Optical Topological Lattices for On-Chip Nanoparticle Trapping and Sorting

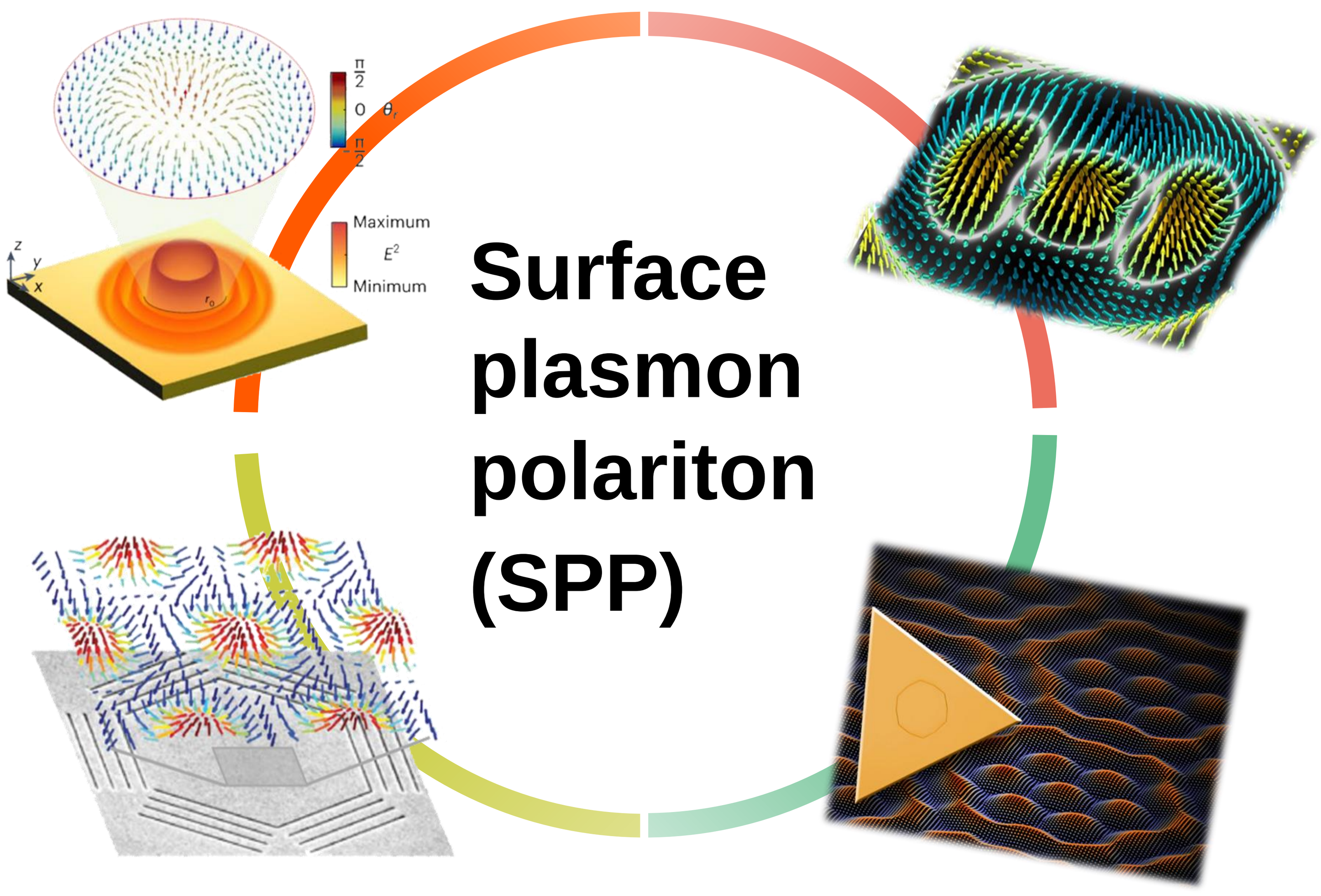
*Xi Xie, Hongyang Xu, and Yijie Shen**

Centre for Disruptive Photonic Technologies, SPMS, NTU, 637371, Singapore

School of Electrical and Electronic Engineering, NTU, 639798, Singapore

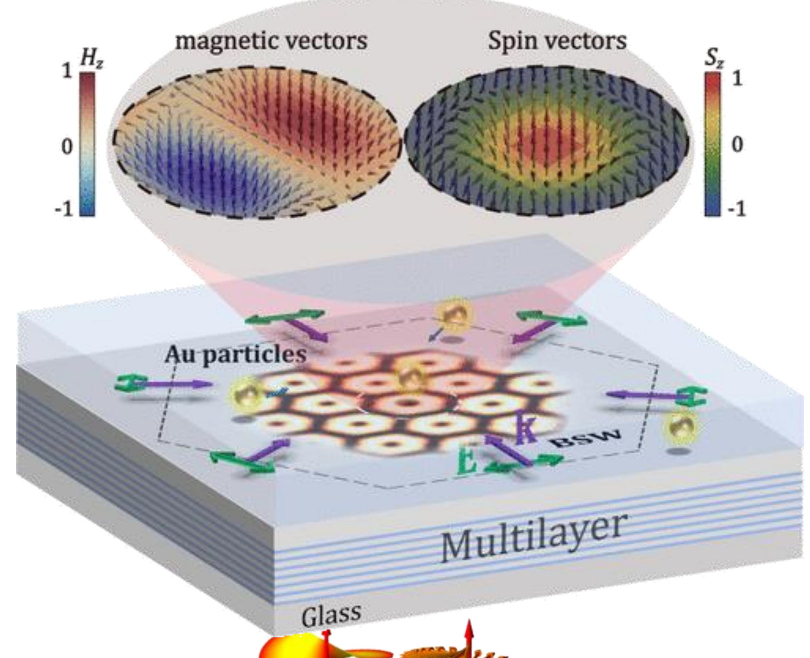
**yijie.shen@ntu.edu.sg*

Multi-particle trapping and sorting are crucial for biomedical diagnostics, drug delivery, and nanomanufacturing, providing a foundation for precise manipulation at the microscale.

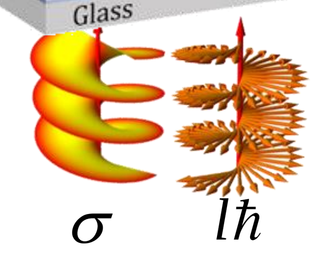


Replace

Our method



Based on **Bloch surface waves** (BSWs) excited on transparent dielectric multilayers.



Total angular momentum of light (TAM=l+σ)

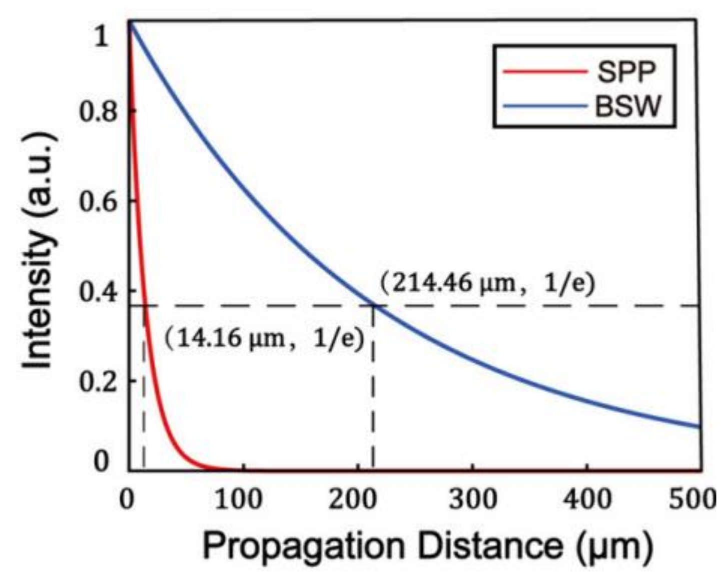
Topological structure light based on SPP[1-4] → Fantastic and Exciting. SPP-based optical lattices have been explored enabling rich topological field patterns.

However, there are some limits:

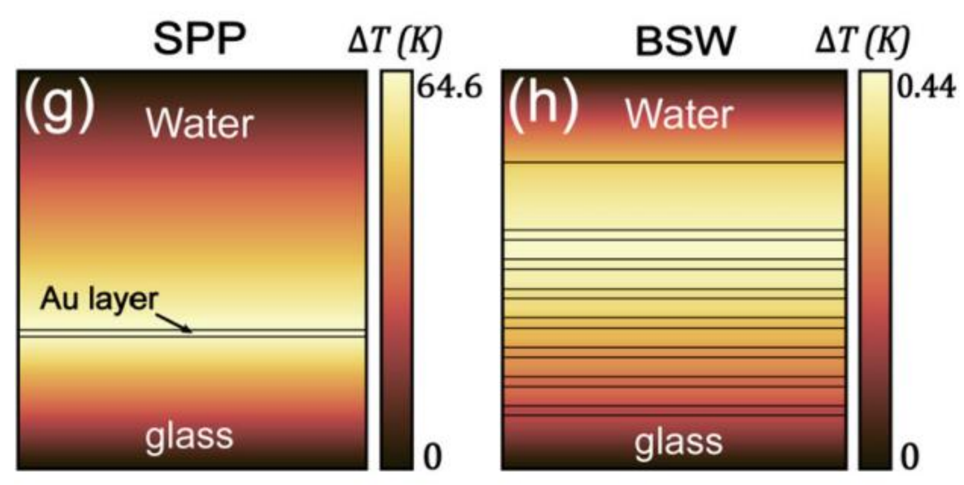
- **Severe Ohmic Losses**
- **Significant Local Heating**
- **Limited Reconfigurability**

Advantage:

(i) Ultralong Propagation (>200μm)



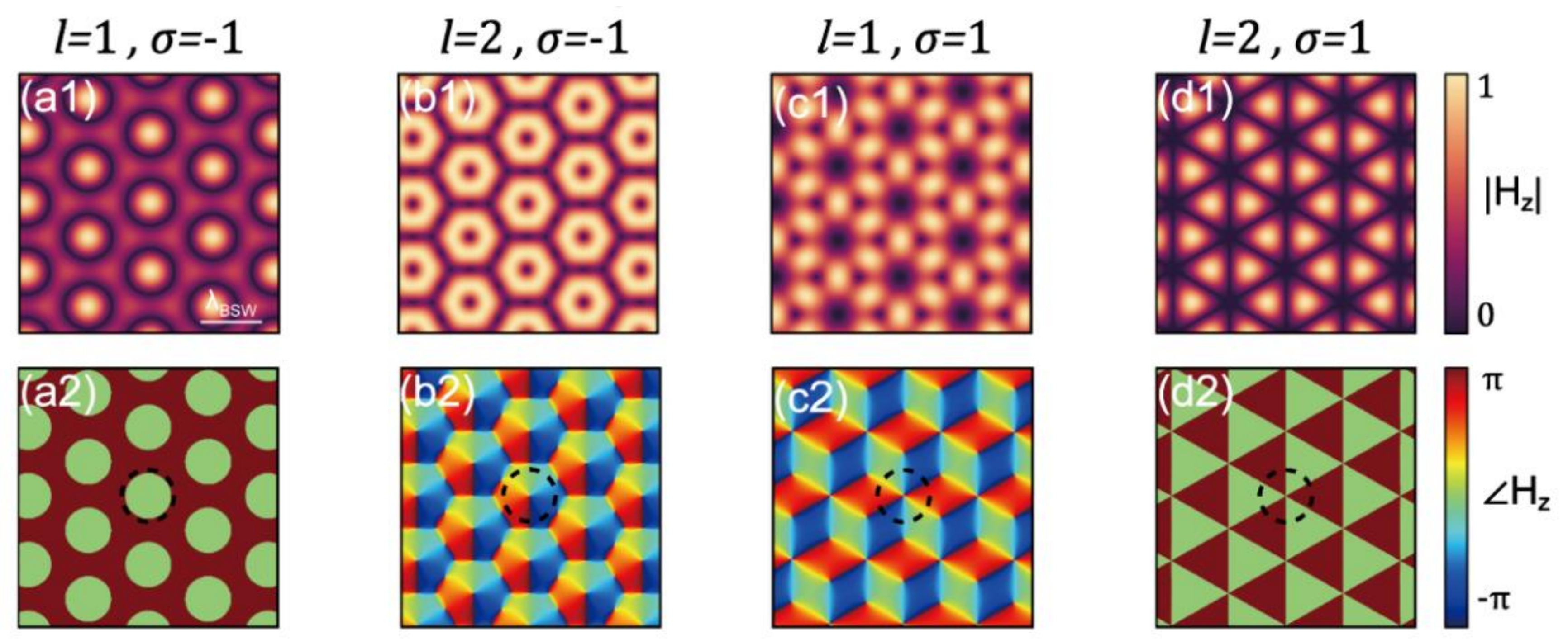
(ii) Slight Thermal Effect



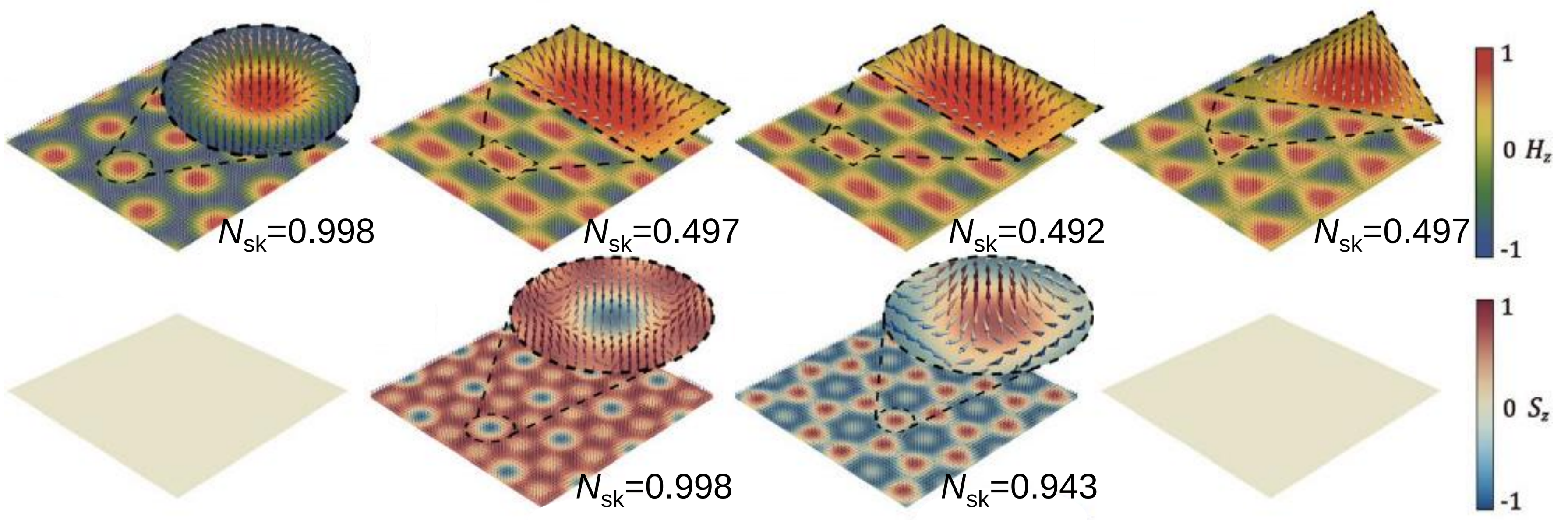
Heat Field Distribution

Topological magnetic lattice

Four distinct magnetic vector lattice configurations are generated by varying TAM: (a) Hexagonal, (b) Hexagonal Vortex, (c) Kagome, and (d) Honeycomb.



Spin angular momentum $S=\frac{1}{4\omega}\mathrm{Im}(\varepsilon\mathbf{E}^*\times\mathbf{E}+\mu\mathbf{H}^*\times\mathbf{H})$



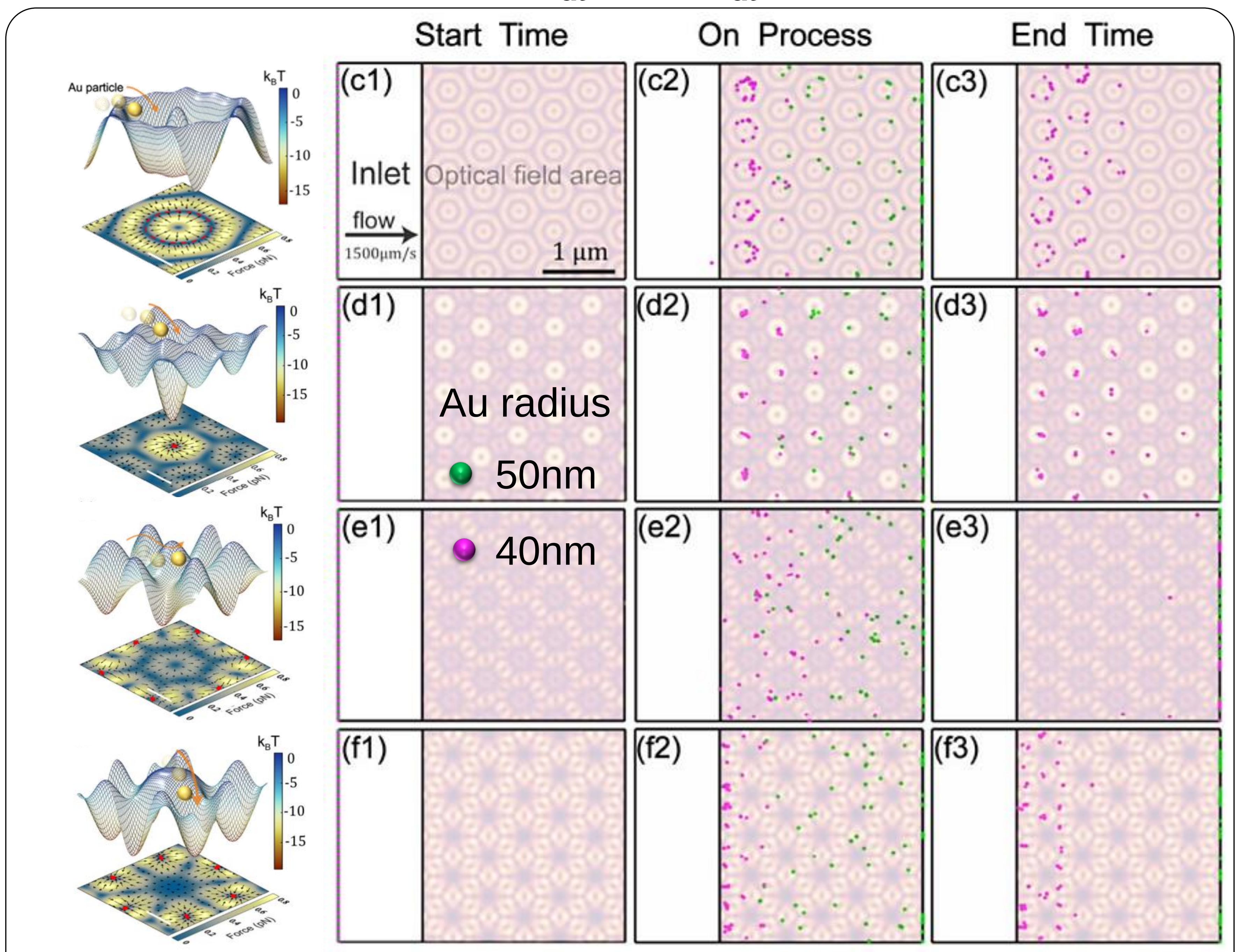
Magnetic (top) and spin (bottom) topological textures reveal topological structures. N_{sk}: skyrmion number.

How to use topological light?

Our answer: for optical trapping and sorting

Optical force $\langle \mathbf{F}_{trap}\rangle=\frac{1}{4}\mathrm{Re}(\alpha)\nabla|\mathbf{E}|^2+\frac{\sigma}{2c}\mathrm{Re}(\mathbf{E}\times\mathbf{H}^*)+\sigma c\nabla\times\frac{\varepsilon_0}{4\omega i}\mathrm{Im}(\mathbf{E}\times\mathbf{E}^*)$

Langevin equation $m_p\frac{d^2r}{dt^2}+6\pi\eta a(\frac{dr}{dt}-v_f)+\mathbf{F}^r_{trap}+\mathbf{F}_{Brownian}=0$



Left: optical potential of one unit cell of each lattice. Right: dynamic size-dependent sorting of gold nanoparticles: the purple one will be trapped in the lattice area, but the green one will pass through.

Conclusion: BSW-based topological magnetic lattices enable low-loss, large-area, and reconfigurable nanoparticle trapping and sorting[5]. The honeycomb lattice exhibits superior sorting performance, offering a promising on-chip platform for biosensing and optofluidic applications.

Reference: [1] Science 361, 993 – 996 (2018); [2] Nat. Phys. 15, 650−654 (2018); [3] Nature 588, 616−619 (2020); [4] Nat. Phys. 21, 988–994 (2025); [5] Nano Letters 2025 25 (26), 10611-10618