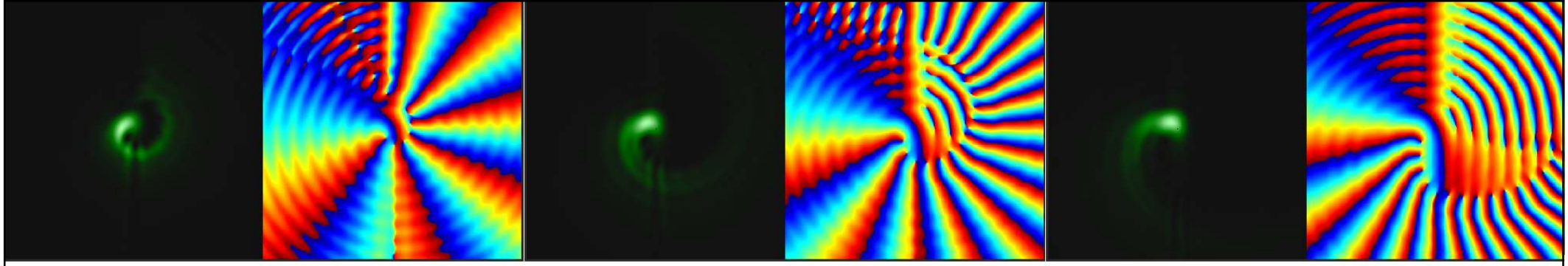

Propagation and focusing of optical vortex beams generated by generalized spiral phase plates

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Design of generalized spiral phase plates

Transmission function of a generalized spiral phase plate (GSPP):

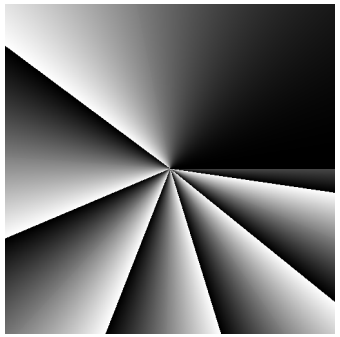
$$T(r, \varphi) = A(r, \varphi)\exp[ig(\varphi)],$$

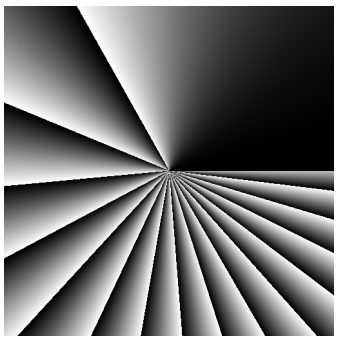
where (r, φ) are the polar coordinates,

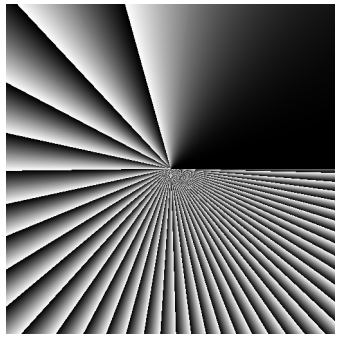
$g(\varphi)$ is an arbitrary real function,

$A(r, \varphi)$ is the amplitude function of the illuminating beam

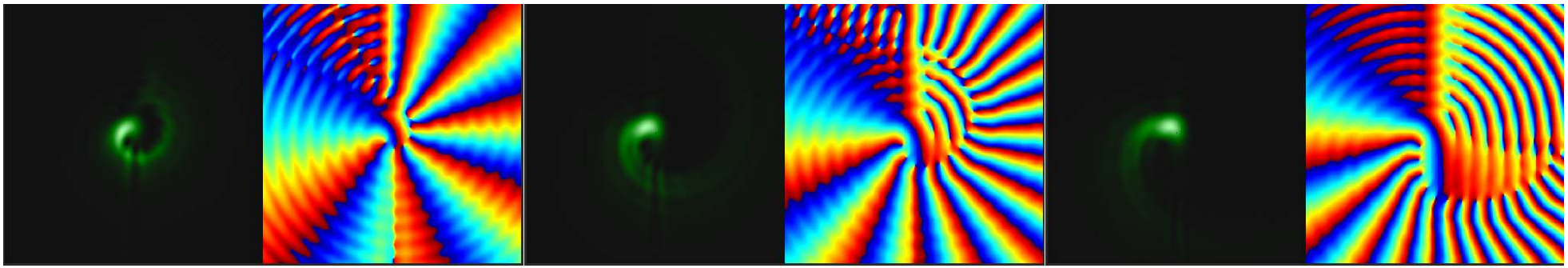
Elements

$\exp[i\varphi^2]$ 

$\exp[i\varphi^{2.5}]$ 

$\exp[i\varphi^3]$ 

Far-field distributions



intensity phase intensity phase intensity phase

Propagation through turbulent media

The propagation of laser beams through the random inhomogeneous medium can be described by an integral, which reflects **the extended Huygens–Fresnel principle**:

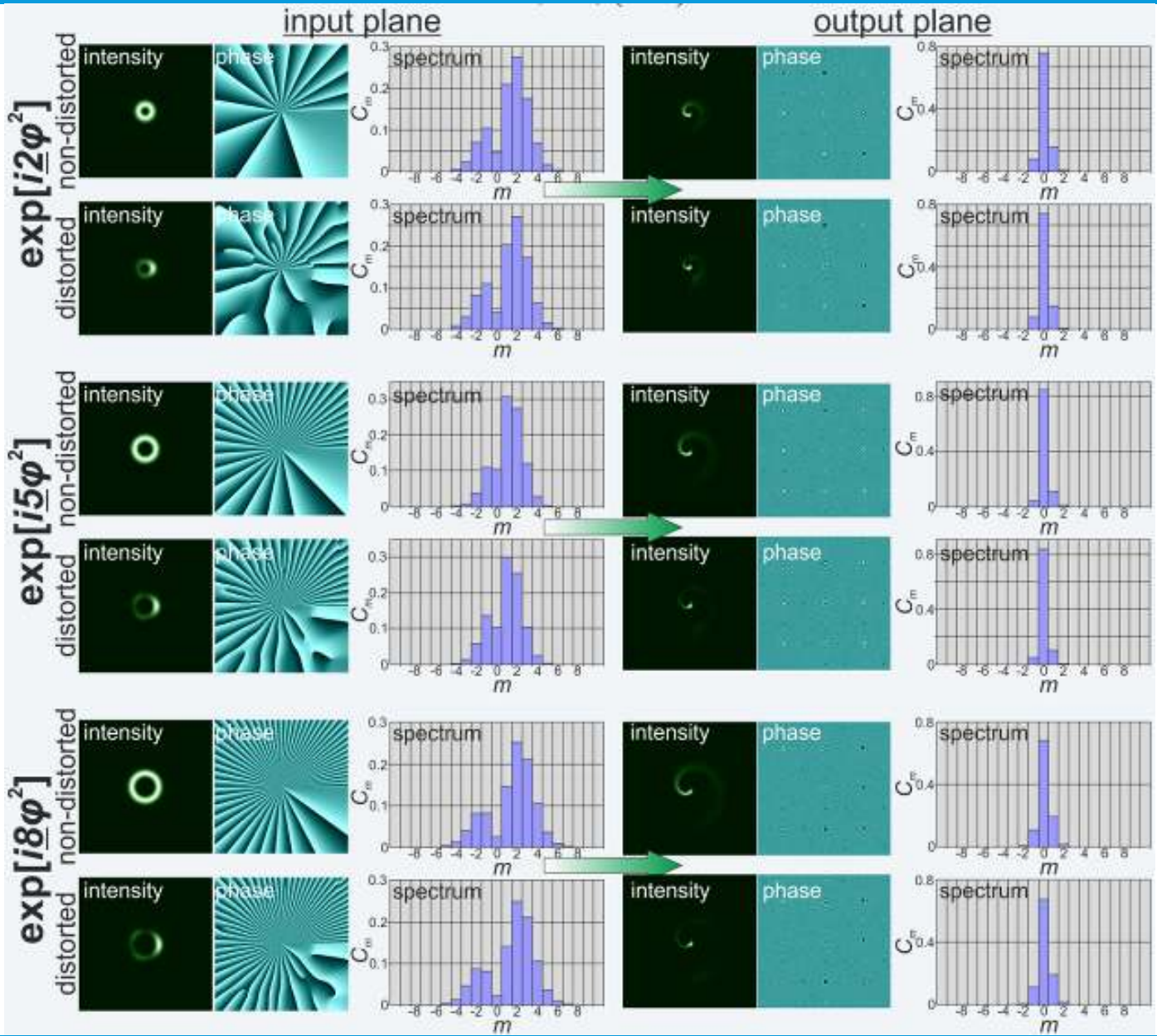
$$E(u,v,z,t) = -\frac{ik}{2\pi z}\exp(ikz)\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E_0(x,y)\exp\left\{\frac{ik}{2z}\left[(x-u)^2+(y-v)^2\right]+\Psi(x,y,u,v,z)-i\omega t\right\}\mathrm{d}x\,\mathrm{d}y,$$

where $E_0(x, y)$ is an input plane field (at $z = 0$),
$E(u, v, z, t)$ is a field located at z-distance away from the input plane,
$\Psi(x, y, u, v, z)$ is a random complex function describing medium irregularities,
ω is a laser radiation frequency,
t is a time moment, and k is the wavenumber.

Input optical signal is defined as follows: $f(r,\varphi) = \exp\left(-\frac{r^2}{\sigma^2}\right)\left(\frac{\sqrt{2}r}{\sigma}\right)^{|\alpha|}\exp\left(i\alpha\varphi^2\right)$

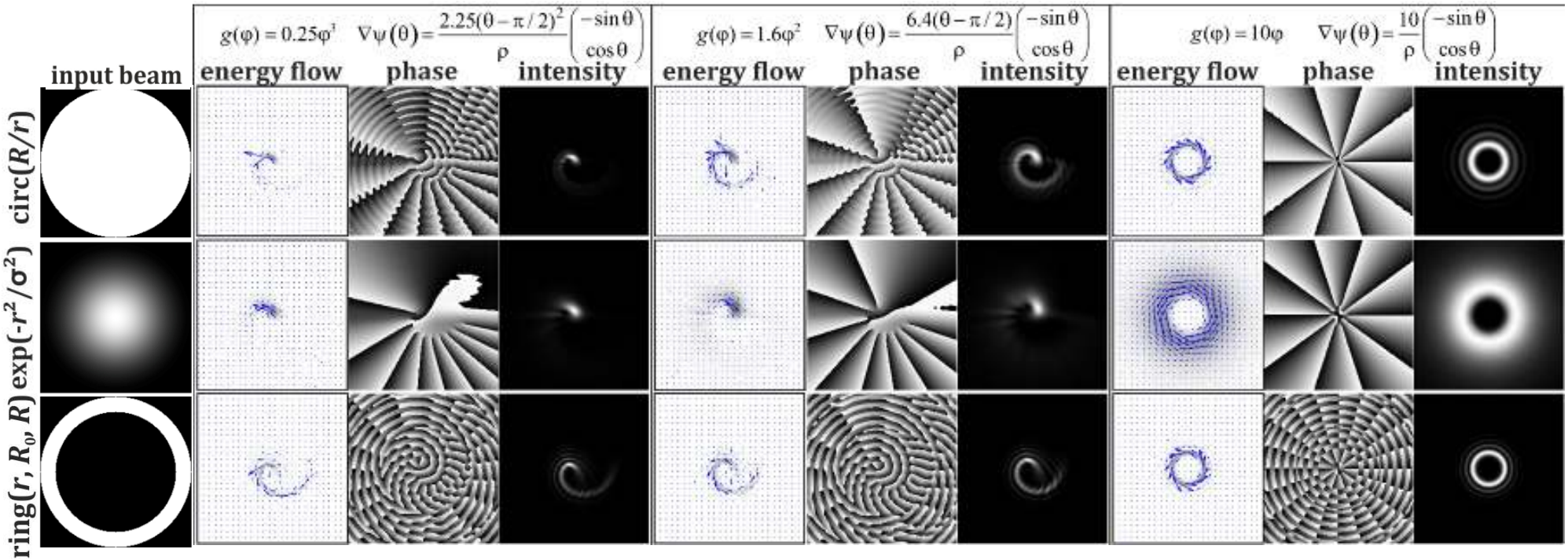
Angular harmonics spectrum is defined as follows: $\sum_m C_m \exp\left(-\frac{r^2}{\sigma^2}\right)\left(\frac{\sqrt{2}r}{\sigma}\right)^{|m|}\exp(im\varphi)$

Propagation through turbulent media



Control of the far-field intensity distribution along the generated light spiral

$$T(r, \varphi) = A(r)\exp[ig(\varphi)]$$

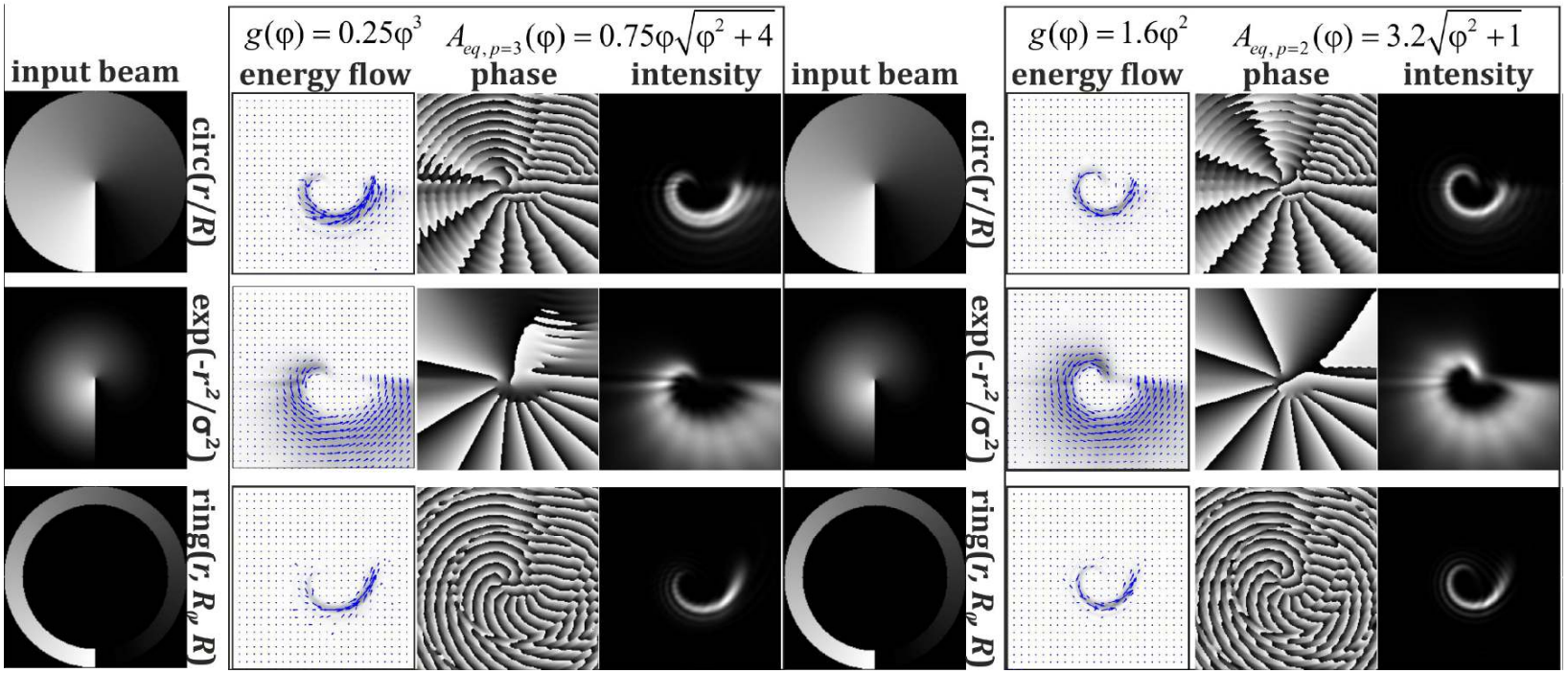


Control of the far-field intensity distribution along the generated light spiral

To compensate for the non-uniformity of the ratio of the area sectors and the length of the curve segments causing the nonuniformity of the intensity distribution along the generated light spiral, the following amplitude function can be used:

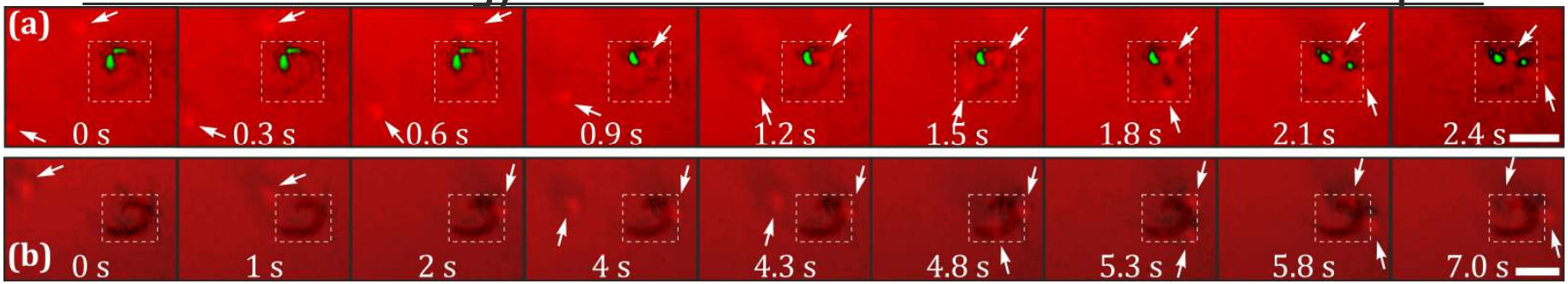
$$A_{eq}(\varphi) = \sqrt{g'^2(\varphi) + g''^2(\varphi)}$$

$$T(r, \varphi) = A(r, \varphi)\exp[ig(\varphi)]$$



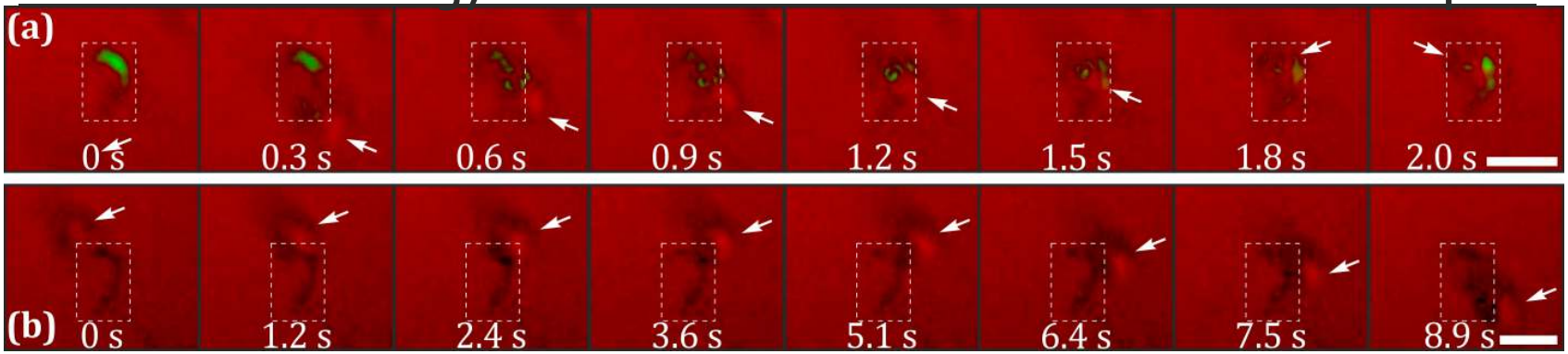
Laser guiding of the particles trapped by different light spirals

The transverse energy flow direction - from "tail" to "head" of the spiral



Movement of 5-μm microspheres trapped by the light spiral generated with the only-phase non-encoded GSPP with the transmission functions $\exp(-0.25\varphi^3)$ (top row), and trapped by the light spiral generated with the amplitude-phase encoded GSPP with the transmission functions $A(r, \varphi)\exp(-0.25\varphi^3)$ (bottom row). The scale bar is 10 μm.

The transverse energy flow direction - from "head" to "tail" of the spiral



Movement of 5-μm microspheres trapped by the light spiral generated with the only-phase non-encoded GSPP with the transmission functions $\exp(0.25\varphi^3)$(top row), and trapped by the light spiral generated with the amplitude-phase encoded GSPP with the transmission functions $A(r, \varphi)\exp(0.25\varphi^3)$ (bottom row). The scale bar is 10 μm.

THANK YOU FOR YOUR ATTENTION!