GREENRAY — LASER TAPESTRY

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ABSTRACT

An interactive laser light tapestry that blends sculpture, architecture, installation and performance. The "loom" designed to weave this "fabric" uses the principle of multiple reflection, producing a visual weave whose appearance is modified by the movement of the audience, who, by participating in this collaborative artistic experience, become co-creators of the work.

An interactive analogue work of art, which did not use digital processing, but which presented itself as a new optical and environmental configuration, as well as a reference for post-digital contemporary art. Computing without a computer, and calculating faster than a computer, presented itself as a contrasting and critical hypothesis to today's computerised and digitised society.

KEYWORDS

Public Art; Interaction; Light.

ABSTRACT

Interactive laser light tapestry that merges sculpture, architecture, installation and performance. The ‘loom’ designed to weave this ‘fabric’ uses the multiple reflections principle, producing a visual web, whose appearance is modified by audience movement that, while participating in this collaborative artistic experience, becomes co-author of the artwork.

Interactive analogue artwork, did not use any digital processing, but is presented as a new optical and environmental configuration and also as a reference to post-digital contemporary art. To compute without a computer, and to calculate faster than a computer, seemed a theoretical criticism and contrasting hypothesis to the actual digital and computerised society.

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Figure 1 - GreenRay.

INTRODUCTION

GreenRay is an urban threshold space, a transition between an exterior and an interior space. In GreenRay, the free and rebellious urban spirit associated with the idea of movement, control and precision seeks to bring together urban tribes in unconventional places. GreenRay allows for the appropriation of urban locations, taking advantage of equipment, obstacles and architecture. It is a 'clean' intervention that does not require special infrastructure and has no permanent negative impact on the landscape, a factor that denigrates the image of urban expressions such as graffiti. GreenRay is an urban experience, using urban infrastructure as scenery and citizens as performers and spectators, thus pointing to future possibilities for the city and for urban art.

GreenRay enlarges the space where it occurs, with participants controlling the light in that space and, consequently, its landscape. It is a spatial project in the form of public street art, combining technology and community. GreenRay encourages the reuse of urban spaces, temporarily giving them a new function: to be both places for social interaction and artistic exhibition.

The GreenRay project presents itself as a concept of urban aesthetics oriented towards the outside of conventional artistic circuits and theoretical artistic discourses. The work takes place outside the spaces of the museum, gallery or studio, and exists in the relationship established with the place where it is presented, promoting an aesthetic approach to that same place. This work, to paraphrase Hawkins (2012), relates to geography; it is an artistic practice based on sites and integrated into their social contexts. The social site, including its community, is the subject, material and audience of the work itself.

GreenRay is a space for sensory exploration, where the presence of the body and its senses are indispensable to understanding the artistic experience, which, not limited to an intellectual act, is apprehended by the complex perception of the body as a whole (Hawkins, 2010). As a space of distributed agency, this intermediary work can easily be identified as what McCormak (2004) considers a place for thinking about the relationships between bodies, concepts and materials of various kinds. GreenRay affirms the equality of media, because I consider that bodies, concepts and any material are media in the context of art and design. Thus, I have updated McCormak's identification, considering GreenRay only as a place to think about the relationship between media.

Within the scope of the written rationale that explains the process of designing and developing GreenRay, it is appropriate to briefly discuss experience, gesture and space in the context of this work, as it simultaneously results in space and gesture, shapes space and gesture, and uses space and gesture as means.

GREENRAY

GreenRay[1]is a "tapestry" of laser light, presented as an interactive intermedia work. The "loom" designed to weave the laser beams consists of two parallel mirrors placed vertically on the floor. Using green lasers with a wavelength of 532nm and the principle of multiple reflection, this work produces a flat visual weave, parallel to the floor - 10cm above it - whose appearance is modified by the movement of the audience, who are challenged to participate in this collaborative artistic experience, becoming co-creators of the work. For the audience, it is both an artistic experience and a physical activity. This work was born from the desire to conceive and produce an interactive analogue work of art that did not use digital (computer) processing but which, at the same time, could be presented as a new optical and environmental configuration, as well as a reference for post-digital contemporary art[2].



Figure 2 - Audience participation in GreenRay.

One of the objectives in the meta-design of this work was its easy and intuitive use by the audience, who can interact with the artistic composition by drawing different patterns, participating in the creation of an interface (with the human body and its movement) that does not require literacy. In GreenRay

[1]http://3kta.net/3greenray.php

[2] Alenxenberg (2011) defines the term post-digital: "Postdigital (adjective) Of or pertaining to art forms that address the humanisation of digital technologies through interplay between digital, biological, cultural, and spiritual systems, between cyberspace and real space, between embodied media and mixed reality in social and physical communication, between high tech and high touch experiences, between visual, haptic, auditory, and kinesthetic media experiences, between virtual and augmented reality, between roots and globalisation, between autoethnography and community narrative, and between web-enabled peer-produced wikiart and artworks created with alternative media through participation, interaction, and collaboration in which the role of the artist is redefined." (p. 10)

there is a phenomenon of non-verbal communication (Mohammadi and Vinciarelli, 2010) in which the emotions, feelings, intentions and social attitudes of audience members are perceived by other members through their facial expressions, gestures and postures. As such, GreenRay is also a social laboratory that encourages socialisation.



Figure 3 - Socialisation provoked in and by GreenRay.

By giving control to the public, they become performers of the artistic work responsible for finalising its conception. When the audience creates or (de)forms the content of the artwork, they transform from receivers to primary providers/emitters. As a process and as a discourse, GreenRay also investigates the relationship between the artist and their audience, proposing an informal configuration that encourages the audience to participate
, interact and enjoy the work without being pressured by ideological messages or positions. By erasing the division and enhancing the connection between artist and audience, this work brings together the dimensions of doing and experiencing.

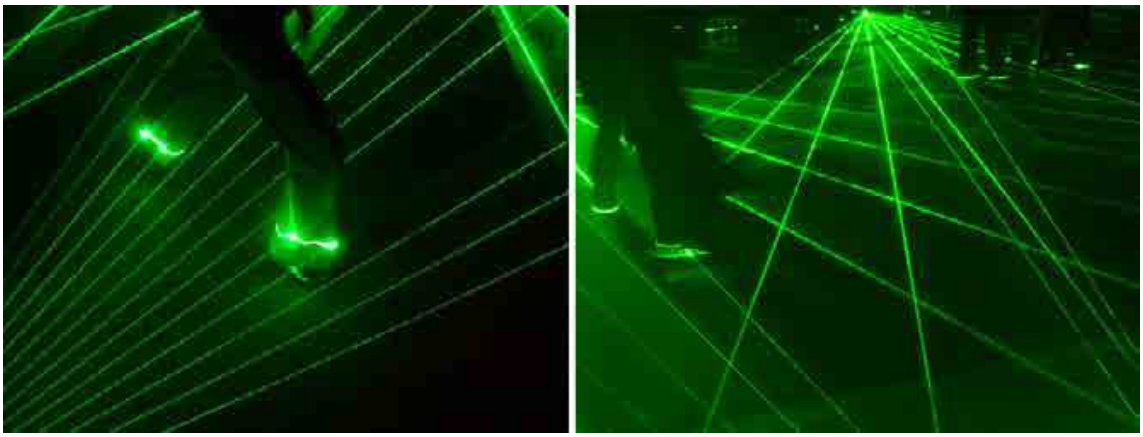


Figure 4 - Appearance of the work transformed by the audience.

The algorithm that integrates and constitutes the work has as its input, as a variable, the position and movement of the body of each member of the audience, which ensures the indeterminacy of the result. But the movement of each member of the audience is also a result, and therefore an output of the system. The work GreenRay is an interaction between human beings provoked by a provocative configuration of laser beams. Simultaneously, it is also the interaction of these same human beings with the set of laser beams. It is a hybrid interaction between media. Between human beings, as media; and between human beings and light beams, both considered media. Human beings and their gestures are the work. Light and its flow, controlled by human gestures, is the work. Light beams without human beings and human beings without

light beams are not the work.

the beams of light do not enable the work. In GreenRay's algorithm, 'inputs' are 'outputs' and 'outputs' are 'inputs'; they are hybrids of inputs and outputs. The laser beams are the result, *the output*, but at the same time they constitute the interface itself and therefore *the input* of the system, of the algorithm (Rangel 2015). It is an intermediate dynamic that transforms its media into hybrids.

Because vision and our very existence depend on light, the practical research that led to GreenRay focused mainly on technologies that can transform the appearance of a space while respecting the existing architecture. Light is a medium that allows for such transformation.

EXPERIENCE

One of the main motivations behind the creation of GreenRay was to provide participants with an experience rather than creating objects that can be exchanged and owned. As a case study, in GreenRay, the experience is the common element among the human beings who participate in it. For the artist, the experience is an intention and is present in all phases of the work's materialisation, from its conception to its realisation. For him, the experimental nature is constant because the work results precisely from the interrelation of experiences made with different material, technical, procedural, conceptual, human, and other means. The construction of the experience is influenced by the artist's experimental work, which provides participants with the experience of the work and simultaneously completes it. In other words, participants experience the work as an audience but also actively participate in the action of making the work, in its finalisation. In turn, the artist can only experience the event of the work when it is experienced by the participants. In this sense, it can be said that there is a certain reciprocity of experience: the artist provides an experience to the participants, who, in turn, provide the experience to the artist. In other words, the participants experience the artist's experience, who experiences how his experience is experienced by the participants, who are also makers of the experience itself (Rangel 2015).

In an era of evident decline, due to the inhospitable growth of consumerist values in a self-destructive capitalist society[3] , in which the attraction and value placed on the possession of objects (which quickly become obsolete and devalued) is almost universal, the production of experiences, even if ephemeral, counteracts this trend and reinforces with optimism the idea that 'we are what we do', to the detriment of the idea that 'we are what we have' or 'we are what we possess'. In a way, GreenRay reveals a political position based on a philosophical principle: 'Doing instead of Having'.

In the literary universe, various types of experience are referred to, such as physical, mental, emotional, spiritual, religious, aesthetic, sexual, virtual, among many others. Arsenault and Bonenfant (2012) consider that 'experience can be divided into its various dimensions, such as technique (techne), ethics (ethos), aesthetics (aisthêtikos), etc.' In turn, each of these dimensions can be further divided into multiple other dimensions. For example, Gallese and Di Dio (2012) consider that 'aesthetic experience is connoted as a stratified state where one can distinguish several dimensions' associated with different forms of relationship with objects, such as 'mere observation, aesthetic attitude, aesthetic appreciation/evaluation and aesthetic judgement'. But for Arsenault and Bonenenfant, 'these dimensions [technical, ethical and aesthetic] cannot be imagined separately from their effects and functions, combined as an inseparable whole that defines the meaning of life'.

It is not the aim of this article to dissect, separate and categorise the possible forms or dimensions of experience. Experience is a continuum, a hybrid that cannot be defined because it is both ambiguous and comprehensive. The experience of an 'expert', the experience of seeing the ocean for the first time, or the experience of mixing materials that had not been mixed before, are at opposite ends of a multidimensional spectrum and have different semantic values. Experience is a constant in life.

[3] It is called self-destructive because of the tendency of capitalist society to destroy existing values in order to 'sell' new values.

Members of the Austrian collective 'Monochrome' (2005), creators of the manifesto 'Experience the experience' [4] consider that "everything is related as experience. [...] everything has to be experiential or presented as 'experience'."

According to Varela (1991), who considered conceptualisation processes to be motivated by the structures of bodily experience, Hall (2010) argues that evolution is more related to our choices through experience than to improvements through adaptation. Experience is synonymous with knowledge and learning. Schinkel (2010), for whom experience is perception or imagination, brings experience closer to aesthetics by considering aesthetics as the experience of the senses. Experience also enhances knowledge. For Giannetti (n.d.), 'the acquisition of knowledge, education and culture are dependent on individual life experiences'. Murdoch (2001) seems to emphasise the importance of context and group experience in learning when he states that 'we learn by paying attention to contexts, vocabulary develops through close attention to objects, and we can only understand others if we somehow share their contexts'.

Thus, GreenRay can be considered as a context for group experience. In GreenRay, participants are confronted with a new environment/context, ready to experiment and for which they had no prior instruction. In other words, the works in question are also contexts for social interaction.

MIRROR NEURONS

GreenRay asserts itself as an experience that enhances knowledge and socialisation. At the end of the 20th century, a group of neurophysiologists at the University of Parma considered that there are neurons that are activated in an individual both when they observe another performing an action and when the individual performs that same action themselves. This group of researchers called their discovery 'mirror neurons'. neurons'[5] or 'mirror neurons', precisely because they are a kind of internal reflection of the actions of others. This discovery was quickly associated with language learning, motor skills, social and emotional processing.

In order to support the relationship between the theme of 'mirror neurons' and the work GreenRay, as well as its potential as an experience that generates knowledge, it is worth making another consideration: GreenRay is also a spatial arrangement, it occupies space and as such implies the movement and motor skills of the participants. Gallesse and Di Dio affirm the fundamental notion of the motor nature of experience and reinforce it: 'It is through movement that the elements available in space can be connected, that objects can be extracted from their background and perceived, that representations and meaning can be formed and articulated' (p. 688). Experts such as Fogassi and Ferrari (2007) state that 'mirror neurons are a class of neurons in the premotor cortex' called 'motor neurons' and that the motor (neuronal) system itself is related to the evolution of language. In the case of the work GreenRay, the movement of the participants is an integral component of the experience that is the work, therefore, there is reciprocal induction of activation of the 'mirror mechanisms' (mirror neurons) of the participants. As Galles-se and Di Dio state, 'the activation of the mirror mechanism for action is typically induced by the observation of ongoing actions, its relevance to the aesthetic experience during the contemplation of static works of art may be insignificant' (p. 692).

In their study, Gallesse and Di Dio, who identify the activation of 'mirror mechanisms' as 'embodied resonance mechanisms', suggest that these resonances also occur during observation.

[4] 'Experience the experience' - http://www.monochrom.at/experiences/

[5] For an introduction to the subject, we suggest consulting the following addresses: http://pt.wikipedia.org/wiki/Neurónio_espelho and https://en.wikipedia.org/wiki/

[6] These experts attempt to justify the 'hypothesis that various components of human language, including some aspects of phonology and syntax, may be embedded in the organisational properties of the motor system and that a deeper understanding of this system may help to explain how language evolved' (Fogassi and Ferrari, 2007).

tion of fixed works of art such as paintings, sculptures, photographs, architectural works, etc. Hall (2010) calls this type of resonance 'kinetic resonance', caused essentially by gesture.

GESTO

GreenRay is a hybrid system composed of humans and non-human components. The non-human components transform from objects into subjects because they act on human participants, causing them to act and react. And these actions and reactions happen as gestures.

Hall (2010) calls these actions and reactions the participants' 'interactive gesture'. This suggests that the experience of the work depends more on what it elicits than on its appearance. In the particular case of GreenRay, it is the essential gesture of the participants that is elicited. The bodily and facial gesture, whose system of performance and understanding is implemented in mirror neurons. Acharya and Shukla (2012) consider that it is from mirror neurons that human language evolved.

In fact, gestures and the imitation of gestures are, for many scholars, the key to language learning, empathy, and many other cultural advances. Neuronal mirror theories as the foundation for the evolution of human language are little more than a decade old. Johnson (2010), an advocate of embodied theory of mind[7], states that much of our perceptual knowledge originates from movement, both in our bodily movements and in our interactions with moving objects. McNeil (2006) states that gestures can be considered as agents of social interaction or as 'social stimuli'. Azar (2005) notes that the fundamental issue in the agency of gestures in socialisation is how the brain moves from understanding actions as actions to understanding actions as symbols.

GreenRay, which intentionally does not use verbal language, stimulates what is perhaps the oldest ancient and most primary means of human communication: gestures; the gestures of the body as a whole. As Hawkins (2012) states, an understanding of the experience of art is not just an act intellectual, but rather the complex perception of the body as a whole.

Supporting gesture as a means of socialisation, it can be concluded that GreenRay is a social and socialising experience. The gestures stimulated by the non-human components in each participant resonate with the other participants who can observe them. Each participant's gestures are therefore stimulated simultaneously by the human and non-human components of the system, in a kind of symbiosis. It should be clarified that in the specific context of the works in question, the gesture, rather than being a result of the work, is also one of the means of the work. The participants' gesture is a means of the work because it acts at the entrance to the system that integrates it and, at the same time, it is a result of the work because the work provokes this gesture.

SPACE

The notion of space deserved in-depth study in the process of designing and materialising GreenRay. Sensitive space is that which is apprehended with the senses. Spatial perception is an exploratory activity mediated by the sensory-motor apparatus of human beings. From an enactive perspective (Noë, 2002), spatial perception is an enactment resulting from the structural fusion of the organism with its environment. In GreenRay, this exploratory activity is precisely provoked, in which spatial properties are accessible to more than one sense (vision).

[7]Scarinzi (2013) summarises embodied mind theory as a rejection of the separation of mind and body, which sees meaning, reason and imagination as embodied and links reason to emotion. In other words, according to Scarinzi, experience and cognition are mediated bodily and depend on the sensory-motor capacities of individuals immersed in a biological, psychological and cultural context that interacts with the environment in a relationship of co-determination. (Although the theory of embodied mind is completely relevant in the context of the present investigation, it is concluded that it is not a relationship of co-determination but rather one of co-indetermination).

Because we have a body, we are spatially located beings and, when awake, we are always looking in some direction. Thus, space is always present; it is a constant in life. The way we perceive the spatial context around us is a fundamental part of our thinking and behaviour. GreenRay, as a spatial arrangement, aims to simultaneously engage the audience's senses of sight, hearing and touch, affecting their choices and behaviours. Reflecting a desire for sensual pleasure, this work provides a configuration that envelops the audience, making them both the element and the fundamental medium of the artwork. The concept of the artistic object, explored in the development of this work, implants information in an environment, constituting a perceptible space modelled for the presence of the audience.

Still within the study of the notion of space, GreenRay appropriated and crossed knowledge from the fields of architecture and visual communication design, among others. The practices/theories of the figure-ground relationship were reused in the solid-void relationship, reaffirming: that empty spaces, formed by the positioning of objects, are as important as or more important than the objects themselves; that three-dimensional spaces are considered positive spaces when they have a defined shape, giving a sense of delimitation; that positive spaces can be defined by an infinite number of elements such as points, lines, planes, or lighting; that spaces that are not explicit but apparent are considered implicit. GreenRay affirms the equality of 'empty' space and solid space. Positive and negative spaces are defined by objects: human bodies; points, at the intersections of laser beams; lines, which are the laser beams themselves; planes, defined by groups of coplanar laser beams; and also by volumes resulting from the interaction of these objects in space. For example, the volume below the laser carpet and the volume above it, or even the volume delimited by the laser beams.

It was interesting to note that human behaviour in GreenRay was heterogeneous. Some people preferred to place their bodies in front of the beams, altering the pattern of the tapestry, while others preferred to avoid the beams by walking only in the spaces delimited by them. It was noted that the latter group, despite being in front of laser beams, behaved as if they were wires. They stated that the space occupied and determined by the laser beams, their physicality and materiality, are perceived in the same way - with conviction - as solid volumes are perceived.

Urban spaces are passages through which bodies, symbols and material things move. Some of them are more threshold-like than others, some even develop into extensive borders (For-näs 2002).

GreenRay is an urban space, a threshold urban space, a space of passage, of transition between an exterior space and an interior space. The work was intentionally conceived as a place of passage and installed in the access area to the Lux nightclub building, so that anyone heading for the entrance to the building was inevitably immersed in the space of the work, being immediately transformed into part of the work.

MULTIPLICATION/GENESIS

The idea for GreenRay came about almost by accident one summer night in 2009, while testing hypotheses for new optical configurations. Given the availability of some laser devices in the laboratory where this work was developed, we intuitively experimented with shining a laser beam onto a CD. Curious visual patterns were immediately observed, caused by the projection onto a wall of the combination of laser light reflected and diffracted by the CD. Despite the temporary curiosity and enthusiasm aroused by the visual possibilities of these patterns, the division of the laser beam into reflected light and scattered/diffracted light, and the consequent loss of brightness (since when the beam is divided, each resulting beam shines with less intensity), led to the choice of a configuration that, instead of dividing the beam, The solution was to use two flat mirrors

parallel. Without wishing to discuss the importance of the mirror in humanity and in particular in philosophy, art[8], mathematics and physics, it is essential in the post-digital context of this work to refer to the idea of multiplication made possible by the juxtaposition of at least two mirrors. It is not our intention to discuss the phenomena of calculation or computation, but, in fact, the multiple specular reflection of the mirror presented itself as a powerful, efficient and instantaneous form of calculation and computation which, despite its simplicity and antiquity, surpasses the capacity of the most modern computing devices when performing the same task[(9)] . Computing without a computer, and calculating automatically faster than a computer, presented itself as a contrasting hypothesis, highly critical of today's computerised and digitised society. In GreenRay, the pattern generated by the combination of laser beams and mirrors is formed at the speed of light. A similar pattern displayed on a screen, calculated by a computer, would be formed more slowly, depending, among other factors, on the processing speed of the computer. This fact would only be contradicted if, hypothetically, there were computers operating at superluminal speeds.

While still in the laboratory, it was decided how the audience would participate and what level of control they would have. Once a small prototype had been built, consisting of two parallel flat mirrors and a green laser beam, it was decided that GreenRay users could participate and transform the work itself, using only their bodies as obstacles to the flow of the laser beams. The phenomenon of multiple reflection was considered a simple iterative multiplication process. In the context of the research that resulted in GreenRay, each iteration corresponds to the path of the reflected laser beam, according to the law of specular reflection, from one mirror to the opposite mirror. The interruption of the laser beam by a user is synonymous with the interruption of the iteration of the multiplication process. By interrupting the laser beam, the user determines the 'multiplier' and consequently the visual pattern that is the product of the 'operation'. Theoretically, mathematical multiplication can be described as a way of adding a finite number of equal numbers. Conceptually and in practice, in the GreenRay prototype, the length of the mirrors is finite, so the number of reflections

is also. Another type of multiplication - amplification - is the transition from the small-scale prototype to the installation of the work in real size: a carpet of light 8 metres wide by 20 metres long
length. The realisation of the phenomenon of specular reflection in the GreenRay installation, in real size - 8m x 20m, raised a series of challenges/constraints that will be described later in this article.

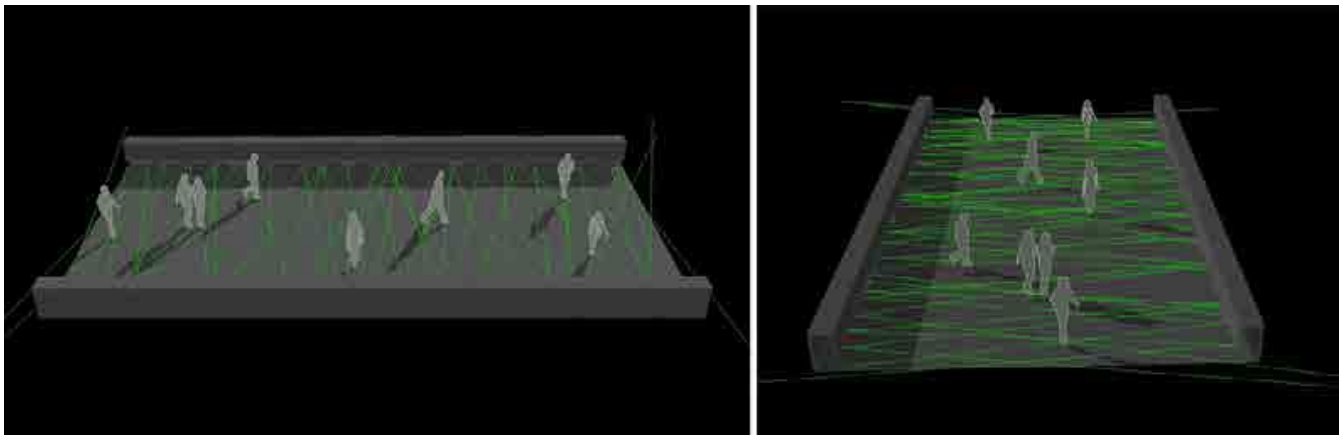


Figure 5 - Models for the STRP festival.

[8] Several artists use mirrors as a medium in their works, both as a way of integrating the audience and as a way of multiplying the image of reality. Among these various artists, we suggest consulting the works of Dan Graham, Jeppe Hein, Bojan-Sarcevic, Anish Kapoor, Ken Lum, Graham Caldwell, Olafur Eliasson, Joachim Sauter, or the United Visual Artists collective.

[9] Consider the classic example of the kaleidoscope, invented in the early 19th century, which has been revisited and mimicked in various algorithms and computer programmes for the creation and investigation of patterns. The kaleidoscope generates patterns 'instantly' or at the speed of light. A computer, with the appropriate display devices, can generate similar patterns, but always at its processing speed.

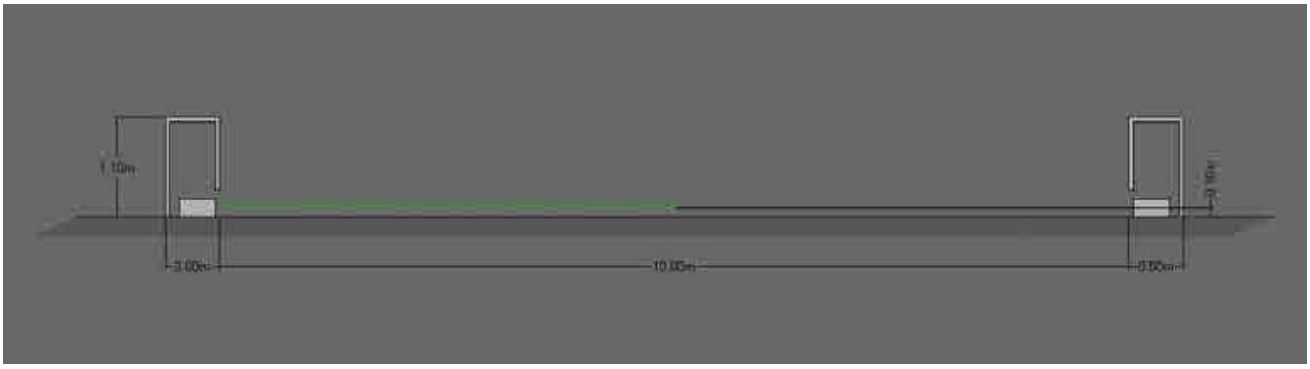


Figure 6 - Technical drawing for the Digital Graffiti festival.

VISIBILITY OF THE LASER

Although light, as an electromagnetic phenomenon, can propagate in a vacuum, for a laser beam to be visible, matter is needed, such as particles in the atmosphere that reflect it. The first presentation of the work GreenRay took place at Cais da Pedra, in front of the Lux Frágil nightclub, next to Santa Apolónia station, on 22 September 2009.

As it is a riverside area on the banks of the Tagus River, and given the annual statistics on humidity levels in the area, it was considered that the night-time 'fog' humidity would be sufficient as a means of reflection to make the laser beams visible. However, a week before the installation of the work, maps produced by weather forecast models were observed which, contrary to all the probabilities of the statistical maps, indicated low cloud cover percentages, below 5%, for the night on which the presentation of the work was scheduled. In other words, by 'coincidence', it seemed to be the driest night of the year, when humidity and fog were necessary for the success and visibility of the work.
lines of laser beams were clearly visible and defined. Thus, bearing in mind Murphy's Law[10] , knowing the statistics and aware that the forecast could be wrong, it was decided to ensure an alternative solution in case low cloud cover was confirmed on the night of the presentation. The solution was to consider the possibility of using a projector to project the laser beams onto a screen, which would be positioned behind the stage.
the statistics and knowing that the forecast could be wrong, it was decided to ensure an alternative solution in case low cloud cover was confirmed on the night of the presentation. The solution was to consider using two haze machines and two fans (to spread the smoke) to maintain artificial cloud cover that was as homogeneous as possible. The weather forecasts were confirmed and it was indeed necessary to use the alternative of producing artificial cloud cover. Although maintaining a relative homogeneity in the density of the smoke was an extremely difficult task in an outdoor environment subject to atmospheric imponderables such as the breeze, the result was assured. All small variations in smoke density were assumed to be a plastic and aesthetic attribute.



Figure 7 - Effect of smoke density variation.

[10] 'Anything that can go wrong will go wrong' (Edward Aloysius Murphy cited in Spark, 2006). Author's translation: 'Anything that can go wrong will go wrong'.

As this is a work created with light, its visual impact is enhanced by a darkened surrounding environment. The location where GreenRay was exhibited is adjacent to the Port of Lisbon, where very powerful lights are normally used for safety reasons. The success of the exhibition also depended on the deactivation of these lights, which are the responsibility of the Lisbon port authorities. The authorisation and action to keep the two lights off during the night of the presentation of GreenRay was the result of a laborious negotiation process.

FROM PROTOTYPE TO FULL SIZE

Another major constraint – viewed as a challenge – in implementing this project was scaling up the small-scale prototype to install the full-size project. The prototype was initially built in the laboratory using a 532 nm, 150 mW class IIIb green laser. Although this class of laser can cause eye damage if pointed directly at the eyes, it was considered that this risk would be minimised by placing the laser beam horizontally, 10 cm above the floor. With two 42 x 5 cm mirrors placed parallel to each other, facing each other at a distance of 21 cm, causing the laser to strike one of the mirrors at an angle of 80º, the phenomenon of multiple reflection was efficient, with the first 12 reflections of the beam having sufficient visibility and brightness for the desired aesthetic result. However, enlarging the installation to full size, with an area more than 2000 times larger than the area in the prototype[11], posed a new challenge: the distance travelled by each laser beam between each reflection was about 50 times greater. This greater distance travelled by the laser beams, combined with the fact that the 'fog'[12] reduces the penetration depth of the laser[13] and that the brightness of the laser beam is considerably reduced after each reflection (despite the use of low-absorption flat mirrors), led to one of the major technical challenges of this project: the choice and assembly of the laser modules.

A need to balance constraints was identified. The 'fog' was necessary for good laser visibility but simultaneously reduced its power along the beam path. Using

More powerful laser projectors increase the distance travelled and visibility of the laser in the 'fog', but also increase the risks for users. GreenRay's setup is the result of a balance between the visibility and aesthetic power of the work and the limits of user safety and legality. After observing and researching typical outdoor laser installations, it was found that the minimum power required to implement GreenRay would be 5 W, class IV[14], which led to the installation of lasers at a totally unforeseen logistical level in terms of safety, legality and cost.

Given that the GreenRay work consisted of audience interaction with the laser tapestry, more specifically, the interruption of laser beams by the audience, and given the date on which the installation would be presented (September 2009), at the end of summer, when many people wear shorts or mini-skirts with their legs exposed, for safety reasons[15] , an optical configuration was chosen that would reduce the power of the laser beams. The solution was to divide each beam into beams of lower intensity. This solution had a dual function: it simultaneously divided and multiplied each beam.

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[11] The prototype measuring 0.42 x 0.21 metres occupies an area of 0.0882 m^2 whilethe actual installation measuring 20 x 10 m occupies an area of 200 m^2 .

[12] In the specific case of the GreenRay installation, the fog would be natural humidity, but in its absence, artificial fog produced by a haze machine was used.

[13] '[...]high surface waves and heavy fog decreases the depth penetration of the lasers.' (Stolt & Rebenhorst, 2011).

[14] Class IV is the highest and most dangerous category of lasers. Lasers in this category can cause skin burns and irreversible damage to the eyes.

[15] The lasers used in the greenray light tapestry are 5W, so their use requires special legal authorisations in accordance with the laws in force in different countries.

Using an optical device called *a grating beam splitter* [16]or beam divider, each beam was divided into 14 beams, i.e., the number of visible beams was multiplied and the power of each laser was divided before it hit the users or mirrors. Without considering the amount of light absorbed by the splitter itself, each of the 14 beams resulting from the division had a maximum of 355 mW. Thus, although still a very dangerous laser power for the eyes, each of the visible beams in the installation could no longer cause damage to the users' skin. On a practical level, the option of using more powerful lasers proved to be very functional and advantageous, as only eight 5W laser devices needed to be aligned for the installation, instead of the 30 20 mW modules initially planned. However, logistically, the use of these state-of-the-art lasers posed a number of challenges. Firstly, in Portugal, the use of laser devices with a power [of]more than 5mW is prohibited for private individuals,and the lasers used in GreenRay are 1000 times more powerful, so it was necessary to hire a specialised company authorised to operate this type of laser. Secondly, in GreenRay, the laser beams also shine on the bodies - legs - of users. This technique is known in professional circles as *Audience Scanning* and is prohibited in some countries, such as the United States and Sweden[18]. As Portuguese law is silent on the projection of lasers onto people for recreational purposes, it was considered that there was no illegality. After researching companies that could safely rent and operate the type of laser required to materialise GreenRay, a Belgian company was chosen because there was no company in the Iberian Peninsula that had the technical and human resources to guarantee the success and safety of the installation. In the presentation of the GreenRay work, eight 5W laser modules were used, divided into 14 beams each, resulting in 112 visible beams before multiple reflection in the mirrors.

CONCLUSION

On the night it was presented, GreenRay was experienced by around 1,400 people. In addition, the audiovisual documentation about it was also seen by several thousand people. This documentation was selected by curators of important publications on lighting and architecture, notably the magazine enlighter[19] , where GreenRay is presented alongside works by authors such as Zaha Hadid and United Visual Artists, and the Media Architecture Institute blog[20] .

The work also attracted the interest of Vivian van Gaal, artistic director of the STRP festival[(21)] ,who officially invited the work to be installed as the gateway to the 2010 edition of this festival. Due to logistical and financial constraints, this invitation could not be accepted. As described, part of this work consists of a sculptural/architectural approach constructed with laser beams and mirrors. Although this may be mere coincidence, and although it is not the first work of art to use lasers or mirrors, it was noted that, following the publication of the documentation on GreenRay in October 2009, other notable works appeared on the international scene that use precisely the same approach: sculptural objects constructed with laser beams and mirrors. Notable among these works are the projects by the GNI collective[22] from 2010 and the Speed of Light project by the UVA collective[23] from 2010. However, the inclusion of the audience in the modelling of the work in GreenRay gives it a distinctive quality: the work moves from being an object to a provocative subject, acting on the audience and leading them to perform actions that they would never perform without the works.

[16]Technical information on laser beam splitting can be found at: http://www.optometrics.com/Products/products_beam_splitters.html#Transmission%20Grating%20Beamsplitters

[17] Decree-Law No. 163/2002 establishes 5mW as the maximum laser power for commercialisation and/or private use.

[18] Consulting an article by Benner (2001) on laser safety when projected onto an audience was fundamental to understanding the feasibility of the GreenRay project.

[19]http://www.enlightermagazine.com/projects/greenray-lux-fragil

[20]http://www.mediaarchitecture.org/green-ray-lisabon/

[21]http://strp.nl/nl/

[22]http://www.gni-projects.com/

[23]http://www.uva.co.uk/work/speed-of-light

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