Trapping the Objectless

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Abstract

Through the epistemological lenses of quantum theory and phenomenological art, the authors describe their collaborative development of several artworks exploring electrodynamic levitation. Comprising diverse ion traps that enable naked-eye observation of charged matter interactions, these artworks question the murky boundaries of perceptibility and objectification.

Keywords: quantum simulator, phenomenology, Paul trap, objectlessness

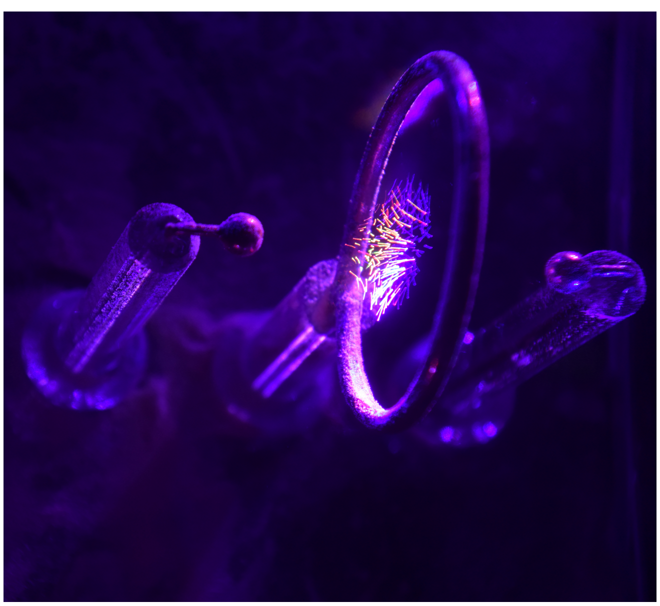
Part 1 (by Evelina Domnitch and Dmitry Gelfand)

Experimental physics is the art of observing the structure of matter and of detecting the dynamic processes within it.

– Wolfgang Paul [1]

Even though our artworks emphatically depart from verbal language and all other forms of symbolic communication, periodically we stumble upon linguistic clues that might elucidate our peculiar inter-scientific, para-philosophical practice. In French, a single word signifies both experience and experiment: *éxperience*. Our endeavors veritably strive to dispel the distinction between these two notions. Is not an experience, but a perceptual experiment? Is it only science's necessity for measurement that distinguishes it from philosophy? When measurements are insufficient, imprecise, or inconsistent with mathematical models, theoretical physicists rely on a philosophical method known as phenomenology - the origins of which stem from Edmund Husserl's phenomenological "Philosophy as a Rigorous Science"[2]. This unlikely trajectory

Fig. 1. In *Ion Hole*, electrodynamically levitated lycopodium spores reveal a quadrupole electric field. (© Evelina Domnitch and Dmitry Gelfand)



was painstakingly paved by mathematician, physicist and philosopher, Hermann Weyl [3]. Though quite distinct from Husserl's approach, the Weylian phenomenology of contemporary physics inherited Husserl's intuition of a "fluid whole, rather than a set of discrete elements"[4]. Among the leading contributors to unified field theory and the foundations of spacetime geometry, Weyl claimed that Husserl's "phenomenological experiences" were more fundamental than the experience of "elements" or "empirical objects":

> A real thing can never be given adequately, its "inner horizon" is unfolded by an infinitely continued process of ever new and more exact experiences; it is, as emphasized by Husserl, a limiting idea in the Kantian sense. For this reason it is impossible to posit the real thing as existing, closed and complete in itself [5].

Reciprocally, philosophy has always been deeply saturated with scientific inquiry, from cosmogony to psychophysics. Although our methods originate from the phenomenological crossroads of science and philosophy, our path has led to a purely non-verbal phenomenological art of observation, eventually stripped of both measurements and metaphors [6].

Among the ongoing philosophical problems in theoretical physics is the inability to describe a quantum system in terms of classical physics. The only way to precisely understand and manipulate quantum phenomena is on their own terms: by means of a quantum simulator - a rapidly evolving methodology initially proposed by the charismatic Richard Feynman in 1981 [7]. Nearly a decade later, Wolfgang Paul, Norman Ramsey, and Hans Dehmelt were awarded the Nobel Prize for having invented the electrodynamic quadrupole ion trap, which enabled physicists to observe for the first time the quantum nature of an individual atom. Finally, instead of measurements comprising averaged statistical values of large ensembles of atoms, an isolated singular atom could be directly probed. The former approach was based on the classical assumption that all atoms behave in exactly the same way as an average of their statistical behavior. The Paul trap, as it is now known (after Wolfgang Paul), proceeded to become an ideal environment for quantum simulation. Furthermore, the Paul trap's ability to address individual atoms opened a tangible route towards quantum computation: designing logic gates not with bulk matter but rather with discrete properties, such as a single atom's spin, to perform logic operations at unfathomable speeds. The Paul trap has also become a valuable tool in numerous domaines besides experimental physics, including chemical analysis, atmospheric science, and aerobiology.

Years before our collaboration with RySQ (Rydberg Quantum Simulator), we had envisioned creating an artwork with a Paul trap. Our perpetual infatuation with weightlessness has incited various artworks exploring such phenomena as optical levitation in Photonic Wind (2013), and acoustic levitation in Force Field (2016) and Sonolevitation (2007). The prospect of electrodynamic levitation offered an unparalleled means of interaction between alternating electric fields, charged matter, light and nearly negligible (piconewton) gravitational forces [8].

Through FEAT (Future Emerging Art and Technology), we were bestowed the magnificent opportunity to collaborate with one of the world's leading ion trap experts, Ferdinand Schmidt-Kaler, head of the Quantum Information Group at Mainz University, and a key figure in the RySQ conglomerate. Schmidt-Kaler is also a direct disciple of Hans Dehmelt, and had the privilege of working with him as well as with Wolfgang Paul and Norman Ramsey for many years. In but a matter of hours after our arrival in Mainz, Schmidt-Kaler helped us construct the first prototype of our ring-shaped Paul trap. He also   recounted a monumental occasion at Rainer Blatt's lab (Innsbruck University), when he observed, along with the Dalai Lama, a single Barium atom glowing inside of an ion trap [9]! The light emitted by the laser-stimulated atom directly reached his eyes through a lens - instead of a metaphor of the light emission captured on a microchip. Schmidt-Kaler and approximately a hundred other witnesses of this miraculous experiment were utterly transfixed. One of the other witnesses happens to be the leader and founder of RySQ, Tommaso Calarco. Together with Schmidt- Kaler and Calarco, we embarked on a mission to transform this single-atom experience into an art installation. Along the way, we have already created two electrodynamic artworks: Quantum Lattice (2016) and Ion Hole (2016).

Instead of single atoms, in Quantum Lattice hollow glass microspheres are levitated to enable naked-eye observation of trapped particle dynamics at room temperature and without a vacuum chamber. (To stabilize the trapped sample and prevent any interactions with air molecules, it is customarily laser cooled in an ultra-high vacuum.) Between the four poles of a linear ion trap, charged microspheres form a cascading latticework characterized by two simultaneous kinetic regimes: micro-motion occurring in phase with the electric field's oscillation period, outlining symmetric as well as asymmetric square-shaped orbits; and vertically oriented secular orbits, occurring on longer timescales in comparison to the oscillation period, and continuously pushing particles towards regions of weaker electric fields.

In the form of a purely optical (mediumless) projection, Ion Hole unravels the subtle micromotion of charged matter suspended in a ring-shaped ion trap. Inside the trap are ionized lycopodium spores that repel one another while being simultaneously pushed towards the center of the trap by alternating electric fields. Consequently, the spores self-assemble into an oscillating lattice known as a Coulomb crystal. The inward and outward “breathing” motion of the lattice occurs in phase with the radio wave frequency of the confining electric fields. By illuminating the spores with a laser beam pulsating synchronously and nearly synchronously with the radio frequency, the particles' rapid oscillations can be viewed in slow motion or even made to seem “frozen” in time. The laser illumination also creates a large-scale projection magnifying the spores' ceaseless orbital dynamics.

After giving center stage to trapped particles floating in a Paul trap, it is important to keep in mind that the crucial aspect of Paul's invention is the specific three-dimensional configuration of a quadrupolar electric field. This delicate high-voltage e xperiment conjures a mercurial vision of reality that emerges from the interaction of charges rather than objects. It is impossible to form an object-oriented mental image of rapidly flow-shifting electric fields, and it is equally misleading to objectify a trapped particle incessantly bouncing within these fields - because it is its ghostly charge that is trapped in the electric well. The materiality of the charge carrier hence becomes elusive as it couples with its environs and unveils their complex morphology. Aesthetically reflecting on the conditions and content of such an experiment propels us to tune into the fluid guise of objectlessness [10].

Part 2 (by Tommaso Calarco)

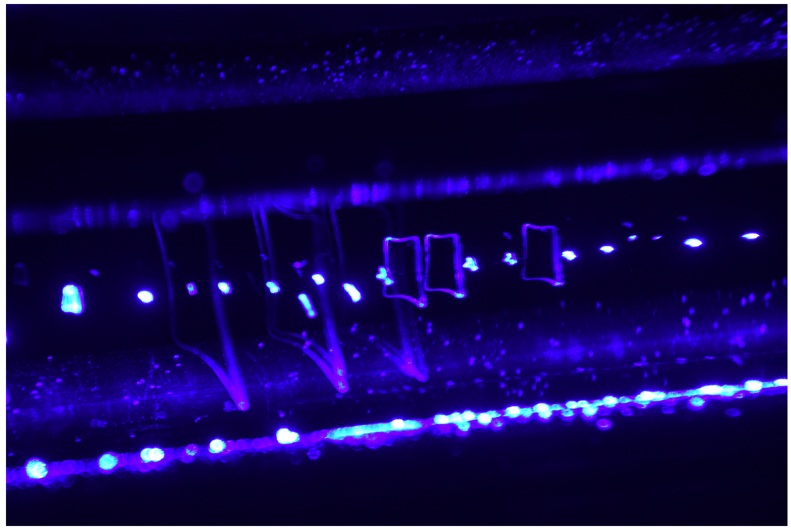


Fig. 2. Hollow glass microspheres float along square orbits in *Quantum Lattice*. (© Evelina Domnitch and Dmitry Gelfand)

The artworks that Evelina Domnitch and Dmitry Gelfand developed in their interaction with the RySQ project under the FEAT program is a particularly limpid example of what their entire opus is doing in an unprecedented and to my knowledge unparalleled way: creating a visual physical experience that touches the heart of the most fundamental aspects of quantum mechanics.

John Bell referred to this as "unspeakable” [11] : the impossibility to attribute locally objective properties to certain quantum systems before they are measured - in other words, the impossibility to speak of such properties before they are observed. The experiment by Alain Aspect [12] that confirmed that impossibility was not only a milestone of last century's science, but also the opening door for the development of quantum technologies such as those the RySQ project is currently pursuing. At the same time it literally left us wordless, in the sense that it guarantees we won't ever be able to experience an intuitive mental image of the physical process that is happening in the experiment - the so-called "objectification," by which a physical systems acquires its objective properties through measurement.

Domnitch and Gelfand's tireless pursuit of art forms avoiding symbolic communication resonates with that very same wordlessness - both in a quite deep philosophical sense and in the very immediate sense of wonder that viewers experience, irrespective of their physical knowledge, when exposed to their art. Their transcending verbal and semantic metaphors, very clearly explained in the text above and even more clearly present in the immanence of their work, hints at the boundaries inherent in the use of words and images to refer to phenomena and objects - a futile attempt when objects, like in quantum mechanics, simply do not exist locally.

For the same reason, perceiving their work can be regarded as a conceptual (non-verbal) metaphor, pointing at the process in which we observe nature, do our best to understand and describe it, manage to do that up to a certain point, but must ultimately give up our pretension to succeed completely.

Ludwig Wittgenstein wrote in the last proposition of his Tractatus: “Whereof one cannot speak, thereof one must be silent”[13]. That is probably true about objectification in quantum mechanics, and perhaps more generally in science. But while you are silent as Wittgenstein prescribes, you may still look, and see, and marvel at what you perceive. This is what Domnitch and Gelfand seem to be doing (and wanting us to do) when they create their work - and this is most certainly what we are doing when we experience it.

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