基于电压影响下圆偏振激光束的特性

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摘要: 采用狭缝光束分析仪和偏振仪测量了从铝薄膜表面反射的圆偏振光的光斑位置和偏振特性随外界直流电压变化情况, 理论拟合激光从铝薄膜反射后的光斑位置与直流电流电压的关系。测量和多次拟合结果表明, 当外电压值从 0 变化到 2.5 V 时, 圆偏振激光在 x 轴和 y 轴上的位置分别是从 -45 μm 移动到 -95 μm, 从 35 μm 移动到 75 μm, 而激光束的光学偏振度基本上不变化。

关键词: 圆偏光; 直流电流; 移位; 斯托克斯参数; 光斑
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Characteristics of circularly polarized laser beam based on voltage

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Abstract: Here, optical spot position and the polarization properties of a circularly polarized laser beam reflected from an aluminum film as a function of the external voltage are measured by a slit beam profiler and a polarimeter. The relation between the spot position of laser reflected from aluminum film and the direct current and voltage is theoretically fitted. The measured and polynomial fitting results show that the x- and y-optical position of circularly polarized laser moves from -45 μm to -95 μm and from 35 μm to 75 μm, repsectively, when the external DC value changes from 0 to 2.5 V, while the degree optical polarization of the laser beam basically do not change.

Keywords: circularly polarized laser beam; direct current; displacement; Stokes parameter; optical spot
Introduction

Garnet is widely researched and used because of its excellent optical, electrical and magnetic properties\cite{1,4}. The polarization plane of a linearly polarized laser beam can be rotated through garnet or reflected from the garnet surface. The garnet surface is linearly proportional to the magnetic field in the laser propagation direction, known as the Faraday effect and the Kerr effect. In our previous work, the interfaces of garnet and graphite can be generated as a function of external direct current (DC) voltage, and the splitting effect is investigated\cite{5}. The changes in optical properties of a circularly polarized laser beam attribute to external conditions. In this paper, the optical properties of a circularly polarization laser beam reflects from a aluminum film, one weakly absorbing media, are researched. The optical position and optical polarization properties of the laser as a function of external DC voltage are researched by slit beam profiler and polarimeter. The optical shift of the circularly polarized laser beam and polarization properties imply a good approach for the design and analysis of optical devices.

1 Experimental principle

Figure 1 is a schematic diagram of the experimental setup. A continuously laser beam with a wavelength of 1 550 nm, with a intensity of 18 mW, goes through Thorlabs mounted zero order compound WPQ10-1550 wave plate, then turns into circularly polarized laser. The circularly polarized laser beam goes into a prism vertically, and reflects from an aluminum film on the oblique side of the prism. After that the circularly polarized laser beam arrives at the Thorlabs CCM1-BS015 non polarized beam splitter. The laser beam is splitted into two optical laser beams, one beam arrives at the Thorlabs BP209-IR slit beam profiler and another one arrives at the Thorlabs PAX5710 polarimeter. Garnet (Granopt Co., Ltd.) GLB1550.2 mm×2 mm×0.39 mm and graphite (10 mm×10 mm×0.3 mm) are fixed under the aluminum film of the prism. A pair of copper electrodes are in contact with graphite at a distance of 1 mm. The polarization characteristics of the laser beam are measured by applying a DC voltage to the copper electrode. In order to character the optical spot conveniently, it is assumed that, the z axis is in the perpendicular direction of the garnet, the y axis is in the plane of the garnet and along the propagation direction of the laser beam and the y axis is perpendicular to the direction of the propagation direction of the laser beam. The optical spot energy distribution of the circularly polarized laser beam are measured by Thorlabs BP209-IR slit beam profiler.

![Fig. 1 Schematic of the experimental setup](image-url)
2 The change of optical position

To evaluate the optical spot position of the laser beam, which reflects from the aluminum film on the prism, the optical spot position and optical spot energy distribution of the circularly polarized laser beams as a function of external DC must be measured. In this experiment, the position of the maximum energy of the circularly polarization laser beam is used to describe the position of the optical spot, as the initial state of 2-dimensional and 3-dimensional optical spot energy show Gaussian distribution shown in Fig. 2.

![2D image](image1.png) ![3D image](image2.png)

Fig. 2 2-dimensional and 3-dimensional optical spot energy distribution

As the optical spot position can be described by the maximum energy of the circularly polarized laser beam, Figure 3 shows the measuring and polynomial fit of the optical spot position when the external DC value changes from 0 to 2.5 V. The x position of the circularly laser beam moves from −45 μm to −95 μm when the external DC voltage increases from 0 to 2.5 V as shown in Fig. 3(a). The polynomial fit formula of the x position of the circularly laser beam can be described by equation (1). $A_1$, $B_{11}$, $B_{12}$ are constant parameters and the parameter values are shown in table 1.

$$y_1 = A_1 + B_{11} \times x + B_{12} \times x^2$$  \hspace{1cm} (1)

The y position of the circularly laser beam moves from 35 μm to 75 μm when the external DC voltage increases from 0 to 2.5 V as shown in Fig. 3(b). The polynomial fit of the y position of the circularly laser beam can also be described by equation (2). $A_2$, $B_{21}$, $B_{22}$ are constant parameters and the parameter values are shown in table 2.

$$y_2 = A_2 + B_{21} \times x + B_{22} \times x^2$$  \hspace{1cm} (2)

![x position](image3.png) ![y position](image4.png)

Fig. 3 Measuring and polynomial fit of optical position of the circularly polarized laser beam as a function of external DC voltage
Tab. 1  The parameter values of the polynomial fit formula of 
x position

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1$</td>
<td>$-49.60520$</td>
<td>$3.39350$</td>
</tr>
<tr>
<td>$B_{11}$</td>
<td>$2.59831$</td>
<td>$6.14903$</td>
</tr>
<tr>
<td>$B_{12}$</td>
<td>$-9.01907$</td>
<td>$2.38979$</td>
</tr>
</tbody>
</table>

Tab. 2  The parameter values of the polynomial fit formula of 
y position

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_2$</td>
<td>$38.77348$</td>
<td>$5.66513$</td>
</tr>
<tr>
<td>$B_{21}$</td>
<td>$-0.86055$</td>
<td>$10.26523$</td>
</tr>
<tr>
<td>$B_{22}$</td>
<td>$6.91859$</td>
<td>$3.98953$</td>
</tr>
</tbody>
</table>

From table 1 and table 2, the value of $B_{11}$ is more than zero, and the value of $B_{21}$ is less than zero, so it can be seen that the $x$ position of the circularly polarized laser beam moves toward to the $x$ negative axis, while the $y$ position of the circularly polarized laser beam moves toward to the $y$ positive axis. So the optical spot position of the circularly polarized laser beam can be controlled by external DC voltage, as shown in Fig. 3.

Figure 4 shows the optical energy distribution of the circularly polarized laser beam at different external voltage. The optical energy intensity in the $x$ position increases from 63.7% to 76.8%, when the voltage increases from 0 V to 2.5 V, while the optical energy intensity in the $y$ position decreases from 50% to 46.6%. So, the optical energy intensity in the $x$ position and $y$ position have different change trend when the external voltage change.

![Fig. 4  Optical energy distribution of the circularly polarized laser beam at different external voltage](image)

3  Polarization properties of the circularly laser beams

The optical spot positions and the optical energy in the $x$ position and the $y$ position of the circularly polarized laser beam show different trends when the external DC voltage value increases from 0 V to 2.5 V. The optical polarization properties of the circularly polarized laser beam also be researched as a function of the external DC voltage value. The degree of polarization may change on propagation precessure in free space and dependent on the spatial location. Figure 5 illustrates the relationship between the Stokes parameter $S_0, S_1, S_2, S_3, DOP$ of the circularly polarized laser beam and the external DC voltage value. The Stokes parameters of $S_1, S_2,$ and $S_3$ can describe all the polarization states of electromagnetic waves, $S_0$ is the intensity difference between horizontally polarized laser beam and vertically polarized laser beam, $S_2$ is the intensity difference between $45^\circ$ polarized laser beam and $-45^\circ$ polarized laser beam, and $S_3$ is the intensity difference between right-circularly polarized laser beam and left-circularly polarized laser beam.
and left-circularly polarized laser beam. The degree of linear polarization (DOLP), degree of circular polarization (DOCP) and degree of polarization can be described by Stokes parameters:

\[
DOLP = \frac{\sqrt{S_1^2 + S_2^2}}{S_0} \tag{3}
\]

\[
DOCP = \frac{1}{S_0} \tag{4}
\]

\[
DOP = \frac{\sqrt{S_1^2 + S_2^2 + S_3^2}}{S_0} \tag{5}
\]

The Stokes parameters \(S_0\) of the circularly polarized laser beam is 0, 6, and basically unchanged when the external DC is less than 1.0 V, then the \(S_1\) changes from 0 to 0, 6 when the external DC voltage change from 1.0 V to 2.5 V. The Stokes parameters \(S_2\) of the circularly polarized laser beam changes from 0 to −0, 9, when the external DC voltage change from 0 V to 1.5 V, while the variation range of \(S_2\) is small. The Stokes parameters \(S_3\) of the circularly polarized laser beam decreases from 0, 8 to 0, when the external DC voltage change from 0 V to 2.5 V. The \(DOLP, DOCP\) and \(DOP\) of the circularly polarized laser beam can be got from equations (3), (4), (5). The \(DOLP\) and \(DOCP\) can be changed, while the \(DOP\) basically unchanged, when the external DC voltage changes from 0 V to 2.5 V.

![Graphs of Stokes parameters and degree optical polarization](image)

Fig. 5  Polarization properties of the circularly laser beams reflect from aluminum film on the prism as a function of DC voltage

4  Conclusion

In conclusion, optical spot position and the polarization properties of circularly polarized laser beam reflected from an aluminum film as a function of the external direct current voltage are measured by a slit
beam profiler and a polarimeter. The measured and polynomial fit results show that the $x$ and $y$ optical position of circularly polarized laser moves from $-45 \mu m$ to $-95 \mu m$ and moves from $35 \mu m$ to $75 \mu m$. The optical energy intensity in the $x$ position and $y$ position have different change trend when the external DC value changes from 0 V to 2.5 V. The Stokes parameter of $S_1$, $S_2$, and $S_3$ can be changed, while the DOP of the laser beam basically do not change. The optical shift of the circularly polarized laser beam and polarization properties imply a good approach for the design and analysis of optical devices.

参考文献:


