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斜光束对校正滤光片匹配准确度的影响

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摘　要:光电积分式的测色仪器中,光探测器的响应必须满足卢瑟条件.这一般是通过精确的匹配校正滤光片来实现的,匹配的准确度与入射光束在校正滤光片中的实际光程有关．由于测量条件的影响,入射光束不可避免地包含各个方向的入射光线,斜光束的存在会使理论计算出的匹配准确度降低.本文采用总误差面积比例最小法来评价校正滤光片的匹配准确度,阐述了校正滤光片匹配的理论依据,验证了斜光束光谱透射对于整个校正滤光片匹配准确度的影响,并提出了考虑到斜光束影响的校正滤光片厚度的修正公式.以“Y”滤光片的匹配为例,证明了修正后的公式对提高匹配准确度的意义.

关键词:卢瑟条件;校正滤色片;斜光束;光谱透过率
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Influence of Oblique Beams on Matching Accuracy of Correcting Filter

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Abstract: Color measurement instruments designed by principle of photoelectric integral, response of photo detector must meet Luther condition, which is realized by matching of correcting filters, and the matching accuracy is relevant to the actual light path in correcting filter. With the impact of measurement condition, the incident light inevitably contains various directions, and the exist of oblique beams reduces matching accuracy by theoretical calculation. The accuracy of matching filter is evaluated using the smallest proportion of total error area, the theoretical basis for correcting filter matching is introduced, the influence of oblique beams to correcting filter′s matching accuracy is proved, and the corrected formula of thickness of correcting filter is proposed when taking oblique beams into account. Take the matching of “Y” correcting filter as an example, the significant of corrected formula to matching accuracy is proved.

Key words: Luther condition; Correcting filter; Oblique beams; Spectral transmission

0 Introduction

Color measurement instruments designed by photoelectric integral, response of photo detector must be proportional to the spectral luminous efficiency curves for human eyes (CIE matching functions)[1]. In other words, it must meet Luther condition, and on this basis to get tristimulus values, chromaticity coordinates and other color parameters. The matching accuracy of Luther condition directly determines the instrument measurement precision. Currently, response meeting Luther condition is mainly get by optical template method and optical filter method. In this paper, optical filter method is used; using several filters with different materials and different thickness to correct the light shines on the photo detector, to get it meets the spectral luminous efficiency curves for humaneyes.

The influence of oblique beams is merely taken into consideration in present application; in many

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researches, it is always discussed according to specific color measurement instruments with specific lighting and detecting conditions, it is always defined as equivalent incidence ratio[2]. This essayproves the influence of oblique beams to correcting filter′s matching accuracy, puts forward the corrected formula of thickness of correcting filter when take oblique beams into account.

1 Correcting filter matching

1.1 Evaluation method of correcting filter matching accuracy

It is difficult to exactly match correcting filter to Luther condition in reality. However, the higher matching degree corresponds to the higher measurement accuracy of instrument[3-4]. The curve of Luther condition is shown in Fig. 1.

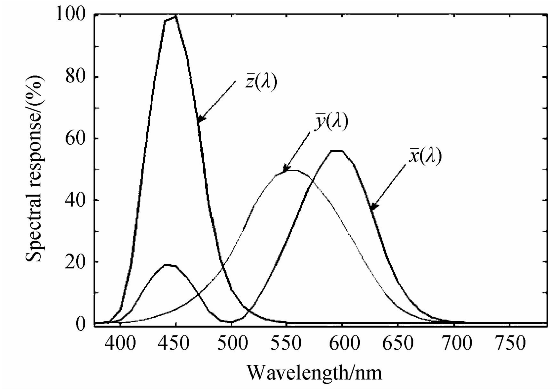

Fig. 1 Luther condition

Chinese metrological verification provides the evaluation method of $V(\lambda)$ correcting filter matching accuracy—smallest proportion of total error area[5], in other words, the mismatching of normalized actual spectral transmission takes the smallest proportion of ideal transmittance curve, the matching error can be formulated as follows

$$f_1=\frac{\int_{380}^{780}|S^*(\lambda)_{\mathrm{rel}}-V(\lambda)|\mathrm{d}\lambda}{\int_{380}^{780}V(\lambda)\mathrm{d}\lambda}\times 100\%=$$
$$0.93584(\mathrm{nm}^{-1})\int_{380}^{780}|S^*(\lambda)_{\mathrm{rel}}-V(\lambda)|\mathrm{d}\lambda\% \quad (1)$$

Note: $S^*(\lambda)_{\mathrm{rel}}$ is normalized relative spectral sensitivity.

$$S^*(\lambda)_{\mathrm{rel}}=\frac{\int_{380}^{780}P_{\mathrm{A}}(\lambda)V(\lambda)\mathrm{d}\lambda}{\int_{380}^{780}P_{\mathrm{A}}(\lambda)S(\lambda)_{\mathrm{rel}}\mathrm{d}\lambda}\times S(\lambda)_{\mathrm{rel}} \quad (2)$$

Note: $P_{\mathrm{A}}(\lambda)$ is relative spectral power distribution of standard A light source; $S(\lambda)_{\mathrm{rel}}$ is spectral response function of photo detector; $V(\lambda)$ is spectral luminous efficiency curves for human eyes.

1.2 Theoretical basis for correcting filter matching

The method of correcting filter matching is combination of several different filters with corresponding thickness[6-7]. Suppose that: the number of matching filter is N; $S(\lambda)$ is spectral response function of photo detector; $V(\lambda)$ is spectral luminous efficiency curves for human eyes; $t_1(\lambda)$, $t_2(\lambda)\cdots t_N(\lambda)$ is spectral transmittance of different filter with 1 mm; H_1, $H_2\cdots H_n$ is thickness of different filters (which unit is mm). When light incident vertically, spectral response function $S(\lambda)$ of combination of correcting filter and photo detector can be formulated as follows

$$S(\lambda)_{\mathrm{rel}}=0.92*S(\lambda)[t_1(\lambda)]^{H_1}*[t_2(\lambda)]^{H_2}\cdots[t_N(\lambda)]^{H_n} \quad (3)$$

Note: 0.92 is impact factor considerate that the incident light will reflect on the surface of correcting filter.

From the equation above, it can be inferred that after filter′s material and model are selected, the matching accuracy of correcting filter is directly relevant to its thickness[8]. In reality, the thickness of correcting filter will influence the light path greatly, when light incident vertically, spectral response can be expressed as formula (3); almost in all photoelectric integral instruments, the light shines on filters will be influenced by lighting and detecting conditions, if still be calculated as formula (3), it will get a great deviation. So the thickness of filter should be changed to H' properly, to make the spectral response of all light equals to the correcting filters with thickness H.

2 Spectral response of oblique beams

Almost in all photoelectric integral instruments, the light shines on filters will be influenced by lighting and detecting conditions to become diffuse light, and includes oblique beams with all directions, as is shown in Fig. 2[9-10]. The

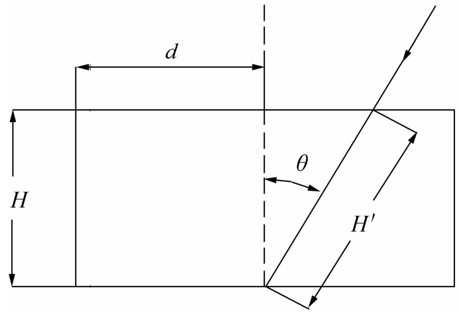

Fig. 2 Actual light path of oblique beam

actual light path of passing through correcting filter is relevant to the angle between light and filter, it can be formulated as follows

$$H'=H/\cos\theta \quad (4)$$

From the equation above, it can be known that due to the influence of oblique beams, the spectral response calculated by formula will get a big deviation. So the thickness of filters should be changed properly in application.

For a point on photo detector, the value of electrical signals generated is the combined function of all light reach to the point with different inclinations , as is shown in Fig. 3. So ,

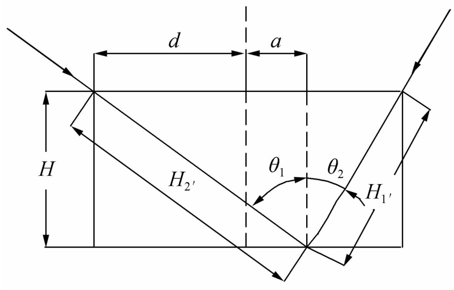

Fig. 3 Spectral response of any point on photo detector

Note: d is filter radius; H is filter thickness get by theory calculation; a is the distance between the point on photo detector and center od filter.

the spectral response of any point on photo detector should be represented by equivalent transmission ratio. Consider the influence of oblique beams, for any point on photo detector; the response should be formulated as follows

$$\tau'(\lambda)=\int_{H}^{\sqrt{H^2+(d-a)^2}}\tau^x(\lambda)\mathrm{d}x+\int_{H}^{\sqrt{H^2+(d+a)^2}}\tau^x(\lambda)\mathrm{d}x \quad (5)$$

So the electrical signals generated of whole photo detector can be formulated as follows

$$F_\lambda=\int_{-d}^{d}\tau'(\lambda)\mathrm{d}y \quad (6)$$

From all the formula given above, when the spectral response is known, the thickness of corrected filter can be derived as follows

$$H'=\int_{0}^{d}\frac{\sqrt{H^2+x^2}}{H}\mathrm{d}x \quad (7)$$

It means the thickness of corrected filter is relevant to the thickness of theoretical filter and its radius.

3 Analysis and discussion

Without considering the impact of the oblique beam, design the "Y" correcting filter according to the method of smallest proportion of total error area in Chinese metrological verification procedures, after calculation and optimization, model of LB6, LB16, BG39 and JB450 were selected, with the thickness of 1 mm, 2. 4 mm, 0. 3 mm and 1 mm respectively, and its matching error is 5. 6%, as "Y_1" shown in Fig. 4. If take oblique beams into consideration, the matching error gets to 14. 3%, as "Y_2" shown in Fig. 4. From the equation (3), filter' s spectral transmittance and its thickness is exponent relationship. So it can be inferred that the influence of oblique beams is equivalent to increasing the thickness of filters. So in application, in order to improve test accuracy, detecting conditions and structure of instrument, the influence of oblique beams must be taken into consideration, and exactly calculate and optimize to deduct filter to proper thickness.

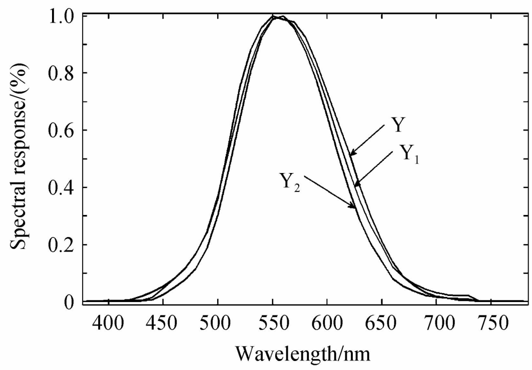

Fig. 4 Matching error at normal incidence and with oblique beams consideration respectively

Note: Y is spectral luminous efficiency curve; Y_1 is spectral transmittance curve at normal incidence; Y_2 is spectraltransmittance curve with oblique beams consideration.

There are many optical instruments designed by principle of photoelectric integral, here take luminancetested by color temperature illuminometer as example to prove the correctness of the formula put forward above.

Under the same test and lighting conditions, use one color temperature illuminometer to respectively get luminance under theoretical calculated filter and corrected filter, which are shown in Table 1.

Table 1 Luminance under theoretical calculated filter and corrected filter

Conditions	Luminance/lx				
Ideal value	1 269. 3	858. 4	565. 8	159. 2	46. 7
Theoretical filter	1 325. 6	910. 4	536. 2	154. 1	43. 2
Corrected filter	1 289. 5	892. 1	576. 4	160. 7	45. 3

The average test error of theoretical filter is 5. 28%; the average test error of corrected filter is 2. 26%. It can be concluded that use corrected filter can improve the accuracy of the instrument testing.

4 Conclusion

For color measurement instruments designed by photoelectric integral, because the limitation of detecting conditions and structure of instrument, the spectral response on photo detector is the combined effect of all light with different angles. Because the influence of oblique beams, the matching accuracy from theoretical calculationwill decrease. So in application, the thickness of corrected filter can be designed by the formula given in this essay to improve the accuracy of testing.

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· 下期预告 ·

粗糙热传导表面下激光介质的热效应

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摘　要:在考虑激光介质与热沉不完全接触导热的情况下,用面热源自适应调整算法计算了激光介质的温度场,研究了其热效应.表面附近相位差存在起伏且深入一定深度使热效应复杂化.随抽运功率的增大,表面附近相位差的起伏增强,而起伏深度变化不明显;接触面积增大,相位差起伏减小,起伏的深度有所减小.抽运功率较小时,热致衍射损耗随抽运功率的增大近似线性增大,高斯光半径越大,增大的斜率越大,当抽运功率增加到一定程度时,热致衍射损耗增大的趋势减缓,半径大的减缓较明显.在抽运光功率变化范围内,半径大的高斯光热致衍射损耗大于半径小的.高斯光半径较小时,接触面积对热致衍射损耗的影响不明显,当高斯光半径较大时,接触面积减小热致衍射损耗增大.

关键词:激光技术;粗糙面导热下热效应;自适应算法;相位差;热致衍射损耗