Abbe's theory

Template:Zkontrolováno

Ernst Karl Abbe (1840–1905)

German physicist and astronomer. He worked as an associate professor at the University of Jena in Germany. In Jena at this time the optician Carl Zeiss was leading the company engaged in the construction of microscope. Until the beginning of his collaboration with Ernst Abbe, however, each of his devices was unique. Ernst Karl Abbe provided the theoretical background needed to construct the [microscope]]. After Zeiss's death, Abbe became the sole owner of Zeiss-Werke. As the founder of the theory of optical instruments, he significantly contributed to their improvement.

Optical instruments bearing his name

- **Abbe Comparator** – is an instrument for the accurate measurement of wavelength visible light. It was first constructed by Ernst Karl Abbe.
- **Abbe's Conspire** – adjustable optical system between the light source and the object stage of the optical microscope for improved illumination of the slide.
- **Abbe refractometer** – a universal instrument for measuring refractive index of liquids and solids.

Terms bearing his name

- **Abbe number** – This number gives us the dispersion power of a given transparent medium in the region of visible light. Abbe's number characterizes the properties of optical glass. Normal values for this number range from 20 to 70. For example, for the construction of lenses, the largest possible value of the Abbe number is best, since this material has a low dispersion (dispersion = decomposition of optical radiation according to spectral composition).
- **Abbe sine condition** – a condition that must be satisfied in order for a pair of nearby points, lying in a plane perpendicular to the optical axis of the system, to appear sharply, i.e. a point as a point.

Abbe's theory

Abbe's theory of microscope, or theory of optical instruments, originated in 1873.

History

As early as 1869 it seemed that the theoretical foundations for the construction of Microscope had been laid, but a microscope constructed according to these theoretical values was less successful than Zeiss's previous products. In further experiments, Abbe found that in his previous calculations he had taken into account only refraction of light, not his bending.

Abbe's microscope theory

This theory explains the principle of image formation in the microscope. The basic idea of Abbe's theory is that every point of an illuminated object becomes a source of secondary spherical waves according to Huygens principle.

Radiation (parallel beam) penetrates the sample, which represents a flat irregular grid for radiation, and in the form of secondary waves enters the lens, reaching its rear focal plane *F'*.

Changes in amplitude and phase changes passing through the sample were described by Abbe by the transmission (i.e. mediating) function F (x, y), where the variables x and y represent coordinates in the object plane, this plane is perpendicular to the optical axis of the microscope. Secondary spherical waves eventually pass into the image plane and their interference creates an enlarged image of the observed object.

To improve the passage of light rays, tvz. Immersion – there is no air between the lens and the cover glass, but a special oil that has the same refractive index (N) as the glass, so the radiation does not have to penetrate two different environments and more of it penetrates into the lens. Immersion is mainly used at larger magnifications. Ernst Abbe defined a relation for useful magnification, i.e., such magnification as human [eye]] can still distinguish clearly.

$Z_{useful} = d_{RLO} / d_{min}$

d_{RLO} represents the distance distinguishable by human eye. For a conventional visual distance (i.e. 25 cm), the resolution of the human eye is equal to 300 μm. The highest quality immersion microscopes achieve numerical apertures (see below) of 1.3 to 1.4. For the shortest wavelengths of the visible part of the light spectrum (which is about 390 nm), the resolution of these high-quality lenses approaches 0.17 μm.

After substituting into the above formula, we get the value for the maximum useful magnification $Z_{useful\ maximum}$ = 1500.

For the choice of useful total magnification, which represents the normal range magnification, Abbe's rule was introduced, which was derived from objective magnification and numerical combinations of numerical aperture. Relationship for Abbe's rule:

$Z_{useful\ overall}$ = (500 to 1000) x NA

NA – numerical aperture

- the characteristic value given by the lens construction is, as well as the magnification, given on the lens housing.
- a dimensionless number that can be expressed as:

NA = n × sin δ

where:

n = refractive index of the environment in front of the lens

δ = half of the apex angle of the beam cone entering the lens

It follows from this relation that the value of NA is directly proportional to the sine of the angle δ.

As mentioned above, the highest quality lenses reach values of 1.3 to 1.4.

If the magnification is outside the normal magnification range, then we speak of either empty (when exceeding the normal range) or minimum (when the normal range is not reached) magnification.

We can talk about empty magnification when using an eyepiece with too much magnification relative to the lens. Unfortunately, this situation does not lead to the observation of new details, but only to an increase in the existing magnification. The given magnification is therefore useless for us => empty. It exceeds the increase in the total useful value, which is expressed by:

$Z_p > 1000 \times NA$

We can talk about the minimum magnification when using an eyepiece with a small magnification in relation to the lens. Such magnification becomes insufficient, because the details resolved by the lens do not increase, but on the contrary, we escape. We speak of a minimum magnification only if its values belong to the interval expressed by:

Z_{min} = (250 to 500) × NA

It follows from Abbe's theory that the only desirable increase for us is the increase of useful total, i.e., the values that are in the interval given by the above relation:

$Z_{useful\ overall}$ = (500 to 1000) × NA

Links

- TOMÁNKOVÁ, Kateřina, Ing., Ph.D., *Mikroskopie 1,* 2004 - http://www.fch.vut.cz/~zmeskal/obring/prednasky_2004/mikroskopie_1%20(katka%20tomankov%e1).pdf -
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- https://cs.wikipedia.org/wiki/Ernst_Karl_Abbe
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Bibliography

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