Tectonics of the Mists : Sculpting the Very Substance of Clouds

Dr. N. Reeves, B. Arch., B. Phys., M.S.Arch.S, Ph.D.
School of Design, University of Quebec in Montreal
e-mail: reeves.nicolas@uqam.ca

Dr. J.M. Chomaz, ENS Paris, Ph.D. Phys.,
Hydrodynamics laboratory, École Polytechnique, Paris-Saclay

V. Cusson, M.Sc.
Music & Techology, McGill University, Montreal

I • Introduction

This aim of this paper is to present the current state of development of a research-creation program that was initiated last year [2020] and that underwent considerable changes from its initial ambitions due to various unexpected consequences of the pandemic situation. The initial objectives of this program, as well as its theoretical and historical roots, have been published in the August 2020 issue of the GASATHJ on-line journal [1] . It should be noted that this research was itself triggered by a Quebec-France competition on the topic of art and sustainable development, for which our lab was awarded the main prize [2]. This on-going program, called *Tectonics of the Mists*, belongs to the much larger, wide-scale *Observatories of the Unreachable [Arts of the Impossible]* program, meant to bring to human consciousness and perception natural phenomena that are impossible to observe or detect with our senses because of size, location, time-scale or informational considerations. Fourteen of these Observatories are currently being designed, developed or implemented. *Tectonics of the Mists* is referred to as Observatory No XIV; for the interested reader, the thirteen others are described on the program's web site [3] .

2 • Shaping Mists, Fogs and Hazes

Tectonics of the Mists is oriented towards the research and development of devices allowing to explore the potential of mist, the very substance of which clouds are made, as a material for art and creation,

and towards the production of artistic works exploiting the unique and singular qualities of this material. As can be readily guessed from these first sentences, the challenges are high. Proteiform and intangible, apparently devoid of any form of internal organization, the cloud has long represented, in science as well as for the poetic imagination, a symbol of randomness and uncontrollability. Like all fluids, it does not have a form of its own : it occupies all the available space around it. All its configurations are ephemeral. Its intrinsic nature seems to contradict the very concepts of organization or geometry. The material of which it is constituted, a very thin aerosol of water and air, is continuously reshaped by several external forces, among which winds and breezes, convection, Archimedes' lift (hydrostatic pressure) and gravity play a major role. It can appear and disappear suddenly with minute temperature or pressure variations. Its shape is so hard to grasp that until very recently, it was said in artistic circles that the perspective of a cloud was impossible to draw [4] .

Fig. 1 – An orogenic cloud, shaped by the winds that climb along the mountain sides.

A few observations, not that frequent but nonetheless revealing, make it possible to moderate and requalify this image. On the one hand, under specific conditions of wind and temperature, certain families of clouds, such as orographic or lenticular clouds, or even the very rare Kelvin-Helmholtz cirruses [5], which sometimes evokes a runic inscription, adopt clear and well-defined forms that can sometimes persist up to several hours.

Fig. 2 – A lenticular cloud, which maintains its shape thanks to rapid and continuous high-altitude airstreams.

On the other hand, it has been established since the mid-1970s, thanks among other things to the works of physicists Michael Feigenbaum [6] and Shaun Lovejoy [7] [8], that the cloud does indeed have an internal organization that can be both quantified and qualified : it can be modelized through a multi-fractal model. The importance of this discovery should not be underestimated : by the very possibility of such a formal description, the cloud escaped the category of random phenomena to join the family of organized objects. But it did not let this happen without reacting : this paradigmatic change triggered a deep upsetting of the very notions of order and organization. A lot of elements of the physical world, ranging from mountains to organic tissues and traditional urban forms, became suddenly understandable

with new formal tools, introducing new species of geometries and assemblages that could be used for modelization and analysis as well as for artistic creation, for archi-tectural composition, and for design as a whole.

3 • The Cloud Artist as a Mistworker

To say that the cloud, by its intrinsic qualities, has fascinated and inspired artists for centuries is an understatement. Innumerable are the pictorial works of all times where its role in the composition is fundamental. It stands as a central concept in the work of the greatest names in contemporary music : it had a profound impact on Xenakis' sound clouds [9], on Stockhausen's sound masses, on Varese's aggregates, and more broadly on the very notion of granular synthesis. More recently, it can be found at the heart of several artistic [10] or architectural [11] installations. Our own work has exploited its singular geometries within the framework of another research-creation program aimed to explore its potential for architectural creation [12] and for musical composition: since the end of the 90s, we have developed a series of twelve meteo-electronic instruments which convert in real time the shape and structure of passing clouds into sound and musical sequences [13] [14] .Thanks to this work, we were able to familiarize ourselves with the behaviour of clouds in time as well as in space, and to better understand the physical properties of aerosols, fogs, vapours and mists.

Our whole research arose from a question, itself resulting from the amount of work and experiments that we devoted to the subject in the last decades : is it possible today, given the rapid development of adaptive control systems and the ever-increasing power of computers, to work the cloud itself as a material, instead of working from the cloud? In other words, to try to become *cloudworkers*, or *mistworkers*, by analogy with the practice of a woodworker? A series of preliminary explorations allowed us to bring a positive answer to this question [15]. They demonstrated the possibility to produce masses of cloudy matter in controlled environments, to shape them with small laminar air flows and very low frequency sound waves, and to maintain the shapes thus created for an arbitrary period of time. The visibility of these shapes and of their movements can also be made clearer by the use of flocks of micro-particles, small objects carried by the airstreams that will look like snowflakes or soft hailstones swirling in the mist. Our first results remain preliminary, but they allow us to foresee the possibility to literally sculpt the mist in order to create objects, and even entire landscapes, in the form immersive environments whose stable, translucent configurations remain constantly ani-mated by internal currents, whirlpools and volutes.

Fig. 3 – First experiments with a very basic setting. Shaping a mist column and a suspended cloud with micro-airflows.

The projects that will eventually emerge from this research-creation do not know any direct precedents. Several former installation or architectural works, like the *Blur Building* (Dillier + Scofidio + Renfro, 2002) [16] or the *Between Life and Non-Life* project (Teamlab, 2020) [17] involve a kind of immersion in clouds. However, despite their very high artistic value, none of them do attempt a real control of the shape of the clouds. Moreover, Teamlab's clouds are not made of aerosols, but of water and soap suds driven by large-scale air currents, which makes it much easier to produce stable objects. The beautiful micro-clouds created by Dutch artist Berndnaut Smilde, already quoted above [13], and that were photographed hovering inside remarkable architectures, were not subjected to any shaping process; they lasted about ten seconds before dissipating.

Experiments directly related to the direct control of mists in the atmosphere remain very rare and embryonic, which is explainable, among other things, by the level of scientific expertise and by the highly technological nature of the systems required for such an approach. Therefore, while the primary objective of our research is clearly in the field of artistic creation, its challenges extend to scientific and technological disciplines, which makes it intrinsically transdisciplinary. Fluids dyna-mics, the domain that studies the behaviour of gases and liquids, is a fascinating and complex field of physics; it is far to be fully explored. For this reason, we designed our art-oriented installations in order to make them also usable as platforms for investigations about several open questions in the field, such as, for instance, transitions between laminar and turbulent regimes in air flows, a phenomenon that is still poorly under-stood and remains the subject of advanced research [18].

At the technological level, the manufacturing of such equipment also requires significant research and development work, in particular in the field of 3D printing, for which we must customize high-precision printers through the of design of new parts and opti-mization algorithms. Given the critical importance for a large number of fields (climate science, biophysics, oceanography, hydraulics, aeronautics, astrophysics, etc.) to better understand the behaviour of fluids and of their mutual interfaces, the possibilities of transferring new techniques and skills, produced in an art and design context, towards the scientific and technological domains are obvious and immediate. The very composition of our core team[19], which includes a physicist specialized in hydrodynamics, an engineer whose field of expertise covers all multi-agents adaptive control systems, and an artist-designer working with sound and clouds for more than 20 years, illustrates the variety of fields covered by the research as well as the cross-disciplinary nature of the challenges that it faces.

4 • Sounds and swirling particles

As mentioned above, along with the study of the behaviour of mist masses, we also investigate the artistic potential of flocks of airborne objects that can be

controlled through sound and micro-airflows. They are the subject of special attention, since they present their own set of constraints. First, their shape must maximize their lift for any orientation in turbulent atmospheres, in order to limit the in-tensity of the air flows required for their levitation. Then, their structure must be strong enough to withstand the physical stresses created by air movements while remaining light enough to be controlled by these same movements. Our current explorations are based on analogies with snowflakes and the internal structure of bird bones. They allowed us to determined that a particular family of shapes, such as the fractal gyroids, possesses the required qualities. However, the generation, modelling and 3D printing of such objects require large amounts of calculation that becomes quickly dissuasive in terms of time and computer resources; their design is currently the object of a specific attention.

This is a particularly important point since it also relates to the design of the sound environment within the structure. Apart from their impact on the mists, the infrasound vibrations used in the installations allow us to study the phenomenon of sound levitation, by which some of the floating objects can hover in mid-air for extended periods of time. It was demonstrated a few years ago that certain types of object, whose dimensions could reach up to twenty centimetres, can remain suspended in space subsonic when submitted with sound waves of the order of one Hertz, directed upwards; and that their movements can be modified by adjusting the frequency and amplitude of these waves [20]. Through this pheno-menon, we hope to be able to work simultaneously on two groups of levitating objects, one being directly influenced by the movement of the mists, and the other, associated with sound waves, remaining partially independent of it, thus demulti-plicating the artistic potential of the whole installation.

5 • A Sequential Development

In methodological terms, our research-creation follows a sequence in which phases dedicated to laboratory research, in which each team works in its own lab for several weeks, alternate with residencies that gathers all teams in a single location, for periods of intensive work that systematically culminate with a public event such as an installation or a performance. This phased way of doing things, which has been a specificity of our laboratory for decades, has long since proven its effectiveness [21].

To the public events, we give the name *DEMo*. The word “demo” itself is well known in digital and media arts, as illustrated by the famous leitmotiv « demo or die », a research-creation equivalent of the « publish or perish » expression encountered in scientific circles. Within the Montreal Hexagram research-creation institute, we gave a new meaning to this word by converting it into an acronym which better translates the role of such events : « D » stands for Demonstration, « E » for Experimentation and “Mo for Monstration”. The event must first act as a proof of concept and feasibility, second validates the authors’ scientific and technological hypothesis, third have the potential to create a worthwhile artistic moment that can be appreciated for itself, without reference to underlying mecha-nisms, devices and theories.

Our own sequence of DEMo's will begin by a series of three installations, described in the next section, in which different mist and particle controlling devices or algorithms will be successively put to work by degree of increasing complexity, in environments that become more and more challenging. They will allow us to explore the unique poetic potential of these intangible materials, in a way that will magnify their singular aesthetic qualities.

6 • Installation I – Echoes of Light from the Mist Grove

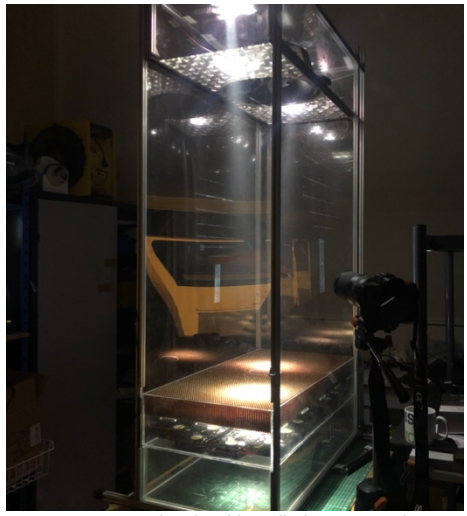

Fig. 4 – A prototype at scale 1/3 of installation, currently used for first experiments at the LadHyx, Polytechnique Paris-Saclay, France. The walls of this version are made of rigid polycarbonate panels. The small fans that produce the airflows can be seen on the bottom, just under the honeycomb panel that parallelize the streams. On the top appear the infra-low frequency loudspeaker that is used to study the effect of sound waves on the mist configurations.

A full-size version of this installation is currently being built in our Montreal lab, while a 1/3 version is already used as an experimental platform in the lab of our French partner. It consists in a tall enclosure, two meters long by one meter wide by four meters high, that looks like a huge vivarium, inside which the state and movements of the atmosphere are controlled such as to generate a mist tree. The walls of the full-scale version are made of stretched heat-shrink membranes. Three of them, on the back and on the sides, reflect the light like mirrors. The front one is transparent.

The mist tree is generated from the bottom up by thousands of vertical microflows of air and aerosols, about 6 mm wide, that are made laminar by passing through panels of honeycomb material. The mist deploys at the top of the enclosure to form the tree canopy, thanks to secondary air flows and sound waves. Since the tree reflects in the mirror walls, it literally creates a mist forest whose images fade as they get progressively lost in the infinite.

Fig. 5 – The full-size version of the installation, currently being built at the UQAM School of Design in Montreal. The double wall on the back houses the mist recirculation system. The openings on the top will house a subwoofer and a planar laser. Three of the four walls will be made from mirror films; the front one will be transparent.

A very low frequency loudspeaker, placed at the top of the installation and turned downwards, creates sound vibrations which locally modify the

density of the aerosols and generate periodic patterns with variable rhythms in the in the shape of the tree. These vibrations are transmitted to the wall membranes, periodically creating slight blurs that propagate in the multiple reflections of the mirrors, potentially adding a dreamlike dimension to the landscape. Several faint light effects, produced by a video projector and plane lasers, create blades of light which, by intersecting the mists, reveal the continuous movements of their internal anatomy and help to improve the definition of the created shapes.

7 • Project II – Tectonics of the Mists

This project actually gave its name to the full research-creation program. Through the expertise that we are acquiring with the first installation, we began designing the final design of a much larger one, in the form of a large, enclosed space, about of a dozen meters long by eight meters wide and five meters high, within which visitors can wander between persistent haze and mist shapes forming nine to twelve mist trees – a promenade in a small mist grove.

Fig. 5 – Rendered image of the mist grove. The visitor wanders among mist trees, in an atmosphere impregnated with a light haze. Planar laser beams intersect the mists, revealing their internal, moving anatomy.

As with the first installation, the walls are made of a stretched mirror film, reflecting not only the images of the trees but also of the wanderers themselves. In this instantiation, the material of which the trees are made is composed not only of mist, but also of myriads of very small semi-transparent objects, like translucent particles or flakes, floating in the atmosphere. The objective is to give the visitor the impression of walking within a snow-laden cloud whose internal movements, influenced by different phenomena, are materialized by those of the particles. The atmosphere, kept in a permanent *chiaroscuro*, remains slightly hazy everywhere. Thin blades of light, created by planar laser beams and video projections, generate oblique planes that discreetly reveal the internal movement of the mists and construct changing architectures of light. Several hyper-directional loudspeakers, creating acoustic beams as precise as light beams, emit a very slight murmur coming from the transposition of the movement of the mists into sound waves when they are disturbed by the displacements of visitors.

At irregular intervals, ultra-low frequency sound waves are heard. They are very powerful and they occur suddenly, like thunderbolts. Emitted by a series of infragrave subwoofers, they transcribe real-time the occurrence of seisms in the earth's crust all over the planet, as detected by seismological institutes and broadcasted in real time via the internet. The amplitude and frequency of these infrasounds are defined by the magnitude of the earthquakes and the distance between their epicentres and the location of the installation. The air displacements they generate locally disrupt the balance

of pressures in the atmosphere, creating oscillations that propagate in the mists for several seconds, shaking the trees of mist, sometimes tearing them into shreds of clouds, creating rapidly changing patterns in the planes defined by the blades of light.

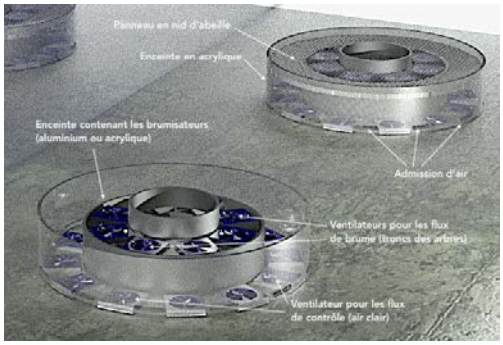

Fig. 6 – Bases of the mist trees (rendered image); stainless steel, aluminum, glass, electronics, mist-generting devices. Small waterproof fans send air and aerosols through honeycomb panels, whose cells divide the airflow in multiple parallel airstreams, allowing them to remain laminar on long distances. The trunk of the mist tree maintains its shape thanks to surrounding jets of clear air.

As can the reader can guest, this large-scale setup can be used not only as an installation, but as a complete platform to explore multiple scenarios that exploit all the possibilities of mists, hazes, fogs, air sprays and vapours as materials when shaped by airstreams, gusts and sound vibrations, and modulated by planar lights. As for any research-creation program, investigations will be made for their own sake, with no specific objectives, leaving open the possibilities to be surprised by unexpected results ; but the work will also be oriented along pre-defined scenarios that will in turn force the development of aim-oriented devices and narratives. *Tectonics of the Mists* is actually the name we gave to one of them, in which, when the earthquakes and the corresponding sounds become particularly powerful, the trees completely disintegrate under sudden gusts of wind, leaving only large and furiously agitated pieces of mist swirling in the air. The visitor, surrounded by a multitude of dancing particles, finds himself at the heart of a storm cloud streaked with planes of light that reveal its internal anatomy like constantly moving cross-sections. The mist then becomes a thick fog that collects in the lower part of the room, forming a lake in which visitors are half-immerged before rising to form a mountain-like wave. The wave then breaks, the fog recondense in trees and the atmosphere returns to its original state. By these atmospheric tsunamis, triggered like ocean tsunamis by seismic events, a dialogue of vibrations and tremors transposed to the human scale opens between the invisible architecture of the winds, the evanescent forest of mists and the massive opacity of the tectonic plates. The total entanglement of geological, atmospheric and biological phenomena and times becomes tangible, perceived through the movement of bodies, the moisture in the lungs, the contact of air on the skin, the vibration of the light and the variations of pressure in the ears. Immersed in the clouds, the lights and the sounds that shake the mist grove, the visitor becomes aware of all the rhythms of the world, of their almost immanent presence, and sees the possibility of harmonizing with them the inner agitation of his soul. Since it calls for all the senses, and since it allows the visitors to perceive real-time the effect of phenomena like earthquakes of all magnitudes that occur in very remote places, sometime very deep in the Earth crust, *Tectonics of the Mists* is directly in line with the intentions the *Observatories of the Unreachable* program.

The expertise we already have allows us to master the technological sequence involved by this narrative, but the whole setup should be seen as an exploratory platform whose potential expands far beyond that of a single performance and opens to a wealth of possibilities. Other scenarios, involving more complex morphologies that may prove much more difficult to control, are already planned for the next phases. In one of them, architectural forms and precise geometries will be generated in order to constitute fog labyrinths that can reconfigure at irregular intervals, so as to make much more difficult for the visitors to find the exit once they entered them.

8 • Installation III – Une Vigie Lacustre (A Lacustrine Lookout)

Finding ways to sculpt mists and clouds in a controlled atmosphere is already a challenging venture. The next step, whose study has already begun in our lab, will lead to a project that adds several degrees of complexity to it. It consists in bringing our mist-controlling techniques in open-air environments with largely unpredictable atmospheric situations.

It would be unrealistic to think that stable forms can be maintained in such contexts, in which all parameters, such as temperature, pressure, pluviosity, electrostatic field, wind speed and direction, and so on, can change from second to second. However, given enough initial energy and control, and with appropriate lighting devices, mist and clouds effects can be obtained with a vocabulary that do not imply fixed figures or shapes, but dynamic elements such as mist jets, fog layers and aerosol fountains of various flows.

The *Vigie Lacustre* is a floating object, several meters high, whose shape evokes the silhouette of a human being lost in a deep inner meditation in the middle of a lake. It presents itself as a sentry, the vertical silhouette of a lookout who moves slowly, night and day, over the surface of the lake. It transposes the variation of atmospheric and underwater events into a vocabulary of sound, light effects and mist phenomena that wraps the sculpture itself in mist dresses, scarves, veils an shawls that play with the wind and the daylight before dissipating in the air.

The project plans to install several *Vigies* in neighbouring lakes - the Quebec province, where the project will first take place, has more than one million bodies of water large enough to be called « lakes » – and to make them communicate through wireless devices, so that a given *Vigie* can translate the data coming from another one, and so that a group of *Vigies*, once installed, can translate together the state of their respective lakes.

As it is often the case for research-creation projects, and like it has happened several times for our works, the origin of this one lies outside of the art context. It comes from the will from local administrations to monitor the individual and collective health of lakes, ponds and swamps that are located in natural or semi-urban environments, and that are threatened by potential chemical

or bacterial contamination as well as by the effects of climate change. The development of monitoring probes in the form of artworks is an efficient way to intrigue and to trigger interest from the surrounding populations as well as from visitors, who may even travel from other regions to see them. They are seen as a powerful vector for awaking consciousnesses to the necessity to take care of these places, to protect them, and to put all the possible efforts to preserve their health.

The underwater probes and sensors that we plan to use measure a dozen parameters. They are precise enough to allow a real-time monitoring of water and to continuously assess its quality, from transparency to biological and chemical contamination, up to a depth of more than twenty meters. The scientific data thus collected will be used by research and analysis laboratories; simultaneously, visitors to the lake will be able to know about its state and health, and about the events occurring in its underwater layers, through the variations of mists phenomena, sound sequences and lighting effects, all directly linked to the evolution of atmospheric or underwater parameters. In the long term, such a project can lead to a network of interconnected artworks that exchange data about the state their respective lake and quickly trigger warnings if local or global contaminations are detected.

9 • The Rocky Road from the Lab to the Real World

We will end up this paper by a topic that may seem anecdotical, but that is actually critical for a large majority of artists working in media arts, science art and digital arts. The premises of our project – to sculpt mists and clouds - might look conceptually simple; the main challenges, which consists in designing and implementing the devices and algorithms required to reach that goal, are essentially technological. However, getting such projects out of the lab and on the public scene, which can be described as the opposite of a controlled environment, involves a fully new set of problems, concerns and constraints related to safety, robustness, reliability and context. They must be considered from the very first phases of the project in order to be taken in account all along its development. Failing to do so can jeopardize the very existence of the work, or at least the possibility to present it in art-dedicated venues, such as galleries, museums or festivals.

An installation project like *Light Echoes of the Mist Grove* (above) must be designed such as to be completely waterproof : the mist-generating devices can use up to six litres of water by hour, which gives about fifty litres for one day – enough to severely damage the floors or the walls of a historical building. To make for this requirement, each part and assemblage was carefully studied so as to create a fully waterproof module, and a complete system for water recirculation was added to it. Needless to say, the complexity of the project was largely increased; without these precautions however, very few venues would have accepted to show it.

The second piece, *Tectonics of the Mists*, will see people wander in a closed room whose atmosphere is filled with micro-droplets of water. Each day, the twelve mist trees will spray over six hundred

litres of water in the air. By their sole breathing, the visitors will unavoidably inhale and exhale large amount of water droplets, which appear as very efficient vectors for carrying and transmitting germs and micro-organisms. In the time of COVID-19, it seemed unthinkable to gather visitors in such an environment, which could become a major super-spreading point.

This risk can obviously be limited by granting access only to fully vaccinated people wearing masks. As it is well known however, even in perfectly safe situations, the appearance of risk may become more dissuasive than the risk itself. This is why, after the first pandemic wave, it was decided to add to the recirculation system a device that would eliminate all germs from the water. In normal regime, air flows and aerosols are captured by openings located at the top of the installation and returned by a set of pipes to the mist production devices, themselves located at ground level. During this journey, the water is separated from the air by recondensation. Installing a UV disinfection device along this path will readily kill all pathogen organisms, thus limiting their lifespan to two or three minutes. As a result, the enclosed area will present far less risk than a public place such as a grocery store, a movie theatre or a train station.

10 • Conclusion

Along this paper, we presented the current and next phases of an on-going research-creation, or, to use the translation of a French well-known expression, of a research-creation in the making. Each of the three laboratories involved in the projects presented above works in its own field of expertise : science (LadHyx), technology (INIT Robots), art and design (NXI Gestatio). In this sense, the research program from which these projects originate, located at the intersection of the three disciplines, is typical of the field of research-creation, and leads to the production of knowledge for each of the three. The possibilities of transfer between disciplines are multiple. They open for the protagonists of each of them, be they artists, students or researchers, unexpected perspectives of joint research and collaboration. The approach undertaken simultaneously by the three researchers may seem arduous; the final artistic results that are sought may seem difficult to achieve; the complexity of the themes addressed is high, and requires advanced expertise in several fields. But this complexity only reflects the complexity of the world to which the projects refer. It testifies for the need, in order to account for this world and to take care for it in the best possible way, to approach its study, exploration and potential for artistic creation from all possible angles.

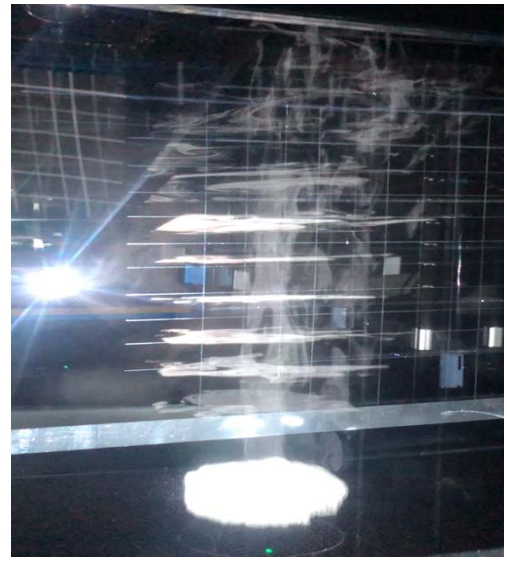

Fig. 7 – Mist structure materialized by planar lights.

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