Interview with Wilhelm Kaenders, Chief Technical Officer (CTO), Founder & President of Toptica

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What was the topic of your PhD thesis?
Coming from the scientific field of atomic physics, I defended my diploma in 1995, focused on autoionization resonances triggered by light. A group from Imperial College was collaborating with us at the University of Bonn on the synchrotron to build laser-based replacements for VUV sources. We were developing a tunable record-high power Lyman-alpha laser source taking advantage of Four Wave Mixing in phase-adjusted krypton-argon gas mixtures. This work led me into the field of lasers, and I became acquainted with Theodore Hänsch's group in Munich. The former postdoc there, Dieter Meschede, was establishing a new laboratory in Hanover for his newly gained professorship, and one of my PhD tasks was to transfer diode laser-based technology for cold atom physics and helping to build a new group there.
I worked on laser cooling, an exciting time when the first magneto-optical trap from the gas phase was invented independently in 1990 by Carl Wieman and Jean Dalibard. Specifically, I focused on chirped laser cooling, slowing down a thermal atomic beam with resonant laser light to allow for imaging atomic beams using permanent magnets. We built various magnetic field configurations (quadrupoles, hexapoles, etc.), aiming to ultimately create a "racing track" for cold atoms. Hexapoles for example can be treated nearly as “classical lenses” for atomic beams and their trajectories, allowing focusing and imaging. While pursuing these objectives, I had to build multiple diode lasers and a lab environment, replacing titanium-saphire and ring dye lasers by low-noise electronic laser diode-based alternatives. By the way, this exciting period saw hydrogen nearing Bose-Einstein condensation, but ultimately, affordable laser diodes

matching rubidium and cesium resonance lines opened new avenues. This environment spurred me to start Toptica later, initially focusing on external cavity diode lasers (ECDL) for laser cooling in scientific fields.

Toptica was initially related to fundamental science
Yes, and fundamental science remains a core part of our activities, constituting about half of our business today. We proudly show at least 14 Nobel laureates in our customer list since we started. There might be more that we do not know about whether they are using our tools or people that are still on the path of becoming "Nobel", who knows in such a vivid field.

How did you choose between pursuing a post-doc position or funding your own business?
I was applying for postdoc positions, trying to synchronize plans with my then-fiancée. However, at that time, I received an offer to start and direct a new business with a budget of DM50,000 flat and three months to be allocated between salary and equipment. After that, our work quickly garnered public funding and interest because of the features of our laser products: tuning, narrowband, and cost-effectiveness. And compared to the academic world, I enjoyed the business environment from day one, as it allows building “ownership” in a different way. Improving technology over many cycles with qualified engineers in the background allows to generate value when sold back into research.

Was the market clearly identified?
I initially worked within an existing company focused on ophthalmology lasers, which helped me discover the independence and field I enjoyed. But my interest was atomic physics and spectroscopy, while my co-founders envisioned medical applications, leading to a mismatch in our goals. After two years, we realized I was better suited to pursue my vision, leading to the foundation of Toptica as an independent entity.

When did you create this spin-off company?
In 1998. We’re now celebrating our 26th year. At the time, there was no Venture Capital interested in this field and we might have failed their ambitions. So the only opportunity was to actually use an existing framework, an umbrella and then move it out with a colleague and with significant personal financial participation.

What have been the main motivations to develop your products?
Our slogan "All wavelengths" reflects our open collaboration style with scientists, who often requested specific product adaptations. Whenever we made something, a scientist came the next

moment to require a similar product but with another given specificity. “Can you match your laser wavelength with strontium?” “Can you also match that with ytterbium?” “Or maybe barium would be better?” The company today has been evolving quite a bit since. Toptica fabricates still the broadest range of diode-based lasers, in addition to fiber lasers, but in addition, also fibre lasers in the shape of ultrafast picosecond and femtosecond lasers, and there is also a new line of CW fibre lasers. We bought a company fabricating semiconductor lasers, called Toptica Eagleyard, which now gives access to our own semiconductor packaging. Last not least, we run a world-leading subsidiary producing most powerful laser guide stars for adaptive optics for astronomy and other fields.

Is Toptica a large company today?

Yes, in total we have about 600 employees and revenues in the order of €140 million in 2024, and have enjoyed steady growth since 1998. We recently acquired the company Azur Light Systems in France for their lowest intensity noise (RIN), and to be closer to the French photonic community. We have founded subsidiaries in Japan, China, and the US, the latter developing a range of its own products while all of them are reselling locally.

How did you start addressing the sector of biophonics?

We bought a company which was in our same building called Till Photonics. This company was doing microscopy for life science, in particular fluorescence confocal microscopy. We naively thought that we could integrate our lasers into a microscope much better than all the other big companies. The microscope instrumentation field is not very large and there are not many companies in the world that can fabricate world-class microscope objectives. And they implement lasers to what we considered to be falling short to the their full potential capabilities. Today, we pursue in addition multi-photon microscopy with ultrafast fiber laser using unique modulation and fiber delivery options.

What have been the main steps in the growth of Toptica?

When we started, we aimed to complement our scientific business with industrial applications. This led us to produce optical disc testing equipment, which was a completely different and new market for us. We leveraged our optoelectronics expertise to test CDs, DVDs, and next-generation formats like Blu-ray and holographic data storage. We pursued this activity for some time, but eventually, we realized that Blu-ray would not achieve the same market success as DVD. Despite this, our production test equipment proved valuable for Sony and Microsoft, just to name a few, but more importantly, it allowed us to build an internal highly professional electronics team.

In 2011, we commercialized our first multi-color diode laser source, which delivers four colors of single-mode laser diodes combined into one single-mode pm fiber. This innovation is again used in confocal microscopy for fluorescence microscopy. This was a significant step as it marked our first industrial multi-color unit, which we produce today in several hundred units of various kinds also for OEM customers.

What have been the latest achievements in term of technology?

Today, our products are becoming increasingly powerful and integrated. In 2020, we began selling complete integrated rack systems that combine multiple of our external cavity diode lasers, femtosecond lasers, and optical frequency combs, in many cases actively frequency-locked to suitable atomic transitions or even optically phase-locked to each other or high finesse cavities allowing linewidths of 1 Hz. These integrated systems are essential for quantum computing applications. Companies working with atoms and ions in the •••

quantum computing industry rely heavily on our devices to make their quantum computers function.
Currently, in our Quantum Technology Solutions group, we are developing a highly precise atomic clock as a substitute for hydrogen masers, using a single ytterbium ion as the optical reference. This requires eight different laser sources to store the ytterbium ion and interrogate it in a quadrupole clock, then investigate and derive an optical frequency from it. In a last optical step, an optical frequency comb then connects this frequency to the current international time standard, cesium 9 GHz rf line. We are the only company in the world which can offer all the required subunits out of one hand.

TOPTICA Photonics AG Headquarters in Graefelfing near Munich / Germany

What are the main application domains that you address with your products?
In general we work in three well-identified markets: quantum technologies and spectroscopy, measurement and processing, and finally, biophotonics. Atomic physics was the first and still important target market, as today it is coined quantum technology. We also address precision interferometry, metrology, non-destructive testing in a market segment that we call "materials" and last not least, we support optical lifecell microscopy. Laser technology is a solution to many problems that do not yet know about its potential and will be explored only if the handling of the laser devices becomes easier and their costs go down. At Toptica, we like relatively small market niches that are fitting our company size and our in-depth level of expertise.

How much do you invest in research and technology?
Our R&D efforts represent between 13 to 15% of revenue annually. This effort is executed by more than 120 physicists, engineers and technicians mainly in Munich. We are proud that we have the full spectrum of engineering qualifications ready in house for our targeted markets.

When did you start working on frequency comb generation?
In 2003, we developed an independent approach to frequency combs. The Optical Frequency Comb is a significant achievement by the groups headed by Theodore W. Hänsch and John L. Hall, who were awarded the Nobel Prize in Physics in 2005 for their discovery. Their method involved stabilizing the carrier-envelope phase by working on the pump system, using an extra control loop. We pursued a different stabilization method that did not require an extra control loop. Instead, we used a scheme based on difference frequency generation, which naturally eliminates the carrier-envelope offset phase through the physics of the process.

What is the main feature of Toptica?
Our main feature is what we call "All wavelengths". The various technologies we implement into our products enable us to cover a broad range of wavelengths or energy bands. This capability is unique. I don't know of any other company that can span such a wide optical frequency band. While this breadth is advantageous, it also presents challenges: these markets are mainly niche and it's extremely difficult to scale-up technology in numbers across such a wide spectrum. Although there is competition in specific subunits of our technology, there is no company that competes with us across the full spectrum of what we offer.

Where are located your headquarters?
TOPTICA Photonics is headquartered near Munich, Germany, where our main development and manufacturing facilities are located.

Are you focusing your sales efforts in Europe or worldwide ?
The company has a global reach with a focus on laser sales for scientific and industrial applications, including dedicated teams in North America, Japan, France, UK, and China.

What are the main assets of Europe for photonics companies ?
Europe stands out as a key region for photonics companies, largely due to its advanced research ecosystem and significant investments in high-tech industries. Germany, together with other European countries are leaders in scientific research and development with world-class laboratories, academic institutions, and large-scale collaborative projects, providing an environment that fosters technological advances in laser and photonic technologies. The region's strong support for innovation in industries such as automotive, aerospace and healthcare also drives demand for photonic applications, making it an attractive market.