Opinions Libres
le blog d'Olivier Ezratty

Decode Quantum with Wilhelm Kaenders from Toptica

Welcome to the 83rd episode of Decode Quantum, the quantum podcast where we like to get in depth in quantum science and technology. I was this time with **Wilhelm Kaenders**, the president and CTO of Toptica. Fanny is not there, again, she's so busy, she's like a minister, sometimes she has meetings that she can't postpone, and so I'm alone today.

Wilhelm Kaenders is the co-founder of Toptica, because he had one other co-founder. He is now its president and CTO. The company is a worldwide leader in lasers used in mostly the academic world, but also in some parts of the industry. Wilhelm did his PhD in quantum physics at the Institute of Quantum Optics in Hanover, in the group of Dieter Meschede. He was behind the technology of the group of Theodor Hänsch at the Max Planck Institute, who became the laureate of the Nobel Prize in physics exactly 20 years ago, 2005.

He pioneered the business of tunable diode laser technology, and also contributed to the development of the technology of the optical frequency comb. He created Toptica back in 1998, which is probably one of the oldest enabling tech companies for quantum technologies.

It's now kind of large "Mittelstand" in Germany, with 600 employees in several countries, probably the largest in the domain. Its lasers are used in many quantum technologies, like for the control of cold atoms.

Wilhelm, I saw a couple of your lasers in Strasbourg just a couple of months ago in the lab of Shannon Whitlock at CESQ in Strasbourg.

You also cover other sectors like astrophysics, and you're going to explain that. The company is based around Munich, and I was lucky to visit you in October 2024. You helped me understand your business, and I visited your fab and saw your products. So once again, welcome, after this long introduction.

Usually, we start with the same question all over again. How did you land in the quantum world?

Wilhelm Kaenders: that's a very early question in my life. I was always interested in physics, or let's say, the question, why? I was starting out with being interested in theology or philosophy, and actually there were some French philosophers that interested me. You might know Teilhard de Chardin, who was an interesting personality, a Jesuit, that was trying to get the linkage between religion and physics, and I think that was something that intrigued me. And actually, a little bit later, when I decided to go for physics, it was Bernard d'Espagnat, which is another interesting person that I found, interestingly in the French environment, where some very fundamental questions were asked, which were coming up because of quantum physics. I think that was my, let's say, my personal road into this field.

Olivier Ezratty: when was that? You were a student, or you were in school?

Wilhelm Kaenders: that's while being at school and then being a student and actually getting that momentum, why quantum has intrigued me. It was the physics first, and then it was quantum, and the discussion about reality, locality, causality, all these questions, which do have an interpretation within quantum physics.

Olivier Ezratty: this is part of what we call quantum foundations, Bernard d'Espagnat is known for that. He was one of the early thought leaders, I would say, in that space. I heard a lot about him. I don't know him, but I learned a lot from him. He's mentioned in the recent book by Alain Aspect. You end up doing a PhD in quantum physics. Do you remember the title of the thesis.

Wilhelm Kaenders: The title was Imaging of Magnetic Optics, no, let's say, Magnetic Imaging of Cold Atomic Beams. So it was atom optics based on permanent magnets being used on atomic beams. So it was a little bit like the old Stern-Gerlach experiment, but a little bit more sophisticated in building not only deflection, but lenses, imaging facilities. We had what we call a slide projector, where we projected cold atoms on a virtual, on a light screen.

Imaging with an atomic beam by Wilhelm. Kaenders, Dieter Meschede et al, 1995.

Olivier Ezratty: usually when you do a PhD like this, we can always wonder what's the part of theory and what's the part of being an experimentalist. I presume there was kind of both of it, but more of an experimentalist. How did you feel doing that job?

Wilhelm Kaenders: it was an experimental role, and I had to build about 10 or 11, of the kind of lasers that I brought into the company as an entrance. So instead of using a titanium sapphire laser or a dye laser, the notion was at the time that one rather uses very dedicated diode lasers. And instead of using sodium, which was the atom of choice, people then found out that the CD compact disc wavelengths (780nm) matched ideally with rubidium. And the metro wavelengths (850nm) matched with cesium. And that was the key for these species to be at the end, to be the species for successful Bose-Einstein condensation experiments.

Olivier Ezratty: In the early years of Toptica, you were more or less connected to that business. You're going to tell that later. So before creating your company, you had a kind of early scientific career. I presume you did bump directly to creating the company. There's a couple of years in between.

Wilhelm Kaenders: there was not much between. I had a stint of research done at Imperial College in London, which actually brought me to the Hänsch Group, because that was about hydrogen spectroscopy or hydrogen cooling. That was the ultimate goal of Hänsch. I think all his life was devoted to understanding the hydrogen atom better and to preparing it for ultimate precision.

Olivier Ezratty: he was in London back then, but now he's in Munich?

Wilhelm Kaenders: No, I was in London, and at the time we had the world record on producing hydrogen alpha light. That was the key interest that he had talking to me.

Olivier Ezratty: Theodor Hänsch was in the UK, or he was in Germany back then?

Wilhelm Kaenders: he worked in Stanford first, but since the late 70s he was in Munich. Actually, a contemporary of Herbert Walther, for people who do know and remember Herbert Walther, somebody who was as important for the positioning of Munich here in the quantum world.

Olivier Ezratty: I think I passed through his office when I was in Munich last October, so that's why I remember. So, what led you to the creation of Toptica? It had a different name, by the way, when you created it.

Wilhelm Kaenders: we started in a company called TUI Laser (and then TuiOptics), which was making excimer lasers. And there the opportunity was to start. This was initially a business unit because the feeling was that these kind of lasers that I used in my experiment, that they would be needed in many other experiments globally. And I could just use my cardbox of addresses that I had from a summer school and could call these people up and say, don't you want to benefit from the technology that was developed in Munich and Hanover by these specialists?

And apparently, that was a good move. And after about two or three years, (in 1998) we took the decision to take the company independent, get myself personally financially engaged. And eventually in 2001 we turned the name into Toptica.

Olivier Ezratty: A key specific of the company is you managed to have eternal growth. You did not need to raise a lot of money as far as I understand. This is a typical story of a German company that grows progressively, accruing more products, some acquisitions, and I mean, self-sustained development. So was it on purpose or are there specific reasons for that kind of growth in the company, from the technology or the business side?

Wilhelm Kaenders: going back into the 90s, 1995, venture capital and private equity were not that well heard of and understood in the German environment. I have a very strong sense of independence, and that is something that you can only maintain if you keep your financial cap sheet clean enough that you can keep it.

Olivier Ezratty: it led you to keep good control of the company, even when it had ups and downs. It was a good way to survive difficult times, for example.

Wilhelm Kaenders: we have been lucky enough that difficult times weren't really present a lot. Of course, there's a lot of fears in between, but mostly they have resolved. You do steady planning of the future, and the future comes many times different from what you've planned, but it's always been positive enough for us to keep momentum up.

Olivier Ezratty: can you tell me the story you told me when I visited you about the stuff you did in the Compact Disk (CD) business and those potential, I would say, these potential value business that you tried to get in and which didn't succeed for whatever reason, and then you had to pivot like we do right now with a lot of startups. So you were an early adopter of the pivot technique for startups to some extent.

Wilhelm Kaenders: I guess that's what entrepreneurship is. It's all about to be flexible in your planning. Well, we have been seeing very early by a personal encounter with Shuchi Nakamura that Gallium Nitride was coming to existence as an active diode material. And that was meeting a development that we had done together with the Optical Science Center in Tucson, where there was a generic disk testing device. So, Toptica became the predominant European provider of optical disk testing equipment to test the hardware quality of a disk, whether it's new media, new materials, new writing schemes.

We were always dreaming not only about the third generation Blu-ray, but also about holographic data storage, going into the fourth generation, where we could have been using our coherent sources at the same time. But as the story was told, Blu-ray did not evolve as quickly and as successfully as the second generation technology DVD, which could repeat the success story of CD. CD mainly targeted on audio, DVD targeted on video. Blu-ray actually was missing that big driver, and it was at the same time eaten up by the bandwidth explosion that happened around 2000, when suddenly the bandwidth was there that big blockbusters like a new James Bond could be played out simultaneously in many places of the world. Beforehand, you had to have three different premieres in either North America, in Europe or in Asia, because the method to replicate information of an optical movie was just not there. Now you can play it out through the bandwidth that's available so the story didn't go further and we at some point had to sell this activity. But we had acquired a lot of very good people who knew not only the physics but also the mechanics and the electronics engineering that's involved in making optical disk drives.

Olivier Ezratty: if I understand well, the devices you did were for testing in production, it was for each CD or each Blu-ray or just for kind of randomized testing?

Wilhelm Kaenders: it was very flexible, it was reading not digitally was reading in an analog fashion any type of disk so it could be even the master typically they are printed so you have to read the metal master from which the stamps, the stamp master and we could read CD we could read DVD, we could read CD-R, we could read DVD-R, all the techniques, phase change, magnetooptical, and then Blu-ray, etc.

But we could also read imperfect disks, disks which had been scratched with the idea,even to the way that we could read copy protection in the disk, we could identify which disk was produced into which optical disk drive. At the dismay of people that might have rather hidden that circumstance in case that disk was found with them in a criminal incident.

Olivier Ezratty: so you sell this activity, when was that, 2000 something, I presume?

Wilhelm Kaenders: it was about 2005, I think. We had a customer, a key customer, who was selling quality control of optical disks as a business. And he took over the whole process, thewhole production chain.

Olivier Ezratty: I remember that 2005 was just the beginning of Blu-ray. There was this battle with HD-DVD, and then it was selected by, I would say, the market.

Wilhelm Kaenders: we were in front of the market, so we've seen that battle happening. It was the Vitterbi decoding for example. We did analyze also the error correction schemes on the disks and could do a full mapping of the signal-to-noise ratio on the disk, identify physical flaws of the disks, whether it's bent, what the signal-to-noise ratio is in different sections, or how it is after multiple usage.

Olivier Ezratty: you sell that activity, so what's left of the company? I presume there was some other stuff, other lasers?

Wilhelm Kaenders: that was always a side activity. That was about 50% maximum of what we did. And we used the gallium nitride diodes that we… entered into the field through this for spectroscopy, but also for printing. Computer-to-plate printing was one of the key features or the key interests at the time. Direct printing, not on a silver matrix, but directly into plastics. So there would be no chemical process, no photographic development process needed.

And there were multiple users of this. They weren't interested in the wavelengths to make smaller features. It was about internal drum scanners, to make faster scanners with the same, with this shorter wavelength. They could make smaller scanners and they could rotate them faster. That was the concept.

Olivier Ezratty: we are still far from the academic needs that you cover right now. Because what I know about what you do is you have a multiple set of lasers. You have two different lasers, you have multiple wavelengths. You have pulsed lasers. There are many lasers, so could you educate our audience about the kinds of lasers that are necessary for their use-use case, and particularly those who are using quantum technologies.

Wilhelm Kaenders: we have been focusing on two core technologies. One is diode lasers, and the other one is fiber lasers, because I believe that this is an advantage. because these technologies are driven by consumer markets. So it's not always easy to be a parasite of high-tech technology, but on the other hand, it drives, of course, the technology as such further. With diode lasers, we generate single-frequency operation, tunability, amplification, and then with nonlinear processes, we could cover all the spectra from 200 nanometer upwards to multiple 10 micron with different processes. And the same prospect we have seen with fiber lasers, which we started in 2003, we saw with fiber lasers, in particular ultra-fast fiber lasers. They can also initiate a lot of nonlinear processes like producing supercontinua, which are not only broad, but they're also still coherent, because they are generated from femtosecond lasers. So, the coherence, the properties of tunability, and control of coherence, spatial control, fast switching, polarization control, these are key features that we have been fostering over the years.

Olivier Ezratty: I'm very curious about how do you make a laser tunable? So, how do you control the frequency of laser, a diode or other kinds of lasers? Yeah. And the second question I have is more to the fiber or the fiber laser, how does it look like? What's the shape and form of a fiber laser.

Wilhelm Kaenders: start with the first question. To make a tunable laser, it has to have spectral gain, which is broadly available. So typically, it's more difficult to make these lasers lase at a special, at a particular frequency and keep them lasing on it. If you think about gas lasers, they have an inbuilt frequency because of the gas that is used as the gain media. In a solid disk, or even more in semiconductor lasers, lasers work in spectral bands. And the tunability is achieved basically by introducing a spectral selection mechanism that you can then tune over the spectral gain band that's available.

Olivier Ezratty: how do you control the lasers to change its frequency.

Wilhelm Kaenders: the spectral selection mechanism in our case is either an etalon, so that's a spectral filter, or it's a grating. So in our case, we work on LITTROW or LITTMAN configurations where you have a spectral selection feeding back into the laser diodet. So it's a self-injection mechanism in which, with optomechanical means, you establish and extend a larger cavity on top of the existing cavity of the semiconductor laser itself.

Olivier Ezratty: my other question was on the fiber laser. So how does it look like?

Wilhelm Kaenders: fiber lasers, why are they intriguing? The fiber itself, it's a waveguide. So you can bend it, you can do what you want with it. The light stays within the fiber unless you bend it too strong. And then you cut it into certain lengths and you put some end caps on it so it becomes a resonator, that the light can go forward and backwards. But now you need to have gain inside. And that is typically done by introducing certain doping materials into the fibe,r in addition to the original material. So when the fiber which is drawn, you implant this as a laser active media. Then you draw it into lenghts and last, you need a pump laser that you can also couple into the fiber from one of the ends. And that's it. It's a fairly simple idea when you can realize it technically. But we have been focusing on ultra-fast, which means now you have to have a certain mechanism in addition to make very short pulses.

And there are various standard tricks. You can have a modulation source inside of the fiber. And we use something that's called saturable absorber mirror, which is also a piece of semiconductor. So anything that we could bring in, semiconductors again with fibers, made that possible for us.

Olivier Ezratty: is it easier to manufacture? The diodes? Lasers? Is it more complicated?

Wilhelm Kaenders: I think it's the same dependence that we have on the raw materials. These are made in big facilities (fabs). Toptica has no fab for semiconductors. We have no drawing tower for fibers. We have to buy these in the market, which has led us to the situation that we have been acquiring a semiconductor company called Toptica Eagleyard some 15 years ago in helping us to have access to these.

Olivier Ezratty: where are the raw materials coming from? Is it coming from a weird place like in China, or is it more accessible?

Wilhelm Kaenders: China is, of course, always a good place for rare materials. The main material system that we use is gallium arsenide. You might have followed the discussion about gallium being under discussion. It is very hard to get material from China these days, harder asit was the case in the past. There is always a dependence because these are very highly purified materials, which are then deposited in an epitaxial growth process grown on wafer material.

And then laterally structured by lithography processes. It's very much like making semiconductor chips. You can make semiconductor lasers, but you need a certain transitions, PN or NP transitions to make a waveguide and get gain into the material. But this is fundamentally known since the 70s.

Olivier Ezratty: can we now make the connection between the various lasers you design and manufacture? Maybe also provide a couple words on the R&D you do within the company. You bet a lot on R&D to develop new products, and that's the way to stay competitive, particularly against other vendors and other countries like the U.S. Then I would like you to explain to me how you connect those different lasers and the kinds of experiments and the kinds of things you do in the academic world and in the industry, particularly cold atoms, trapped ions, and photonic computing. And maybe photonic-based quantum communication. So, there are a lot of use cases there, which are part of the second quantum revolution. So, where are your lasers all over the place.

Wilhelm Kaenders: when I did my PhD, the lasers were particularly suited for that application of doing laser cooling, because you must be exactly on resonance with this atom, such that it absorbs the energy. So, it absorbs the energy of the photon, but it doesn't absorb the energy of the photon alone, but also the momentum of the photon. If you do that from all sides the poor atom has no other chance in in being in a standstill in some ways or a physicist would say they acquire as an ensemble they acquire a certain temperature which is tremendously low if you do it properly. You're really going into the nano kelvin regime easily, which means the atoms only have a few centimeter per second residual velocity and if you have a collection of these cold atoms together they become quantum objects in themselves. The so-called de Broglie wavelength is inversely proportional to the velocity and that means if they are slower, they start to become larger quantum objects and they start to overlap with each other. Similar interference phenomena as we see that with water for example on a water surface, And they become a joint quantum object. That's the so-called Bose-Einstein condensation. Or similar arrangement of cold atoms where people have been starting to make artificial solid state systems by arranging them in an optical field array, which are now used, for example, as neutral atoms in a quantum computer simulation or quantum computer setting.

Alternatively, you can use the same force, of course, on ions. But they are not kept by the light fields, they are kept by electrical fields as they are charged. But the cooling and the manipulation and the quantum processing, the qubit preparation and reading are still done in these cases by laser fields. And that is sort of the link to my past. About the main market for us at Toptica today is providing these laser tools, not only for universities, for schools, but also into the emerging field of quantum computing, where we have the luxury of having that long tradition. People know us from the past, and automatically they take us in into their startups as the provider of the first laser sources.

Olivier Ezratty: It was the case when I visited one of the labs at MPQ in Munich, in Garching. I saw a couple of cold atom experiments, there was Toptica all over the place. By the way, can you explain also the different kinds of lasers we use, for example, to control cold atoms? Because you cool them with lasers, then you control them, the SLMs, the AODs that read out. We have about five to seven different lasers to control those atoms, so it's a boon for a laser company.

Wilhelm Kaenders: that is true. There are multiple versions, of course, which are based on the specific atomic element that is used, and the elements are chosen by the ease of access of certain atomic excitation levels. Typically, they take the strongest resonance, the one that the atom absorbs the easiest and has the highest energy, to absorb, to cool the atom to get that in place.

Typically, when you look into our environment, the atoms, the molecules that are around, they're about 300 meters a second fast. Now, that is a huge difficulty to catch them. But nevertheless, if you do that in a vacuum tank, have these atoms streaming into the vacuum tank, you can shine laser light on them and reduce their temperature, reduce their velocity. In a controlled fashion, that you can really keep them in very shallow traps.

Traps which are only a few degrees, a few Kelvin deep, you can keep them for a long period of time. But, of course, they still are absorbing light from the environment, blackbody radiation or others, and then you have to permanently cool them again down. Actually, not only in an ion trap, you would cool them down even into a ground state of the trap. That's a mechanical-motional ground state, which is also quantized.

And if you have done that, if they are prepared for long enough, then you can start doing a quantum operation. You can do a gate operation, but that needs another laser or a set of lasers, depending on which excitation you have chosen as a qubit. So one of these ion experiments of the most extreme case has about 10 to 12 of our lasers in place, which all have to go in sync. Now, to do a quantum operation, you have to do for a quantum operation all the different steps.

Olivier Ezratty: when are you going to grow the number of cold atoms in a quantum computer? I've seen plans with tens of thousands of them or Caltech had an experiment with 6,100 of them. I think it's one of the largest experiments so far. Will we need more powerful lasers for all the lasers that are used, or, some of the lasers will need to be more powerful than others?

Wilhelm Kaenders: that is true, and well, they don't. Power is one of the requirements , for example, to hold the atoms in place. Power determines the depth of the potential wells in which these atoms are filled. They depend, the depths depend on the power. But there are also others where you can be more subtle. For example, if you just want to fix certain "holes" in the excitation spectrum, they're always, escapeways for atoms which will then not be trapped anymore, so you can fill that with lower powers. Other light sources are needed for ionization for diagnostic purposes so they can be weaker but in general having more atoms would require higher powers and lasers. And that's why we have been active in an acquisition of a French company based in Bordeaux which helps us to get this power level up to the required level which is about a hundred Watts in some cases but at the same time this laser source has to be intensity noise reduced to an extreme level that only this company has been mastering so far.

Olivier Ezratty: it's Azur Light System, so now it's called Toptica I presume?

Wilhelm Kaenders: now it's called Toptica France, but we still kept their local identity. And the transition, I think, helps both of us because now we can combine our product offering into one offering for a potential quantum computer customer.

Olivier Ezratty: You probably know why I asked your question because as a cofounder of the Quantum Energy Initiative, I'm looking at the energetics of quantum computers. So I'm always trying to understand which are the sources of power, which grow proportionally with the number of qubits you control. But even though you explained to me that you need many lasers and the power is going to grow with the number of atoms you control, it seems to be still a reasonable (?) level. I mean, do you know how if you take the total of the 10 lasers you need, of the six to seven lasers you need to control all these atoms, what's the power right now? The total power ?

Wilhelm Kaenders: if you talk about a 100-qubit system today, we'll probably need about 120 watts of optical power, and you probably need one kilowatt of electrical power or a little bit more to produce that power if you take efficient laser sources, diodes, and fibers. If you would go for gas lasers, it would be a factor of 100 more. But– you have to utilize the light you have more efficiently, which means building cavities where you can.

So enhance the power by resonating it and recycling the power in some ways. Just don't waste it, but bring it back and reuse it by bringing it back into the experimental zone.

Olivier Ezratty: it means that if you scale the system to, let's say, 50,000 atoms, you won't scale properly. Unfortunately, the one kilowatt you mentioned, I hope so, but it's what I heard. So there are efficiencies on the way.

Wilhelm Kaenders: that's true for certain types of atomic or ion-based computing. There are others where the scaling will happen maybe in the radio frequency regime, where the laser itself will only used for fundamental cooling and controlling the atoms and holding them. But then you have other means of exposing the atoms to radiation, which could be radio frequency sources, which are less specific, much harder to focus, so there are other concerns.

Olivier Ezratty: we covered mostly the cold atom and the trapped ion systems. Are your systems also used in quantum communication and also, I would say, photonics-based computing.

Wilhelm Kaenders: they are. Not as a backbone, as I can see today, for the process itself, but for the testing requirements, our exquisite level of photonic spectral tuning is an important ingredient to specify and qualify the photonic computer components. So there we have people who like our lasers and regularly build them up for production purposes, also for experimental purposes, but I will say it's a hard time for us to see them surviving if that really becomes a reality. I think that's for photonic computing.

Olivier Ezratty: until now, most of the systems were academic systems or very small systems. If you take QuEra, PlanQC, and Pasqal, they built less than a couple of units. Those companies, they expect to build more systems, they're going to be installing data centers and so on. So I presume you have a lot of discussions with those vendors. They have new constraints, new requirements. So how is the technology dialogue is going on between the vendors and you as a company? What kind of new constraints you have to follow with building lasers that are going to be in production, not just in academic labs.

Wilhelm Kaenders: the topic, size, weight, and power, but also cost is an eternal discussion. And I can see that our lasers are a substantial part of the cost bill for these computers. You just mentioned the atom computing, the atom-based, neutral atom-based computing, but of course, there are also the ion-based ones. There's IonQ, Atom Computing, there's Quantinuum, there's Eleqtron, there's NeQxt, there's QuEra, there's Universal Quantum, There's Oxford Ionics, just to name a few. There are so many in all parts of the world. They have different concepts. Each of them is a little bit different. For us as TOPTICA, the dream is to be a commodity for all of them, something where they can just utilize the service that we can provide in a similar fashion so that we can help all of them in their specific needs.

Olivier Ezratty: is it different to have a laser in a lab, in an academic lab, and in a data center? So, are there specific constraints in that world? Oh, yeah. I don't know, the stability of temperature or whatever.

Wilhelm Kaenders: typical optical physics lab has a very well-controlled environment. It's very similar to a semiconductor fab environment. People try to control the temperature below 1°C change over the day, the humidity is controlled. There's very little pressure fluctuation. And, of course, if you want to have that level of control of a laser source, that's helpful. In a data center, I don't expect this environment.

It will hurt the lasers as well as it will hurt, of course, the optomechanics, the physics package, which in the end is the system that holds the quantum computer. So I think both worlds have to learn that these environments have much more stringent requirements. And for us, that means building lasers more compact, more integrated, and integrating also the waveguides, the delivery of the light, the modulation, the switching, everything together in a convenient fashion, maybe by fiber to the physics package where then these become active.

Olivier Ezratty: If you look at the systems from cold atoms vendors, they are still academic products. Do you see the same optical table, optical components or the either you've got the lasers, the electronics. At some point, there's going to be a kind of shrink wrapping of all of that in a tighter form factor or is it going to stay as a physics experiment on the wheels.

Wilhelm Kaenders: we started that process some five years ago in building something that we call T-RACK. And I think that we are, and I don't even only think, I think and believe we are the only company in the world who has the full wealth of optical solutions that are needed for these applications in one hand, and we can also start to integrate. We have been very early digitizing our controls so they can now be connected together in a digital fashion, to a central control station.

It could be a frequency comb combined with a wavemeter, with a high finesse cavity, with a Hertz line width, 10 lasers, each of them then being modified by electro-optic modulators, introducing side bands, acoustic optic modulators for switching. All this could be integrated into one specific arrangement, serving this particular customer. This has begun. We have customers that are requesting us to do this.

And that is, of course, a nice proposition for us for the future to build these types of hardware, supply units for customers like that, which is something that we can do easily because we have so many quantum physicists in our rows anyways. I think that we have about 50 people which are fundamentally from the QT field itself, and they are capable and knowledgeable enough to support these actors in this field.

Olivier Ezratty: you mentioned something very important at the beginning of our discussion, which is your product contains a lot of electronics. And you can see that you have full racks of electronics for controlling lasers. So in a way, you're a laser company, but also an electronics company because you design a lot of your own electronics. So what is that? I mean, what is special in there? Probably software as well. So what is more classical in electronics and software, in these products.

Wilhelm Kaenders: I think this linkage of optics and electronics has been always very close because what I would call, we are a company of the "controlled photon". Controlled means that you have, you can exercise the control of the photon in all of its degrees of freedom that it has. And for this, you need to have, exquisite electronic engineers. And that has been always the case. We love semiconductors. And we love diode lasers, semiconductors, and fibers because they have control bandwidth that allows us to exercise this control by electronic means. And that means high-end analog electronics, but then packaging this into a digital environment so that it's repeatable and addressable from the outside world in a controlled fashion.

Olivier Ezratty: can we say that the quality of electronics influences the so-called phase noise that you have in lasers, which can generate some problems, some trouble when you control your random, so it's connected to electronics.

Wilhelm Kaenders: you try to generate the laser light without these disturbances, with as little phase noise as possible. But then there are techniques where you can use reference cavities or other technologies. Techniques that you can then use to reduce. the phase noise in the relevant bands, which means basically shifting the noise into spectral bands where it doesn't harm the application.

Olivier Ezratty: your goals are to productize lasers, to address larger volume markets. You're going to increase the power, reliability, you're going to make sure that it fits into the constraints of getting outside the labs. Did I summarize it well?

Wilhelm Kaenders: yes, true, and what we are utilizing is our background in the industrial side. You mentioned the optical disc storage. We also provide lasers for life science, for microscopy usage, all diode and fiber based, but also for semiconductor testing. And there we learned the lesson of industrialization and productization, and also producing, in about 1,000 pieces per year, which is also, a skill set in its own, which I think many companies in this field still have to learn.

Olivier Ezratty: I missed one point, which I like a lot. Astrophysics. Explain to me what you do in astrophysics. It's entirely different from everything we said until now.

Wilhelm Kaenders: you would think it's different, but in some ways it's not, because it's atomic physics in the sky. We were tasked by the European Southern Observatory some 17 years ago, whether we could build a high-power narrowband laser to play with sodium atoms, which are 100 kilometers up in the sky, coming out of the depths of the universe. They trickle down on our Earth. In about 100 kilometers, they're still an atomic species, but then as they come down, they react with the atmosphere and become molecules.

And this is a layer which is stretched around the world. It's not always steady. It has winds. It has… subtleties to it but it can be used as a projection screen if you bring a high power lasers up you can have these lasers make these atoms fluoresce and the fluorescence can then be captured by these big telescopes. If you have a small spot from which the fluorescence arises it is an ideal point source. If you remember in physics an ideal point source makes plane waves if you are far away from the source and a plane wave tells you that it doesn't go through the atmosphere and has not seen turbulences. Turbulences are a problem for astronomy because they distort the images. That's why Hubble has been put in space because there are no turbulences anymore. But Hubble is limited in physical size. These big earthbound telescopes which are 30+ meters in the latest generation are under construction right now. The one that is under construction is 35-meter wide. That's the extremely large telescope (ELT) that's been built by the European Southern Observatory (ESO). They use first six and then eight of our lasers to correct atmospheric distortions by using these kind of high-power orange-colored lasers which are resonant with the sodium sky.

They filter the sodium light out, and then, by employing wavefront correction, they have a very clear view through the sky on the stars, but not only on the stars but also on space debris or other objects that are flying out there. And with these, you can also transmit high-power laser power into the sky.

Olivier Ezratty: Is it connected to what we're talking about? Is it called adaptive optics?

Wilhelm Kaenders: yes. You detect the wavefronts as they come through the turbulent skies, and then you can compensate these turbulences by adaptive optics means, which basically means that you press the receiving mirror from the bottom with very little actuators, such that the differences in optical beam paths, which is a fraction of a wavelength, can be compensated. This is an amazing technology. You can have these very big telescopes working diffraction-limited.

Olivier Ezratty: we're going to end now about the technology. We're going to talk about ecosystem things. I happen to have met you the first time at the QUIC meeting, Q-Expo. It was in June in Amsterdam last year. And so I presume if you were there, it means that you belong to the, I would say, the European quantum ecosystem, for some aspect (?). So, I mean, what's your views on the… The European quantum technologies ecosystem. Do you believe that we can count as a region?

But I can tell you a story which happened last week. I was in Boston at an MIT event, and there was one guy, Andy McAfee, bumped on me. I was in a panel with Will Oliver, and he said, has Europe any chance? So it was very hard for me. So I was trying to say, we have good companies. We have Toptica. We have BlueFors. We have, I mentioned you, and so we have scientists. We have a lot of investment in science in Europe, even more than in the U.S. There's some hope. But he said, well, small hope. So what's your view on that?

Wilhelm Kaenders: first of all, you mentioned the QuiC initiative. I've been one of the founders of it because I believe it's important that we have a voice towards the European government. That's the main point for QuiC, and we have seen a very supportive environment. So for Europe, the EC is this. That's one thing. Whether we have a chance in Europe in the long run, I think that is a different issue. We have, I think, at least the broadest well-educated group of people for this field.

I think fundamentally we are very well set. We have a long tradition, multiple decades of very well-trained people in different positions in the companies, also quite good engineering skills on top of the physical insights that you need to do, that you need to bring up for quantum physics. But, of course, we have not a financial backing in the way that U.S. companies have. If a market is evolving too fast, and that has been an experience for Toptica in the past also, when the telecom bubble was interested in tunable lasers at the time, here have been other big waves coming and going in the past, for this year, they need big money. This is not a bootstrapping arena anymore. Public funding has been helpful, but also the scale and the speed that I can see now needed to be standing at the forefront of quantum computing is very difficult to hold. In the competition with other companies, in particular, when you are stock-listed and you see the valuation of these companies, it is skyrocketing. They just produce another press release and their value doubles. With this financial power, they absorb so many smaller companies' know-how, which can fill the knowledge gaps that these bigger companies might have at the time, but they just buy into these developments. Yes, that's a big danger. We've seen that happening in multiple fields. Europe has started activities. We have been leading the world. We are the world leader in technology today, but in the end, it's the financial market that decides who wins.

Olivier Ezratty: is there another explanation? I mean, we are a fragmented market, fragmented many countries, 25 languages and so on. So, is there a way to overcome that fragmentation and to consolidate the market? So, do we need to consolidate the demand, the offer, to have larger players? What makes the U.S. successful is economies of scale, the larger companies because the market is larger. So, is it just a matter of funding or is it a matter of the structure of Europe and the way the industry is being organized.

Wilhelm Kaenders: in the first place, I think high-tech in the U.S. is driven by defense needs. So, I think that that is… It's something that is a reality, that we in Europe don't have in any other type and form. IARPA, DARPA, DOE, DOD, these are big funders of fundamental research, fundamental sciences. This we don't have. And I think particularly the small startup communities, the high-end, the deep tech community that benefits a lot from this consistent spending and funding in these arenas.

I think that deep tech in Europe still has a chance to survive, but it will not grow to the same level that is possible in the U.S. Because for this growth, there you need financial means. It's not enough to be an expert, not enough to be your local specialist. You really need to be able to capture the market before others do it. In the end, it's not about the best product. It's about being the first in the market. And that's a financial.

Olivier Ezratty: does it mean that we need European funds? We have the EIB, but that's not enough. So, EIB is the public bank. So, we need a kind of large private funding organizations.

Wilhelm Kaenders: funding is only part of the equation. We need markets. We don't need funding as such. We need big markets that need these devices. And today, I'm pretty happy with the markets as they are slow enough for European companies to hold the speed that's requested. But if the market now accelerates, then we'll see European companies dropping out.

Olivier Ezratty: you're part of the Munich ecosystem. It looks like in Germany, it's one of the largest, if not the largest, quantum ecosystem. Can you talk a little bit about how you view the Munich ecosystem in quantum, specifically? We need to be a key place in Germany, probably universities and so on. But there are probably a couple of reasons that are interesting to know.

Wilhelm Kaenders: Munich has one of the longest-lasting laser story for Germany. Siemens was one of the first companies to develop lasers. So that's a laser story. And from this, there have been a lot of different companies being founded based on this laser story. I think for this specific quantum story, it's the Max Planck Institute of Quantum Optics (MPQ), which was originally coming out of the Institute of Plasma Physics.

And the two founding fathers of this are really, and I mentioned them before, Herbert Walther and Theodor Hänsch. They have been building this into the process. The prominence that this place has, accelerating and attracting a lot of talent over the years, and being the center of the community, very similar to the place in France, around the ENS, where you also see over years an accumulation, the Laboratoire Kastler Brossel, where there's an accumulation of know-how, tradition of teaching, and a stimulation, an atmospheric stimulation of young people to go and go into some depth.

Olivier Ezratty: there's some kind of duality in Munich, because it's a bit like Paris. You have downtown Munich with LMU and so on, the universities, and you've got Garching, which is more like Saclay. There's some similarity.

Wilhelm Kaenders: and there is, of course, a very wealthy population living close to the mountains, where there is a certain entrepreneurship, a tradition of entrepreneurship. Even if these people are now… Well, many of them… come here for retirement, there is enough wealth that can be put into startups and enjoyment in seeing small companies grow.

Olivier Ezratty: Germany was one of the, if not, it was the largest country in Europe with regards to its national quantum initiative, because officially the plan is about 3 billion euros plus the regional' investments, so it's larger than France, larger than the Dutch, of course, because it's a smaller country, so how did, this plan fare so far? So, driving the academic world on one hand and driving the industry world on the other hand, are you satisfied with what happened? Did you benchmark it?

Wilhelm Kaenders: I think the equation has not been closed, the ends have not been, equated yet. We don't know what comes out in the end. There is a very strong academic tradition here in Munich in terms of laser or quantum companies. I think that that is something which is equally strong in other parts of Germany. What we do have is institutional support with Fraunhofer and DLR.

They have been investing heavily into it. We have a lot of early starters, quantum computing systems now in comparison with each other. I think they're not all strong enough to survive. So it's a starting phase. But I think that these institutions have understood that they need to invest into products by companies. In the end, we don't need funding as a company. We need investment into products. We need customers. Okay. We need people who acquire products, pressure that's associated with a product development compared to just funding. You have to deliver and you are responsible for a result. So I think that has been nice so far. Actually it also has been helping companies from the UK and from France to deliver their products into Germany. IBM has a strong position within Germany. So we have a traditionally open economical situation.

We're not only a big seller of goods, but we're also absorbing and supporting goods from other countries if we find them useful and suitable. So an open economic situation is something that suits Germany the best and it's really frightening to see how the world is changing on that. Whether it's export control for us. Or whether it's tariffs, the world is changing. And that will have an effect on this quantum nature of products. We need the world. We need the global intellectual potential of the world to make quantum a success.

Olivier Ezratty: It's a common effort.

Wilhelm Kaenders: In the early days, it was said there's only engineering left. I don't believe it. There's a lot of intellectual power that still has to go into it to make it meaningful. But it will. I'm a believer of the quantum world.

Olivier Ezratty: it's always this debate around science and engineering. Which one is more important and where are the risks or uncertainties? We maybe share that it's both ways. Not just only engineering. Yeah. Like some people say, I hear a lot that it's only engineering problem. I mean, to developers, it's a mix of everything. DLR is a very important organization in Germany because it's the branch of government which does also procurement. So it's a customer of many companies, including companies outside Germany, like you mentioned. So they play a very key role. Do you believe that it's going to be difficult, not just in Germany, but to make sure that governments have a long-term, approach with Quantum? Because that's what's needed. You're going to fold everything in five years. So do you believe it's possible to do that efficiently.

Wilhelm Kaenders: the marketing people play well. I think the government has certain fears. One fear is, of course, that part of the historic records, can be, deciphered. So that transparency, secure believed material might appear, which shows certain flaws in the past. That seems to be a big driver. But also, of course, national security defense will become a more important driver also in Europe. So in some ways, we are catching up to what the US has been enjoying in the deep tech area, that defense interests have been pushing fundamental developments.

Whether quantum is already that far today, that it becomes more than just a scientific endeavor, I doubt. I think today, defense problems are more down to the ground, more down to earth. Quantum can do something, but that's the long run. If we have another 10 years, yes, maybe. But that's not the discussion that we're having. We are having a discussion right now in Germany, how to spend the money, yes, within a very short time period.

Olivier Ezratty: so we're nearing the end of our discussion. I was with Wilhelm Kaenders, the president and CTO and cofounder of Toptica, the leading laser company, at least in the quantum world. We'll meet other CEOs and CTOs from companies throughout the world in the forthcoming episodes. Thank you, Wilhelm.

Wilhelm Kaenders: thank you for giving me the opportunity, Olivier. Pleasure.

Cet article a été publié le 28 avril 2025 et édité en PDF le 28 avril 2025.