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Latyev, S.M.; Jablotschnikow, E.I.; Padun; B.S.; Frolov, D.N.; Tabatschkov, A.G.;
Theska, R.; Zocher, K.-P.

Laboratory for automated assembly of microscope lenses

Section 5.1 Precision & Optical Engineering

This paper is about the concept of a laboratory for the automated assembly, verification and adjustment of barrelled microscope lenses under batch production conditions. Preparatory efforts are contributed by a new design of unified microscopic lenses as well as in the development of the “Virtual Assembly Method”. The employment of this method to the assembly process of unified microscopic lenses opens new potential in cost reduction while keeping the optical quality at unchanged high level.

The automation of assembly processes of complex optomechanic and optoelectronic components and subassemblies is a challenging task since multiple error sources are influential to the commonly ambitious quality standards

In particular deviations of the optical characteristics as well as geometrical variations of the optical and mechanical parts have a strong impact.

In many cases this problem can not be solved or adequately delimited by tighter tolerances in order that the associated technological and economical effort is not affordable. This is in specific the case for the assembly of optical lenses. Very often adjustment is the only method to eliminate or compensate errors in an economical manner. The effort in adjustment can be reduced through the analysis of the particular single errors and their influence to the overall system under use of the “Virtual Assembly Method”. In specific the automated assembly of microscope lenses is highly complicated since they are diffraction limited multiple-unit optical chains with highest demands to the optical quality. Following Abbe the optical resolution ε is determined by the light wavelength λ and the aperture A ($\varepsilon = \lambda / (2A)$). Figure 1 shows the layout of a microscope lens of a novel unified design with a high percentage of unified elements.

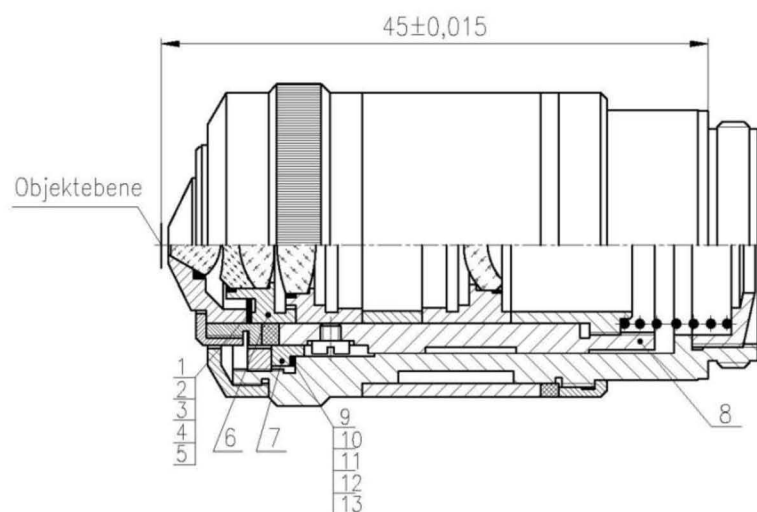


Figure 1 Layout of a microscope lens of a unified design

The correction of the spherical aberration of all elements caused by deviations in the index of refraction (Δn_e), vertex thickness (Δd), the air gap (Δt) and the refractive radius (ΔR) is done up to now manually by iterative variation of the number of spacers (Position 1-5). That results in a time and labour intensive mounting and dismounting process. Applying the "Virtual Assembly Method" the tuning length for minimized spherical aberration can be calculated in a mathematical model hence the assembly can be done in one step. The mentioned critical deviations of all elements need to be measured beforehand since they are required as an input in the mathematical model (Figure 2).

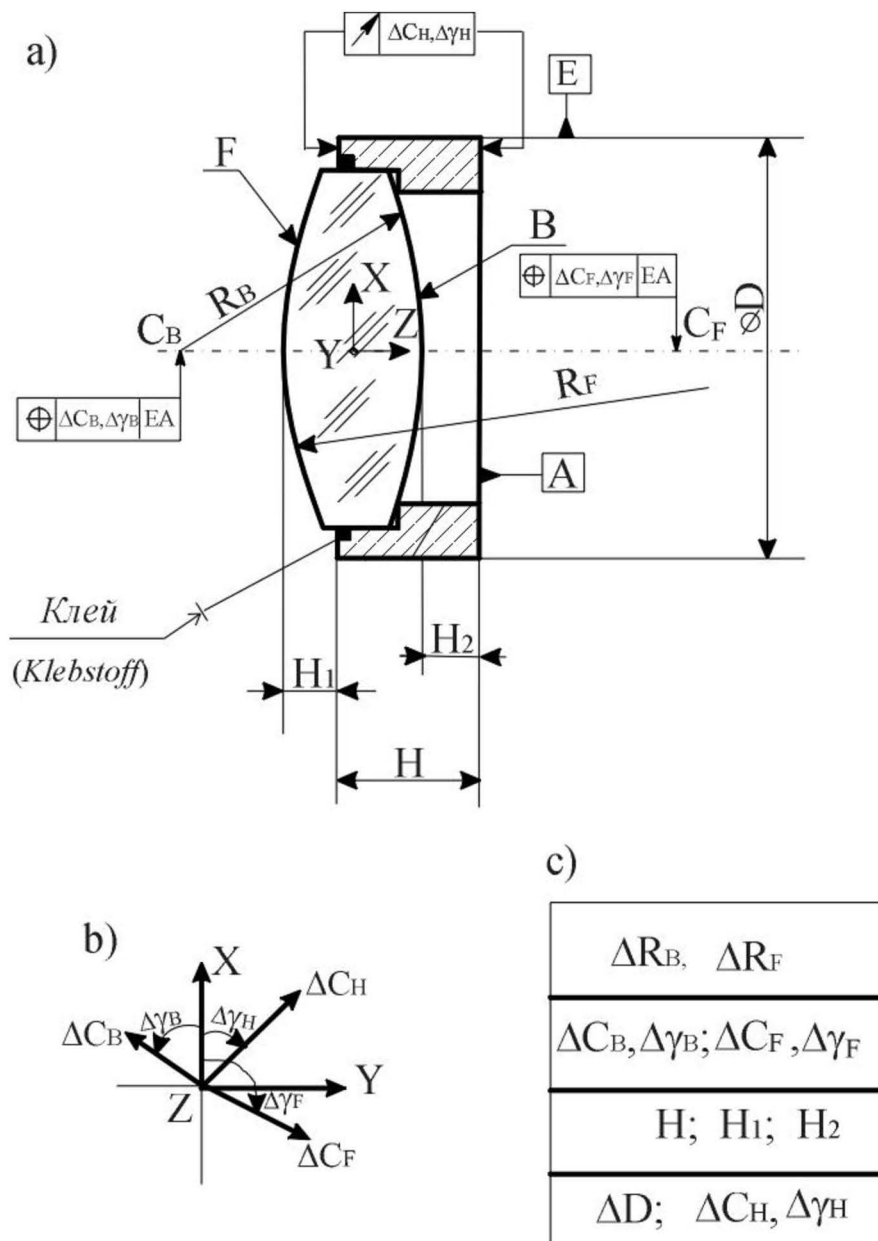
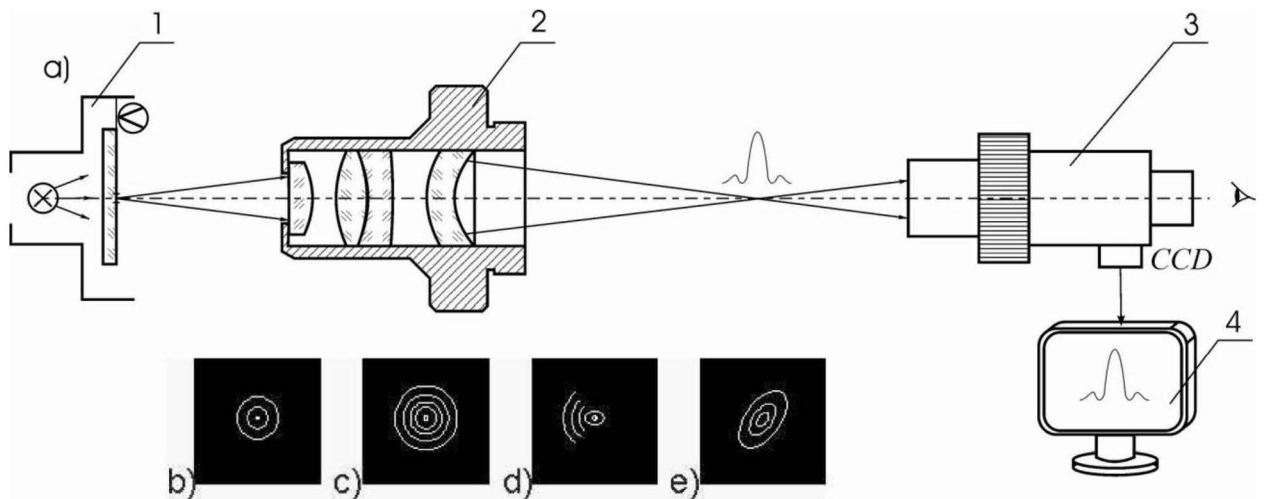


Figure 2 Critical deviations at a single mounted lens

The residual decentration of all optical subgroups to the barrel cylinder (#8, Figure 1) generates coma that classically derives compensation by a lateral shift of subassembly #6 after completion of the mounting process. This lateral movement can be done through a borehole in cylinder #8. The adjustment process can be avoided in a similar way as described for the spherical aberration. It needs the preliminary determination of

the decentration of all optical surfaces and utilisation of the “Virtual Assembly Method”. The mathematical model used for this purpose allows the determination of the mounting orientation of each subgroup individually. Figure 2b shows the parameters to be measured. A precondition for the utilisation of the method is a tolerance calculation of the whole optical system that guaranties that the residual errors are small enough. The final check of the optical quality is done by the diffractive image of the lens under use of a CCD- matrix (Figure 3)



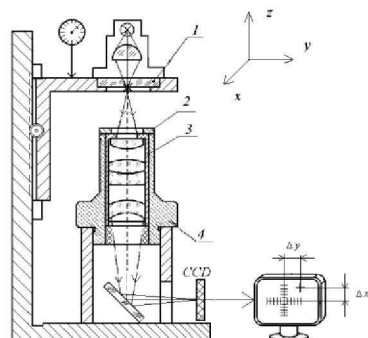
Legend: 1 illuminated pinhole, 2 microscope lens, 3 frame grabber, 4 computer

Figure 3 a) Scheme of the check setup b)-e) typical diffractive images

Information's about the optical quality can be derived from the analysis of the Point Spread Function (PSF). Types and quantities of the residual optical aberrations can be identified. Is the optical quality in accordance with the expectation the next step can be taken.

The mechanical standard length (distance in-between the object plane and the mounting surface (A, Figure 1) and the centration of the optical system needs to be adjusted. In difference to the common way of the correction by machining the mounting surface to the dedicated length in centered state the new design allows the adjustment by a linear shift(given by a spacer #9- #13) and rotation of the cylinder #8.

Figure 4 shows the principle of a setup to measure standardised mechanical length and centration



Legend: 1 illuminated reticle, 2-4 microscope lens

Figure 4 Principle of the measuring set up

Currently ITMO together with a consortium of industrial partners and TU Ilmenau are in the process to establish a laboratory for automated assembly of microscope lenses with unified design following the “Virtual Assembly Method”. The laboratory will incorporate all necessary process steps like assembly, measurement and adjustment. Figure 5 shows the flow chart of the laboratory.

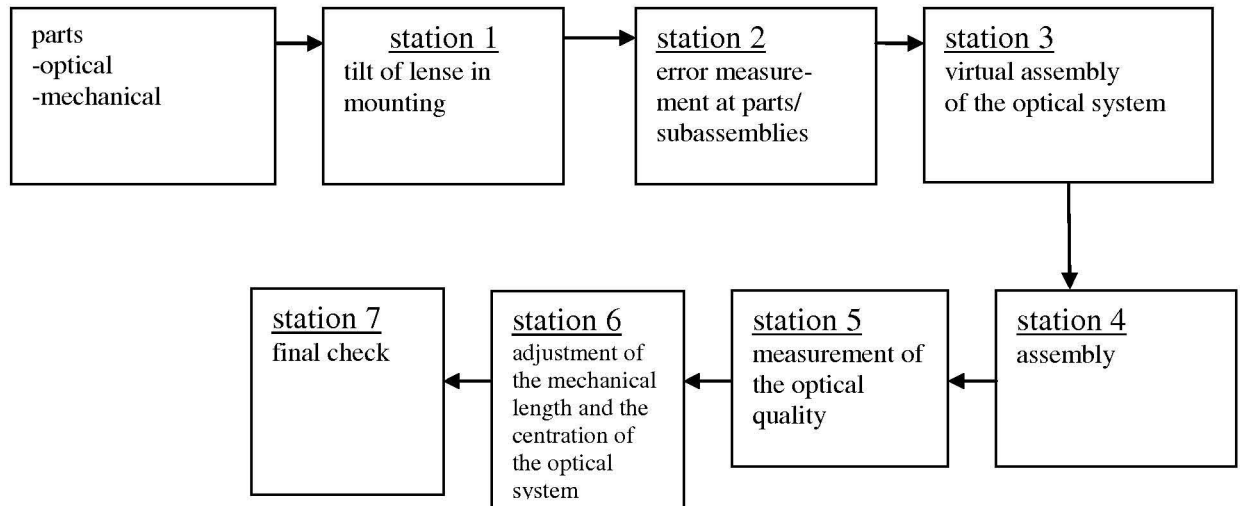


Figure 5 Flow chart of the laboratory

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Authors:

Latyev, S.M.; Jablotschnikow, E.I.; Padun, B.S.
 State University of Information Technology, Mechanics and Optics Sankt Petersburg (ITMO)
 Frolov, D.N.; Tabatschkov, A.G.; „FOKUS“Enterprise Sankt Petersburg
 Theska, R.; Zoher, P.
 Technische Universität Ilmenau
 98693 Ilmenau
 Phone: +49 3677 69 3957
 Fax: +49 3677 69 3823
 E-Mail: rene.theska@tu-ilmenau.de