# DEMONSTRATION OF ABBE'S DIFFRACTION EXPERIMENTS

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This will be a live video demonstration of the famous experiments devised by Ernst Abbe to illustrate his 'Theory of the microscope and of microscopical imaging' [1] – his fundamental work on the microscope, which was published in 1873. Abbe, then a lecturer in physics, astronomy and mathematics at the University of Jena, joined the firm of Carl Zeiss in 1866 with the task of placing the design of microscope objectives on a sound scientific basis. He approached the subject from first principles, and his work revealed that information about fine detail in the object is transmitted to the image by the rays diffracted by that detail, and it led to the formulation of the famous equation which appears on his memorial in Jena:


where

$d$ is the minimum resolvable distance
$\lambda$ is the wavelength of the imaging radiation
$n$ is the refractive index of the medium between the objective lens and the object, and
$\alpha$ is the 'semi-angular aperture' of the objective lens.

By providing the theoretical basis of image formation, Abbe's theory pointed the way towards achieving the ultimate resolving power of the light microscope.

Abbe's diffraction experiments provide the best non-mathematical way of understanding imaging in the microscope, and they remain equally relevant today. The demonstration will use a replica of the equipment designed by Abbe himself, and a specially-adapted microscope. This is fitted with two video cameras, so arranged that the diffraction pattern formed in the back focal plane of the objective is seen in the upper part of the screen, and the image that derives from it in the lower part.

Experiments to be demonstrated include:

- Reducing the aperture of the objective, showing the effect on resolution of fine detail
- Illuminating with light of different wavelengths – features will be resolved in green light but not in red
- Obstructing the zero-order (undiffracted) beam so that it does not contribute to the image
- Altering the image by removing first-order beams
- Demonstrating that the final image results from the interference of diffracted beams
- Producing a phase-contrast image (not done by Abbe, but it follows from his theory)
- A 'journey up the microscope' from the back focal plane to the image plane, showing how the diffracted beams expand and overlap, and ultimately give rise to the image.

[1] E. Abbe, "Beiträge zur Theorie des Mikroskops und der mikroskopischen Wahrnehmung" *Schultze's Archiv für mikroskopische Anatomie*, **IX**, 413-468 (1873).