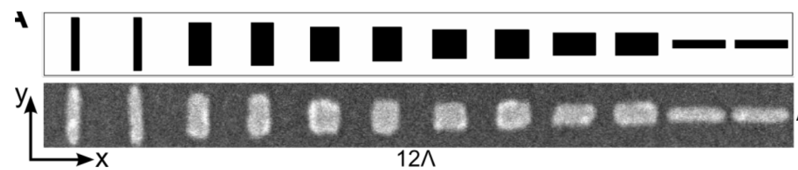
(A) Super cell. (B and C) TM pol. (D and E) TE pol.

Elements are arranged in pairs in order to lower the diffraction angle.

Efficient and broadband response

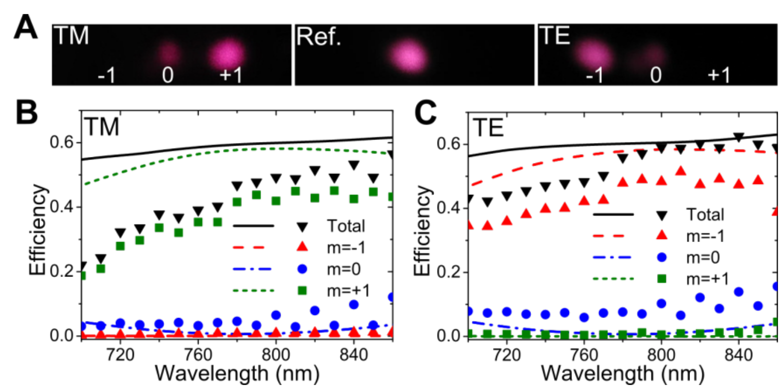
Experiments

Fabricated super cell:



Fabrication quality is quite satisfactory

Optical characterization:



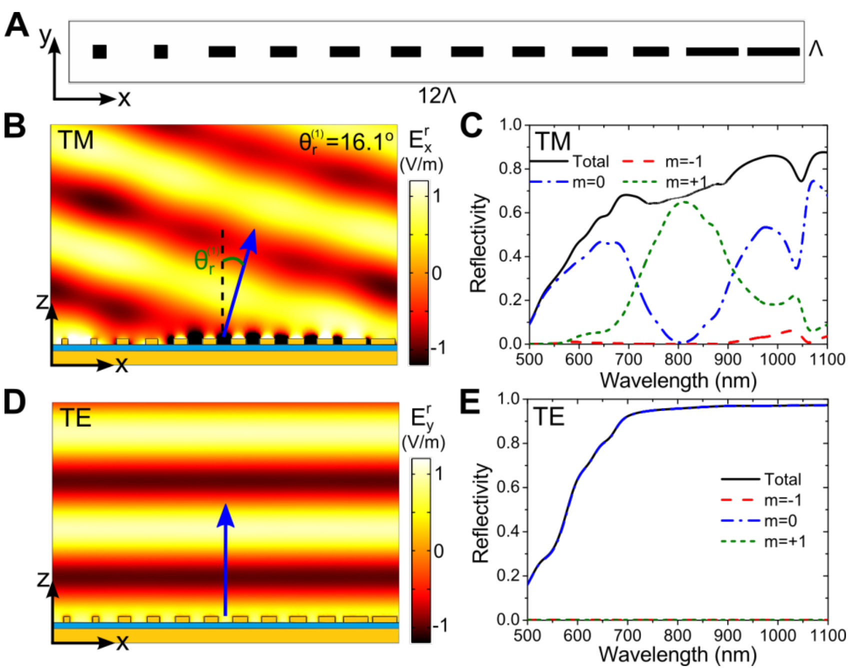
(A) Diffraction spots. (B and C) Diffraction efficiencies. Curves: simulations; Markers: Experiment.

Metasurface functionality is robust against fabrication tolerances.
Lower efficiency compared to theory.

Sci. Rep. **3**, 2155 (2013).

GSP-based phase-gradient metasurfaces: Independent control of two polarizations!

Simulations



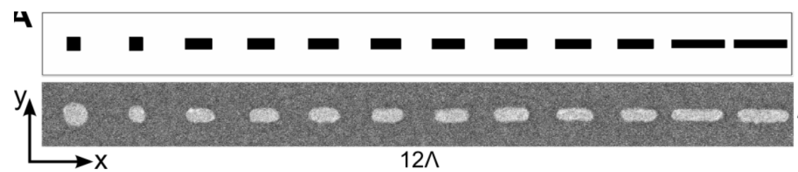
(A) Super cell. (B and C) TM pol. (D and E) TE pol.

Elements are arranged in pairs in order to lower the diffraction angle.

TE waves are specularly reflected

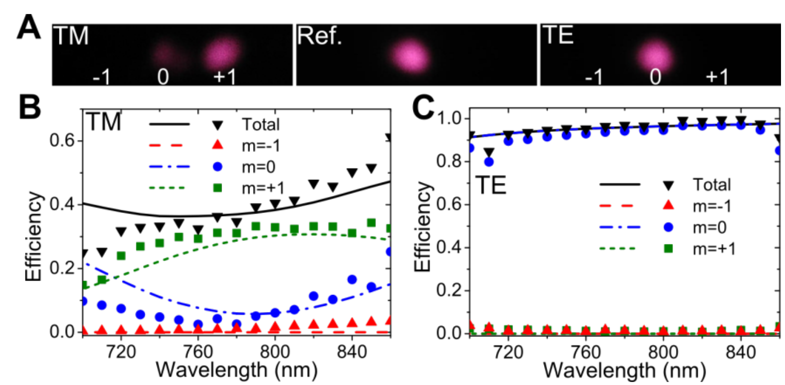
Experiments

Fabricated super cell:



Fabrication quality is quite satisfactory

Optical characterization:



(A) Diffraction spots. (B and C) Diffraction efficiencies. Curves: simulations; Markers: Experiment.

Good agreement between measurements and simulations (include additional losses).

Sci. Rep. **3**, 2155 (2013).

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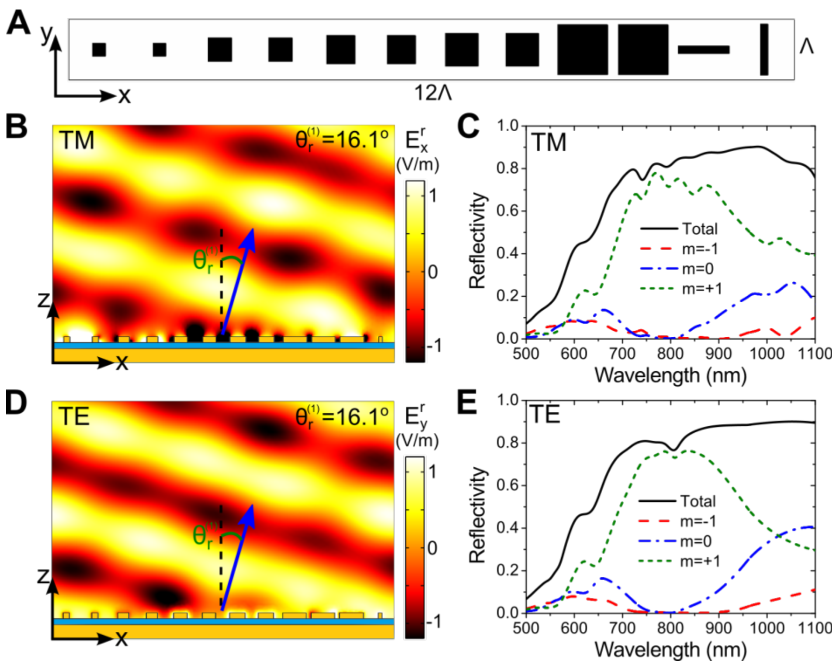
GSP-based phase-gradient metasurfaces: Independent control of two polarizations!

Simulations



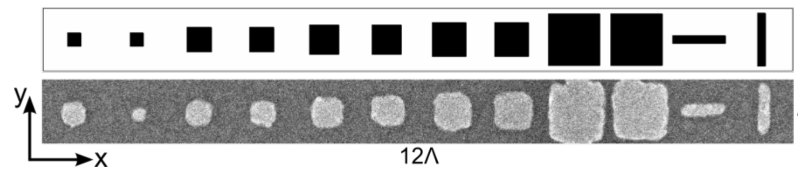
(A) Super cell. (B and C) TM pol. (D and E) TE pol.

Contour lines of 250º do not intersect, so the last two elements are not a pair.

Efficient and polarization-independent beam steering

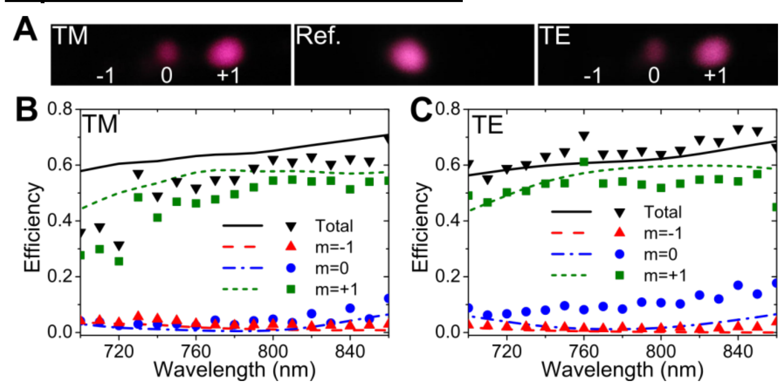
Experiments

Fabricated super cell:



Noticeable imperfections

Optical characterization:



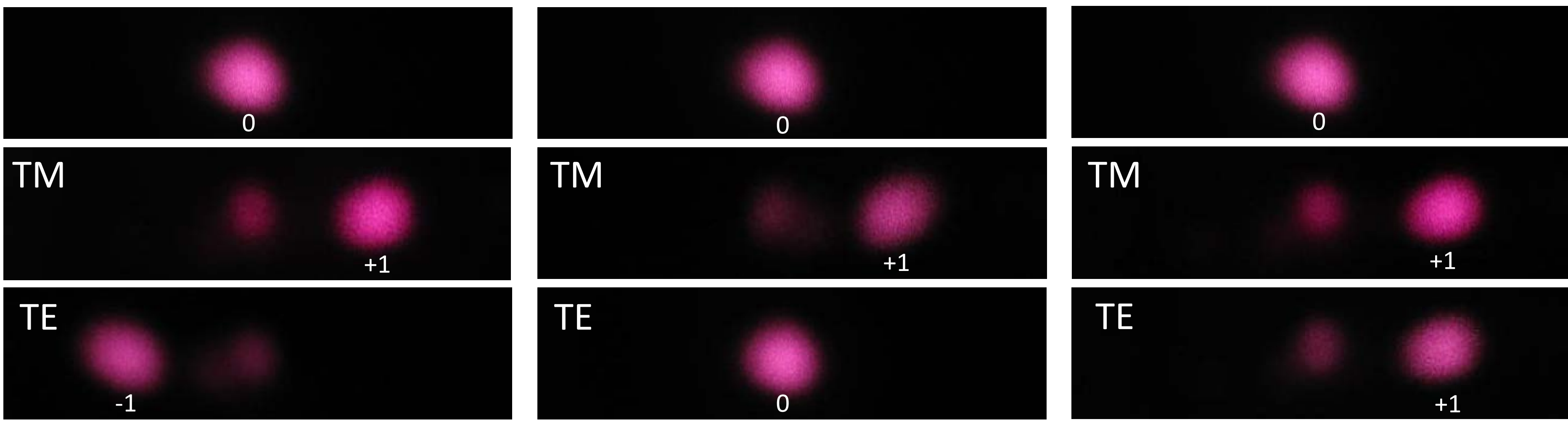
(A) Diffraction spots. (B and C) Diffraction efficiencies. Curves: simulations; Markers: Experiment.

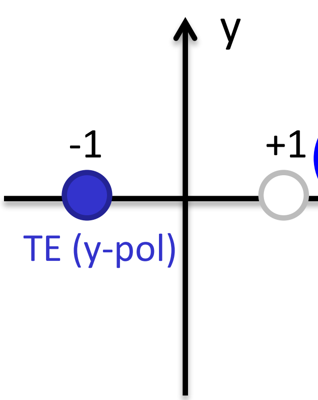
Functionality is robust against fabrication imperfections.

Sci. Rep. **3**, 2155 (2013).

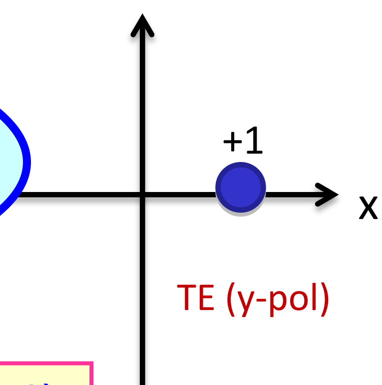
GSP-based phase-gradient metasurfaces: what can be next?

Case 1 | Case 2 | Case 3





This approach can be extended to coupling to SPP modes!



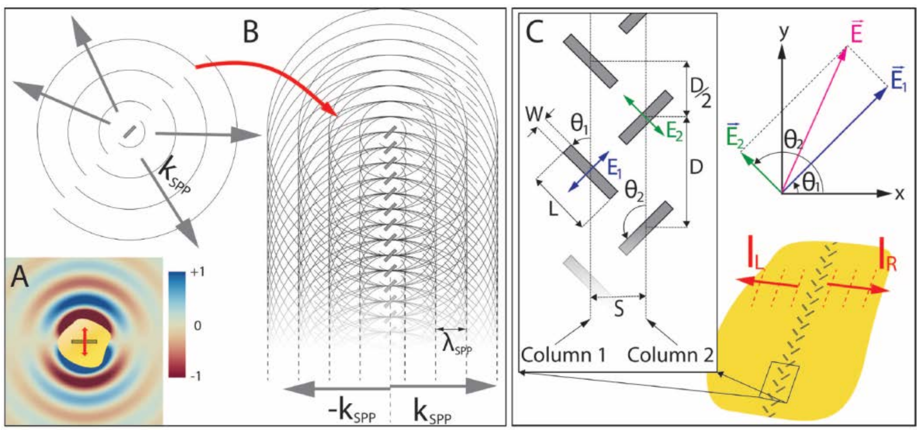
Sci. Rep. **3**, 2155 (2013).

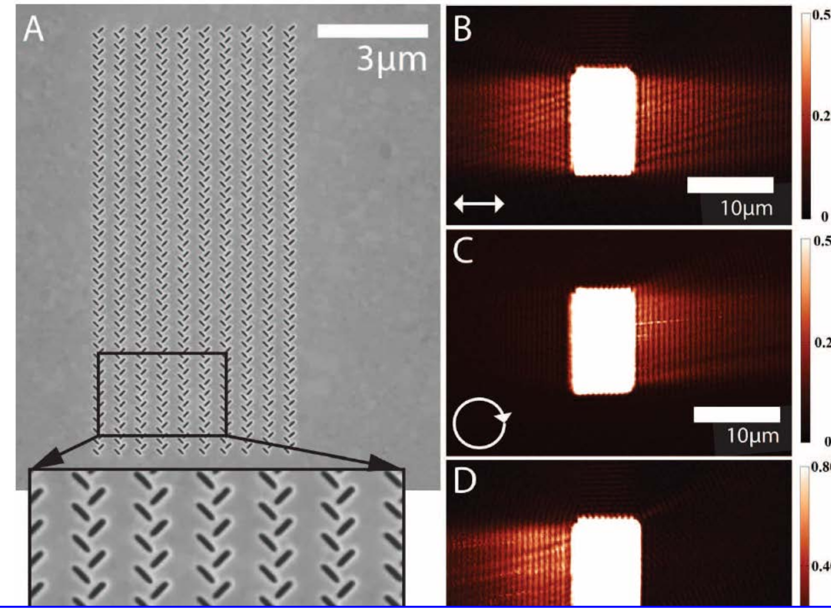
Phase-gradient metasurfaces:
Unidirectional & polarization-controlled SPP couplers!

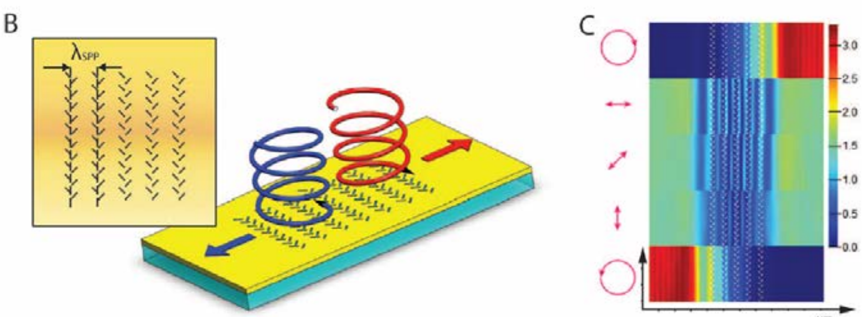
Polarization-Controlled Tunable Directional Coupling of Surface Plasmon Polaritons

Jiao Lin,[1,2]* J. P. Balthasar Mueller,[1]* Qian Wang,[3] Guanghui Yuan,[3] Nicholas Antoniou,[4] Xiao-Cong Yuan,[5] Federico Capasso[1]†

SCIENCE VOL 340 19 APRIL 2013







Light: Science & Applications (2013) 2, e70; doi:10.1038/lsa.2013.26

www.nature.com/lsa

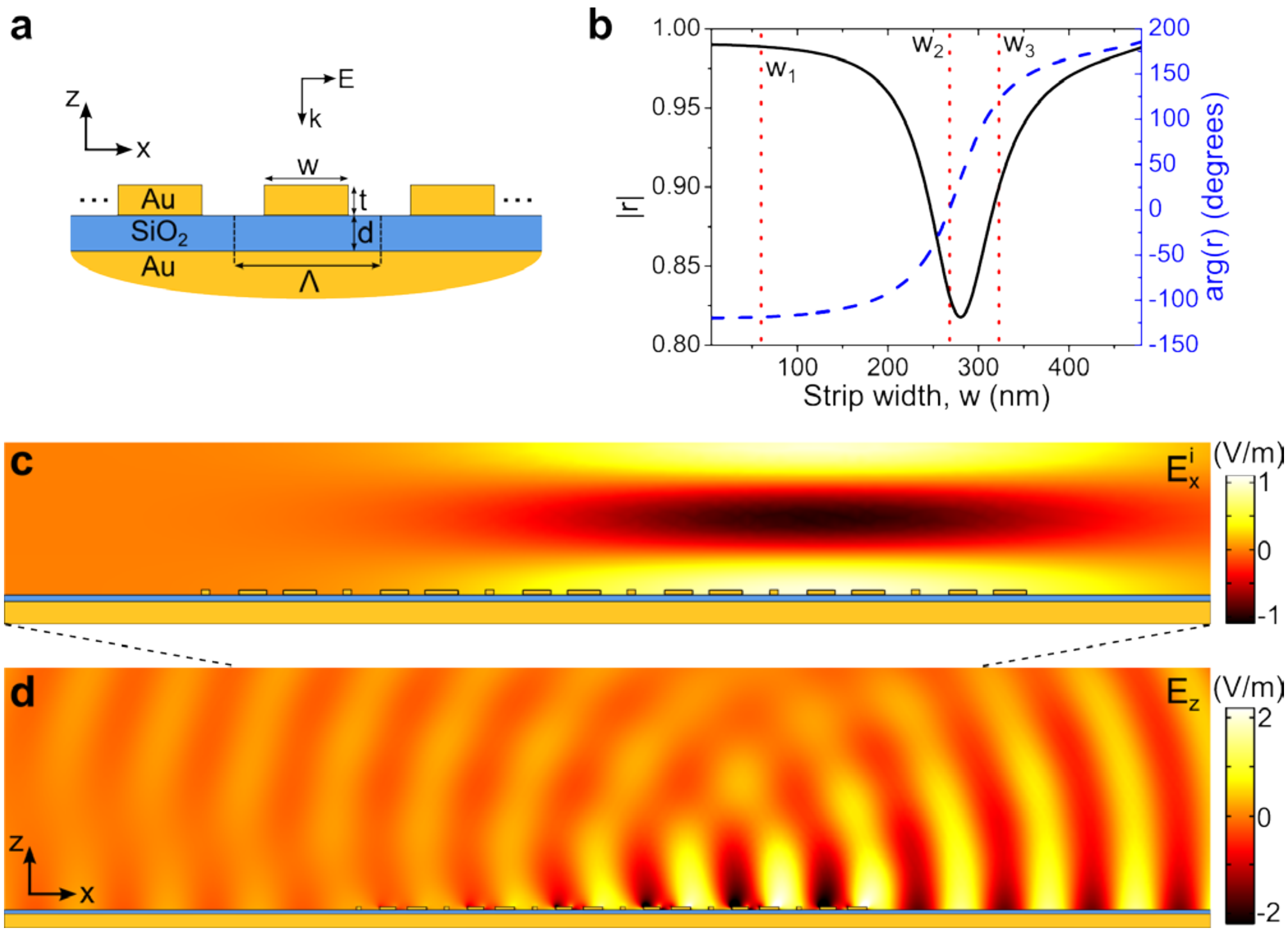
ORIGINAL ARTICLE

Helicity dependent directional surface plasmon polariton excitation using a metasurface with interfacial phase discontinuity

Lingling Huang*[1,2], Xianzhong Chen*[1], Benfeng Bai[2], Qiaofeng Tan[2], Guofan Jin[2], Thomas Zentgraf[3] and Shuang Zhang[1]

GSP-based phase-gradient metasurfaces: Unidirectional & polarization-controlled SPP couplers!

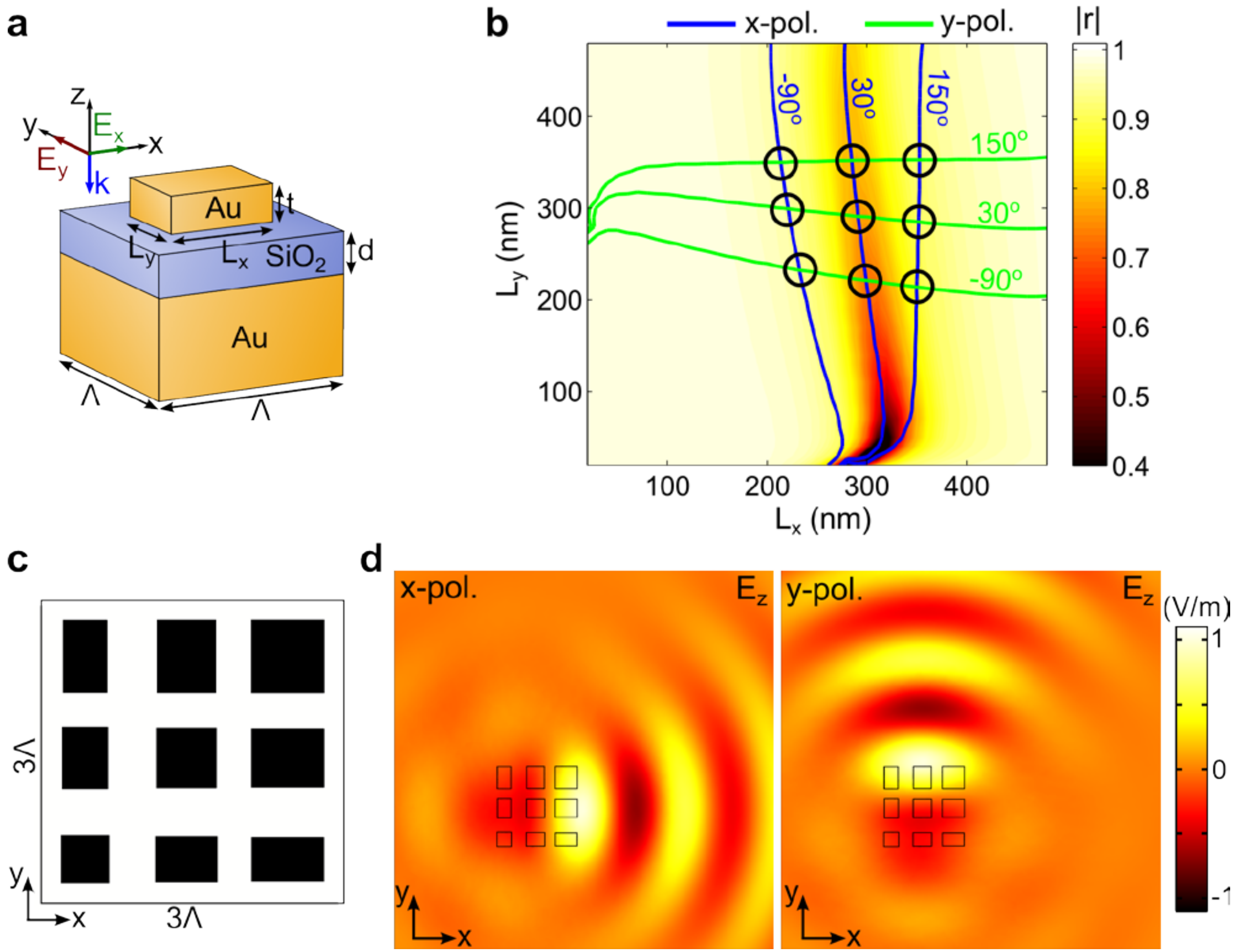
1D configuration:



Light: Science & Applications, *2014*

GSP-based phase-gradient metasurfaces: Unidirectional & polarization-controlled SPP couplers!

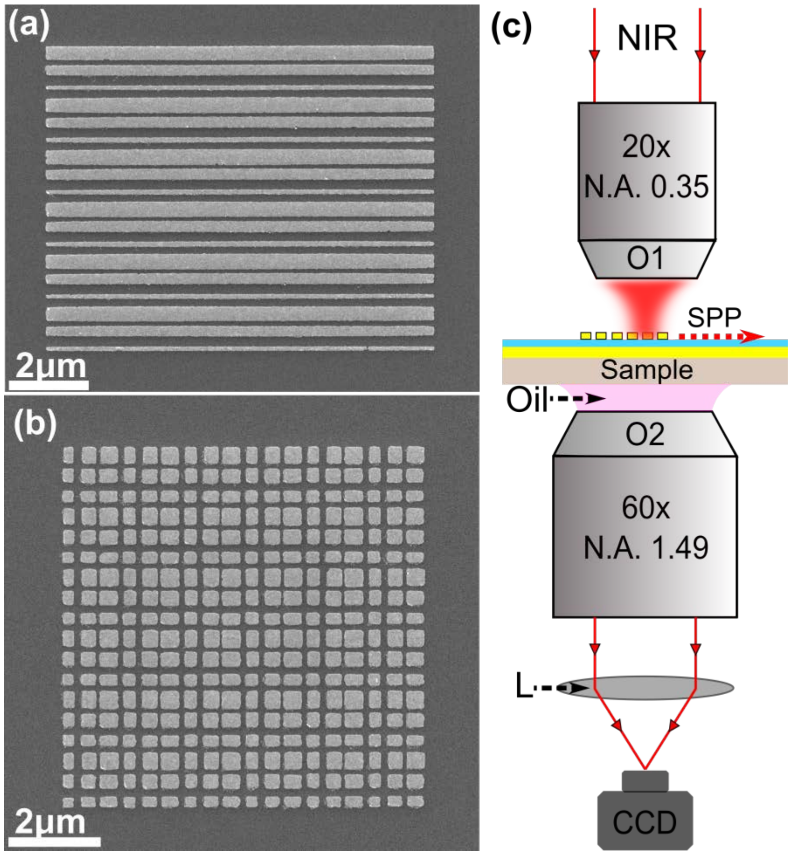
2D configuration:

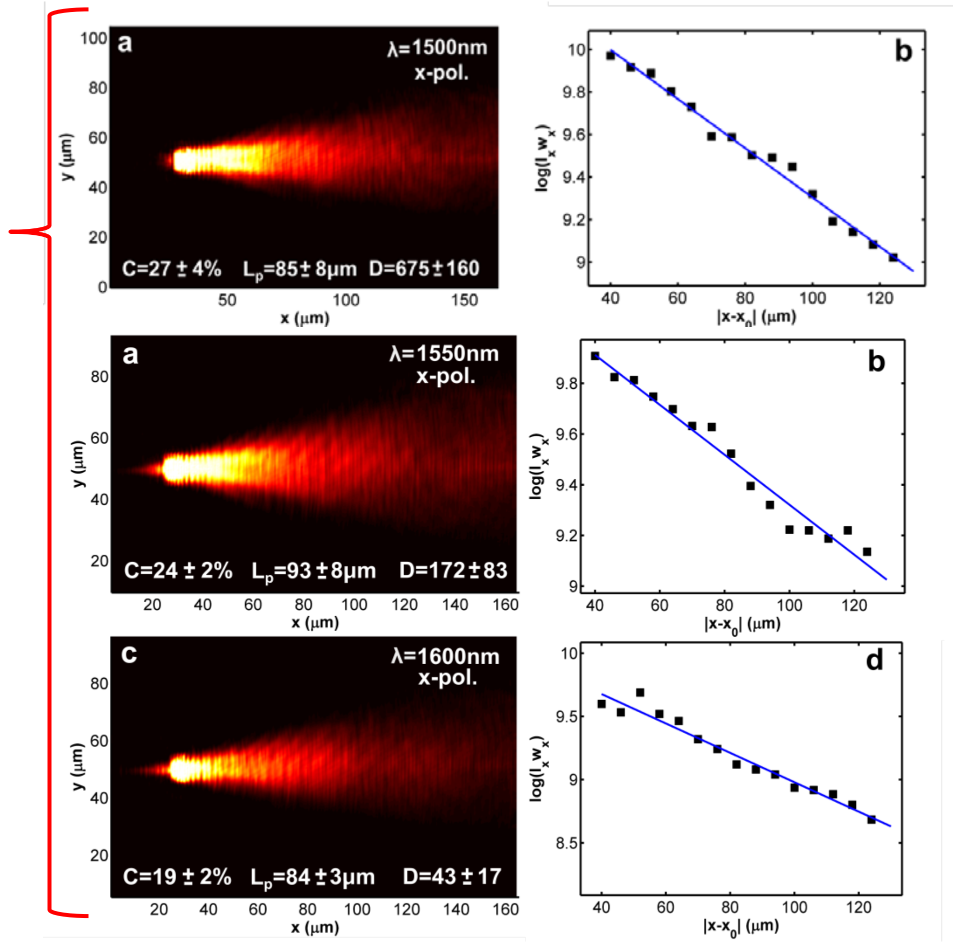


Light: Science & Applications, *2014*

GSP-based phase-gradient metasurfaces:
Unidirectional & polarization-controlled SPP couplers!

Experimental verification:

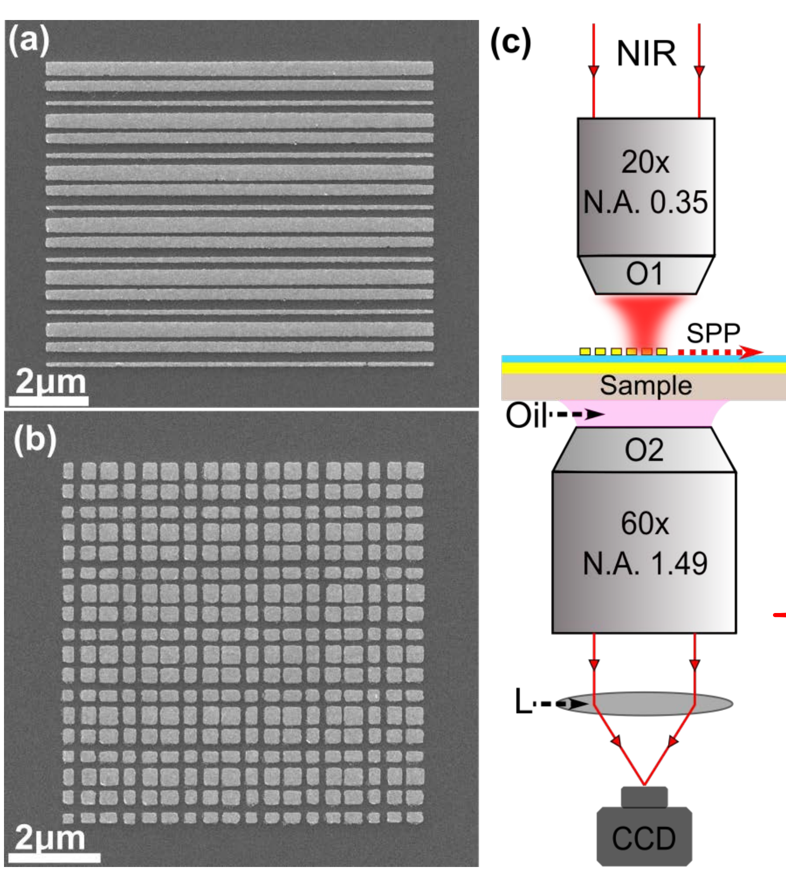


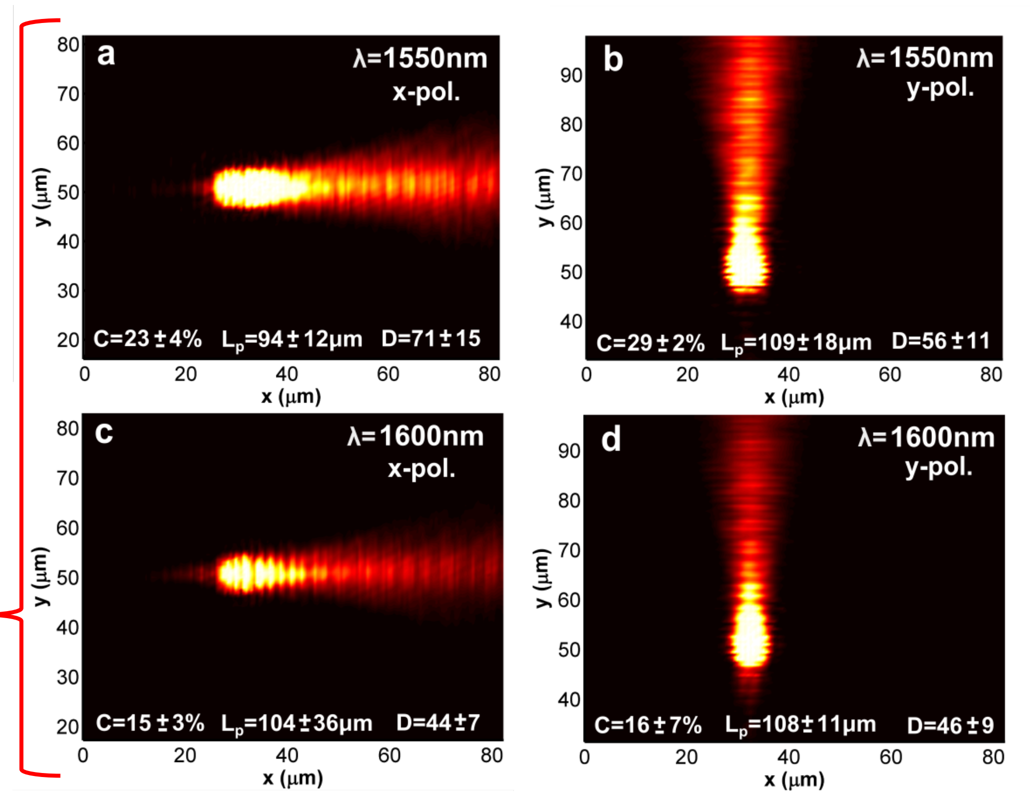


Light: Science & Applications, *2014*

GSP-based phase-gradient metasurfaces:
Unidirectional & polarization-controlled SPP couplers!

Experimental verification:





Light: Science & Applications, *2014*

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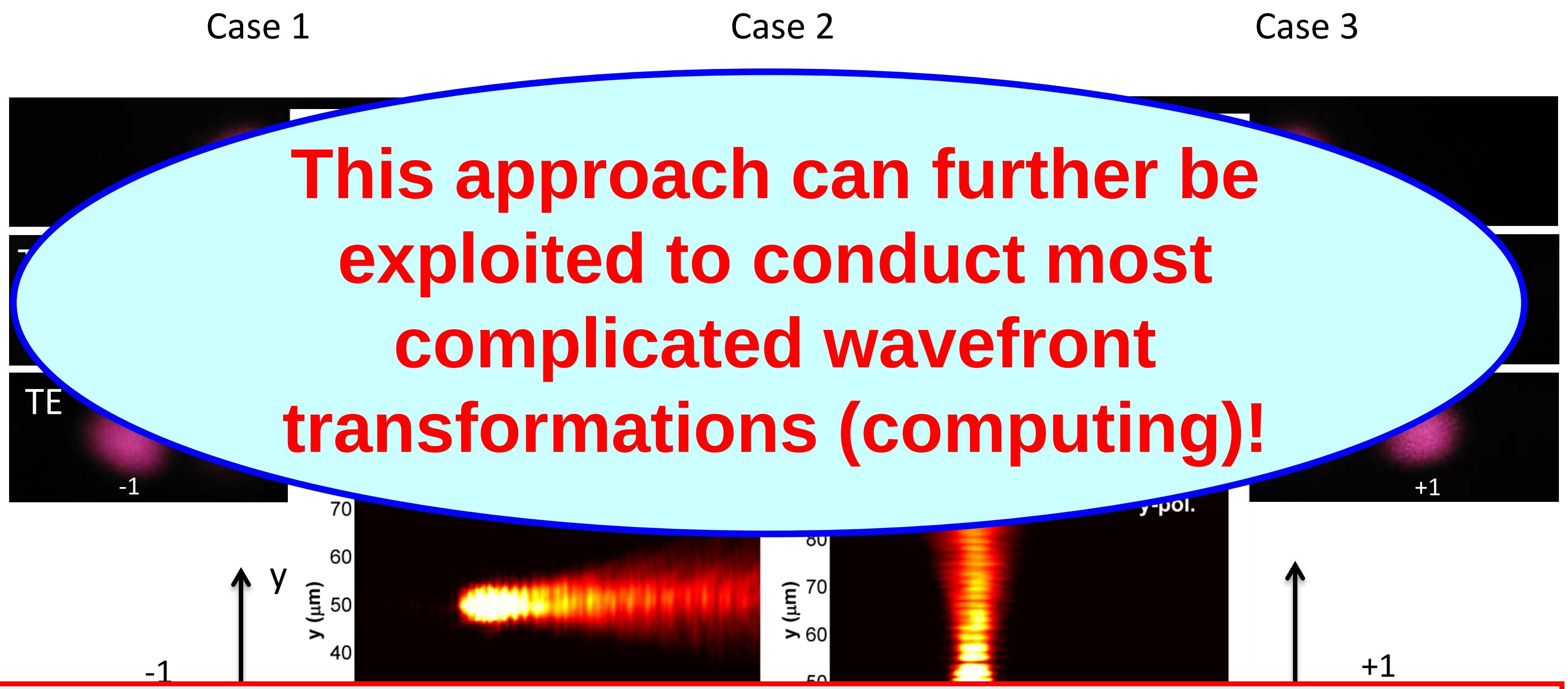
Sergey I. Bozhevolnyi

GSP-based phase-gradient metasurfaces: what else can be done?



This approach can further be exploited to conduct most complicated wavefront transformations (computing)!

GSP-based gradient metasurfaces can efficiently and independently control orthogonal polarizations, including coupling to surface excitations!

Metasurfaces: performing mathematical operations!

Performing Mathematical Operations with Metamaterials

Alexandre Silva,[1*] Francesco Monticone,[2*] Giuseppe Castaldi,[3] Vincenzo Galdi,[3] Andrea Alù,[2] Nader Engheta[1]†

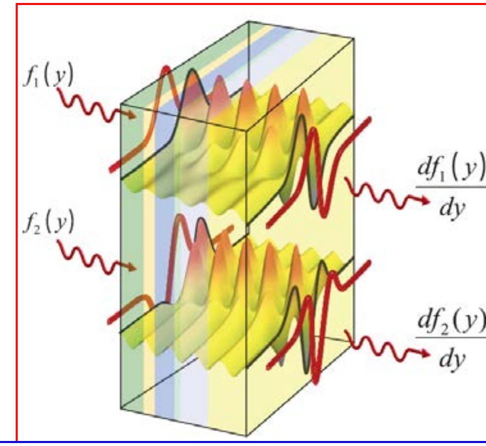
10 JANUARY 2014 VOL 343 SCIENCE

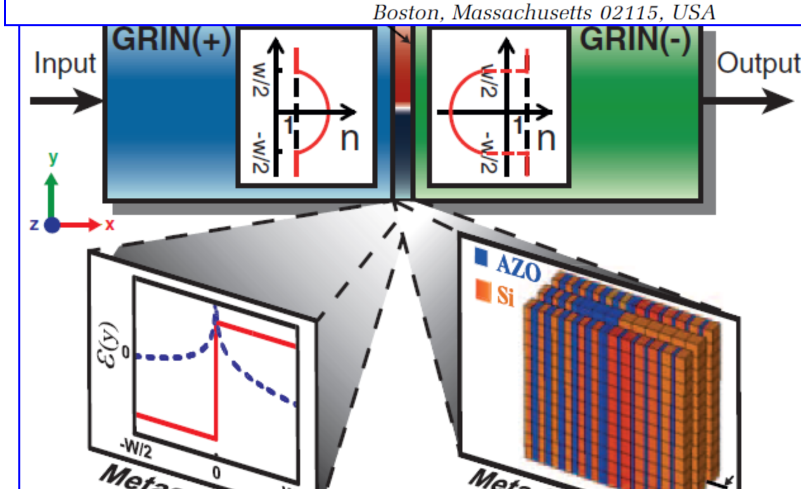
Metasurfaces nanoantennas for light processing

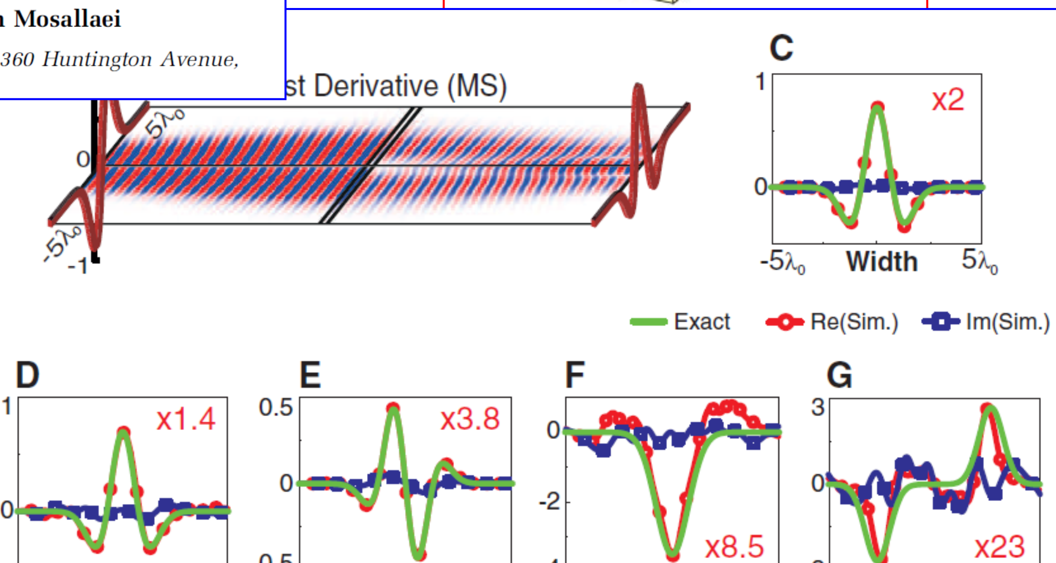
Vol. 30, No. 9 / September 2013 / J. Opt. Soc. Am. B

Mohsen Farmahini-Farahani,* Jierong Cheng, and Hossein Mosallaei

Department of Electrical and Computer Engineering, Northeastern University, 360 Huntington Avenue, Boston, Massachusetts 02115, USA







Amplitude & phase gradient metasurfaces are wanted!

Optical holography with phase- and amplitude-gradient metasurfaces

nature COMMUNICATIONS

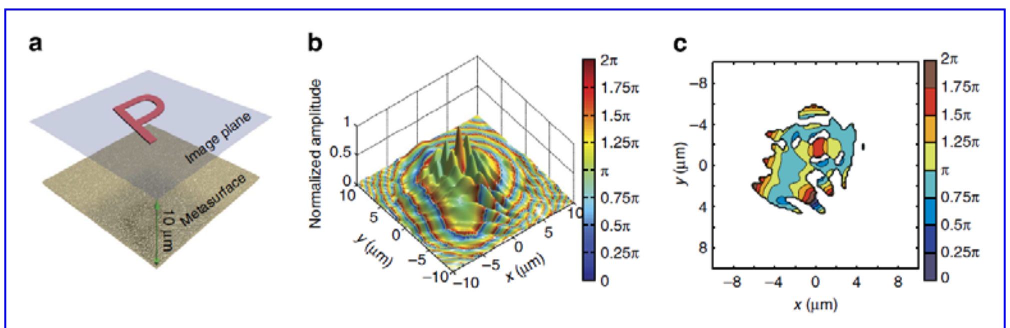
ARTICLE

Received 28 Apr 2013 | Accepted 23 Oct 2013 | Published 15 Nov 2013

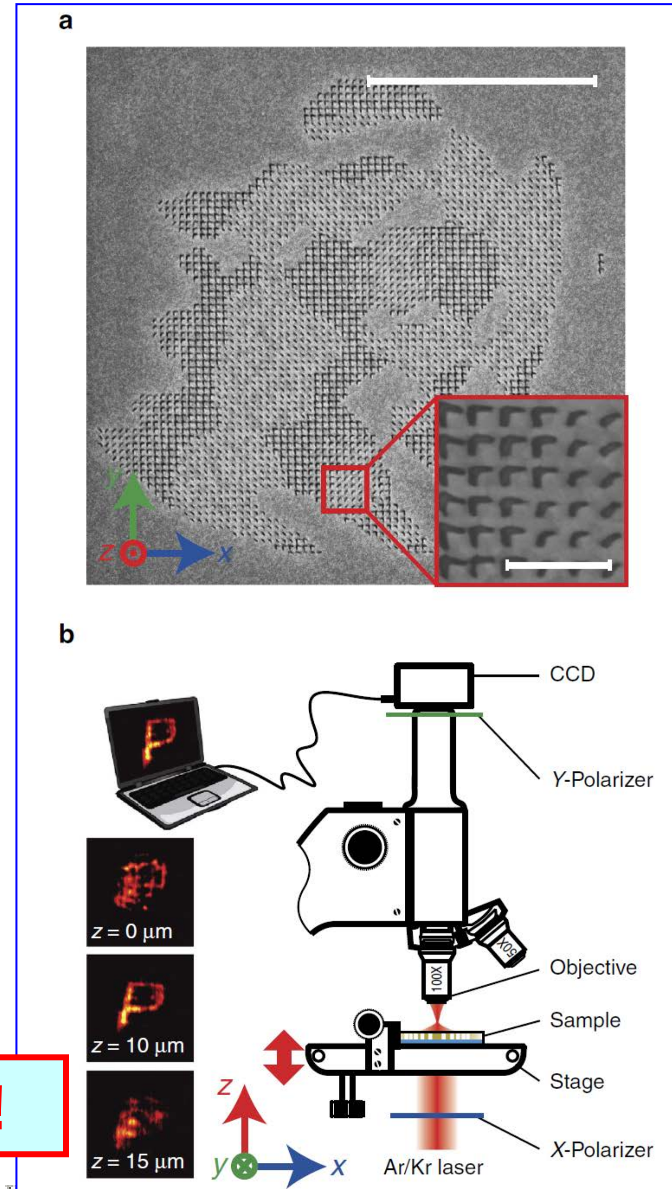
DOI: 10.1038/ncomms3807

Metasurface holograms for visible light

Xingjie Ni[1], Alexander V. Kildishev[1] & Vladimir M. Shalaev[1]



The discrete eight-level phase distribution with a two-level amplitude modulation to accommodate the antenna designs.



Note low sampling and low efficiency!

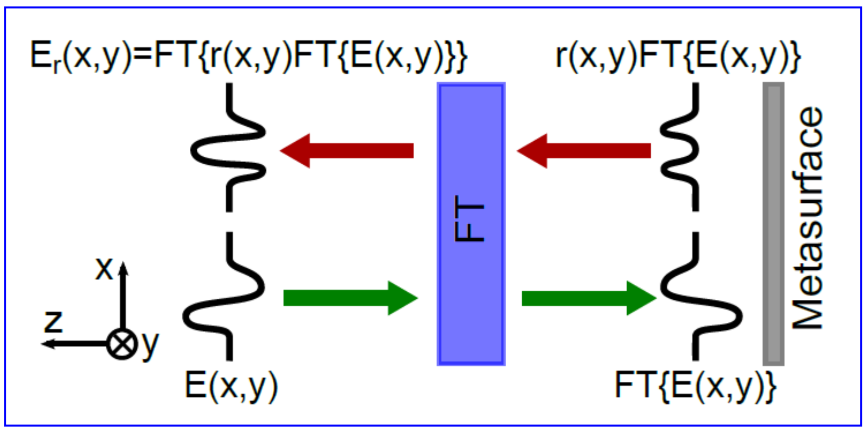
GSP-based amplitude & phase gradient metasurfaces for analog computing

NANO LETTERS Letter
pubs.acs.org/NanoLett
Nano Lett. 2015, 15, 791−797

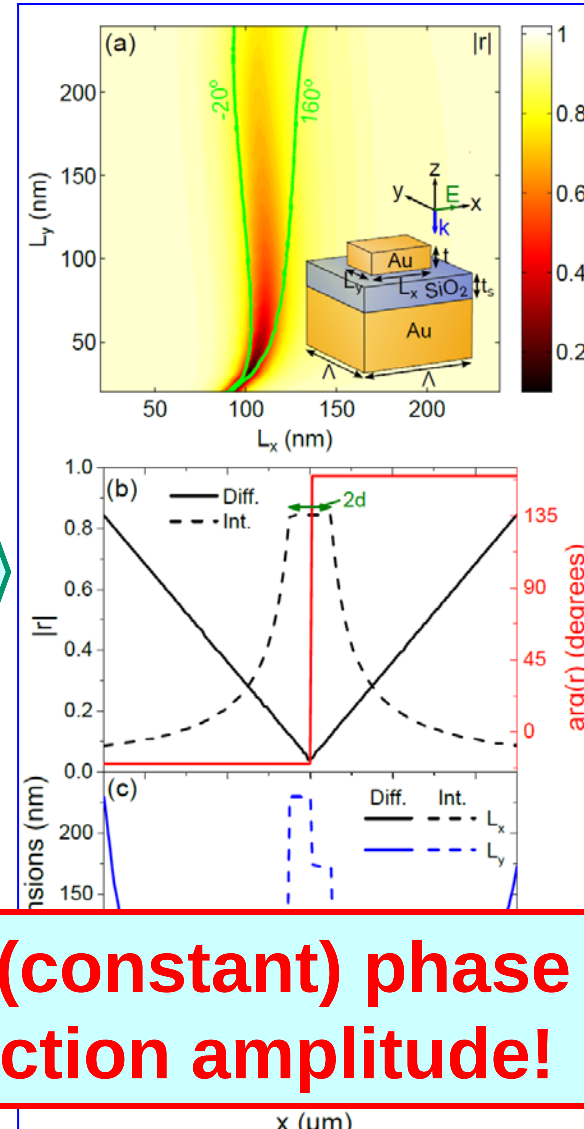
Analog Computing Using Reflective Plasmonic Metasurfaces

Anders Pors,*[,†] Michael G. Nielsen,[†] and Sergey I. Bozhevolnyi[†]

Reflection configuration:



Design of differentiator and integrator **metasurfaces**



Main challenge: obtain the opposite (constant) phase for the same (spatially varying) reflection amplitude!

GSP-based amplitude & phase gradient metasurfaces for analog computing

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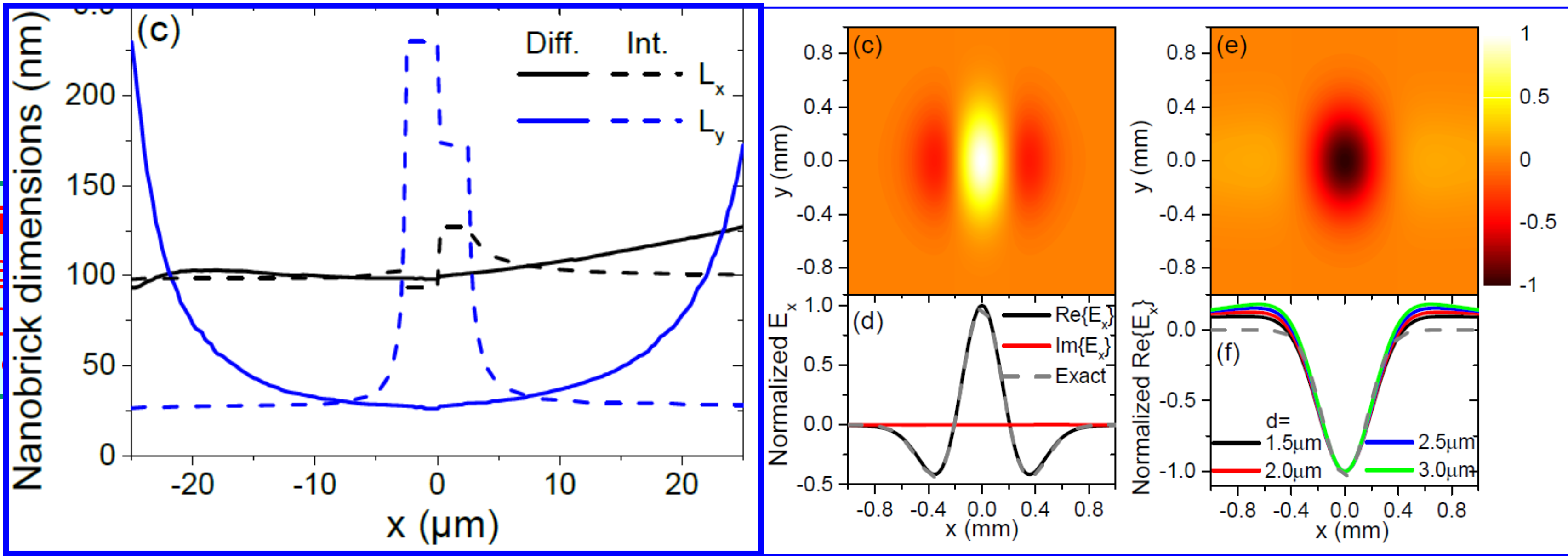


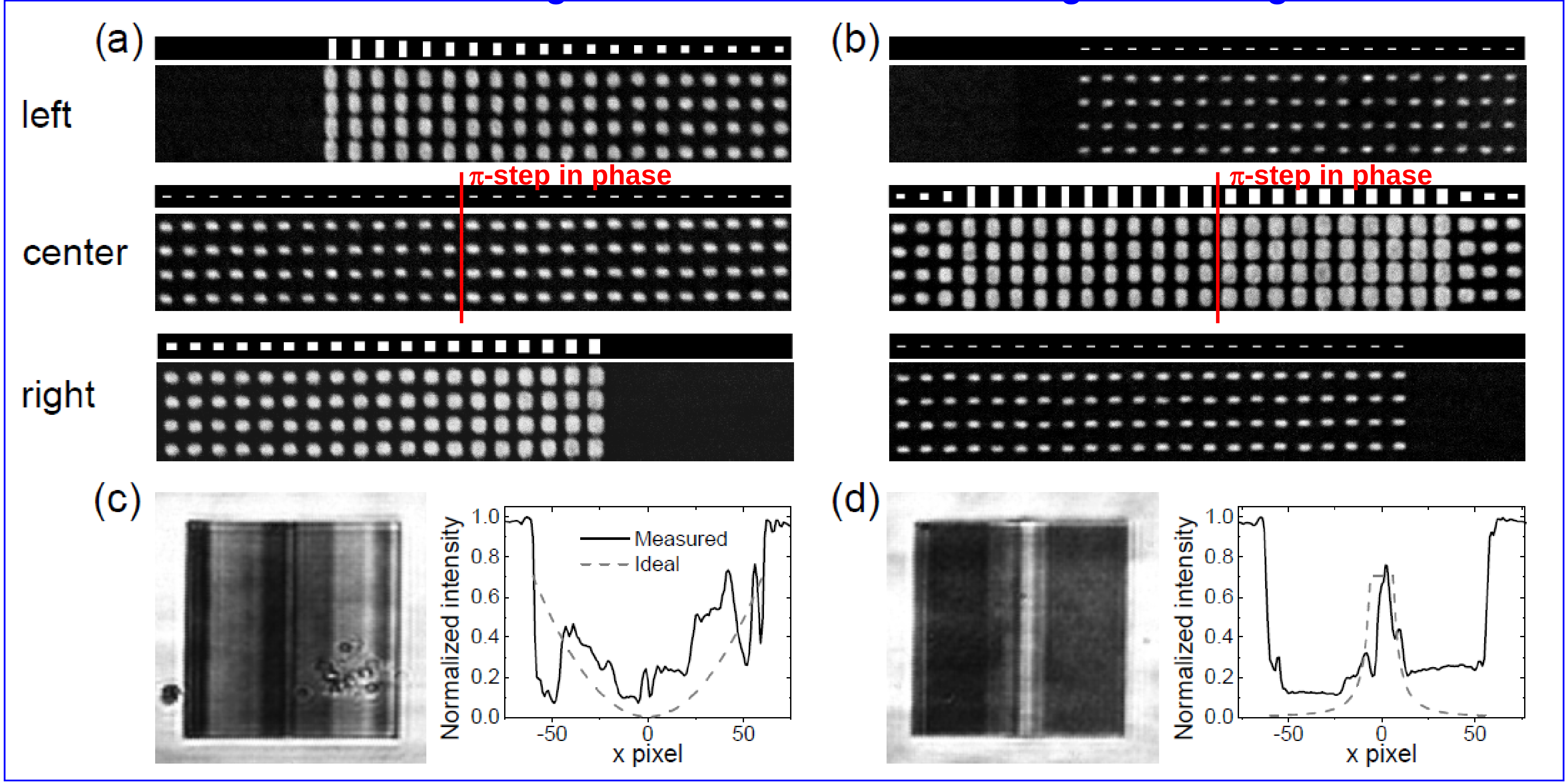
GSP-based metasurfaces can do the job!

In practice, it is going to be very difficult!

Nano Letters **15**, 791 (2015)

GSP-based amplitude & phase gradient metasurfaces for analog computing

Differentiator configuration: **Integrator configuration:**



Nano Letters **15**, 791 (2015)

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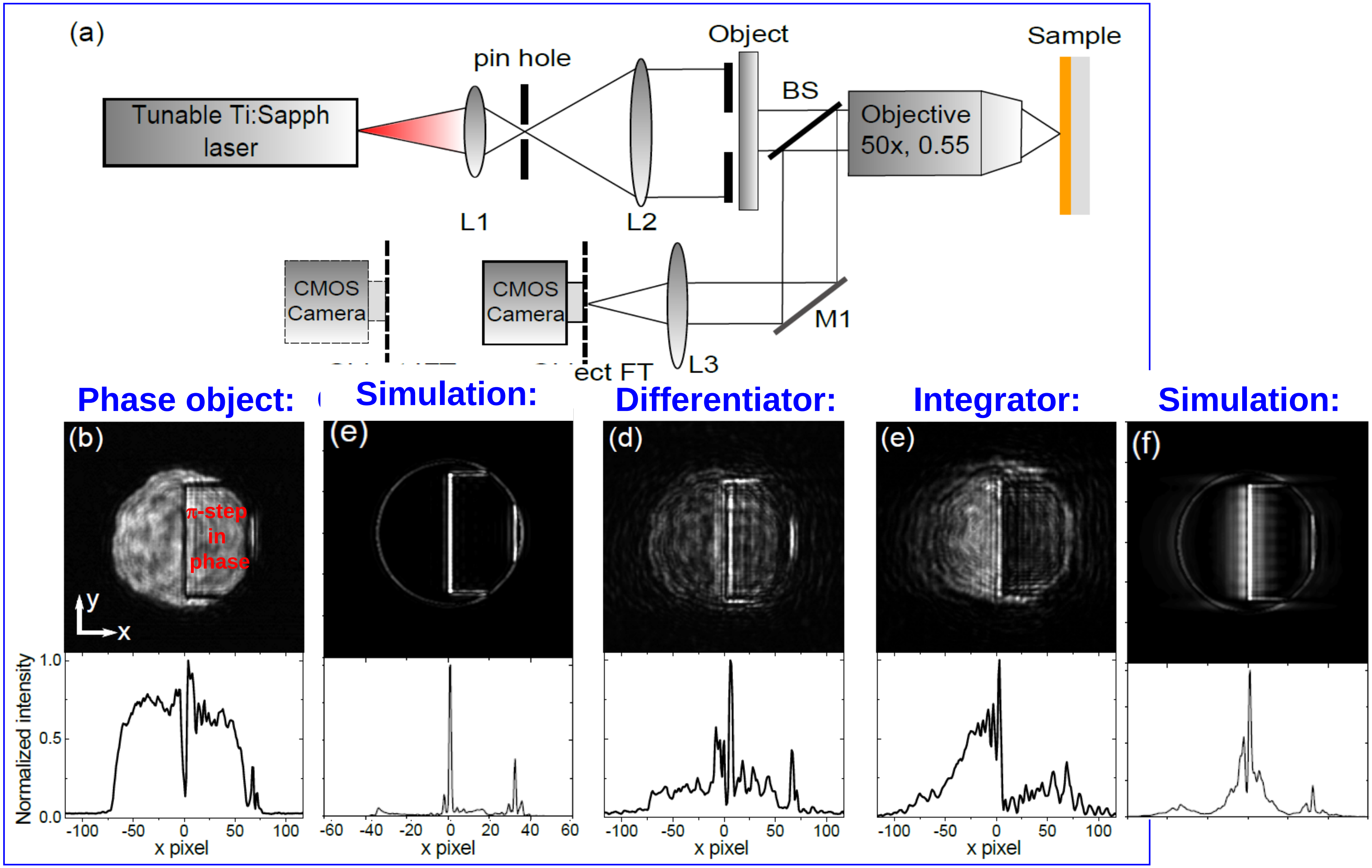
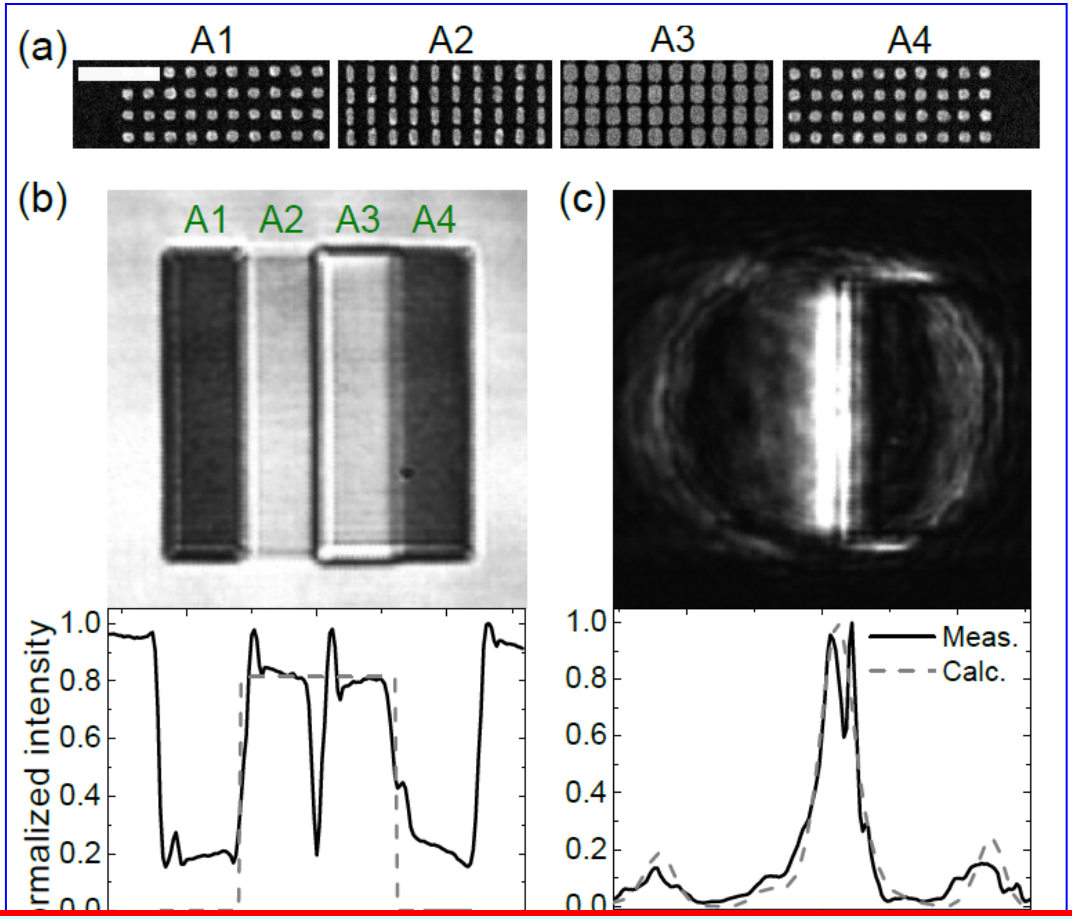
Sergey I. Bozhevolnyi

GSP-based amplitude & phase gradient metasurfaces for analog computing



GSP-based amplitude & phase gradient metasurfaces for analog computing

Poor man's integrator metasurface:



GSP-based metasurfaces can do the job!

Nano Letters 15, 791 (2015)

GSP-based phase-gradient metasurfaces for instantaneous SOP analysis

Monochromatic plane wave propagating along the *z*-axis:

$$\vec{E}(\vec{r}) = \begin{pmatrix} A_x \\ A_y e^{i\delta} \end{pmatrix} \exp(ikz)\,; \;\; A_x > 0,\; A_y > 0$$

State of polarization (SOP) is completely determined by A_x/A_y and δ: only two quantities have to be measured!

Main challenge: realization of simultaneous one-step measurements of all polarization contrasts!

$$s_1 = A_x^2 - A_y^2,$$

$$s_2 = 2A_xA_y\cos\delta = A_a^2 - A_b^2, \quad (\hat{\mathbf{a}}, \hat{\mathbf{b}}) = \tfrac{1}{\sqrt{2}}(\hat{\mathbf{x}} + \hat{\mathbf{y}}, -\hat{\mathbf{x}} + \hat{\mathbf{y}})$$

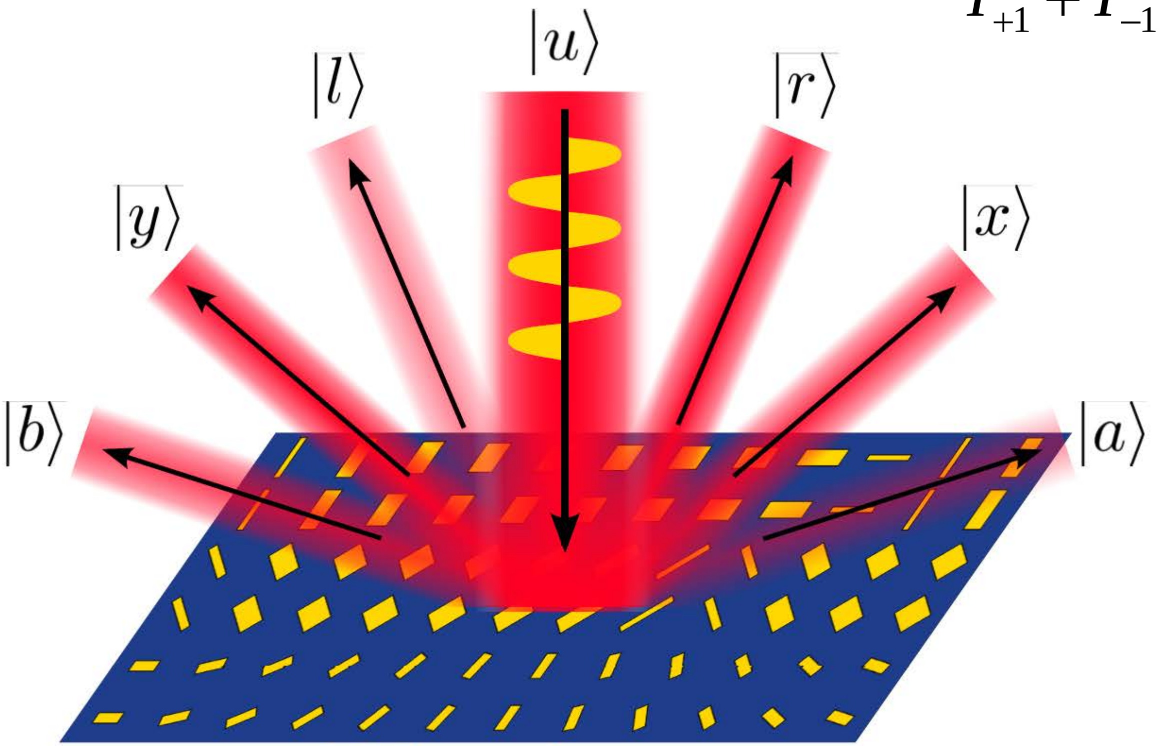
$$s_3 = 2A_xA_y\sin\delta = A_r^2 - A_l^2. \quad (\hat{\mathbf{r}}, \hat{\mathbf{l}}) = \tfrac{1}{\sqrt{2}}(\hat{\mathbf{x}} + i\hat{\mathbf{y}}, \hat{\mathbf{x}} - i\hat{\mathbf{y}})$$

Optica **2**, 716 (2015)

GSP-based all-polarization sensitive birefringent metasurfaces

Targeted operation principle:

$$D_{1,2,3} = \frac{I_{+1} - I_{-1}}{I_{+1} + I_{-1}} = \frac{A_u^2 - A_v^2}{A_u^2 + A_v^2} = \frac{s_{1,2,3}}{s_0}$$



Anders L. Pors

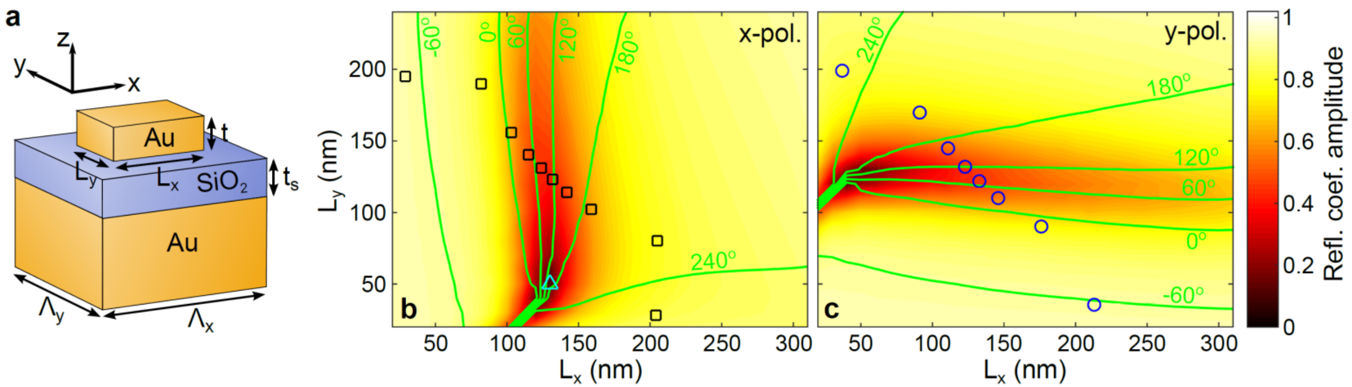
Michael G. Nielsen

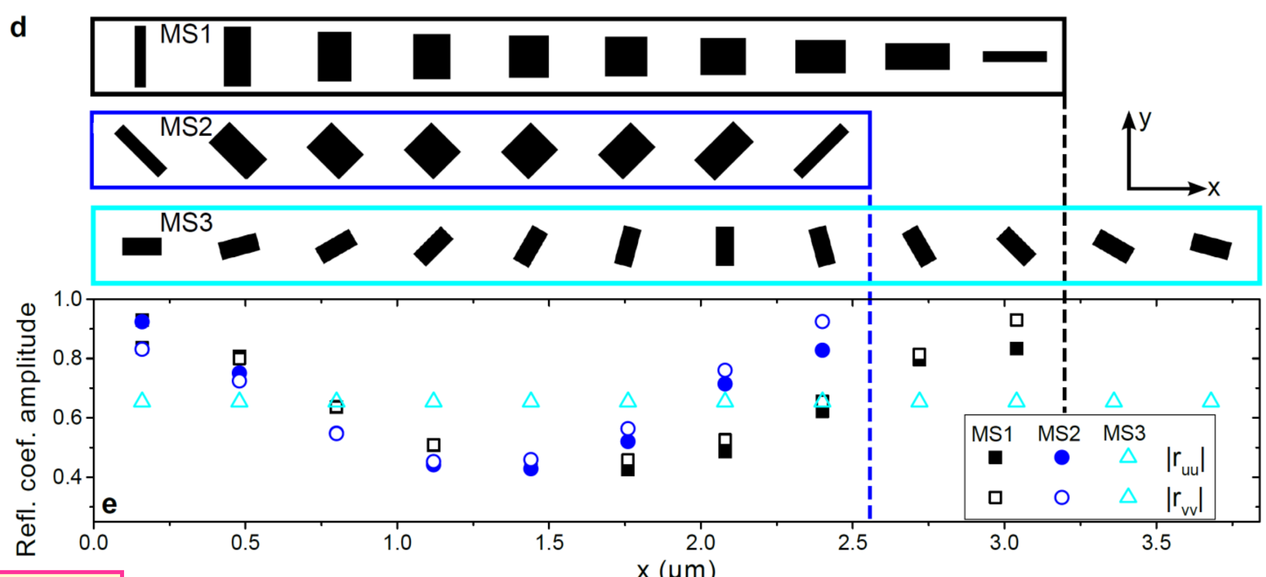
Optica **2**, 716 (2015)

GSP-based all-polarization sensitive birefringent metasurfaces

Design considerations:

t = 40 nm
t_s = 50 nm
Λ_x = 320 nm
Λ_y = 250 nm



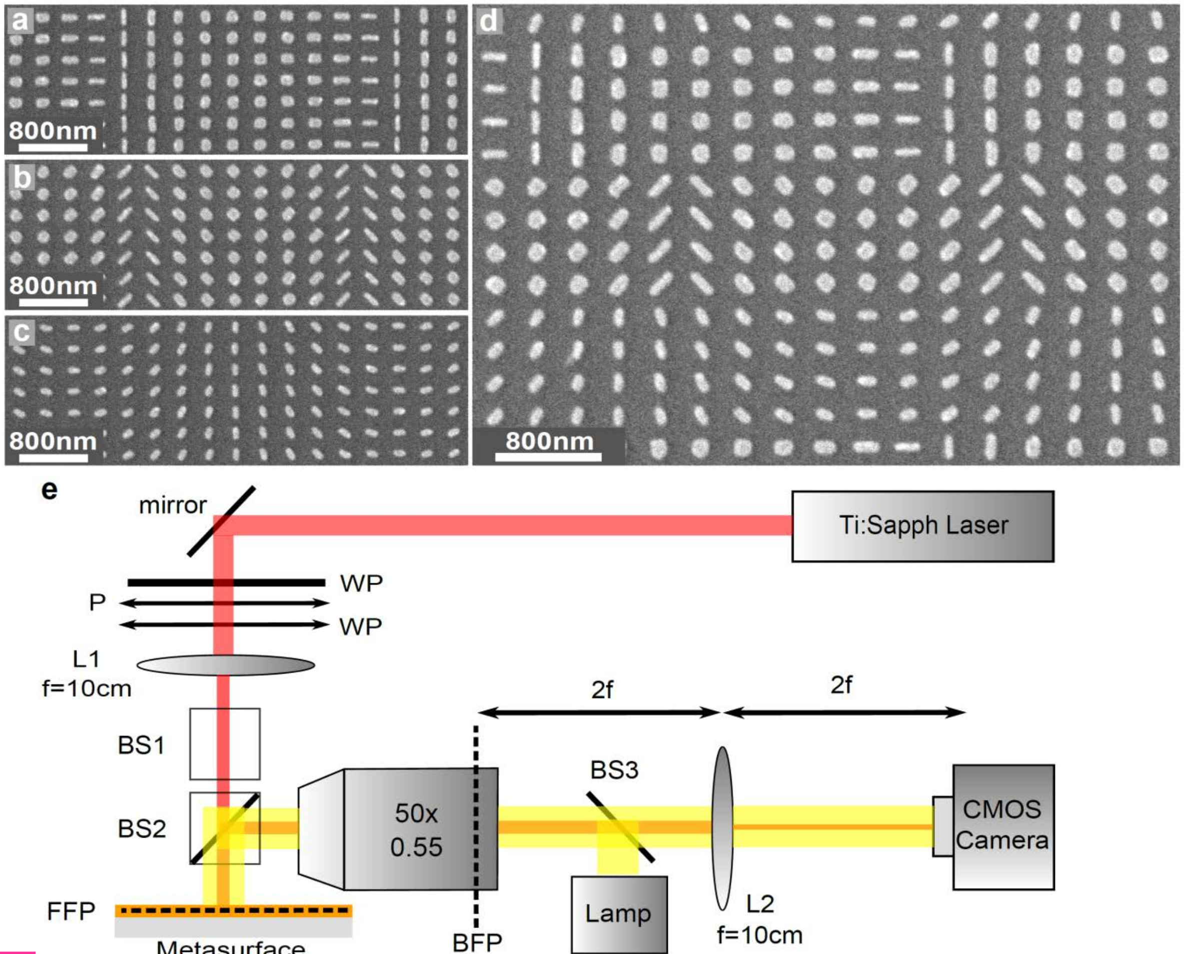


$$\alpha_{\pm 1}^{MS_1} = \pm 14.5°$$
$$\alpha_{\pm 1}^{MS_2} = \pm 18.2°$$
$$\alpha_{\pm 1}^{MS_3} = \pm 12.0°$$

Optica **2**, 716 (2015)

GSP-based all-polarization sensitive birefringent metasurfaces

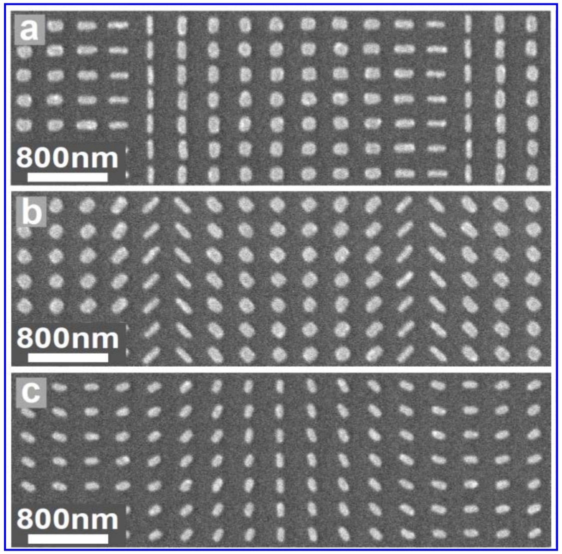
Fabrication and characterization:



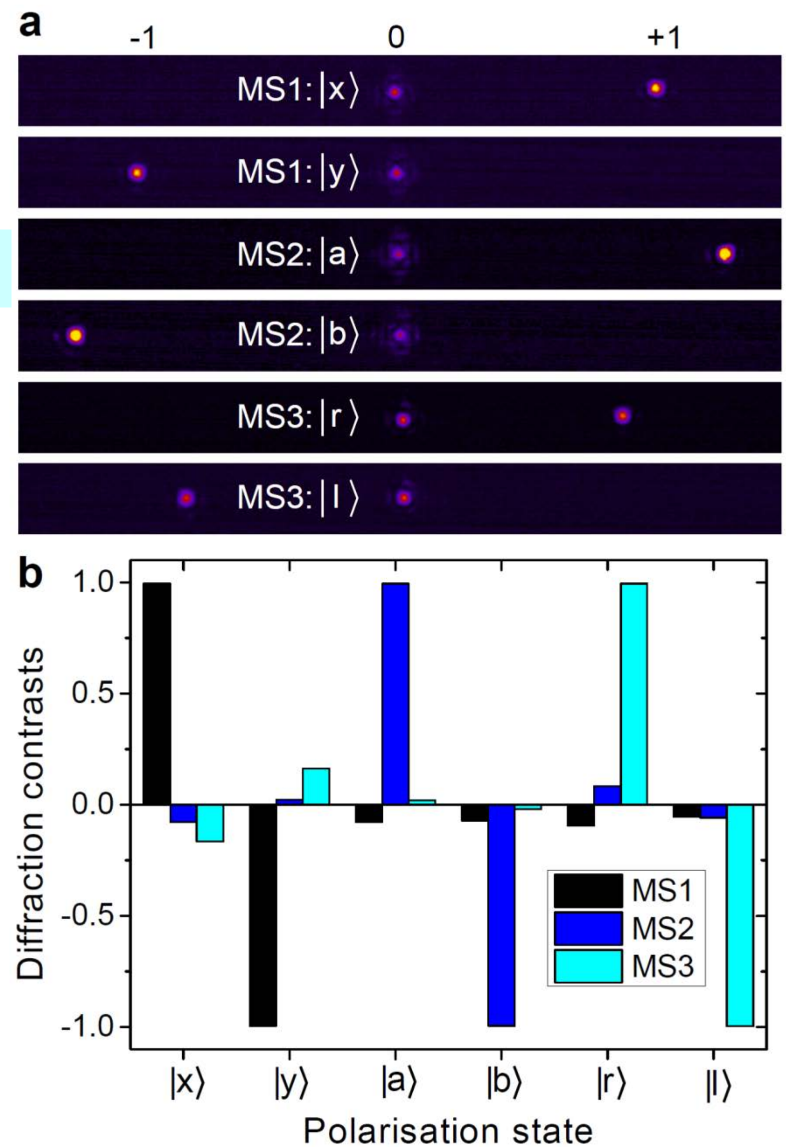
Optica **2**, 716 (2015)

GSP-based all-polarization sensitive birefringent metasurfaces

Characterization results:



λ = 800 nm



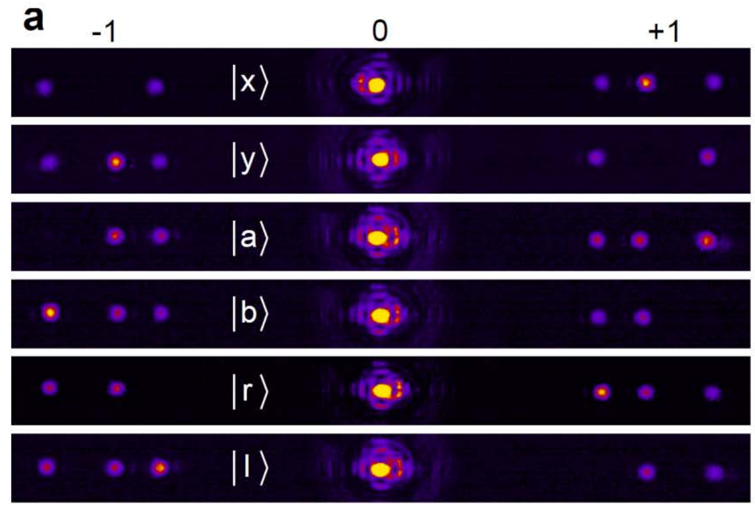
Diffraction contrast deviations of up to 0.15 are ascribed to fabrication imperfections, and to imperfections in optical components (in particular, in the quarter-wave plate).

Optica **2**, 716 (2015)

All-polarization birefringent metagrating

Characterization results:

λ = 800 nm



NATURE PHOTONICS | VOL 9 | NOVEMBER 2015 |

news & views

METASURFACES

Simultaneous Stokes parameters

Techniques for determining Stokes parameters, which fully define the polarization state of a wave, require multiple measurements, thus potentially leading to inaccuracies. Researchers now show how to simultaneously determine the parameters for visible light using periodic metal structures.

Thomas Lepetit and Boubacar Kanté

Thomas Lepetit and Boubacar Kanté are in the Department of Electrical and Computer Engineering, University of California San Diego,

The operation wavelength range is ~ 750-850 nm

Optica 2, 716 (2015)

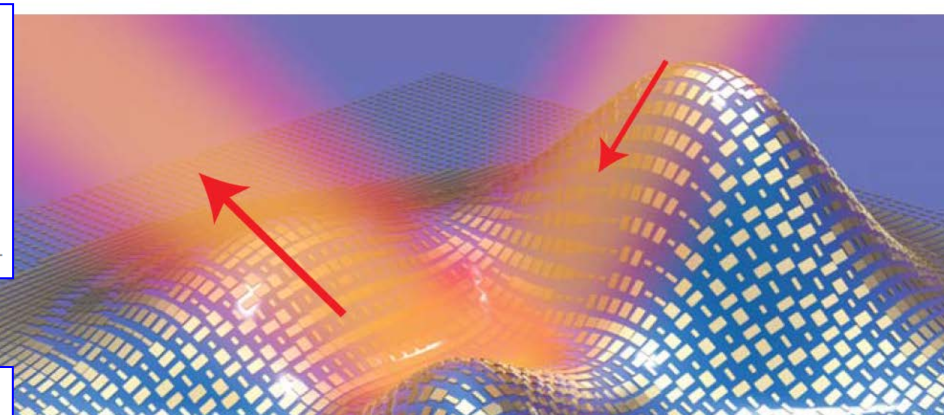
GSP-based phase-gradient metasurfaces: skin-tight invisibility (carpet) cloak!

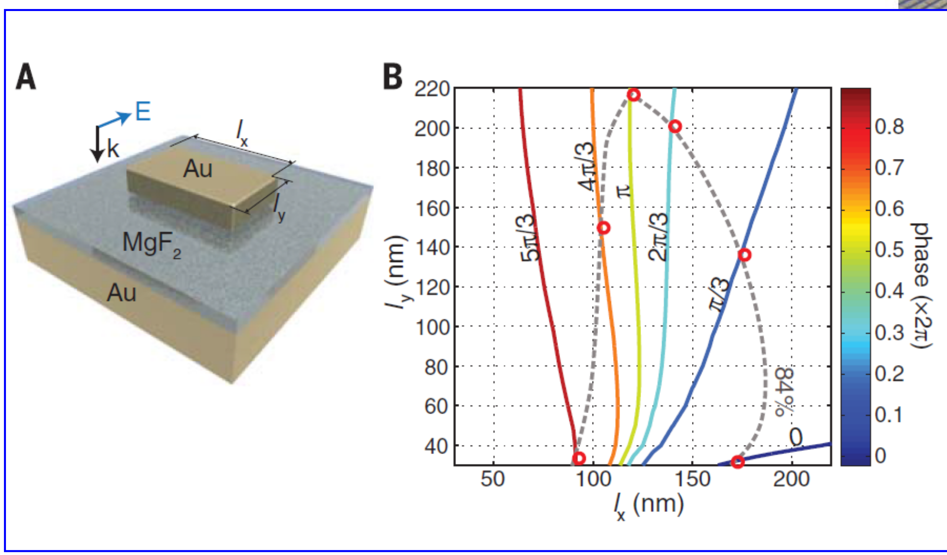
APPLIED OPTICS

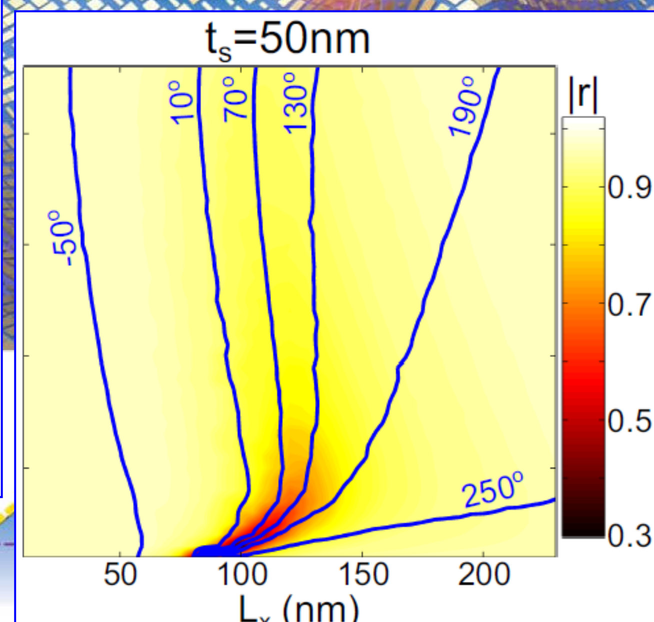
An ultrathin invisibility skin cloak for visible light

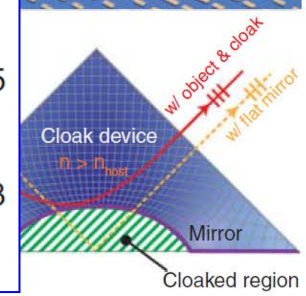
Xingjie Ni,[1*] Zi Jing Wong,[1*] Michael Mrejen,[1] Yuan Wang,[1,2] Xiang Zhang[1,2,3]†

1310 18 SEPTEMBER 2015 • VOL 349 ISSUE 6254









Sci. Rep. **3**, 2155 (2013).

V d

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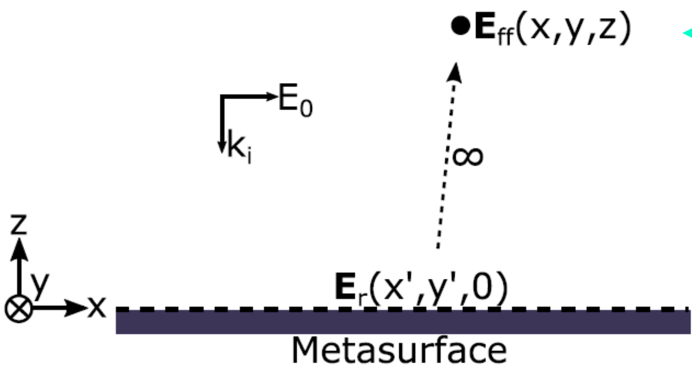
Can … deal
d … ?

Can we implement optical stealth technologies, i.e., nullify backscattering (radar) cross section?

GSP-based gradient metasurfaces: Random-phase optical metasurfaces



$$\mathbf{E}_{\mathrm{ff}}(\mathbf{r}) = 2ik\frac{e^{ikr}}{4\pi r}\hat{\mathbf{r}} \times \left[\hat{\mathbf{z}} \times \iint_A \mathbf{E}_{\mathrm{r}}(\mathbf{R}', 0)\, e^{-i\mathbf{K}\cdot\mathbf{R}'} \mathrm{d}x'\mathrm{d}y'\right],$$

Isotropic metasurfaces with uniform random phase response:

For $r_{ms}(x',y') = a\exp\left[i\phi(x',y')\right]$ and PDF: $p(\phi) = \dfrac{1}{2\pi},\ -\pi < \phi < \pi$

$\Rightarrow$ then PDF of the far-field intensity: $p(I) = \dfrac{1}{\bar{I}}\exp\left(-I/\bar{I}\right)$

Similar to scattering from atmosphere (density fluctuations)!

Sci. Rep. **6**, 28448 (2016).

GSP-based gradient metasurfaces: Random-phase optical metasurfaces

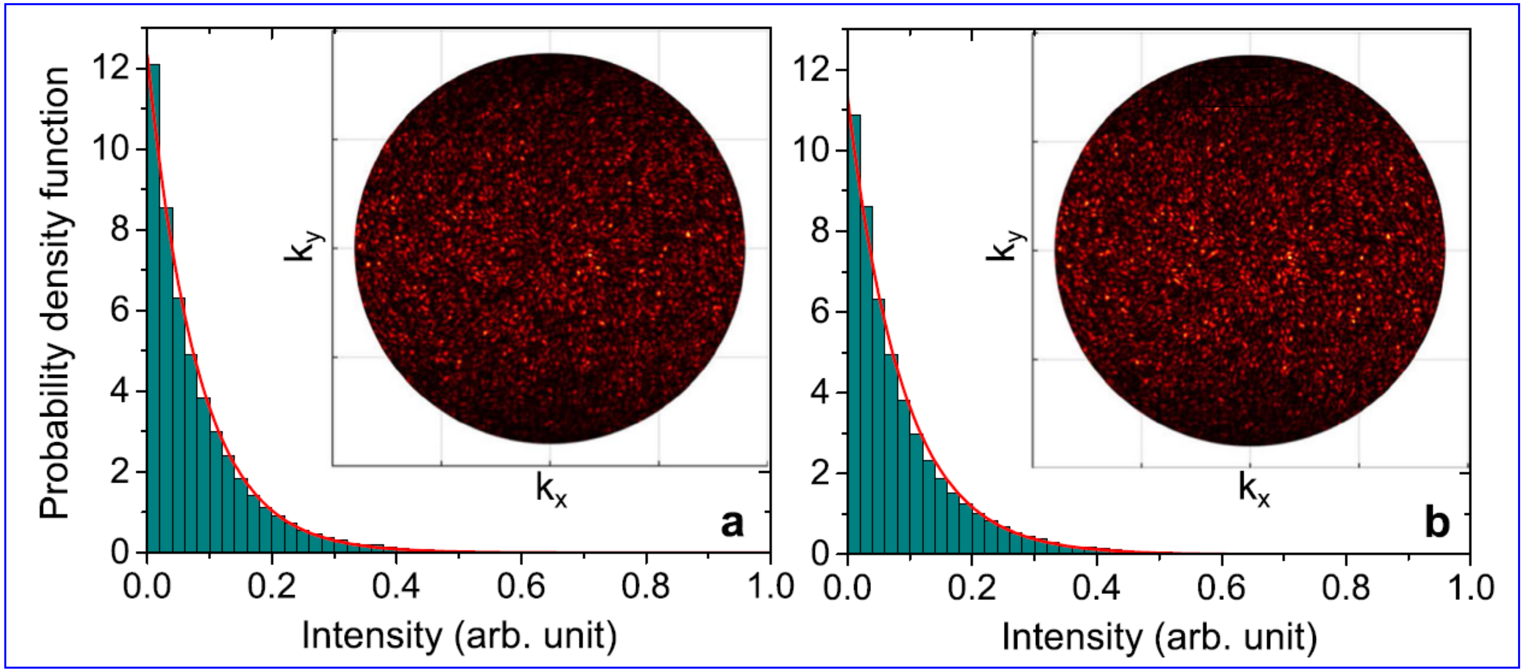


Figure 2. Numerical modelling of scattering from ideal random-phase metasurfaces. Probability density function of the far-field intensity from an array of 200 × 200 unit cells for excitation by (**a**) *x*-polarised incident light when unit cells feature random phases described by equation (3); (**b**) *x*-polarised incident light when the random phases of the unit cells are represented by a discrete random variable that takes on values $(0, \pi/2, \pi, 3\pi/2)$,

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Sci. Rep. **6**, 28448 (2016).

GSP-based gradient metasurfaces: Random-phase optical metasurfaces

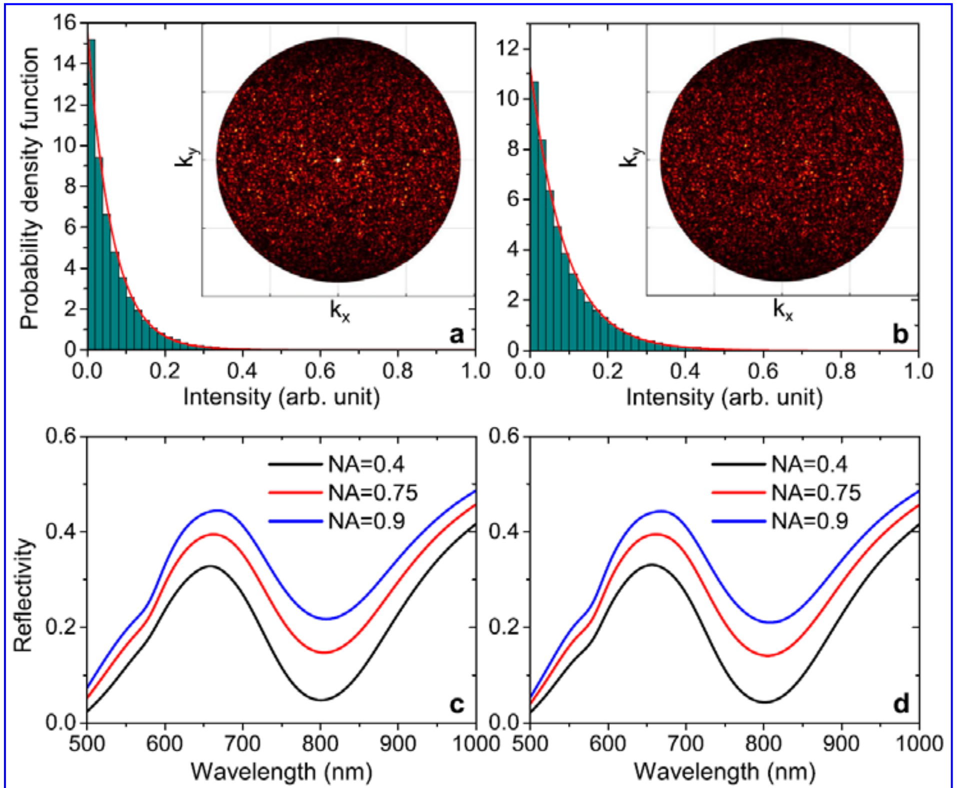
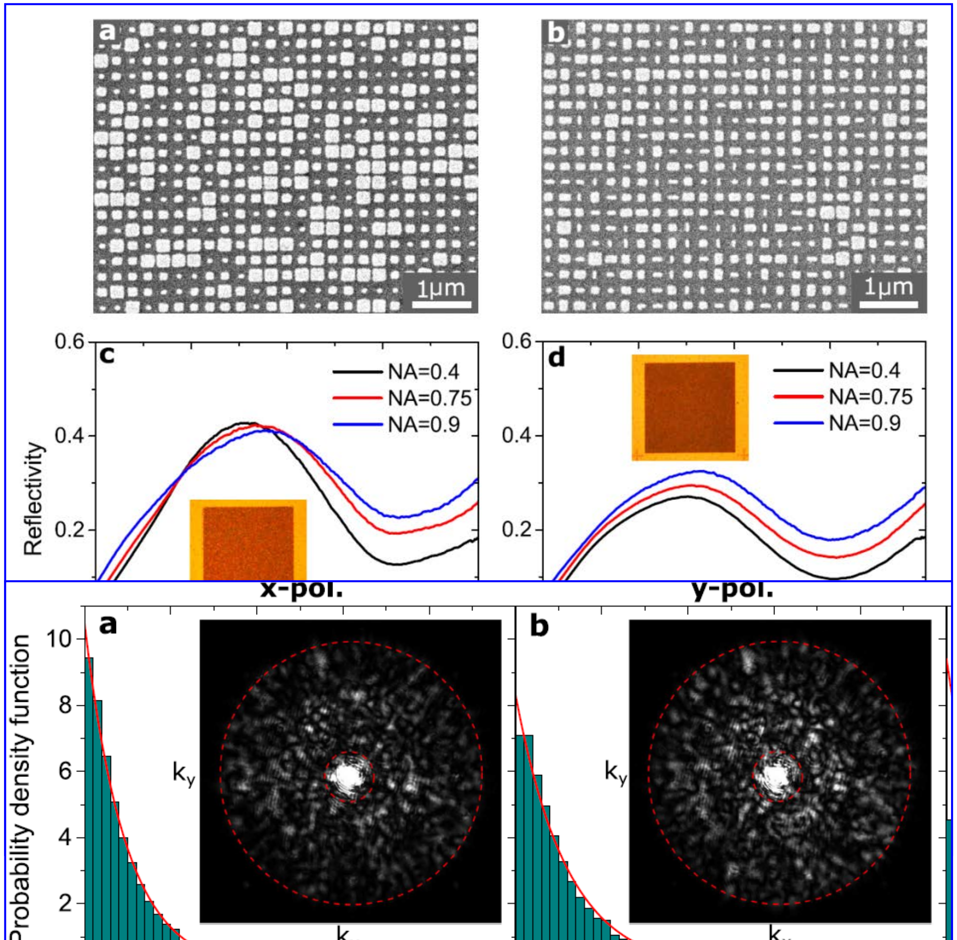


Figure 4. Numerical modelling of scattering from random-phase GSP-based metasurfaces. (**a**) Calculated (histogram) and theoretical (red line) PDF of the far-field intensity (when neglecting specular reflection) from an array of 200 × 200 unit cells for excitation by *x*-polarised incident light when the four types of nanobricks, defined by the intersection of contour lines in Fig. 3b for $L_x = L_y$, appear with equal probability in the array. The inset shows the associated Fourier image of the far-field intensity within the NA = 0.9. The image is



Optical stealth effect can be achieved with proper design!

Sci. Rep. **6**, 28448 (2016).

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Instead of out look

The Question:
Can one realize one-shot spectropolarimetry (i.e., complete plane-wave characterization)?

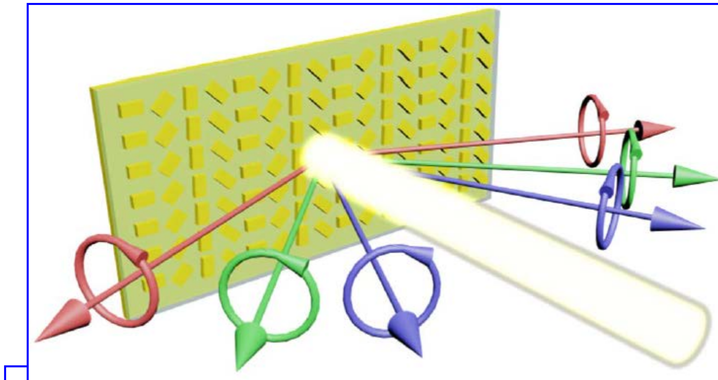
GSP arrays for chiroptical spectroscopy

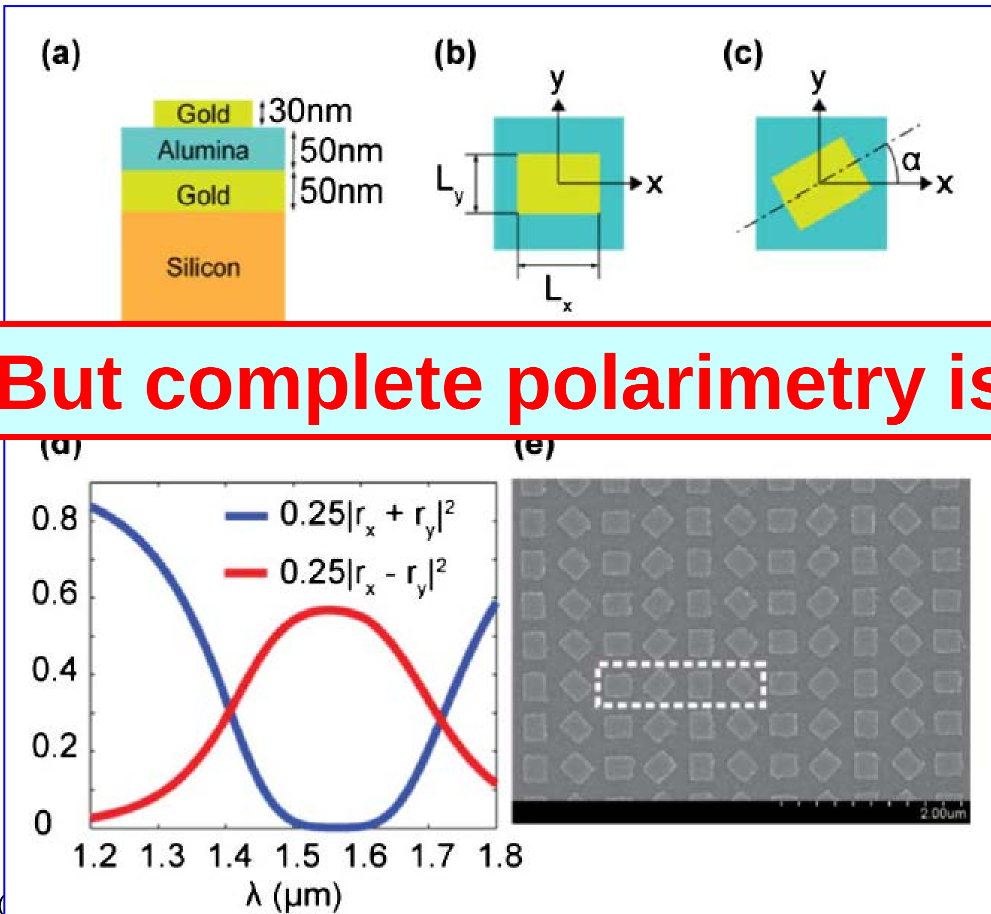

Letter — Vol. 2, No. 10 / October 2015 / Optica 860

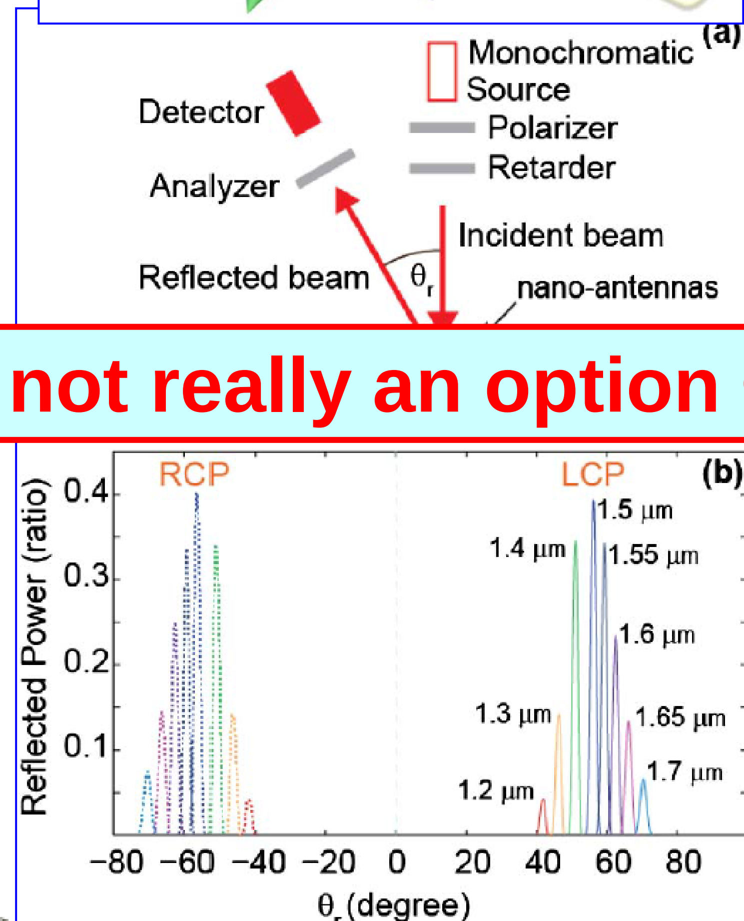
optica

Photonic spin Hall effect in gap–plasmon metasurfaces for on-chip chiroptical spectroscopy

Amr Shaltout,[1] Jingjing Liu,[1] Alexander Kildishev,[1,2] and Vladimir Shalaev[1,*]







But complete polarimetry is not really an option ☹

GSP metasurfaces for spectropolarimetry

IOP Publishing
Nanotechnology 27 (2016) 224002 (7pp) doi:10.1088/0957-4

Integrated plasmonic metasurfaces for spectropolarimetry

Received 7 December 2015
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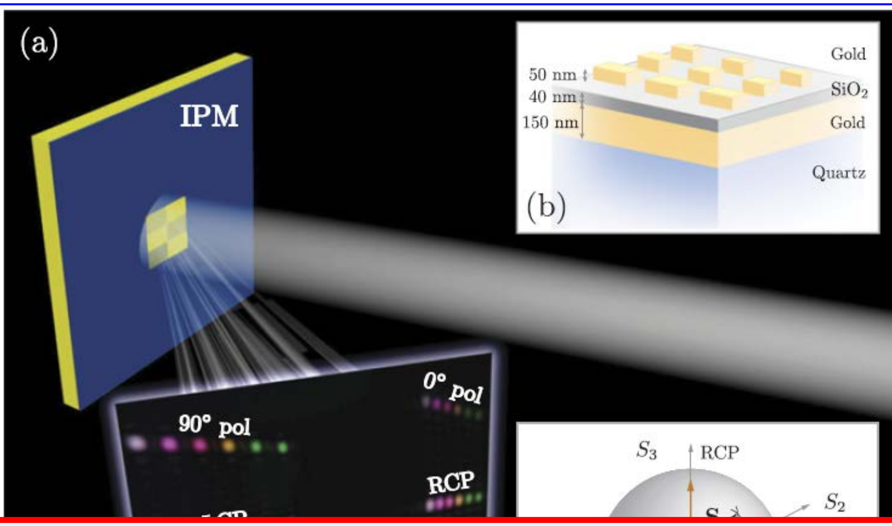
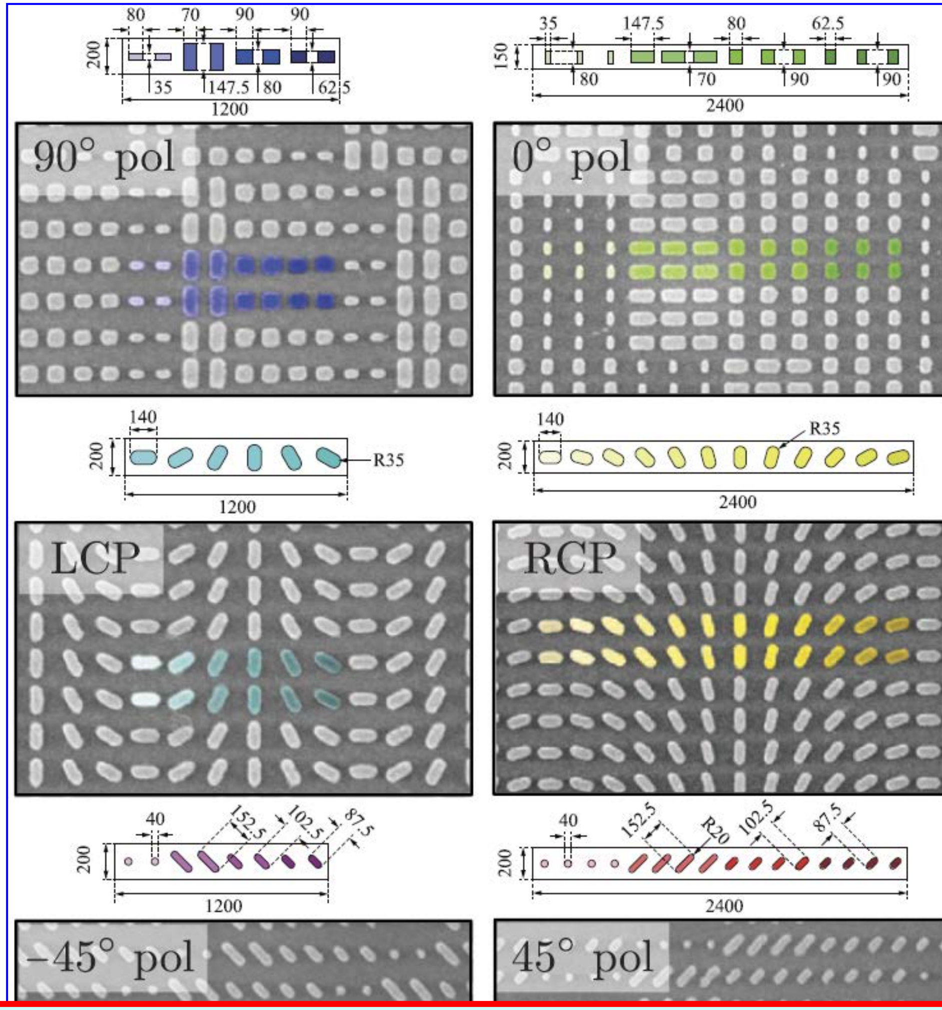
Wei Ting Chen[1], Peter Török[2], Matthew R Foreman[3], Chun Yen Liao[1], Wei-Yi Tsai[1], Pei Ru Wu[1] and Din Ping Tsai[1,4]

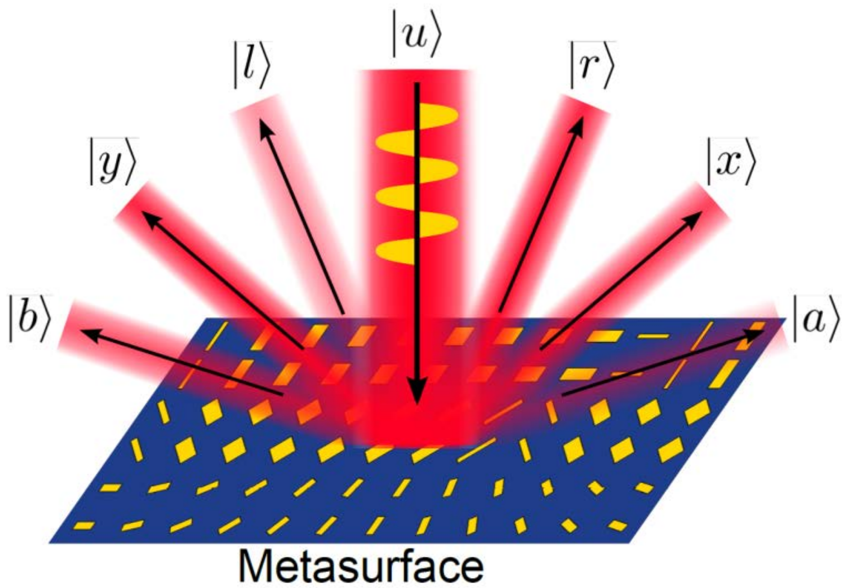
[1] Department of Physics, National Taiwan University, Taipei 10617, Taiwan
[2] Blackett Laboratory, Department of Physics, Imperial College London, London, SW7 2BW, UK
[3] Max Planck Institute for the Science of Light, Günther-Scharowsky-Straße 1, D-91058 Erlangen, Germany
[4] Research Center for Applied Sciences, Academia Sinica, Taipei 11529, Taiwan



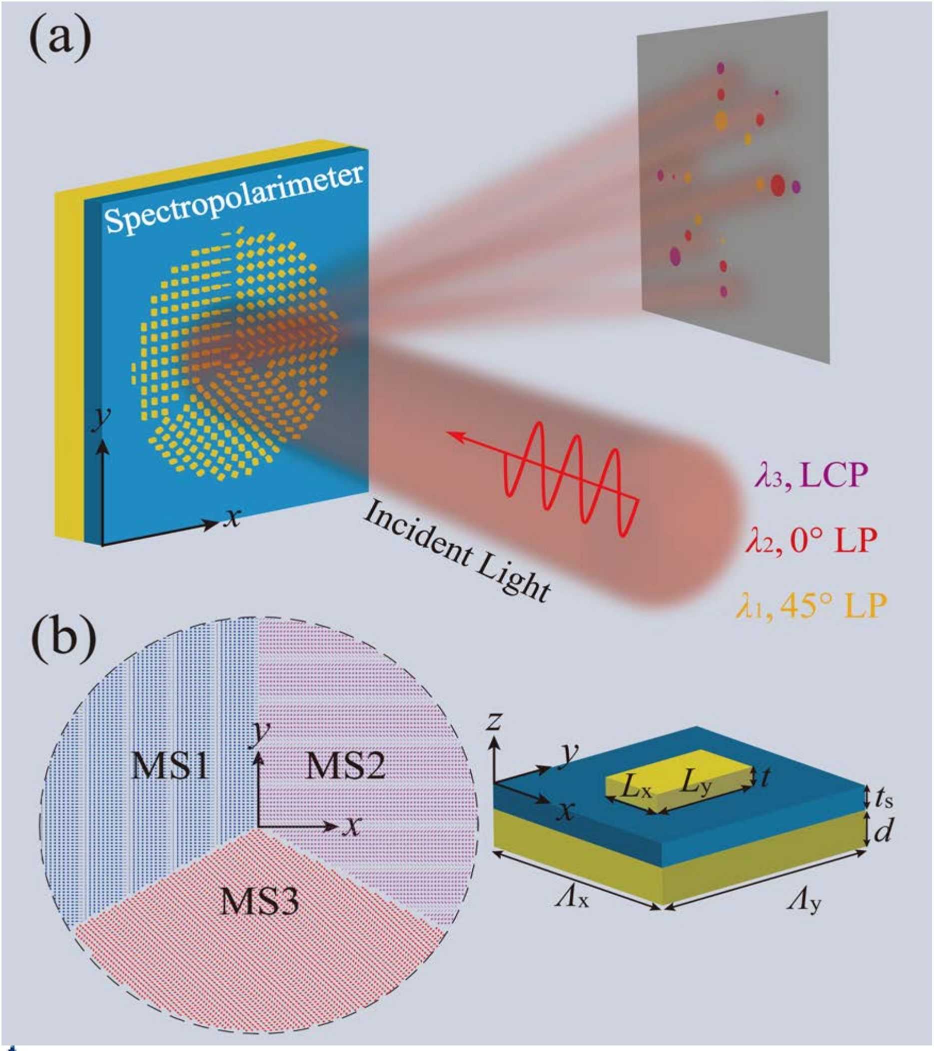


Careful adjustment of beam shape and position are essential!

GSP metasurfaces for spectropolarimetry

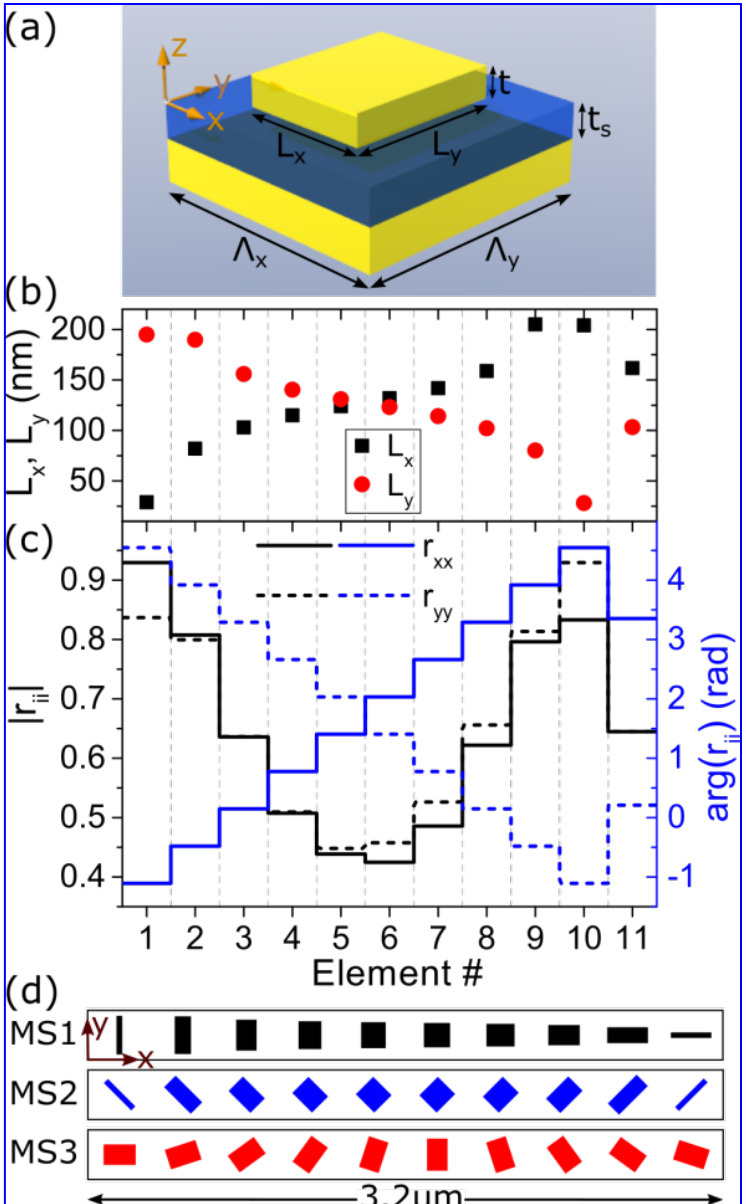


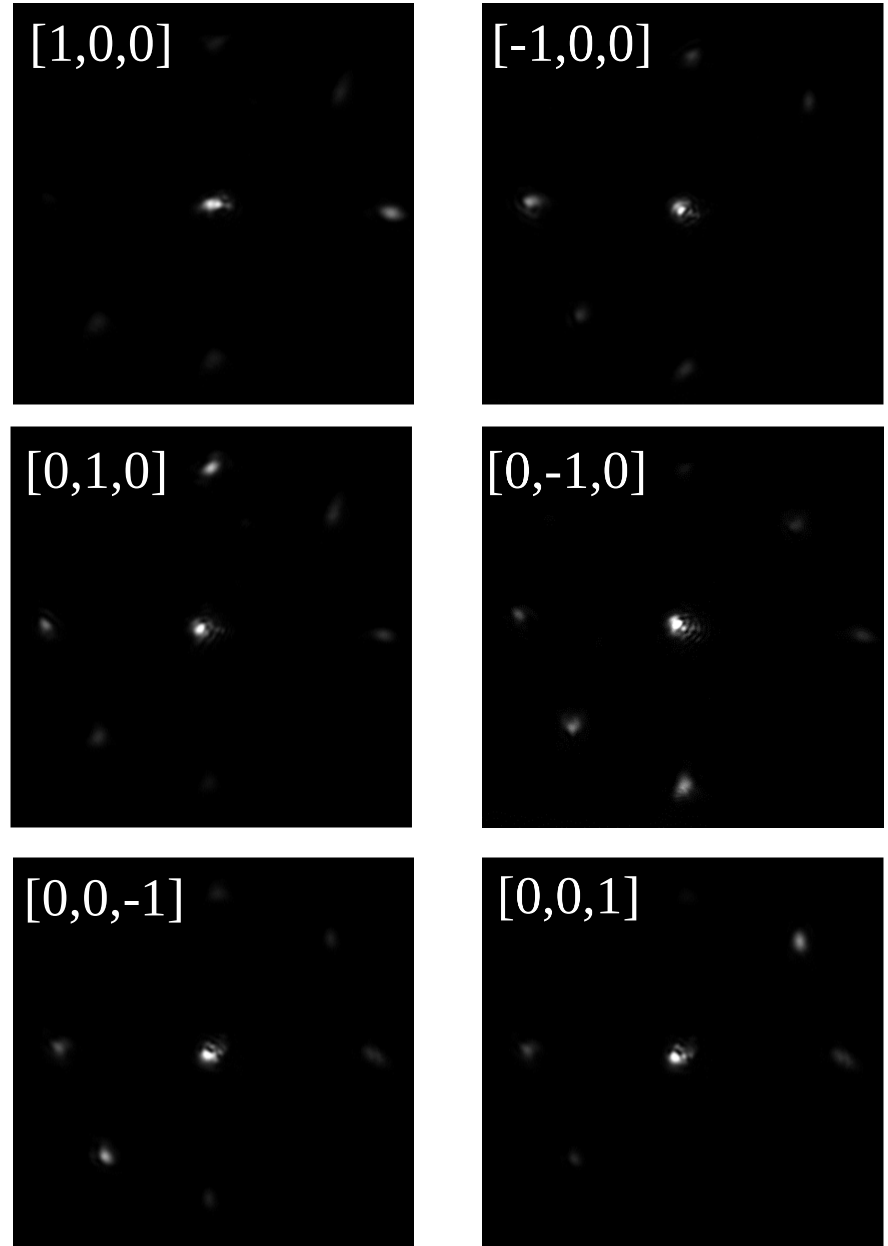
"Mercedes" design



STILL IN WORKS…

GSP metasurfaces for spectropolarimetry



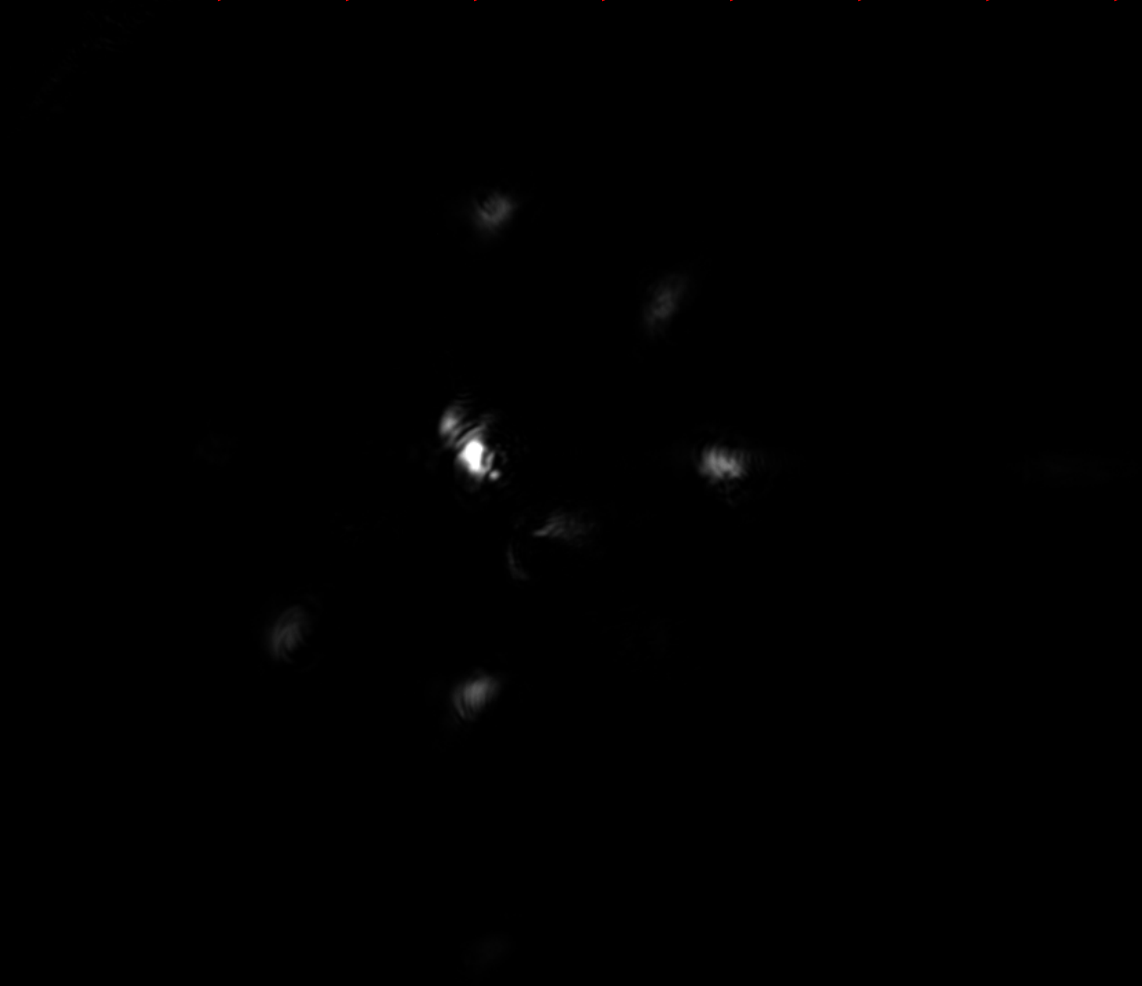


d = 64 μm, LP90deg

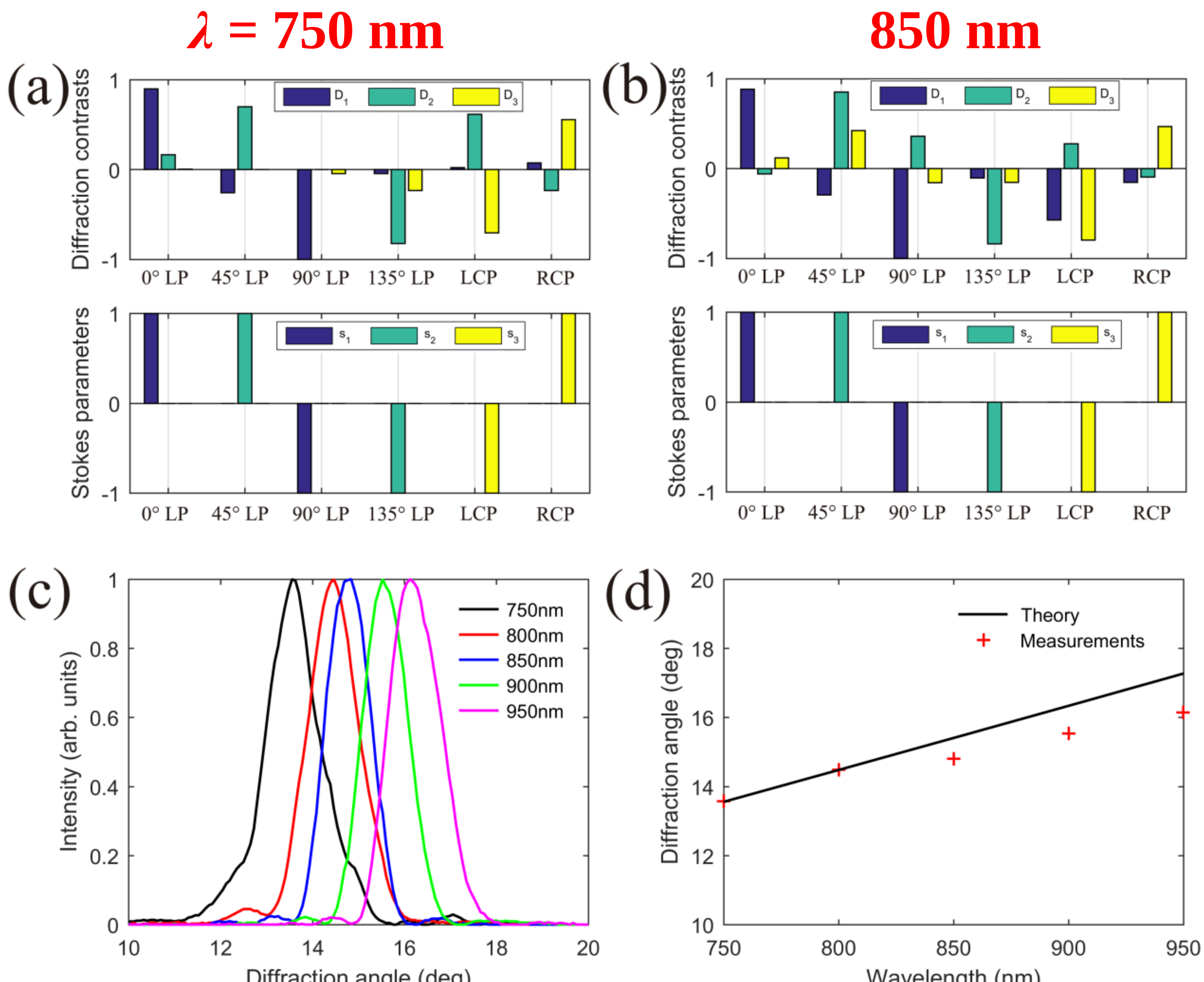
λ = 710, 730, 750, 780 800, 830, 850, 880, 900, 930, 950, 980, 1000 nm

d = 64 μm, LP0deg

λ = 710, 730, 750, 780 800, 830, 850, 880, 900, 930, 950, 980, 1000 nm



GSP metasurfaces for spectropolarimetry



STILL IN WORKS…

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