# Through the Looking Glass

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> You see, to me it seems as though the artists, the scientists, the philosophers were grinding lenses. It's all a grand preparation for something that never comes off. Someday the lens is going to be perfect and then we're all going to see clearly, see what a staggering, beautiful world it is…[1]
>
> - Henry Miller

The most primitive and traditional proposition of architecture, but also a truly radical and modern proposition is one of reformation of materials. To begin the reform one must have plans, or models, which show in advance the forms into which the material could be reformed. Plato called these models, or forms: "Ideas". For him, they were immutable matrices of perfect form, or eternal truths that reside beyond the imperfect physical world. The Platonic plan is not a plan for action, but for contemplation. It gives rise to the classical notion of pure metaphysics.[2] On his footsteps came Aristotle, not concerned with the recognition of forms as immutable entities but with formation as a gradual process found in experience. He called this process of unfolding of physical reality " "Energeia". The Aristotelian concept, with its concomitant research of the "dynamic principles" and the "four causes" —material, efficient, formal and final— laid out the foundations of western science and technology.[3] This is a plan for action; for making and doing. It grounds metaphysics in real everyday experience, providing, as it were, with a "center of gravity". And, it gives physics a fluency, a direction looking to the other side of reality, animating it with a "center of levitation".

My choice for a daily occupation is to experiment in the gap between materials and ideas, between the concrete and the abstract. And then, traverse that space, which I define as *work-space*, by approaching its two opposite ends as paradoxical coincidences: the "Idea of Materials" and the "Material of Ideas".

> There are clay ideas, and there are ideas forever carved of gold or of our precious glass. And in order to determine the material of which an idea is made, it is enough to pour into it a single drop of strong acid. One of these acids was known to the ancients too: "reductio ad finem".[4]

Reduction to the end! This is the concept of analysis: to take apart a compound into its simplest parts. In so doing, I am searching for an understanding of the substance out of which something is made, and also what is the thing made with that substance. In simple terms, the reciprocal influence of form and material. As a practical craftsman, it is only proper that I should be concerned with matters of form. But I should not forget that alongside the formal interest, before the first line is drawn, there lies a whole prehistory: the nature and capacity of materials. The aim is to work without preconception of either optimum form or optimum material. It is rather, to experiment critically, but freely, trying to determine the practical boundaries and coincidences between the two —looking for technical and aesthetic "common sense".[5]

I have selected glass as a material for experimentation. Out of technical and epistemological necessities, metals will also be part of the work. I do this simply in order to refocus my attention. Contrary to the habitual assumptions of the language, glass is a non-crystalline material and metals are crystalline —in their molecular structure.

It is necessary, for me, to rectify the notion that the structure of glass is that of crystal. Even more, that as a matter of physics, glass is unequivocally a solid. The study of solids is mainly a matter of geometry. The building blocks of a solid can be considered as arrays of atoms and clusters of molecules that have a precise distribution over the field of matter. Before a liquid can crystallize it must have in it a seed —a small crystal. A seed is often made of small groups of atoms attached to foreign particles or irregularities on the surface of the container holding the liquid. In the case of crystalline solids, almost all metals, atoms aggregate around the seed forming a perfectly repetitive structure: a closely packed spatial arrangement of regular and deformed polyhedrons.

Crystallization normally takes place when a liquid is cooled to a particular temperature, or freezing point. At this point the liquid is affected by a sudden heat loss to its surroundings. This burst of heat is the effect of a phenomenon

by which atoms or molecules, initially in a state of randomness, move into the highly ordered geometrical field of crystalline structure. Some liquids become extremely viscous near the freezing point, impeding the formation of crystals. The more the temperature drops the more viscous the liquid becomes, turning rigid gradually, on an asymptotic curve to infinity. Glass is not a crystal but a supercool liquid of infinite viscosity.

The degree of molecular ordering in glass is dependent on the speed of cooling. In the practice of glassmaking close attention is paid to the techniques of quenching (rapid cooling) and annealing (slow cooling). The game plan of the glassmaker is that of checkmating the liquid between time and temperature.[6]

The geometry of glass structure is the geometry of disorder on the way to order. The art of the glassmaker can be explained in terms of thermodynamics, chemical bonding and molecular architecture.[7]

My immediate task is to activate materials. To make them work by the introduction of force. To put the materials "in tension" (or attention) by making a series of experimental probes. These probes should be taken as discrete units of fabrication that have no ulterior motive other a double index: than encode, and decode, one structural-optical and other aesthetic-visual.

The singular target of each probe, and the incremental aim of the series, is that of research and further definition of glass as a building material. The double index is an intrinsic necessity after the proposition that the act of building has a physical, as well a metaphysical effect. In the words of Valéry:

> By dint of constructing —he put it with a smile— I truly believe that I have constructed myself…Here I am, says the Constructor, I am the act.[8]

The first, structural-optical, is a physical index. Structurally, it deals primarily with mechanical properties, such as resistance to forces of tension, compression and shear. Optically, it refers to the behavior of glass in relation to the light: reflection and absorption, refraction and color, transparency and opacity. A great deal of information may be obtained by spectral analysis —one may say that matter communicates with us by means of the light that it emits, and with which it interacts. Indeed, one may go further and say, with Louis Kahn, "Material is spent light".

The second, visual-aesthetic, is a metaphysical index. Didn't Klee say: Art does not reproduce the visible but makes visible?[9] By the function of the optical, sensory eye, it communicates with the visual, the mind's eye. A close encounter between mind and matter, form and material. By means of sight we move to insight, Outward sight and inward vision, and vice-versa. Such experience enables the "I" to draw inferences about the inner object from the optical exterior. To look is to examine the structure of appearances:

> Not to say that behind appearances is the truth, the Platonic way. It is possible that visibility is the truth, and what lies outside visibility are only 'traces' of what has been or will become visible.[10]

What is the effect of visibility? It is a form of energy continually transforming itself: a solidarity between who is looking and what is being looked at. An exchange, a transitive agreement between the subject and the object. The effect of visibility is an "affection" of the body, and an "affect" of the mind (Spinoza).[11] The aesthetic index is a wake up call, prompting an intuitive movement of the "forms of internal sensibility" (Kant).[12]

A particular aesthetic is that, which in the name of beauty and the satisfaction of our sensual appetite, looks at buildings primarily as beautiful things. If dominant, it may turn the architect into what Northrop Frye may call: a beautician.

I think, with Fernando Pessoa, that we can formulate "an aesthetic based not on the idea of beauty but rather on that of force…constructing new kinds of works" that could not be foreseen or accepted by those subscribing univocally to the aesthetics of the beautiful.[13] Force not understood as brute uncritical violence, but as the introduction of human sensibility and desire into the substance of matter. This driving force is a kind of functional penetration of sensibility, made abstract as intelligence, and made effective as scientific inquiry and technical production. It is born out of a tectonic intuition of the nature of materials, their capacity to bear and transmit energy, and their ability to embody particular forms with greater or lesser efficiency. The human force spent in the act of construction is reflected twice: as "materialized ideas" and "idealized materials". Now, we may go further than Louis Kahn, and say that: material is spent desire.

## MECHANICS

Mechanically, even though apparently at rest, glass in its rigid state is always at work. When molten glass cools, the outer surfaces become cooler and rigid sooner than the inner mass. As cooling continues, the inner mass will contract putting the outer layers, which are already rigid in compression. Inversely, the outer layers will, in opposition to further contraction, set tension in the inner layers. If only one side of a flat glass pane is heated, that side wants to expand. But is held back by the other side, which itself is being stretched. This tug of war of compressive forces on one side and tensile forces on the other side causes a deformation, or warping of the plane, eventually leading to fracture. Permanent strains are always present in glass due to the antimetrical forces acting between the outer surfaces and the inner layers. Temporary strains are due to differences in temperature from side to side. Theoretically, the tensile strength of flat glass is approximately 1000 kilograms per square millimeter; in practice it has only 1 percent of that value. The compressive strength is 10 times higher.[14] The working strength

of glass can be increased manifold: tempering by heat, plate laminating, and by chemical treatment of the surface. To cut, or break glass it is sufficient to scratch its surface, breaking the continuity of the compressive layer. Microscopic flaws of the surface reduce its strength considerably. The strength may be regained with a bath in hydrofluoric acid, which gives the glass a smooth, virgin surface.

> The form, then, of any portion of matter…may in all cases be described as due to the action of forces. In short, the form of an object is a 'diagram of forces'.[15]

## OPTICS

It is possible to make forces visible through polarization and reduce perception to a diagram of light. The development of optical theory and technology in the twentieth century has been astonishing. Corpuscular ideas of light, after having been forgotten for a century, reappeared when Einstein postulated the existence of "quanta" of light. As a result, Newton's *Optiks*, in its curious blend of corpuscular-theory with wave-theory, is now found to be inconsiderable agreement with modern views.[16]

Moved by the logical clarity of the "definitions" and "axioms", I ventured further to examine the "propositions" and the "proofs" by experimentation. Of immediate interest are the first five propositions of Book I, dealing with the composition of sunlight, the colors of the spectrum, refraction, and reflection. And the first seven propositions of Book II, regarding the permanent colors of natural bodies and their analogy to colors of thin transparent plates.

With this enticement and ammunition, I proceeded, with my students, to construct a number of probes made of glass, metal, water, and air. I resisted the temptation to add to the arsenal, at this point, the plethora of a new generation of sophisticated glasses: colored, filtered, multi-coated, dichroic, et cetera. There is sufficient challenge, at the beginning, in the work that one can do with clear sheet glass.

Only part of a beam of light striking a glass plane will pass through it. Some of the light is reflected at the front surface; the remainder passes through the glass, where part is absorbed as heat, and part reflected at the second surface. The percentage of light transmitted depends on the optical properties of the glass and on the wavelength of the incident light. Visible light extends from about 400 nanometers for violet light and 700 nanometers for red light —a nanometer is one millionth of a millimeter. The angle of refraction of a beam of light passing through a pane of glass is in inverse proportion to the wavelength: the shorter the wavelength the larger the angle, and vice versa. The dominant feature of sunlight, as seen through Newton's prism, is a color continuum extending over the entire visible spectrum, from red to violet.[17]

> Between the parts of opaque and color'd Bodies are many Spaces, either empty, or replenish'd with Mediums of other Densities; as Water between the tinging

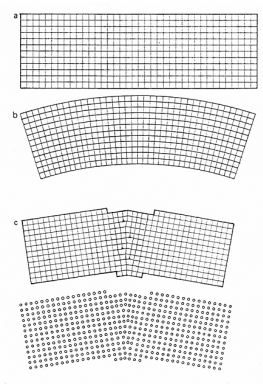

Fig.1 Diagrams of elastic and plastic deformations.

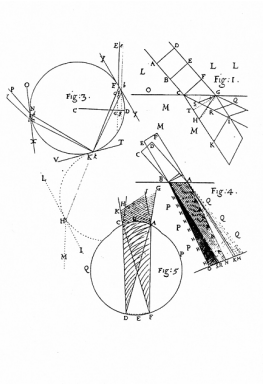

Fig.2 Diagrams of light paths in the eye and other media.

> Corpuscles…Air between the aqueous Globules…and for the most part Spaces void of Air and Water, but yet perhaps not wholly void of all Substance…PROP.III, BOOK II.[18]

## VISIBILITY

The diagram, being visible, is the symbolic representation of invisible processes, forces, structures. The totality is the surface, which is now the sum and origin of all that one sees. Seeing is a synthesis that allows the passage from the exterior to the interior, from spectroscopy to introspection. The phenomenon changes from extension to intention: the category from "quantity" to "quality".[19]

The synthesis achieved by our consciousness has a different sense of time from that of mere physical measure. Consider the example given by Bergson: in the space of a second, red light —which has the longest wavelength, and therefore the least frequent vibrations— realizes 400 billion successive vibrations. To form an idea of this number we would need to separate the vibrations sufficiently to account for each one. The smallest interval of time that we can detect, according to Exner, is 0.002 seconds. If we were to add these intervals, so that each of the 400 billion vibrations is accounted, and separated from the next by 0.002 of a second, 25,000 years would elapse at the end of the operation. The perception of red light, experienced by our consciousness in one second, would require 250 centuries for its empirical demonstration.[20]

Working with glass, we are working in the realm of light. We are diagramming space with light. Space is part of that realm, "part of the continuity of events within it…It is not a mere container." My interest lies in the position of glass, not as a fill-in material, but as a material of structure. Without a rigid bias against what you may call structure, let me say that, for me, it is what is sufficient and necessary for construction. And add, with Louis Kahn, that: "Structure is the giver of light."

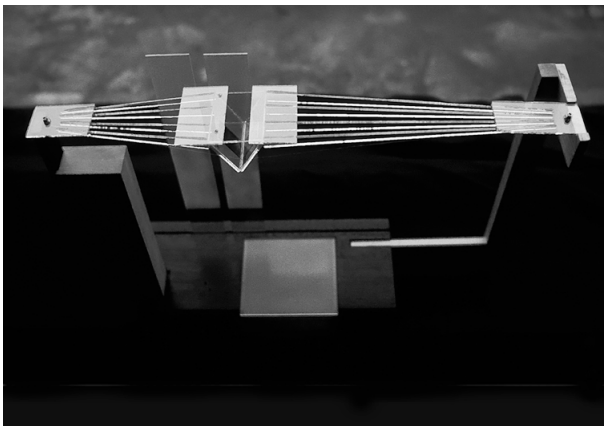

Fig.3 Holleman compression-tension probe.

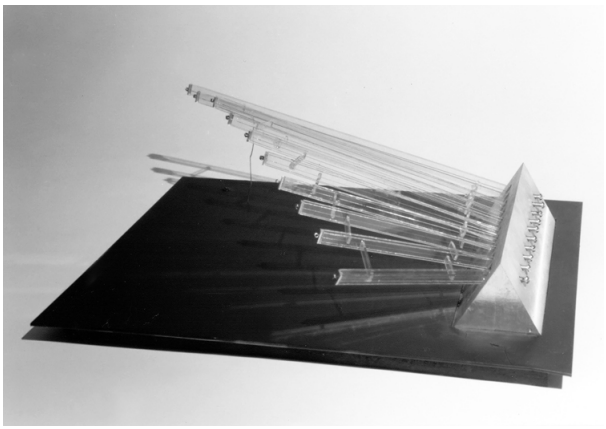

Fig.5 Gehrwig "Optigraph" structure.

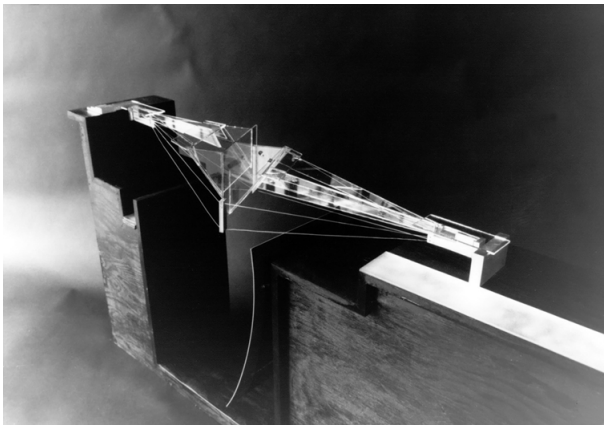

Fig.4 Holleman light "Spectrum Splitter".

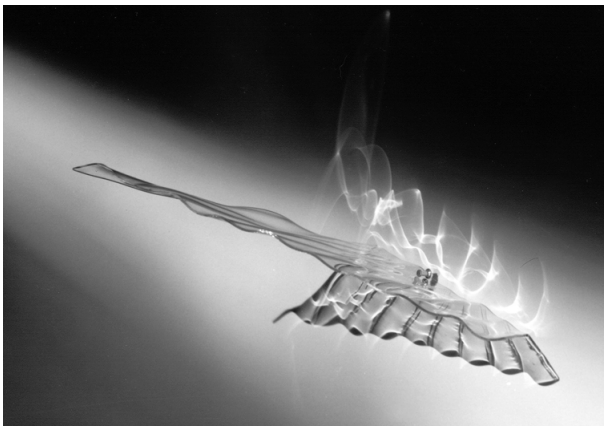

Fig.6 Gehrwig "Optigraph" plane

> Between the curtains and the window: a space like the lines on which music is written: but three-dimensional, and the notes of light, rather than sound.[21]

## AESTHETICS

If we are moved by Kahn, we may move to Kant and speak of aesthetics as the condition of inner experience. Where, "Time is therefore to be regarded as real, not intended as object but as the mode of representation of myself as object."[22] I cannot search for empirical data her. To look here is to overflow the outline, the category, the name of what it is. I must abandon myself to my own devices of reflection and speculation: "looking for the autonomy of the inside". The surface becomes the site of a departure that works up the slope of tactile sensations, the optical model, and of geometry of perception, to arrive at an "architecture of vision". Paradoxically, the site of departure becomes the site of arrival, and the "status of the object is profoundly changed, so also is that of subject." The inside and the outside mark the limits of the infinite fold that separates or moves between matter and memory. The line of inflection is materialized in the mind but idealized in matter, "the search for a model of the fold goes directly through the choice of a material".[23]

Whether it is paper or glass, the aesthetic "affect" is ne of levitation from the "kingdom of nature" to the "kingdom of grace".

> And from the inside, too, I'd duplicate
> Myself, my lamp, an apple on a plate:
> Uncurtaining the night, I'd let dark glass
> Hang all the furniture above the grass
> And how delightful when a fall of snow
> Covered my glimpse of lawn and reached up so
> As to make chair and bed exactly stand
> Upon that snow, out in that crystal land![24]

## NOTES

[1] Gilles Deleuze, *Spinoza: Practical Philosophy*, City Lights Books, San Francisco, 1998, p.14.

[2] Plato, *The Republic*, Bk. X, Penguin Classics, Hamondsworth, 1984

[3] Aristotle, *Physics*, Bk. II, Ch. 3-9, and *Metaphysics*, Bk. I, Ch. 3-10, J.A. Smith and W.D. Ross (ed), *The Works of Aristotle Translated into English*, Oxford U. Press, Oxford, 1952.

[4] Yevgeny Zamyatin, *WE*, translated by Mirra Ginsburg. Avon Books
[5] The notion of "common sense", is here derived from Immanuel Kant's *Critique of Judgement*, translated by J.C. Meredith, and further expounded in Gilles Deleuze, *Kant's Critical Philosophy*, U. of Minnesota, Minneapolis, 1983.
[6] Checkmating is here a reference to Primo Levi's "Time Checkmated", *The Mirror Maker*, Schocken Books, New York, 1989, p.71-76.
[7] R.J. Charles, "The Nature of Glasses", *Scientific America*, September 1979, p.127-136.
[8] Paul Valéry, "Eupalinos, or the Architect", *Dialogues*, Bollingen/Princeton U. Press, Princeton, 1989, p.81, 148.
[9] Paul Klee, *Notebook Volume I: The Thinking Eye*, Lund Humphries, London, 1978, p.76.
[10] John Berger, *The Sense of Sight*,
[11] Deleuze, *Spinoza: Practical Philosophy*, p.48-51.
[12] Immanuel Kant, *The Critique of Pure Reason*, translated by N.K. Smith, St. Martin Press, New York, 1965, p.66-91.
[13] Fernando Pessoa, *Always Astonished*, City Lights Books, San Francisco, 1988, p.70-73
[14] Rune Person, *Flat Glass Technology*, Plenum Press, New York, 1969, p.27.
[15] D'Arcy Thompson, *On Growth and Form*, Cambridge U. Press, Cambridge, 1977, p.11.
[16] Isaac Newton, *Optiks*, Dover, New York, 1979, p.lx-lxiv.
[17] Ali Javan, "Optical Properties of Materials", *Scientific America*, September 1979, p.239-248.
[18] Newton, *Optiks*, p.249.
[19] Kant, *The Critique of Pure Reason*, p.111-115.
[20] Henri Bergson, *Matter and Memory*, Zone Books, New York, 1989, p.205-206.
[21] Berger, *The Sense of Sight*, p.220.
[22] Kant, *The Critique of Pure Reason*, p.79.
[23] Gilles Deleuze, *The Fold: Leibniz and the Baroque*, U. of Minnesota Press, Minneapolis, 1993, p.19, 35-37.
[24] Vladimir Nabokov, *Pale Fire*, Vintage International, New York, 1989, p.33.