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Simulation of autofluorescence effect in microscopic lenses

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The use of fluorescence in microscopy is a well-known technology today. Due to the autofluorescence of the materials of the optical components, the contrast of the image is degraded. The autofluorescence effect is usually modelled by raytrace and volume scattering and calculated by the brute force method, which is extremely time consuming and therefore difficult to be implemented in the optical design process.
In order better understand the impact of the autofluorescence effect of different lens groups on the image, an analytical model has been derived. Under certain approximation, it has been found that on the detector, the intensity of the autofluorescence light which is generated by a thin slice of glass in a lens element can be written as:

$$\Delta I = C \cdot \pi p_i^2 (n_i u_i)^2 \frac{1}{n^2 h^2} \Delta d \qquad (1)$$

Where C is a constant normalization factor $\pi p_i^2 (n_i u_i)^2$ is the Etendue of the system, n is the refractive index of the material, h is the marginal ray height and Δd is the thickness of the glass slice [1].

In order to accelerate the calculation of the autofluorescence effect and overcome the limitation of the analytical model, we have developed a phase space based method, which directly calculates the conversion efficiency between the excitation and acceptance light in the phase space in every slice. With the help of the phase space method, we are able to accelerate the calculation by a factor of 10^4 compared to the brute force method with a comparable accuracy. We applied the new method on a large collection of different types of microscopic lenses, the simulation results reveals certain dependence of the autofluorescence effect on the structure of the lens and lens elements.
Fig. 1-2 show two examples of the simulation results, in which the layout and the geometrical contribution from different lens elements are shown. In Fig. 1 the lens is a high NA system with very short working distance, from the simulation results it is seen that the contribution from the front element, in which the marginal ray height is very small, is extremely large, this corresponds to the conclusion from equation 1. Fig. 2 shows a high NA microscopic lens with longer working distance, in this case the geometrical contribution of the front element is much smaller compared to the system in Fig.1, but the contribution from the rear group is more critical. This is due to the fact that in the +-+ structure the marginal ray heights are small near the two inner concave surfaces, and the two meniscus lenses are rather thick.

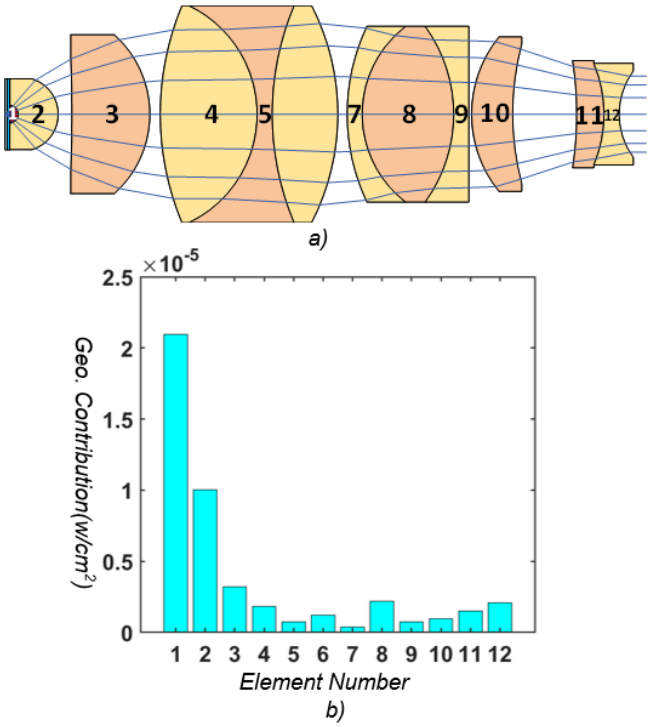

Fig. 1. Geometrical autofluorescence contribution from different lenses of a high NA microscopic lens with short working distance [2] in arbitrary units.

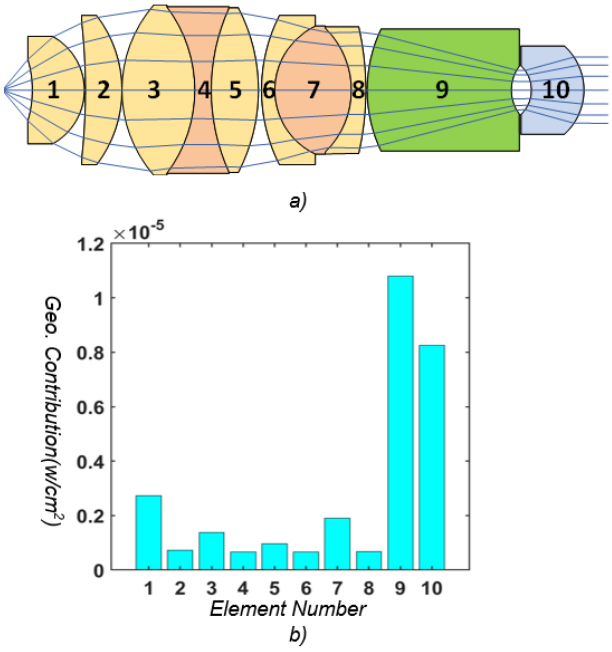

Fig. 2. Geometrical autofluorescence contribution from different lenses of a high NA microscopic lens with long working distance [3] in arbitrary units.

References

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