The Beauty of Laser Lines

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Submitted to the Department of Architecture on May 7,1993,
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Abstract

A line, the simplest way to express an artist's feelings or interpretation of an object, has its own emotions that an artist can employ for her purpose. Laser light, the most self-concentrated, self-sustained and directed, has its unique characteristics that no other medium can imitate. When a line and laser light are combined, the result is a knife-cut clean laser line that catches the viewer's breath.

Artists, who have chosen the laser as their tool, need to make laser line images more attractive than laser light itself. In other words, artists must find the *beauty* of laser lines. Otherwise, the tool of the work dominates the artist's work itself.

In this thesis, I having already chosen the laser as my tool, tried to find the *beauty* of laser lines by first learning the technical aspects and the characteristics of lasers. Then I examined previous works done by other laser artists, before working with lasers myself. I designed four laser projects in order to find "the beauty of laser lines," and the details of my works will be presented in this thesis.

Thesis supervisor: Otto Piene
Title: Director, Center for Advanced Visual Studies

Introduction

"I shall get it, by simplest, by the minimum of means, which are the most apt for a painter to express his inner vision. We are moving toward serenity by simplification of ideas and means. Our only object is wholeness. We must learn, perhaps relearn, to express ourselves by means of line." [1]

--Henri Matisse--

Line, the simplest interpretation of an object, has its own emotions that an artist can employ to express her feelings. When such a line is combined with laser light, the most self-concentrated, self-sustained and directed medium, the result is a "breath-taking", "knife-cut" clean line that provides endless visual potential.

[1] Gowing, Lawrence. henri matisse 64 paintings. The Museum of Modern Art, New York. 1966

The invention of the laser was a significant advancement not only in sciences but also in visual arts. Before laser technology was easily available in the 1970's, lamps, incandescent lamps and neon tubes were available for artists. However, the lamp and the incandescent lamp do not have either a distinctive color or uni-directionally emitted light. A neon tube, while having a specific color, also does not have uni-directionally emitted light. Therefore, after the laser was invented, its characteristics such as coherence, high intensity, spectral purity, directability and sharp form, stimulated artists' imaginations.

From the late 1960's artists and composers like Robert Whitman, James Turrell, Carl Frederik Reutersward, Iannis Xenakis, Otto Piene, Paul Earls, Rockne Krebs, Horst H. Baumann, Barron Krody, Lowell Cross, Friedrich St. Florian, Willard Van De Bogart, Dani Karavan and others started to create the field of laser in art. After 1975, the number of laser related works increased, because of the birth of commercial laser show companies.

Since laser light has its own strong characteristics, the artists who are using the laser light as a tool of their expression need to design stronger images than the laser light itself. In other words, only when the laser images are visually more attractive than the laser light , can the beauty of laser line be fully achieved.

In this thesis The Beauty of Laser Lines, I will first explain the technical aspects of laser and laser light generated images. Then in chapter 5, I will present my works. Finally, I will discuss the concept of and the means of achieving the beauty of laser lines as a conclusion.

Acknowledgments

I owe an enormous debt of thanks to a great many people who helped me along the path that has led to my wonderful experiences at CAVS and this thesis.

My family, I do not know how to thank them. The words 'thank you' is just not enough. Mom and Dad! I know you had hard time trying to understand the so called 'westernized' daughter, and had even more difficult time trying to hide this for me. I really respect your patience and love toward your children.

My advisors, Otto Piene and Paul Earls who have guided me and pushed me, I offer my heartfelt gratitude. Without your guidance I do not know what I might be doing now. Christopher Janney, my thesis reader, thank you for sparing your time.

Accepted by ________________________________

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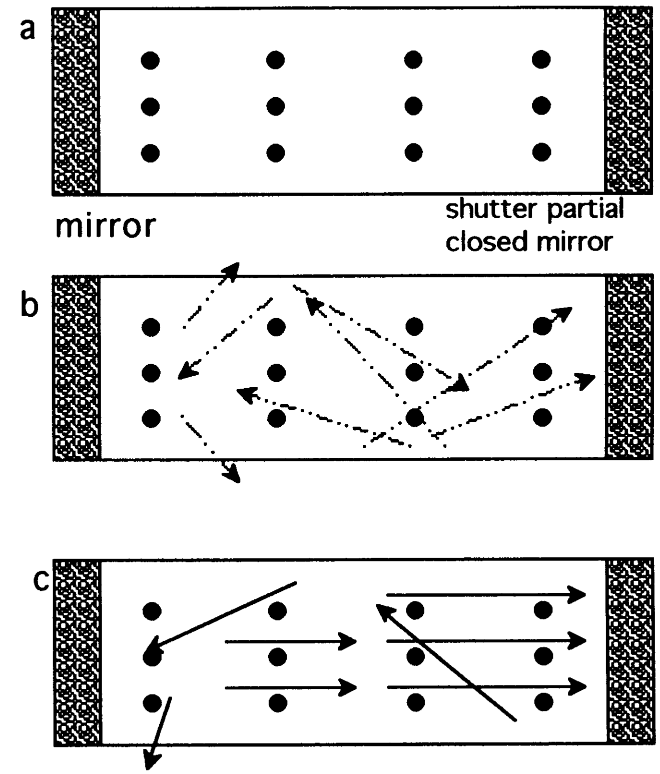
Laser light

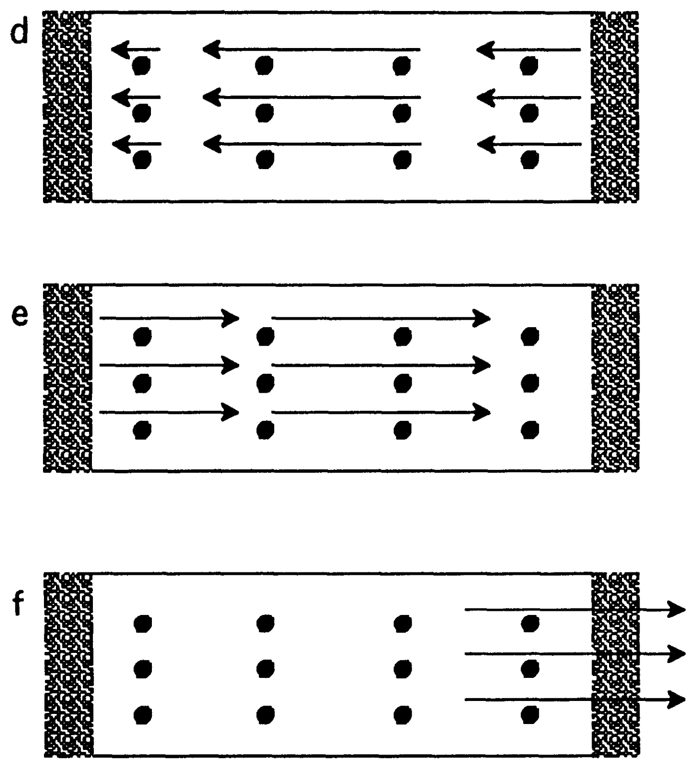
Laser means light amplification by stimulated emission of radiation. Then, how does laser light differ from ordinary light? According to the book Laser and Light,

> "In brief, it is much more intense, directional, monochromatic and coherent. The light emitted by an ordinary source, such as a candle or incandescent lamp consists of uncoordinated waves of many different lengths, that is, it is incoherent and more or less white. The waves of laser light are coordinated in space and time and have nearly the same length. This coherence and chromatic purity, and also the intensity of laser light results from the fact that in a laser excited atoms are stimulated to radiate light cooperatively before they have had time to do so spontaneously and independently. The directionality of laser light arises from the geometry of the laser. These properties of laser light suggest many uses for it not only in technology but also in physics.

Most lasers consist of a column of active material that has a partly reflecting mirror at one end and a fully reflecting mirror at the other. In a typical solid laser material, a ruby crystal, the active ingredients are chromium atoms interspersed in the crystal lattice of aluminum oxide. The laser is primed by pumping these atoms, by means of a flash of intense light, to an excited state. With a preponderance of atoms in that state the system can be stimulated to produce a cascade of photons, all the same wavelength and all in step, by triggering the emission of energy that drops the atoms from the excited state to a lower energy state. A photon carrying this quantum of energy, on striking an excited atom, causes it to emit a photon at the same frequency, and the light wave thus released falls in step with the triggering one. Waves that travel to the sides of the column leave the system, but those that of to the ends of the column along its axis are reflected back and forth by the mirrors. The column, whose length is a whole number of wavelengths at the selected frequency, acts as a cavity resonator, and a beam of monochromatic, coherent light rapidly builds in intensity as one atom after another is stimulated to emit photons with the same energy and direction. It is as if tiny mechanical men, all wound up to a certain energy and facing along the axis of the laser enclosure, were successively set in motion by other marchers and fell into step until they became an immense army marching in unison row on row (the plane wave fronts) back and forth in the enclosure. After the laser light has built up in this way it emerges through the partly reflecting mirror at one end as an intense, highly directional beam. Light intensities as high as a billion watts per square centimeter have been produced."[2]



[2]Arthur L. Schawlow. Laser and Light. Scientific American. W.H. Freeman and company, San Francisco, 1969



"a". the atoms are in the ground state (black circles)
"b, c". the light rises atoms to the excited state (dotted arrows), if an emitted photons (arrows) strikes another excited atom, it stimulates further emission
"d, e, f". then photons traveling precisely parallel to the long axis of the laser are reflected back and forth between the two mirrored surfaces, stimulating a cascade of photons. The cascade culminates in a coherent beam of light, which flashes through the partially silvered mirror with an intensity of millions of watts.

Different types of lasers

1. Helium -Neon

This gas laser is the most common and economical visible laser.

A. Output power

less than a milli-watt to less than 100 milli-watts

B. Wavelengths

540 ~ 3400 nm

C. Colors

Red, Green

D. Continuous Wave

*Applications

The HeNe laser has been involved in many applications because it is inexpensive, reliable, and one of the first commercially available lasers, but diode lasers are starting to replace them.

1. Alignment and positioning
2. Reading and scanning

3. Writing and recording data
4. Holography
5. Instrumentation

2. Ion Lasers

There are two main types of Ion lasers, both types use an active medium of gas-Ar or Kr. The Ion laser requires the use of a sophisticated plasma-tube. To produce the tube requires high technology and a special manufacturing plant. Argon lasers have long been the backbone of scientific research.

A. Output power
few milli-watts to 30 watts

B. Wavelengths
270 ~ 1100 nm

C. Colors
Green, Blue, Red

D. Continuous Wave

*Applications

Argon lasers have become the standard sources for a variety of applications due to the blue-green output. The energy at these wavelength is much higher then those produced by Krypton or HeNe in the red.

1. Printing
2. Medical
3. Laser shows
4. Spectroscopy
5. Pumping dye lasers

3. Carbon dioxide lasers

The CO_2 laser is one of the most versatile type on the market today. The active medium is a mixture of CO_2, Nitrogen and Helium. It emits in the infrared region, either as a single line selected by the user or the strongest lines in an untuned cavity.

A. Output power
under 1 watt to kilowatts

B. Wavelengths
9000 nm ~ 11000 nm

C. Continuous Wave and Pulsed beams from nanosecond to milliseconds pulse widths

*Applications

1. Materials Working
2. Heat treating
3. Marking letters or symbols
4. Range finders
5. Lidar-used similar to radar with a further range
6. Possible laser beam weapons

4. Copper and Gold vapor lasers

These lasers are the most important members of a family of neutral metal vapor lasers that emit in or near the visible region.

A. Output power

tens of watts

B. Wavelengths

510.6 nm ~ 578.2 nm

C. Pulsed with rep rate of several kilohertz

*Applications

The biggest single application for copper vapor lasers has been in pumping dye lasers. The high average power makes it possible to obtain a higher wavelength tunable dye output than when pumping with an argon laser.

5. Dye Lasers

There is a lack of lasers tunable across wavelength ranges. A dye laser offers this flexibility, but requires a dye to be pumped by another laser. This use, in conjunction with doubling crystals expands the wavelengh range from UV to IR. The active medium is inorganic dyes that have a certain wavelength coverage.

A. Output power

milli-watts to tens of watts

B. Wavelengths

from UV to IR range

C. Continuous and pulsed, the rep rate can be from several hertz to megahertz

*Applications

1. Time resolved spectroscopy
2. Photochemistry
3. Light shows - dye lasers are used to generate varicolored beams for shows and displays

6. Ruby Lasers

The first laser demonstrated, they are used in many commercial products. They have been replaced by other lasers in many areas.

A. Output power

100 milliwatt to 100 watt

B. Wavelengths

around 690 nm

C. Color

Red

D. Pulsed with rep rate of few Hertz with pulse width being 3 picoseconds to 35 nanoseconds

*Applications

The biggest single application for ruby laser is Holography. Other applications include those typically covered by Nd:Yag lasers.

7. Neodymium Lasers (Nd:Yag)

Nd:Yag is the most common type of lasers usually grouped together as solid-state lasers. The active medium is a solid material most often comprised of yttrium aluminumgarnet, a synthetic crystal with a garnetlike structure doped with neodymium.

A. Output power

milli-watts to tens of watts

B. Wavelengths

266 ~ 532 nm, 1064 ~ 1340 nm

C. Pulsed and continuous wave--rep rate goes from hertz to 100 megahertz

*Applications

The Nd:Yag is a dependable source of photons and energy and therefore has become regular in many applications.

1. Lidar applications
2. Printing
3. Medical
4. Resister trimming and marking
5. Optical tweezers

8. Diode Lasers

Semiconductor diode which emits a coherent laser beam. It is the newest development and is being used for many applications.

A. Output power

milli-watts to 15 watts

B. Wavelengths

720 ~ 900 nm, 1000 ~ 1700 nm

C. Continuous wave source

*Applications

The range of applications for diode lasers has broadened rapidly beyond the fiber-optic communications.

1. Digital audio-disk-CD
2. Videodisc system
3. Fiber optic communication
4. Laser printers
5. Bar-code reading
6. Pump source of Neodymium -Yag lasers

How is it possible to draw lines with a laser

The laser light emitting from its tube, and hitting a surface is simply a dot. Then how can people draw lines with the laser?

> "Sound travels relatively slowly, approximately 300 meters/sec. The ear is scaled to make very rapid distinction in the flow of incoming information. And the ear, unlike the eye, has little "persistence of imagery"; changes of information at the very fast rate of electronic music are easily perceived by the ear as independent elements. The ear/brain then gives musical coherence to these events. Only the educated eye can clearly register similar rates of image changes - the eye tends to retain its last image, clearly demonstrated when one closes one's eye after looking at a light - the light remains "visible" to the closed eye for many seconds.
>
> The eye and the ear do operate similarly in integrating repetitive events. If two separated points of light, or two spikes of a sound wave, such as is produced by a motor, repeat more than 20-40 times/second, both organs register these individual events as one continuous event - a line of light to the eye, a continuing tone to the ear.
>
> Laser projections use this simple principle to make connected-dot line drawings appear to be continuous lines. The laser beam is directed around the stored coordinates of the pattern rapidly enough for the eye to register the event as continuous. The "persistence of imagery" properties of the human eye makes this possible."[3]

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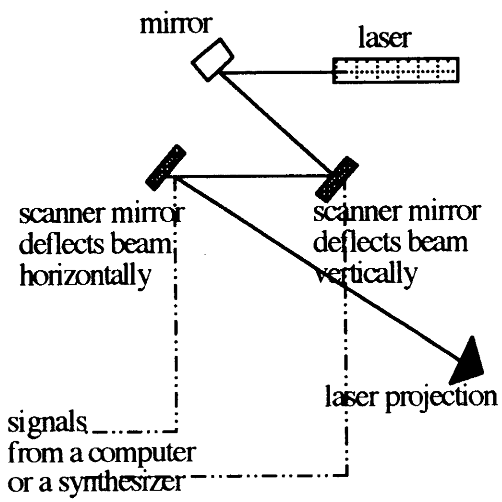
[3]Earls, Paul. The sight/sound relationship in the hamburg installation. Mehr Light Ed. Achim Lipp and Peter Zec Hamburg: Fielmann: Vertried,E. Kabel, 1985

Laser projection



Laser projection setup with two mirrors

A laser beam is deflected by two perpendicularly oriented mirrors that are controlled by computer connected scanners. One mirror traces the horizontal points of a drawing, and the other traces the vertical points. Together, they are able to reproduce drawings.

Two scanners receive signals by a computer or a synthesizer that locates the points. Also, there is a three-scanner system that gives more freedom in drawing, like disconnected lines and three dimensional rotating effect. There are several softwares for laser projections, using APPLE, IBM, AMIGA, etc. I have used the Ampersand laser system created by Walter Zengerle for Paul Earls.

LISSAJOUS FIGURES

What are Lissajous figures? According to the McGRAW-HILL ENCYCLOPEDIA OF Science & Technology,

> "Plane curves traced by a point which executes two independent harmonic motions in perpendicular direction, the frequencies of the motion being in the ratio of two integers. Such figures produced on the screen of a cathode-ray tube, are widely used in frequency and phase measurements."[4]

In other words, by analyzing Lissajous figures, we can make frequency and phase measurements of the two independent harmonic motions that were generating the figures.

First, I will explain about how to measure the frequency, the phase and the amplitude of the two independent motions. Then I will discuss the relationship between Lissajous figures, determined by the electric voltages from a synthesizer and sound waves.

Frequency measurements

Time dependent, harmonic motions can be usually expressed as,

$$A\sin(Bt+C) \qquad \text{................} \textbf{equ.1.}$$

A: amplitude
B: frequency
C: phase
t: time

If B1 is the frequency of the vertical axis' harmonic motion and B2 is the frequency of the horizontal axis' harmonic motion, the ratio of B1 and B2 determines a general shape of a Lissajous figure of those two perpendicularly positioned harmonic motions.

For example, if the ratio of the supplied harmonic motions B1:B2 is 1:1 ,and if there is either no phase difference or amplitude difference, the equation can be

[4]Mcgraw-Hill, Inc. McGRAW-HILL ENCYCLOPEDIA OF Science & technology. 7th ed. Vol 10.

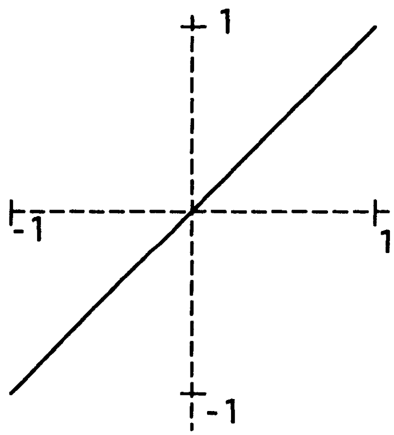
written as in **equ. 2,** and the Lissajous figure is the one shown in **fig. 1.**

$ft1$=sin B1t and $ft2$=sin B1t ....**equ. 2.**

$ft1$: harmonic motion of X axis

$ft2$: harmonic motion of Y axis

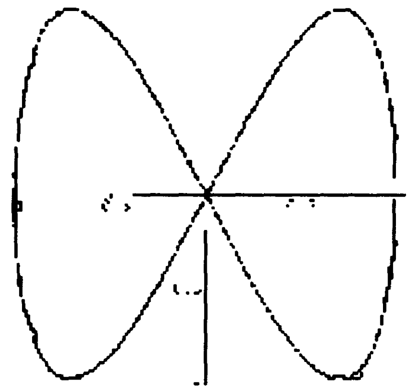
B1 : frequency of $ft1$



............**fig. 1.**

If the ratio B1:B2 is 1:2 with no other differences, then the equation can be written as in **equ. 3.** and the Lissajous figure is the one illustrated in **fig. 2.**

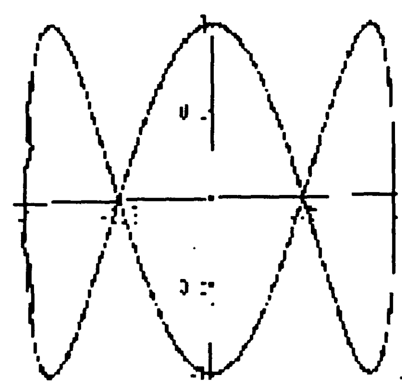
$ft1$=sin B1t and $ft2$=sin 2B1t ....**equ. 3**



..............**fig. 2.**

If the ratio B1:B2 is 1:3 without any other difference, then the equation can be written as in **equ. 4.** and the Lissajous figure is the one illustrated in **fig. 3.**

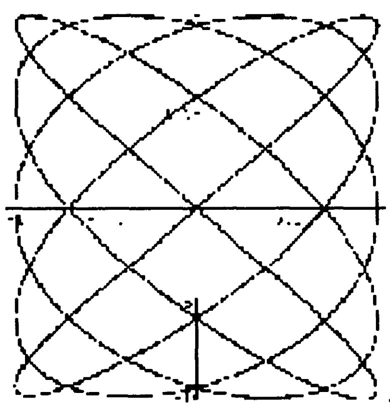
$ft1$=sin B1t and $ft2$=sin 3B1t ....**equ. 4.**



...........**fig. 3.**

If the ratio B1:B2 is 5:4 without any difference, then the equation can be written like **equ. 5.** and the Lissajous figure is **fig. 4.**

$$ft1 = \sin B1t \text{ and } ft2 = \sin \frac{4}{5} B1t \text{............} \textbf{equ. 5.}$$



............**fig. 4.**

Phase measurements

"Phase measurements usually involves two signals of the same frequency. In this case Lissajous figure is an ellipse of which the shape and the orientation depend on the relative phase and relative amplitude of the signals. The relative phase ϑ is given by the equation

$$\sin \vartheta = \pm \frac{B}{A}$$

in which A is the maximum half-height and B is the intercept on the Y axis." [5]

Equ. 1. is a general way of expressing a harmonic motion. In this equation C is the phase of the motion. If there is a phase difference in two perpendicularly positioned motions, Lissajous figures become distorted.

For example, if the phase of X axis' harmonic motion, C1, and that of Y axis' harmonic motion, C2, are the

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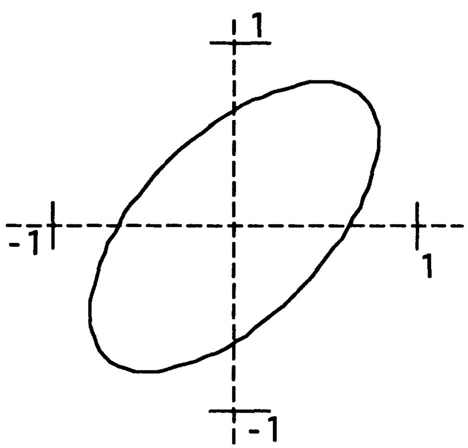
[5] Mcgraw-Hill, Inc. McGRAW-HILL ENCYCLOPEDIA OF Science & technology. 7th ed. Vol 10.

same, without any difference, then the equation and the Lissajous figure are same as in **equ. 2.** and **fig. 1.**

However, if the phases C1 and C2 are different by $\frac{\pi}{4}$, without any difference, then the equation can be expressed as in **equ. 2a.** and the Lissajous figure is the one in **fig. 1a**.

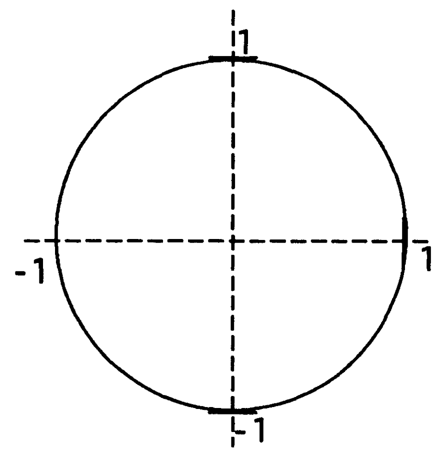
$ft1 = \sin B1t$ and $ft2 = \sin(B1t + \frac{\pi}{4})$............**equ. 2a.**



........**fig. 1a.**

If the phase C1 and C2 are different by $\frac{\pi}{2}$, then the equation can be written like in **equ. 2b.** and the Lissajous figure is the one given in **fig. 1b.**

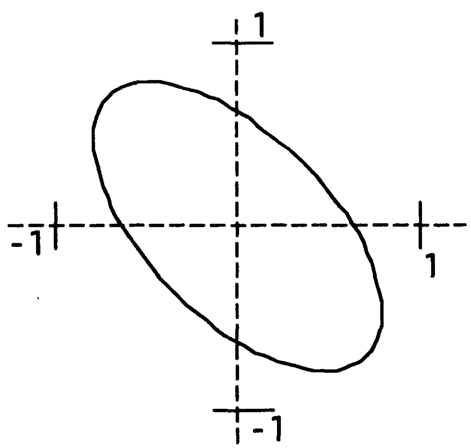
$ft1 = \sin B1t$ and $ft2 = \sin(B1t + \frac{\pi}{2})$............**equ. 2b.**



.......**fig. 1b.**

If the phase difference is $\frac{3\pi}{4}$, without other differences, then the equation is given in **equ. 2c.** and the Lissajous figure is shown in **fig. 1c.**

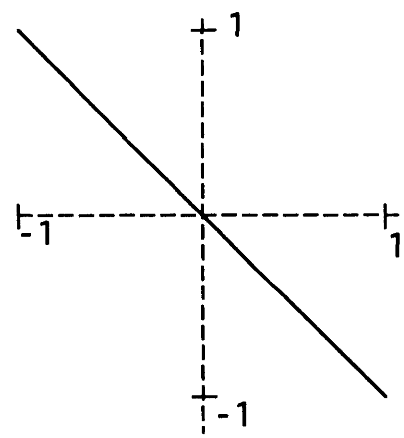
$ft1$=sin B1t and $ft2$= sin (B1t + $\frac{3\pi}{4}$)............**equ. 2c.**



.......**fig. 1c.**

If the phase difference is π then the equation is **equ. 2d.** and the Lissajous figure is **fig. 1d.**

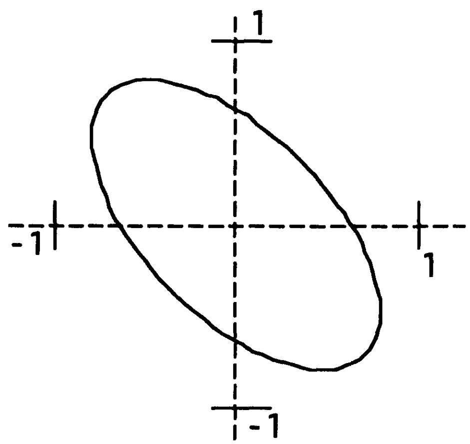
$ft1$=sin B1t and $ft2$=sin (B1t + π) ....**equ. 2d.**



........**fig. 1d.**

If the phase difference is $\frac{5\pi}{4}$ without other difference, then the equation is **equ. 2e.** and the Lissajous figure is **fig. 1e.**

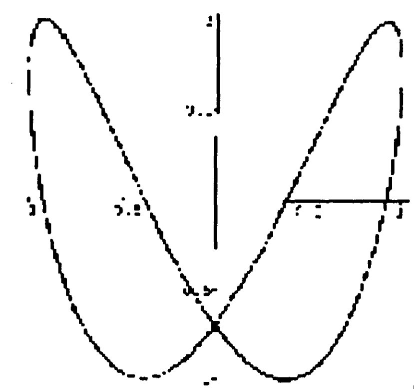
$fi1$=sin B1t and $fi2$= sin (B1t + $\frac{5\pi}{4}$)........**equ. 2e.**



.........**fig. 1e.**

Now, if there is $\frac{\pi}{4}$ phase difference, in addition to 1:2 frequency, then the equation changes to **equ. 3a.** and the Lissajous figure changes to **fig. 2a.**

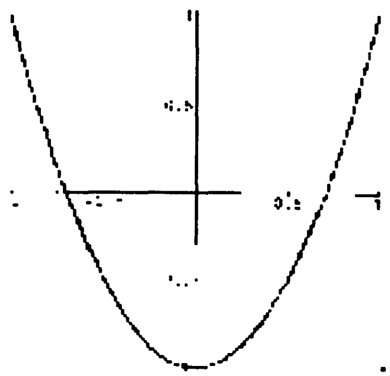
$fi1$=sin B1t and $fi2$= sin (2B1t + $\frac{\pi}{4}$)...........**equ. 3a.**



........**fig. 2a.**

If the ratio is still 1:2 and the phase difference becomes $\frac{\pi}{2}$ then the equation is **equ. 3b.** and the Lissajous figure changes to **fig. 2b.**

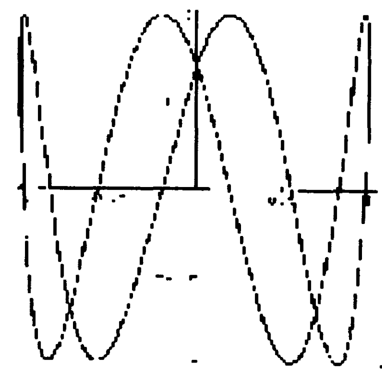
$ft1 = \sin B1t$ and $ft2 = \sin(2B1t + \frac{\pi}{2})$........**equu. 3b.**



........**fig. 2b.**

If the frequency ratio is 1:4 and the phase difference is $\frac{\pi}{4}$, then the equation is **equ. 6.** and the Lissajous figure is **fig. 5.**

$ft1 = \sin B1t$ and $ft2 = \sin(4B1t + \frac{\pi}{4})$.......**equ. 6.**



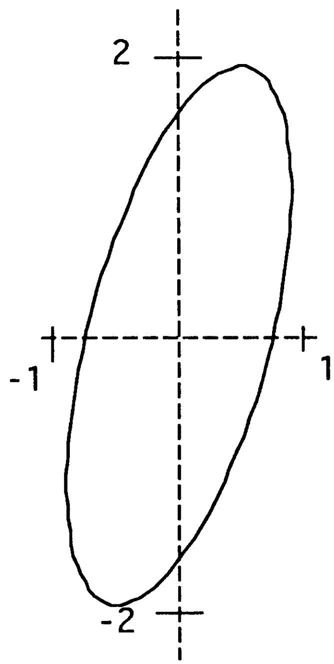
................**fig. 5.**

When the phase is continuously changing, the pattern will evolve smoothly through all of the figures illustrated above.

Amplitude

In **equ. 1.** the amplitude of the harmonic motion is A. Amplitude determines the size of the Lissajous figures. As an example, **equ. 2a.** has $\frac{\pi}{4}$ phase difference, but the amplitude of both X and Y axis' harmonic motions A1 and A2 have the same value, in previous cases 1. When A1/A2 changes to 1:2 then the equation turns into **equ. 2aa.** and the Lissajous figure is stretched as in **fig. 1aa.**

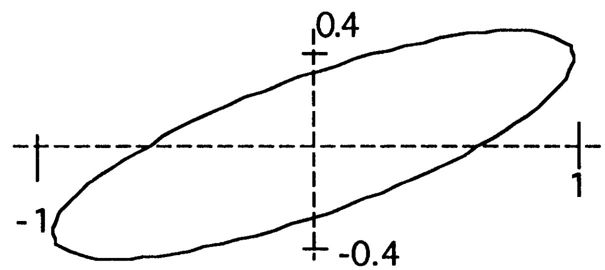
$ft1$=sin B1t and $ft2$=2 sin $(B1t+\frac{\pi}{4})$.........**equ. 2aa.**



..............**fig. 1aa.**

When the ratio of A1/A2 becomes 2:1, then the equation becomes **equ. 2ab.** and the Lissajous figure is expressed like **fig. 1ab.**

$ft1$=2sinB1t and $ft2$= sin $(B1t+\frac{\pi}{4})$........**equ. 2ab.**



......**fig. 1ab.**

Sound waves

A sound traveling through a medium has characteristics of a wave. In other words, we can describe the sound by a harmonic motion equation.

$$A\sin(Bt + C) \text{ ....} \textbf{equ. 1.}$$

	A	B	C
harmonic motion	amplitude	frequency	phase
sound wave	volume	pitch	spatial position

.....tab. 1.

For example, I will use the sound waves from a synthesizer. According to **tab. 1.** the amplitude is the volume, which means the maximum range of the volume from the synthesizer is the maximum size of the Lissajous figure. In other words, larger Lissajous figures can be obtained by increasing the volume.

Also from **tab. 1.** pitch can be explained as frequency. In a keyboard, each octave has 12 keys and each key has $\sqrt[12]{2}$ frequency difference. In other words, when the frequency of one of C keys' is F, then the frequency of the next C# key is F $\times\sqrt[12]{2}$. Since frequency works as a ratio, it does not matter whether I push low C and E keys in the same octave or higher C and E keys in the same octave. Both will show the same Lissajous figures, except that scanners respond to low frequencies with wider movement than higher frequencies.

For example simultaneously pushing two keys whose ratio B1:B2 is 1:2 results in **fig. 2.** Lissajous figure. Conversely, seeing **fig. 2.** indicates that two sounds have 1:2 frequency ratio.

When the two previous factors, frequency and amplitude, are changing we can detect it by our ears. However, phase difference, in this case spatial position, cannot be detected by our ears.

Previous Lissajous figures were time-fixed, stable figures. However, when the sound waves are changing, then the Lissajous figure is also changing as time goes on. This phenomenon sometimes creates a rotating image effect and a moving line effect.

For example, if the phase difference is changing from $\frac{\pi}{4}$ to $\frac{3\pi}{4}$,then the Lissajous figure also changes from **fig.1a.** to **fig. 1c,** which creates a rotating effect. Although our ears cannot detect the changing phase , our eyes can.

By pushing other keys, we can generate different frequency, phase and amplitude relations, and this allows us to make more complex Lissajous figures and time dependent effects.

Ampersand laser system

The following information comes from the manual for the Ampersand laser system.

These commands, all of which begin with the & character, are used to display and manipulate previously created laser image files. These statements can be used to immediately execute the given command, or they can be embedded in a BASIC program for deferred execution.

SOME DEFINITIONS:

Buffer: A portion of memory set aside only for storage of image files. This system has 10 such buffers (#0 - #9) ; each may contain a different image, or copies of the same image. Images are stored on disc when they are created. They can later be transferred from disc to one or more of buffers for instant display or manipulation.

Buffer #0 is the display buffer. When an image is placed in Buffer #0, it will be displayed instantly by the laser. Buffer #1 - #9 are extra buffer for file storage. So that fast manipulative commands can be excuted without waiting for the needed image files to be read from disc.

SRC - the source address of an image files; it can be in one of two forms: #(buffer) - the contents of that buffer; (" ") - the name of an image file.

COUNT - a number from 0-65535. Often used for display purposes. Where each unit equals approximaely one millisecond.

BYTE - a number from -127 to 127 ; -1=225. Used for speed, size and polarity variations.

ADDR - the destination of a command; can be a point in an image file, or a buffer number.

The commands: Each command consists of an Ampersand (&) followed by two or three letters and list of parameters required by the specific command. Each parameter is separated by a comma from adjacent characters. Each time a command is invoked, the whole parameter list must be provided. If a parameter is missing or needed punctuation is missing a SYNTAX ERROR will be generated. And the command will not be executed.

BLend - Blends one image into another

DeLay - Sets the time between points in the X,Y laser display

ERase - Deletes the point at <addr>, copying the rest of the image down

GeT - Reads the X and Y values of the point at <addr> into the variables

sparKLe - The sparkle effect is produced by temporarily stopping the output display

LoaD - Gets an image from disk and load it at the address specified

MoVe - Move the image at <src> to the address at <des>, adding the offsets given by <xoff> and <yoff>

NumPnts - Count the number of points starting at <src> to the end of the image

RdSet - Read the seven images in the file <fname> stored on disk into buffers #1 through #7, and updates the parameter information in memory

SHrink - Shrink an image by factors of two, reads the value of each point starting at <src>, shifts the value right by <nx> and <ny> bits for the x and Y values respectively and writes them starting at <addr>

SLow draw - Moves the image at <src> to the output buffer one point at a time, waiting <cnt> between points

nSaVe - Saves the image starting at <addr> to disk file <sname>, saving the delay and size information as well

set SiZe - Sets the analog gain of the output display. The range is from -127 to 127, with -127 to -1 giving images upside down and backwards from positive values.

UnDraw - Slowly undraws an image

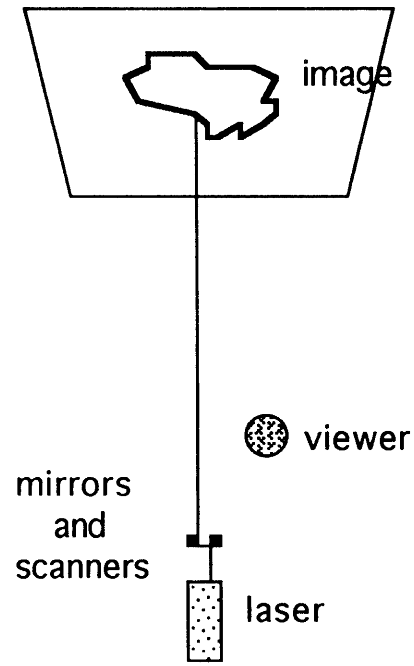
VEctor - Move setions or whole images around, rounds the values of <xoff> and <yoff> down to even numbers, then adds these values to all the points in the range between <src> and <addr>

WaiT - Waits for 'cnt' times through a software timing loop

My work using the Ampersand system

My first semester (fall'91) project was created using the Ampersand system with background music. I composed the music using a synthesizer and Sample Cell and Performer software. The laser was 8mW,He-Ne red light laser with a two-scanner system. The main theme was my internal uneasiness caused by a sudden change in my life. I took images from Korean culture and wrote a poem that represents how deep that uneasiness was.

In using the Ampersand system, the most important thing is not how to draw images well, but how to orient and manipulate the images. For example, if I show the sun first and rain afterwards, it tells a story of rain after a sunny day. However, if I show rain first and then the sun, the story is the sun after a rainy day, which is opposite from the previous one. Also, if I change a size of a bird from 127 (full size) to 0 (a dot), it looks as if the bird is flying away from the viewer. On the contrary,



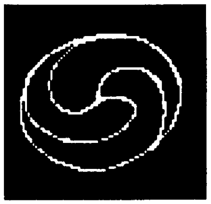
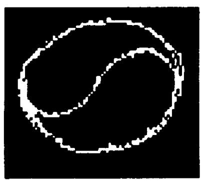
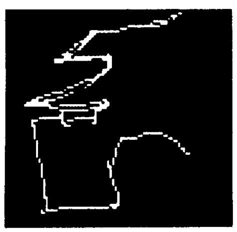
Front image projection

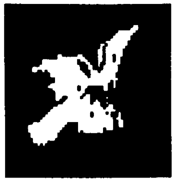
if the size changes from 0 to 127, it looks like the bird is flying towards the viewer. By using these different feelings from different image orientations and manipulations, I tried to express myself effectively.

The speed or flow of loading different images is also important. Since each image has its own impression I need to give enough time to the viewer to get that impression. If the time interval is too long, the viewer will start to get bored and will not concentrate. If the timing is too fast, the viewer will not be able to follow the flow of the images.

The poem that I wrote and used with the Korean images is,

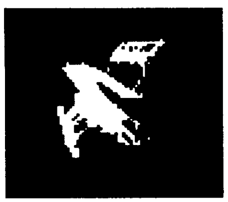
TWO BLACK EYES
AMONG BLUES
TEAR DROPS ARE
TOO LUXURIOUS.

PICTURE	COMMAND	EXPLANATION
 "O9"	10 &LD,"O9",#0 20 FOR X=1 TO 127 30 &SZ,X 40 &WT,20 50 NEXT	Load the image "O9" and change the size from a dot to its maximum size.
 "O2"	60 &LD,"KOREA",#0 70 &LD,"O1",#0 100 &LD,"KOREA",#0 114 &WT,2000 115 &LD,"O2",#0	Load the image "KOREA", "O1" and "KOREA", in turns and then load "O2" and stay for a second.
 "DOOR"	120 &LD,"DOOR",#6 170 &SD,"DOOR",1500 180 FOR X=1 TO 280 190 &VE,#0;0,#0;1000,X,0 200 &WT,44 215 &KL,5,5,5	Slowly draw "DOOR", then vector it horizontally for 280 unit length. While vectoring, use the sparkle effect.



"BIRD"

"BIRD"



"BIRD"

```
230 &BL,#1,20,20
240 FOR X=1 TO -87 SPET -1
250 & VE, #0; 0, #0; 1000,(- 1
*X/O.2),(-1*X/0.7)
266 &WT,800
270 NEXT
```

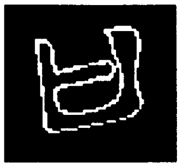
Blend "DOOR" into "BIRD"

Vector "BIRD" to the northeast direction.

```
280 FOR X=127 TO -127 STEP
-1
290 &SZ,X
300 &WT,30
301 NEXT
311 &KL,30,30,30
```

Change the size to a dot then bring up the upside down "BIRD" to its maximum size, then use the sparkle effect.

```
315 &LD,"CH",#0
320 &LD,"B",#0
325 &WT,2000
          .
          .
356 &LD,"P",#0
360 &WT,1500
365 &LD,"H",#0
```



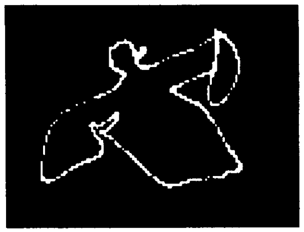
"P"

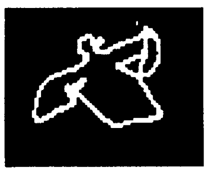
Load "CH","B","P","K","P","H"

```
366 &LD,"OO",#1
367 &BL,#1,40,40
368 FOR X=127 TO 1 STEP -1
369 &SZ,X
370 &WT,33
371 NEXT
```

"OO"

Blend "H" into "OO" then change its size to a dot.



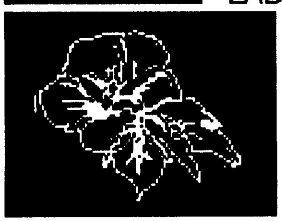


"LADY1"

```
375 &LD,"LADY",#0
376 FOR X=1 TO 127 STEP 15
377 &SZ,X
378 &KL,35,35,35
379 NEXT
410 FOR X=127 TO 1 STEP -1
430 &WT,22
431 Z=100(1/X)
432 &VE,#0;0,#0;1000,Z,Z
440 &SZ,X
450 NEXT
```

Bring up "LADY1" from a dot to its maximum size while this is happening. Use the sparkle effect.

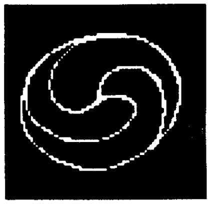
While changing the size back to a dot, vector "LADY1" to the northeast direction.



"FLOWER1"

```
460 &LD,"FLOWER1",#0
470 FOR X=1 TO 127
480 &SZ,X
490 &WT,20
500 NEXT
510 &KL,30,30,30
520 &UD,1000
```

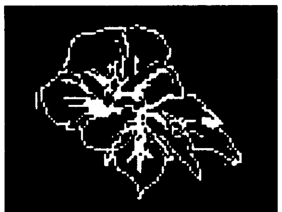
Bring up "FLOWER1" to its maximum size, then use the sparkle effect and slowly undraw it.



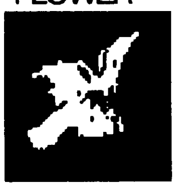
"OO"

```
530 &SD,"OO",2000
580 &KL,30,30,30
590 &UD,2000
```

Slowly draw "OO" then use the sparkle effect and then undraw it with the same speed as the slow draw.



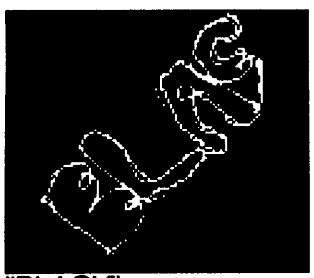
"FLOWER



"BIRD"

```
600 &LD,"FLOWER",#0
605 &LD,"O",#7
606 &LD,"O1",#2
610 &BL,#5,40,40
620 &BL,#6,20,20
630 &BL,#3,40,40
650 &BL,#7,40,40
```

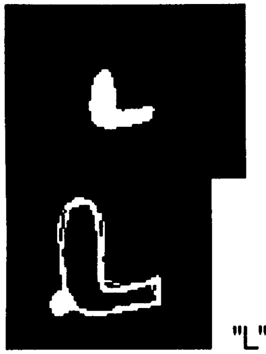
Load "FLOWER" then blend into "KOREA", into"DOOR", into "BIRD", and into "O".



"BLACK"

```
770 &LD,"BLACK"
780 FOR X=1 TO 43
790 &VE,#0;0,#0;1000,10,10
800 &WT,400
810 NEXT
```

Load "BLACK" then vector it to the northeast direction.



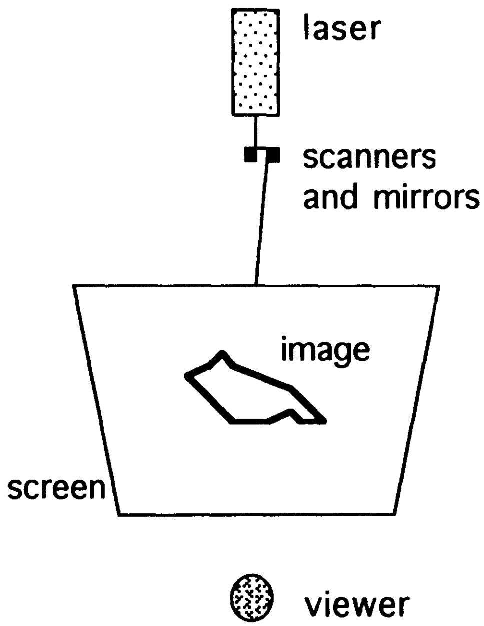
"L"

```
1160 &LD,"L",#0
1170 FOR X=1 TO 127
1180 &SZ,X
1190 NEXT
```

Bring up "L" from a dot to its maximum size.

My second semester work (spring'92) was also done by using the Ampersand system. Unlike the first semester project, it was a rear image projection.

For a display space, I drew a traditional Korean dragon on the wall, around the screen. The screen was attached in the middle of the wall and the size of the



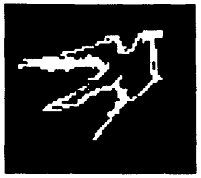
Rear image projection

wall was approximately 9 by 11 feet. The screen was a paint of a plum tree, size 4 by 4 feet, on Korean black ink painting paper. The paint for the dragon was a black light paint and two black lights were illuminating the wall from the above. Along the wall, I hung the bamboo forest painted gauze. I tried to use a TV light which dramatically changes according to the displayed images. However, the texture of the light coming from a TV did not go well with either black light or laser light.

The theme for this work was freedom and I used various kinds of bird images. They were randomly loaded and manipulated. There was no systematical order in selecting images and how to manipulate them. Even I could not tell what was going to happen next.

I decided to use this method because this was not a timed show, but an installation; it was better not to have either an obvious ending or a starting point. In installations viewers tend to keep moving, sometimes coming back to see it again. Therefore, I need to show different images with different manipulations for the viewers who are unpredictably coming back.

IMAGE | COMMAND | EXPLANATION

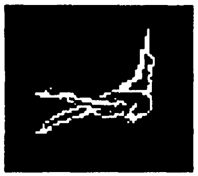


"A"

These eight images were put into buffer #1 to #8 and randomly loaded by command 110 to 130 and 209.

```
110 S=(RND(1)*20)
120 S=INT(S)+1
130 PRINT S
209 &MV,#S,#0,0,0
```

Randomly pick one number from 1 to 9 and load image in that picked buffer.

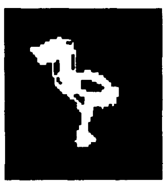


"B"

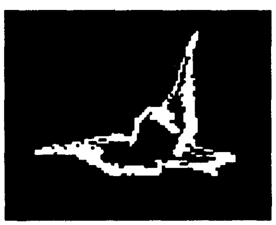
By command 183 to 189 what kind of manipulation will be done to this randomly picked image is judged.

```
183 C=(RND(1)*20)
184 C=INT(C)+1
185 IF C>10 THEN GOTO 183
186 E=127-B
187 IF C=3 THEN GOTO 320
188 IF C<4 THEN GOTO 235
189 IF C>6 THEN GOTO 206
```

Randomly pick one number and if it is bigger than 10 then pick again. If the number is 3 then goto 320.
If the number is smaller than 4 then goto 235.
If the number is bigger than 6 then goto 206.



"C"

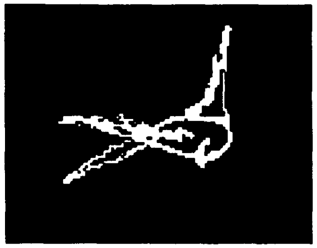


"D"

If C=1 or 2 then the image goes through size change

```
235 &MV,#S,#0,0,0
240 FOR A=127 TO B STEP -1
250 &SZ,A
269 &WT,30
270 NEXT A
280 FOR D=B TO 127 STEP 1
290 &SZ,D
300 &WT, 180
310 NEXT D
```

If the number C is 1 or 2 then change the size of the image from its maximum to random number B, which is between 127 to 1, then again bring up to its maximum size, 6 times slower than before.



"E"

If C=3 and also S=3 then the image goto the same size but with a different B value. However, if S is not 3 then vector the image according to the command from 321 to 324.

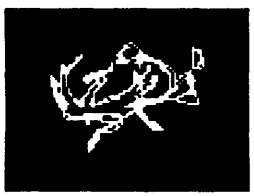
When the value of C is changing from 3 to 6, the image goes through the same size changing effect, but the speed and B values are all different.

```
187 IF C=3 THEN GOTO 320
320 IF S=3 THEN GOTO 188
321 FOR M=1 TO 30
322 &VE,#S,#0,0,0
323 &WT,200
324 NEXT M
370 GOTO 101
```

When C=3 and S is not 3 then the image vectors to the north direction 30 unit length. After this, pick another image and start again.

"F"

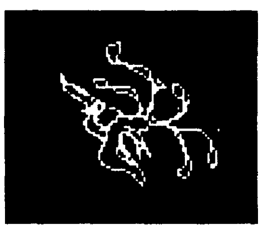
If C=4 or 5 or 6 then image goes through the command from 201 to 205.



"G"

```
201 FOR Z=127 TO B STEP
-1
202 &SZ,Z
203 &WT, 122
204 NEXT
205 GOTO 110
```

When C is bigger than 6 and B is smaller than 40 then goto 110 and pick up a new image and pick up B and C values again.



"H"

If C>6 and also B<40 then get the new image from the command 110.

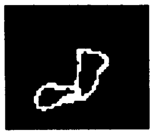
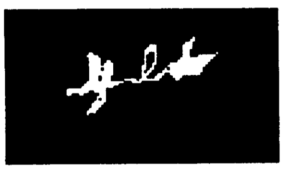
```
189 IF C>6 THEN GOTO 206
206 IF B<40 THEN GOTO
110
```

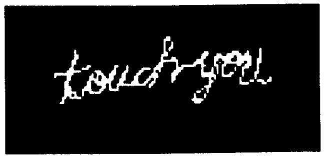
The other spring '92 semester work was for Prof. Tod Machover's electronic music class. The music was written using Performer software, a Yamaha keyboard and Proteous. My projection was done as a part of a concert at the Media Lab. The synchronization of music and laser image projection was done manually, and there was no connection between laser system and music system.

The title of this music piece for the laser image projection was Emotional Oboe. The images for this piece were a poem that I wrote while I was working on Emotional oboe. The poem is,

If I do
touch you
with my
red heart
there is
none
can remove
it.
.
.
.
Stop
Slow down
and
help me
make you
Suddenly
and forever
emotional.

When I was using words as images, my concern was how to write these words on the screen. My question was how I can treat each word as one image that has its own feelings and meanings, only because it is used in this poem. Since the order of images that were going to be loaded was fixed according to the poem, I was concentrating on how to manipulate these words so that the meanings and feelings of the words can be properly expressed.

IMAGE	COMMAND	EXPLANATION
  "LIGHT"	10 &LD,"LIGHT",#0 20 &SD,#0,5000	Slowly draw the image "LIGHT".
 "SMP1"	40 &LD,"SMP1",#2 50 &MV,#2,#0,0,0 60 FOR X=1 TO 127 70 &SZ,X 80 &WT,99 90 NEXT 100 &WT,1000	Load "SMP1" and change its size from a dot to its maximum size. Then wait for about 0.2 second before the next image comes up.

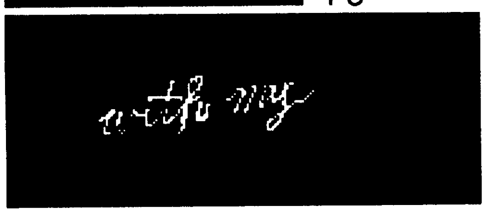


"P2"

```
110 &LD,"P2",#0
115 &WT, 5000
120 FOR X=127 TO 1 STEP -1
130 &SZ, X
140 &WT,55
150 NEXT
```

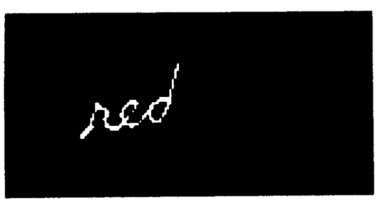
Load "P2" then about a second later bring down its size to a dot.

"P3"




```
160 &LD,"P3",#1
170 &SD,#1,5000
175 &WT,300
```

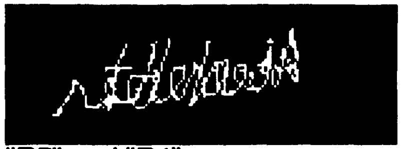
Load "P3" and slowly draw it.



"P4"

```
180 &LD,"P4",#1
190 &SD,#1,5000
195 &WT,500
```

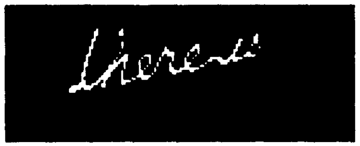
Load "P4" and slowly draw it.



"P5" and "P4"

```
200 &LD,"P5",#0
```

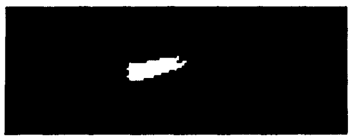
Load "P5".



"P5"

```
210 &UD,2000
```

Slowly undraw "P5".

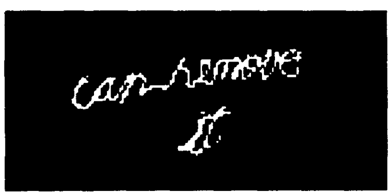


"SMP1"

"SMP1"

```
205 &LD,"SMP6",#3
225 &MV,#3,#0,0,0
230 FOR X=1 TO 127
240 &SZ,X
250 &WT,44
260 NEXT
265 &KL,1000,100,100
```

Load "SMP1" and bring up its size from a dot to its maximum size and then use the sparkle effect.



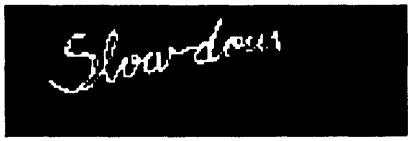
"280"

```
280 &LD,"P7",#0
```

Load "P7".

<u>Before the next half of the poem, I ran the random bird program that I had used for my rear image projection.</u>

"P12"



"P12"

```
10 &LD,"P12",#1
20 &SD,#1,1000
```

Load "P12" and slowly draw it.

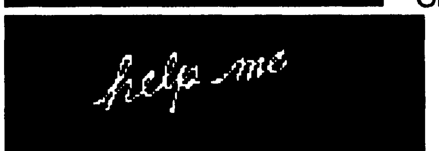
"P14"

"P14"

```
30 &LD,"P14",#0
35 &WT,1500
40 FOR X=127 TO 1 STEP -1
50 &SZ,X
60 &WT,66
70 NEXT
```

Load "P14" and then bring down its size to a dot.

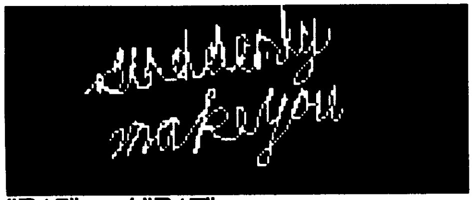
"SMP16"



"SMP16"

```
80 &LD,"SMP16",#0
90 FOR X=1 TO 127 STEP 10
100 &SZ,X
120 NEXT
```

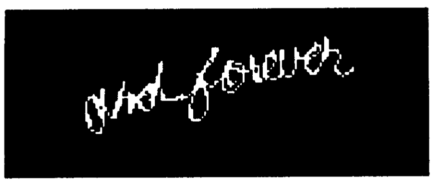
Load "SMP16" and bring up its size from a dot to its maximum size.



"P15" and "P17"

```
130 &LD,"P15",#0
140 &WT,2000
150 &LD,"P17",#0
160 FOR S=1 TO 86
161 &VE,#0;0,#0;1000,0,-1
162 &WT,150
163 NEXT
```

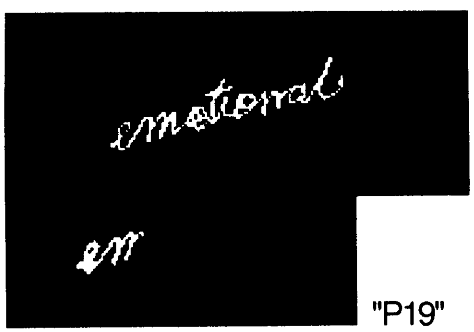
Load "P15" then load "P17" and vector it down to 86 unit length.



"P18"

```
170 &LD,"P18",#0
190 FOR X=1 TO 40
191 &VE,#0;0,#0;1000,0,2
192 &WT,333
193 NEXT
```

Load "P18" and vector it up to 80 unit length.



"P19"

```
180 &LD,"P19",#1
200 &BL,#1,40,40
210 &KL,90,90,90
220 &UD,3000
```

Blend "P18" into "P19" then use the sparkle effect and then slowly undraw it.

My work using Lissajous figures

For my third semester (fall '92) work, I used Lissajous figures from sound waves, coming from a synthesizer. The synthesizer has a stereo signal system, that sends two different waveforms to two different channels, right and left.

In order to form the laser images, two mirror-mounted scanners are neccesary. One is for the X-value and the other is for the Y-value. If the X-value scanner is connected to the output for the left channel and Y-value scanner to the output for the right channel, then both scanners are moving according to the phase, the frequency and the amplitude of the wave forms that are coming from the synthesizer.

Therefore, when the wave forms from the synthesizer are changing, the laser images are also shifting. While music is being produced by the synthesizer, the laser images keep transforming accordingly. The role of the signals from the synthesizer as a piece of music is explained in the conclusion, Sound from a synthesizer.

The most important issue in this piece is the 3-D display of the laser images. To do this, there should be an object that can capture the laser light as the light passes through the object. For the light capturing object, a netlike white fabric is used. Because of its net-like structure that allows light to travel freely through the fabric, the white fabric most effectively creats the 3-D burning fire effect. The fabric is placed at the inside of a 1500 X 500 X 500 mm Plexiglas tube for protection. Also, a poem is written on the fabric so that the viewers can read it while the laser light is hitting the fabric. The poem that I wrote for this piece is ,

Burning, burning, burning my heart
hoping you will get warm
feeling my heart melting down
touching empty space of heart
crying out loud,
"I would rather feel pain,
than live with stone heart!!!"

In most laser image projections, the relationship between the images and the viewers is that of the movie and the spectators. However, this installation gives viewers a new experience in how to look at the laser images. Because the Images are forming and moving inside the transparent Plexiglas tube, people can get different viewpoints by walking around the tube.

The laser light passing through the tube creates two major effects. One is the 3-D burning fire effect and the other is turning the poem into red as if it feels pain. The poem represents the words that the laser light tries to say to the viewers. When there is no laser light inside the tube no one can read the poem, because there is not enough light to read. When the laser light goes through the tube, the poem changes to bloody red and throws the words into the readers' eyes.

By using---1.the intense red light from the laser, 2.the poem that came from my heart, 3.the 3-D display of the images---I am trying to give warmth and a poetic aspect to the installation. I want to hear people saying, "look at that burning red light," instead of saying, "look at the laser light."

Thesis project

Title: Free Me

Introduction

Whenever I am dealing with laser light, my primary concern is how to make laser line images visually stronger than the light itself. Since the laser light is brighter than other lights, like incandescent lamps and neon tubes, viewers' eyes are first attracted to the brightness of the laser light, and then their attention moves to the images. In other words, the tool of the work dominates the work itself.

In order to avoid this domination, where and how to present laser line images must be carefully chosen. Depending on the display space, there is a significant difference in impression of the images, because the laser line images change their shapes according to their display space. In other words, by changing the display space, I can try to make the viewers' eyes to see the images first, so that they can say, "look at that red images" instead of "look at the laser light."

The thesis piece "Free me" is divided into two parts for the change of the display space. One is two dimensional space and the other is three dimensional space. The 2-D space is the floor of the pit and the 3-D space is the "burning field", that is constructed on the floor of the pit. By moving the images from the 2-D to the 3-D space, the impression of the images are also changing and this effect makes the images visually more attractive.

Images

Two kinds of images are used. One is line drawings of birds and words used for traveling from the 2-D to the 3-D space. The words are from the poem,

Free me!
Free me!
Free me!
Let me free me
by burning me!

The other image is the Lissajous figures for the 3-D display space,"Burning field." "Burning field" requires continuously changing images for the burning effect. The Lissajous figures of sound waves from a synthesizer is suitable for this purpose. (Detailed explanation is in the "Burning field " part)

Two dimensional space

Most laser image projections are done on flat surfaces, like walls of buildings or screens. Since the laser images are "re-forming" their shapes according to the projecting surfaces, flat surface is quite effective to make viewers catch the images easily. However, easy recognition of the shapes of the images is not enough to steal the viewers' attention from the bright laser light itself.

When I am thinking of the laser images on the 2-D space, words like "stuck on the wall", "imprisoned", "fixed", "immovable" and "inanimate", come to mind. No matter how recognizable the images are, I always feel that there is something missing in them. They are bounded by the wall and cannot be freed from the display surface, and appear to be very unnatural and restricted. In my opinion, these feelings are the result of the lack of the depth of the images, which the images on a 2-D space cannot avoid. The floor of the pit is the two dimensional space for the thesis project.

Three dimensional space,"Burning field"

Three dimensional space represents the freedom and the "soul" of the images. As the images that were imprisoned in 2-D space are moved into the 3-D space, they gain their depth, and the freedom to defuse and "re-shape." Through this activity they start to come alive, and the images that contain freedom and soul captures the viewers' attention. The freedom and the soul of the 3-D images will make viewers say, "look at those 3-D red images."

Burning field

"Burning field" is the 3-D display space for the traveling images. The "Burning field" requires two elements. One is an object that can capture both the traveling images (from 2-D to 3-D space) and the Lissajous figures that are expressed by laser light. The other is the Lissajous figures of sound waves for the "burning field" effect.

For the light-capturing object, a net-like fabric is used. This fabric has two characteristics. One is from a net-like structure and the other is from its strings that are forming the fabric. Holes of the netlike structure allow laser light to go through the material so that the traveling images can have depth. The strings of the fabric is glittering as the laser Lissajous figures are passing through.

As these glittering parts keep shifting, the fabric field gives the burning field mood. To make this continuous shifting of the glittering parts, the Lissajous figures should have endless changes of their shape. The Lissajous figures shaped by sound waves are ideal for this purpose, because the sound waves can easily be changed using a synthesizer. In other words, changing the sound waves will change the Lissajous figures, and since the continuously changing laser Lissajous figures are projected all over the fabric field, the shifting of the glittering parts creates the "Burning field."

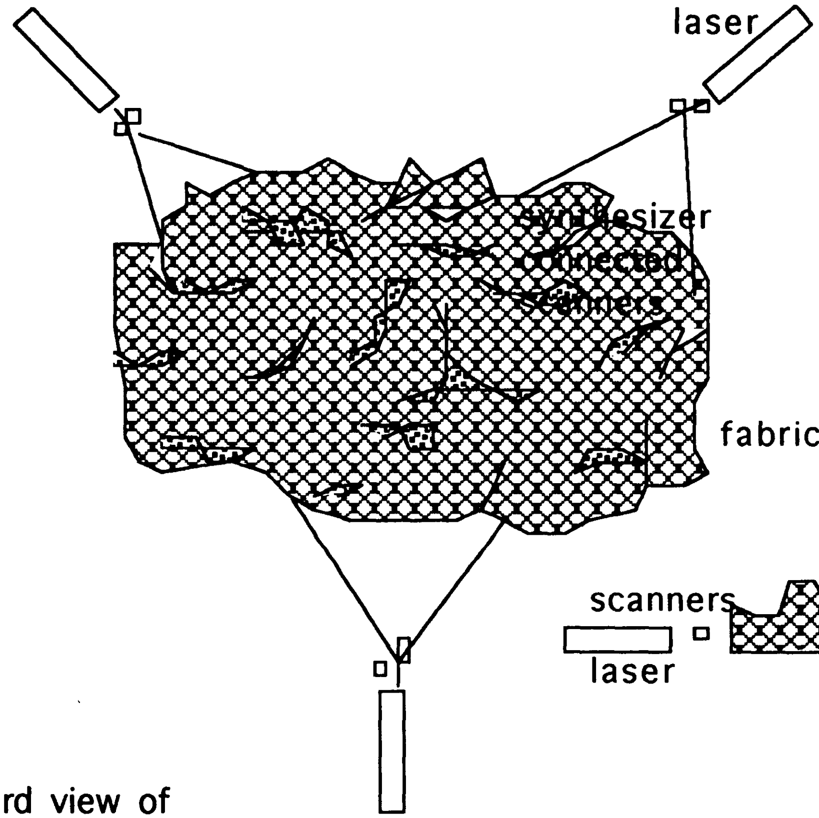
Sound from a synthesizer

The main role of sound from a synthesizer is not what it sounds like, but what kind of Lissajous figures are produced. Therefore, the types of sounds were chosen based on the visual effectiveness of Lissajous figures. In other words, the look of Lissajous figure is more important than the quality of sound in this piece.

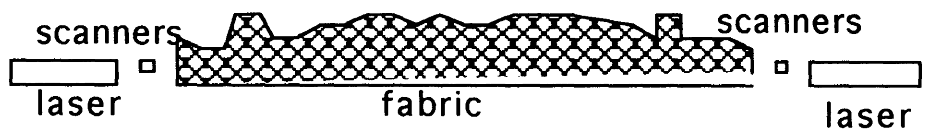
After selecting sounds, the next consideration is how to well organize the sounds so that their sound qualities can be harmonized to each other. Which means writing a song with those selected sounds. Since sound also stimulate the auditory sense as the images to the visual sense, even though the sound quality is not as important as sound's Lissajous figure, the sound quality has effect on the viewer's impression of the piece. This is why the organization of the sounds should also be considered.

Equipment

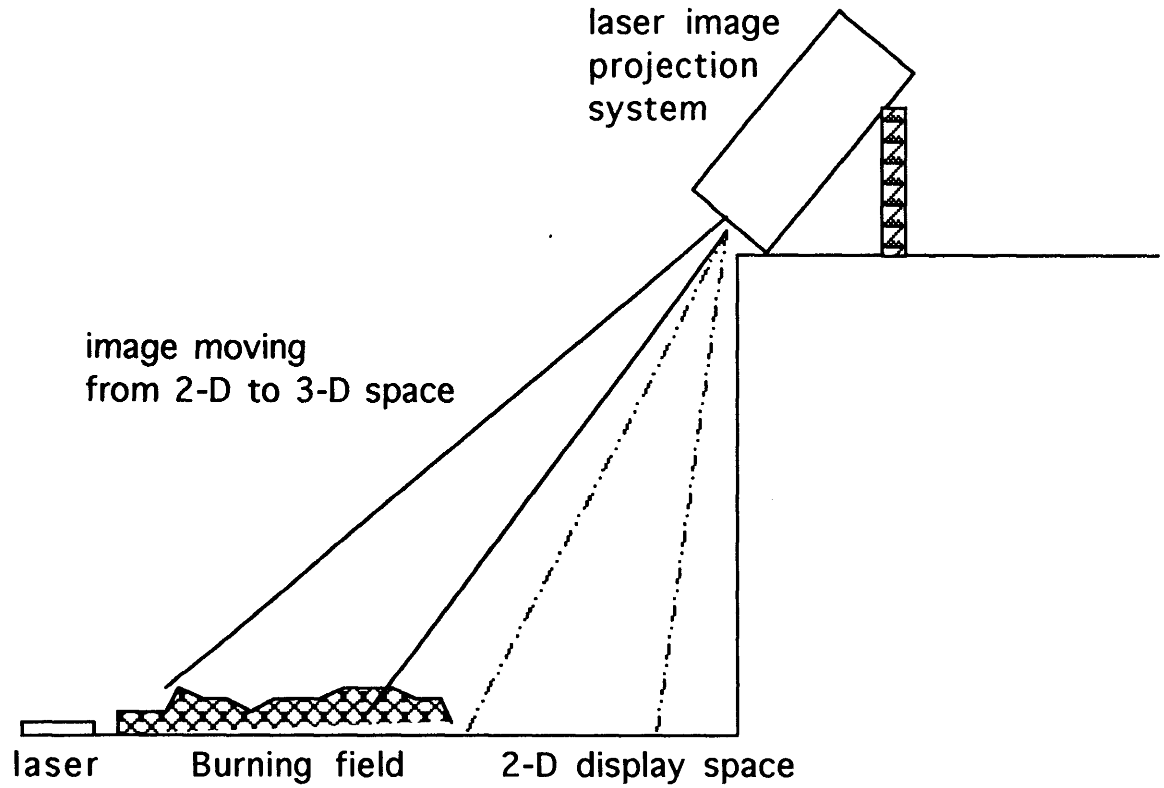
name	quantity
5mW laser	4
closed loop scanner	one pair
open loop scanner	three pairs
mirror	four pairs
synthesizer	1
speaker	one pair
net-like fabric	
wire	



Bird view of
burning field



section of
burning field



section of the setup

Theme and Intention

I believe almost every artist's theme of her work is related to her current interests. This is so in my case, because the motivation that lead me to design a piece starts from my everyday life. The theme of my first project was "uneasiness of my life after a sudden change of living environment," the second one was "safety and emotion," and the third one was "evolution of my emotions." These days my primary concern is freedom--freedom from the "unwritten social law" that will lead me to freedom of thinking. Also, a bitter feeling toward myself that I do not have the courage to break the chain of unwritten social law. In Korea there is an old unwritten social law that states:

> "A woman should obey her father,
> when she is young.
> A woman should obey her husband
> when she gets married.
> A woman should obey her son
> when she gets old."

No matter how the world has changed and the east and the west cultures are beginning to integrate, there is an unchangable way of thinking in Korean society that has been embedded into people's minds for more than five thousand years. This basic rule of living in the relationship between a daughter and her father has not changed and has been accepted by the people without any question. Therefore, when someone tries to get away from the general way of thinking in her society, the society and the family start to exert even greater power over this person. If such domination has not been so powerful, Korean society would be different from the way it is now. However, the immutability of the Korean society indicates how powerful this domination is.

Even though I am living my life, the life is not mine: my life is controlled by my parents. If I begin to insist on the possession of and control of my life, the society and my family would blame me by using the phrase,"undutiful to my parents." And this is the worst phrase of which a child can be blamed. Therefore, only by overcoming the pain that is as painful as burning my own body, can I say that I am the "owner" of my life. This is my current interest-- the issue of possessing my life as my own-- and thus, is the theme of my current work.

In this thesis project, 2-D display space is the representation of the restricted place and imprisoned thoughts. The images that are staying in that space can have visually *clean* recognition of their shapes. However, they only have opinions that are washed away by the brightness of the laser light. They have given up their strong visual attraction by choosing to stay in a safe area for keeping their shapes.

3-D display space,"Burning field," represents the space of freedom and 3-D space has distinctive qualities that 2-D space cannot have-- the freedom to have depth. The images will no longer keep their original shapes when they are moving into the 3-D space. However, by adding the depth to their re-formed shapes,the images can gain the freedom to change their shapes and can obtain the "beauty of laser lines" that will not be washed away simply by the brightness of laser light.

The images that are in the "Burning field" have a risk that they might not be seen very well because of the brightness of the "Burning field" itself. However, by harmonizing with the glittering parts of the "Burning field," and by continuously showing different shapes from those in 2-D space, the images in 3-D space wil out -shine the brightness of laser light. In other words, the courage of taking risk offers the power to achieve greater beauty.

Compared to the "knife-cut" clean shapes in 2-D space, sometimes unrecognizable, endlessly changing and "freed to have depth" 3-D images are having real life and are full of soul , and thereby, have qualification to possess the beauty of laser lines.

A historical perspective

This chapter is mostly taken from T. Kallard's LASER ART & OPTICAL TRANSFORMS, and Ans van Berkum's science * art.

Laser imagery as an art medium uses modern optics and electronic technology, along with traditional equipment to produce its works of art. The artist working with a laser can draw, paint and inter-weave sound with motion in black-and -white and color. Today the tools are available. Two and three-dimensional abstract forms as well as representational images are created by laser modulators, synthesizers and holography.

Laser technology was developed in the 1960's and 70's. When invented, lasers immediately fired artistic imaginations. Coherent light with its high intensity, spectral purity and pencil-like form was a new medium that begged for exploration. Modern artists began to team up with scientists and engineers in the belief that the creators of our time should work with up-to-date means. They felt the development of new technical tools would result in new fields of creativity. Many artists/ scientists and scientist/artists came to work with lasers as an outgrowth of their work in other media. The work done by many individuals during the past fifteen years represents an extension of the traditional idea of art, and also of media. During the past few years the opportunities for laser artists to exhibit works at museums, galleries and planetarium have grown considerably.

Going back in time to 1925, Laszlo Moholy-Nagy, a Hungarian artist, predicted that light would bring forth an entirely new kind of art. He wrote: " It is probable that future development will attach the greatest importance to kinetic, projected composition, probably even with interpenetrating beams and masses of light floating freely in the room without a direct plane of projection; the instruments will continually be improved so that it will be able to picture." among the major artists of the 1920's and 30's only Moholy-Nagy worked with both light and movement. He traveled from Europe to the U. S. and in Chicago founded the Institute of Design where until his death in 1946, he was Director.

Moholy-Nagy's principal theoretical work, "Vision in Motion" was published posthumously in 1947.

Fifty years ago Moholy-Nagy called for 'drawing with light' and 'light in place of pigment'. He spoke about the one-ness of art, science and technology. He said: "People believe that they should demand hand execution as an inseparable part of the genesis of a work of art. In fact, in comparison with the inventive mental process of the genesis of the work, the question of its execution is important only so far as it must be mastered to the limits. The manner, however, - whether personal or by assignment of labor, whether manual or mechanical - is irrelevant."

In 1936 Alexander Korda commissioned Mohoy-Nagy to design the special effects for the film, "The shape of Things to come," based on the novel by H. G. Wells. Moholy-Nagy's light modulators represented the beginning of a kinetic light art which flourishes in today's laser age.

'Op Art' is defined as a visual fine art (painting or sculpture) that evokes strong visual responses by utilizing various optical effects ('Op Art' meaning 'optical art'). Moholy-Nagy did the spadework for this school in 1942.

It was Moholy-Nagy who invited his countryman Kepes to come to the United States to teach at the Institute of Design in Chicago, which was originally the "New Bauhaus". Based on his teaching experiences there, Kepes published, "The Language of Vision," in 1945. He organized an exhibition at Harvard's Carpenter Center for the Visual Arts on the concept of "Light as a Creative Medium" in 1966. In 1946 Kepes began to teach at the Massachusetts Institute of Technology and founded the MIT Center for Advanced Visual Studies in 1967.

Nicolas Schoffer ,in the 1950's, began to construct what he named "Luminodynamic Spectacles." They were seen in the parks and city's spaces. His "Cybernetic Tower," built in 1961 in Liege, Belgium, "radiated" music and light in motion.

Otto Piene and Heinz Mack of Düsseldorf formed Group ZERO in 1957, to explore new technology as new means in art. Mack exploited reflective metal surfaces and Piene used stencils to modulate light and project his 'light painting' on the wall, ceiling and floor. From the 1960's on, Piene used the sky as a space or stage for 'sky events'.

Another group, GRAV, was founded in Paris in 1960 by Julio Le Parc. Gruppo T followed in Main, Gruppo N in Padua, Equippo 57 in Spain and other groups in Holland and Germany. All explored the potential use of movement and light.

During the 1950's John Healy created 'light boxes' which projected moving shapes onto walls and screen and Frank Malina created his "Lumidyne" construction. Malina's work was presented in the Kunst Licht Kunst exhibition in Eindhoven, Holland and Germany. Malina founded the journal "Leonardo" a forum for artists and scientists to describe their research on new material and techniques and to express their thoughts as to what their work meant.

The pioneer American kinetic-light art group, USCO, was formed in 1962. Gerd Stern was a founding member and spokesman for the group. It consisted of artists, engineers, poets and filmmakers who created audio-visual performances and set up a light display in an abandoned Garnersville, New York, church.

The laser was invented in 1960 and within a few years Co-Op-Art, as Leo Beiser calls it ('Co-Op' for 'coherent-optical'),was born. Two years later, in Sweden Carl Frederik Reutersward began his exploratory work with lasers. Later, in 1968, he used laser light in a production of "Faust" in Stockholm. Joel Stein designed installations for projecting laser images on a stage for a ballet produced by Michel Descombey at the Opera Comique in Paris. During the late 1960's Robert Whitman and James Turrell used laser light in museum projections. Rockne Krebs, Mike Campbell and Baron Kody constructed an 'environmental room' for "Laser Light : A New Visual Art," an exhibition organized by Dr. Leon Goldman at the Cincinnati Art Museum in December, 1969. These 'rooms' were filled with mirrors and some smoke to make the criss-crossing laser beam visible. Rockne Krebs, for example, used six He-Ne lasers and four co-planar mirrors. The mirrors were slightly bent, giving the reflected images within the 'room' a curved effect and the impression of a complicated network of brilliant red light. In 1971, with the help of argon and He-Ne lasers and mirrors, Rockne Krebs created "Dry Passage." This multi-colored, three-dimensional light structure was made for 'Art and Technology 'at the Los Angeles County Museum of Art. Also in 1971, Willard Van De Bogart created laser images in concert with the Los Angeles Philharmonic Orchestra. The images were projected onto a 40' X 40' screen through a complex of optical glass, fiber optics; rippled plastics and mirrors.

In the early 1970's Elsa Garmire, a laser physicist at the California Institute of Technology, did pioneering work in the development of laser art. She experimented with the ability of various materials, placed in black boxes, to alter laser light by reflection and refraction. She passed a laser beam through such on optical box and projected it onto a wall, screen, or photographic film. In other instances the light was aimed at printing paper, to record negative black-and -white 'lasergrams'. Garmire's team and Ivan Dryer's company, Laser Images, Inc., made abstract films recording the ballet of forms set to music. Some of her laser photographs were exhibited at the photosphere Gallery in Los Angeles.

In 1968 Lloyd G. Cross invented Sonovision, which produced a visual display of sound by projecting a modulated laser beam on an opaque surface or translucent screen. Music, a complex of many frequencies at any given instant, was represented as a mixture of pure tone patterns. This petal-type and Lissajous patterns were not only in correspondence to the music but also repeatable each time a particular passage was played. This device, and similar ones, later became an important part of the instruments used to make laser projections as background for poetry readings, mime, ballet and stage productions.

The term 'light show' is commonly used to describe projected kinetic art. During the 1970's a new technique evolved: scanning projection, or computer controlled X-Y scanning. With X-Y, it is possible to project preconceived nonrepresentational forms, line-form drawing and illusions of three-dimensional surfaces. These projections can be aimed at walls, clouds, balloons or mountains. They may be used safely indoors when aimed at a surface such as a planetarium dome. All over the world laser light shows are becoming more and more numerous.

In England, John Wolff has been involved with large scale laser displays for many years. He is a leading exponent of laser light shows and it was through the work of Wolff that "The Who," a pop group, began using laser light effects during their performances. The group's concerts were punctuated with a few 90-second bursts from their eleven lasers. During the summer of 1976 Wolff and Paul McCartney put on a laser show for the "Venice in Peril" fund - an event organized by UNESCO. Wolff is a member of HOLOCO, a group established at Shepperton Studio Center for the purpose of developing and producing optical effects. The other participants of HOLOCO group are Nick Phillips, a Senior Lecturer at Loughborough University, where HOLOCO's research into holography is done, and Anton Furst, who has been involved in design, special effects and holography since 1967.

In 1975 CAVS at the Massachusetts Institute of Technology hosted a conference on the use of new technology by the arts, "ARTTRANSITION." In 1976 the American Association of the Advancement of Science held a symposium called "Art, science, and Technology in Shaping the Environment of the future."

Artist Reginald Pollack produced a light show in 1977 at Pennsylvania State University. He used eight He-Ne lasers to project abstract images on a screen during the school's annual arts festival. Computer-generated laser images were made to interact to the music of Bach and Stravinsky. For the past several years Professor Rustum Roy, also of Penn State, has been collaborating with artists in a program to educate faculty and students in the pioneering of commissioned art works, as well as annual science in art competition.

The summer of 1978 saw nightly laser events being held in Washington, D.C. "Icarus," a sky opera, sponsored by the Smithsonian Institution and the Massachusetts Institute of Technology, was created by composer Paul Earls and artist Otto Piene of MIT's Center for Advanced Visual Studies. The laser imagery for Icarus was projected on steam screens which rose from "Centerbeam," a huge, 140-foot sculpture array which displayed MIT artworks. The Ar-Kr laser beam was microprocessor manipulated to create images such as flying birds, minotaurs and a poem, which was written in laser light.

Thirty-six thousand watts of power were into a water-cooled argon laser to produce the sky display at "photokina'78" held in September of that year in Cologne, Germany. That blue-green laser beam appeared over the city and across the sky and connected the municipal art museum on the West bank of the Rhine with the tower of the fair complex on the East. Laser artist Horst Baumann set up an array of mirrors in the tower to deflect the principal beam at the Gothic cathedral as well as other points of interests in the area.

Laser, the light amplifier that creates the purest possible concentration of light is the latest catalyst in light art. From 1975, there has been a enormous growth of the number of commercial laser show companies. Therefore it is impossible to search out all those laser related works after 1975. However, some of the selected works are listed in the table of "Previous Works."

Previous works

ARTIST	*YEAR*	*EQUIPMENT*	*TITLE*
Pablo Picasso	1949	flash light	Light painting
Man Ray	1937	flash light	Space writing
Robert Whitman and James Turrell	1967		gallery-museum projections
Carl Frederik Reuterswárd	1968	Laser -video image	Study for "Swedenborg Dreams"
Rockne Krebs	1969	6 He-Ne lasers, co-planar mirrors The mirrors are slightly bent, giving the reflected images within the "room" a curved effect.	Aleph 2

Barron Krody	1969 at the Cincinnati Art Museum	Laser beam reflected against mirrors	Search, an "environmental room" was constructed for Laser Light
Friedrich St. Florian	1970 at MIT then in Washington	laser	Explorations
Williard Van De Bogart	1971 Laser images created in concert with the Los Angeles Philharmonic Orchestra	The images were projected on a 40' X 40' screen through a complex of optical glass, rippled plexiglass, fiber optics and mirrors.	The-Apollo 14 Collection
Rockne Krebs	1971 Minneapolis, Courtesy Walker Art Center, Minneapolis	Argon lasers and photon structures	Walker night passage

Rockne Krebs	1971 in collaboration with Hewlett-Packard for Art and Technology, courtesy Los Angeles County Museum of Art	Argon and He-Ne lasers, mirrors	Day Passage
Rockne Krebs	1973	laser	Sky bridge Green
Horst H. Baumann	1977 in Kassel	Ar-Kr lasers	Laser-Environment
Paul Earls	1977 in Kassel	Ar-Kr lasers	Center beam
Paul Earls	1977 at Harvard university	Ar-Kr lasers	Dreamstage installation
Reginald Pollack	1977 at Pennsylvania State University	eight He-Ne lasers to project abstract images on a screen	
Dani Karavan	1978 laser beam connecting the dome of Florence Cathedral and the Belvedere fortress	Argon	Rayons laser
Paul Earls and Otto Piene	1978	laser	Icarus/Center beam
Paul Earls	1985	Kr laser	Hamburg Installation Mehr Licht

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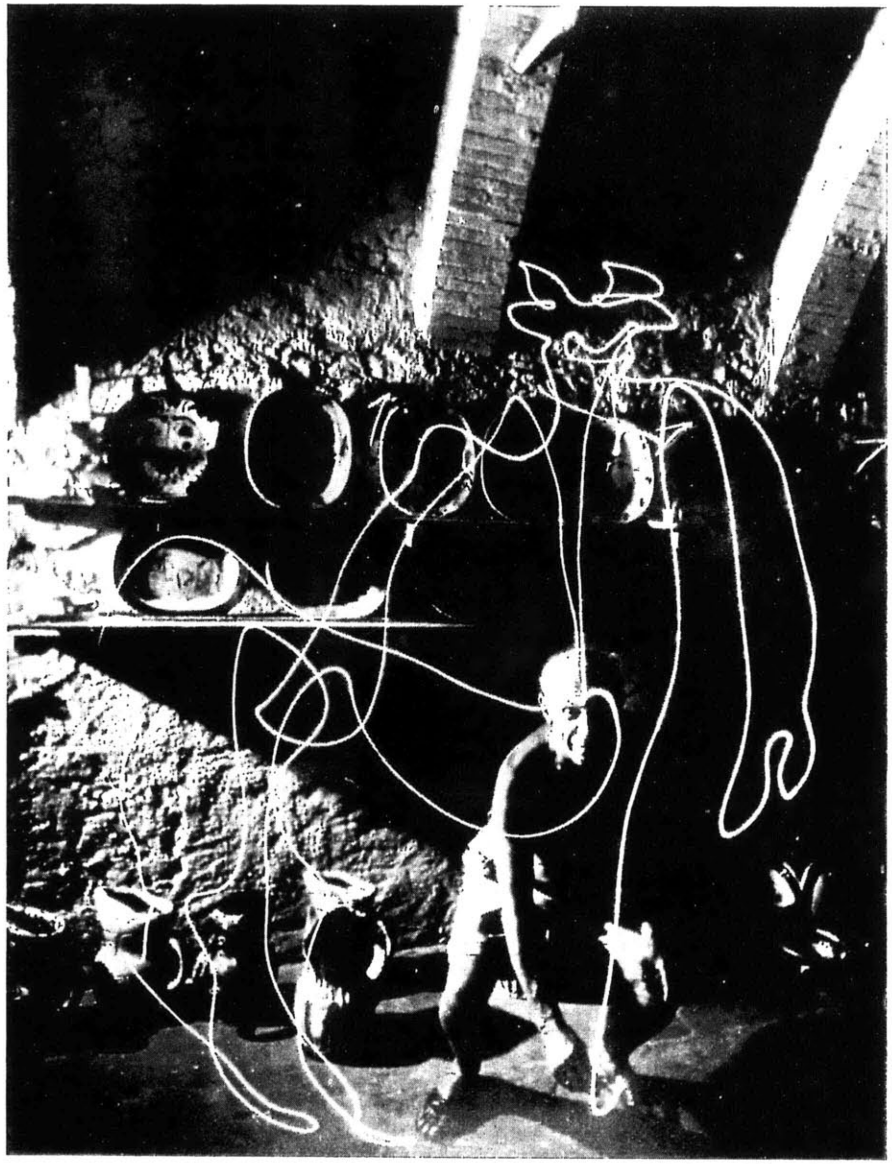
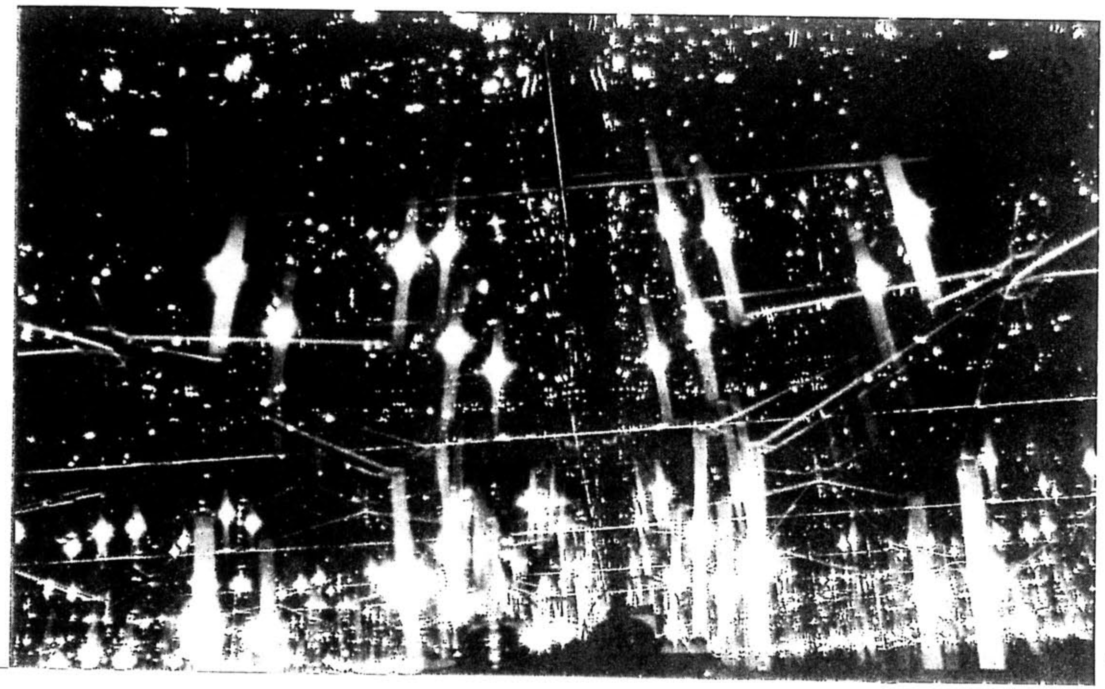
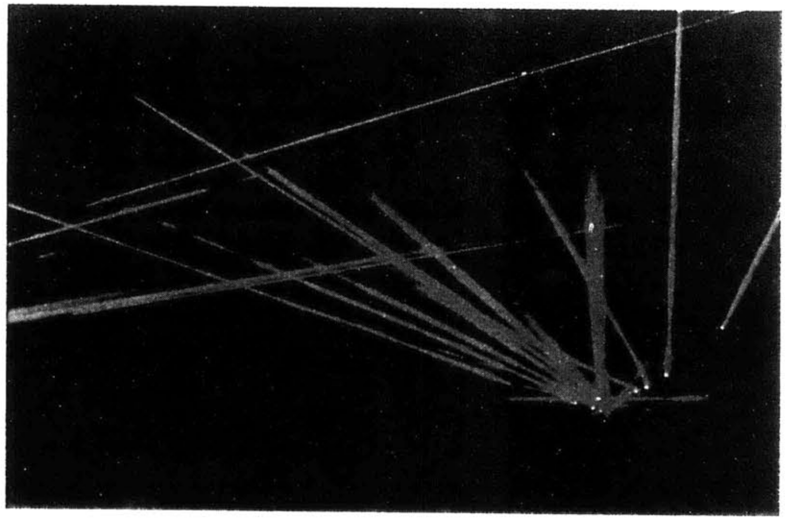
Picasso drawing with light, 1949.
The line elements of the llight drawing are created consecutively, as with every other drawing, and must be recorded by a camera to produce the total effect.

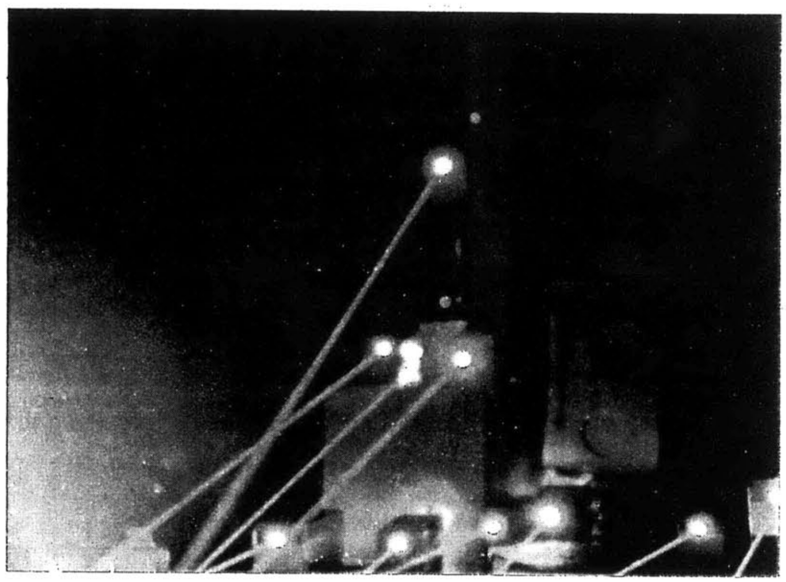


Barron Krody. *Search*, 1969. Laser beams reflected against mirrors. *Search*, an "environmental room," was constructed for *Laser Light: A New Visual Art*, an exhibition at the Cincinnati Art Museum in December, 1969. Collection The Cincinnati Art Museum.

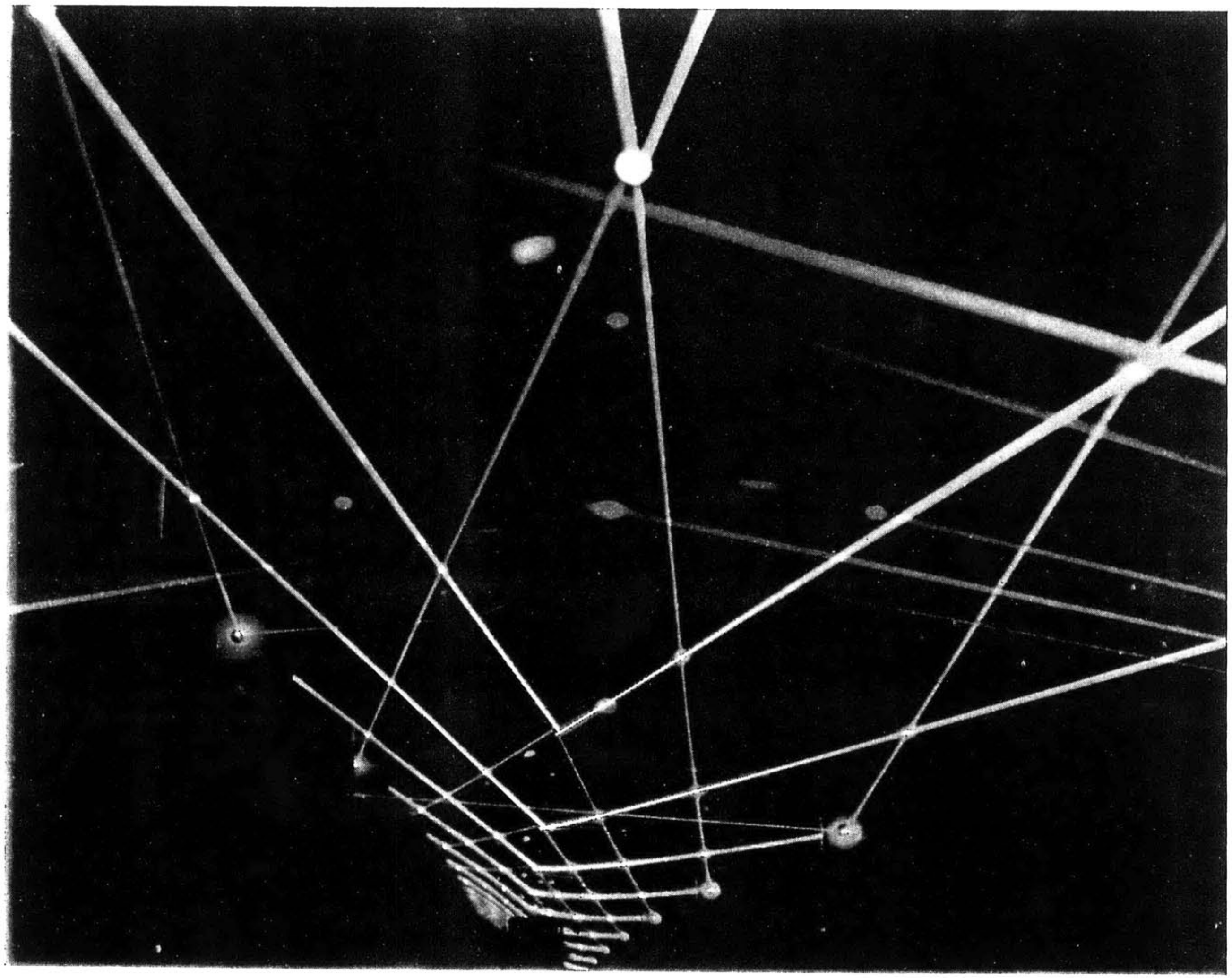




Rockne Krebs. *Aleph 2*, 1969. 6 helium neon lasers, 4 6′ x 10′ co-planar mirrors. The mirrors are slightly bent, giving the reflected images within the "room" a curved effect. Courtesy Corcoran Gallery of Art, Washington, D.C.

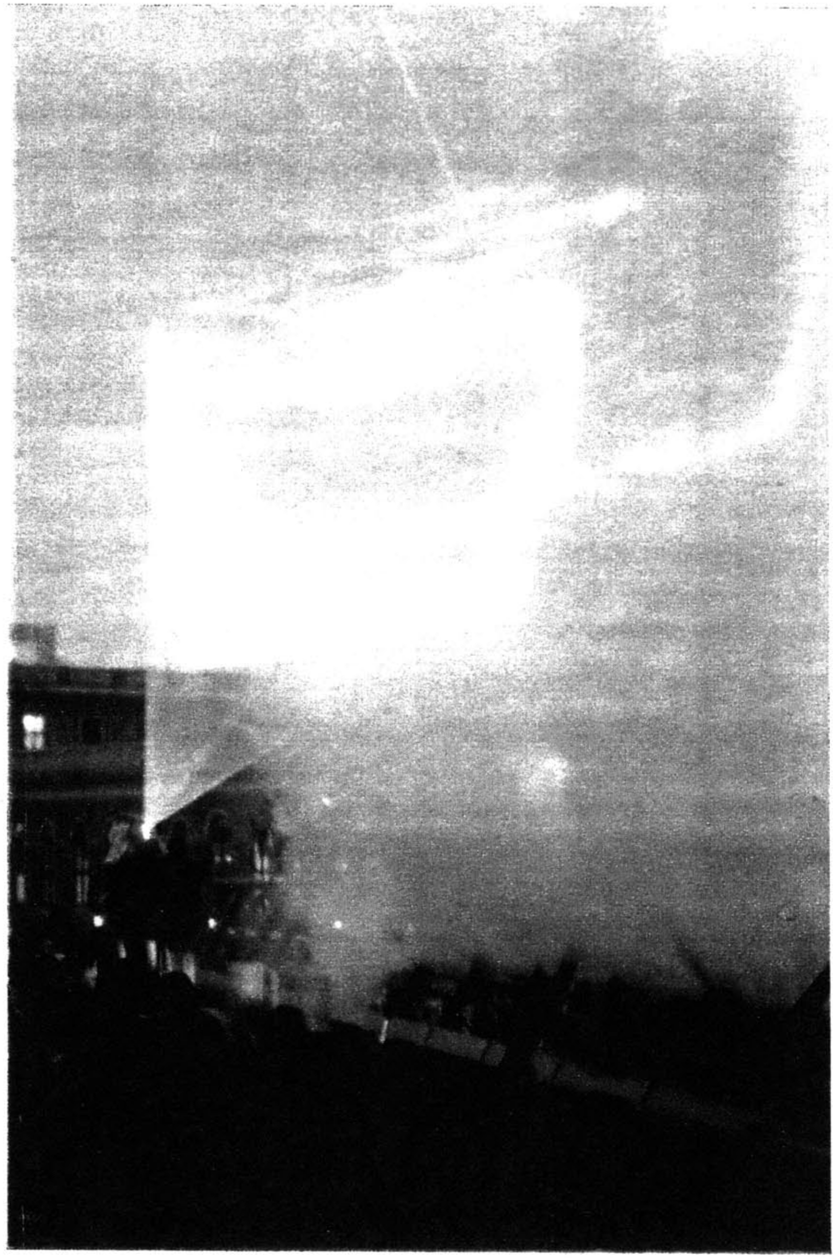


Willard Van De Bogart. *The-Apollo 14 Collection*, 1971. Laser images created in concert with the Los Angeles Philharmonic Orchestra. The images were projected onto a 40′ x 40′ screen through a complex of optical glass, rippled plexiglass, fiber optics, and mirrors.



Rockne Krebs. *Day Passage*, 1971. Argon and helium-neon lasers, mirrors. Executed in collaboration with Hewlett-Packard Corporation for *Art and Technology*. Courtesy Los Angeles County Museum of Art.

Rockne Krebs. *Walker Night Passage,* 1971. Argon lasers and photon structures. Courtesy Walker Art Center, Minneapolis. Photo by Eric Sutherland.



"Centerbeam"
documenta 6
Kassel, Germany, June 24
through October 2, 1977
by 14 artists with science
and engineering advisors
Center for Advanced Visual
Studies, M.I.T.
with "envelope" laser
projection (Paul Earls,
Gyorgy Kepes)
on steam (Joan Brigham)
photograph: Dietmar Loehrl

Paul Earls, Otto Piene. Icarus, 1978.

Photographs

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Picasso drawing with light, 1949

Lasergrafie, Verlag George D.W. Callway, Munchen, Germany, 1975

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Barron Krody. "Search", 1969

Rockne Krebs. "Aleph 2", 1969

Willard Van De Bogart. "The-Apollo 14 Collection", 1971

Rockne Krebs. "Day Passage", 1971

Rockne Krebs. "Walker Night Passage", 1971

Art and The Future, David Douglas. Praeger Publishers, Inc., New York, 1973

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Paul Earls and Gyorgy Kepes. "Envelope", 1977

Centerbeam, Otto Piene and Elizabeth Goldring. CAVS, MIT, Massachusetts, 1980

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Paul Earls and Otto Piene. "Icarus", 1978

Mehr Light, Achim Lipp and Peter Zec. Hamburg, 1985