Simultaneous and Efficient Spin-State and Wave-front Manipulation with Meta-surfaces

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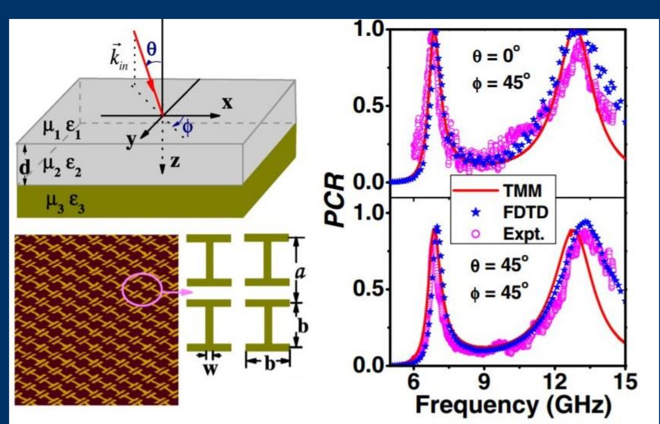
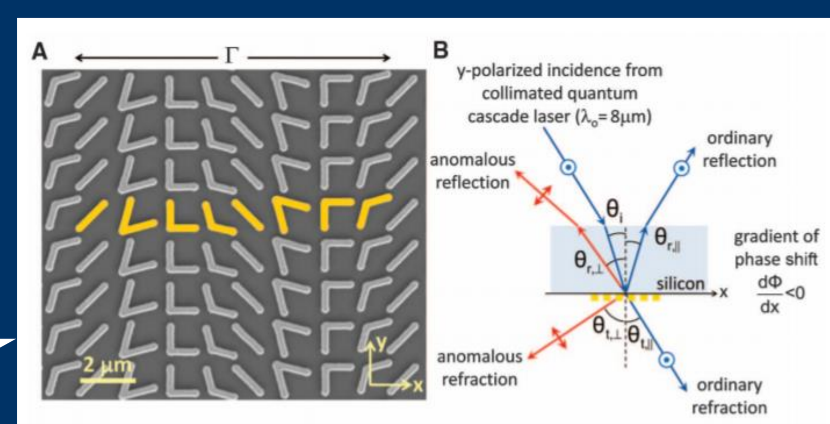
I. Backgrounds



[1]Jiaming Hao et al. PRL. 99, 063908 (2007)

Fig. 1 Polarization manipulation with meta-surface



[2]Nanfang Yu et al. Science. 334, 333 (2011)

Fig. 2 Wave front manipulation with meta-surface

- **Motivations**

1. Propose a general platform to control these two important properties: global wave-front and local spin state, especially for some complicated but important cases like： realizing inhomogeneous local spin state and PW-SW conversion at the same time.
2. Use the meta-platform to explore new physics and realize more fancy functionalities :

Eg. Vector Vortex SPP Coupler

II. Basic idea & Dipole-Model Calculations

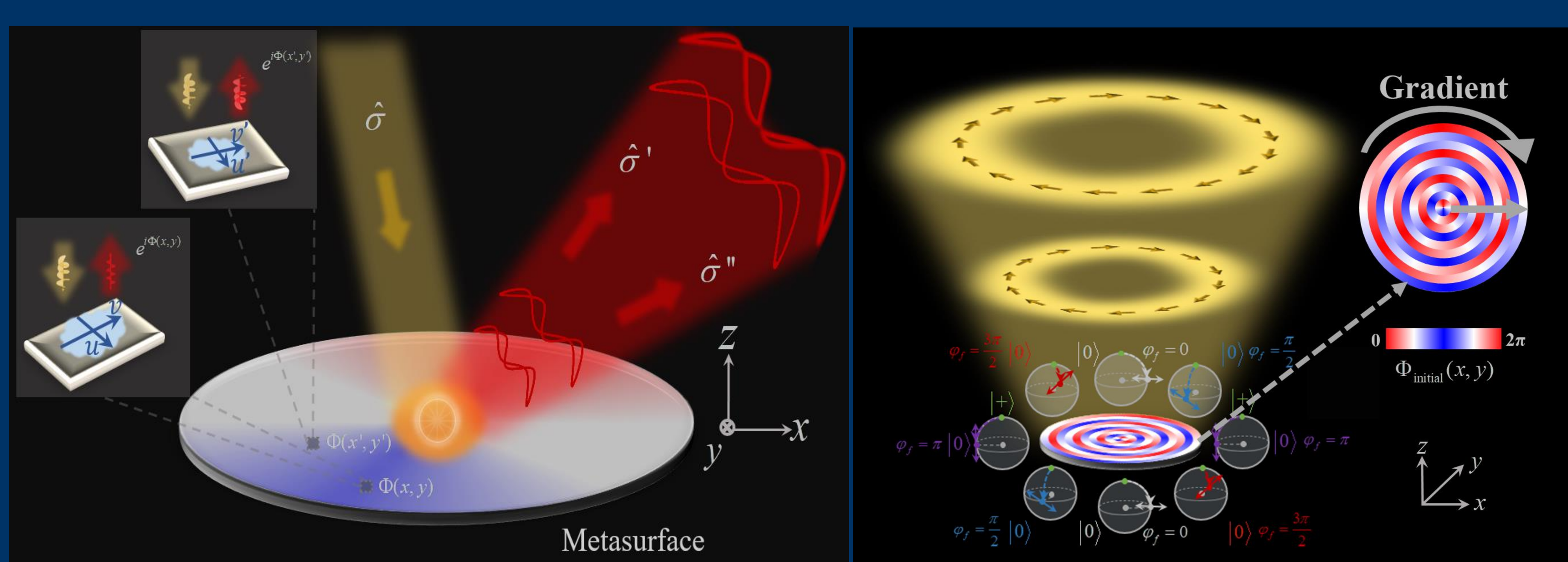


Fig. 2 Simultaneous manipulation of local spin and global wave front.

- **Key Points**

A set of meta-atoms, each of which can:

1. Convert the local spin-state of incident light to an arbitrary state on Poincare Sphere $(\theta_f(x,y),\varphi_f(x,y))$
2. Possessing any required initial phases $\Phi_{\text{initial}}(x,y)$

- **Dipole-Model Calculations**

Treat each meta-atom as a pair of dipoles and calculate :

Pattern seen as an Emanative Vector Vortex beam

$\longrightarrow$ Arbitrary $(\theta_f,\varphi_f,\Phi_{\text{initial}})$ ⟺ Arbitrary {Local Spin State / Global Wave Front}

III. Meta atom design strategy

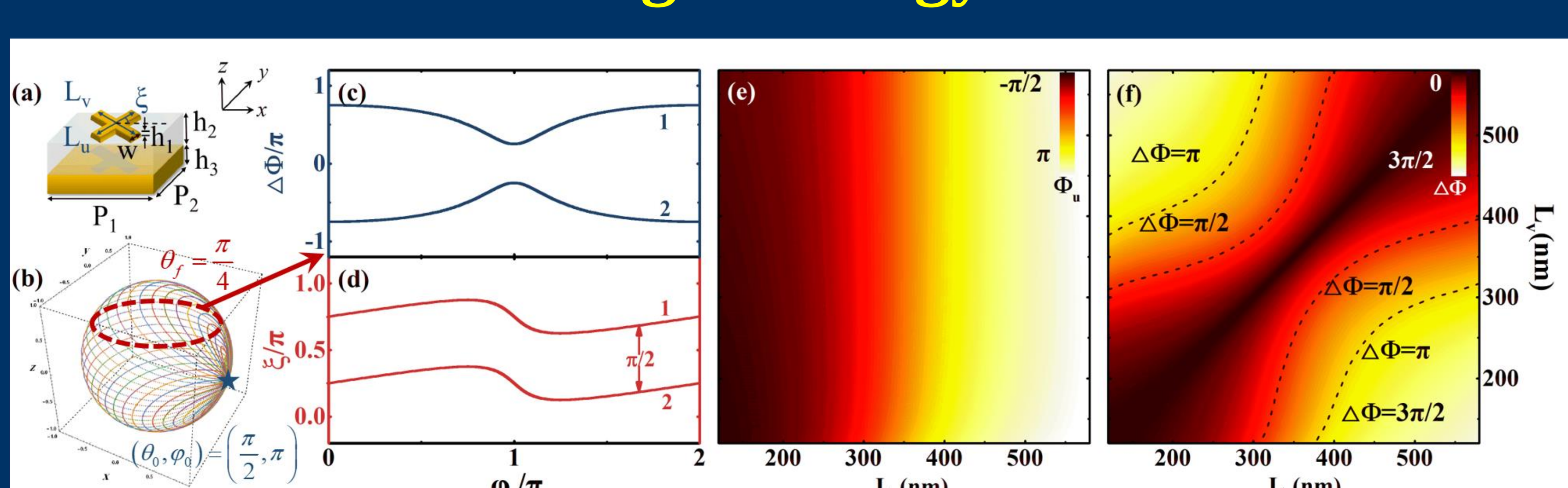


Fig. 3 Design guideline of MIM tri-layer meta-atom for reflection geometry

$$\begin{pmatrix} L_u \\ L_v \\ \xi \end{pmatrix} \Leftrightarrow \begin{pmatrix} \Phi_u \\ \Delta\Phi \\ \xi \end{pmatrix} \Rightarrow \begin{pmatrix} \Phi_{\text{initial}} \\ \theta_f \\ \varphi_f \end{pmatrix} = \begin{pmatrix} \Phi_{\text{initial}}(\Phi_u,\ \Delta\Phi,\ \xi) \\ \theta_f(\Delta\Phi,\ \xi) \\ \varphi_f(\Delta\Phi,\ \xi) \end{pmatrix}$$

Three degrees of freedom $(\Phi_u,\Delta\Phi,\xi)$ with considerably large variation range provides unprecedented ability to freely manipulate $(\Phi_{\text{initial}},\theta_f,\varphi_f)$, i.e. to realize arbitrary local spin state and initial phase for each meta-atom

IV. Benchmark Case: Anomalous Reflection Quarter Wave Plate

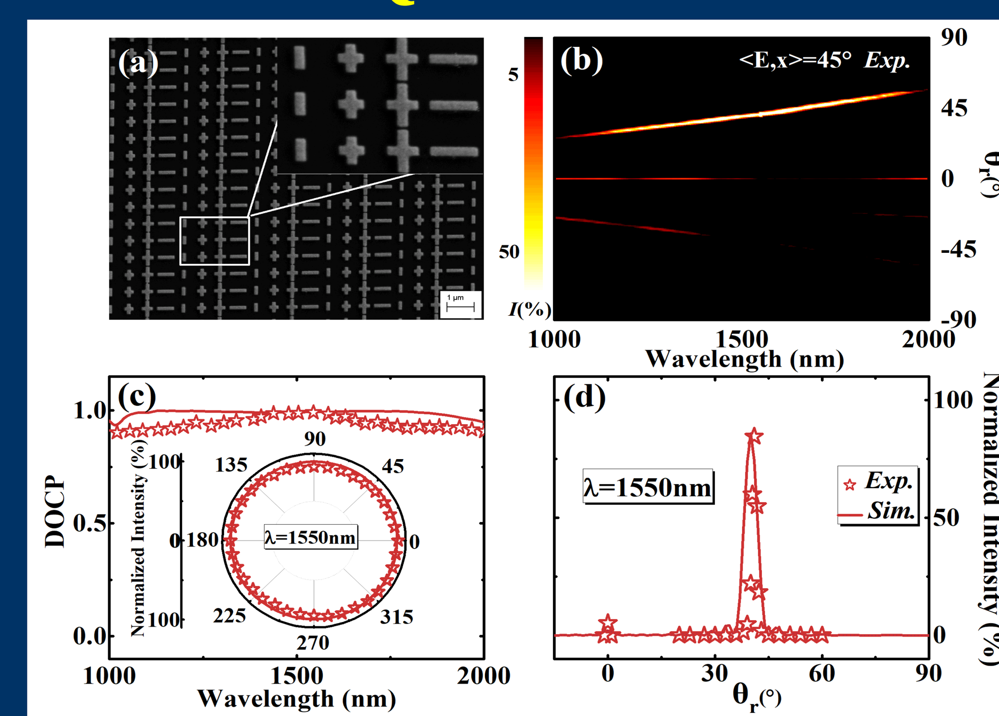


Fig. 4 AR quarter wave plate

Anomalous reflection, converted uniform polarization with

- Absolute AR efficiency : 84% at center (@1550nm)
- Over 50% in a 45% relative bandwidth
- DOCP: ＞90% (1000nm~2000nm)

V. Vector Vortex SPP coupler

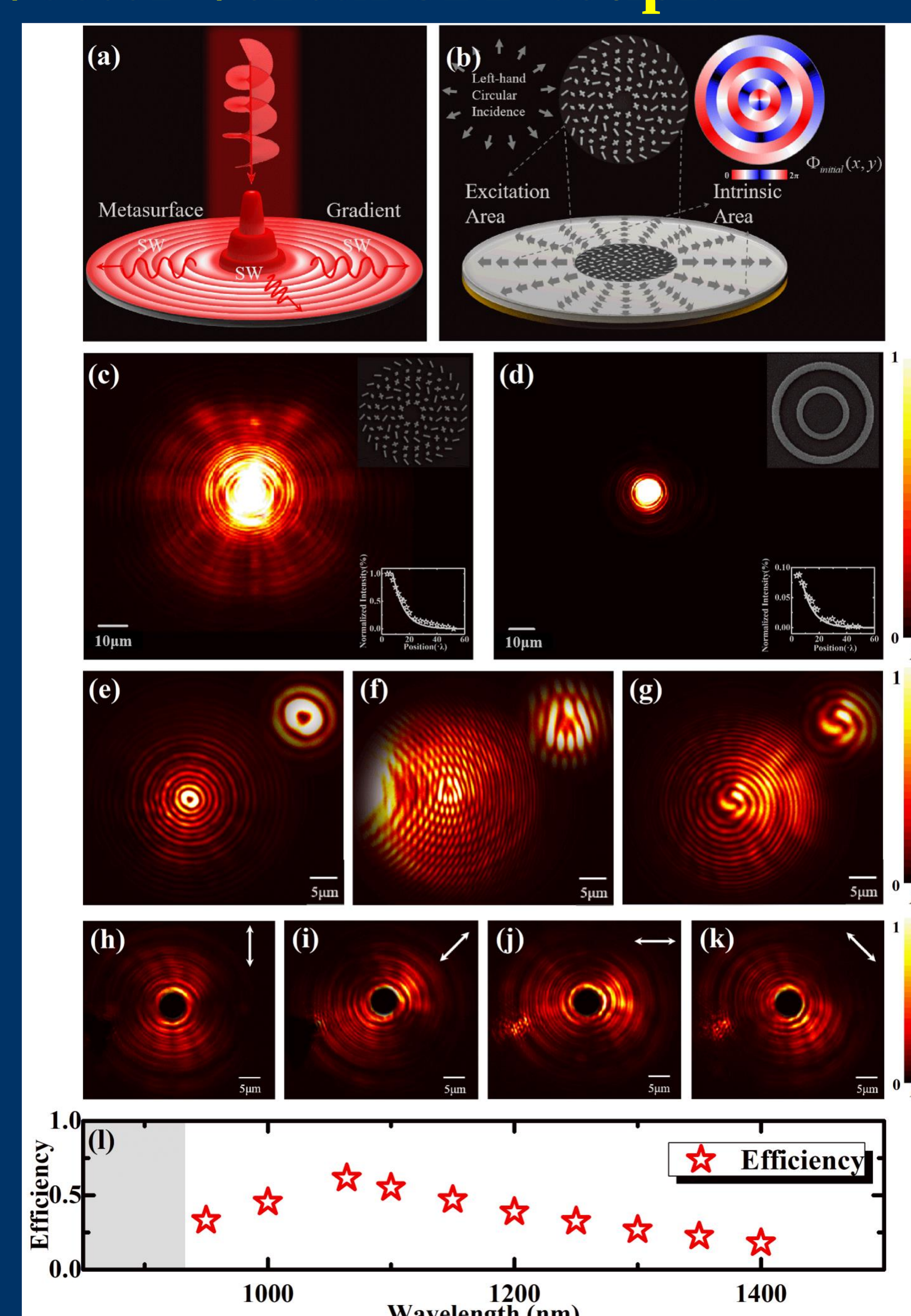


Fig. 5 Vector dispersive SPP coupler

- Leaky wave experimental result:

Cylindrically polarized SPP exhibiting inhomogeneous polarization distribution and vortex properties

Absolute SPP coupling efficiency : 61.4%at center (@1064nm), over 20% in a 40% relative bandwidth

VI. Conclusions & Perspectives

1. A general meta-platform proposed for arbitrary local spin and global wave front control.
2. High efficiency and broadband AR wave plates and vector vortex SPP coupler realized numerically and experimentally.
3. Even more fancy physics and functionalities to be explored based on this platform…

References

[1] J.M. Hao, et. al. PRL. 99, 063908 (2007)
[2] Nanfang Yu et al. Science. 334, 333 (2011)
[3] Nanfang Yu et al. Nano Lett. 12, 6328−6333(2012)
[4] Fei. Ding et al. ACSNano.10,1021, 4111−4119(2015)
[5] Dongyi Wang et al. Draft in Preparation (2019)