Chirality is an essential consideration in the field of life sciences and pharmaceutical industry because most biomolecules and pharmaceuticals are chiral, and optical rotation measurement is a simple and efficient means for identification, purity test and content detection of chiral materials. However, there are some drawbacks in existing methods, such as small measurement range, non-real-time performance, low measurement accuracy and resolution. This paper presents a novel system to implement optical rotation measurement, and pixelated polarization cameras and Stokes parameters are employed in the system. The polarization information of linearly polarized incident light can be recorded and extracted by a pixelated polarization camera and Stokes parameters respectively. Experiments demonstrate that the proposed system has the necessary advantages for optical rotation measurement, such as real time, wide range (−90° to +90'), high accuracy (1×10⁻⁴°) and high resolution (±6×10⁻⁶°). Thus, this measurement system has great practical prospects in the hospital clinical diagnosis, chemical research, sugar production and pharmaceutical industry.

1. Introduction

Optical activity is an important feature of the chiral molecule, which manifests itself as rotation of polarization plane of linearly polarized light that travels through the chiral molecule [1]. The optical rotation (OR) is a physical quantity for evaluating the optical activity, which is essentially a rotation angle related to chiral molecules, and in direct proportion to the solution concentration and the light path length. Almost all organic molecules that constitute the living organisms and the majority of drug compounds for human use are chiral [2,3]. However, the chiral drugs have two enantiomers (levorotary and dextrorotary) which exhibit significantly different effects on biological activity, such as pharmacology, toxicology, metabolism, and the enantiomers are difficult to identify because of the identical chemical and physical properties. The simple and effective way to distinguish these two enantiomers is to measure the opposite rotation directions based on OR. In addition, the solution concentration and the specific rotation of the chiral molecules are accurately, instantly and conveniently obtained during the measurement, which is very useful in drug identification, impurity inspection and content determination. Hence, OR measurement has been widely used in many research fields, such as hospital clinical diagnosis [4,5], chemical research [6], sugar production and pharmaceutical industry [7]. On that basis, a more accurate polarimeter may improve the safety of the drugs and reduce the development costs, which could be extremely valuable in the purity measurement of drugs with toxic impurities [8] and the content measurement of precious spices and essences.

According to the optical path structure, the main methods for OR measurement can be mainly grouped into three categories: 1. Polarizer-Analyzer, 2. Polarizer-Faraday Modulator-Analyzer and 3. Laser-Phase Modulator-Analyzer. In the first category, method of symmetrical angles is a classical method that locates the extinction point based on the sinusoidal curve of light intensity after the detector [9]. And a method for improving the accuracy of OR measurements by curve-fitting is presented, which achieved an accuracy of 0.001° [10]. In the second category, a synchronous polarimeter with linear response is established
by low-pass filtering the product of the photodetector output and the current through the Faraday Modulator [11]. The scheme achieves a high accuracy $(1.3 \times 10^{-4})$ while the measurement range is very small (only about $0–0.08^\circ$). In another scheme, the Faraday Modulator is used as an oscillation generator to rotate the polarization plane in a range of angle that includes the extinction direction of the analyzer. And the range of the rotation angle on both sides of the extinction direction is not the same. Thus, the waveform of the light intensity after the analyzer is the linking of two different sinusoidal signals, and then the OR is obtained by measuring the signal width [12]. This scheme is unable to implement real time measurement, and the measurement range is only the maximum Faraday modulation angle $(2.3^\circ)$. In the third category, a self-referenced polarimeter generates two kinds of phase retardation angles by an electro-optic modulator, and two intensity signals (double OR and zeros) in the photodetector are created when the linearly polarized light passes through the optically active solution for the second time [13]. This scheme achieved high-resolution $(\times 2 \times 10^{-5})$, but the accuracy is not so high because of the systematic errors caused by the complex photoelectric structures and the formula approximation. Another polarimeter amplifies the OR signal by the phase difference of the reference path and the measurement path [14], and the resolution is increased from $1 \times 10^{-4}$ to $3.63 \times 10^{-5}$ by the improved phase difference polarimetry [15]. However, the rotation stage (resolution is 0.01°) limits the accuracy and the real-time performance which is an essential capability for high-pressure liquid chromatography systems [13]. In summary, the polarization plane of linearly polarized light needs to be rotated or detected by an additional magneto-optic component or a rotating electromechanical component respectively, or the phase of the light needs to be modulated by an electro-optic component (phase modulator) in existing methods, which will lead to the following problems: (a) the scheme in the first category has the deficiencies of non-real-time performance and relatively low measurement accuracy $(0.001^\circ)$ due to the motorized rotation stage; (b) the scheme in the second category has a quite limited measurement range $(-2.3$ to $+2.3^\circ)$ and a complex photoelectric structure because of the Faraday modulator; (c) the scheme in the third category has limited accuracy because of the complex photoelectric structures containing laser interferometer light path and the phase modulation. Hence, scientists have been exploring a method of measuring the OR, which could increase the real-time measurement range, accuracy and resolution.

In recent years, pixelated micro-polarizer array (PMA) has achieved considerable development due to its great utilization potential for polarized light detection [16–21]. And electron beam lithography has promoted the development because of its better resolution. In our previous work, a PMA fabricated by electron beam lithography was integrated into a CCD sensor for the real-time visible imaging polarimetry [22]. And in our other works, the real-time phase measurement for some special optical fields has been implemented based on the integrated pixelated polarization camera (PPC) [23–25]. The capability of the PPC to detect the polarization information of polarized light inspired us to design a completely novel system for OR measurement, which has the potential to overcome the deficiencies in the three categories.

In this paper, a pixelated-polarization-camera-based polarimetry system (PPCBPS) is proposed, which is expected to simultaneously achieve real-time, wide-range, high-accuracy and high-resolution measurement for OR. Moreover, the concise optical path with a PPC is successfully established and the algorithm based on the Stokes parameters is presented. The experiments measuring the OR are carried out, which would verify the feasibility and the reliability of the proposed system.
2. Principles

2.1. The pixelated polarization camera

For PPC, high extinction ratio means low noise and less cross-talk of adjacent units (Fig. 1(a)). Thus, developing a PPC with a high extinction ratio generally facilitates high measurement accuracy of PPCBPS. The developed PPC is composed of a CCD (SONY ICX285AL, monochrome, 1360 × 1024, 6.45 μm × 6.45 μm pitch, 12 - bits) and a pixelated micro-polarizer array (PMA, 1000 × 1000), and each pixel unit of the CCD is aligned with the unit of the PMA (Fig. 1(b)). The aluminum PMA was fabricated on a light-transmissive glass substrate by electron beam lithography (Fig. 1(b) and (c)) [22]. The pitches of the PMA units are 6.45 μm × 6.45 μm, surrounding the units is a 1 μm wide opaque area to reduce cross-talk of adjacent units. The unit of the PMA is a blocky metal nano-grating, which is composed of periodic and parallel metallic wires. The cross section of the grating is rectangular and the period, depth and duty ratio are 140 nm, 100 nm, and 0.5, respectively. When the metal grating period is smaller than the light wavelength, the grating acts as a linear polarizer due to the polarization and non-diffraction effect, and the cross polarized light passes through the metallic nanowires and the parallel polarized light is blocked [26].

The integration process is improved by integrating the PPC with a six-axis micromanipulator. At the wavelength of 589.44 nm (For the yellow light of spectrally purified sodium, the wavelength is taken as the mean optical centre of gravity.), the average extinction ratio of the PPC we developed reaches 31 (Fig. 1(d)). Under the same measurement conditions, it is higher than the extinction ratio (average 21) of a commercial camera 4D-M (4D Technology, PolarCam Snapshot Micropolarizer Cameras). In the PPC, each adjacent 2 × 2 pixel areas constitutes a super-pixel unit (SPU), and the polarization directions of the SPU are 0°, 45°, 90° and 135° respectively. Hence, the SPUs will simultaneously record the light intensity and the polarization information when the linearly polarized incident light irradiates on the CCD.

2.2. The optical path

When a beam of linearly polarized light passes through the optically active substance, the polarization plane is rotated because of the specific spatial configuration of chiral molecules [1]. In order to measure the rotation angle while eliminating the deficiencies in existing methods, the PPCBPS based on the PPC was established (Fig. 2). The wavelength of the laser (Changchun New Industries Optoelectronics Technology Co., Ltd. MLL-FN-532-1.5 W) is 532 nm, and the stable laser beam is then transformed into a non-polarizing point light source after passing through an integrating sphere (NEWPORT 3-Port Integrating Sphere, 4 in.) and a pinhole. After being collimated and polarized by the Lens and the Polarizer, the linearly polarized light propagates into the polariscope tube (length L). If the substance in the polariscope tube is optically active, the polarization plane of the linearly polarized light will be rotated α degrees. Finally, the linearly polarized light S_{in} after the polariscope tube was recorded by the PPC.

In this measurement system, real-time, wide-range, high-accuracy and high-resolution OR measurement is possible, because the PPC eliminates the requirement for additional components in existing methods, such as magneto-optic components, the rotating electro-mechanical components and the electro-optic components, etc. And therefore, PPCBPS has a more concise structure.

2.3. The algorithm

In order to extract the OR from the image recorded by the PPC, we proposed a novel algorithm. The polarization states of a linearly polarized incident light after a polarizer can be expressed as

$$\vec{S}_{in} = M_f \vec{S}_m.$$  \hspace{1cm} (1)

Where $\vec{S}_{in} \in \mathbb{R}^{4 \times 1}$ and $\vec{S}_m \in \mathbb{R}^{4 \times 1}$ are the representation of Stokes parameters of the linearly polarized emergent light and the linearly polarized incident light, respectively (Fig. 3(a)). And $M_f \in \mathbb{R}^{4 \times 4}$ represents the Mueller matrix of the polarizer [27],

$$M_f = \frac{1}{2} \begin{bmatrix}
(p_x^2 + p_y^2) & (p_x^2 - p_y^2)x_{2p} & y_{2p} & 0 \\
(p_x^2 - p_y^2)x_{2p} & (p_x^2 + p_y^2)x_{2p}^2 & y_{2p} & 0 \\
y_{2p} & 0 & 2p_xp_y & 0 \\
0 & 0 & 0 & 2p_xp_y
\end{bmatrix} + \frac{1}{2}(p_x - p_y)x_{2p}^2.$$  \hspace{1cm} (2)

In the formula above, $p_x$ and $p_y$ are the transmission coefficients of the electric field amplitude of the polarizer along the x axis and the y axis respectively, and $x_{2p}$, $y_{2p}$, $x_{2p}^2$ and $y_{2p}^2$ are the simplified form of $\sin (2p\alpha)$, $\sin (4p\alpha)$ and $\cos (2p\alpha)$, respectively. And $\alpha$ is the angle between the polarization direction of the polarizer and the x axis.

The single pixel gray value of the image recorded by the PPC can be expressed as follows,

$$I_{cm} = g(1000) \cdot \vec{S}_{in} + d = g(1000) \cdot M_f \vec{S}_m + d = \vec{A}_f \cdot \vec{S}_m + d.$$  \hspace{1cm} (3)

Where $g$ and $d$ is the gain and dark offset of the pixel respectively. The vector $\begin{bmatrix} 1000 \end{bmatrix}$ acts as a selection of the light intensity of the emergent light, and $\vec{A}_f \in \mathbb{R}^{4 \times 1}$ is the combination of the gain and the first row of
Here, $A \in \mathbb{R}^{4 \times 4}$ and $d \in \mathbb{R}^{4 \times 1}$ is consist of $\vec{A}_{i}$ and $d_i$, respectively, and $i$ represents the pixel units with different polarization directions in the SPU, which can be $0^\circ$, $45^\circ$, $90^\circ$, $135^\circ$.

In order to obtain the matrix $A$ and the dark offset vector $d$, the PPC must be calibrated and the performance inhomogeneity of different pixel units are eliminated in the calibration [27]. The experimental device for the calibration is the same as Fig. 2 when the polarscope tube is filled with deionized water. The dark offset vector $d$ can be obtained when the sodium lamp is turned off, and the four gray value curves recorded by SPU are obtained when the polarization plane of linearly polarized light is rotated by a motorized rotation stage (THOR-LABS PRM1Z8) with $5^\circ$ interval (Fig. 3(c)). According to Malus’ law, the four curves are fitted with four sine curves respectively, and the fitting curve equations are obtained,

\[
I_{m,i} = a_i + b_i \cos(2\phi) + c_i \sin(2\phi).
\]  

When the incident light is linearly polarized, Eq. (4) can be rewritten as follows,

\[
I_{m,i} = \vec{A}_{f,i} \cdot \vec{S}_m + d_i = \vec{A}_{f,i} \begin{bmatrix} S_0 \\ S_0 \cos(2\phi) \\ 0 \\ S_0 \sin(2\phi) \end{bmatrix} + d_i.
\]  

Here, $\phi$ represents the angle between the polarization direction of the linearly polarized incident light and the polarization direction of the $0^\circ$ pixel unit of the SPU, and $a_i, b_i$, and $c_i$ are the constants calculated by the fitting. And $S_0$ is the light intensity of the linearly polarized incident light.

Hence, $A$ can be calculated by the combination of Eqs. (5) and (6),

\[
A = \frac{1}{S_0} \begin{bmatrix} a_0 - d_0 & b_0 & c_0 & 0 \\ a_{45} - d_{45} & b_{45} & c_{45} & 0 \\ a_{90} - d_{90} & b_{90} & c_{90} & 0 \\ a_{135} - d_{135} & b_{135} & c_{135} & 0 \end{bmatrix}.
\]  

In the OR measurement, $A$ is only needed to be measured once because it is the constant characteristic matrix associated with the polarization properties and the gain of the SPU.

From this, the incident light can be calculated in real time,

\[
\vec{S}_m = A^{-1}(\vec{I}_m - d).
\]  

And then, $\phi$ can be expressed as follows,

\[
\phi = \frac{1}{2} \arctan\left(\frac{S_{\phi,2}}{S_{\phi,1}}\right).
\]  

Here, $S_{\phi,1}$ and $S_{\phi,2}$ are the second element and the third element of $\vec{S}_m$ respectively. Finally, the OR can be calculated in real time,

\[
\alpha = \phi_i - \phi_e.
\]  

In the formula above, $\phi_i$ and $\phi_e$ denote the polarization direction of linearly polarized incident light in the presence of optically active solutions and deionized water respectively, and $\phi_0$ is a constant in the actual practice. In fact, the number of calculated OR is $500 \times 500$ which corresponds to the number of SPU because the image size of the PPC is $1000 \times 1000$ pixels. And the final OR is taken as the average of OR calculated by all SPU.
3. Experiment and analysis

3.1. The measurement errors

In order to easily obtain the measurement accuracy and resolution of the pixelated-polarization-camera-based polarimetry system (PPCBPS), the rotation of the polarizer controlled by the motorized rotation stage (THORLABS PRM1Z8, achievable incremental motion (min): 25 arcsec, max percentage accuracy: 0.08%, home location accuracy: ± 0.2°) is used to simulate the rotation of the polarization plane of linearly polarized light. This simulation makes it simple and accurate to obtain and change the OR. A polarization direction of the linearly polarized light is recorded by the PPC (monochrome, 1000 × 1000, 12-bit) when the polarizer is fixed at an angle (simulated OR, \( \alpha \)), and about 500 × 500 polarization direction data are calculated by the proposed algorithm and the corresponding light intensities in the SPUs (Fig. 4(a)). The average of the \( 2.5 \times 10^5 \) polarization direction data is the final measured polarization direction (Fig. 4(b)). The measured ORs are the difference between the real-time measured polarization directions and the initial measured polarization direction, and a series of ORs are measured when the polarizer (simulating the OR) is continuously rotated from \(-90^\circ\) to \(90^\circ\) at \(5^\circ\) intervals (Fig. 4(c)). At the same time, there is a standard line that represents the measured OR is equal to the simulated OR. Hence, the measurement errors are calculated by the difference between the measured ORs and the standard line (Fig. 4(d)).

Due to the statistical laws, two different normal distribution fitting of the polarization direction data can be easily found through the histogram, as shown in Fig. 4(a) and (b). One of the normal distribution fitting is consist of the desired data, which can be measured when a normal linearly polarized light beam is projected onto the PPC. And the expectation of the desired normal distribution deviates from zero because of the home location accuracy of the motorized rotation stage, which could be eliminated in calculating the ORs. Another normal distribution fitting is made up of undesired data, and it can be observed when the diffraction light spots caused by the dusts on the polarizer are projected onto the PPC. The projection of the diffraction light spots will affect the normal light intensity, and the projection area will vary with the rotation of the polarizer, which results in the regular variation of the measurement errors (Fig. 4(d)). Hence, the measurement errors are mainly a gross error caused by the dusts on the polarizer, and it could be avoided by using clean polarizer and dustless environment. Besides, the gross error is almost constant when the rotation angle of the polarizer is within a very small range (0–0.04°) which is beyond the measurement range in blood glucose monitoring. At the same time, the random error is estimated to be incredibly tiny because the measured polarization direction is the average of \(2.5 \times 10^5\) spatial repetition measurements. Therefore, the systematic errors could be the main source of the measurement error in the small range, which can be explained by the inequality between the measured OR and the simulated OR when the polarizer is deflected, as shown in Fig. 5. In general, the systematic errors vary linearly over the small range, and a rough equation of the systematic errors is obtained by the linear fitting of the measurement error (Fig. 4(d), low right corner),

\[
s_{\text{system}} = 0.01305 \cdot \alpha. \tag{11}\]

Here, the polarizer is rotated from 0° by a minimal incremental motion (25 arcsec) to eliminate the rotation angle errors caused by the gear clearance of the motorized rotation stage, and the simulated OR and the measured OR are subsequently recalibration to 0°.

3.2. The measurement accuracy and resolution

To obtain the measurement accuracy and resolution of PPCBPS, a series of small ORs are measured when the ORs are simulated by the rotated polarizer. After cleaned by a simple dust blower, the polarizer is first rotated twice from 0° at about 0.0069° interval (THORLABS PRM1Z8, achievable incremental motion (min): 25 arcsec, max percentage accuracy: 0.08%) to eliminate the rotation angle errors caused by the gear clearance of the motorized rotation stage, and the simulated OR and the measured OR are subsequently recalibration to 0°.
Fig. 5. The schematic diagram of systematic errors.

Fig. 6. The optical rotation measured by PPCBPS. (a) The measured polarization direction data are obtained by the corresponding SPUs, when the polarization direction of the polarizer is 0°. (b) The histogram of the measured polarization direction data. The average of the polarization direction data is the final measured polarization direction. (c) The measured optical rotations are linearly fitted, and compensated by the systematic errors (Eq. (11)). (d) The measured systematic errors and the compensated systematic errors. (e) The measurement accuracy. (f) The measurement resolution.
continues to be rotated at the same interval until four different polarization camera is set. As the simulated ORs, the four polarization directions are recalibrated to 0°, 0.0068°, 0.0135° and 0.0203°, and the measured polarization directions can be calculated by the proposed algorithm and the recorded image (Fig. 6(a) and (b)). Compared with Fig. 4(b), the histogram of the measured polarization directions after dedusting is almost normally distributed. The 2.5 × 10⁵ spatial repetitive measurements reduce the random errors to incredibly tiny magnitude, and the measurement sensitivity of the polarization direction is almost unlimited because the final measured polarization direction is the average of the so many repetition measurements. Corresponding to the simulated ORs, the measured ORs are obtained by subtracting the initial measured polarization direction (α = 0°) from the real-time measured polarization directions (Fig. 6(d)). According to Eq. (11), the measured ORs could be compensated by the systematic errors equation (Fig. 6(d)). However, the compensated systematic errors are not equal to the measured systematic errors which is obtained by the difference between the fitting line and the standard line (the measured OR = the simulated OR), because the systematic errors equation is just a rough estimate. The difference between the compensated ORs and the standard line is the measurement accuracy (Fig. 6(e)). Due to the linear relation between the simulated ORs and the measured ORs, the linear fit residual of the measured ORs is taken as the measurement resolution (Fig. 4(f)). The measurement accuracy and resolution is about −1 × 10⁻⁴ and ±6 × 10⁻⁵ respectively, it is higher than the resolution in the cited literature (3.63 × 10⁻⁵) [11,15]. Moreover, the measurement accuracy could be further improved with a more accurate systematic error equation which could be obtained by more elaborate calibration measurements. And the accuracy (0.08%) of the rotation angle of the motorized rotation stage also limits the measurement accuracy and resolution, which indicates that the actual accuracy and resolution of PPCBPS is much higher than the measurement value.

3.3. Optical rotation measurement of sucrose solution

To verify the practicability of PPCBPS, an experiment was performed to measure the OR of sucrose solution. To compare with the commercial polarimeter (Anton Paar MCP 500, 589.44 nm, accuracy 2 × 10⁻⁵, resolution 1 × 10⁻⁵, response time 12 s) directly, the laser of the PPCBPS is replaced by a sodium light (589.44 nm). Meantime, the relationship between optical rotation α and solution concentration C can be express as follows,

\[ \alpha = \frac{1}{C} \alpha \frac{1}{C} \lambda C. \]  

(12)

Here, \( \alpha \) represents the specific rotation which is related to the temperature \( t \) and the wavelength \( \lambda \). Different concentrations of a set of sucrose solutions is prepared using volumetric flack at about 20 °C, and the sample mean and the standard deviation of the optical rotation of the three repeated measurements for one sucrose solution are listed in Table 1. PPCBPS works at about 21 °C, and the length of polariscope tube is 50.8 mm. Meanwhile, the environment temperature of the MCP 500 is 20 °C, it is adjusted by a temperature control system, and the length of the polariscope tube is 100 mm.

<table>
<thead>
<tr>
<th>Concentration (g/100 mL)</th>
<th>MCP 500</th>
<th>PPCBPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \alpha (°) )</td>
<td>( \alpha (°) )</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0.0022</td>
</tr>
<tr>
<td>0.0397</td>
<td>0.0205</td>
<td>0.0007</td>
</tr>
<tr>
<td>0.3441</td>
<td>0.2185</td>
<td>0.0004</td>
</tr>
<tr>
<td>0.7159</td>
<td>0.4818</td>
<td>0.0018</td>
</tr>
<tr>
<td>1.0958</td>
<td>0.6992</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

Each OR corresponding to the different concentrations is measured by PPCBPS and MCP 500 respectively. The polarization direction is recorded by the pixelated polarization camera (PPC) in real time, and 500 × 500 data are calculated by the proposed algorithm (Fig. 7(a)). The sample mean of the three repetitive measured polarization direction is taken as the final measured polarization direction (Fig. 7(b)), and the measured OR is the difference between the real-time measured polarization direction and the initial measured polarization direction (\( \alpha = 0° \) i.e. \( C = 0 \text{ g/100 mL} \)) (Fig. 7(c)). According to the ICUMSA International Sugar Scale [29], the standard specific rotation is 66.58 (\( \tau = 20 °C, \lambda = 589.44 \text{ nm} \)), and the standard line between the ORs and the solution concentrations could be obtained with Eq. (12). Therefore, the measurement accuracy is difference between the measured ORs and the standard line. The accuracy of PPCBPS is about ±0.02° for measuring a high concentration of sucrose solution, and it is better than that of the MCP 500 (Fig. 7(c) and (d)). The R-square values of the linear fitting of the measured data are almost identical: 0.9998 (MCP 500) and 0.9995 (PPCBPS). The temperature difference at 1 °C has a negligible effect (approximately 0.01%) on the OR [28]. However, the touch on the PPCBPS during replacement of the sucrose solution could introduce the gross error, which can be observed from the larger error bar (Fig. 7(c)). Besides, the unstable light intensity of the sodium light also results in low measurement accuracy, which can be proved by comparing the different variance of the two normal distribution in Figs. 6(b) and 7(b). Encouragingly, the above factors that cause low measurement accuracy of PPCBPS could be eliminated easily by industrial integration, standard operation and laser source. The low error bar in the MCP 500 indicates that the measurement is standardized and the system is stable, and the measured OR twice as large as that of PPCBPS could cover a larger range of systematic errors. Hence, the low measurement accuracy is likely caused by the large systematic errors (Fig. 7(d)).

4. Conclusion

In this paper, a novel optical rotation measurement system based on pixelated polarization camera (PPC) is proposed, which overcomes the drawbacks in existing methods such as non-real-time performance, small measurement range, low measurement accuracy and resolution. The PPC and the Stokes parameters are employed in the optical rotation measurement to record and extract the polarization direction respectively, which eliminates the requirements for additional magneto-optic component, rotating electromechanical component and electro-optic component, etc. Hence, the concise optical path reduces the systematic errors. The 500 × 500 spatial repetitive measurements reduce the random errors to incredibly tiny magnitude, and the measurement sensitivity is almost unlimited because the measured OR is the average of the 2.5 × 10⁵ spatial repetitive measurements. The average extinction ratio of the PPC reaches as high as 31. Combined with the calibrated PPC, the algorithm presented for calculating the optical rotation (OR) is simple and efficient. After replacing the laser with a sodium light, the accuracy of the system is still higher than that of a high-performance commercial polarimeter, which is proven in the concentration measurement of the sucrose solution. Further, experiments demonstrate that the system with a laser source has real-time performance, wide range, high accuracy −1 × 10⁻⁴ ° and high resolution ±6 × 10⁻⁴ °, and the actual performance could be higher on condition that a more accurate calibration method is available. The proposed system promises higher metrological performance with industrial integration, standard operation and the constant PPC’s performance enhancements, and it would show great practical prospects in the fields of the hospital clinical diagnosis, chemical research, sugar production and pharmaceutical industry.
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