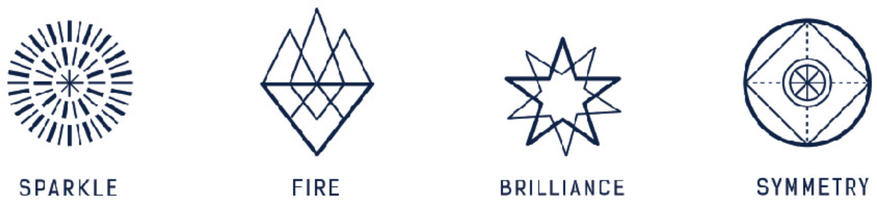
THE SCIENCE OF LIGHT BEAUTY

Understanding the Role of Light Performance in Diamond Grading



Beyond the 4Cs, Light Performance adds a new dimension to diamond grading. It provide a rich, comprehensive and objective view of a diamond's visual beauty.

EXECUTIVE SUMMARY

The 4Cs have worked faithfully and tirelessly for the diamond industry, giving three generations of diamond buyers a solid and reliable yardstick for diamond grading. In a changing marketplace driven by technology and the desire for a more profound reason to purchase, it's time to find a new approach to enhance the 4Cs. Retailers need to give the current generation of consumers a deeper, up-to-date experience of the diamond's unique character. And the answer is Light Performance.

With the development of science-based measurement of the variables that make up the diamond's interaction with light, it is now possible to give a Light Performance grade based on an objective standard of light beauty.

New approaches to Light Performance measurement have created Light Performance grading that is accurate, reliable and quantifiable.

Working together, Light Performance and the 4Cs are a powerful, modern approach to diamond evaluation. When the Light Performance grade and the 4C evaluation result are combined, they hold an incredibly rich story of the diamond that can be passed on to the consumer.

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1- INTRODUCTION

Unlike other gemstones, the diamond's appearance is a direct consequence of the way the stone interacts with light. Direct measurement of a diamond's performance in the light provides a holistic approach to diamond grading that combines all parameters that affect diamond beauty, such as proportions, clarity, color and symmetry.
At the same time, light performance measurement presents an objective standard of what has always been a debatable evaluation, subject to the perception of the individual viewer.

This creates a new and revolutionary way for diamonds to be valued and appreciated, by sellers and buyers alike.

The diamond's appearance is based on two optical attributes:

1. Refractive Index (RI) - RI is the relative speed of light in the diamond compared to empty space. The RI of diamonds is 2.417, substantially higher than most other gems. The RI is the source of the brilliance of diamond.

2. Dispersion - Due to the fact that every color travels in the diamond at a different speed, dispersion turns white light into its color components. The difference in RIs between the violet and the red defines the diamond's dispersion. This dispersion of diamond is 0.044, which is one of the highest values for any natural, transparent gemstone.

The Key Determiner of Light Performance

Cut and craftsmanship is the vital determiner of a diamond's light performance. In addition to natural inclusions and flaws, difference in proportions is indicated in the difference between each individual diamond's appearance.

Throughout the history of diamond cutting, from point cut, single cut, Mazarin cut, old mine cut, old European cut to the current modern cut, the effort to extract beauty from the diamond has been ongoing. However these historical efforts to perfect the diamond appearance, including Marcel Tolkowsky's famed "ideal cut" model, were conducted with the limiting nature of 2D graphical and mathematical imaging available at the time, which only took into account 16 main facets and the table. Modern advents in computerization and 3D modelling have enabled the analysis of diamond cut to reach new depths of precision.

The Traditional Approach: Brilliance, Fire & Scintillation

Much research of diamond cutting traditionally defined three concepts of a diamonds appearance: Brilliance, Fire and Scintillation, and the relational balance between the three. In 1919, Marcel Tolkowsky published his calculations, taking into account both brilliance and fire. Limited though they were when compared to modern standards enabled by advanced computerization capabilities, Tolkowsky's calculations were a breakthrough that formed the basis for all brilliant cut modifications and standards. With Japanese research in the 1970s and 80s resulting in the development of the Firescope, an analysis of the optical performance of all 57 facets of the diamond enabled further progress towards an Ideal cut that displayed even higher levels of Brilliance and Fire.

Through the years, there have been many cut standards devised and published, such as American Standard, Practical Fine Cut, Scandinavian Standard, Ideal Brilliant, Parker Brilliant and more. Cut grading is addressed independently from the other 3Cs (Carat, Color and Clarity). Most cut standards determine the cut grade by craftsmanship factors, particularly the symmetry and polish quality grades.

Some of the more renowned approaches to determining cut grade include:

Linear approach

There are several grading standards that use the linear approach. The linear approach is based on a selected parameters. For example, Excellent cut denotes table proportion between 53% and 59%, or Very Good cut between 50% and 53% and also between 59% and 63%.

The same grading is conducted for all proportion values participating in the grade analysis.
The final grade is the lowest grade found for all parameters. Some laboratories added limiting factors, i.e. the sum of the crown angle and pavilion angle for Excellent cut should be between 78° to 82°.

GIA Cut Grading approach

The GIA Cut Grading approach is based on computerized calculations of the proportions (average values) of the diamond in terms of Brilliance, Fire and Scintillation. Factors are given to each one of the parameters (the factors are not disclosed). The result of this calculation is a figure that expresses the "beauty" of the diamond. These calculations are conducted for an entire set of proportions numbering in the tens of millions. This range of figures is divided into 5 grading groups, Excellent to Poor. Note that there are other parameters added to determine the final grade, such as symmetry and polish.

AGS approach

AGS cut grading uses the actual 3D model of the diamond, rather than average parameters used in other standards. Based on the 3D model, the algorithm calculates two groups of parameters:

1. Group 1 – Brightness, Fire, Leakage, Contrast Weight, Ratio, Durability and Tilt

2. Group 2 – Girdle, Culet, Symmetry and Polish (the last two are visually estimated by the grader).

The total grade is calculated based on these parameters. The grading is denoted by numerical values, with 0 as the best cut grade. The AGS also has a proportions-based cut grading system.

Light Performance Approach: Brilliance, Fire, Sparkle and Light Symmetry

Since a key element in the diamond's appearance is its cut and craftsmanship, the Light Performance approach, developed by Sarine, is a holistic analysis of cut that measures and grades the beauty of the diamond as seen by the observer. The Light Performance grade is based on calculations of the sum of the diamond's cut, color, inclusions, standard of polishing, and a host of other factors affecting the diamond appearance.

The light performance grading system was developed based on analysis of more than 23,000 diamonds in several countries and from multiple manufacturers and retailers. The variations and distribution of the diamonds researched covered most of RBC diamonds that comprises the diamond trade. Diamonds measured were sourced from manufacturers that are known for providing the best cut diamonds, as well as from manufacturers of diamonds with poor cut grade and clarity of I3.
Such a broad variety and volume of diamonds enabled the acquisition of an enormous pool of data about light performance, and specifically the interdependency of light performance and clarity or cut grade.

The data was used as the basis for the development of a grading scale for four parameters that provide a comprehensive summary of light performance: Brilliance, Fire, Sparkle and Light Symmetry. These parameters are an extension and refinement of the commonly used parameters of Brilliance, Fire and Scintillation used to examine a diamond's beauty, providing a more thorough and complete analysis of light performance based on cut factors. The Light Performance approach also presents a new concept of total grading based on the combination of the four individual parameters into one summary light performance grade.

2– MEASURING LIGHT PERFORMANCE

There are two methods for measuring and determining the light performance of diamonds:

1. Indirect – examining the proportions and the 3D model of the diamond, using techniques such as ray tracing
2. Direct – measuring the components of the diamond's Light Performance

The direct approach requires generating a hemispherical environment for the diamond that provides a 360-degree setting in which light performance features can be observed. The environment must not be static, as the appearance of the diamond varies depending on the observation point, stone movement and lighting changes.

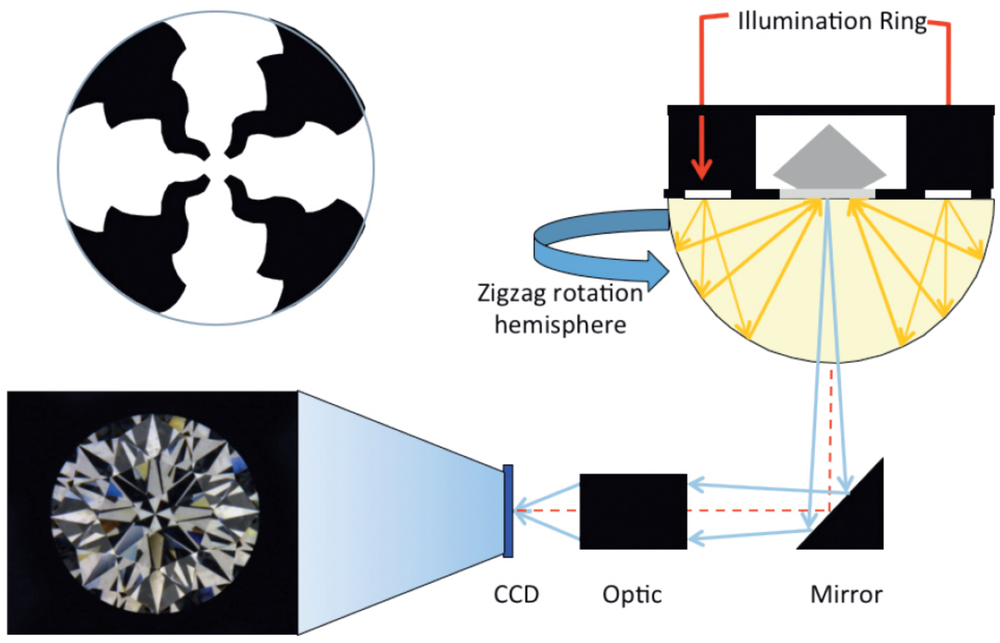
The GIA attempted the use of multiple patterned hemispheres for testing the brilliance of diamonds during its cut grade research. The patented hemisphere designed by Sarine (see fig.1) addresses the four parameters defined as affecting light performance. Featuring a zigzag of black and white patterns of equal area, the hemisphere rotates during the measurement sequence so part of the light hits the white portion of the hemisphere and is returned as diffused white light to the diamond, and part of the light is absorbed by the black portion of the hemisphere.

Fig.1

With this arrangement, some portion of the diamond at a certain orientation will receive white light only, some portion will receive no light at all, and some portion will receive partial light.

The Sarine Light system for measuring lightperformance generates multiple images of the diamond under different illumination conditions.

The system is comprised of the following main components:



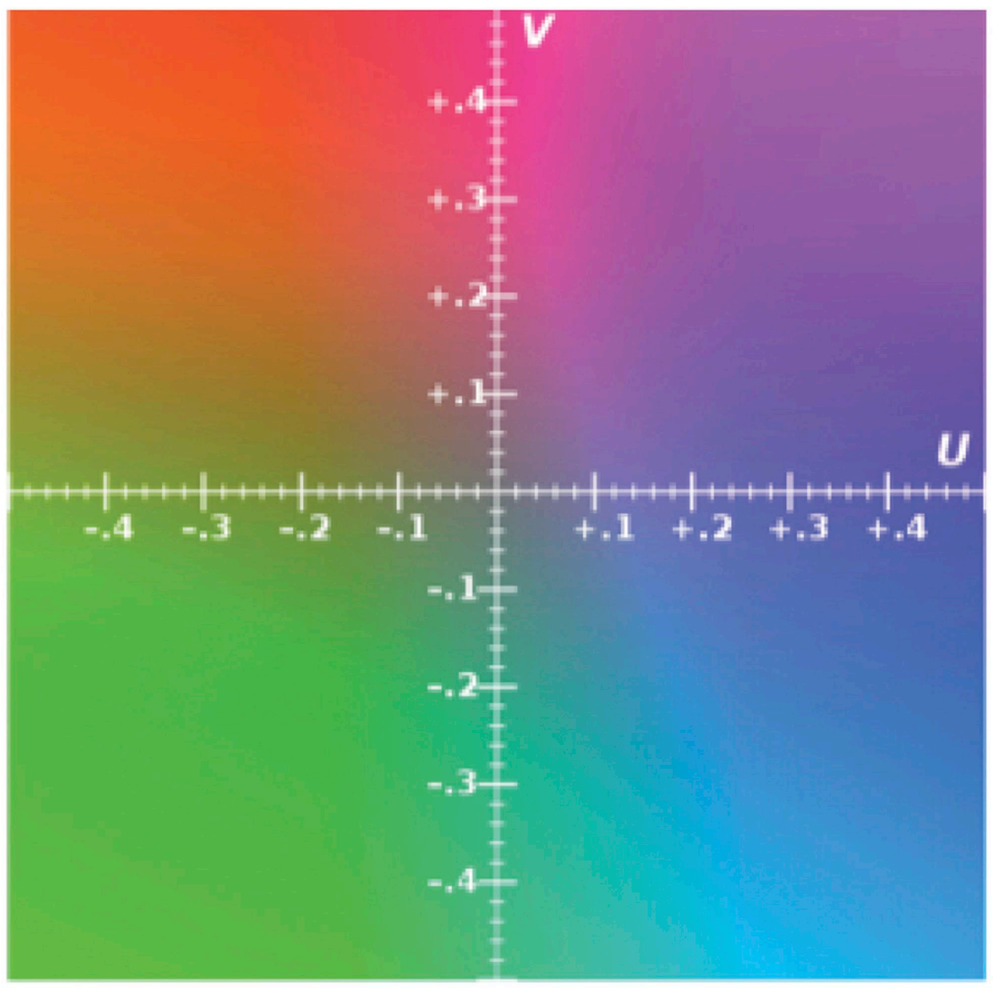
- **Transparent platform -** The diamond is placed on the platform and centered via a special tool. During the measuring cycle, the diamond is fully enclosed and is not exposed to any external light.
- **Illumination ring -** Utilizing a multiple LED source in white color.
- **Hemisphere -** The hemisphere rotates during the measuring cycle, with light return to the diamond differing with each movement.
- **CCD camera -** Recording up to 180 images of the diamond each time the hemisphere rotates to a new position. (A 1 carat diamond will record approximately 1 million pixels).
- **Software -** based imaging analysis.

Image analysis

The system records three components for each pixel of the images taken by the CCD camera. These components are known as YUV.

- Y denotes luminance, representing the perceived brightness in an image (the "black-and-white" or achromatic portion of the image). Luminance is typically paired with chrominance. Luminance represents the achromatic image, while the Chroma components represent the color information.
- U and V are the chrominance (color) components.

Here is a typical UV plate:



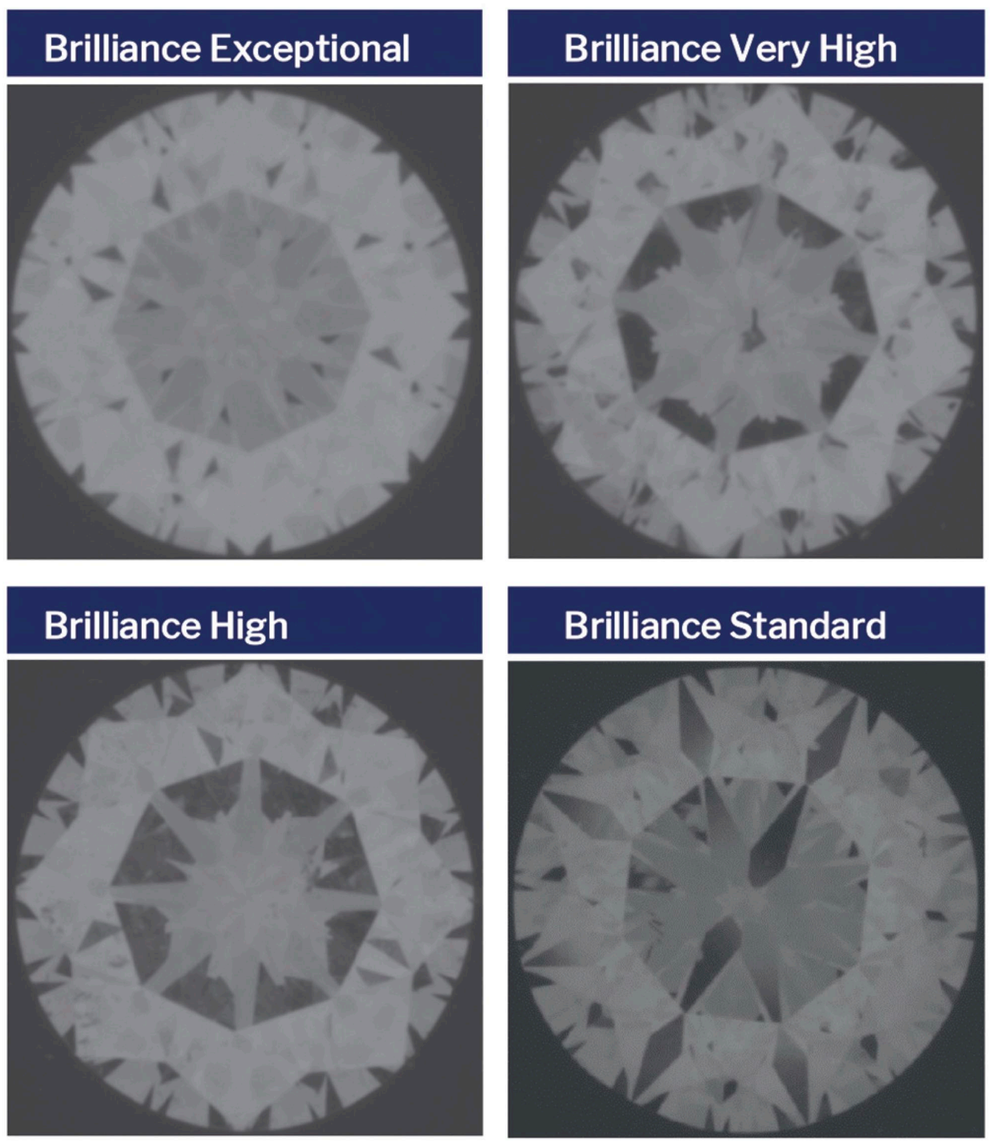
The values of the UV describes the color and its saturation – the higher the value, the color is more saturated. The absolute saturation of a color is described as $= \sqrt{(\Delta U)^2 + (\Delta V)^2}$

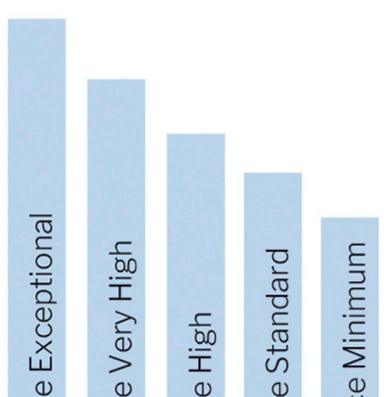
Based on these pixel component recordings, the Light Performance system defines and measures four parameters that cover all aspects of a diamond's light performance. They are Brilliance, Sparkle, Fire and Light Symmetry.

3- LIGHT PERFORMANCE PARAMETERS

Measuring Brilliance

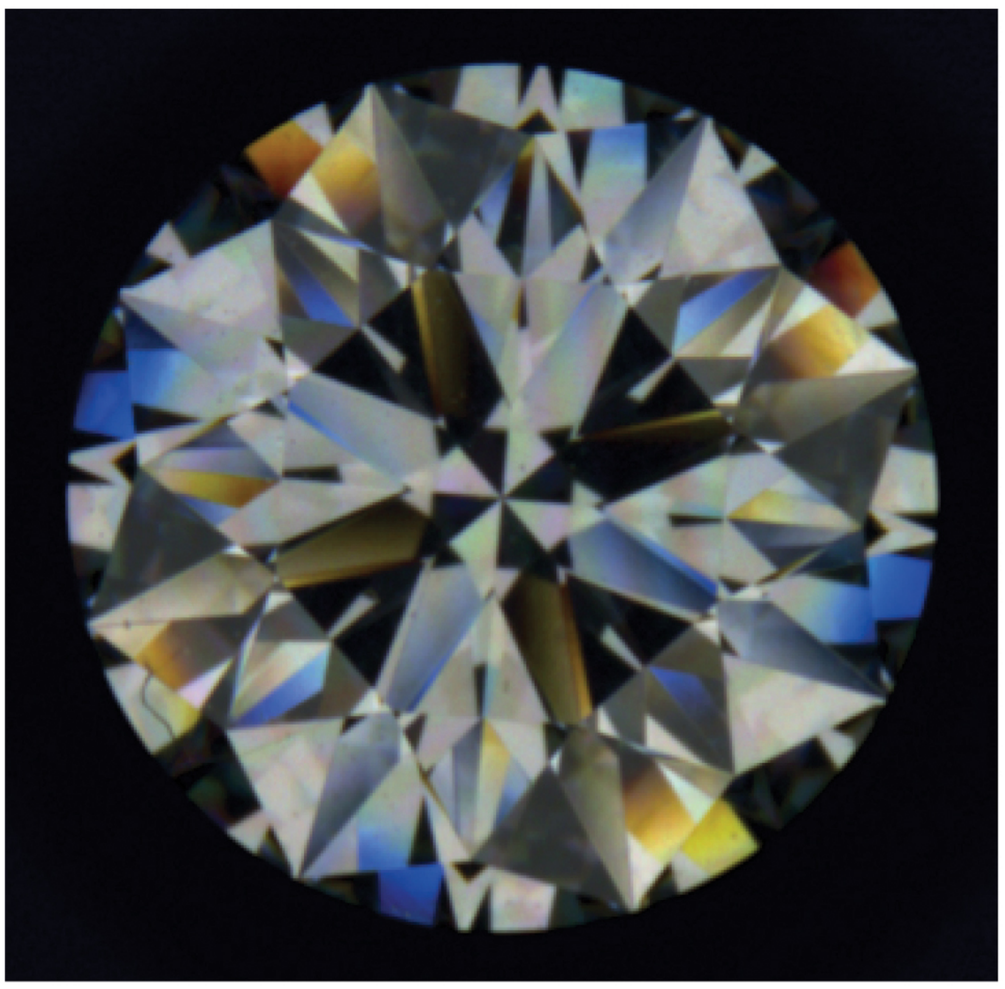
Brilliance is defined as the intense bright light that shines from the diamond. Brilliance is calculated as the average gray level (luminance or Y component) of the composition image (the image of the diamond composed of all the images taken by the CCD camera) as recorded inside the outer edge of the image. The higher gray level will provide a higher brilliance level. The images below demonstrate five levels of brilliance.

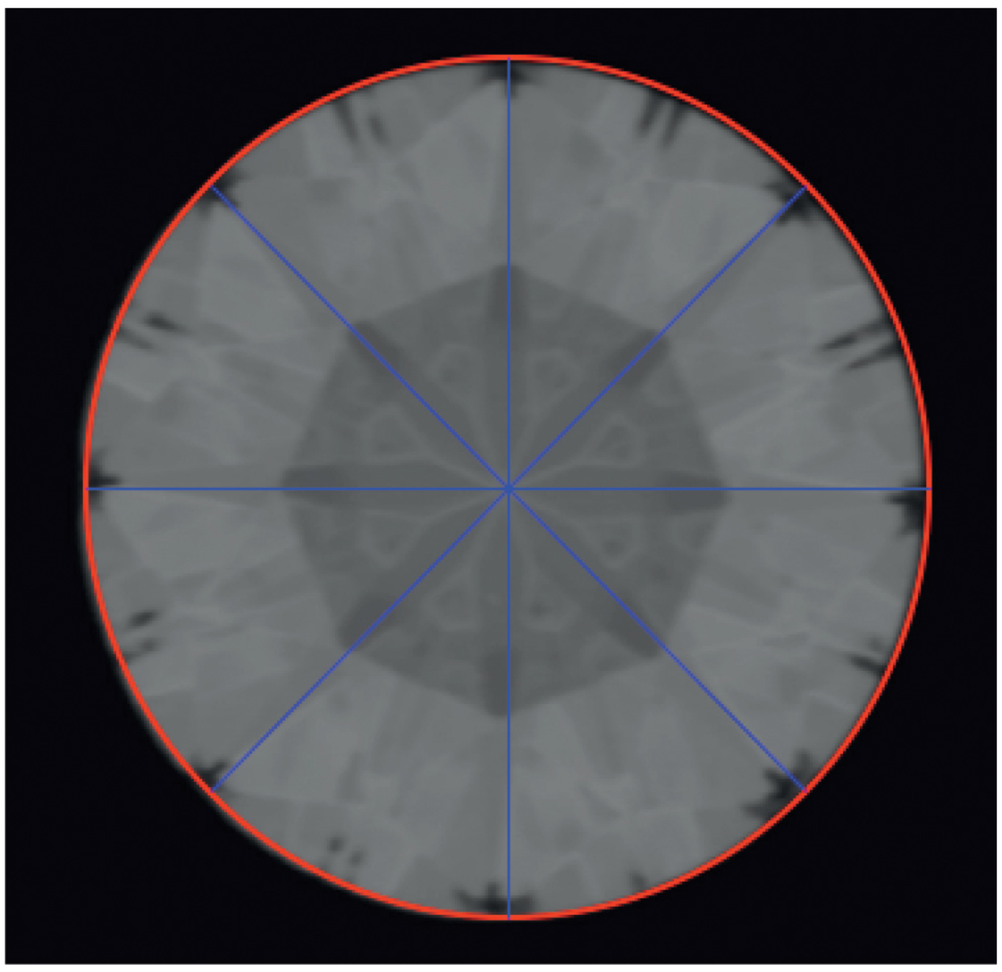




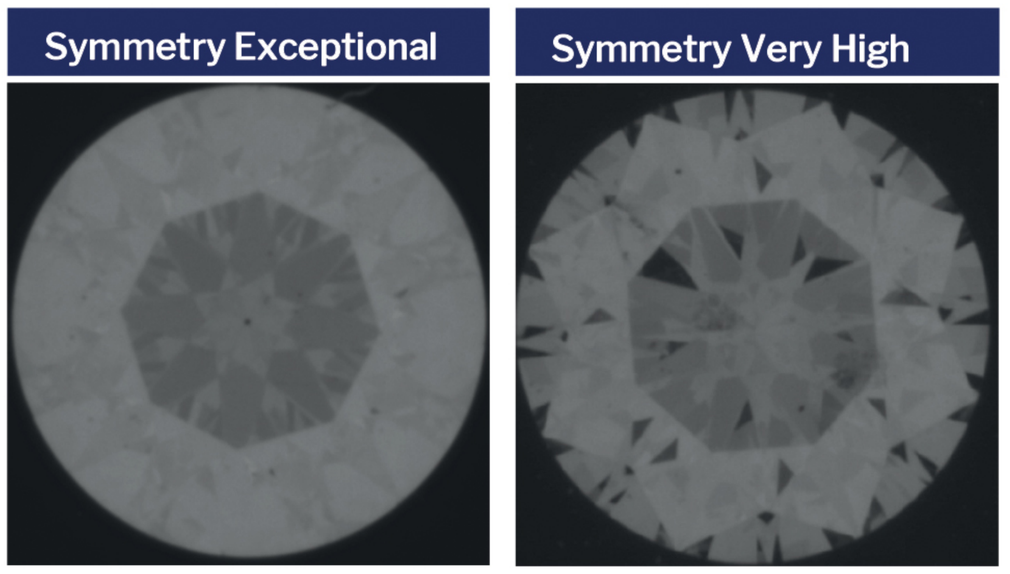
Measuring Light Symmetry (round brilliants)

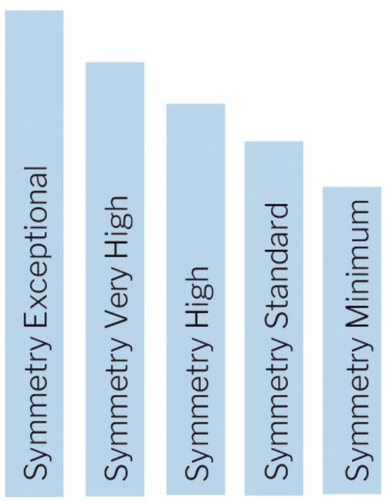
Light Symmetry is defined as the measure of light distribution in the diamond, based on cut and inclusions. Light Symmetry is calculated by composing one gray level image from the multiple images recorded by the CCD camera. The mean gray level is calculated by an algorithm which measures the luminance or the Y component values of 8 corresponding pixels from the segments, at differences of 45 degrees.





Then the system calculates the difference between the actual gray level of each cell and the average of this group. Next, the difference of this group of pixels is calculated. This is repeated for the entire image. The sum of all the sums of all the groups is the symmetry calculation. The higher the value, the lower the symmetry. Note that low symmetry may be a result of non-symmetrical polished facets or the presence of internal inclusions.

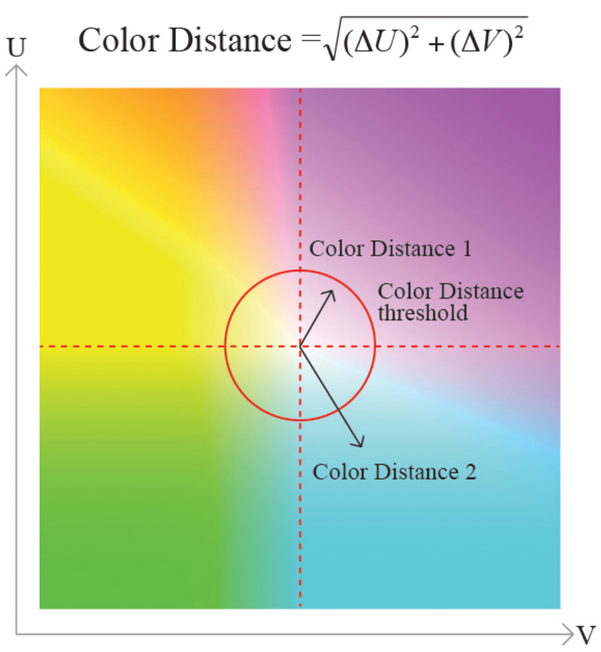




Measuring Fire

Fire is defined as the vivid colors of the rainbow that radiate from within the diamond.

The first step in assessing the diamond's Fire is assigning a Fire value to each pixel in the multiple images taken of the diamond. This is achieved by calculating the color distance. Then the color distance is assessed as to whether it is greater than the threshold value. If it is below the threshold, this pixel has a Fire value of 0 (see Color Distance 1 in image below). If it is above the threshold, it is a legitimate Fire pixel (see Color Distance 2 in image below).



The second step is to note if the pixel belongs to a cluster of pixels, or if it is an isolated pixel that may be due to an optical artifact, with no effect to the Fire as perceived. To do so, the system considers only pixels that are part of a large enough cluster. If the pixel doesn't belong to a cluster, it again receives a Fire value of 0.

Once Fire measurement is complete, the system analyzes two parameters of Fire: Static Fire and Dynamic Fire.

Static Fire

Static Fire determines the total Fire effect. Static Fire grading is achieved by calculating the sum of all color magnitudes from all the images, factored by the size of the diamond as measured by the system. This method is designed to prevent low Static Fire readings for all small stones with a small quantity of pixels.

Dynamic Fire

Dynamic Fire is the measure of how the relevant pixel changes during varied illumination situations at different positions within the hemisphere. If the change is above a certain threshold, the pixel is considered as contributing to the Dynamic Fire, and the scale of the change is recorded. The sum of the recorded changes is the Dynamic Fire calculation.
Total Fire is calculated using the Static Fire and the Dynamic Fire values with different factors.

Measuring Sparkle

Sparkle is defined as the flashes that burst out of the diamond as it moves Sparkle is calculated via measurements of Contrast, Dynamic Fire and Static Fire (with different factors).

Contrast

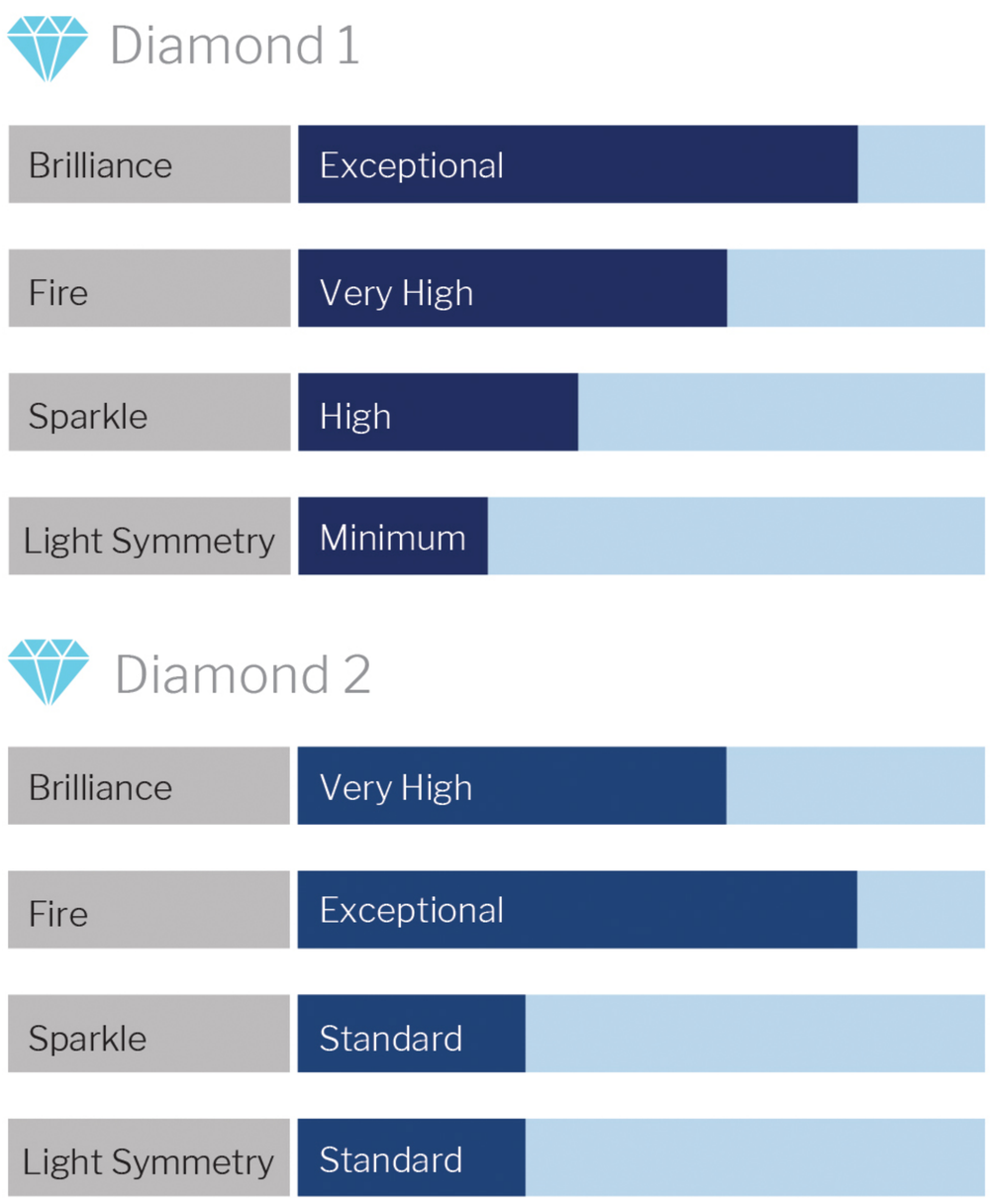
The system analyzes changes in the diamond's appearance due to changes in illumination. Specifically, each pixel is analyzed as to how its gray level (luminance or Y factor) changes under different light conditions, via images taken at different rotation positions of the hemisphere.
If the change is above a certain threshold, the pixel is marked as having a contrast.
By dividing the quantity of marked pixels by the total quantity of pixels in the stone, the contrast is determined. Contrast is higher when the value of the calculation is higher.

4– GRADING LIGHT PERFORMANCE

A common problem with the 4Cs grading system is the conflict that arises when comparing various diamonds. Seethe following table; which diamond is the better choice?

4Cs	Diamond 1	Diamond 2
Carat	1.05	1.05
Color	G	H
Clarity	SI1	VS1
Cut	Excellent	Very Good

The same conflict may arise with Light Performance. Here's a comparison of two diamonds with the same carat weight, color, clarity and cut, with the following individual Light Performance parameter gradings:



Based on these gradings, it is difficult to state with certainty which of the diamonds has better Light Performance.

Although the Light Performance approach entails four parameters, for purposes of trade, it is preferable to present a unified grade that summarizes the diamond's light beauty. This enables clarity in comparison of two or more diamonds. In cases of diamonds having similar grade, the consumer may look for the diamond that matches his/her personal preferences, such as higher level of Brilliance, or more intense Sparkle.

Total Grade Scaling

The scaling of the total grade is based on four grades, with grade divided into sub-grades featuring a star system, from three stars (highest) to one star (lowest). The total grading system includes 9 possible grades:

There are numerous possible grade combinations of the four Light Performance parameters, which can be mapped into the various total grade levels. Here are some examples:

Diamond No.	Possible Grade Combinations for the 4 Light Performance Parameters: Brilliance, Sparkle, Fire & Light Symmetry					Total Light Performance Grade
	Exceptional	Very High	High	Standard	Minimum	
1	4	0	0	0	0	Ultimate ★★★
2	3	1	0	0	0	Ultimate ★★☆
3	3	0	0	1	0	Ultimate ★☆☆
4	2	0	1	0	1	Premium ★★☆
5	1	0	1	0	2	Premium ★☆☆
6	1	0	0	0	3	Classic ★★☆
7	0	1	0	0	3	Classic ★☆☆
8	0	0	0	1	3	Low ★★☆
9	0	0	0	0	4	Low ★☆☆

*This table is for demonstration purposes only. It shows a small selection of the many possible combinations that create the total light performance grade.

5- HOW LIGHT PERFORMANCE GRADING ENHANCES THE DIAMOND SALES PROCESS

When a layperson is searching for a diamond, the 4Cs information, such as VS2 clarity and G color, is limited in its meaning. In most cases, the consumer is not well versed enough in diamond analysis to comprehend the effect of the size of the culet or the consequence of the small natural near the girdle in the diamond pavilion. The retail customer is actually seeking a diamond with their preferred stone cut and shape, diamond setting, stone quality, stone size and price tag, rather than a host of

'technical' information about the diamond that is more of interest to diamond professionals. Let's take an example of two diamonds being sold side by side in a jewelry store:

4Cs	Diamond 1	Diamond 2
Carat	0.55	0.55
Color	G	E
Clarity	SI1	VVS1
Cut	Excellent	Excellent

According to the price list, the first diamond is valued at half the cost of the second diamond. However, when comparing light performance, there may be a case where Diamond 1 in fact outscores Diamond 2. Customers who prefer the light beauty of Diamond 1 over the rarity of Diamond 2
will choose to purchase Diamond 1 at half the price. The light performance grading enables a deeper pricing policy that helps consumers find the best fit according to visual preference and budget, and enables retailers to provide a more focused, personalized purchase experience that meets the needs of the new millennial generation of customers.

6– CONCLUSION

The Light Performance approach provides objective, technology-based comparison of diamonds. Rather than having to rely on the word of the seller, the wary millennial consumer will receive the technological proof they crave, due to their inherent trust in technology over the salesperson.
The 4Cs alone cannot deliver complete information about a diamond's appearance to the consumer. Adding light performance parameters generates reliable and trustworthy information that answers commonly asked questions about the diamond's appearance.

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A version of this article, entitled "The Sarin Light System" by Akiva Kaspi, featured in Gems & Jewellery journal, vol. 22, no. 8, Nov/Dec 2013, p. 12-15

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