Alignment autocollimator-based microscope adjustment and its quality assessment

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Abstract. We report a custom microscope setup whose mechanical and optical components are adjusted by the means of an alignment autocollimator (AAC). Residual centring and angular misalignments of the components towards the microscope's optical axis are below 500 µm and 1 mrad, respectively. We further perform measurements of dot structures with diameters close to the diffraction limit (nominal diameter = 200 nm; chrome on glass mask) as suitable measures for the evaluation of the microscope's adjustment and to determine/ visualize the optical aberrations, which affect the image formation of microscopes.

1 Introduction

High-accuracy, dimensional, optical microscopy depends on model-based data evaluation. Only then it is possible to determine bidirectional measures such as diameters or widths, which refer to distances between two opposing edges, reliably. Rigorous simulations of the entire microscopical imaging process are the foundation of such model-based evaluations. The simulations require a variety of experimental parameter of the microscope setup to be known. For example, the optical aberrations are required, among other parameters, for a comprehensive model of the microscope's imaging system [1].

The optical aberrations like Coma, Astigmatism, and spherical aberration have a distinct impact on the microscope's imaging performance and are influenced by the state of the microscope's adjustment. So, misalignments of optical components can be responsible for additional optical aberrations.

At PTB, we started to employ AAC for the alignment of optical elements of high-accuracy dimensional microscopes. Thereby, the centering and angular misalignments of the microscope components are reduced to a minimum. In this contribution, we use measurements on a chrome dot with a nominal diameter of 200 nm to verify the quality of the alignment. If the acquired dot images are visibly affected by optical aberrations and the adjustment procedure should be repeated. Otherwise, the effect of the residual aberrations is not as prominent, and the microscope is operational. This contribution does not focus on the determination of the optical aberration based on the use of dot structures. These findings have been already reported in [2]. This work emphasizes on the alignment strategy applied as an example to a custom PTB microscope and the dot measurements as a fast and immediate measure for the adjustments' quality assessment. Therefore, the instructions and the sequence for the alignment strategy for this specific case is provided in section 2 before the dot measurements are described in section 3. Finally, we conclude in section 4.

2 Microscope alignment

The microscope under consideration is based on the optical components of the Vistek Semiconductor LMS IPRO4. However, the components are assembled in a custom setup. It is a UV-reflected light microscope with an illumination and imaging NA of 0.44 and 0.55, respectively. The magnification is 200x. The microscope is equipped with an overview microscope which has a magnification of 50x and uses visible light. The adjustment procedure for this microscope uses the same principles and is therefore omitted.

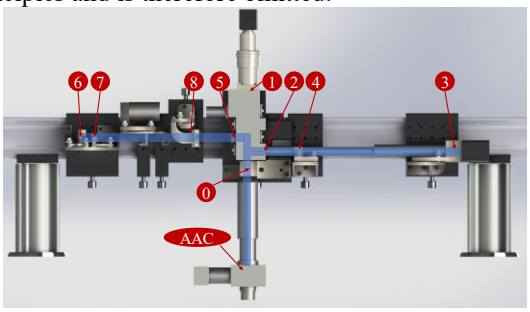

Fig. 1. Application of the AAC at the custom microscope of PTB

In figure 1, the AAC is attached to the custom microscope and the single alignments steps are indicated. Step 0 precedes the attachment of the AAC. Here the microscope's empty objective holder is aligned parallel to the surface of the supporting optical table. This is performed by employing a chromatic confocal distance sensor. Usually, a misalignment angle of the objective holder of 1 mrad is sufficient. Next, the AAC is attached to the empty objective holder. Subsequent steps are performed by the combined use of the AAC and different alignment targets at the position of the respective microscope component. The mounts of all components to be aligned can correct for lateral and angular

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misalignments. Through an iterative alternation between the two modes (imaging and autocollimator) of the AAC and the necessary adjustments at the mounts, the respective alignment target in the mount is aligned. Subsequently the target is replaced by the matching microscope component.

Concerning the sequence of the alignment steps, the main microscope body must be aligned first with an alignment target at position 1 of figure 1. The two beam splitters of the UV-microscope are positioned inside of that body. They separate the elevated illumination beam path from the lower imaging beam path. Their alignment steps are 2 and 5, assuming that the entire imaging path is configured before the illumination beam path. After the alignment of the beam splitter, the other components of the imaging beam path are aligned starting with the component which is the furthest away from the AAC. Thereby, lenses and other components can be already inserted without diffracting or blocking the AAC's emission. The measurement camera is aligned in position 3. Position 4 represents the location of a lens. The alignment of the imaging beam path follows the same order. The positions 5-8 correspond to the illumination path beam splitter, an optical fibre, and two lenses. The optical fibre feeds the light from an UV-LED into the microscope setup The supporting VIS-microscope is then adjusted likewise, before the AAC is removed and replaced by the objective. The resolution of the AAC for the centring alignment decreases with a larger distance between the AAC and the alignment target. While it is roughly 70 µm for the illumination beam splitter, it is just below 500 µm for the position of the fibre. The angular resolution is independent of the measuring distances at 1 mrad. The specimen table on top of a smooth (surface roughness < 1µm) granite block is placed below the objective. The last step of the microscopes adjustment requires a Bertrand lens (BL). With the BL inserted, the objective's back-focal plane is projected into the microscope's image plane on the camera. This is shown as the large aperture in the top left of figure 2. Now it is possible to insert and adjust the aperture diaphragm in a flexure stage of the illumination beam path, while monitoring the progress on the camera. When the aperture diaphragm is centred in respect to the objective aperture, it blocks most of the illumination beam path, too. Only a narrow well centred beam is allowed to pass perpendicular and then be focused by the objective onto the sample.

In a last step the field stop is centred and adjusted along the optical axis such that its edges reach maximum sharpness. The microscope is operational.

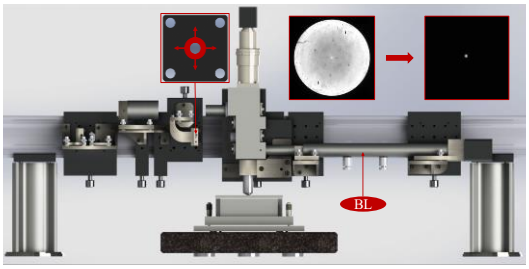

Fig. 2. Alignment of the aperture diaphragm with the BL

3 Dot measurements and evaluations

For the system evaluation a chrome dot on a high-quality photomask is measured. Prior structure widths measurements on the sample yield a fabrication offset of 20-30 nm for structures on that sample. Therefore, the nominal 200 nm wide dot has an effective diameter of 170-180 nm.

he dot measurements consist of repeated series of images in different height distances from both sides of the focal plane. The resulting stack of images is referred to as a focus series. Repeated focus series can be averaged due to the high measurement stability of the mechanical setup. In figure 3, the images a) and c) show the same dot after two different adjustments according to the above-described procedure. Asymmetries in the images are made visible by performing a least-squares fit of a Gaussian to the centre of the focal dot measurement. By subtracting the respective fit from a) yields to visible asymmetries in b) while the same procedure leads to a symmetric image in d) when c) is evaluated.

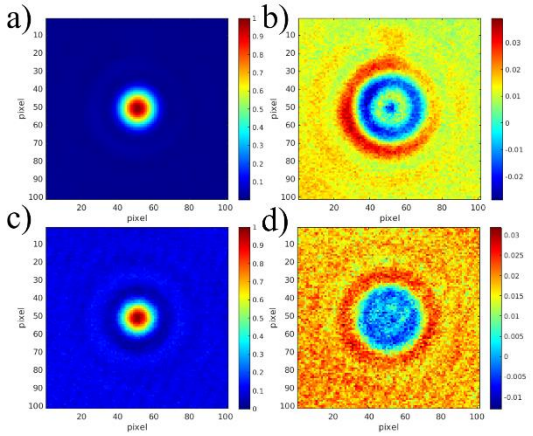

Fig. 3. Averaged, focal dot measurements and evaluation for an unsuccessful (a, b) and a successful (c, d) alignment of the microscope

4 Conclusion & Acknowledgement

This contribution provides an AAC-based alignment scheme for microscopist and a fast assessment technique, which is in-line compatible. Asymmetries in the dot measurement of the focal image uncover non ideal adjustments states. Since the asymmetries will be present in all subsequent measurements, a repetition of the entire alignment procedure might be the best decision.

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