NET – THE NEW EDGING TECHNOLOGY

During the last years basic research has been carried out to analyze the possibilities to optimize the finishing process by using new technologies. Especially the potential of additive manufacturing technologies has been investigated. It has been demonstrated that glazing by using a hybrid manufacturing technology ('New edging technology') is feasible and offers a number of significant advantages. One of the important benefits is a perfect fitting quality combined with very high process reliability. Furthermore it has to be ideal for industrial and remote edging even under difficult circumstances. This article gives an overview regarding the technology, its benefits and future prospects.

By Jörg Luderich and Christian Pöpperl

LOOKING FOR THE PERFECT FIT

The basic goal of the finishing process is to achieve a perfect geometrical match between two parts - the edge of the lens and the rim of the frame. A process comparable to the physical coupling of two mechanical parts but with additional requirements regarding aesthetics and optical functionality.

A perfect fit can be defined by:

- a precisely centered lens (position, axes),
- no visible frame deformation,
- no loose fit, no movement of the lens under load (axes),
- low physical tension inside the lens,
- optimal cosmetics regarding the visible edge thickness and the visibility of the bevel.

Although modern precision equipment (edger, tracer, centering device) is available from different sources it is still a challenge to realize a perfect fit. Cost aspects (e.g. can you effort to trace every frame?) and basic problems (e.g. low quality frames, interaction of the bevel profiles of lens and frame, tool wear,…) are limiting the economically achievable finishing quality, see figure 1.

Especially when it comes to remote edging jobs from different selling points with different frame tracers a significant effort is needed to compensate for the different deviations of every single unit. If the fitting is not perfect the whole system crashes and - even worse - a delay in the eyeglass delivery may effect the final customer. In other words:

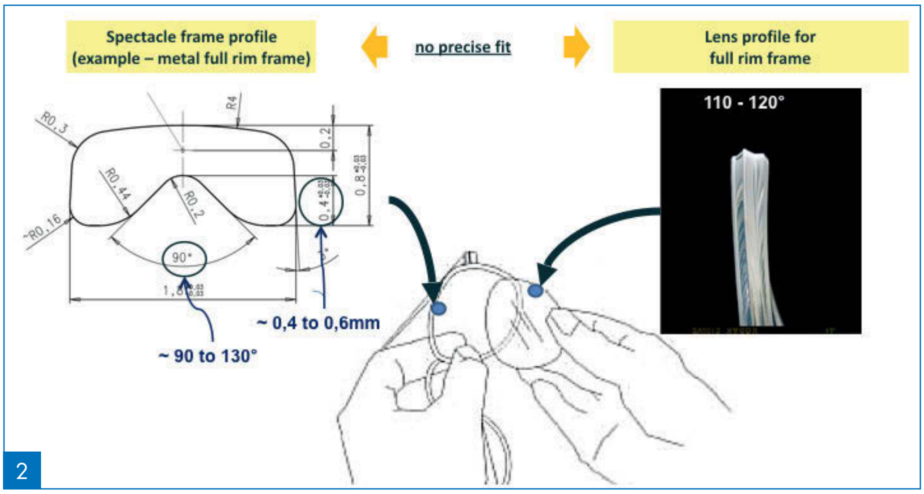
A perfect fit realized with a high process reliability – '100% first-time-fit' – under industrial conditions is essential to earn the full benefits of the remote edging idea.

To achieve this goal we first should have a look at the state of the art which has been achieved so far. It is obviously that edging technology has undergone tremendous changes and improvements during the last decade. Quality of edgers has never been better and a variety of bevel types can be manufactured with relative ease. At the other hand some basic drawbacks are still the same (see figure 2).

One of the most important issues is the quality of the frame data available to the edger. Subjects as the importance of the '3D-circumference' and the modification of the lens shape to adjust for different curves

1

A non-optimal fit between the lens and frame becomes visible by tension optics.



2

By using form tools with specific groove dimensions bevel geometries are created which fit more or less to the rim of the frame.

are well known. Taking the 3D-circumference into account improves the fit rate significantly but is not enough if you want to achieve a '100%-first-time-fit'. The next step would be to get more information regarding the geometry of the frame groove and the inclination of the rim. Is it a triangle or has it a rounded shape? What angle or radius has the groove? How deep is it? What inclination at which location? – Information not available from state of the art tracers.

A new tracer generation with the ability to measure these parameters would be a possible solution. But as soon as this information would be available the next limitation will show up. Today we produce all bevels with a limited number of geometries depending on the number of tools available; depending on the philosophy of the machine manufacturer approx. 110 to 120° for a standard V-bevel. But what to do if the triangle groove in the frame has a 90° angle and a depth of 0.4mm not matching your 110°/ 0.6mm tool? Machining the bevel profile by means of a NC milling process might be an answer – increasing cycle time and production cost.

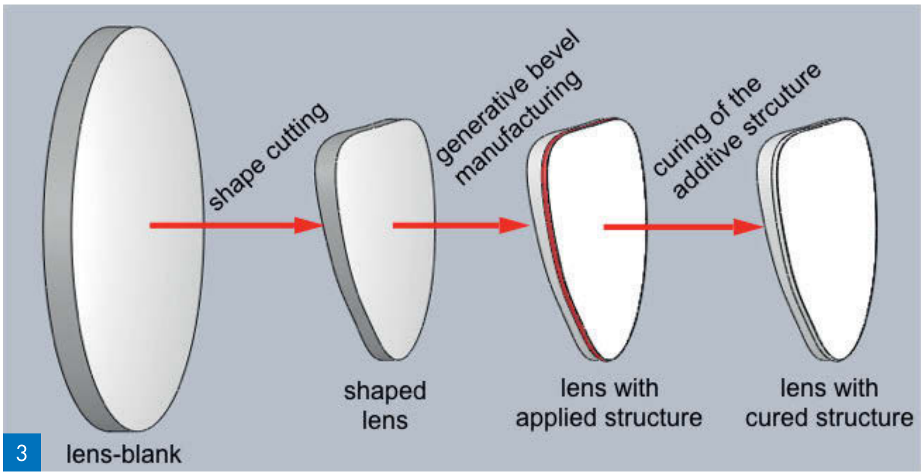
Despite the great progress in recent years, there are fundamental limitations that cannot be overcome with today's technology.

Just looking at these few points it became obvious that the attempt to create a perfect fit using the available technology will lead to more complex and more expensive solutions; a good reason to review other technologies regarding their potential relating to finishing.

THE IDEA

Giving ourselves the freedom to rethink the existing finishing technology in principle the two following points became clear early:

- The spectacle lens is optimized with regard to its optical properties. It is not intended to compensate geometrical tolerances for the mount, is often brittle and not very elastic. From a mechanical point of view, today's lens materials are certainly not the optimal solution for a mechanical connection.
- Modern edgers and tracers work in the µm precision range to achieve a good fit between lens and frame. For the centering of the glass in front of the eye, however, some 0.1mm are sure enough.



3 Edging process using hybride production technology

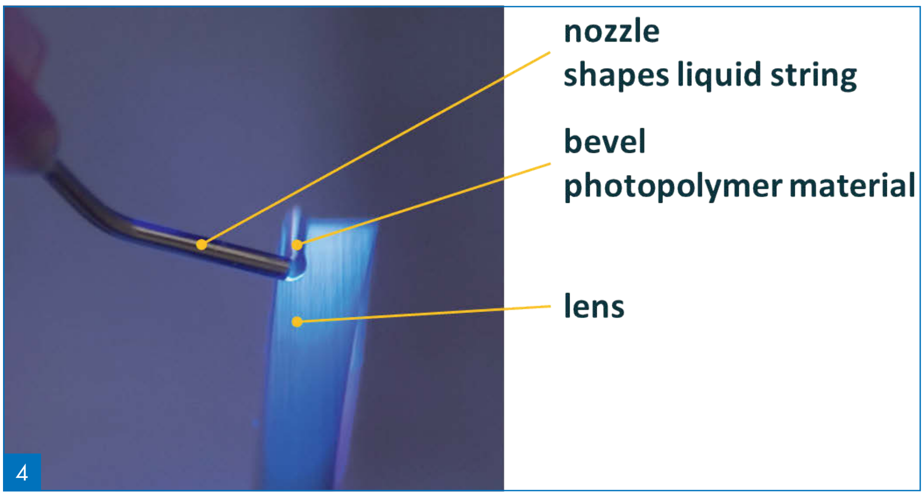
Obviously both issues can be improved by using an additional element in between lens and frame. An element with optimal material properties regarding its mechanical function and with the ability to compensate with its elasticity tolerances of the tracing and edging process. Building up the additional element by using something comparable to 3D printing technologies would allow creating almost any kind of bevel without limitations by tool geometry.

The basic idea was born. Printing an elastic bevel at the edge of a lens would open up completely new perspectives. The bevel could largely adjust itself to the groove of the rim. It would be by far precise enough regarding the optical centering but would compensate tolerances of the tracing process. Remote edging jobs from different selling points with different frame tracers would be no longer an issue.

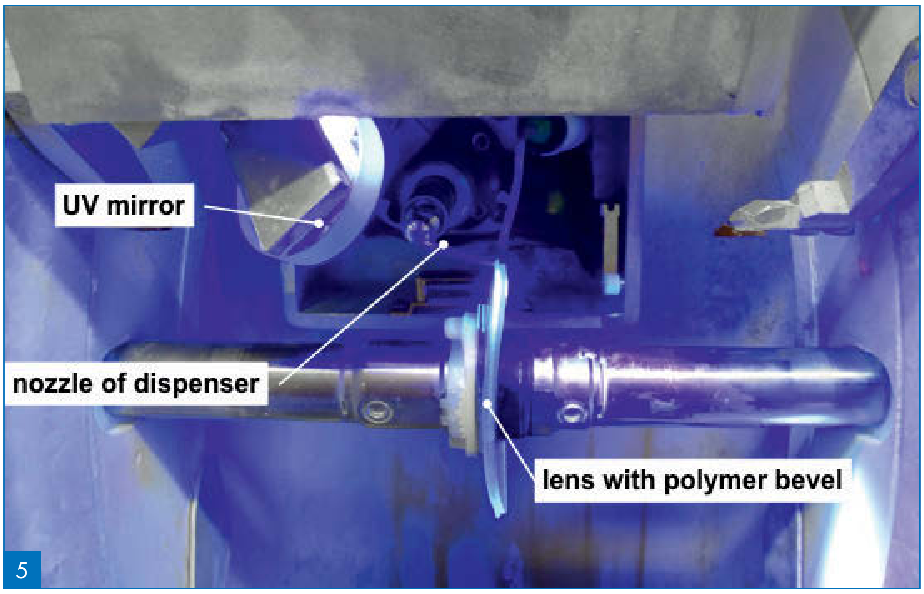
The process itself has been designed as a hybrid production process combining a classical machining process and a generative manufacturing process. Figure 3 shows the principle.

The new edging process consists out of two major steps. In the first step the lens is shaped out of the lens blank – in principle comparable to state of the art edging. What makes a big difference is the fact that this process is not limited to milling or grinding processes. For standard flat or V-bevels alternative 2D cutting methods like laser- or waterjet-cutting might be used in the future to increase productivity and to avoid tool wear.

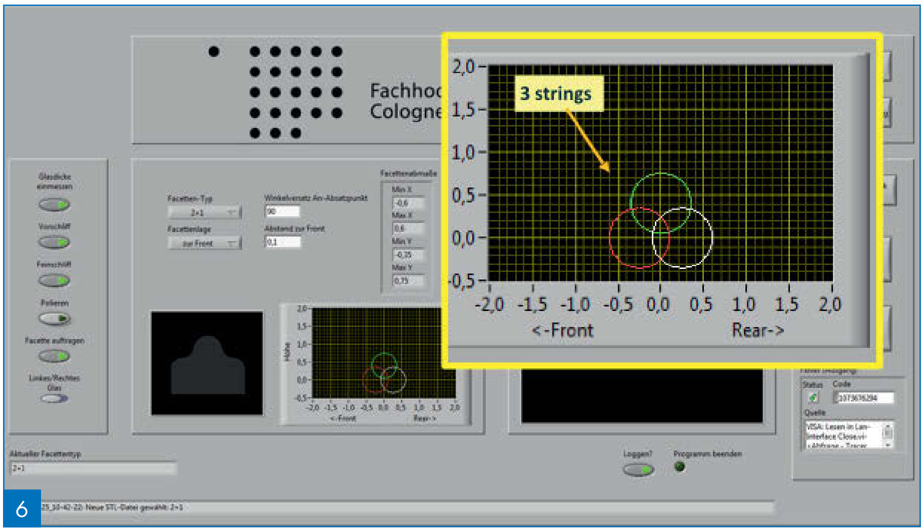
During the second step the bevel is produced by a 3D printing process. In figure 3 the use of a bevel out of a UV curable photopolymer is shown. Based on a digital model the bevel is build up out of single drops or small strings of material. Figure 4 shows the printing of a string.



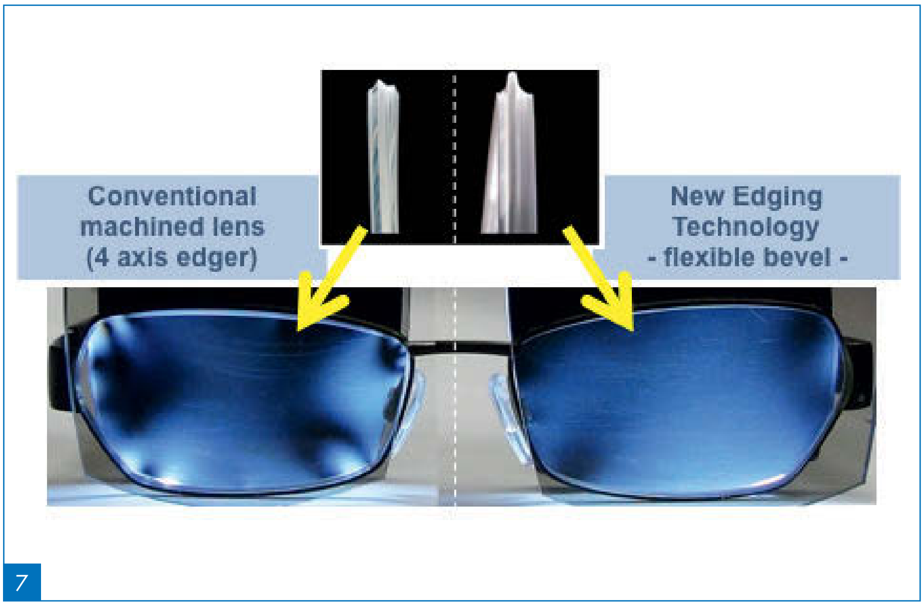
4 Bevel build up out of a string of a UV curable Polymer.



Test set up.



Screen of the controller showing a three string arrangement.



Full rim metal frame: Comparison of fitting quality of a conventional machined lens and a lens produced by NET (New edging technology).

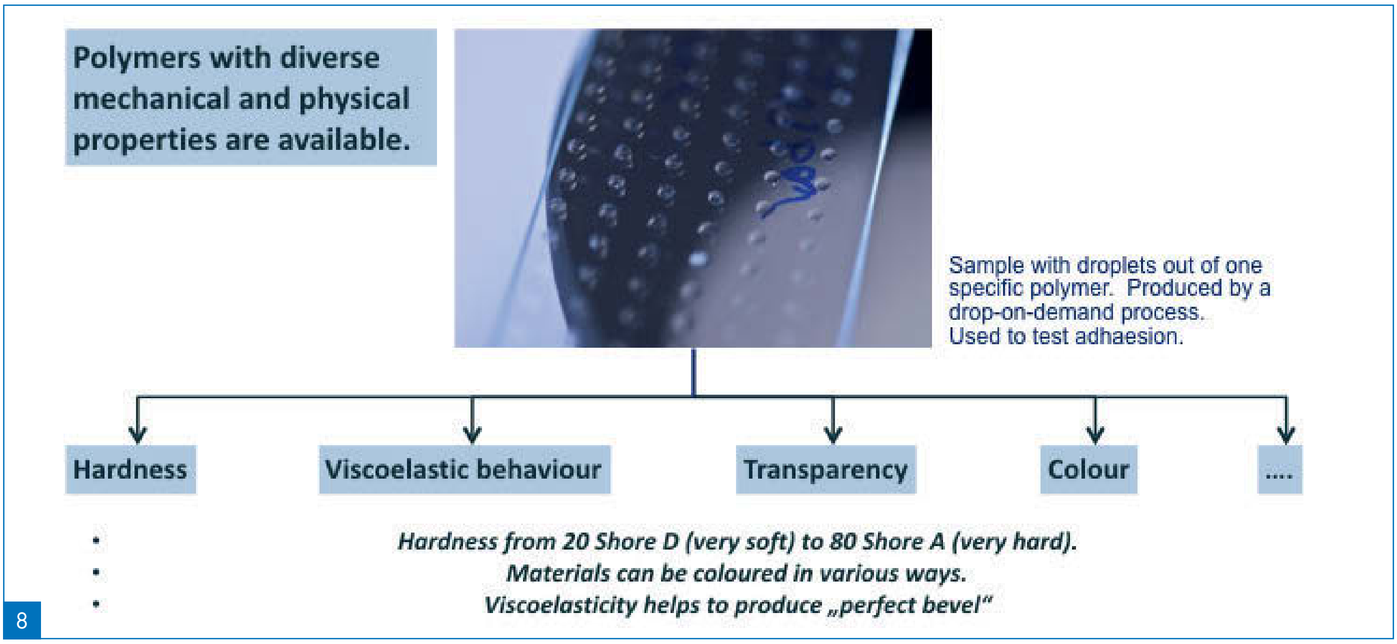
TEST SET UP AND PRODUCTION OF TEST LENSES

An important concern of the research work is to investigate the applicability of the new process as realistic as possible. It was therefore very important not only to produce test patterns, but also lenses and eyeglasses that could be tested under practical conditions. For this purpose, a test stand has been developed on the basis of a commercially available edger, shown in figure 5.

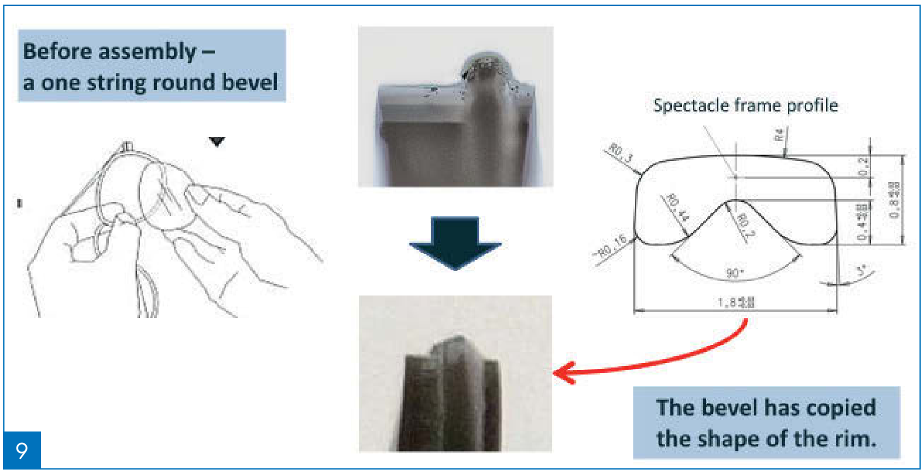
This configuration allows to carry out all necessary steps of a glazing process – from the scanning of the frame to the centering of the lenses up to the edging process. All components required for the printing process, such as the dispenser and the UV light source, were integrated in the housing of the edger, shown in figure 5. The needle of the dosing device, the drying unit and the mirror used for the deflection of the UV radiation can be seen. All components can be withdrawn from the machining area and are protected by a flap (at the top of the image) during the conventionally performed edging processing by grinding.

To be able to control the new production process it was essential to create our own software. Figure 6 shows a view of the screen. Using the software, the number and the position of the polymer strings to be applied

INSTEAD OF INCREASING THE PRECISION AND COMPLEXITY OF EDGER AND TRACER WHY NOT USE AN ADDITIONAL ELEMENT TO COMPENSATE FOR TOLERANCES?



Photopolymers and other polymers can be chosen out of a large range of materials.



A bevel out of a material with viscoelastic properties will copy the shape of the frame rim – ideal for a perfect fit with lowest tension.

THE NEW EDGING TECHNOLOGY IS INSENSITIVE TO TOLERANCES UP TO A FACTOR 5 COMPARED TO STANDARD MILLING TECHNOLOGY.

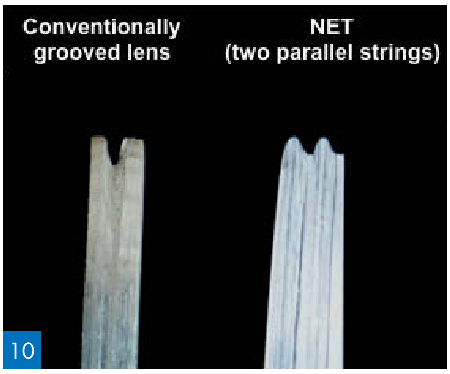
can be determined and their position can be positioned anywhere on the lens. In Figure 6 an experiment with three round strings is shown by way of example.

The test set up was used to produce spectacles of different kind – full- and half-rim. In cooperation with one of the leading German opticians eyeglasses have been glazed and their quality evaluated. Figure 7 shows for example a full rim metal frame. By using a conventional machined lens for the right side and a lens produced by NET (New Edging Technology) for the left side a direct comparison of the fitting quality have been accomplished.

The tension in the lens demonstrates the fitting quality. While the right lens shows a typical tension distribution, the elasticity of the bevel equals the tension in the left lens. A perfect fit as the result of the use of an optimal bevel material. The shape of the elastic bevel is shown in the upper part of the picture. It is slightly higher and smaller than a standard V-bevel. During the fitting process the shape will change due to the elastic and viscoelastic material behavior and will match the geometry of the rim groove. Based on the results of the experiments it can be stated that the new technology is insensitive to tolerances up to a factor 5 compared to standard milling technology - a huge difference if you are looking for a high process reliability and '100%-first-time-fit'.

THE OPTIMUM BEVEL MATERIAL

Intensive work has been carried out and is still going on to find an optimum bevel material, shown in figure 8. The material must have a high adhesion combined with different optical materials. The connection should be able to carry a high load especially during the fitting process (e.g. 'cold' fitting of full rim plastic frame) without any problems, it should be durable under all conditions including resistance regarding sweat, cleaning supplies and so on. It needs to have an aesthetic appearance in combination with colored lenses or used at a half-rim frame (see figure 7). In contrast to todays options it's hardness and elasticity can be selected to optimize the result. There are many different polymers with diverse mechanical and physical properties available:



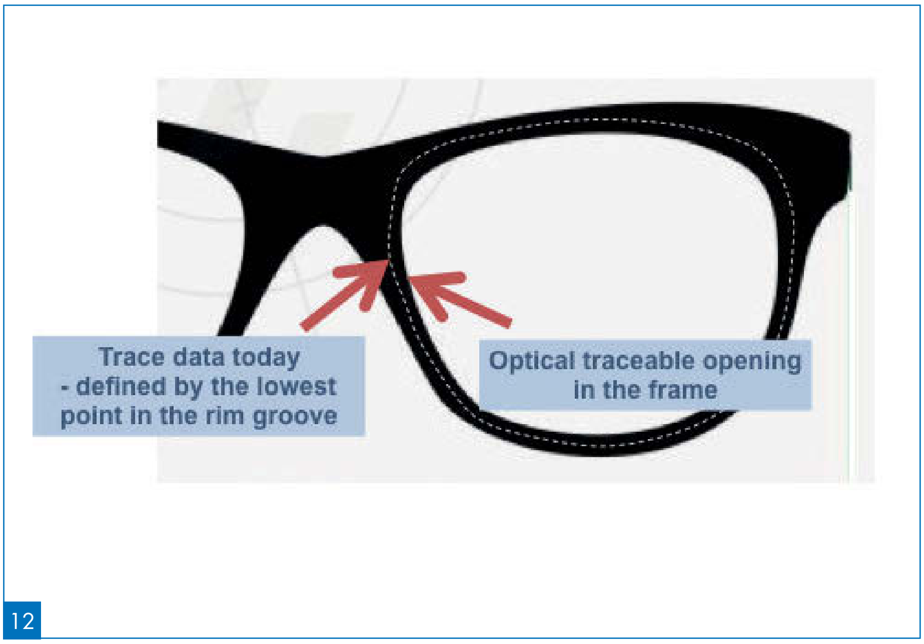
No need to groove a lens for a half-rim frame. Two parallel strings will do the job without weakening the edge of the lens.

from rubber like materials to rigid ones; from crystal clear to opaque or transparent. Coloring in all colors is possible – but is limited regarding saturation when using photopolymers.

Simply summarized:

Choosing an additional material between lens and frame opens up many new opportunities. The bevel material might be chosen in a way that the bevel adapts itself to the rim of the frame. If the material has a viscoelastic behavior it will copy the shape of the frame rim after some time, see figure 9. Result: Best fit and lowest possible tension.

Comparison of lenses edged based at conventional tracer data and based at the geometry of the opening in the frame.



Different trace data usable for edging.

The technology is by far no limited to V-bevels. Figure 10 shows the comparison of two grooved lenses for half-rim frames. Left side a standard lens, right side a lens produced with NET.

Main advantage is that the edge of the lens is still intact and the risk of breakage is reduced. Furthermore the risk of breakage is no longer the limiting factor regarding the edge thickness. Smaller edges are possible and by that the weight of lenses can be reduced.

INFLUENCE AT TRACING AND ORDERING PROCESS

Another interesting point is the impact of NET at the tracing and ordering process. Today edging is based at tracer data measured by a mechanical stylus which collect the data at the lowest point in the groove of the frame. Regarding cosmetic aspects this is not the ideal solution.

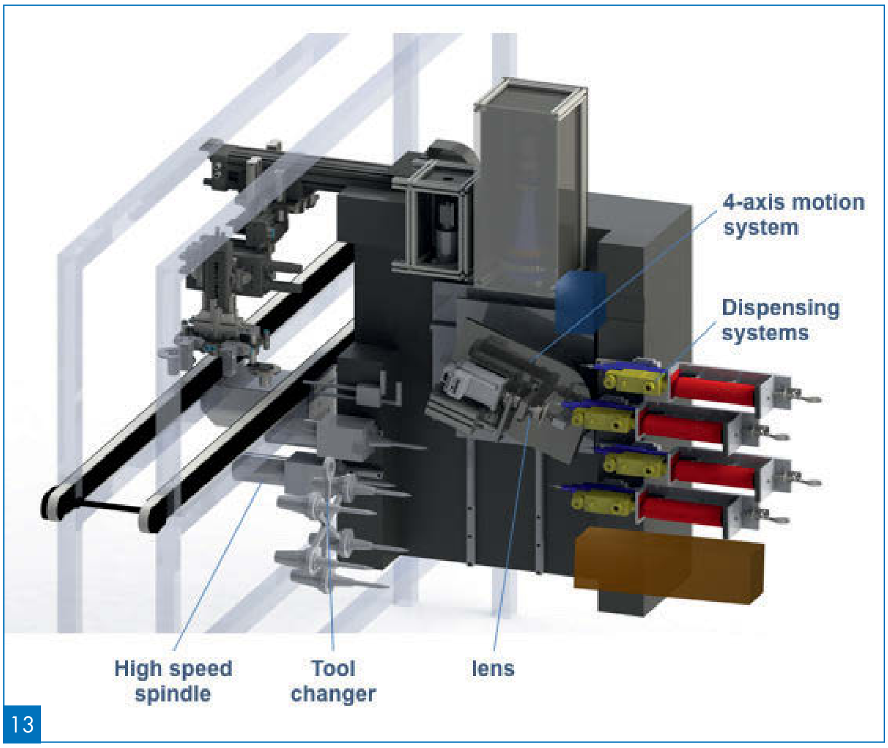
To improve aesthetics the opening in the frame is the much more interesting information. Machining a lens based at the groove data or at the shape of the opening will lead to certain differences regarding the appearance, shown in figure 11.

Using the data of the opening will give better cosmetics (comparable to the use of a so called mini-bevel) and – which makes it even more interesting – it's geometry is much easier to measure. Well known camera and imaging technology can be used to get the trace data. No further need for a mechanical tracer.

By using NET it is not necessary to measure the depth of the rim groove precisely. If the bevel is designed in a proper way and the bevel material has an adequate elasticity we will get a sufficient fit. This will allow the use of state of the art imaging technology for the tracing process.

A CAMERA BASED TRACING AND ORDERING SYSTEM BECOMES FEASIBLE.

Using imaging techniques in a modern lab will speed up frame tracing and might allow a fully automatic process. At the point of sale it will ease operation. Some further investigations will be carried out in the future to check if the use



13

Concept of the hybride machine designed to show the full potential of NET.

of consumer cameras (smartphone, notebook,..) is feasible to collect trace data with sufficient precision. This might open some new possibilities of ordering eyeglasses via ecommerce.

THE BENEFITS

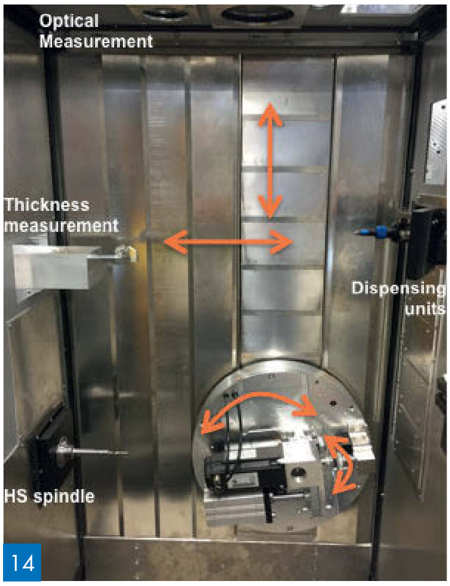
Basic research has been carried out to analyze the potential of additive manufacturing technologies in the finishing area. The expected benefits especially regarding a perfect fitting quality with a very high process reliability could be confirmed. Additionally interesting potentials regarding tracing and the ordering process are obviously. Based at the research work done we can state as follows:

- New Edging Technology can compensate tolerances up to a factor 5 compared to state of the art edging.
- A cost-effective "100% first-time-fit" is feasible.
- Optical tracing technology might substitute tactile tracers.
- New opportunities for remote edging are opening up.

There are several more benefits, some of them mentioned above. As we are talking about a 3D printing technology it is clear that there is the ability to do much more.

THE NEXT STEPS

The test set up described above has been used to achieve the proof-of-principle regarding the new technology. To be able to show its full potential a much more sophisticated machinery is necessary. Figure 13 shows the concept drawing of a machine able to make use of the full potential of NET.
The new machine is designed with a high speed spindle for the roughing of the lens. A 4-axis motion system allows the positioning of the lens in almost every orientation. Up to 5 dispensing systems with different polymers are integrated to build up even complex 3D structures. Two different optical measurement systems will be used for research purposes. The hardening of photopolymers can be performed with an integrated UV source. The main goals of the next step are to confirm the results under industrial like production conditions and to produce lenses with an additional 3D printed functionality. Figure 14 shows a view inside the working chamber. As this edger is designed mainly



Working chamber of the research edger.

for research purposes it offers space for additional functions and could be modified without too much effort.

FUTURE PROSPECTS

From our point of view the technology described has the potential to lead to some fundamental changes in finishing; especially if '100% first-time-fit' and a high process reliability are key issues. Using optical tracers at the point of sale would ease the ordering process and would open new opportunities for remote edging.

By developing an industrial type machine a strong basis to discover the full potential of the new technology becomes available now. It will take some time to get the edger to full functionality and before further reliable results will be available. Anyhow – we see NET as a promising chance and opportunity to redesign not only the processes but also the product (the lens) itself.

ACKNOWLEDGEMENT

We would like to thank all students and employees which have supported the progress of the project and the core team during the last years. Their efforts have been of tremendous value for the achieved result. Figure 15 shows the team in 2016.

Subsidized by:

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Team in 2016.

Jörg Luderich

After finishing his academic studies in mechanical engineering, he started his professional career first as Research Assistant and later as Chief Engineer at the Fraunhofer Institute in Aachen. Focused at high and ultraprecision machines and metrology he got his PhD in 1993. In 1995 he was appointed Head of R&D of Weco, Düsseldorf. After the merger with the former Rodenstock Instruments and the ProLaser group he was responsible for a large product range from finishing equipment to instruments for optometrie and ophthamology. In 2002 he founded the company Lumos GmbH which he succesfully established in the field of precision engineering and as supplier of equipment for opticians. In 2010 he became Professor at the Cologne university of applied sciences (TH Köln) - still focussed at his passion: Innovative processes and machines in the field of precision engineering.

Christian Pöpperl

Christian Pöpperl received his Master of Engineering from the TH Köln. He started his professional career in the R&D area of Lumos GmbH in 2009 – specialized in the field of automated testing instruments. In 2011 he became First Research Assistant and later Project Leader at the TH Köln. His work in the area of alternative methods for the finishing process was honored several times and lead to different inventions and patent applications. In 2017 he started the company 'Shape engineering' to commercialize his ideas and solutions.