"Do you speak quantum?" A quantum physics and art exhibition

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Abstract. We describe the design and realization of an interactive art exhibition on the theme of quantum physics. The exhibition comprises five installations, developed by a group of scientists and artists based in Zurich, Switzerland, at the time of development. The installations are interactive art pieces, and their goals are to raise awareness of the general public and policy and government officials toward quantum computing, to provoke viewers' questions on how quantum phenomena work, and to inspire them to learn more about quantum physics. Scientific experts in the field acted as ambassadors during the exhibition, delivering a guided experience to the visitors. The exhibition was showcased during the World Economic Forum held in Davos, Switzerland, in January 2020 as part of the Eidgenössische Technische Hochschule Zürich Pavillion. [DOI: 10.1117/1.OE.61.8.081807]

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1 Introduction

Quantum technologies and quantum computing have undergone tremendous developments in the last decade. Their disruptive potential, with impact on a wide range of fields and industry sectors, has resulted in significant private and public investment. However, access to and understanding of quantum technology largely remain limited to individuals who are highly educated in the field. A number of educational and outreach activities have been initiated in recent years to lower the barrier to entry to the field and to reach wider audiences, including investors and managers who are interested in evaluating the opportunity. In addition to online courses, games,[1] and scientific fairs, exhibitions on quantum physics to be displayed in museums and at events are one type of outreach activity that widens the reach to a wide variety of visitors with different backgrounds and ages. There have been several exhibitions on quantum physics developed and displayed in recent years. Two examples are "Quantum physics for everyone," an interactive installation developed by the Institute of Photonic Sciences researchers and outreach specialists and hosted at the CosmoCaixa science museum in Barcelona,[2] and "Quantum: the pop-up exhibition," a traveling exhibition developed by the Institute For Quantum Computing based in Waterloo, Canada.[3] In addition, this year a team of researchers from Eidgenössische Technische Hochschule (ETH) Zürich (including scoping and ideation efforts by the authors of this paper) unveiled an interactive experiment that allows visitors of Technorama (The Swiss Science Centre in Wintherthur, Switzerland) to see individual ions with their bare eyes. In this paper, we describe a five-piece exhibition on quantum physics developed by a group of scientists from ETH Zurich (Chiara Decaroli - project lead, Maciej Malinowski, Christoph Fisher, Celeste Carruth, and Jonathan Home) and a group of artists and interaction designers from We Are Lucid[4] (Marco Ehrenmann, Fabian Ellenberger, and Jonas Scheiwiller) that was coordinated by the ETH Global team (Simone Bucher).[5] What makes this exhibition unique is that each piece was developed as a collaboration between scientists and artists, in which the

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scientists scoped and developed the pieces and the artists incorporated interactive elements into them and transformed them into visual, audience-friendly pieces (one of the pieces, "entangled orbs" was developed entirely by the scientific team alone). As a result, each installation is a stand-alone art piece that can be experienced as such. This expands the impact that each piece has on the visitor. Indeed, visitors can experience and enjoy each installation purely as an interactive art piece, without any link to quantum physics. The visual and interactive pieces draw visitors in, and without them noticing, they provoke questions around quantum physics and the world in which we live. This is a radically different approach to educational installations developed with the goal of teaching a specific concept to the visitors. Art is used here as a means to inspire the visitor to learn more about science. The exhibition that we developed may or may not be supplemented by scientific ambassadors: outreach specialists who guide the visitors in their experience of the art pieces and weave in quantum physics concepts to enrich and deepen the visitors' experiences. The exhibition was showcased for 1 week at the World Economic Forum held in Davos, Switzerland, in January 2020 as part of the ETH Zurich Pavillion (3D tour of the Pavillion[6]). Visitors of the exhibition ranged from high school students and ETH alumni to policymakers and government officials to thought leaders and influencers from a variety of industries and organizations throughout the world.

2 Exhibition

The exhibition was titled "Do you speak Quantum?" to highlight the new language on which quantum technologies are based, a language that is different, surprising, and at times puzzling compared with those to which we are accustomed. The exhibition was made up of five stand-alone installations, each telling a story related to quantum physics. As the visitors came through the front door, they found themselves in the world of the quanta. Along a dark, long corridor they encountered the first installation, "The Qubit Forest," which showed them quantum error correction in action; followed by the "Particle Ballet," where they could make particles dance, trapped by invisible fields; and "Many Worlds," an illuminated tunnel with infinite versions of itself. In the main exhibition hall, they interacted with "Entangled Orbs," spheres that were magically connected to each other despite being separated by several meters, and the exhibition centerpiece, "The Pond of Possibilities," which showed them how waves can be made to interfere with each other to perform quantum computations.

2.1 *Qubit Forest*

The Qubit forest is a large installation made of three adjacent panels. Each of the panels is an infinity mirror. Within the panel, a series of LED lights flash in different colors and according to a specific pattern. The pattern is a visualization of quantum error correction based on the surface code.[7] When an error occurs, one qubit flashes in red. Error correction is implemented using the neighboring qubits. The resulting effect for the visitors is to feel fully immersed in an infinitely large machine, in which individual particles—or qubits—are switched on and off to perform operations. The aim of the piece is to communicate the complexity and scale of a useful quantum computer, as well as to provide a simple visual explanation of what error correction is and how it can be implemented. Figure 1 shows a photograph of the installation and two visitors marveling at the infinite pattern of lights. Scientific ambassadors describe to visitors what error correction is, why it is important for quantum computers, and what the scale of fault-tolerant quantum computers is.

2.2 *Particle Ballet*

The Particle Ballet is a dust Paul trap, a device that uses electrical fields to hold in space charged dust particles.[8] The mechanics of this device are the same as those that lie at the core of quantum computers based on trapped ions, except that the latter uses individual charged atoms instead of dust particles.[9] Visitors can peek into a viewing window, through which they can see the illuminated dust particles dancing in space. They can also use a lever to change the trap parameters, directly affecting the arrangement—or choreography—of the dust particles. This is shown in Fig. 2. Dust traps are robust and simple devices that elegantly illustrate our ability to control

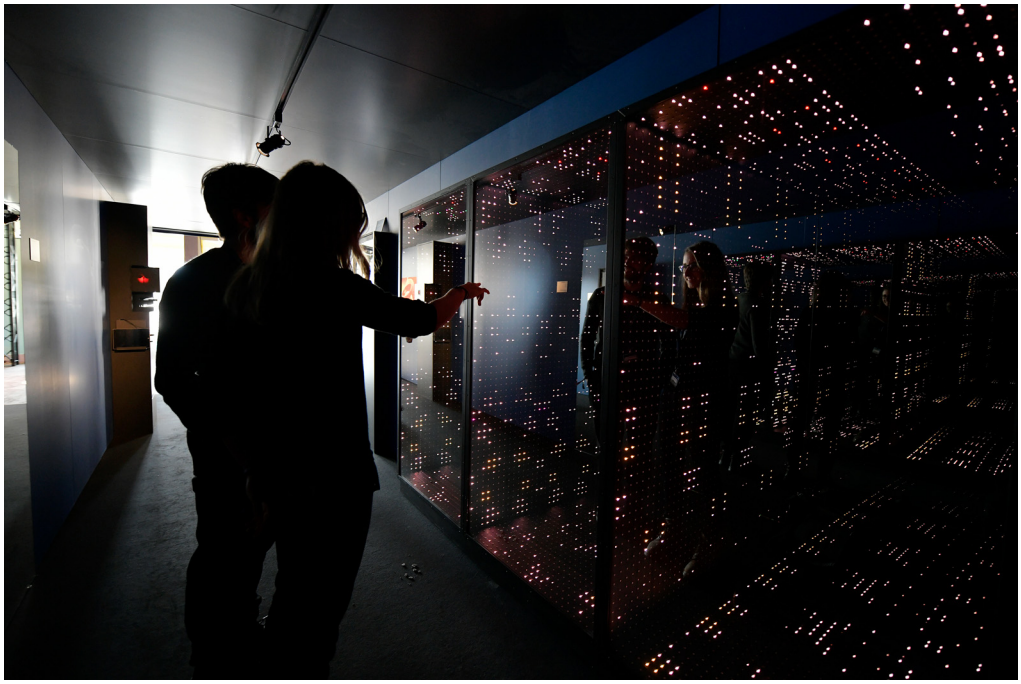

Fig. 1 The Qubit Forest. Image credit: ETH Zurich/Andreas Eggenberger.

Fig. 2 The Particle Ballet. Image credit: ETH Zurich/Andreas Eggenberger.

and manipulate small particles, as illustrated in Fig. 3. As the visitors interact with the piece, the scientific ambassadors discuss how they manipulate individual atoms in the laboratory every day.

2.3 *Many Worlds*

Many Worlds is a small installation that consists of an illuminated tunnel that can be tilted and twisted, thus creating an infinite different realization of itself. This piece is inspired by the Many

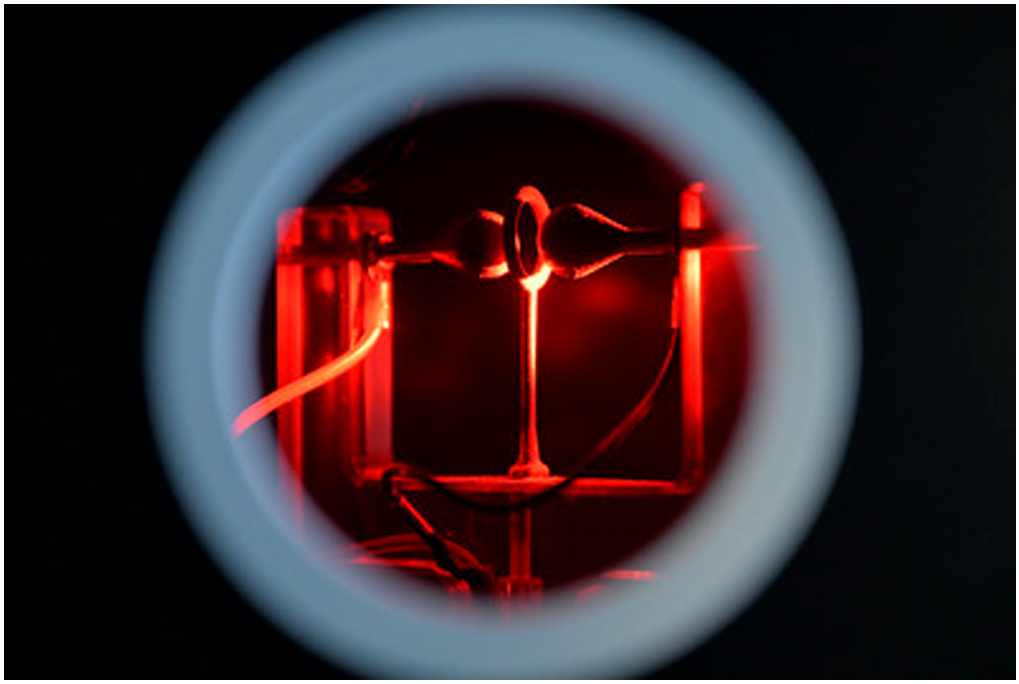

Fig. 3 The Particle Ballet: detail through the viewing window. Image credit: ETH Zurich/Andreas Eggenberger.

Worlds interpretation of quantum mechanics.[10] As visitors lose themselves in the piece, scientific ambassadors tell them about the different interpretations of quantum mechanics and how, although we have a well-developed quantum language, its interpretation is still under debate and an active research topic.

2.4 *Entangled Orbs*

Entangled orbs is an installation comprising five spheres, separated from each other by several meters, as can be seen in Fig. 4. Each sphere hovers above a small base. One of the bases has a knob, which the visitors can turn. As the knob is turned, all spheres revolve in the same way, despite not being connected. This piece aims at revealing one of the most fascinating and strange phenomena of quantum physics: entanglement, which Albert Einstein famously described as a “spooky action at a distance.”[11] Visitors are struck by their own surprise, watching the spheres move in unison, and enjoy trying to figure out how they are connected to each other. Within the base of each sphere, there is an electromagnet repurposed from a “levitating globe” toy. Furthermore, a large permanent magnet is attached to the base of the sphere on the inside.

The magnetic repulsive force pushes the sphere away, resulting in the effect of a sphere suspended in space. Additional permanent magnets inside the base can be rotated via an electronic circuit. When these magnets rotate, the sphere follows due to a pair of permanent magnets glued to the inside of it. The position of all orbs in the room is controlled by a rotary encoder attached to one of the bases, which streams position instructions over WiFi.

2.5 *Pond of Possibilities*

The Pond of Possibilities is the centerpiece of the exhibition. It is a large circular tank with a transparent bottom, filled with water and suspended from the ceiling. A strong light hangs above the tank, creating an image of the pond on the floor, as shown in Fig. 5. As visitors approach the pond and “step into it,” sensors detect their movement and activate actuators that lightly tap the water, creating a wave. The result is that visitors create waves as they step into the pond. The waves interact with each other, creating interference patterns. We use this piece as an analogy in which each visitor is a qubit, emanating a wavefunction. As each qubit’s wavefunction interacts

Fig. 4 Entangled Orbs. Image credit: ETH Zurich/Andreas Eggenberger.

Fig. 5 The Pond of Possibilities. Image credit: ETH Zurich/Andreas Eggenberger.

with the others, quantum computation is performed. This provides a simple, very intuitive way to show how quantum computers work.[12]

3 Visitors’ Experiences and Impact

Two thousand visitors viewed the exhibition in January 2020. Their visit was supplemented with scientific ambassadors, who guided them through the exhibition. The scientific ambassadors

Fig. 6 A visitor interacting with a scientific ambassador. Image credit: ETH Zurich/Andreas Eggenberger.

were the scientists who developed the installations, as well as volunteer PhD and postdoc students. An ambassador typically spent between 5 and 20 min discussing a specific piece with the visitors. Figure 6 shows an interaction between a visitor and a scientific ambassador. Visitors were very engaged, interested, and inspired by the art pieces. The installations successfully served the purpose of provoking questions—such as ”How does this work? What does this piece represent?”—which became the basis for discussions with the ambassadors. Several high school

Fig. 7 A young visitor interacting with the Entangled Orbs. Image credit: ETH Zurich/Andreas Eggenberger.

classes also visited the exhibit; each ambassador guided a small group of five to seven students through each piece. Although each ambassador gathered qualitative feedback from the visitors, who commented directly on the exhibit and their acquired awareness and understanding of quantum computing, we did not formally collect any feedback from the visitors. To better understand the level of impact of a similar exhibit, we recommend incorporating formal assessments in the future, in the form of feedback surveys that can be distributed to the visitors after their experience. Moreover, data such as the total time that a visitor spent interacting with the pieces and with the scientific ambassadors could be collected and analyzed more quantitatively. As this was a first-of-a-kind project, with efforts contributed by volunteering PhD students and the interactive designer group over the course of 8 months, we limited ourselves to a qualitative assessment of the success of the exhibit. Guidelines on evaluation methods for future exhibits can be found in a number of resources.[13–15]

4 Supporting Material

Supporting material in the form of articles and videos was created during the development of the exhibition and during the WEF. Articles such as "This is how a walk on the beach can help explain quantum computing"[16] and "Scientists can make particles dance together. This is how"[17] spun directly from the exhibition and can be found online, along with videos showcasing the pieces and the visitors experiencing them (Fig. 7).

5 Conclusions

We have described "Do you speak Quantum," an art exhibition on the theme of quantum physics. We argue that using art to provoke questions and inspire visitors is a powerful way to introduce them to complex quantum physics concepts such as error correction, quantum computation, and entanglement. We have briefly described the five installations developed for the exhibition by a collaborative multidisciplinary team of scientists and artists and have highlighted the interactive element around which each piece revolves. Visitors have engaged with the installations, as well as with the ambassadors guiding their visit, and have reported going back home filled with interest and fascination for the language of quantum technologies.

Acknowledgments

The project was conceived by CD, thanks to the opportunity presented by ETH Global - Office of the president and the curator Simone Bucher to develop an exhibition for the ETH Pavillion at the WEF. CD assembled and led the team of scientists from the Trapped Ion Quantum Information group at ETH Zurich, developed ideas for the installations with inputs from the whole team, and worked on articles and supporting material. The artists and interaction designers from Lucid brought to life most of the installation pieces (Qubit Forest, Many Worlds, Pond of Possibilities) and their interactive elements with inputs from the scientific team. Entangled orbs were conceived by Celeste Carruth and developed mainly by Christoph Fisher with help from MM and Celeste Carruth. Jonathan Home proposed the idea for the Pond of Possibilities. Particle Ballet was developed and lent to the exhibition by the Physics Department of ETH Zurich, based on a lecture experiment called "Paul Trap."[18] We kindly thank the ETH Global team and Simone Bucher for their support throughout the development and delivery of the exhibition.

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