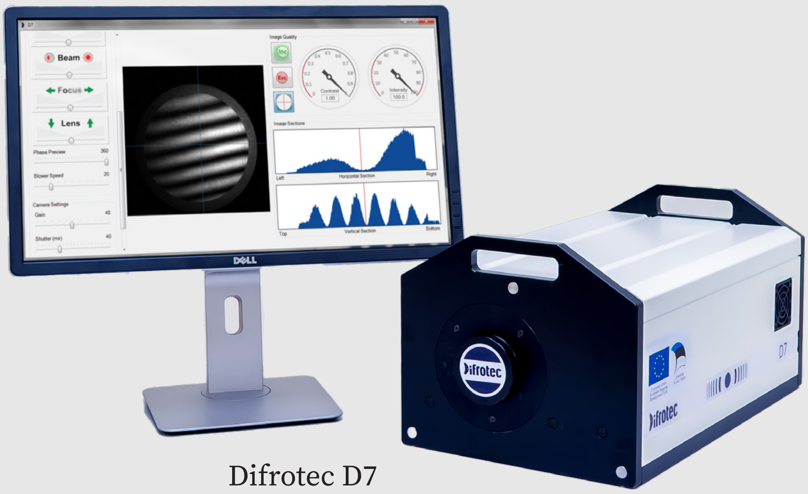
An intrview with Mariia Voznesenskaia

Difrotec

It has been my pleasure to interview Mariia Voznesenskiaia, CEO of Difrotec, located in Tartu, Estonia, to learn more about the origin of the company and the development of their D7 point diffraction interferometer.

About Difrotec
We have over 30 years of experience in mathematical modeling of optical systems and optical image processing, development of computer models of assembly, adjustment and testing of high precision optical systems for DUV and EUV lithography, and over eight years' investigation of point diffraction wavefronts applied to testing optics with a wide range of parameters.

Interview by Christopher Penniman
May 19, 2022



Difrotec D7
Point Diffraction Interferometer

Can you talk about the origin of Difrotec and how the company was started?

To talk about the origin of Difrotec, I need to start with my father, Professor Nikolay Voznesenskiy and how he came to develop the concept for our interferometer. My father received his education from ITMO University in St. Petersburg, specializing in optics and fine mechanics. In the mid-90s, he worked with Carl Zeiss in Germany, LG in Korea, and some companies in the US and other countries. During this time, he presented his scientific research and practical works at exhibitions and conferences organized by SPIE and OSA. It was here that he received feedback from the market that there was a need for a new type of high-accuracy surface measurement equipment. Optics manufacturing techniques were developing rapidly, and old methods were not good enough to meet the tight specifications of modern optics.

As you know, opticians say, "You cannot manufacture what you cannot measure," meaning that you cannot guarantee what you make without adequate testing and quality control.

In the world of optics manufacturing, typically, Fizeau interferometers are used for measuring the surface figure of polished and coated optics. My father worked extensively with this type of interferometer during his time at ITMO university and knew all the advantages and disadvantages of this measurement technique. Based on this, he decided to apply another principle that was originally introduced in the 1930s, the point diffraction interferometer. However, without a laser, the realization of this new principle, even in a laboratory setting, was not possible. After the discovery of the laser, at least some scientific realizations were possible for point diffraction interferometry, however, from an industrial application perspective, it was still not practical, and that is why Nikolay chose to start working with it. From the beginning, he received positive feedback on this idea, and all the companies he worked with stated that if a point diffraction interferometer could be developed into a stable piece of measurement equipment, it would be highly beneficial to the advancement of optics.

In 2002, we moved to Estonia and established a company which was the predecessor to Difrotec, and we worked with Belarusian and Estonian partners to develop our first prototype. At this time, there were mainly only Zygo interferometers in the market, and at least, in the beginning, the idea was not to be a direct competitor to them but to offer an alternative technology, to develop a new product based on the point diffraction measurement principle. Later, when Estonia joined the European Union in 2004, the registration rules for Estonian companies were adapted to EU registration rules, and there was a lot of help available for startup companies, so we decided to start again with a new company in 2009 called VTT-NTM. We received a lot of help and support from the EU, Estonia, and a number of mentors, accelerators, and business advisors.

They all suggested that we change the name of the company because no one could understand what VTT-NTM meant. Also, there is a scientific centre in Finland called VTT, so in the end, we decided to change the name. After some brainstorming, Nikolay came up with Difrotex; however, in the end, we decided to change “x” into “c”, and Difrotec officially became a new name of the company in 2015.

The original motivation for starting the company was based on your father’s experience in the industry and the feedback he received on his ideas on what could be improved from an interferometry standpoint.

Yes, exactly, there was a real need for measurement equipment that could overcome the limits of traditional interferometers. When my father worked on his doctoral thesis on diffraction elements, which are used in the telecommunications market, he discovered special diffraction effects from small features on thin metal and glass plates, and these findings were used in his later work.

Are there any other companies working on the same technology as the D7?

As of today, there are no other point diffraction interferometers on the market that can be compared with the D7 in terms of its real-world usability for a range of applications. I only know of one company that can produce a point diffraction interferometer; this is Institute for Physics of Microstructures in Nizhny Novgorod, Russian Academy of Science, we worked with them a little in the past, but their version has sufficient limitations and is not usable in an industrial setting.

What were the most significant challenges in developing the D7?

It's hard to say what was the biggest challenge, but if we take them in chronological order, the first one was learning how to use optical fibres; at that time, it was not clear how to apply them in the interferometer. In the beginning, the interferometer was not very stable, and we had to keep it covered while in use, so this air convection influence was significant. Implementing the optical fibres to transport the laser light drastically reduced air convection influence inside the interferometer; even if we take off the cover, there is no disturbance at all. As we made the interferometer more stable and reliable, we could even withdraw from the fibres; however, we did not because fibres also make it much easier to focus the light. We have two beams inside interferometer, and putting them into the fibres, separating them and making them independent from each other was one of the greatest achievements that we had.

Another challenge was the pinhole; this is the crucial element in the interferometer. There is a thin glass plate with a metal coating, and there is a small hole in the coating, which is about one wavelength size; it can be different, depending on the requirements of the measured optics and the field of view that the customer orders. It is a very small hole of the correct round shape that was a big challenge to make. The first step was to develop the coating process; depositing metal on a thin glass plate is a big problem, and the coating needs to be very smooth without any holes or bubbles. The combination of the metallic layer thickness and how it is deposited on the glass plate affects the surface quality and optimising both is the key to having a perfect pinhole. During the development process, we tried different metals and a lot of deposition processes, seeking support from our partners in the US and Germany. Finally, we found the right technology, and this process is our trade secret.

The second step is making the pinhole itself because it should be perfectly circular; the shape of the pinhole is critically important in our measurement technique. If you have seen our patent or scientific papers, the pinhole is inclined at a 45-degree angle and the light goes through directly. This entrance angle eliminates parasitic or stray light that can come through the coating or reflect from the pinhole's walls.

The last challenge was to make the interferometer stable and not sensitive to vibration or environmental conditions. To support this goal, we spent considerable time developing the internal mechanics, choosing the best materials and selecting the right phase-shifting unit. Phase-shifting is a principal unit inside the interferometer and is vital to the stability and accuracy of the measurement results; if the phase-shifting does not work well, you will have no repeatability or accuracy. To give you an idea of how stable our systems are, the interferometer we had in our lab has been here since 2015 and presented at several exhibitions around the world, and it always functions perfectly. After transportation, it takes ~15-20 minutes to get everything aligned and up and running, so the stability of mechanics inside was a significant challenge we needed to solve.

It would seem the biggest challenges that you faced, turned into the biggest advantages of the product.

Yes, they turned into advantages, and the principle itself is the main advantage. Traditional Fizeau interferometers use reference optics to compare the optic being measured with the reference optic. Reference optics are usually costly and must be fitted by size and aperture. They also must be meticulously maintained to keep the quality because the surface must not change, but it changes on a very small level.

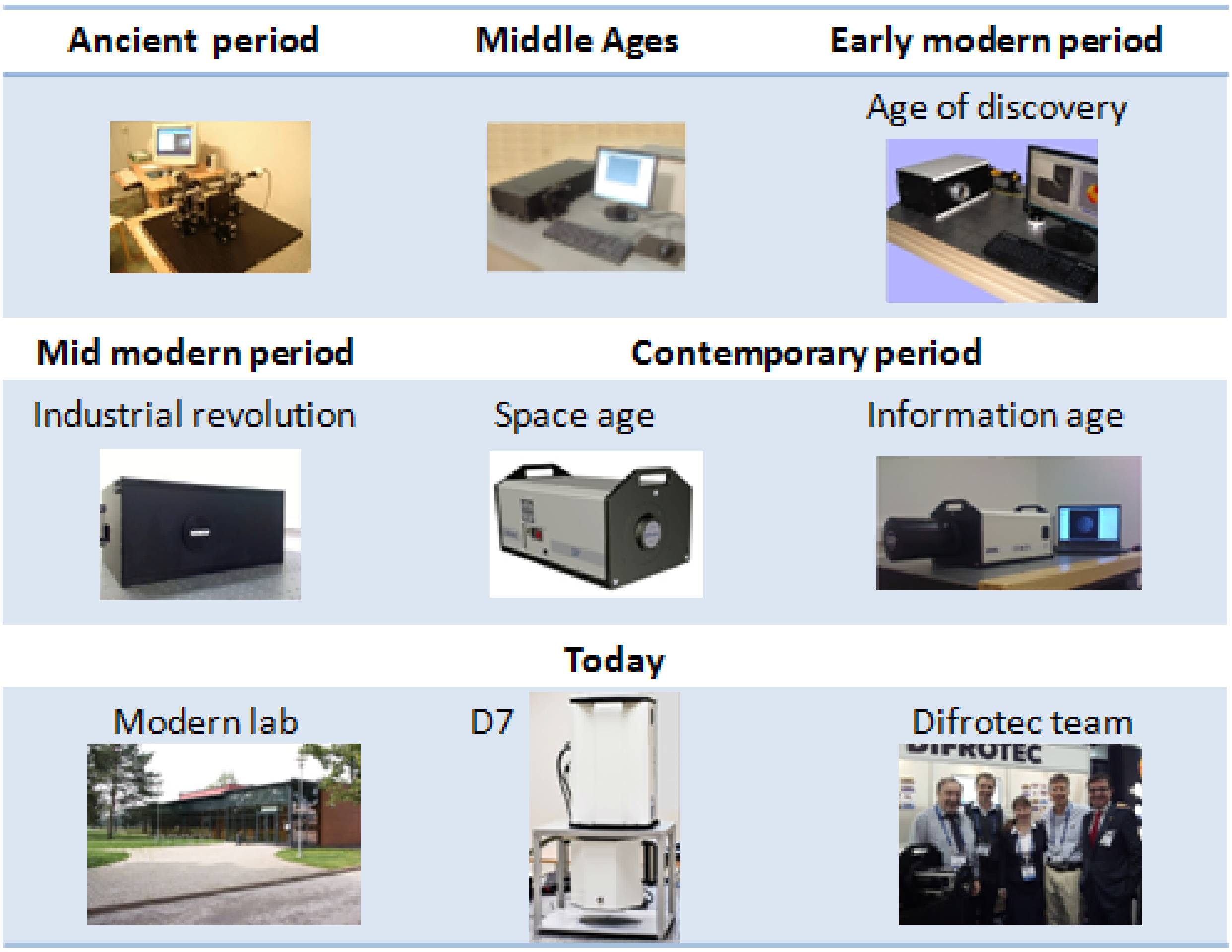
Nobody knows what the reference optic's true surface is because there is no comparison or a better reference optic to compare it to. So, these references can sometimes be a huge headache for the user because they are so expensive, and the prices can even be higher than the interferometer itself. It is not only the metrology limitation but also the economic limitation due to dependence on reference optics. Our principle of point diffraction helps to get rid of those reference optics because the reference is inside; it is a perfect spherical wavefront diffracted from the pinhole. Our interferometer incorporates two very nice, very interesting principles of light and optics: interference and diffraction. The diffracted wavefront does not need any additional reference or any additional maintenance, it always gives the same result and is very stable.

Additionally, the D7 can measure more than one wavelength; this means both single-wavelength interferometry and two-wavelength interferometry while solving the ambiguities in the measurement of the integer number of wavelengths.

By comparing the measurement results for the different wavelengths, we can determine the heights of steps or depths of trenches with very high accuracy. This capability is ideal for applications such as testing wafer topography in the semiconductor industry, measuring diffraction optical elements, computer-generated holograms and many others.

Its pretty fair to say the company has come a long way over the past twenty years.

Yes, absolutely; a few years ago, we made a timeline of Difrotec technology history with the same periods as human history. This picture shows the story of Difrotec's developments and accomplishments until 2016.



Does the D7 also require any accessories?

We do have accessories, but in comparison to Fizeau, our accessories are not used as reference optics. Our accessories work like collimators, they convert the convex spherical wavefront coming out of the interferometer into a flat or concave wavefront, and that is all they do, nothing else. So, that we can measure concave surfaces directly, without any accessories. Another advantage of our interferometer is that the influence of the accessories can be excluded from the measurement result. For Fizeau interferometers, the influence of the reference optic cannot be excluded; however, in our system, we can remove 99%, which is implemented in our software.

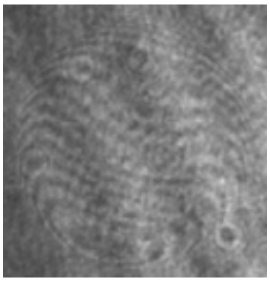
This makes our accessories more universal and cheaper, and it doesn't influence the measurement result. If you use Fizeau interferometer with reference optics, then basically what you have in the end is that the surface being measured is covered or hidden behind the reference optics, and you cannot separate these two surfaces. In our interferometer, what we have at the end, the result, is only the surface, with only small micro-influences from the accessory optics, but they are not important to the overall result and have an insignificant impact on the quality of the measurement.

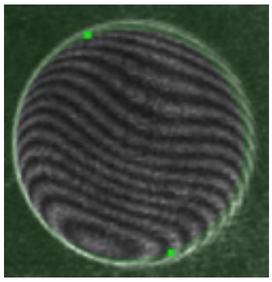
Does focusing on the pure surface of optics allow you to see a higher level of detail?

Yes, and this is especially important for high-accuracy optics for semiconductor lithography and space applications. For example, if you know the real surface of the optic after manufacturing, you can compensate for any deviations when you assemble the optical system and increase the system's overall performance. Another area where this is important is the measurement of aspheric and free-form optics; this is a big headache, especially with a high level of aspheric departure. Optics with surfaces that reflect and interfere with each other making it hard to distinguish one from another. No interferometers, including ours, can take the whole surface at once. It's here that our interferometer has a considerable advantage over other interferometers because we have those two fibres, with two independent beams, which allows us to separate one surface from another, and we can regulate the contrast to improve the measurement.

We recently finished a project for the European Space Agency, where we had to measure the AR (anti-reflection) coated surface of the optics installed in the optical system. When all those complicated optics are already inside the assembled telescope, no traditional interferometer can detect each surface separately. This is not a problem for our interferometer; we can detect a signal from each surface and make an interferogram with good contrast. This is achieved through our automatic contrast regulation based on the independent control of the two beams inside the interferometer, allowing us to see the optical surface even for optics with very low reflection. Thanks to this technology, we can improve the contrast of the interferogram.

Automatic Contrast Regulation (Before/After)





The difference is amazing; when you first catch the signal from the surface, you see something like grey mist and nothing other than the image noise. However, after regulating the contrast, which only takes one or two seconds, you can see an interferogram with high contrast of the target surface. This information about each surface inside makes it possible to compensate for surface defects and improve the system's quality.

What would you regard as the most significant achievement of Difrotec at this stage of the company?

I think it is the technology itself; we have developed a stable and reliable system with the highest accuracy and repeatability of any interferometer on the market. Also, our system can work in a range of different environmental conditions that other interferometers cannot. Of course, if the environment is damaging to the system, the lifetime of the interferometer will be shorter than the typical range of 20 – 30 years.

From the business side, we have had a number of challenges to overcome, such as limited visibility in the market, long-established legacy suppliers and perceived limited demand for our product. However, having undergone this long journey, we realize now that the market is actually quite large and trying different strategies to cover potential opportunities is an ongoing challenge.

Additionally, learning what to present and how to present this technology to investors was not easy; when you talk to investors, they do not understand the technology and why people need it. Local investors are more knowledgeable about software companies and do not understand hardware companies like us. Especially in Estonia, we are known for IT-related business, and there are many IT startups here. Fortunately, we have established strong investment from partners that understand what we do and what solutions we offer to the market.

Where do you see Difrotec going from here?

Our goal is to be recognised as a world-class interferometer manufacturer and for our D7 to be associated with high-accuracy measurements and high quality. We want to create new standards in interferometry and precise optical testing. Currently, we are broadening our network and strengthening our brand visibility while looking for new partners and exploring options for how to enter new markets in Asia and Europe.

Difrotec OÜ

Teaduspargi 13,
50411 Tartu, Estonia

+372 590 16617
difrotec@difrotec.com

Interview Series: 2022-2