Abbe’s theory

In 1866, Ernst Abbe and Carl Zeiss cooperated together to improve the optical performance of microscopes. Only until then microscopes and microscope objectives were being produced by trial and error; some having exceptional optical performance but others having undesirable features. Abbe and Zeiss knew that they could only get an optimum and consistent performance on a complete theoretical basis. (Gundlach, 2005)

Abbe discovered after many calculations and experiments that the diffraction image in the back focal plane of the objective is essential for image formation. (Gundlach, 2005)

“No microscope permits components (or the features of an existing structure) to be seen separately if these are so close to each other that even the first light bundle created by diffraction can no longer enter the objective simultaneously with the non-diffracted light cone.” Ernst Abbe, 1873. (Gundlach, 2005)

Light rays diffracted by the specimen from the objective of an optical microscope are fundamentally important in Abbe's theory. Fine details of the specimen will not be visible, unless diffracted rays of light from the specimen are captured by the objective. (University, 2005)

Diffraction forms the image of light absorbing specimen. The light shows the specimen's structure consists of grating of different shapes of holes. A specimen will give a consistent bright image if the rays of light passes through the specimen undiffracted. Information is carried by the diffracted light over and around the structures of the specimen. (Logg, 2006)

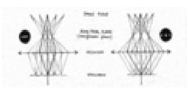

Figure1

If for example, a plane wave, which is parallel light, shown in figure 1, would enter from under and onto the optical axis, different diffractions of different angles would emerge. If there will be for instance smaller periodicity between the grids, meaning a smaller distance, the angles will be greater. (Logg, 2006)

Figure 1, shows two gratings with different periodicity, through which parallel light can pass. In the rear focal plane of the objective occurs a diffraction pattern. Take into account, that a wider spread of the diffraction pattern is resulted from smaller distance of spaces. (Logg, 2006)

The Fourier transform of the image appears in the diffraction pattern in the objective's focal plane.The appearance of bright spots on a line resembles the grid. From this the zeroth order is the central spot. In the objective's back aperture, all light that will go through the sample undiffracted, will pass this spot. The spots next to the zeroth order are the first diffraction orders and the next the second etc. An evenly intense image in the image plane shown in figure 2, shows the blocking of all spots except from the zeroth order. Blocking all light but the first order spots will result in an image with an intensity variation having the same frequency as the grid. The second and third diffraction order alone gives a false period. Nevertheless, a reasonable image of the specimen can only be obtained by adding the four orders (zeroth to third). (Logg, 2006)

Ernst Abbe concludes that only when the objective captures at least two of the diffraction orders, will an image be formed. Even finer details can be resolved if more diffraction orders can be captured by the objective. (Logg, 2006)

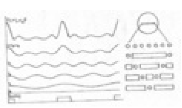

Figure2

When blocking different diffraction orders in the plot, as shown in figure 2,it shows the image of a grating (image to the left)The intensity of image of the grating should look like $I_{grating}$. (Logg, 2006)]

Links

- Limit of resolution of optical microscope
- History of light microscopy
- Comparison of microscopic techniques/resolution

Bibliography

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