干涉颜料的表征

Characterisation of Interference Pigments

颜料处理入射光并部分反射它。这些反射成分触发人眼中颜色刺激，并由大脑转换成颜色。这种光的处理通过物理方式描述，通过生理方式转化为颜色。这种处理真的如何发生，我们无法识别。例如，如果将红色和黄色颜料混合成橙色，则该橙色看起来可能与橙色颜料相同。然而，混合物反射曲线缺乏橙色颜料的典型谱图。

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原则上，颜料在整个光谱范围内反射，例如，绿色颜料不仅反射在绿色中，而且反射在红色，黄色和蓝色光谱区域中——只是强度弱得多。

干涉颜料反射曲线通常可以是两个或三个显示出广泛增加至最大值。与吸收颜料一样，不可能从反射中推断出所感知的颜色。此外，当入射光角度发生颜色偏移时，干涉颜料会发生反应：如果在与光泽度（非规则反射）相同差异角度下入射光变平，则其颜色会变为较短波长。这种转变是着色干涉颜料基本特征。白色干涉颜料没有像铝颜料那样色移。

如果观测到接近光泽干涉颜料颜色然后远离它，则当颜料应用于白色背景时，可以观测到从反射颜色到透射颜色变化。这种变化发生在20°和30°之间。透射颜色明显弱于反射颜色。并且对此补充如下：入射光线通过相移开始部分地在颜料

Pigments manipulate the incoming light and partially reflect it. These reflected components trigger a colour stimulus in the human eye, which is transformed into a colour by the brain. This manipulation of light is described by physics, the transformation into a colour by physiology. How the manipulation really happens, we cannot recognise. For example, if a red and a yellow pigment are mixed to give orange, then this orange may look the same as an orange pigment. However, the blend's reflectance curve has a typical saddle that lacks in the orange pigment. In principle, pigments reflect in the entire spectral range, as, for example, a green pigment reflects not only in the green, but also in the red, yellow and blue spectral areas – only much weaker.

Reflectance curves of interference pigments generally show broad increases to the maxima, of which they may also have two or three. As with absorbing pigments, it is not possible to infer the perceived colour from the reflections. In addition, interference pigments react when there is a change in the angle of the incident light with a colour shift: If the illumination is flattened at the same difference angle to the gloss (aspecular), its colour shifts to shorter wavelengths. This shift is an essential feature of the colour interference pigments. White interference pigments have no colour shift like aluminum pigments.

If one observes a colour interference pigment close to the gloss and then moves away from it, the change from the reflection colour to the transmission colour can be observed when the pigment is applied to a white background. This change occurs between 20° and 30° off gloss. The transmission colour is significantly weaker than the reflection colour. And it is complementary to this: the incident light rays are initially reflected on the surface of the pigment partly by phase shift. The other part passes through the metal oxide layer (e.g.

表面上反射。另一部分穿过金属氧化物层（例如，二氧化钛）。在载体薄片边界层处，相应地有一部分被反射，这使得颜料与第一部分光平行并与之干涉。发生这种情况时，某些光波被放大或衰减。剩余部分光线将颜料放置背后。由于缺少从光学致密介质到光学较薄介质相移导致互补色。

反射颜色是干涉颜料典型颜色，由发生在干涉颜料中多次反射和折射形成。所得到的反射颜色很大程度取决于围绕载体薄片金属氧化物折射强度及其层厚度。这两个因素都由生产者决定，用户对其没有影响。但用户可通过干涉光学特性——当照射从陡峭变平时发生颜色偏移获得有关颜料信息。

通常，干涉颜料，以及铝颜料或两种颜料混合物可通过干涉和非垂直线组合来描述。干涉线是陡峭，经典和平面照射a*b*-值连接线。通常，测量针对15°和45°照明，每个光泽度角度与15°角度不同。不同于具有相同差角的平面入射光，由于光反转，可使用45°/as-15°（45°照明/非规则光-15°）几何形状。如果光通路以这种几何形状反转，则该几何形状对应于60°/as15°几何形状，即具有相同15°差角平面入射光。

该非规则光线在45°固定照射角度下测量得到。在这里，测量仪器制造商提供15°、25°、45°、75°和110°差异角度（不规则光）。前三个差异角对于干涉颜料表征很重要。如果将两条线组合在一起，您将获得具有颜色干涉颜料典型锚形状。在这种情况下，具有平面照明干涉线总是逆时针弯曲。白色干涉颜料和铝颜料没有这种典型特征。对于它们来说，干涉线几乎是非规则光线延伸，因为白色干涉颜料和铝颜料反射更多，但在更平整入射光时不会显示颜色偏移。

如果将不同干涉颜料及其混合物与吸收颜料进行比较，则可以看出干涉线几乎保持不变。如果蓝色干涉颜料与红色吸收颜料混合，您可以看到光泽附近蓝色干涉色。如果不进行观测，将蓝色干涉颜料与红色吸收颜料混合没有意义。进一步偏离光泽，吸收颜料颜色影响占主导地位。即使在改变其折射率肯定对所得颜色有影响的介质时，也保留了干涉颜料基本性质。因此，当掺入塑料而不是涂料时，蓝色干涉颜料不会变绿。

干涉颜料是具有其自身光学性质的个体主义者，因此甚至可区分结构相同的颜料。这些属性知识是有帮助的，特别是对

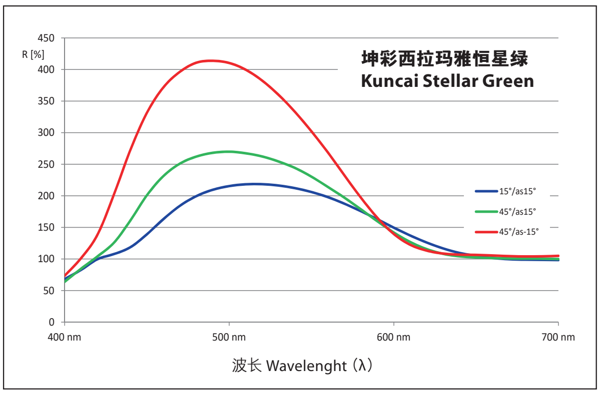

图1：干涉颜料典型颜色反应：如果入射光更平坦，则转换为更短波长。
Figure 1: Typical reaction of colour interference pigments: Shifting to shorter wavelength if illuminated flatter.

titanium dioxide). At the boundary layer to the carrier platelet, in turn, a part is reflected, which leaves the pigment parallel to the first part and interferes with this. In doing so, certain light waves are amplified or attenuated. The remaining part of the light rays leaves the pigment on the backside. Due to the lack of phase shift from the optically denser to the optically thinner medium results in the complementary colour.

The reflection colour is the typical colour of an interference pigment that results from multiple reflections and refractions in the interference pigment. The resulting reflection colour depends, among other things, on the strong refractive metal oxide that surrounds the carrier platelet and its layer thickness. Both factors are determined by the producer and the user has no influence on it. But he can get information about the pigment via the optical properties of the interference - the colour shift when changing from steep to flat illumination.

Typically, interference pigments, but also aluminium pigments or mixtures of both pigments can be described via the combination of the interference and the aspecular line. The interference line is the connecting line of a*b*-values for steep, classic and flat illumination. Usually the measurements are used for illuminations of 15° and 45° with a difference angle to the gloss of 15° each. Instead of the flat illumination with the same difference angle, the geometry 45°/as-15° (45° illumination/aspecular -15°) can be used due to the light reversal. If the optical path is reversed with this geometry, this geometry corresponds to a geometry of 60°/as15°, i.e. a flat illumination with the same difference angle of 15°.

The aspecular line results from measurements at a fixed illumination angle of 45°. Here the manufacturers of the measuring instruments offer difference angles (aspecular) of 15°, 25°, 45°, 75° and 110°. The first three difference angles are important for the characterisation of interference pigments. If you combine both lines, you get a typical anchor shape with colour interference pigments. In this case, the interference line with the flat illumination always bends counter-clockwise. This typical feature is not found with white interference pigments and aluminium pigments. For them, the interference line is nearly as an extension of the aspecular line, as both white interference pigments and aluminium pigments reflect more, but show no colour shift when illuminated flattener.

If one compares different interference pigments and their blends with absorbing pigments, it will be noticeable that the interference line remains almost the same. If a blue interference pigment mixed with a red absorbing pigment, you can see the blue interference colour near gloss. If it were not to be observed, it would make no sense to mix the blue interference pigment with a red absorbing pigment. Further away from the gloss, the colour influence of the absorbing pigment predominates. Even when changing the medium, whose refractive index definitely has an influence on the resulting colour, the basic properties of an interference pigment are retained. Thus, a blue interference pigment does not turn green when incorporated in plastic rather than coatings.

Interference pigments are individualists with their own optical properties, so that even structurally identical pigments can be distinguished. Helpful is the knowledge of these properties, especially with adjustments of unknown colours. Here, the interference line plays a major role: it reflects the optical properties of each interference pigment. It is all about the form of this interference line, its absolute position

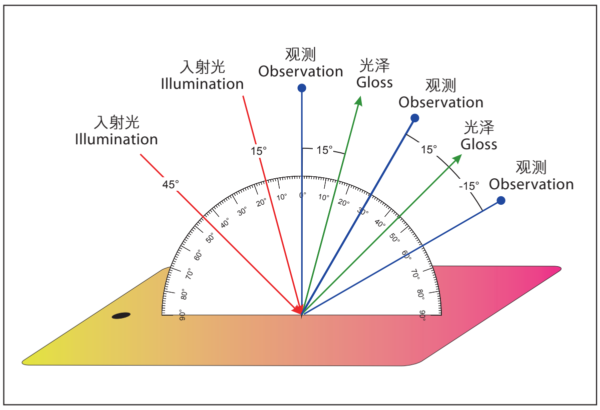

图2：几何形状（入射光和观测）选择来限定干涉线。
Figure 2: Selection of geometries (illumination and observation) to define the interference line.

未知颜色的调整。这里，干涉线起主要作用：它反映了每种干涉颜料的光学性质。这完全是关于干涉线的形式，它在a* b* -图表中的绝对位置起次要作用。与主体干涉线相比，它可以通过彩色和铝颜料在位置上发生移动。相应位置也取决于其初始值为45°/as15°。为了表征和识别干涉颜料，对颜色位置进行独立地评估。测量值相对表示提供了能够更准确地识别干涉颜料光学性质的优点，例如也可以在共混物中。该方法未检测到任何吸收颜料。然而，它还显示了白色和彩色干涉颜料之间差异以及干涉和铝颜料之间的差异：白色干涉和铝颜料在入射光更平坦时反射水平更高。然而，与颜色干涉颜料一样，没有额外色移。这种颜色偏移与更平坦入射光下的更高反射相结合是颜色干涉颜料的典型特征，可用于识别和表征。

这是描述用于更详细地表征干涉颜料的方法。基底是许多不同类型和混合的面板，用所提到的几何形状测量。根据每种情况下测量值干涉线（测量几何形状15°/as15° -45°/ as15° -45°/as-15°）和非规则光线（测量几何形状45°/ as15° - 45°/ as25° - 45°/ as45°）。没有使用额外的几何形状，因为它们对干涉没有直接影响。

干涉光线和非规则光线组合代表每种单独的干涉颜料。为了描述它，定义了六个参数来描述光线的位置和路线：首先，将x轴和y轴坐标系放置在a * b * - 值中，几何形状为45°/

in the a*b* – chart plays a secondary role. Compared to the interference line of the masstone, it can be shifted in position by coloured and aluminium pigments. The aspecular line is also positioned accordingly with its initial value at 45°/as15°. In order to characterise and identify the interference pigment, the evaluation takes place independently of the colour location. The relative representation of the measured values offers the advantage of being able to more accurately recognise the optical properties of an interference pigment, for example also in blends. This method does not detect any absorbing pigments. However, it also shows differences between white and colour interference pigments as well as differences between interference and aluminium pigments: White interference and aluminium pigments reflect at a higher level when illuminated flatter. However, there is no additional colour shift as with colour interference pigments. This colour shift, in combination with the higher reflections at flatter illumination, is a typical feature of colour interference pigments which can be used for identification and characterisation.

Here is a method described to characterise interference pigments in more detail. The bases are many panels of different types and blends, which were measured with the mentioned geometries. The measured values form in each case the interference line (measuring geometries 15°/as15° – 45°/as15° – 45°/as-15 °) and the aspecular line (measuring geometries 45°/as15° – 45°/as25° – 45°/as45°). The additional geometries are not used because they have no direct influence on the interference.

The combination of interference and aspecular line represents each individual interference pigment. To describe it, six parameters are defined which describe the position and the course of the lines. First, a coordinate system with x- and y-axis is placed in the a*b* -value for the geometry 45°/as15° (45° illumination/aspecular=off gloss 15°). This geometry is contained in both lines and is thus a common starting point. With this transformation, the different parts and angles of the two lines now get a unique assignment, which are reflected in the six parameters. For the parameters, ranges are determined from existing, known patterns, with which queries then take place in a database. These queries take place one after the other, which means that the selection is increasingly concentrated on the sought-after interference pigment. It is also useful to create sample blends with interference and aluminium pigments in order to collect appropriate measurement data. The calculation and definition of the parameters are based on the following descriptions:

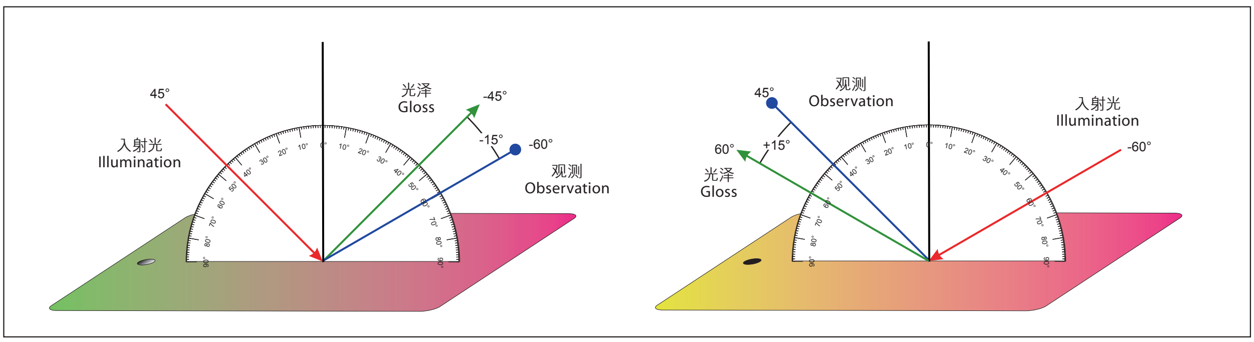

图3：由于光路径反转，45° / as-15° 与60° / as15° 相同。
Figure 3: Due to reversing the light path, 45°/as-15° is equal to 60°/as15°.

as15°（45°入射光/ 非规则光 =偏离光泽15°）。这种几何形状包含在两条线中，因此是一个共同起点。通过这种变换，两条线不同部分和角度现在得到一个独特的分配，这反映在六个参数中。对于参数，范围由现有已知模式确定，然后在数据库中进行查询。这些查询一个接一个地进行，这意味着选择越来越集中在广受欢迎的干涉颜料上。创建具有干涉和铝颜料的样品混合物以收集适当的测量数据也是有用的。参数计算和定义基于以下描述：

参数s1:

从陡峭到经典照明（15°/ as15°和45°/ as15°）干涉线部分与x轴形成一定角度。绿色干涉颜料具有比红色干涉颜料更小的角度。因此，该角度取决于反射颜色，因此是干涉颜料第一个重要指示参数。

参数s2:

第二个参数也指干涉线。它描述了干涉线两部分之间的角度。它并不总是180°，但它可以偏离这个值。这部分由15°/ as 15°至45°/ as 15°和45°/ as 15°至45°/ as-15°干涉线部分形成。

参数s3：

该参数反映了从15°/ as15°到45°/ as15°部分的长度。

参数s4：

参数4表示15°/ as15°到45°/ as15°和45°/ as15°到45°/ as-15°两个部分的比率。该比率是长度的重要组成部分。结合参数3，可确定干涉线长度。

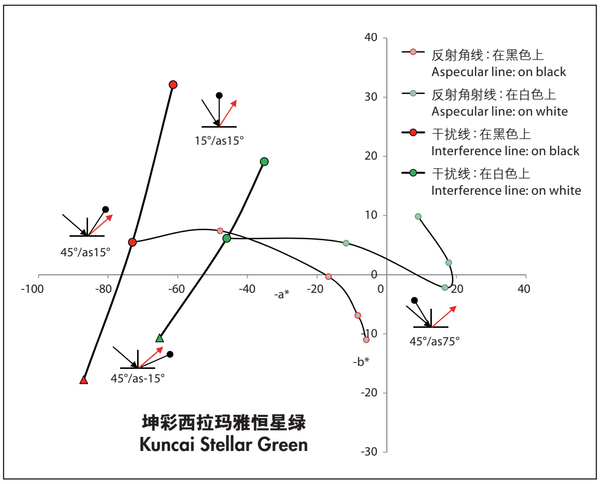

图4：干涉颜料最好用干涉线（15° / as15° - 45° / as15° - 45° / as-15°）和非规则线（45° / as15° - 45° / as110°）描述。图表显示了相同颜料在黑色和白色背景上颜色偏移。
Figure 4: An interference pigment is best described by the interference line (15°/as15° - 45°/as15° - 45°/as-15°) and the aspecular line (45°/as15° - 45°/as110°). The chart shows the colour shift of the same pigment on black and on white background.

Parameter s1:

The part of the interference line from the steep to the classical illumination (15°/as15° and 45°/as15°) forms a certain angle to the x-axis. Green interference pigments have a smaller angle than, for example, red interference pigments. The angle is therefore dependent on the reflection colour and is thus the first important indication of an interference pigment.

Parameter s2:

The second parameter also refers to the interference line. It describes the angle between both parts of the interference line. It does not always have to be 180°, and it can deviate from this value. The parts are formed by the portions of the interference line of 15°/as15° to 45°/as15° and 45°/as15 to 45°/as-15°.

Parameter s3:

This parameter reflects the length of the part from 15°/as15° to 45°/as15°.

Parameter s4:

Parameter 4 indicates the ratio of both parts from 15°/as15° to 45°/as15° and from 45°/as15° to 45°/as15°. The ratio is an important component than the length of the second leg. In combination with parameter 3, the length of the interference line can be determined.

Parameter s5:

For interference pigments and their blends the aspecular line runs approximately in the direction of the achromatic point. Therefore, the angle between the x-axis and the line segment 45°/as15° to 45°/as25° is used for the characterisation.

In the case of green interference pigments, the angle is very large (between 270° and 360°), while it is significantly smaller for red interference pigments (180° to 270°).

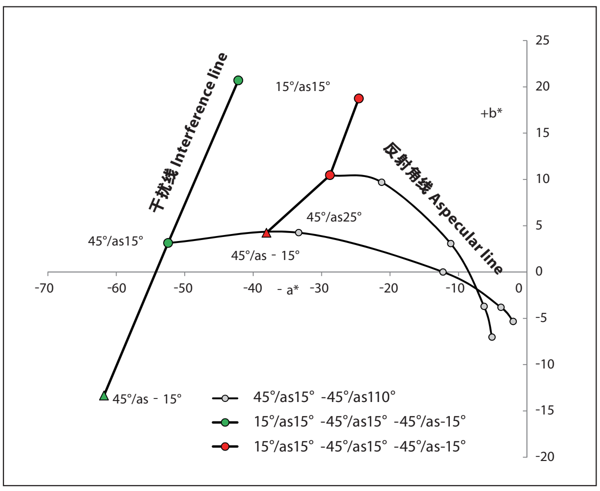

图5：两种不同干涉颜料（XillaMaya 恒星绿和珍珠绿）显示出不同光学性能。
Figure 5: Two different interference pigments (XillaMaya Stellar Green and Pearlgreen) show different optical properties.

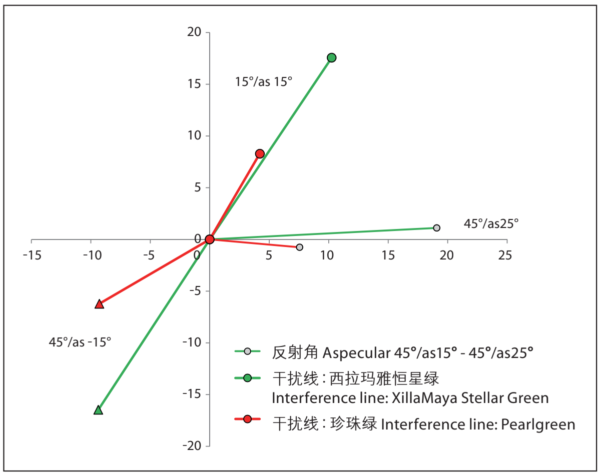

图6：选择45 / as15° 几何光线测量值作为坐标系零点。从这里计算出s1至s6不同数据。
Figure 6: The measured value of the geometry 45 /as15° is selected as the zero point of a coordinate system. From here the different data s1 to s6 are calculated.

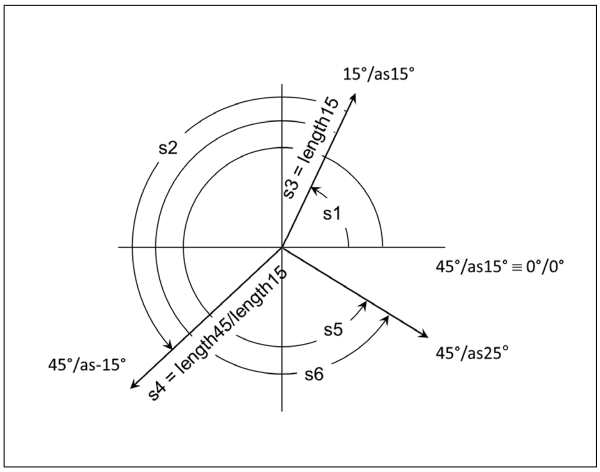

图7：通过子线角度及其长度来计算s1至s6值。这些值用于数据库查询。
Figure 7: The values s1 to s6 are calculated by the angles ween the sub-lines and their length. They are used for the query in a database.

参数s5：

对于干涉颜料及其混合物，非规则线大致沿着消色点方向延伸。因此，x轴和45 /as15°至45°/as25°之间线的角度可用于表征。

对于绿色干涉颜料，角度非常大（在270°和360°之间），而对于红色干涉颜料，角度则小很多（180°至270°）。

参数s6：

第六个参数指的是干涉线第一部分与所述非规则线部分之间的角度。它对应于参数s5和参数s1之间的差异。

术语s1至s6是任意的。出于实际原因，角度值被转换为0到1000之间。所有实验都表明，即使使用相似颜料，也可以基于这些参数进行区分。

为了测试这种方法，我使用了不同干涉颜料及其混合物数据库。我首先选择了一些干涉颜料，并从数据库中确定了它们s1到s6值。通过此选择，我为每个参数设置了范围。第一次测试使用ChromaFlair 190进行，其颜色的渐变平面入射光的黄橙色转变为红色、紫色和蓝色至绿色的陡峭入射光。所有ChromaFlair 190样板都可立即在数据库中找到。由于其色度，这种颜料很容易被识别为主色调。由于同一制造商提供类似的颜料，因此使用该方法的区别是合适的。

珍珠红

第二次尝试时，我从数据库中出现的制造商中选择了珍珠红作为主色调和混合物。在使用s1第一个查询中，发现了71种图案，除了珍珠红和其混合物外还有不同颜色的干涉颜料。使用s2进一步查询将结果减少到31个样板，再次使用其它一些干涉颜料。用s3进行第三个查询产生了19个点击选项的珍珠红和较少相似的干涉颜料。使用s4第4个查询，剩下16个模式，在下

Parameter s6:

The sixth parameter refers to the angle between the first part of the interference line and the described part of the aspecular line. It corresponds to the difference between parameter s5 and parameter s1.

The terms s1 to s6 are arbitrary. The angles are converted into values between 0 and 1,000 for practical reasons. All experiments have shown that even with similar pigments a differentiation based on these parameters is possible.

To test this method, I have used a database of different interference pigments and their blends. I first selected some interference pigments and determined their values s1 to s6 from the database. With this selection, I have set a range for each parameter. The first test was carried out with ChromaFlair 190, whose colour gradient from yellow-orange runs with flat illumination over red, violet and blue to green with steep illumination. All ChromaFlair 190 panels could be found right away in the database. Due to its chroma, this pigment can easily be identified as a masstone. Since similar pigments offered by the same manufacturer, a differentiation with this method is appropriate.

Pearlred

For the second try, I chose Pearl Red from a manufacturer that appears in the database as a masstone and in blends. In the first query with s1, 71 patterns were found, in addition to pearl red and its blends also different colour interference pigments. The further query with s2 reduced the result to 31 panels, again with some other interference pigments. The third query with s3 yielded 19 hits of pearl red and less similar interference pigments. And with the 4th query with s4, 16 patterns remained, which was reduced to 12 in the next query s5. These 12 patterns were exactly the manufacturer's pearlescent pigments in the database.

I have repeated the process with pearl red from another manufacturer. The query with its parameters provides only this pearl red in the database.

表1：s1至s6值显示干涉颜料特性。特别地，色彩颜料可以更好地区分。
Table 1: The values s1 to s6 characterise the interference pigments. In particular, colour-like pigments can be distinguished better.

	珍珠绿 Pearlgreen	恒星绿 Stellar Green T60-24	珍珠蓝 Pearlblue	银河绿 Galaxy Green T60-23	珍珠红 Pearlred	日晒红 Solaris Red T60-21
s1	166	175	381	367	774	770
s2	843	809	889	886	799	769
s3	2,033	929	2,664	1,485	2,709	1,420
s4	940	818	895	1,314	724	857
s5	9	984	270	253	573	539
s3	843	809	889	886	799	769

一个查询s5中减少到12个。这12种图案正是数据库中制造商的珠光颜料。

我用其它制造商的珍珠红重复了这个过程。带有参数的查询在数据库中仅提供此珍珠红。

珍珠蓝

使用第一个参数s1的查询导致来自不同制造商的珍珠蓝以及类似颜料77个点击选项。第二个查询将这些命中减少到26，并且在第五个查询中找到了该制造商所有12种蓝色干涉颜料。

用不同制造商的珍珠蓝颜料重复该过程。同样，该查询完全导向了这种颜料。

恒星绿

根据测量的干涉线（15°/ as15° - 45°/ as15° - 45°/ as-15°），通常可以读取干涉颜料的颜色区域。其位置说明了适当的光学过程。更难以区分类似的颜色干涉颜料。例如，选择珍珠绿KC9235和XillaMaya恒星绿进行测试。

与类似颜料相比，XillaMaya 恒星绿具有比珍珠绿更广泛的干涉范围。然而，在低浓度下，该跨度可以更短并且与珍珠绿相当。然而，它们仍然因干涉和非线性线的排列而不同，这在计算的参数中可识别。

这些参数清楚地显示了XillaMaya恒星绿和珍珠绿之间的差异，因此可区分两种颜料。使用干涉颜料与吸收有色颜料的混合物的实验导致相同的结果。

所描述的方法可更快且更准确地识别干涉颜料。它是一个简单的工具，尤其适用于修正。为此目的，制备具有已知干涉颜料的各种样板并作为校准标准进行测量。各种参数根据测量值计算并用于数据查询。将具有相同干涉颜料的不同样板的参数设置为查询区域，而且可根据查询的需要将此范围设置得更大或更小。

干涉颜料的颜色测量不限于颜色或颜色变化，还提供额外的信息以唯一地描述和识别颜料。这有助于再现颜色，例如，在修补漆和原产汽车涂料中。

Pearlblue

The query with the first parameter s1 resulted in 77 hits for pearl blue from different manufacturers as well as similar pigments. The second query reduced these hits to 26 and with the fifth query all 12 blue interference pigments of this manufacturer were found.

The process was repeated with a different manufacturer's pearl blue pigment. Again, the query led exactly to this pigment.

Stellar Green

Based on the measured interference line (15°/as15° – 45°/as15 – 45°/as-15°), it is usually possible to read the colour area of an interference pigment. Its position indicates appropriate optical processes. More difficult is a differentiation of similar colour interference pigments. As an example, the pearl green KC9235 and the XillaMaya Steller Green were chosen.

XillaMaya Steller Green has a much wider range of interference than pearl green, even compared to similar pigments. At low concentrations, however, this span can be shorter and comparable to that of pearl green. However, they still differ by the arrangement of the interference and aspecular lines, which is recognisable in the calculated parameters.

These parameters clearly show the differences between a XillaMaya Stellar Green and a pearl green, so that a differentiation of both pigments is possible. Experiments with mixtures of interference pigments with absorbing coloured pigments lead to the same results.

The described method identifies interference pigments faster and more accurately. It is a simple tool, especially for refinish. For this purpose, various panels with a known interference pigment are prepared and measured as calibration standards. The various parameters are calculated from the measured values and used for the data query. The parameters of different panels with the same interference pigment are set as the query area. And this range can be set larger or smaller as needed for the query.

The colour measurements of interference pigments are not limited to colours or colour changes, but also provide additional information to uniquely describe and identify the pigments. This results in assistance to reproduce colours, for example, in refinish and OEM car coatings.