Our team

Adrian Beňo

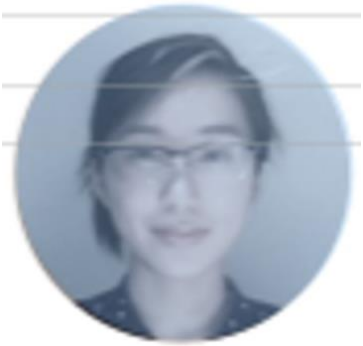
I am a second year student at TU Delft pursuing BSc in Aerospace engineering. I focused my honours research on intelligent/adaptive control. This is a broad topic that requires understanding of many domains such as flight mechanics, deep reinforcement learning and conventional control. In my studies, everything gets very technical/goes-into-detail very quickly. Thus I joined CERN HPD summer school to learn about the ability to keep a high level overview and rather focus on the importance of connecting previously unconnectable and realizing that “engineering acrobatics” is not always a solution to actual market demand. Also, I wanted to understand the functioning of an interdisciplinary team, which on one hand is crucial in bringing new points of view to the table, but at the same time one of the most difficult environments to operate in. My hobbies include playing piano (jazz) and doing sports.

Kamilla Dajani

I am a MSc Business Information Management student, specializing in Data Science, at the Rotterdam School of Management. The honours programme covers a data analytics project, robotics process automation workshop, and a machine learning case study. However, all these activities relate to a business setting, whereby technological solutions can enable more accurate data insights and efficient processes. Subsequently, The CERN HPD summer school interested me as it concerns the bridgeway of technical, scientific, and social mindsets with the motion to connect and cover all the market areas, from the product functionalities, to feasibility, and to market need. I strived to explore how a team of different backgrounds, expertise, and personalities can work together and simplify a project to a level everyone can operate on.

Wessel Garsten

I am a master chemistry student at the university of Amsterdam and the Vrije universiteit in Amsterdam. I specialize in organic chemistry and catalysis. During my study I primarily learned about how to make and analyze molecules but, the study in my option lacked a bit in designing and developing. Cause if you know how to make it but don't know what to make why bother. This was the reason I joined the HDP summer school program. I also liked the lectures that would be given about the marketing aspects of the project as this is something I have not had before. Finally to work with new technology that is not readily available and make a completely new purpose for it seems like a fun challenge and puzzle to solve.



Clio Feng

I am a second-year bachelor of computer science and engineering student at TU Delft. In my study, I focus on the data track, regarding efficiently dealing with large quantities of data, intelligently collecting data, and extracting useful patterns from the data, consisting of computational intelligence, data mining, and big data processing. Besides data science and AI, I am also interested in physics, which is the reason why CERN HPD summer school appealed to me. In addition, the innovative part of the program intrigues me as an opportunity to not only focus on what we currently know but also challenge the current technology into making new applications that could create an impact.

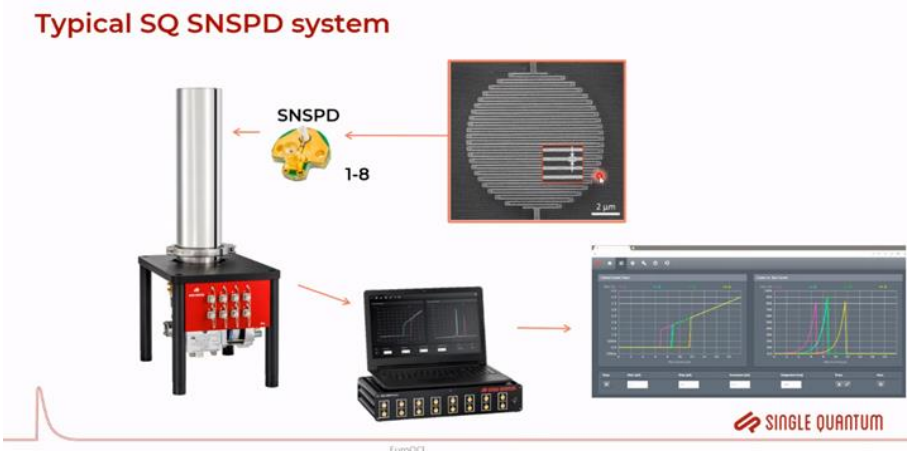
Innovation process

CERN HPD and innovation process overview

The idea behind CERN HPD summer school is to use the very advanced technologies developed in collaboration with CERN in more “mainstream” domains. By this we mean to find novel applications of highly specialized technologies, which otherwise would only be used for their original purposes. It is very important to realize that in the case of this summer school it is not important to understand all the technical details and inner workings of the technologies themselves. But rather to keep a high level understanding of the capabilities and limitations of the technology, so that novel applications do not break the laws of physics and do not belong to the pure science-fiction realm. Note that our team is multidisciplinary and includes a person without technical background, who should also be able to explain how the technology works in its principle. The level of understanding of the technical details should be at the level of ability to explain to “your 7 year old nephew”. As such, the innovation process can (and is encouraged to) yield even “science science-fiction” applications. That is applications which would require all the inner workings of the different technologies to be sorted out in the future, but their existence in the future is probable (possibly due to highly probable / coming technological advancements or future research).

First contact and technology introduction

Our innovation process thus started with an interview with experts from the company **SINGLE QUANTUM** (https://singlequantum.com), namely Dr. M. Castaneda and MSc. B. Valerio, who have very clearly communicated a high level overview of the workings of their **superconducting nanowire single photon detector (SNSPD)**. They also pinpointed the strengths and weaknesses of their product, their position on the market and competitive advantage. This is very important since the main selling points of this technology are to be exploited in new applications.



A sample image from their presentation is included above. For example, it was enough to understand from their presentation that there are some sensors that are kept very cold to

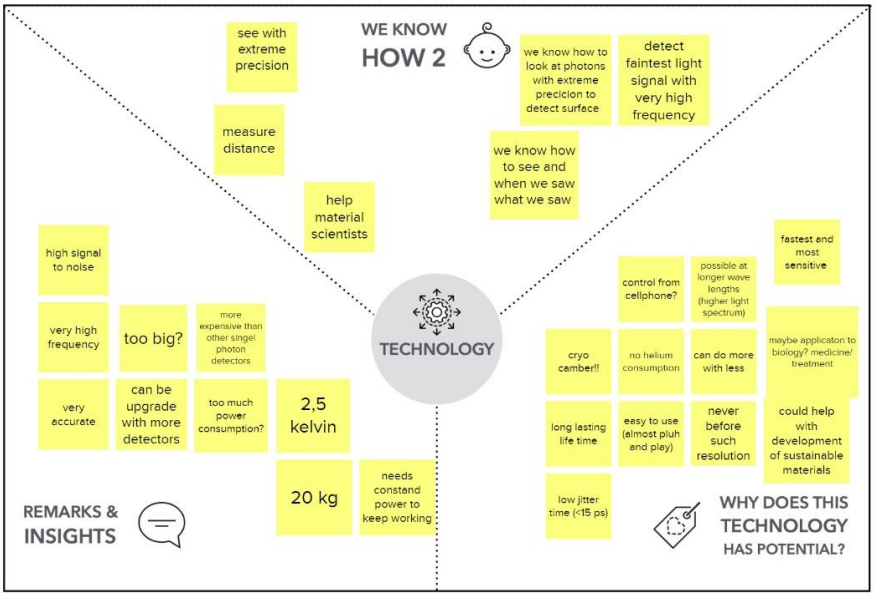
detect single photons at various wavelengths and these can be detected at high rate (measurement time of single detection is very short). The detection signal is then sent to a computer, from which data can be easily retrieved. Other important technical aspects are discussed later. The fact that the photon detectors are nanowire and superconducting and kept at cryogenic temperature of 2.5 [K] is unimportant now, as this does not bring any necessary information for the first stage of the innovation process - ideation.

Ideation process

Ideation is the stage of innovation when new ideas are born. At this stage, only superficial understanding of the technology is required and wild ideas are very welcome and encouraged. For example, seemingly unrelated fields could be brought together and joined via revolutionary vision. This would not be possible if we always thought in terms of all the technical details, which would almost always hinder any innovation. This is due to a variety of reasons, such as that the necessary connection between A and B might not be readily available, or would require further research. The most important thing to realize at this point is that we seek solutions to problems, period. No matter how wild or far fetched. It is always surprising to see that the “far fetched” ideas are usually not that unrealistic as they might sound at first. At this stage, we seek conceptual connections, birds eye view and big picture visualization. Technical details can be investigated later. The following are various stages of the ideation process undertaken by our team, milestones reached and choices made.

(1) Unbundling technology - divergent stage

We started with conceptual understanding of the technology. Firstly, we filled a canvas with remarks/insights about the technology. This is to help us create a better picture of the possible uses of the technology, so that its strengths are clear and can be readily exploited. At the same time, any “weaknesses” should also be addressed. Secondly, we filled a canvas with “Why does this technology has potential?”. This is to better understand the possible market targets. For example, one of the points is that the SNSPD is an easy to use, almost plug-and-play product. This could suggest that the product could be used on a personal level and could reach the general public at some point, rather than only research centers, as is the situation right now. Another example is low jitter time, which is currently the best on the market. This led us to exploit domains of use where high frequency is highly valuable, such as internet communication and ranging. From these two approaches, we tried to summarize our technology in a “We know how to…” sentence. This claim should be general enough so that the specifics of the technology are omitted and only the functional aspect remains. Below are a few concepts that were later iterated on.



To help with possible applications of the technology, we listed around 100 sectors to ease the process. For each sector, three sub-sectors were listed where the technology could be of use. This is shown below.

Army	position (laser pointers) (A)	protection (armor)	weapon building	Informatics \computers	Light sensors	Brightness adjustor	quantum computer (c)	Printing \publishing	paper quality	scentific dating of old book
agriculture	vegatible	pest control	sample environment (air,water) (K)	medicine \biology	drug development	genetics		Real estate	Quality check of material	security of transition
Health Care	drugs (production, quality, research)	doctors \surgeons (equipment, disease detection) (K)	air quality, water quality	Supply chain	inspect for drugs in shipment	secure transactions for trade		warehousing	parcel tracking	transition security
Public Safety	Police and crime scene investigation (forensics)	firefigting	drugs	Luxury goods	inspect the quality of clothes	watches	diamond	Entertainment	film	music
Transport	auto (self driving, parking, comfortable)	train (fast, electronics)	plane (material development)	Renewebles \emth, sustainable	recycle plant	emission detector		Automation	computerchips	sensors on robots
Manufacturing	3D printing	robotics (W)	digital twin, AI	Optics	(bio)medical imaging (K)	microscopy		Delivery	drones (navigation, collision avoidance)	ensure the transition is fair
Education	on-line / physical	primary, secondary, university	research	Sports	f1	supplements	fixing small parts	Space	telescope(W)	Satellites (navigation), clock) (A)
Fashion	textile production	cleaning of clothes	use the image generated for fashion inspiration	Law \legal system	crime scene investigation (forensics)	randomness of case allocation	evidence authentication			
Art	fraud detection (carbon 13) (W)	quality control	use to generate art for micro-world	Cosmetics	precise rescearch	plastic surgery	cosmetics production process			
Food (drinks)	Farming (soil - agriculture - animals)	food quality - assurance	taste (even chemicals)	Management	big company management	schedule creator \ keeping				
Energy	electrical (power supply, maintanance, cables...)	gas (leak check, transport, obtaining)	sun (photovoltaics)	Weather \forecast	simulation, modeling	measuring (temperature, humidity, pressure) A	magnetism, sun waves			
Chemical industry	metals, plastics	pharmacy		Telecommu-nication	network secuity	internet, 3, 4, 5G, optical cables	quantum communication			
Finance	banking (security - crypto) (c)	treding (fast - optic cables)	insurance	Gaming	hardware	internet speed	RNG			
Civil engineering	construction (equipment)	materials check - development (concrete, wood)	architecture	Electronics	Semiconductors, microchips					
Tourism /hospitality	Petrology	bank transactions for tourists	scientific analysis for Archeology and petrology (c)	Politics	security of voting	security of communication (and bugs)	security of government file			

This is the diverging stage of the converging-diverging ideation process, when very many possible solutions are generated at first, some of them being wild, so that later, during the converging stage, only the most feasible and market demanded applications can be selected. Since during the ideation process no boundaries are placed so that creativity and association based ideation can reach its full potential, games were played to aid the ideation sessions.We developed two brainstorming games ourselves. The first one utilizes small lego figures. Each figure is selected at random and has a profession. The game is to come up with as many uses of our technology for that profession.

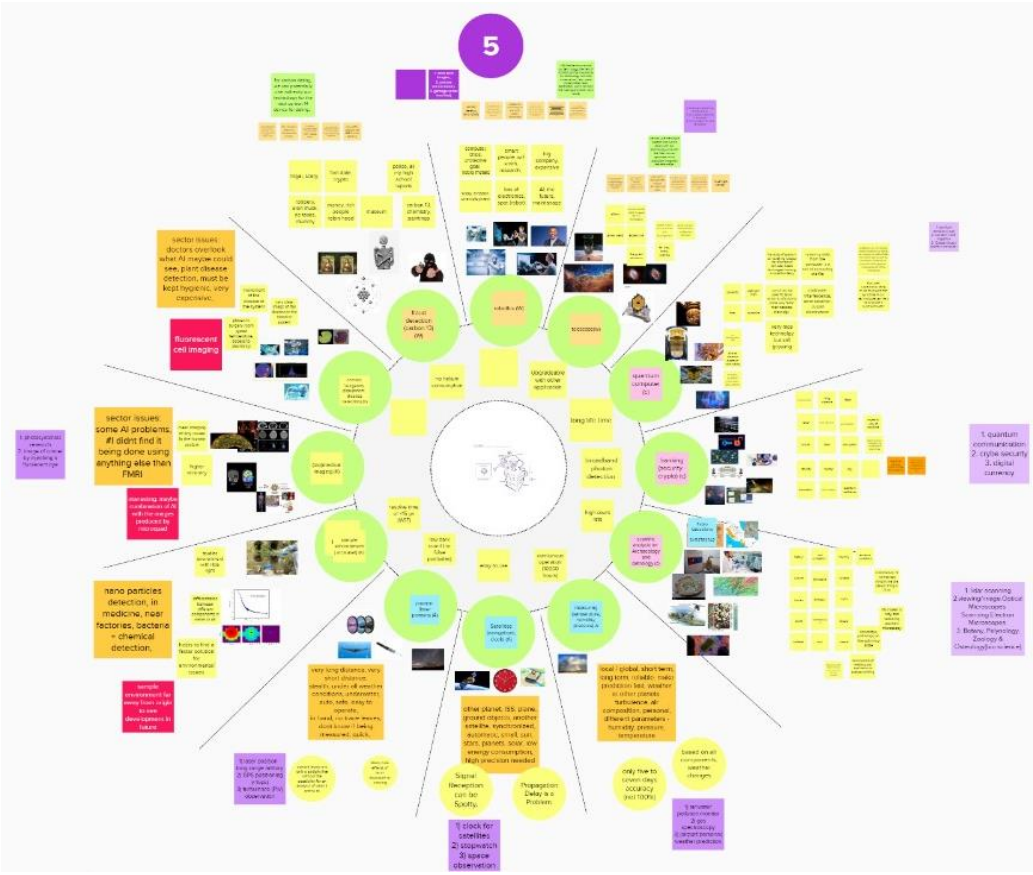
The other game involved word associations with each letter in the alphabet. The game is to come up with the meaning of the associations that were made, in the context of the technology itself.

Main takeaway

It turns out that the application we ended up choosing was thought of during the lego game. This is thanks to the multidisciplinary team where each member had different associations for the same lego figure and the best ideas followed as reactions to other member's ideas. Even though the game is simple and might sound silly at first, if you devote your thinking fully to the game and listen to others' ideas, wild concepts start to crystallize into more tangible ones. "Trusting the process" is definitely one of the main take-aways.

(2)Unbundling technology - convergent stage

During the convergent stage, feasibility of the applications becomes more important. Some applications remain in the science-fiction realm, while others sound more promising. We started with filtering out twelve most promising applications in terms of feasibility (is this even physically possible? - based selection) and market demand, see below. If there is no market for the application, then the application is useless, regardless of the advanced degree of "engineering acrobatics" involved. This is very important to realize. Many times advanced technologies never end up being the *next best thing*, only because there is no market demand for them.



Two of the most influential presentations given during the summer school were the ones about exponential thinking and ripple effect. This aided greatly in selection of the final application.

Milestones in decision making

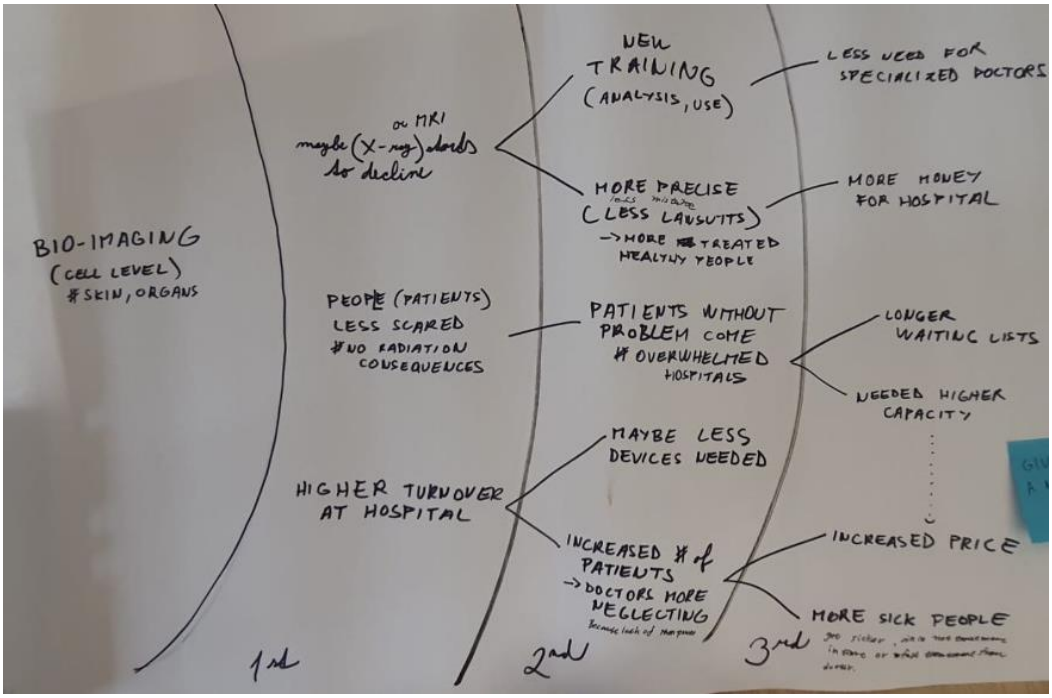
Exponential thinking

As emeritus professor of physics Albert A. Barlett famously said: “The greatest shortcoming of the human race is our inability to understand the exponential function.”. This comes very true in innovating. It almost does not matter that something is twice or three times as powerful. New technologies, at least the ones trying to introduce some sort of paradigm shift, such as tackling global warming, or introducing a new way of computing have to change the scales at exponential level. They have to introduce concepts that allow for a 10^(to the power …) level of improvement. Otherwise it is just perfecting the already existing and no innovation is being done. Novel ideas should aim at the exponent. This is one of the milestones that our selection procedure comes down to. The final application, quantum key distribution, is an idea that reaches towards the future and offers a completely new level of security. Even though the necessary technology to make it widely available is not yet there, research is being done and the necessary founding methodologies and experiments were already conducted.

Ripple effect

Another aspect of the innovation process is considering the effect that a certain application could have in the future. It is not uncommon for well-intentioned solutions to end up causing more harm somewhere else or even negatively impacting the very thing they were designed to solve. Thus it is very important to consider the possible impact of the solution in more than

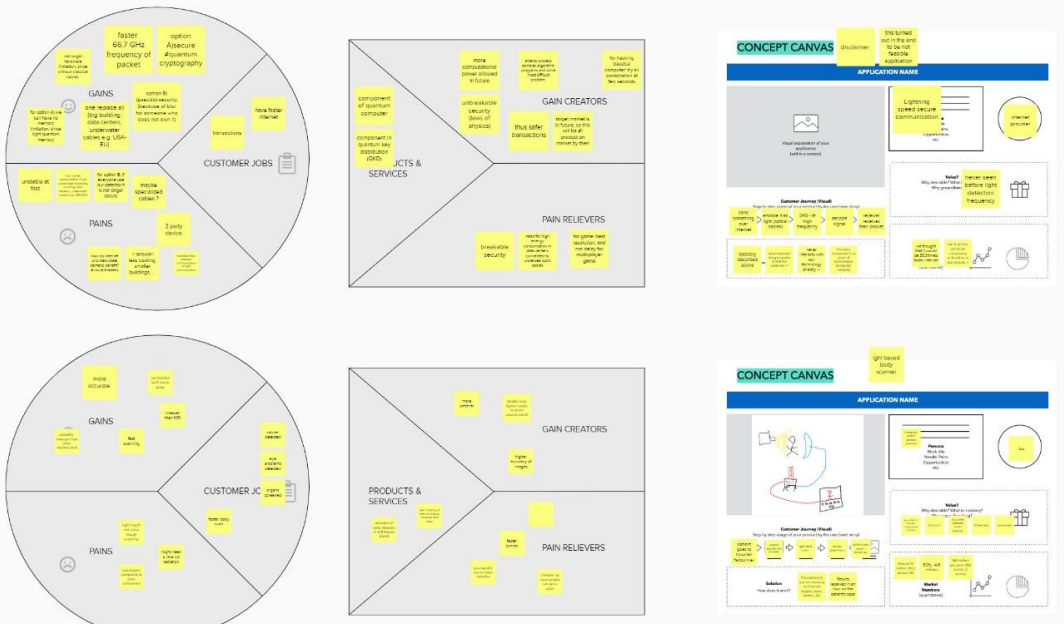
the first and obvious wave. To facilitate this, we considered a three wave ripple effect, where each wave builds on the outcomes of the previous wave, hypothetically propagating the technology's impact in time. This is not only important for the societal impact but also economical. We learned that market analysis should always include some sort of ripple effect analysis. An example of such analysis we conducted is presented below.



Final decisions and takeaways

Final selection of the application for our technology was also based on the feedback from experts representing the actual market. This includes scientific experts who confirmed or disproved some of our earlier assumptions, but also representatives from companies that would be the future customers buying our product.

One of the main outcomes of this process is that some of our technological assumptions were wrong. But wrong in a special way. We were able to get an interview with an architect of the underwater sea optical cable network who completely disproved some of our assumptions about how these networks function. It turns out that the technology that is behind these networks is more complicated (almost secret) and cannot be easily found on the internet. At the same time this experience confirmed that early communication with the market leaders is very important - never assume anything and always confirm even the most trivial of things. On the other hand, thanks to this we were able to find new applications that were better suited and feasible. This is how we confirmed that quantum key distribution is the more interesting option.



The remaining thing was to summarize and realize all the pains of the industry and how our technology relieves them. Similarly, to consider all the gains created and jobs fulfilled. This was also done using concept canvas and is shown below.

Problem definition

Following our conversations with experts, we acknowledge that we may be at the edge of the quantum revolution. The emergence of quantum computers in the next ten years can provide individuals access to unparalleled process power with endless advantages, such as hacking. Subsequently, the increasing vulnerability of cryptographic systems highlights the needs to change and improve the current situation.

Today's cybersecurity relies heavily on cryptography that offers a set of mathematically based methods for delivering essential security services. These include:

(1) Confidentiality: limiting who has access to data)
(2) Data integrity: ensuring that any unauthorized modifications to data are discovered
(3) Authentication: identifying the correct source of data).

Every day, we depend on cryptography to protect activities such as online banking, mobile calls or social media.

Cryptography is based on keys, which function similarly to physical keys. For instance, encryption is the digital equivalent of sealing data within a box. The contents of the box can only be retrieved by those who have access to the key. Key distribution with the right individuals is an issue in cryptography. There are numerous methods for distributing keys, none completely secure enough. Therefore, the main issue is that a device with great processing power, such as quantum computers, has the ability to break the code behind the key encryption, and access the data.

Solution

Technical details:

In the current quantum key distribution and quantum communication, we normally use fiber-optic cable, which we send through individual photons (particles of light). There is already the application of QKD for undersea optic cable. However, for our application, we apply it using satellites in space, which even increases security.

What makes out application more approachable to reality, with the other single-photon detector with a frequency of 66.7 Gbps, the wavelength sequence does not match the speed of the information sending and the speed the detector can receive. However, with our single quantum detector, we can detect an even higher frequency of 2 Gbps, which is 30 times faster.

Solution:

In general, we apply the concept of QKD, by using satellites to distribute quantum keys to the end users, which each will use our single quantum detector to detect the key sent from satellites.

Therefore, since the process is end-to-end users, there is no third party involved, meaning there is less chance the key will be leaked. In addition, since we are using a light signal, if any third party tries to eavesdrop on the information in the midway, they will have to measure the system. Therefore, applying one of the fundamental aspects of quantum mechanics, the process of measuring a quantum system will disturb the system in the meantime, we can detect eavesdropping. First, we use quantum entanglement and transmit information(“ the key”) in quantum states, is through light from the satellites. we set a certain threshold for the quantum system, which if the disturb is below a certain threshold, the key will be produced, otherwise, no secure key is possible and communication or transaction is aborted.

User story:

When Alice and Bob want to communicate a secret message (such as Bob’s online banking details) over an insecure channel (such as the internet).

For classical communication, there will involve a third party, and an additional communication channel to share the secret keys with Alice and Bob. However, we cannot trust the additional communication channel if someone wants to read the message.

However, for our quantum communication channel, Alice and Bob no longer need to wonder if someone tries to read Bob’s message before it gets to Alice.

In addition, since we are using satellites, we no longer care about the implementation of the cable. We can send the key across space, from earth to mars, or vice versa. Therefore, we can not only ensure secure communication on earth but also interplanetary communication.

Impact

Although our technology is still a couple years (5-7) away from the market, as the technology needed is not yet available it can be very impactful. The technology has to be coupled with satellites to be used and the quantum encryption is not yet available. With the use of the microquad (actually the single photon detector) we can use ensured that faster and safer internet can be transported.

This can be helpful for a lot of companies and branches such as: banks, government, financial institutions, IT firms (Google, Microsoft and Tesla) and space (NSA, ESA). Currently the frequency used by company like mentioned above is 2 gbps with our technology that could be 66,7 good which is an increase of about 30 times the current speed.

Big companies like Google are already thinking about moving towards systems that use Quantum Cryptography so using our technology can help move this process forward faster. So finally with our technology we can over high security with a high signal to noise ratio at a high frequency that might even be used for space communication one day.

Individual reflection

Adrian

During the course of the summer school I had the chance to learn more about myself from the feedback from others and I changed some of my opinions and views. This was the first time I worked in a truly multidisciplinary team (aerospace engineering + chemistry + computer science + business and administration). I realized that engineering students tend to easily get consumed by technical details which often demonstrates itself in very quick negative judgment towards the new wilder ideas. If we were not previously schooled to pay attention to this and try to turn off the inner (too) strict reality check, we would never come to some of the most interesting ideas we had. I was once personally asked not to judge novel ideas too quickly and I am very thankful for this feedback. This in turn allowed me to let even my own creativity flourish.

The ideation process was indeed a very enriching experience in a multidisciplinary team. To strengthen this point even more, after a conversation with CERN IdeasSquare employee Catarina Batista, she recommended the book *Range* by D. Epstein, which discusses exactly the importance of bringing different fields together, backed by research. Some of the hardest problems in many fields were solved by outsiders to those fields. And I will definitely apply a similar approach to my own honours project.

It was also very interesting to observe the team dynamics, which at times were very rough, were always resolved by conversation among the team members. I realized that the importance of communication in a team is crucial, even the smallest of things are definitely worth sharing.

Regarding the methodology used during the ideation process, I think it is more widely applicable than just for ideation process. The importance of keeping conceptual understanding and bridging ideas based on conceptual association already allows me to read papers more quickly and filter the important from the details that can be resolved later.

Apart from these more obvious aspects of the summer school, I learned about others that there is no point in being afraid to contact others just because you do not want to look “stupid”. It turns out that people are actually nice and if you approach them nicely, they are usually keen to help and explain even the most basic of concepts. One of the biggest personal take-aways from this course is thus also: never postpone talking to people and always check things with others.

Kamilla

Ideation process. In terms of team dynamics, our team at first struggled to have a mutual agreement on the roles, tasks, and brainstorming. I realized that with multidisciplinary teams, each individual can have a distinct thought and work approach. Subsequently, during brainstorm sessions, I, for instance, was thinking of new ideas which are currently not in the market and critique the potential profit and market desirability. Alternatively, other team members questioned the technical feasibility and product specifications, rather than market ones. The outcome was several contradicting perspectives on the attractiveness of an idea.

Furthermore, as we did not address the communication issue early-on, tension was built and I was demotivated to put effort and actively engage in team discussions, as we either cut-off one another, did not listen, or brushed off the effort and ideas. We later discussed the problem and reflected on what we all did not like and how we, individually, can improve. In turn, our brainstorm sessions and teamwork improved and we felt as part of a team.

Methodology. Once we agreed on the desired field, there was a knowledge gap between the technical and non-technical team members, this meant that we had to either teach one another or divide tasks. At first, we chose the latter; the outcome was a feeling of being left-out. Hence, we decided to dedicate time for all four of us to learn about the topic, ask questions, and join expert discussions together. It was really interesting to discuss our thoughts openly and question the technology and market with people who work in the communication field. This phase was a setting stone in maturing our idea.

Summary. Overall, the CERN Summer School was an eye-opening experience in terms of information gained and experience in a team. From now onwards, (1) open communication about how team members feel in the team, their expectations, and obstacles, (2) listening and acknowledging the efforts of others, and (3) reflecting on the team's progress, the positives, the negatives and next steps are all major aspects of the team, in complement to the tasks and project.

Wessel

The start: During the CERN summer school I had a change to work with People from fields know almost nothing about and visversa. With a little bit of rough start, I think mainly because not everyone could always be at the lectures in person, the team dynamic was a bit lacking. I think thats because we are mainly working on projects with People from our own field and usually think alike. The communication was not perfect and I greatly underestimated that part. In the beginning of the project I preferred to think realistic about what we could do with our technology and quick turned ideas from other teammates down because in my eyes it could not be done right now.

Redemption: after listening to the lectures and speaking with experts I came to find out that only thinking realisticly is not the goal of the summer school. And that just because an idea could not make tomorrow doesn't mean it will never be realised. That realisation together with a (heated) discussing with the group about working together and getting people involved, really got our project going through the roof. We listen to each other and came up with the weirdest/ best ideas in the last few days.

In regards of the methodology once we understood how to communicate better we quickly narrowed the choices of fields down to two. Everybody jumped into their role and together we talked to scientist at Cern and did a market analysis. It was surprising that every scientist we talked to at Cern was more than happy to help and give there opinion about our ideas and what they think we can improve.

In summary the Cern summer school was successful we made a beautiful concept together with the group. I learned a lot about teamwork, design thinking, entrepreneurship and myself.

Clio

During the summer school process, this does not feel like a regular academic course to me, but more like a bittersweet journey. I learn a lot not only from working in a multidisciplinary team but also benefit a lot from the methodology process. In addition, I feel the CERN Ideasquare creative environment really has a positive effect not only in terms of mentality but also help us to realize the solution in terms of the prototype.

Team dynamics

For the ideation process, in terms of team dynamics. The multidisciplinary aspect did bring new ideas and aspects from different sides in terms of the idea generation process.
However, the main difference between the team can be seen in the deciding process as with the different considerations presented, which sometimes could lead to conflict. To be more specific, this could be a result of each prioritizing or valuing one aspect more, which could result from different educational backgrounds, preferences, or the previous experience being totally irrelevant.
As team dynamics are not only related to background and skill but mainly to the mutual agreement on building an inclusive and respectful team working atmosphere. I learn through open and honest communication and work we can work to achieve an environment everyone is comfortable sharing ideas, feel valued, and is validated for the work they put in.

Methodology

There are several parts that I very much enjoyed and learned a lot from :

First, ask the experts to validate our idea. Conversations with experts surprisingly are where one of our best ideas originated from, and through more following-up conversations, either the idea got validated or shifted directions. I feel talking to people that know the technology the best can have more great attributes in its potential areas. For me, this is also one of my biggest takeaways — don’t afraid to approach people, and there is always inspiration coming out of it.

Second, the prototyping process is also very fun for me. The hand on experience not only helps all the team members to visualize the idea but also brings us more on the same page in understanding the more technical side of the solution. In addition, everyone is part of the process and I feel satisfied with what we make as a team.

Finally, the presentation and pitch were also very helpful in organizing and finalizing the idea.

In summary, CERN summer school was a fruitful experience for me, as I learn a great deal about team dynamics, physics, and entrepreneurship.