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Interview with Rachel Grange

Professor at ETH Zurich, expert in optical nanomaterials, nonlinear optics and integrated photonics.

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During your early years, when did science become meaningful to you?
I think back to that critical age between 12 and 15, when you are already asked to pick a high-school track. I chose Latin because I loved history and French, I read a lot. I didn't have a scientific heroine; my "heroes" were athletes, especially the Swiss-German skiers winning all the medals, and even a Swedish skier who was incredibly strong. I don't come from a scientific family, but I loved visiting my father's mechanical workshop, where he repaired trucks. That hands-on, practical side of things fascinated me. I already liked the idea of "doing" science.

How did you end up specializing in physics?
In high school there was a reinforced math and physics track, I took it. Physics was exciting but very abstract. A math teacher from high school showed us mathematics from a useful angle, such as probability, statistics, and conics, which convinced me that at EPFL, science would be concrete and useful. I chose physics more for the challenge than out of a calling. I considered moving to the German-speaking part of Switzerland, but adding a language barrier on top of the difficulty of physics felt like too much. So I chose EPFL in Lausanne, in the French-speaking region. I also liked chemistry and almost ended up there, but on the open day, after visiting the physics section, I stopped to chat at the café and never made it to chemistry!

How long was the training at EPFL?
It was still the diploma system, four and a half years. First, two propedeutic years, like an accelerated preparatory cycle; then two and a half years with more specialized courses, either theoretical or applied physics, and the diploma project. EPFL remained fairly generalist, which suited me. I took everything experimental and avoided overly abstract classes.

Where do optics and materials come in?
We often start with optics in high school, sometimes even before mechanics. At EPFL I wanted something practical, so a teaching assistant helped me get into a lab where I worked on some of the first multicore fibers, measuring their polarization. That's when optics really took hold for me, and it never left. I also hesitated about nuclear physics. The campus has a mini-reactor for lab classes, and seeing fuel rods up close is impressive. The broader energy debate convinced me we needed good physicists to avoid disasters.

How did the move to Zurich for your PhD happen?
I graduated at the end of 2001, with the formal certificate in February 2002, wanted to do a PhD, and thought learning German would help a career in Switzerland. I applied to Ursula Keller's group because I liked the topic and because she was a woman leading the lab, something I had never experienced. My PhD focused on semiconductor saturable absorber mirrors (SESAMs). I didn't grow the materials, colleagues did the epitaxy, but I handled the design, clean-room processing, and linear and nonlinear optical characterization. The group pursued record-setting lasers at telecom wavelengths and titanium-sapphire. I built and ran the setups to measure recovery time and saturation fluence for passive mode-locking, a SESAM replacing a mirror with a Bragg stack plus absorber. I started in March 2002 and defended in March 2006.

What were your expectations after your PhD defense?
I had poured so much into the lab that I needed to step back. Despite good conditions, I was burned out and had never dreamed of becoming a professor. My husband was finishing his medical specialty, and I didn't want to leave Switzerland at that time. I looked for a job in industry, but the telecom sector was in crisis, and my applications didn't pan out. I even tried the patent office. I then joined the Swiss State Secretariat for Education and Research, working a year and a half on research policy and OECD indicators. It was interesting, but I missed the lab within six months.

What brought you back to the lab?
Colleagues told me that Demetri Psaltis had moved from Caltech to EPFL as dean. I thought, "Caltech comes to me," and it seemed the perfect opportunity to work in an international group without moving to the US. That is why I joined his lab as a postdoc in nonlinear optics and microfluidics. It was a great topic after my PhD because it bridged laser-building and laser-enabled applications. We set up new labs with equipment arriving from Caltech, bought an optical table, restarted old titanium-sapphire lasers. A small team of three to four people worked very efficiently. I stayed about three years, around 2007 to 2010, and two children were born during that time. I had always received a great support from my supervisor. The • • •

research topic was a niche field but we managed to publish solid work, though not "super high-impact."

What was the next step to build on this successful position?

I applied to many positions in Europe and I got 2+2-year fellowship in Jena that had exactly the infrastructure I needed: two large optical tables, the right laser, and clean rooms, so I could invest in people. I carried out research in nonlinear nanophotonics, frequency conversion, and microfluidic integration for on-chip analysis. Our third child, my daughter, was born in 2012 in Weimar. The lab was very well equipped, and the four years went by quickly.

How did you transition to ETH Zurich?

I obtained an SNSF Professor position at ETH, a four-year, non-tenure-track appointment, hosted by Jérôme Faist. After three years, the department opened a women-only call, and three of us were hired on tenure track in 2018. I was fast-tracked, became associate professor in 2021, and full professor in August 2025.

What was your research program at ETH?

Scientifically, I remained focused on nonlinear materials and moved into thin-film lithium niobate, TFLN. Early films, homemade in Jena, would break, so I sonicated damaged chips to make nanowires and nanoparticles for nonlinear optics. Back in Zurich, in 2015, we first tried to fabricate films ourselves, and then obtained commercial films around 2016. The obvious first demo on TFLN is the electro-optic modulator based on a Bragg design to add a twist to the typical Mach-Zehnder ones. ETH's critical mass of researchers matters a lot: other labs had 100-GHz test benches with unique, very high-end setups. That ecosystem is essential for a young group to ramp up.

What are your main research lines today?

I tend to run two main axes and let good ideas in as long as they touch χ(2) nonlinear materials. That is my core and it keeps the group curious and agile rather than locked into a single track. The first track is a very applied, fabrication-intensive axis: integrated photonics on TFLN, that spans from classical electro-optic modulators to integrated quantum photonic devices with many options of technology transfer into start-ups. The second is a more fundamental axis, nonlinear nanophotonics including scattering in disordered nonlinear media, lighter on fabrication but rich in physics. ETH's base funding let us sustain both. And I have always enjoyed writing grants, it is my creative moment, building the architecture, blending ambitious and safer goals, distributing roles, setting milestones. Experimental discovery is wonderful, but the making of a research idea is also very stimulating.

How are those axes organized in practice?

Integrated photonics on χ(2) materials mainly relies on state-of-the-art nanofabrication, to achieve on-chip periodic poling and electro-optic modulation. We work with monolithic integration rather than hybridizing with other materials, at least for now. Target applications are telecom, classical and quantum optics. The platform is transparent from the visible to the mid-IR, which let us go far beyond 1.55 μm. This is all top-down in-house fabrication in our cleanrooms. I recruit PhD students who are willing to dedicate time in the cleanroom to fabricate for themselves and others. We do not keep know-how with one technician. We pass it peer to peer, from senior PhDs to newcomers, which naturally forms a 4 to 5 person subteam that handles training and handover of process flows.

Second, for the bottom-up approach, we do not synthesize nanoparticles and we have a long-running informal collaboration with a team in Italy. Those χ(2) particles allowed us to study absolute nonlinear responses in complex media, which is unusual because films and random assembly often hide geometry and volume effects. We are also working on solution processing of nonlinear materials suitable for integrated photonics, which represents a convergence of our two research areas.

How do you achieve absolute measurements in scattering media?

We wanted to control the probed volume and the structure, not just average over an uncertain film. Classical drop-cast layers suffer from coffee-ring and thickness uncertainty. We therefore built self-assembled microspheres from the particles, measured their volume by electron microscopy, and even made cross-sections to estimate filling fraction and porosity. With precise volume and geometry, we could model the signals and, demonstrate random quasi-phase matching.

I am proud that we pursued absolute nonlinear measurements under femtosecond pumping and then matched them to models we developed in-house when no one wanted to do the theory. There was skepticism from colleagues trained on bulk crystals who expected random media to wash things out. Getting the numbers right was a long, careful process, but it convinced people.

How did this expertise in nonlinear optics feed back into integrated photonics?

In integrated photonics I initially wanted to stay with electro-optics only, not frequency conversion. One PhD student kept pushing for periodic poling. I resisted, thinking there were groups with decades of head start. This PhD student convinced me eventually and we developed a poling setup. It took about three years to make the process robust. After that, conversion efficiencies were strong, CW operation became natural, and we achieved spontaneous parametric down conversion (SPDC) on-chip. In parallel we built the quantum benches, which also took two to three years to reach the level we wanted. Such a sensitive setup with low temperature detector in the near infrared allowed us to explore SPDC from III-V nanowires, whose nonlinear tensors are roughly one order of magnitude larger than $LiNbO_3$. A single nanowire a few microns long and a couple of hundred nanometers wide can already generate a high rate of entangled photons, which is conceptually very appealing.

$LiNbO_3$ remains the best suited material for frequency conversion. It is not deposited as single crystal by pulse laser deposition (PLD) or epitaxy, so we purchase TFLN wafers and then do top-down processing. $BaTiO_3$ is attractive for electro-optics and can be deposited or grown more easily, though for frequency conversion $LiNbO_3$ is clearly ahead.

You have strong expertise in $LiNbO_3$ and $BaTiO_3$, how do they compare for your projects?

$LiNbO_3$ remains the best suited material for frequency conversion. It is not deposited as single crystal by pulse laser deposition (PLD) or epitaxy, so we purchase TFLN wafers and then do top-down processing. $BaTiO_3$ is attractive for electro-optics and can be deposited or grown more easily, though for frequency conversion $LiNbO_3$ is clearly ahead. Rather than trying to beat performance records in this very competitive environment, we often differentiate our research by original design and features. For instance, we pushed Bragg modulators rather than only standard Mach-Zehnder layouts. Another recent development of those materials in my team, is their synthesis as solution processed films that can be easily nanoimprinted without the needs of complicated etching process. We just demonstrated metasurfaces and metalenses with frequency conversion and electro-optic effects.

Do you impulse collaborations with industry?

When we were temporarily unable to apply to certain European calls from Switzerland, I deliberately diversified funding with industry-funded PhDs, always under conditions that protect the student's ability to publish, speak at conferences and finish a thesis. A good illustration of this partnership starts when a start-up wanted a compact, no-moving-parts spectrometer for space payloads, since bulk optical spectrometers are heavy. We developed an electro-optic on-chip broadband spectrometer. The original idea was theirs, but we did the full device and characterization.

After the ETH News website offered us a space to highlight our research, on nonlinear metasurfaces, several companies reached out. One possible collaboration is related to solar energy where metasurfaces could concentrate light onto small, very efficient cells to power small devices.

How do you position your group in the quantum optics landscape?

We build enabling technology for quantum sciences. Miniaturization is the challenge: integrated sources from nonlinear media for entangled-photon generation, combined with superconducting detectors, with demanding high-speed and cryogenics performances. I do not believe there will be a single winning platform. Silicon, $LiNbO_3$, $BaTiO_3$, III-V each have a their advantages. Some companies are raising hundreds of millions round of financing. We will not compete on scale and record performance. Nevertheless, we may contribute original designs, clean proofs of concept, and robust building blocks.

How do you handle tech transfer and spin-offs from the lab?

I try to support young founders from my team by providing the infrastructure they need to incubate deeptech projects for one to two years, helping to remove pressure from them. If their first attempt doesn't succeed, they can pivot to something new and still benefit from the knowledge and experience they have gained. We currently have three startups in motion, including Versics, founded in 2022, which develops telecom modulators in the 60 to 110 GHz range. I am a co-founder, but I focus on scientific support and infrastructure. I leave business execution to those who want to live it every day.