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Generation of OAM light

Using interferogram and binary hologram

introduction

Orbital angular momentum of light (OAM) is certain type of light beam having angular momentum. Laguerre-Gaussian modes would be one of OAM light.

motivation

OAM light would be projected to some two-dimension materials. By comparing the incident light and reflected light, some optical properties of some two-dimension material could be determined.

Method1:binary hologram

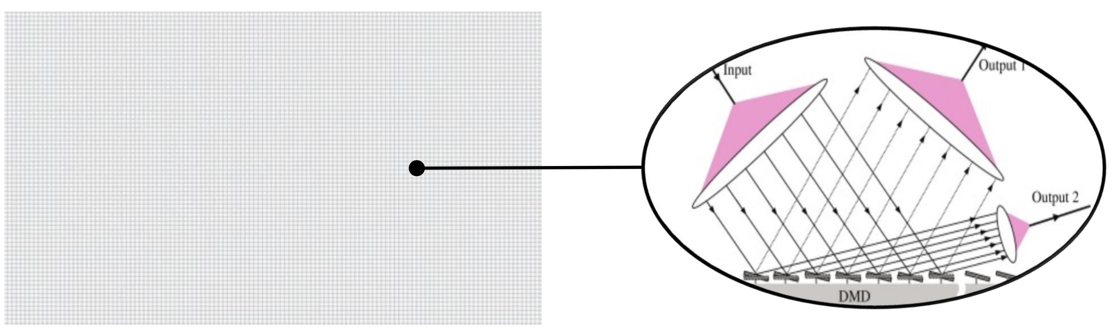

Fig. 1. compact arrangement of mirrors on DMD and local enlarged graph

digital micromirror device (DMD) is made by thousands of micromirror arranged very closely in a plane. Each single micromirror is controlled by electrical signal independently. Which means reflected light toward different directions could be obtained by a specific program. So DMD is perfect for generating a binary hologram.

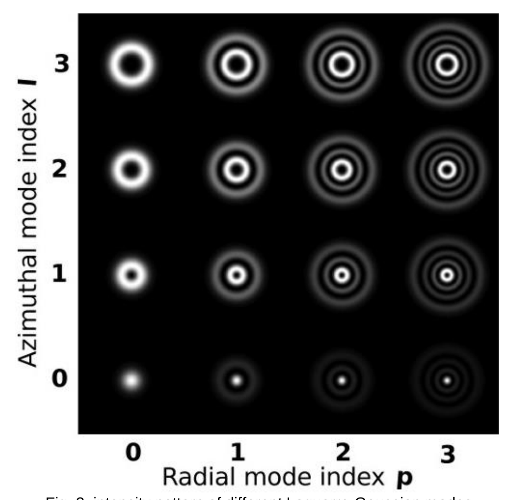

Fig. 2. intensity pattern of different Laguerre-Gaussian modes

Laguerre-Gaussian modes of Gaussian beam is solution of paraxial Helmholtz equation, one of OAM light, that we aiming to produce. Which has following form

$$\mathcal{E}_{p\ell}(r,\phi,z) = A\frac{w_0}{w(z)}e^{i\ell\phi}\left[\frac{r\sqrt{2}}{w(z)}\right]^{|\ell|}L_p^{|\ell|}\left(\frac{2r^2}{w^2(z)}\right)e^{-r^2/w^2(z)}e^{ikr^2/2R(z)}e^{-i[(2p+\ell+1)\tan^{-1}(z/z_0)]}$$

Eq. 1 Laguerre-Gaussian modes of Gaussian beam

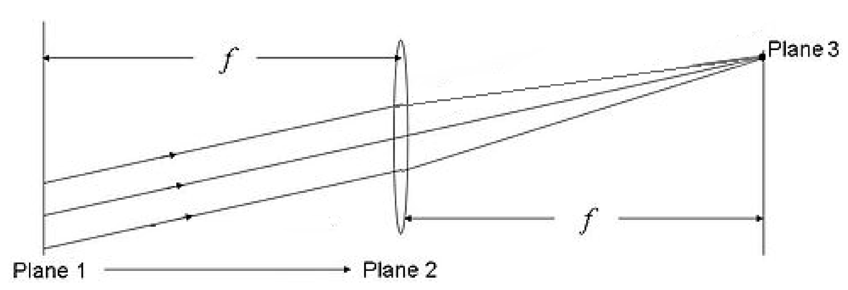

Fig. 3. Fourier transforming property of thin lens

The generation of OAM light is based on some theories in Fourier optics.
Using paraxial approximation, in rectangular coordinate. The scalar light field at plane3 in above diagram could be considered as 2D-Fourier transform of scalar light field at plane1.

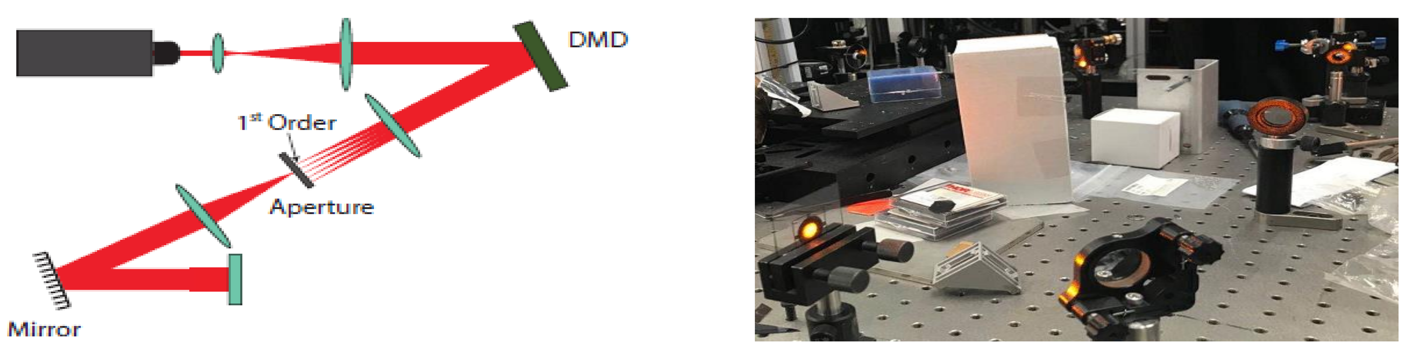

Fig. 4. experimental setup for generating OAM using binary pattern on DMD

By setting up optical apparatuses as the Fig.4. An arbitrary light field could be generated by set DMD appropriately. Then our goal is to find the Corresponding pattern of DMD to generate OAM light.

$$u\left(\vec{P},t\right) = A(\vec{P})\cos\left[2\pi vt + \phi\left(\vec{P}\right)\right]$$

$$u(\vec{P},t) = Re\left\{U(\vec{P})e^{-i2\pi vt}\right\} \qquad U(\vec{P}) = A(\vec{P})e^{-i\phi\left(\vec{P}\right)}$$

Eq. 2. the scalar field for a monochromatic wave

As shown in Eq. 2 the scalar field of any monochromatic wave can be expressed as above form, including Laguerre-Gaussian modes of Gaussian beam by adjusting *A(P)* and ϕ*(P)*.

$$T(x,y) = 1/2 + 1/2\,\mathrm{sgn}(\cos[2\pi x/x_0 + \pi p(x,y)] - \cos[\pi w(x,y)])$$

$$w(x,y) = \frac{1}{\pi}\arcsin[A(x,y)] \qquad p(x,y) = \frac{1}{\pi}\varphi(x,y)$$

Eq. 3. two-dimensional binary hologram to generate arbitrary light field

In Eq. 3 we can see that T(x,y) has periodic, thus such function behave like Fourier series, and the propagation of light from DMD to aperture (in Fig.4) through a thin lens can be regards as Fourier transformation of light field on DMD. If the function have Fourier series feature, after Fourier transformation of it. The result would be three light spots (like Dirac delta function). Then we use computer simulating the process to confirm our prediction


Fig. 5. rescaled light intensity field after one Fourier transformation

If we filter out the first order term ($n = 1\ or\ -1$), blocking the light field at other places. Then performing Fourier transformation once again, the light field we want would be on the plane f (focal length of lens) apart from the second lens (in Fig.4)


Fig. 6. L1 P0 Laguerre-Gaussian modes reconstructed by DMD vs the one generated by computer

Method2:interferogram

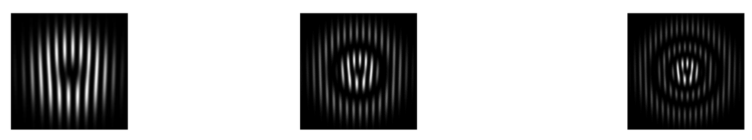
Fig. 7. some computer generated interferograms

We can print certain pattern on transparent film to make interferogram. Use different Grayscale at each pixel to control the light transmittance at that pixel.

$$t(x,y) = 0.5A(x,y)\{1 + \cos[(2\pi x/x_0 - \varphi(x,y)]\}$$

Eq. 4. two-dimensional interferogram to generate arbitrary light field

if we perform Fourier transform on the equation above, we get sum of three terms due to the periodic property of the function. Then filter out +1 or -1 term and block others before doing one more Fourier transformation. Finally we could get the light field we want.


Fig. 7. L1 P0 Laguerre-Gaussian modes reconstructed by interferogram vs the one generated by computer

reference

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