全方位探讨涂料色彩

Colours Seen from All Sides

Photo

与其它涂料性能一样，目前对涂料色彩有视觉和仪器评估，并且评估用来确定颜色，以及在标准色和调整色之间进行比较。现在我们在传统的视觉评估方法上辅之仪器评估，应该比视觉评估更客观，更简单，更安全。

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由于涂层中的彩色颜料有部分吸收入射光并且在所有方向上散射，人的视觉和仪器能进行相对容易地判断。色彩测量仪器具有 45° 定向照明或球面几何构形，视觉评估是在窗户或光棚中进行的，以获得可比的和可重现的结果，两者结合增加了金属涂层与铝颜料的使用，也促进了视觉和仪器评估的新方法的发展。随着仪器评估的发展这里已经出现具有多种测量几何形状的便携式设备。再次照明是在 45° 测出，在相应的光泽角度 15°、45° 和 110° 下测量，这些角度应该是视觉方面的，但是在仪器上测试的话，我们就可以任意选择角度，可以在 25°~75° 之间随意定义额外的测量角度。

目前，便携式测量仪器仍然以这些几何构形与 -15° 几何构形组成，但是在最开始，这些便携式测量仪是用来测量金属涂层的。在八十年代后期，我们用便携仪器来测量在新兴涂层中使用的干涉颜料，但是没有考虑这些颜料的物理及光学性质。其实铝和干涉颜料的颜色和效果高度依赖于测量时的几何结构，即照明和观察的组合。这既适用于视觉，也适用于仪器评估。理想情况下，这两种方法应该得到相同的结果。仪器评估的原理来自视觉，是利用物理上的反射，即通过仪器进行的测量被转换成反映视觉印象上的生理颜色值。但是由于在窗户或轻舱内进行观察与测量结果不相关，特别是在涂层效果的情况下，所以涂料实验室经常会听到批评。这种两种结果不一致并不是由于测量方法的不准确性导致误差或颜色值的转换，而是由于视觉和仪器评估中使用了不同几何结构的测量。测量几何构形的选择对两种评估方法都起着决定性的作用。另外，干涉颜料的光学性质也需要选择相应的几何形状测量。

As with other coatings properties, colour is nowadays assessed both visually and with instruments. And this assessment serves to determine the colour and also the comparison between a standard and an adjustment. The traditional method of visual appraisal was complemented by appraisal using instruments, which should be more objective, simpler and safer than the visual one. Colour pigments in the coatings, which partly absorb incoming light and partially scatter in all directions, can be judged relatively easily both visually and using instruments. Measuring instruments are available with a directional illumination at 45° or with spherical geometry. It took the increased use of metallic coatings with aluminum pigments to promote the development of new methods in visual and instrumental assessment: the visual assessments were and are made at the window or in a light booth to obtain comparable and reproducible results. The development of assessment using instruments has resulted in portable devices with multiple measurement geometries. Here again, illumination was introduced at 45°; was measured at 15°, 45° and 110° from the corresponding gloss angle. These angles should result from visual aspects but were chosen arbitrarily like the additional measurement angles defined at 25° and 75°.

Today, portable measuring instruments still work with these geometries complemented by the -15° geometry. Originally, these geometries were intended for measuring metallic coatings. In the late eighties, the use of interference pigments in emerging coatings was measured with the same devices and geometries, without taking into account the physical and optical properties of these pigments. The colour and effect of aluminium and interference pigments are highly dependent on measurement geometry, i.e. the combination of illumination and observation. And that applies both to the visual and the instrumental assessment. Ideally, both

总之，主要可以通过三个方法来进行测量，这三个方法可以独立的使用也可以一起用：第一个方法，在窗户和轻舱内进行视觉评估；第二个方法，便携式测量仪器提供的少量测量的几何形状；第三个测量方法涉及了干涉颜料的光学性质，这是 Zeiss 公司设计的 GK311/M 光谱仪用于测量不同的面积和相关的测量几何结构。该设备由 Hermann Gerlinger 博士团队在 80 年代末开发，基本概念包括可调节的照明头和可调节的测量头，两个磁头都安装在半钢轨上，软件可以调整角度位置以 5° 的增量变化，可以将照明调整到 65° 和最高 -45°，检测器可在 45° 和 -65° 之间调节，这台仪器几乎可以测量 250 个可测量的几何结构。虽然只有这个设备只有几个拷贝，但是一台设备仍然功能齐全。

视觉评估

在窗口进行视觉评估时，样品板要放在第一个位置，以便观察者观察光泽。在初始位置上，光泽角（也就是反射角）与照明角度相同，而且正常坐标位于它们之间的样品面板上。举例来说，假设照明角度是 +15°，那么，光泽角就是 -15°。在这里我们使用角度惯例，根据该惯例，照明侧上的角度被指定为正，观察者侧上的角度为负值，根据光学原理，入射角等于反射角。

观察者现在将样品向上倾斜或向下倾斜。在所有情况下，它们与光源之间的角度始终保持不变，在本例中始终为 30°。另一方面，在便携式测量仪器的情况下，照明和观察者之间的（非特异性）差异角度随着每个测量几何的改变而变。（**图 1**）

如果观察者向自己倾斜样本，照明角度会增加。同时，观察者和光泽角之间的（非特异性）差异角度增加。例如，照明角度从+15°变化到+45°，则光泽角度从-15°变化到-45°。其中观察者的角度为 +15°，这对应于 30° 照度的差异，和观察者与光泽度之间 60° 的（非特异性）差异角度（**图 2**）。

如果面板从观察者移开并向下倾斜，从最初照明角度移动到正常，例如从 +15° 到 +5°。相应的光泽角为 -5°，观察角度为 -25°，这对应于观察者和光泽度之间有 -20°（非特异性）差异角度。如果观察者将样品进一步向下倾斜，则照明角度移动到法线然后改变边线，例如到 -10°，光泽角则位于 +10° 的另一侧，观察角度变为 -40°，观察者和光泽之间的（非特异性）差异角度现在为 50°（**图 3**）。

当我们在上下倾斜时，必须考虑一个重要问题：由于光线反转，颜色值会几乎相同。例如，+10° 照度和 -20° 观测的测量结果理论上与 +20° 照度和 -10° 观测的测量结果相同（**图 4**）。如果在向下倾斜时获取测量值，你会发现得到与向上倾斜时相同的结果。因为差异对眼睛来说非常轻微的话，人们几乎以为是相同的颜色或相同的颜色梯度。最终，无论是向上还是向下倾斜样品面板，都可以获得相同的颜色印象（**图 5**）。

methods should yield the same result. Finally, assessment by instruments is derived from the visual: the physical reflection value, that is the measurements by instruments are translated into physiological colour values that reflect the visual impression. Nevertheless, the criticism is often heard from coating labs that observation at the window or in the light cabin does not correlate with the measurement results, particularly in the case of effect coatings. The contradiction is not due to the measuring methods' inaccuracy or errors or with conversions of the colour values, but to the different measuring geometries used in visual and instrumental assessment. The selection of measuring geometries plays a decisive role for both assessment methods. In addition, the optical properties of the interference pigments call for a corresponding choice of measurement geometries.

In summary, we direct our view to three areas that are presented individually and interpreted together: the first area comprises visual assessment at the window and in a light cabin. The current portable measuring instruments provide only a small selection of measurement geometries. They supply the second area of investigation, the third area deals with the optical properties of interference pigments. The GK311/M Spectrometer by Zeiss was used to measure the different areas and the associated measurement geometries. This device was developed at the end of the 80s by Dr Hermann Gerlinger's team. The basic concept comprises an adjustable illumination head and an adjustable measuring head. Both heads are arranged on a steel half rail and software enables their position to be changed in 5° increments. It is possible to adjust the illumination down to 65° and up to -45°. The detector is adjustable between 45° and -65°. This allows almost 250 measurable geometries to be made. Only a few copies of this device were built; one device is still fully functional.

Visual matching

When making a visual assessment at the window, the sample panel(s) are first positioned so that the observer is looking at the gloss. In this initial position, the gloss angle (= angle of reflection) is the same as the angle of the illumination, and the normal sits perpendicular between them on the sample panel(s). As an example, suppose that the angle of the illumination is +15° to the normal. Accordingly, the gloss angle is -15°. Here the angle convention is used, according to which the angles on the illumination side are designated positive and those on the observer side negative values, although according to the optical principle the angle of incidence equals the angle of reflection.

The observer now tilts the sheet or sheets upwards to themselves or down away from them. In all cases, the angle between them and the light source always remains the same, in this example always 30°. In the case of portable measuring instruments, on the other hand, the difference angle (aspecular) between illumination and observer changes with each measurement geometry (**Figure 1**).

If the observer tilts the sample sheet toward themselves, the angle of illumination increases. At the same time, the difference angle (aspecular) between the observer and the gloss angle increases. For example, if the illumination angle changes from +15° to +45°, the gloss angle changes from

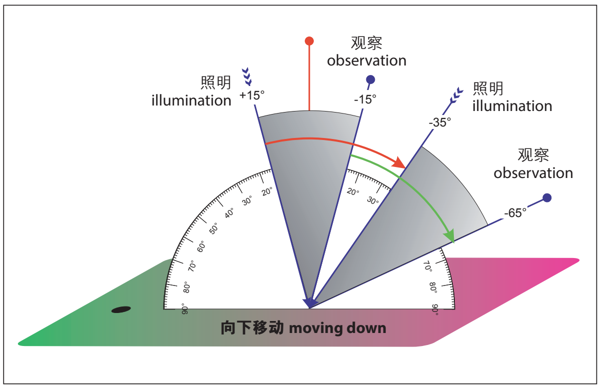

图 1：在这个例子中，窗口的起始位置对于照明是 + 15°，对于观察是 -15°，即照明和观察之间的差异角度是 30°。观察随着面板向下倾斜而增加。在第一阶段中，反射角是负的，即观察与光泽角相反。进一步向下倾斜面板，增加了不规则角度。

Figure 1: In this example, the starting position at the window is +15° for illumination and -15° for observation, i.e. the difference angle between illumination and observation is 30°.The observation increases with tilting the panel down. In the first steps the aspecular angle is negative, i.e. the observation is opposite to the gloss angle. Tilting the panel further down, the aspecular angle increases.

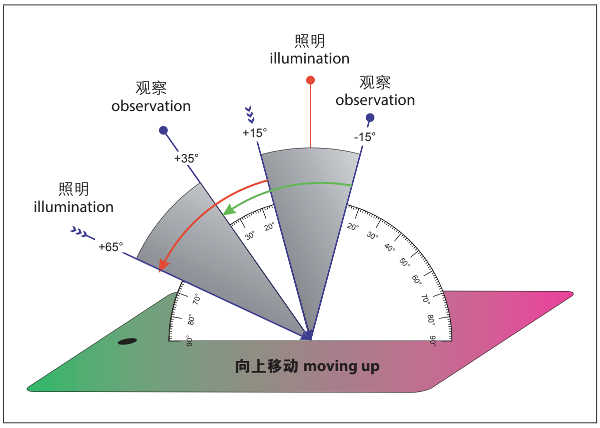

图 2：向上倾斜面板，照明角度在增加，并且反射角（观察和光泽之间的差异角度）也在增加。照度和观察之间的差异角度保持不变。

Figure 2: Tilting the panel up, the angle of illumination is increasing and the aspecular (difference angle between observation and gloss) is increasing, too. The difference angle between illumination and observation remains the same.

这种测量方法测量涂抹上去的涂料差异会很大，测试结果比较明显，是一个良好的测试方法。但是测量喷雾上去的涂料的话差异很小，但是这取决于喷雾时用的质量。

其它观察方法也会产生相同的结果，如果把样品片倒过来再背对着窗口进行测试，那么在向前和向后倾斜时会产生相同的情况，即使在轻舱内，里面的灯箱根据客户的规格进行设计，你也会得到相同结果。这里，样本面板通常从上方垂直或在 45° 以下照射，然后向前和向后倾斜，其中不

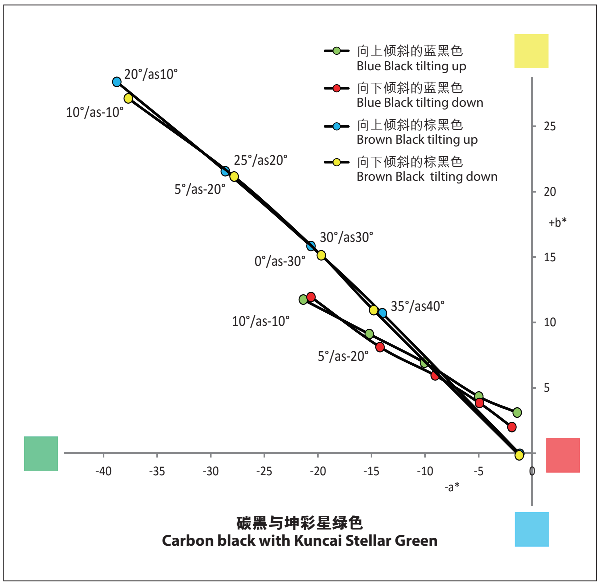

图 3：在窗户边上下倾斜面板，可获得相同的颜色行程。在这个例子中，显示了两种不同的碳黑混合物：在 10/-10 和 20/10° 附近开始接近光泽，当向下或向上倾斜时，色度降低。

Figure 3: Tilting a panel up and down at the window, you get the same colour travel. In this example two blends with different carbon blacks are shown: Starting near gloss at 10/as-10 and 20/as10°, chroma decreases when tilted down or up.

-15° to -45°. The angle of the observer is then +15°, which corresponds to a difference to the illumination of 30°. This results in a difference angle (aspecular) between observer and gloss of 60° (**Figure 2**).

If the panel is moved away from the observer and tilted down, then initially the illumination angle moves to normal, for example, from +15° to +5°. The corresponding gloss angle is then -5° and the observation angle -25°. This corresponds to a difference angle (aspecular) between observer and gloss of -20°. If the observer tilts the sheet down further, the angle of illumination moves to the normal and then changes sides, for example to -10°. The gloss angle then lies on the other side at +10°. The observation angle changes to -40° and the difference angle (aspecular) between observer and gloss is now 50° (**Figure 3**).

An important issue must be taken into consideration when tilting up and down: due to the light reversal, the colour values are almost identical. For example, measurements of +10° illumination and -20° observation theoretically correspond to measurements of +20° illumination and -10° observation (**Figure 4**). If you take the measurement values when tilting downwards, you will notice that you get almost the same results as when tilting upwards. Differences are so slight to the eye that one perceives practically the same colours or the same colour gradients. Ultimately, it does not matter if you tilt the sample panel up or down, you get the same colour impressions (**Figure 5**).

The differences are greater with drawdowns. This results in a preferred orientation, which becomes noticeable when measuring. The difference is small in sprayouts, but may depend on the quality of the spray application.

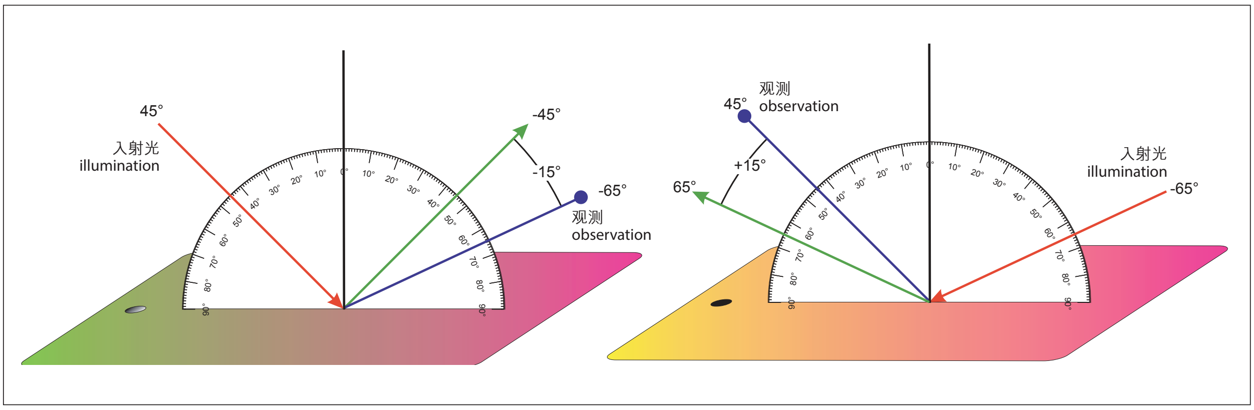

图 4：由于光线反转，您可以交换照明和观察：45° / -15° 等于 60 / + 15° 。
Figure 4: Due to the light reversal, you can exchange illumination and observation: 45°/as-15° is equal to 60/as+15°.

同几何构形的测量方式是可以比较的。

视觉测量与仪器的测量相比有一个重要的优势，视觉测量样品时的样品被测的面积明显更大。这种测量方法在距观察者正常距离且具有正常尺寸的情况下，顶部和底部边缘之间的视角约为 20°。

视觉测量在开始时接近光泽，但是当向前和向后倾斜时，观察者远离光泽，因为它们对窗户和照明的位置保持不变。但是便携式测量仪器保持照明的位置，而且观察角度随每个几何构形改变而改变。在干涉颜料的情况下，颜色在过程中改变的大小，视觉测量和仪器测量会得到不同的结果。

仪器评估

颜色效应和梯度高度依赖于它们被照亮和观察到的几何构形，特别是干涉颜料。便携式设备测量时与视觉测量不同，它不会受涂料质量大小影响。选择较少的几何构形会限制所附带的数据量。但是即使在 ASTM 标准测试方法中定义从光泽度的（非特异性）角度 -15° 处引入附加的几何构形，同样需要来自许多用户的大量工作。直到今天，测量设备中出现的情况以及角度名称的含义仍然让许多用户无法理解（**图 6**）。

由于测量几何形状改变时亮度的变化，注入彩色颜料的涂料显示的色彩改变很少或几乎没有，但是具有干涉颜料的混合物却具有光泽度。干涉颜料的光泽在最亮处缩小，并且随着距离的减小而减少，这样的现象可以通过便携式设备测量出来。便携设备的探测器以恒定的照明角度从光泽角度越来越大的台阶移开，用这种方法，可以测量和记录随着几何构形的不同干涉涂料发生明显变化的特殊现象。这样的例子有碳黑颜料混合，碳黑颜料当它是细颗粒颜料时是蓝色的，然而当它为粗颗粒时是褐色的。当这两种碳黑颜料与相同的干涉颜料混合时，在同样光亮的条件下，蓝色碳黑的混合物比褐色的碳黑混合物看起来更暗。亮度比（和色度）是随着与光泽的距离变化而变化，蓝色碳黑颜料混合物的亮

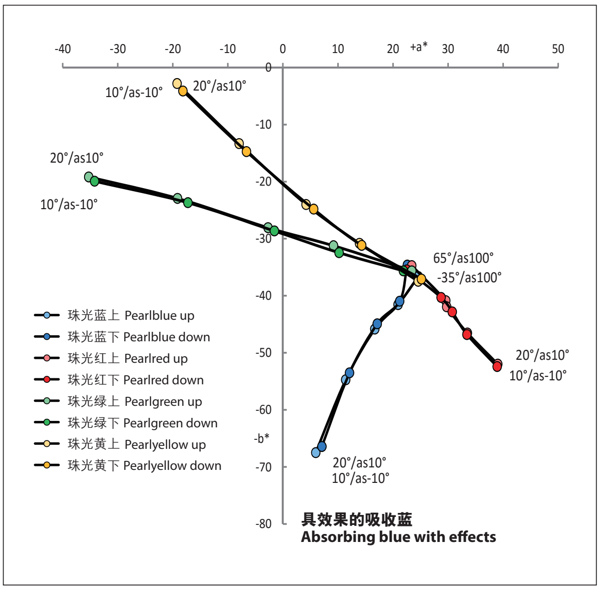

图 5：当在窗口倾斜面板时，在光泽附近可以观察到最高亮度，当面板倾斜时它会减小。光的可逆性原理可以导致类似的现象发生。不同的珠光颜料也具有相同的吸收蓝。
Figure 5: When tilting a panel by the window, the highest lightness is observed near the gloss. Accordingly, it will decrease when the panel is tilted. The fact that the same or similar values occur is due to the principle of the reversibility of light. Different pearl pigments are blended with the same absorbing blue.

Other methods of observation yield the same results: if the sample sheet is held upside down and then tested with its back to the window, then the same conditions result when tilting forwards and backwards. Even in a walk-in light cabin, you will find these conditions; other light cabins are designed according to the customer's specifications. Here, the sample panel is often illuminated from above vertically or under 45° and then tilted forward and backward. The sequence of geometries is comparable.

One aspect of the visual checks should not be forgotten: the area of a sample sheet is significantly larger in contrast to the measuring spot of an instrument. At a

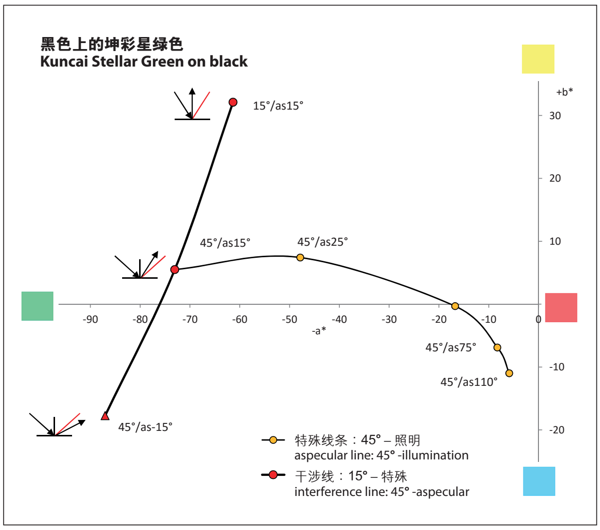

图 6：便携式仪器的读数会导致一些特殊线条，该线结合了从 45°/15° 到 45°/110° 的 a * b * 值。将干涉线（不同的照度，相同的反射角）添加到反射角线行中会产生典型的锚形。

Figure 6: The readings with a portable instruments leads into the so-called aspecular line. This line combines the a*b*-values from 45°/as15° to 45°/as110°. Adding the interference line (different illumination, same aspecular) to the aspecular line results in a typical anchor form.

度比变化没有褐色碳黑颜料混合物的大。这种现象在碳黑颜料和铝颜料的混合物中也存在，我们可以通过视觉和仪器来描述它亮度的变化（**图 7**）。

测量彩色透明干涉颜料时，我们把相应彩色透明干涉颜料的涂层应用于白色背景，从反射到透射颜色的变化是可以测试出来的，其中仪器评估要优于视觉评估。这些颜料在表面上具有典型的反射颜色，但是由于缺少相移，穿透颜料的光线会在背部产生互补的透射颜色，仪器测量时测量了恒定照明角度以及它们（独特的）差异角度的光泽度变化，确保了对这种光学特性的正确描述，其中（独特）差异角度指在 20° 和 30° 之间的（独特）差异角度，它的选择取决于颜料的类型（**图 8**）。

便携式设备通过选择不同的几何构形来表现涂料及其颜料的部分颜色特性。视觉测试表现颜色属性的不同部分，所以两种测试可以给出不同的结果。因此，重要的是我们应该把两种结果结合起来进行最佳评估。

光学性能

颜色评估的第三种方法涉及到光学性质，这种方法最开始独立于之前的视觉和仪器测试，它对色彩测试中提出了是否能够符合和如何符合这些方法的问题。

当以不同的角度和具有相同的（非特异性）差异角度照明，铝颜料会改变它们的亮度。当在固定照明角度以不同的特殊角度观察时，它们也会改变亮度。查看相应的反射曲线，其中有反射水平的变化，但没有位移。

normal distance from the viewer and with a normal size, the viewing angle between the top and bottom edges is approximately 20°.

The visual examination starts close up to the gloss; when tilting forwards and backwards, the observer continues to move away from the gloss, as their position to the window and lighting remains constant. The portable measuring instruments maintain the position of the illumination and the angle to the observation changes with each geometry. In the case of interference pigments, which have a more or less pronounced colour travel, a different process is observed than the one that results from instrumental measurement.

Instrumental assessment

Colour effects and gradients, especially of interference pigments, are highly dependent on the geometries by which they are illuminated and observed. The fact that the portable devices use geometries that are different from those used in visual matching does not say anything about their quality. The choice of fewer geometries also limits the amount of data that comes with each additional measurement. Even the introduction of an additional geometry at -15° from gloss (aspecular) angle, as defined in the ASTM standard test method, has required a great deal of work from many users. What occurs in a measuring device and what the angle designations mean remains incomprehensible to many users even today (**Figure 6**).

A coating infused with colour pigments shows little or no colour travel; a coating with interference pigment particular has a glossiness because of changes in lightness when the measurement geometries change. Its gloss is at its brightest close up and decreases the further away you get. This behaviour can be described using portable devices. The detector moves away in bigger and bigger steps from the gloss angle at a constant illumination angle. In this way, special phenomena can be recorded that are visually described with other geometries. An example of this is blends with carbon black pigments: as fine-particle pigments they are bluish, as coarse ones, they are brownish. When mixed with the same interference pigment, the mixture of bluish carbon black is much darker than the mixture with the brownish when looked at close up to the gloss. The lightness ratio (and chroma) changes depending on the distance from the gloss: The mixture with the bluish carbon black becomes lighter than the mixture with the brownish. This behaviour can also be detected in mixtures with aluminum pigments. The change in lightness can be described both visually and using instruments (**Figure 7**).

An advantage for instrumental assessment over the visual can be seen in the colour properties of colourful, transparent interference pigments: if a corresponding coating is applied to a white background, the change from the reflection to the transmission colour is recognisable. These pigments have a typical reflection colour on their surface; light rays that penetrate the pigments generate a complementary transmission colour on the back due to the missing phase shift. The constant illumination angle of the measuring instruments as well as their change from the difference angle (aspecular) to the gloss ensure the correct

根据干涉原理，照射角度的变化时干涉颜料会做出反应。当颜料或相应的涂层被均匀地照射时，具有相同的反射角，反射曲线波长会变短，即红色干涉颜料变成黄色，黄色干涉颜料变成绿色，绿色就会变成蓝色。用改变的照明时的角度进行测量能够清楚地显示反射曲线和 a* b* 颜色值改变的现象（**图 9**）。

这种现象是干涉颜料的典型现象，我们可以用来识别干涉涂料。干涉色素特定的测量几何构形为 15°/15° – 45°/15°

description of this optical property: between the difference angles (aspecular) of 20° and 30° there is an intermediate area in which change takes place, depending on the type of pigment (**Figure 8**).

Portable devices display part of the colour properties of a coating and its pigments with their selection of geometries. Visual matching shows a different part of the colour properties and can therefore give different results. Therefore, it is important to combine both outcomes to make an optimal assessment.

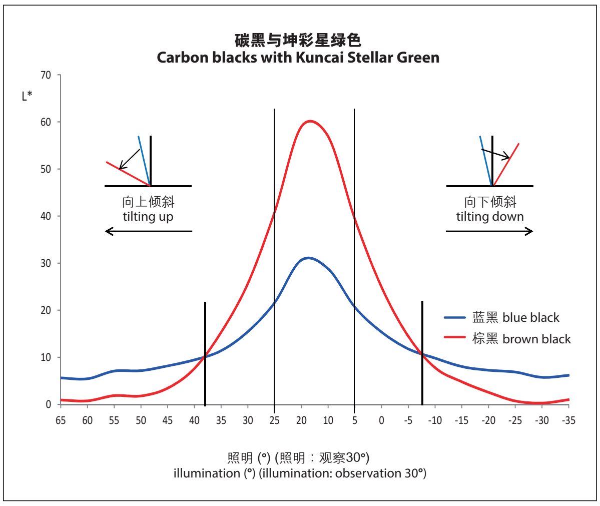

图 7：蓝色碳黑的混合物比褐色的碳黑混合物看起来更暗，这样会使颜料失去光泽。
Figure 7: Blends with bluish carbon black are darker near gloss than blends with brownish carbon black, that turns around going off gloss.

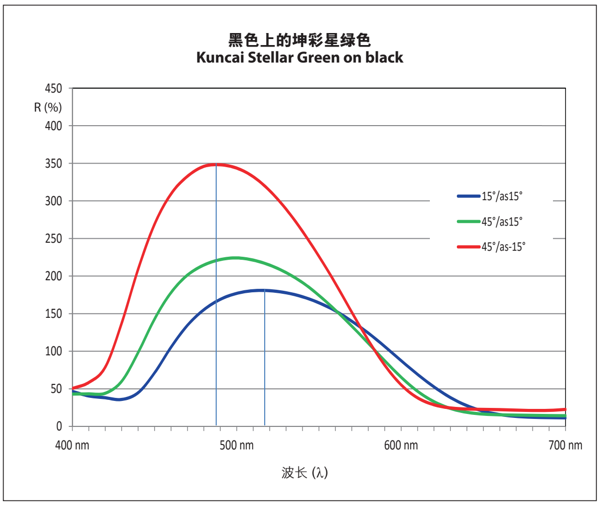

图 9：当均匀照射时，干涉颜料会反射更短的波长。这是干涉颜料的典型特征，可用于鉴定干涉颜料。
Figure 9: Interference pigments shift to shorter wave length when illuminated flatter. This is typical for these pigments and can be used for their identification.

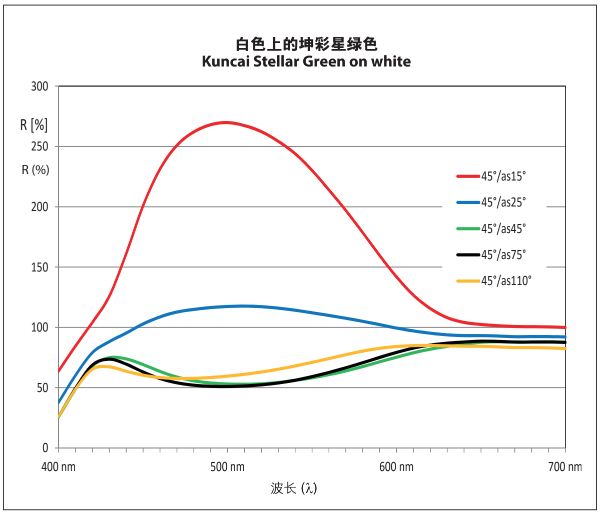

图 8：假如彩色透明干涉颜料应用在白色背景板上，测量光泽线时，会显示从反射到透射颜色的变化。过渡范围与光泽角度呈 20° 至 30° 之间。
Figure 8: If colourful, transparent interference pigments are applied to a white background, the colour change from the reflection to the transmission colour is shown when measuring the gloss line. The transition range is between 20° and 30° from the gloss angle.

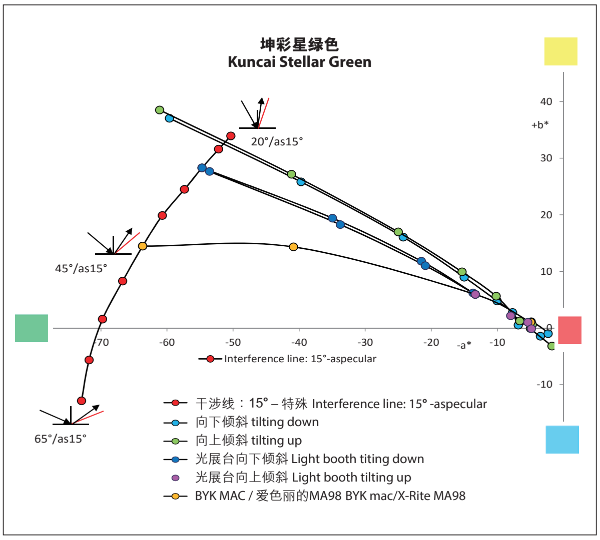

图 10：不同方法的结合：在窗户和光展台上进行视觉评估，用便携式仪器进行仪器评估和用由于干扰而导致的光学特性评估。
Figure 10: Combination of different methods: Visual assessment at a window and in a light booth, instrumental assessment with a portable instrument and optical properties due to interference.

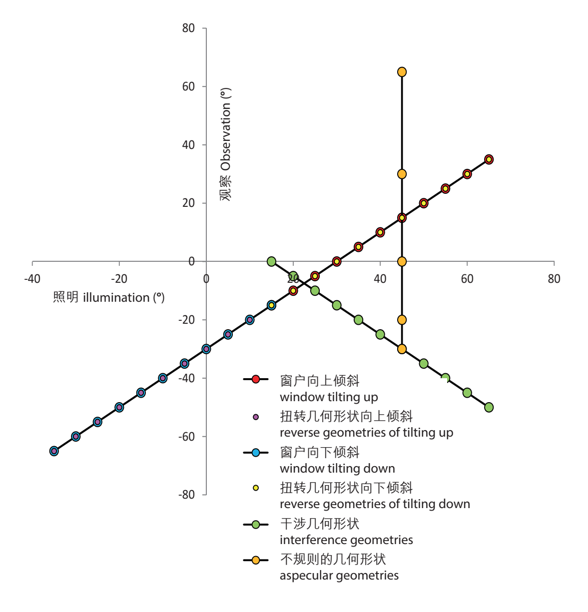

图 11：相似的反射角线，但有不同的干涉线。这个真实的例子导致不同的视觉评估，但是与实际仪器的评估相同。干涉线的测量显示这些批次之间的差异。

Figure 11: Similar aspecular lines but different interference lines: This real example results in different visual assessment but same assessment with actual instruments. Measurement of the interference lines show the different between these lots.

– 65°/15° 的干涉线和 45°/15° – 45°/25° – 45°/45° 的特征线的。45°/25° – 45°/15° – 65°/15° 连接时，臂总是逆时针指向 45°/15° – 65°/15° (**图 10**)。

用便携式设备测量时，一些几何构形没有办法测量，但是由于光反转的原理，我们可以使用 45°/-15° 几何构形来代替 60°/15° 几何构形。这种几何构形是它在 45° 处被照亮并且在 -60° 处 (对应 -15° 的反射角) 被观察。如果反转光路，则以 60° 照明，并以 45° 观察 (对应 15° 反射角)。这样 45°/-15° 对应 60°/15°。干涉色素的光学特性测试可以部分使用这种「技巧」。

结语

三种评估方法都有各自的优点：在大多数情况下，视觉评估就像人手动来回移动样本，比较两个样本来检测颜色差异。便携式测量仪器是在给定的测量几何形状情况下，检测出样品的色差。光学性质则用不同的测量几何形状来表征和区分干涉色素 (**图 11**)。如果您想对样品进行视觉评估，建议您用从上到下以平行的方式移动测量面板，同时改变照明角度。假如您拿起样本并翻过来，它也会被均匀照亮。如果您放下样品，它会被照亮并被观察的更明显。如果您想要使用便携式测量仪器来测量，评估中将包含 45°/-15°。彩色干涉颜料测量时将手臂从45°/15° – 45°/-15° 逆时针「弯曲」，而铝颜料手臂 45°/25° – 45°/15° 直线运行。

Optical properties

The third aspect of colour assessment deals with optical properties. These are initially independent of the described methods of visual and instrumental colour inspection. The description of properties raises the question of whether and how they can be adapted to those methods.

Aluminium pigments change their lightness when illuminated at different angles with the same difference angle (aspecular). They also change their lightness when observed at fixed illumination angles with different aspecular angles. Looking at the corresponding reflection curves, a change in the level of reflection is noted, but no displacement.

According to the principles of interference, interference pigments react to the change in angle of the illumination. With the same aspecular angle, the reflection curves shift to shorter wavelength when the pigment or the corresponding coatings is illuminated more evenly, i.e. red interference pigments shift to yellowish, yellow interference pigments to greenish and green to bluish. Measurements with changed illumination angles clearly show this behaviour in both the reflection curves and the a*b* colour values (**Figure 9**).

The behaviour is typical for each interference pigment and can also be used for identification. The characteristic anchor shape formed by the interference line with the measurement geometries 15°/15° - 45°/15° - 65°/15° and the aspecular line with 45°/15° - 45°/25° - 45°/45°, is specific for an interference pigment. In the connection of 45°/25° - 45°/15° - 65°/15°, the arm always points 45°/15° - 65°/15° counter-clockwise (**Figure 10**).

These geometries cannot be realised using portable devices; due to the principles of light reversal, the 45°/-15° geometry can be used instead of the 65°/15° geometry. It is illuminated at 45° and observed at -60° (corresponds to -15° aspecular) with this geometry. If you reverse the light path, it is illuminated at 60° and observed at 45° (corresponds to 15° aspecular); 45°/-15° corresponds to 60°/15°. The optical properties of an interference pigment can be partially captured using this "trick".

Summary

All three descriptions have their merits: visual assessment is more like the human behaviour of moving the sample sheet back and forth. In most cases, two sample sheets are compared to detect colour differences. Colour differences can also be detected with the portable measuring instruments as long as they occur with the given measurement geometries. The optical properties require different measurement geometries to characterise and differentiate interference pigments (**Figure 11**). If you want to assess them visually, it is recommended you move the measuring panel in a parallel fashion from top to bottom while simultaneously changing the illumination angle. If you hold the sample sheet up and look over it, it should also be illuminated evenly. If you lower the sheet, it is illuminated and observed to be steeper and steeper. If you want to achieve similar results with portable measuring instruments, the 45°/-15° is included in the assessment. Colourful interference pigments "bend" the arm from 45°/15° - 45°/-15° counter-clockwise, while aluminum pigments run straight in relation to the arm 45°/25° - 45°/15°.