ARTIST'S ARTICLE

Chromatic Notation of Music: Transforming Bach and Webern into Color and Light

Brigitte Burgmer

ABSTRACT

The author describes the development of her color:tone system, which began with her coloring of the harmonic structures in the Prelude in C Major from *The Well Tempered Clavier,* Part I, by Johann S. Bach. She describes her Extended Circle of Fifths, which condenses the harmonic system into one gestalt. Besides converting Bach's Prelude to color, she has converted three other preludes by Chopin, Busoni and Scriabin and an early 12-tone study by Webern. Burgmer describes and evaluates her experiment in composing music with colors: She used her color:tone system to create a new piece of music as an addition to Webern's "Piano Piece." She also discusses her transformation of music graphics into holograms. She contends that these music holograms have their own aesthetic value and exist independently as artworks, parallel to the musical pieces on which they are based.

I work conceptually with different media. Since the beginning of the 1980s, I have produced a body of installations and holographic objects incorporating painting, sculpture and sound. My first music-related artwork was *Sounding Railings,* which I designed for MediaPark Cologne in 1992 [1]. The two steel railings near the park's central lake are composed of musical instruments—bars, tuning forks, bells and gongs—within a solid metal framework. These elements are arranged in a number of small and large groups, creating a rhythmically interesting ornament. The height of the instruments changes step by step, so the *Sounding Railings* generate different tone colors and pitches as the passerby plays them (with a key, for instance, or some other object). Both a visual aesthetic and an aural concept were relevant to the design, as well as technical and architectural conditions. The *Sounding Railings* serve as railings and musical instruments at the same time. This work, which involved studies of urban design and musical structures, led me to the following research in color and music.

A Color Palette for Bach

I first began to develop the color:tone system as an independent project, unrelated to the visual artwork I was doing at the time. But I had been looking for a means of visually understanding music ever since I began playing the piano. I had always used colors to structure music notation. Having been introduced to the concept of Funktionsanalyse [2] by my teacher, composer hans w. koch, I adopted this idea to systematize my use of color. The Prelude in C Major from Bach's *Well Tempered Clavier,* Part I, which I played enthusiastically at that time, is ideal for this sort of harmonic analysis, because the form of the broken chords is the same in 32 of 35 measures. Through analysis of each chord and of the harmonic development of the work, I was able to see how Bach varied cadences [3] and sequences [4] inside a tight frame. As a visual artist, I wanted to see this analysis of harmonic form and function depicted in colored graphics. For my representation of this prelude I developed a palette of colors, beginning with a brilliant sunny yellow for the tonic C and cyan blue for the dominant G. My choice of the color yellow was based on my synesthetic perception of the sound, whereas the choice of blue was based on the contrast between cold and warm colors. I chose green, a mixture of these opposing tones, to represent the subdominant. The colors of the fundamentals C–F–G of the C major cadence in the resulting palette are therefore yellow–green–cyan blue. Next I chose orange for the parallel tonic, as it is a warm color close to yellow; the parallel dominant became magenta; the parallel subdominant, a mixture of orange and magenta, which produced red. The colors of the fundamentals A–D–E of the A minor cadence are thus orange–red–magenta.

Since my color system is based on these two cadences, I faced a problem concerning the six other tones of the chromatic scale. I related them to their neighbors through brightening, darkening and mixing colors. Following is a list of the tones as they appear in the prelude:

B (bar 3): dark blue
F sharp (bar 6): light green
C sharp (bar 12): light orange
B flat (bar 12): violet
A flat (bar 14): blue-green
E flat (bar 22): dark red

The colors of this scale do not span the color spectrum, as do the colors used in certain historical attempts to construct color organs [5], such as mathematician Louis-Bertrand Castel's Harpsichord for the Eyes and Alexander Rimmington's Color-Organ. The construction of both of these instruments was based on an analogy between sound and light wavelengths, but the results were different. C was blue in Castel's spectral scale and red in Rimmington's.

When I developed my color system I was not concerned with experiments involving synesthetic perception, but rather with visualizing the structure of music.

The Extended Circle of Fifths

Intrigued by the image of the harmonic development of the Prelude in C Major that my color:tone system had produced, I entered the results of my analysis into what I called the Extended Circle of Fifths (Fig. 1). Usually, the well-tempered tonal system is represented by the Circle of Fifths, a visualiza-

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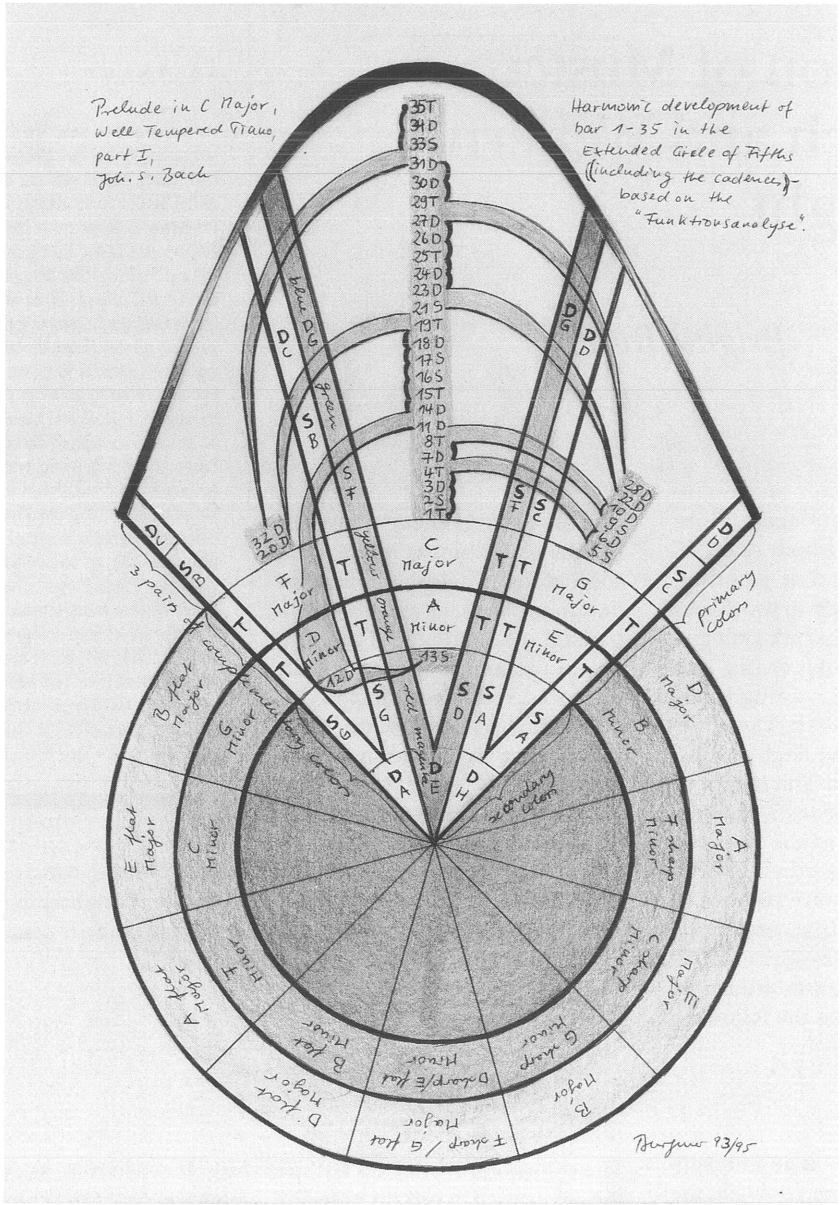


Fig. 1. A visualization of the harmonic development of bars 1–35 in the Prelude in C Major to Bach's *Well Tempered Clavier*, Part I, using the author's Extended Circle of Fifths. Colored pencil, 29.8 × 21.1 cm, 1993. This visualization reveals the harmonic development of the prelude as an image similar to a baroque ornament. The cadences of C major and A minor—arranged in the order G–F–C–A–D–E—are assigned color values ranging from cyan to magenta.

tion that resembles a clock face [6]. The Circle of Fifths represents only the 12 major and minor keys, whereas this extended circle combines the keys of C major, F major, G major and the parallel minor keys with all their cadences in order to illustrate my harmonic analysis. The C major and A minor cadences are arranged in the order G–F–C–A–D–E according to the spectral order of their corresponding tones: cyan blue–green–yellow–orange–red–magenta.

In this table (Fig. 1) I listed each bar of Bach's Prelude, starting with the perfect cadence of the first four bars—tonic–subdominant–dominant–tonic (indicated in the table as 1T–2S–3D–4T, respectively)—in the section of C major and proceeding to list the other bars according to their harmonic function. When the colors of the bars are connected in a line, the resulting image of the harmonic development appears similar to a nearly baroque ornament, though it is not completely symmetrical.

I then designed the entire Extended Circle of Fifths. Figure 1 shows the combination of the color spectrum G–F–C–A–D–E with the cadences opposite F sharp major/G flat major and D sharp minor/E flat minor, representing all 12 tones on the vertical axis as both tone and color. The scale can be completed on any other axis and in each of the six rings of the circle.

The principle behind the Extended Circle of Fifths is demonstrated in Fig. 2. The placement of the tonic C is indicated by the six black segments in the semicircle. If we understand the figure as analogous to a clock face, then C major is the segment at 12 o'clock. Each possible function of C is shown in the other segments. Starting from eight o'clock, these functions are the dominant parallel (Dp) in A flat major, tonic parallel (Tp) in E flat major, subdominant parallel (Sp) in B flat major, dominant (D) in F major, tonic (T) in C major and subdominant (S) in G major. The hatched segments in the figure demonstrate the six positions and functions of F sharp/G flat in the other semicircle. This configuration is the same for each of the other 10 tones. The harmonic system has thus been condensed into one single gestalt, rotated 12 times—one rotation through the circle for each tone.

Tonal and Atonal Colors

After I made this color study of harmonic theory, I undertook the chromatic notation of the "Piano Piece" by Anton Webern. This was the first in a series of chromatic notations I made in 1993. Webern's composition is a very early 12-tone study in his sketchbook of 1925 (opus posthumous), and instructions on how to perform the second part are incomplete. Webern composed the "Piano Piece" with a 12-tone series that disregards traditional tonality. Since he gave up all harmonic relations (such as those visible in the chords of Bach's prelude), harmonic analysis of the piece was not possible. I was curious to see how a 12-tone composition would look in a visual representation that would include the aspect of time. I converted the notes into colors without taking into account the differentiations of pitch or the performance instructions. The G clef and the bass clef are separated by a line representing c'. Along this time axis, the duration of the tones is registered horizontally and that of the chords vertically. I was surprised by the beauty of the irregular and nevertheless constructed order—

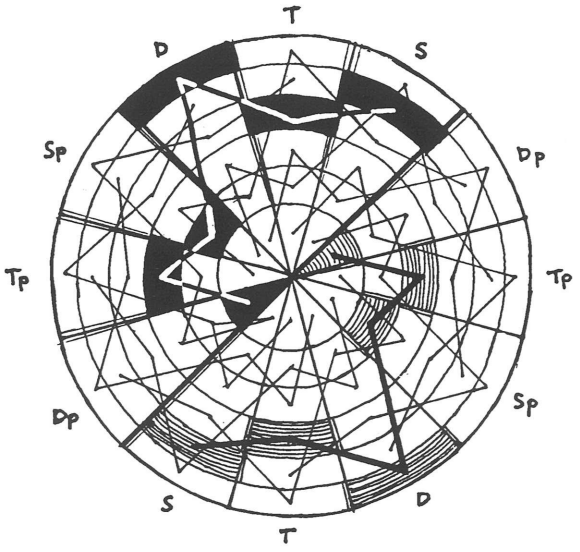


Fig. 2. Extended Circle of Fifths, black ballpoint pen, 29.8 × 21.1 cm, 1994. This graphic image includes the 24 keys and all their cadences, condensing the law of the harmonic system into a single gestalt that is the same for all 12 tones of the chromatic scale. If we consider the circle as analogous to a clock face, C major is at 12 o'clock. The six possible functions of C are shown in the black segments. Starting at eight o'clock, they are as follows: the dominant parallel (Dp), tonic parallel (Tp), subdominant (Sp), dominant (D), tonic (T) and subdominant (S).

somehow similar to a "wild regularity" without repetition of any motif—and decided to continue with a chromatic notation of Bach's Prelude in C Major.

Then—for the purpose of structural comparison—I completed notations of three other preludes. Several composers have composed cycles of preludes referring back to the *Well Tempered Clavier*. I chose preludes in C major from three such cycles of 24 preludes: Frédéric Chopin's op. 28 in C major, Ferruccio Busoni's op. 37 and Alexander Scriabin's op. 11. The chromatic notations of these preludes demonstrate characteristics of their architecture [7]. For example, the repeated figure of two "stairs" in each bar of Bach's Prelude in C Major vividly illustrates the change of tones. When I reflected on the visual structure of the chromatic notations I realized that the harmonic development and the strong fundamentum of Busoni's prelude were similar to Bach's. Busoni built a solid and regular architecture, with one exception: the "black hole" in bar 32. Composed in 1881, Busoni's prelude seemed in this respect more traditional than Chopin's composition of 1839. Chopin repeated and rebuilt musical "modules," moving them from bass clef to the treble clef and vice versa. Of the three, Scriabin created the most irregular architecture. He composed different rhythms of pauses in the bass clef only in the first 12 of 26 bars, whereas the continual and quick change of tones in the treble clef creates a striped pattern resembling (to hazard a disrespectful comment about the piece as music) an awning—but one so unusual and marvelous that no one could have invented it. We can also see that Busoni has more in common with Bach than with Chopin, considering the substructure of the bass.

But there can be no greater contrast than the one between Bach's Prelude, based on classical harmony, and Webern's atonal "Piano Piece." Webern's tonal architecture is atomized; each measure is different. My chromatic notation of this piece became a symbol of atonality in general for me. Abandoning the laws of harmonic chords and the gravitation of tonal centers leads to varied, free-floating constructions. They remind me of the dramatic breaks in the natural sciences during the first decades of this century, which radically changed the static *Weltanschauung* [8].

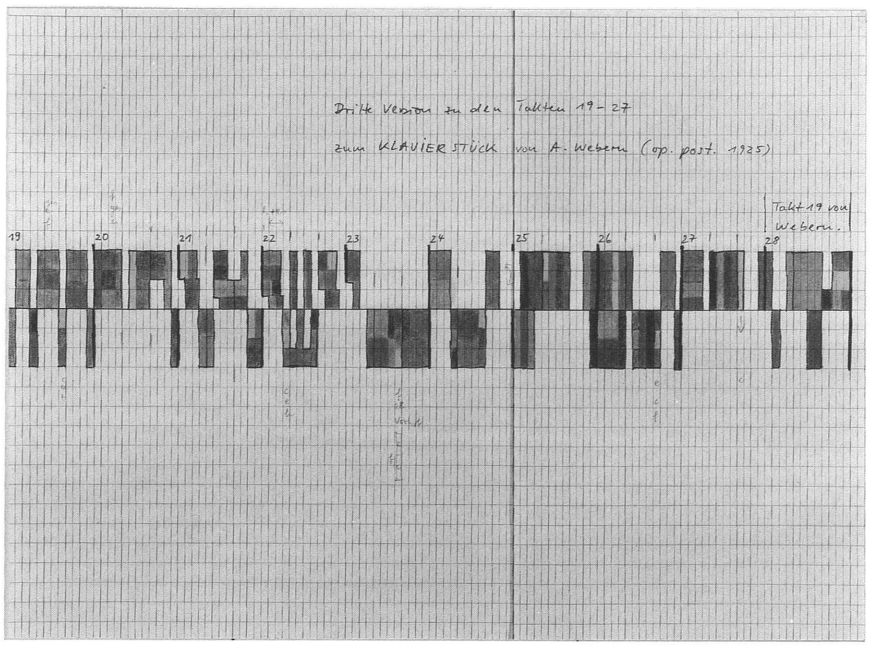
Music itself cannot be depicted, although many titles of artworks refer to it, such as *Fugue in Two Colors* by Frank Kupka (1912) [9]. Most artists who are influenced by music create works that are visual analogues of their subjective sensations, their feelings and what they imagine when listening to the music. Having studied the effects and affects of color, shape, space and dynamics, they relate pictorial elements to musical ones.

For me, musical graphics exhibit their own beauty in their composition, color, shape and rhythm, as if it were inevitable that the quality of music manifests itself when converted into color and form.

Composition of Colors

Inspired by the beauty of the chromatic notation of "Piano Piece," I risked an artistic experiment: I attempted to use color to compose additional bars for this piece (Fig. 3). Corresponding to the series of tones Webern chose for the piece (A–B flat–B–G sharp–G–C sharp–D–E flat–F sharp–F–E–C), the series of colors in my chromatic notation was orange–violet–dark blue–blue-green–cyan blue–

Fig. 3. Third version of bars 19–27, from the author's addition to Webern's "Piano Piece" (op. post. 1925), colored pencil, 1993. Using Webern's 12-tone series, the author derived color values that cover the spectrum and painted music. The G clef and the bass clef are separated by a time axis representing c', and the duration of the tones is registered horizontally, without incorporating differentiation of pitch or performance instructions.



light orange–red–dark red–light green-green–magenta–yellow. I analyzed the results of my chromatic notation in order to derive rules of visual composition for my addition to the piece.

There are some recurrent structural elements in Webern's composition, such as the triplets in the second part, but it is obvious that he composed each measure totally distinctly, and it is fascinating to see how he did so with the 12-tone series. It was a challenge to invent new and appropriate color structures for the piece without the support of a piano.

I created three versions of nine bars for the "Piano Piece," which itself has 19 bars; each version is meant to be integrated as bars 19 to 27, with Webern's bar 19 becoming the final bar 28. Eventually, I transformed the last of these versions into musical notation, fixing the pitch of the tones and adding performance instructions (Fig. 4).

This experiment was not a serious effort to compose "good Webern-like music," but a pleasurable effort to paint music. In fact, I found the painted tones of the nine bars more beautiful and fitting than their sound; visually, the chromatic notation is somehow similar to the "Piano Piece," but, if the intention were to produce music that conformed to Webern's personal style, the chromatic notation would need improvement.

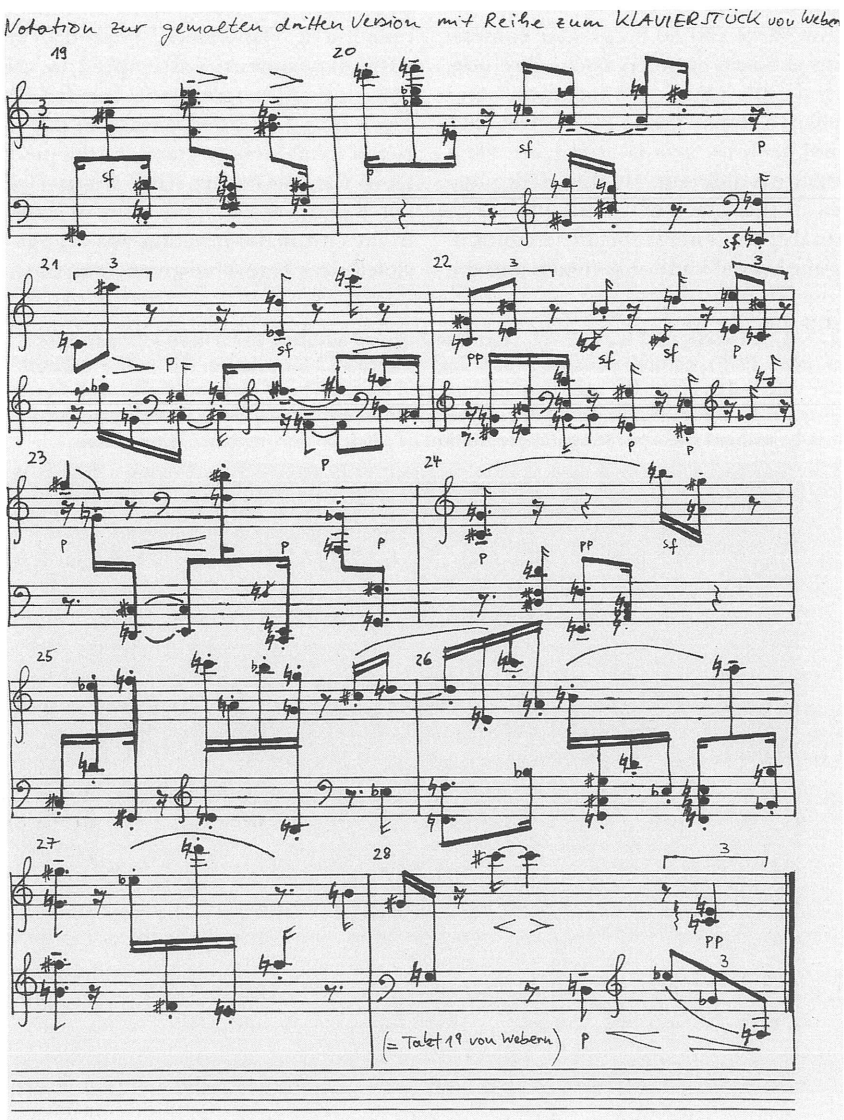
MUSIC HOLOGRAMS

I discovered the possibility of transforming the drawings into holograms in the spring of 1993. The Photo Engineering Department at the Institut für Licht und Bautechnik (ILB) at the Fachhochschule Köln had just developed a new technique for making holographic optical elements (HOEs), and one 2-×-1-cm HOE would match one unit of my chromatic notations. I was impressed by the wonderful brightness and beauty of a first trial in red, blue and green. Joerg Gutjahr, a professor at the Institute, had an open ear for my project, even though (or perhaps even because) the automatic exposure system with the helium-neon (HeNe) laser would have to be improved to complete it. Over a period of about 3 months, photo engineers Anton Kraus, Peter Schuster and Gerhard Samland and student Silke Maassen developed a more flexible exposure system and computer software for my music holograms.

HOEs are generated in the same way that other three-dimensional holograms are, by exposing the gelatine-silver emulsion of holographic film with laser light. Processing generates a pattern of microscopic lines in the emulsion that diffract the light. When these diffraction gratings are illuminated with a halogen lamp at the same angle as the reference beam used during the exposure, the nature of diffracted white light is visible in different angles as a band of spectral colors corresponding to the respective wavelengths. If from the horizontal axis the observer perceives the hologram as green and moves up with respect to this axis, the color will shift to yellow-green, yellow, orange and red; as one moves down, the green will shift to blue-green, blue and violet. The same HOE seen from a position above the horizontal viewing axis will appear blue; from below, red, depending on the viewing angle with respect to the horizontal. The spatial configuration of laser, optical elements, object and film is always important in holography, but it is essential for making HOEs of the chromatic notations.

I wanted to transform three chromatic notations to holograms: my renditions of Bach's Prelude in C Major and Webern's "Piano Piece" (Color Plate) and my Extended Circle of Fifths. First of all, we had to provide a palette of 12 distinct light colors for the 12 tones of the chromatic scale, and these colors had to remain totally stable. The engineers at ILB made initial tests with 50 exposures at different angles, producing light with wavelengths between 300 nanometers (nm) and 800 nm in order to find the exposure angle for each color. But everybody was astonished to see the results: no one could distinguish more than six colors within the visible spec-

Fig. 4. Brigitte Burgmer, color composition in addition to Webern's "Piano Piece," translated into standard musical notation (1993).



trum, and not twelve tones, as I had planned, or even the seven colors of the rainbow. Given this limitation, I decided to relate the cadences of C major and A minor to the spectral order shown in Table 1.

Although we got wonderful colors such as deep purple and dark blue from our first tests, these mixed secondary colors could not be used, because they would change when viewed from different positions [10]. For the six other tones of the scale, I selected a second set of the same spectral colors, this time darkened by a raster screen of black lines. I referred once again to the major and minor keys according to the spectral order established for the first set (Table 1).

Table 1. The author's spectral order of tones for creating chromatic-notation holograms. Two spectral orders of six stable colors were produced by the engineers at the Institut für Licht–und Bautechnik (ILB) in Cologne. The author then related these tones to the cadences of C major and A minor and the cadences of F sharp major (G flat major) and D sharp minor (E flat minor), which are opposite in the Extended Circle of Fifths.

Color	Light Wavelength in Nanometers (nm)	Note
cyan	460	G
blue-green	506	F
yellow-green	534	C
yellow	570	A
orange	600	D
red	650	E
dark cyan	460	D flat/C sharp
dark blue-green	506	C flat/B
dark yellow-green	534	G flat/F sharp
dark yellow	570	E flat/D sharp
dark orange	600	A flat/G sharp
dark red	650	B flat/A sharp

For the hologram of my addition to Webern's "Piano Piece," I decided to change the relation of color to tone, because the basis of his composition was no longer a harmonic chord, but a selected series of tones. As a result, the 12 tones of the series now cover one bright, pure spectrum and one dampened spectrum of the primary colors. Combining the bright and dampened colors in the following pairs improved the impression of one spectral band: dark cyan, cyan; dark blue-green, blue-green; dark yellow-green, yellow-green; dark yellow, yellow; dark orange, orange; dark red, red. Since the rainbow is an easily recognizable figure, the series of the "Piano Piece" can be identified visually.

It is essential for the holographic representation of the music pieces that the colors do not change. Independent of its position, a red for the tone D should appear the same anywhere above or below the line of sight and should not shift to orange or violet, as it normally does with a change in viewing angles. A new and complex software has been written by the team to realize this constancy in the varied reconstruction angles. These geometric calculations limited the height of the holograms to 40 cm, because colors could quickly shift to invisible ultraviolet or infrared at any larger size.

As a means of working with this constraint, I decided to divide the two music pieces and the Extended Circle of Fifths into two panels each—resembling two pages of notation—for transformation into holograms. Then I designed a grid as a visual interface to process the data for generating the general output of the whole score. The tones of the Prelude in C Major and the "Piano Piece" were coded as numbers. The computer-controlled laser exposed all HOEs sequentially with an exposure time of 3–4 sec for each element. Thus the 613 tones of Bach's prelude are represented through 1,954 singular HOEs, each of them resulting from its own individual calculation. The color configurations of the Extended Circle of Fifths were not exposed sequentially, as were the diffraction gratings of the music pieces. Instead, each color was exposed separately, one after the other, through the use of masks—e.g. red was exposed in six positions at the same time (Fig. 2). The engineers used a computer to design the masks, which they enlarged, exposed onto film and used to cover the holographic film during the exposure. After processing, the film was machine-laminated onto glass; I covered the six panels with Plexiglas and framed them with flexible lead tape.

Conclusion

These holograms must be reconstructed in the right geometric setting, referring to the geometry of the original exposure. The three diptychs are arranged with about 6 cm distance between the two panels in each diptych. There is a halogen lamp for each panel placed at an angle of 30° at a distance of 3 m. The colors of the music holograms can be seen as intended if the viewer stands 5 m in front of the holograms and has a point of view in line with the holograms' horizontal axis. As soon as the viewer's line of sight departs from a height of 1.55 m, the colors change. For example, from a higher position, green shifts slowly to orange, then red, then to invisible infrared; from a lower position, green shifts to blue, then violet and invisible ultraviolet. The colors do not change as long as the viewpoint is at the horizontal axis. During the first exhibition of the music holograms in Cologne [11], visitors were stunned by the extraordinary luminosity of the kaleidoscope of brilliant colors, which glowed at a distance of 80 m or perhaps more. The colors seemed to float in the air, because the holographic film is transparent and disappears.

When I began to develop my chromatic notation system, I had intended it to be a tool for analysis; I make no claims as to a broader validity for this invention. It was a way to illustrate musical laws and, after all, an artist's method of approaching music.

The concept of the Extended Circle of Fifths may be considered a contribution to the history of music theory. In it, the abstract harmonic system reveals itself in a clear and aesthetic gestalt. I see the transformation of the pigments into colored light as a fundamental step forward, in which Webern's rules of composition are reflected in the laws of physics. The insubstantial and transparent quality of music holograms brings them closer to music than other forms of visual representation, but the holograms do not succeed as interpretations of music, because the strong primary colors are not really adequate to express the sound. Just as art can be viewed as parallel to nature, the music holograms have to be seen as parallel to music. They are, so to speak, a "symphony of colors."

References and Notes

1. The *Sounding Railings* opened at the MediaPark Cologne on 30 June 1992 with a 16-min live performance by four musicians from the group Drums Offf

Chaos and computer-aided sound generation by GIMIK: e.V. Cologne. With the exception of the drums, all sounds originated from one railing. A stock of sounds had been computer manipulated and composed in sequences of sound patterns prior to the concert. Their parameters were permanently varied by a random generator. The *Sounding Railings* were equipped with about 20 pick-ups, which triggered the preprocessed sound patterns in response to the dynamic stimulation. The sound patterns were combined with the live sounds in real time.

2. See, for example, Diether de la Motte, *Harmonielehre* (Munich: Deutscher Taschenbuchverlag/Bärenreiter Verlag, 1985).

3. Cadence indicates the close of a phrase, or the falling away to a traditional harmonic resolution. Examples are the authentic (dominant–tonic) or plagal (subdominant–tonic) cadence.

4. Sequence is the repetition of a melodic or harmonic phrase some tones higher or lower.

5. See, for example, Kenneth Peacock, "Instruments to Perform Color-Music: Two Centuries of Technological Experimentation,"*Leonardo* **21**, No. 4, 397–406 (1988). Viennese composer Josef Matthias Hauer developed spectral color systems for the Circle of Fourths and the Circle of Fifths in 1919–1920. See Karin von Maur, ed., *Vom Klang der Bilder—Die Musik in der Bildenden Kunst des 20. Jahrhunderts* (Munich: 1985); see also Helga de la Motte-Haber, *Musik und Bildende Kunst—Von der Tonmalerei zur Klangskulptur* (Laaber: Laaber-Verlag, 1990) and de la Motte-Haber, "Übersetzungen—Transformationen," *Positionen* No. 11 (1993). Jack Ox and Peter Frank describe the system of her rotatable color-wheel, created especially for her Bruckner cycle, in "The Systematic Translation of Musical Composition into Paintings," *Leonardo* **17**, No. 3, 152–158 (1984).

6. The Circle of Fifths is based on the well-tempered system and is often illustrated with an outer ring representing the 12 major keys in steps of fifths and an inner ring containing their parallel minor keys.

7. I refer here to the composition of music as harmonic construction, a kind of musical "architecture."

8. When Webern's teacher, Arnold Schoenberg, emigrated to America in 1933, he met Albert Einstein, whose theories fundamentally changed the Western concepts of time and space. The cubist artists had given up representing a logical Euclidean world, and the surrealists had turned the ratio of rationality and the unconscious upside down.

9. "I'm still groping in the dark, but I believe, that I can find something between hearing and seeing, and I am able to produce a fugue in colors like Bach did with tones." This statement made by Frank Kupka in 1913 must be considered a metaphor, because he wrote in a different context that he "never intended to depict music." See Von Maur [5] pp. 29, 362.

10. While the primary colors shift continuously with the movement of the observer, the secondary colors do not exhibit the same continuity. A purple, which is a mixture of red and blue light, will not shift in color in the same way everywhere. Research for more complex calculations is necessary to compensate for the unpredictability of these changes.

11. *Soirée im Heliosturm—1 Flügel und 100 Bilder* was an event held in the Helios Tower (the old building of a colonial factory that produced helium lamps) in Cologne in June 1994. An exhibition of paintings by Deva Wolfram and my musical artwork was accompanied by three concerts introducing different stages of composer Muzio Clementi's work, explained and performed by Stefan Irmer.