The Application of Lasers to Compose Pictures: The Method of Superpositioning

Attila Csáji and
Norbert Kroó

ABSTRACT

'Painting with light', through the use of lasers as monochromatic, coherent light sources, has become a reality for artistic expression in this century. This paper describes the authors' attempts to utilize the possibilities of laser art, while they report on their experiences with various applications.

Most visual art of the future will be painted by light.

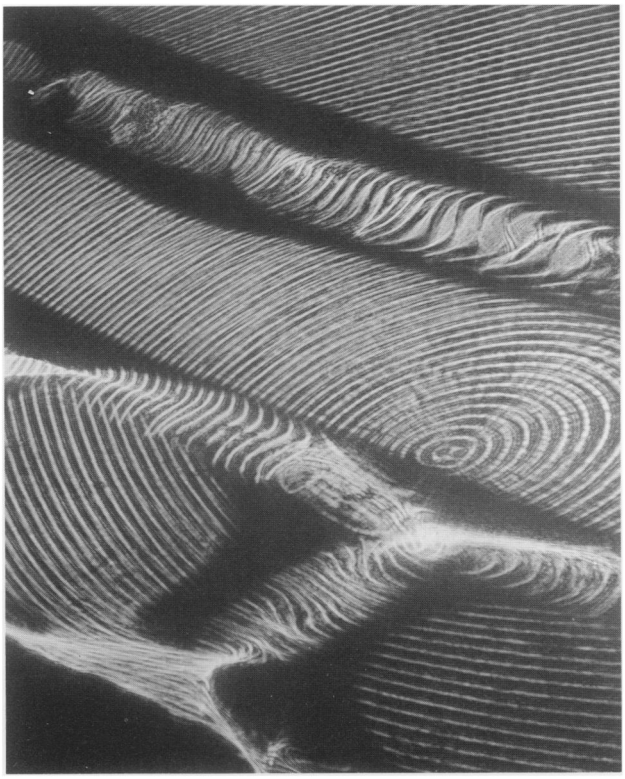
—László Moholy-Nagy

Our stormy age has raised many questions, one of which involves the relationship between modern science and art. Many people think that science and art are in contradiction. This feeling is based on two arguments: first, that modern science is a threat to mankind, with art unable to block this threat; second, that science and art are developing in opposite directions. Neither of these arguments is supported by fact.

Science and art have, perhaps, never been as close to each other as they are now. Both are creative disciplines; both have the tendency to synthesize. Many scientists are involved in some kind of art, and some of them even consider science to be a special form of art.

Bridge-building between the two disciplines is an aim of many people today, although scientists approach this problem from a different direction than do artists. Swiss drama writer Friedrich Dürrenmatt (winner of the Nobel Prize in literature) compares his writing to quantum mechanics, stating that the 'absurd' is present in both. At this point, logic and reality confront each other.

Fig. 1. ***In Wave Fields*****, multi-laser-interference pattern transformed by various optical elements, 1980. (Photo: Csáji)**



PATTERNS

According to Norbert Wiener, originator of cybernetics, "One of the most interesting aspects of the world is that it can be considered to be made up of patterns. A pattern is essentially an arrangement. It is characterized by the order of the elements of which it is made rather than by the intrinsic nature of these elements" [1].

For example, when we look at a written text, our first impression might be that it is static. But, in fact, it is intimately connected with different processes. First of all, a pattern has been formed. The written text was first conceived, then printed, then read and so forth. When we look at a pattern, processes in our brain are induced that lead to the perception of the pattern. Similarly, patterns induce processes in other biological systems or machines. Both the formation and recognition of patterns are connected with dynamic processes.

One should distinguish between manmade patterns and patterns that have been created by nature. Manmade patterns often serve a purpose, for example, such patterns may be connected with spoken or written language, with music or visual arts. There are many other types of manmade patterns, created by machines, buildings and so forth. Patterns created by nature may be formed by the inanimate world or by biological systems.

Attila Csáji (artist), Photon Art Studio, Kisgömb n. 30, Budapest, Hungary.

Norbert Kroó (educator, physicist), Central Research Institute for Physics, The Hungarian Academy of Sciences, Konkoly Thege, Ut 29-33, Budapest, Hungary.

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Coherence

The roots of coherence lie in the *dual nature* of all elementary particles; this means they can be defined either by their properties as particles with mass, momentum and kinetic energy; or defined as waves (with wave vectors) that oscillate with well-defined frequencies. This is true for photons, phonons, spins and bosons as well as plasmons, neutrons and electrons. This dual nature of elementary particles is the basis of the theory of complementarity, which states that matter has two complementary 'faces' that cannot be seen simultaneously. If, for example, we are interested in the particle character of matter, its corpuscular properties are observed; if we are interested in its momentum, we observe the wave-properties. The principle of complementarity was utilized by physicist Niels Bohr, the founder of the quantum model of atoms, and his co-workers in varied fields, including biology, psychology, anthropology and ethnology.

Much attention has been paid to the coherence of light since the end of the nineteenth century. Opticians are the most experienced in the field of coherence, since they have dealt with the concept for the longest time. What, then, is the significance of coherence? Basically, coherent light sources are responsible for producing interference effects when two beams of light are superposed.

Interference, with the sun as an incompletely coherent source of light, has been used to clarify several basic aspects of physics. Recognition of the role of interference phenomena of light increased after the discovery of lasers, as they are light sources that best display coherent properties.

Interference Patterns in Art

Interference patterns are created by light scattering from an object. In each case the pattern results from the Fourier transform of the function describing the surface geometry of the object.

In the mid-1970s we formed FOTON-ART and launched a research program to work out methods for using coherent laser beams to create patterns. Our aim was to succeed at arranging the coherent light emitted by lasers into preplanned pictorial patterns [2].

We were aware that esthetic quality does not depend on whether something is judged to be 'art' at a given time. In ancient times, the Greeks did not regard sculpture as art, yet today sculpture is the representative form of expression of that age; no one doubts that it is art in every sense of the word.

It was our belief that 'light art', by combining science and technology to produce a visual effect, could similarly become a representative form of expression of *our* age. One of the principal features of art in the twentieth century involves the great variety of available media and tools of art with which artists can choose to work. At the same time, new genres—even mixed genres—have been created, resulting in the broadening of the definition of art.

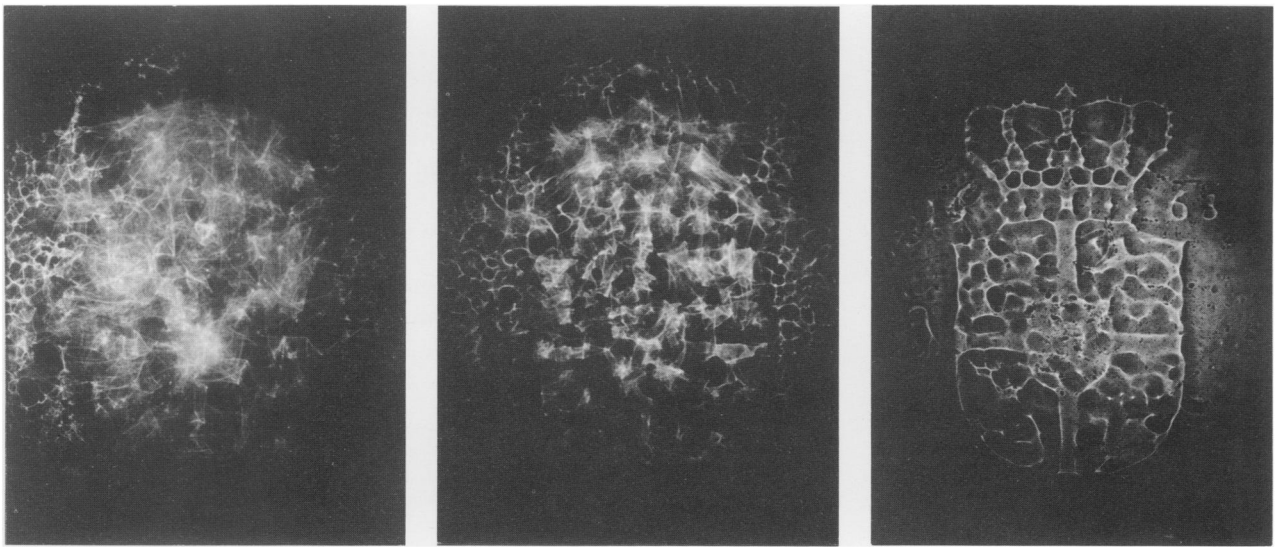
Light Art

When we started our research, we believed that the discovery of the laser, this new source of light with its special qualities, provided insight to ideas that the Bauhaus followers had once expressed. With prophetic inspiration, painter and photographer László Moholy-Nagy wrote in the early decades of the twentieth century that most visual art of the future would be painted by light. He encouraged painters to acquaint themselves with the shining purity of light—with its wavelengths, colorimetry and with the possibilities inherent in artificial sources of light. He believed that painters should augment their own creative instincts and emotional powers with knowledge of science and technology. Moholy-Nagy found the significance in Malevich's blank canvas to be the ultimate simplification of the picture.

The concept of using disembodied light in art was very stimulating to the Hungarian avant-garde, and numerous works of this sort became part of the international art scene. Pianist Sándor László constructed a 'light organ' designed to accompany music with colored light patterns. Sculptor and composer Nicolas Schöffer is best known for his metallic mobiles and plastics in which light plays an important role. He recognized that dynamics is the most original characteristic of our technical civilization and created artworks that were machines that metamorphosed before our eyes. This became the basis for kinetic art.

Hungarian Györgi Kepes, a founder of the New Bauhaus and a 'light artist', wrote that the revolutions that keep changing the concept of form, the playful flirtation with shapes and techniques, must give way to more serious commitment. He wished to contribute to the successful reunification of man and

Fig. 2 Figurative metamorphic laser process (left to right), 1987. The coat of arms of Denmark emerge from interference patterns.



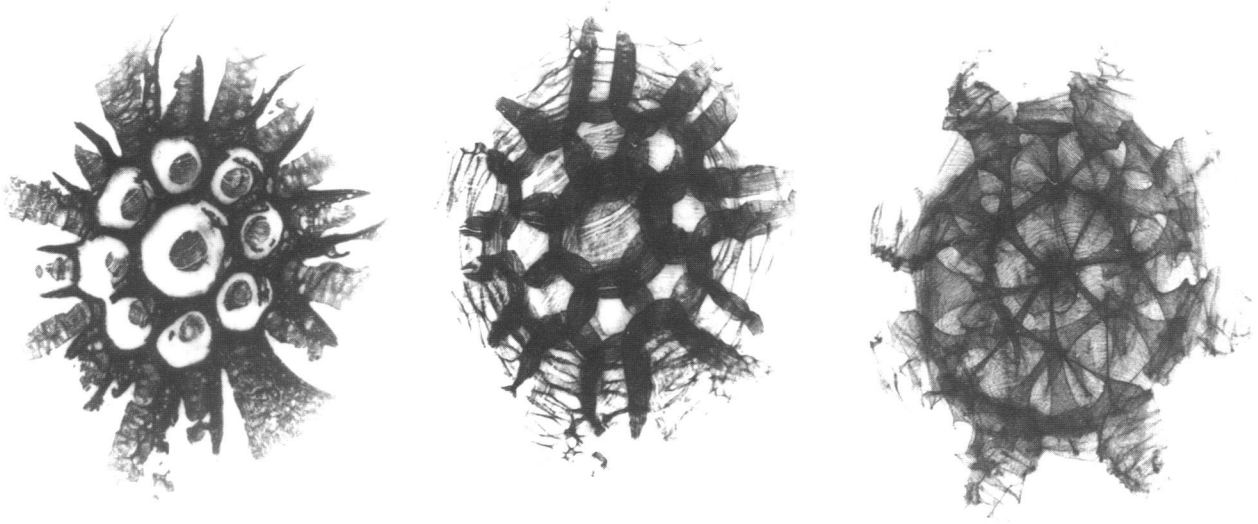


Fig. 3. ***Cell Crystals,*** **laser-light art, 1980. These images illustrate the use of nonfigurative metamorphic processes in light art.**

nature. Kepes founded the Center for Advanced Visual Studies at the Massachusetts Institute of Technology to advance new technologies and relationships among new scientific discoveries and art.

Because artist and Nobel Prize winner Denis Gábor invented holography in Hungary, holographic studios were operating there earlier than they were in its more-advanced neighbor, Austria. The Hungarian National Gallery staged an exhibition of holograms and art in the same year as did the German Film Museum in Frankfurt.

The Hungarian National Gallery also staged FOTON-ART's first show in January 1980. The media reported that there was 'laser fever' in Budapest, and that never before had there been an event in Hungarian art of such proportions with such diverse audiences. We presented *Struggle,* a light symphony and laser environment that was visited by 20,000 spectators in just a few days. The total number of visitors to the exhibit reached approximately 300,000.

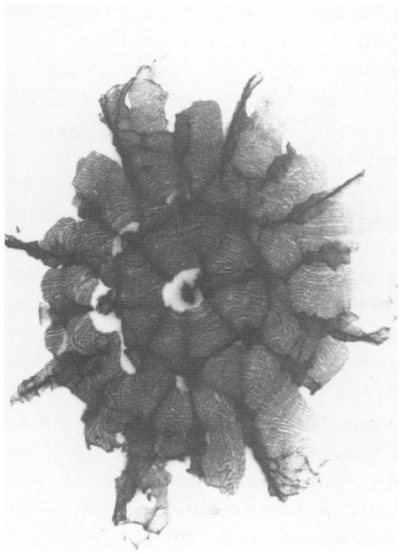
SHARED ADVENTURE

In our collaboration as painter and physicist, we systematically divided and coordinated our respective concepts and activities, allotting to the scientist the task of introducing the painter to the physical aspects of our work.

Our cooperation laid the foundations for the kind of relationship that had been expressed by Moholy-Nagy, with one of us, the physicist, providing a suitable background for the painter's work. The painter's role included finding the right means of pictorial expression, discovering and progressively narrowing the relationships among the tools used and working out the ways in which a spectacle could be designed to provide the appropriate setting for visual contemplation. First of all, the irregular flashes of light, the simple geometric forms and the isolated characteristic interference patterns were carefully analyzed. Gradually, we reached the point where we were able to correlate transilluminated transparent surfaces with interference patterns defined by the Fourier transforms of the given surface.

The quality of mobility intrinsic to this phenomenon demanded that we do more than mere static analysis but, rather, also analyze the dynamic processes involved. Soon our observations of the dynamics of forms took on new aspects in which the individual pictures became less important than their ability to undergo metamorphosis.

This metamorphic process showed most clearly that the tools were broadening our senses, not only by creating new information, but also by opening new areas of perception leading to new sensual experiences and harmonies (Fig. 1). Direct insight into these processes is characteristically a twentieth-century phenomenon. We consistently came across parallels between our light art and other twentieth-century art forms, from gesture painting to Op Art. Our research was often slowed by the revelation of such parallels, for we were tempted to embark on stray adventures; however, these findings were significant. We set them aside temporarily to concentrate on the definition of causal relationships. We realized that in order to make these manifestations suitable for visual contemplation we had to uncover the essence behind the metamorphic processes. Parallels with other completely different nonfigurative art forms in this century signify a continuity between the inner and outer worlds, creating the possibility, hitherto unknown, of breaking down the barriers dividing the experiences and cultures of this age.



Next, we ordered the relationships we had uncovered. It was no longer appropriate to confine ourselves to the analysis of details. Instead we had to look toward producing entire processes, developing a rhythm to broaden the character of the metamorphoses.

A designer of a light-art show must consider not only formal aspects but also the proportions among the various

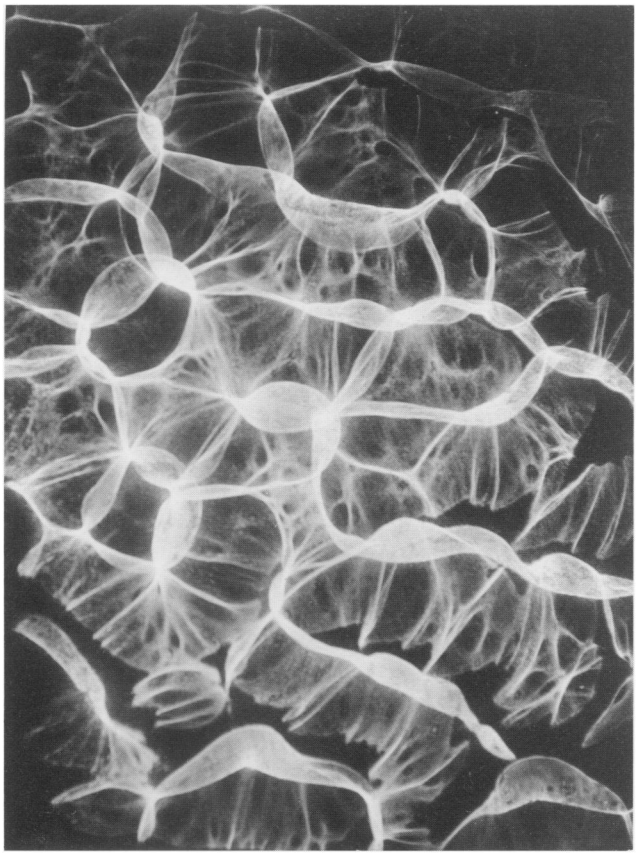


Fig. 4. *The Fifth or the Sixth*, a laser-animation film, Budapest, 1984. The imagery in this film continually transforms from one state to another, from star clusters to living cells, from crystals to infinite space. (Courtesy of Pannonia Film Studios)

parts of the surroundings of the spectacle. In putting these considerations into practice we found new definitions that led to a novel method for redefining the picture. Following the success of our exhibit at the National Gallery, we patented the technique of light art and its tools in January 1980 [3]. The tools comprise a flexible lens-and-prism network that lines up along a laser beam. At the core is a transparent disc that carries the pictorial information. A key feature of the procedure lies in the coordinated use of manual and computerized technology. We first made drawings of the motifs, reduced them photographically to the desired size, projected them onto metal or some other material, then cast them from a clear plastic material. The resulting transparent, clear disc contained the composed pictorial information in plastic form. A motif captured on the transparent disc could be anything from a flower to a human head, from a Coke bottle to a shop logo, depending on how the surface was adjusted. We called this plastic disc the 'objective picture'. This plastic objective picture is transformed by the coherent laser beam to interferences correlated with the optical system and its setting. In this way the motifs on the disc could be changed not only in size but also transformed into different shapes. We could project the motif as it was designed, or we could transform a plastic motif into characteristic interference patterns. The method was especially suitable for making the relationship between perception and physical laws tangible. Through what we called 'pre-holographic pictures' we reached pure laser interference. It was this method that we used to develop the Danish coat of arms at the Bela Center in Copenhagen (Fig. 2).

Organic and continuous pictorial changes created the transition between the world as we perceive it with our naked eyes and the precise, mathematically definable light interference. This meant that in the pre-holographic pictorial transition, the objective picture and the interference patterns were perceived simultaneously, but mixed in varying proportions. This metamorphic process held infinite possibilities in forms created by pure laser light.

Our Experiences

Using our method we were able to create a variety of shapes and movements that seemed to occur on various levels of material organization. We first expressed this in our program called *Cell Crystals* (1980) (Fig. 3 and Color Plate A No. 1), which presented an exotic world, a journey into the secrets of nature. The experience brought about a sense of being in a cool laboratory and coming into direct contact with nature, as though looking through an electron microscope while zooming in on fibers and benzene rings, on DNA spirals and crystalline structures. Viewers participated in the action in real time, since the projection was not merely two-dimensional, but a whole environment. These projected forms have infinite focal depth and allowed the projection to be shaped into any geometric configuration. This allowed for maximum stimulation and even enabled viewers to seem to become part of the screen.

The concept of evoking the hidden aspects of nature appeared in our work again and again. This concept also gave rise to *The Fifth or the Sixth*, the first Hungarian laser-animated film, which we made in 1984 at Pannonia Film Studios. It was screened at the Hungarian National Gallery, at the Modern Museum of Art in Paris during their exhibition entitled *Electra* and at the German Film Museum coinciding with the hologram exhibit *Licht-blicke*. The film presented paradoxical correspondences between microcosm and macrocosm by showing living cells forming out of star clusters, and infinite space rising out of crystals (Fig. 4). The configurations were born out of each other, they 'rhymed' throughout their incessant transformations. This was the key that controlled our knowledge of the world, it was the metamorphosis of primeval structure.

To a degree, our encounter with these forms inspired our interactive light mobile *Laser Eye* (1985), a variation of which can be seen in the transit lounge of Budapest's Ferihegy Airport (Fig. 5). It shows an eye-like frame; there is a sand-blasted glass surface that behaves in a way similar to the retina of an eye, transmitting information to its 'brain'. On the inside surface, the reflected light beam creates a metamorphosis. Moreover, the composition is analogous with the beginnings of optics: Euclid explained vision by stating that the eye emitted light beams that sensed objects on contact. If coherent light from a source passes through transparent objects (e.g. the plastic discs mentioned earlier) a relationship may be established between various hierarchic levels of nature. As the light mobile reacts with the environment, it establishes some sort of connection between three different spatial experiences.

One of these spaces is created through dynamic metamorphoses and takes the viewer into the hidden layers of matter. It is a closed, planned program that

frequently evokes the world of 'cellular crystals', patterns of the microcosmic world.

The second space is the world we live in, the world as we know it. In the transit lounge at Ferihegy airport, this space is the environment of the light mobile. If we stand in a given place, the mobile senses our presence and causes green light-emitting diodes (LEDs) to light up. We can make contact, play with it by moving our hand, changing the configuration on the sand-blasted glass surface by touching certain spots. We can speed up the transformation of patterns, rewrite the character of the patterns or induce a bright variety of colors in the background.

The third space is an antithesis of the first one. It is the (macro)cosmic infinity of the air and the oceans. This space relates to the environment, to air travel and the diverse parts of the world, to flights leaving and arriving. At the moment before a plane lands or takes off, the electronic machinery of the mobile receives pulses from the airport's electronic control system. At the eye's interior, at a given point, a large floating shape reminiscent of a bird appears, formed by the scanned laser light. It starts out as a point, grows larger, and, as the amplitudes increase, the bird-shape flaps its wings and seems to fly toward us. When the wings touch the edge of the screen the configuration bursts, and from its center a continually growing-then-bursting spiral springs forth: the landing signal. During take-off the process is reversed: the bird shrinks as it flies away, and the spiral shrinks down to a dot.

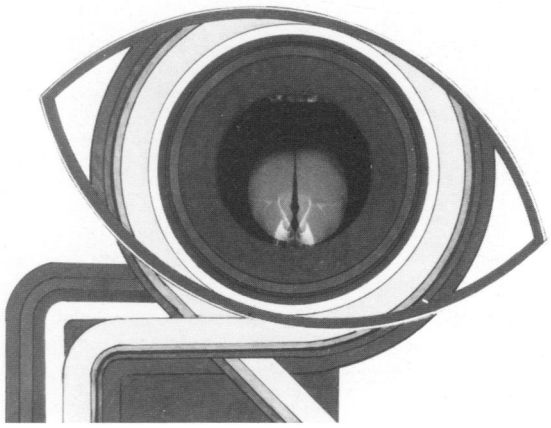


Fig. 5. ***Laser Eye,*** **interactive light mobile, 1985. The kinetic movements of this artwork are influenced by the airport environment, including passengers.**

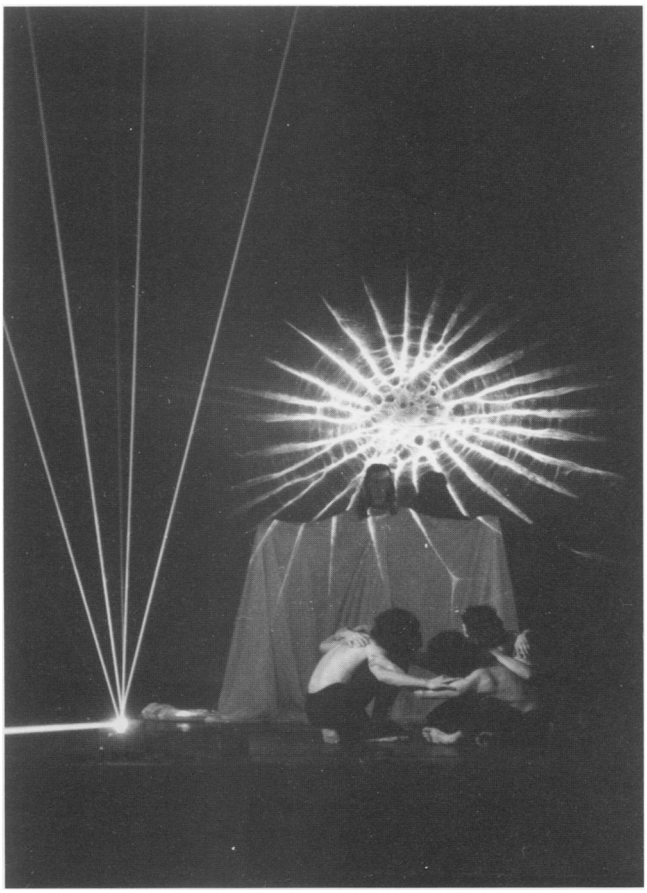


Fig. 6. ***Relations,*** **laser-light art and dance, 1983. (Photo: Korniss)**

The mobile manifests laboratory observations, everyday experience, research and games, space and sensing.

A completely different source of inspiration was the historic atmosphere of the medieval ruins of Diósgyõr Castle, the setting for our laser *son et lumière* entitled *Sparkling Well of the Past.* It opened with the unfolding of pages of a book that grew to the size of the wall (an enormous 14-×-27-m screen) to reveal a peculiar well, from which the laser drew sparkling creatures. It was an unusual metamorphosis. Little medieval bronze figures and metal engravings were transformed, changing their structures and manifesting themselves as photons in pure colors sparkling out of a fine network of interferences. These images became recognizable, then were transfigured anew, metamorphosing again and again.

The laser changed medieval coin figures into creatures of light. The naively charming Roman patterns, ascetic gothic figures and beautifully dignified but feeble miniature kings all sprang from the well, taking shape as projections on the huge screen mounted between two medieval bastions.

We want to create new traditions, but only after reliving already existing traditions. We used these methods in the theater for grotesque plays, dramas and modern dance concerts. The key element of each spectacle was the method of superpositioning, resulting in different transformations; we also

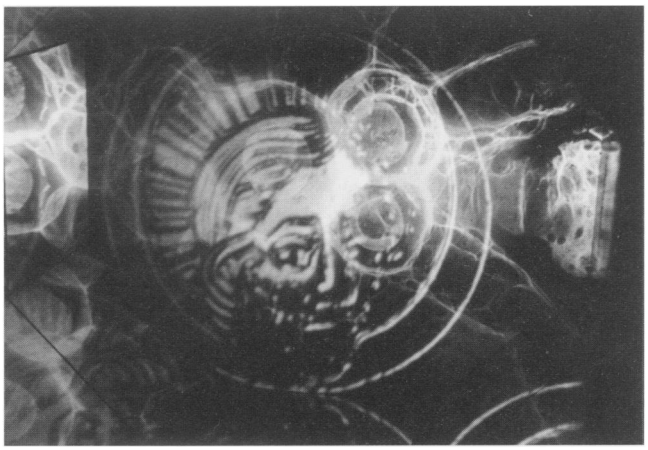


Fig. 7. *The Mount of Olives*, laser-light art and drama, 1985. Through the manipulation of laser-light beams and the phenomena of interference, the head of Christ has filled the entire scene of this biblical stage play.

used scanners and three-dimensional light-dynamic elements.

We worked extensively with the modern dance group Budapest Táncegyüttes led by Antal Kricskovics. For the premiere we designed *Relations*, a light accompaniment that continually changed the mood. Dance is an art form that uses the most elementary movements, and light is one of the greatest experiences of man. Now, these two phenomena met by way of the laser (Fig. 6).

The light-choreography was created after meticulous analysis of the music and the dance. In an ideogram we combined the color and intensity of the laser light, the positions of the basic light mobile, the supplementary optical tools (cylinder lenses, optic grids, prisms, etc.), the transformation and dynamics of the shapes, the position of the motifs on stage and so forth. All this was combined with the dancers' movements and the music. Light-choreography, like that of dance, requires thorough preparation and practice. In part, the mobiles became light instruments while the staff was divided into different specialty groups; those dancers with stronger visual and musical senses were placed in the proximity of the mobile. This was because we could not control everything electronically; this also made it possible to adapt to slight inconsistencies in the movement and positioning of the dancers. Moreover, this placement also allowed changes in the stage to be accommodated.

The light mobile, similar to a musical instrument, was able to combine and execute diverse functions. Its basic task was to act as a precisely articulated light accompaniment, but it also took over traditional theater-technical functions such as that of spotlighting.

For *Solitude* (1983–1984), primarily a solo dance, the stage was almost completely dark. From this darkness, an inwardly spiraling, variously bright and colored bubble brought out the dancer. Like a spotlight, the bubble followed her, and, as she danced through moods of despair, fear, isolation, pain and hope, the colors of the bubble also changed, all while engulfing her in light. At times the light would seem to dissolve, and a green flame would break out of the circle then withdraw into the background, only to reappear.

Next, at the other end of the stage, across from the girl, appeared a man, also lying prostrate on the floor. In the darkness a ray of light reached out for him toward the center of the stage. As the girl and the man approached each other, an increasingly intense ray of light pointed to the girl. As the two figures drew nearer, the light on the girl began to move, the rays multiplying, then separating, finally forming a grate. When the man and the girl crawled by each other, the grate closed and became a wall of light. The use of the light mobile as a spotlight, supplemented with a few light-dynamic elements, greatly expanded the traditional possibilities of the spotlight. Only in the closing scene did the light bubble explode, with a multitude of shapes running upward, as the girl's prayer was fulfilled amid a whirl of light. In the closing moments, the dynamics of the light determined the scene.

The method we used in Veronica's scene in the drama *The Mount of Olives* created an entirely different character. The director of this biblical drama wanted Veronica to become mad and in her madness to project visions onto her veil. Our task was to create these visions by means of laser light. First we marked the actress's position and movements, with the size and position of the veil as she was holding it. Next all other lights were extinguished, leaving only the laser's light to set off Veronica's figure on stage. The laser light slowly narrowed, pointing to the veil, whereupon whirling shapes appeared. These shapes were chaotic, representing the reflections of madness. Then, slowly, they began to merge into the reflection of a head. At times the rays creating the head would collapse again into chaos. At last, the rays came forth, more clearly defined, as Christ's head (Fig. 7), which became larger than Veronica, embraced the entire scene and the stage, finally engulfing Veronica herself.

CONCLUSION

The revolution of science and technology is something that cannot be slowed or stopped, regardless of the consequences. Possibly civilization is suicidal or, forever seeking the realization of new dreams, driven to search for matter, tools or energy in order to reshape the world. Once human beings searched for the philosopher's stone. We now know that this stone is not a material object, but rather represents living ideas. Our ability to continuously adapt and transform reality means that we can always find new ways to govern the changing world.

References and Notes

1. H. Haken, *Pattern Formation by Dynamic Systems and Pattern Recognition* (Berlin: Springer-Verlag, 1979) p. 2. Norbert Wiener was an American mathematician and the originator of cybernetics.

2. See Norbert Kroó, *Új Írás* **XX**, No. 6 (1980) p. 83 (in Hungarian); Attila Csáji, *Új Írás* **XX**, No. 6 (1980) p. 86 (in Hungarian).

3. A. Csáji, N. Kroó and J. Tóth, Hungarian patent No. 182.793.

Glossary

Fourier transform—a mathematical relationship between the energy in a transient energy spectrum and that in a continuous energy spectrum of adjacent component frequencies.

coherence—if two light waves are superposed so as to produce interference effects, and there is a constant phase relationship maintained between them, the waves are coherent. Sources of coherent light are necessary to produce observable interference effects.

interference—interaction between two or more waves of the same frequency emitted from coherent sources. The wavefronts are combined according to the principle of superposition, and the resulting variation in the disturbances produced by the waves is the interference pattern.

complementarity—in quantum mechanics, the wave and particle models are complementary. A measurement proving the wave character of radiation on matter cannot prove the particle character in the same measurement, and vice versa.

dynamics—the branch of applied mathematics that studies the way in which force produces motion.

superposition—the placement of one configuration on another in such a way that corresponding parts coincide.

vector—a vector or vector quantity is one that has magnitude and direction, e.g. force and quantity.