Optical Diffraction and Interference using Single Photon Counting
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In this experiment the wave and quantum properties of light can be studied and measured with high precision and within many aspects. The often complicated diffraction and interference patterns can be measured quantitatively and the results compared with theory. Effects of single-, double-, multiple slits, gratings, razor blade, disks and balls are measured in a wide dynamic range of up to $10^4$ using single photon counting as the detection technique. A fine stepper motor driven linear motion unit allows scanning of the patterns with a precision of a few microns. A 50 μm optical fiber is used to transmit the light from the plane where the effects are displayed to the single photon detector, a fast and very sensitive photomultiplier. The effects can be stored, displayed and evaluated on a computer. The use of single photon technique takes into account the quantum nature of light.
Optical Diffraction and Interference: Required Knowledge

- Diffraction of light
- Huygens principle
- Fraunhofer and Fresnel diffraction
- Wave-particle dualism, Heisenberg uncertainty principle
- Interference patterns
- Diffraction and interference behind various objects: slits, double, multiple, grating, razor blade
- The so-called Poisson point

- Basic optical set-ups
- Single photon counting technique
- Physics and technics of basic lasers
- Beam expander and spatial filter
- Technique of micro-stepper motors and linear motion stages
- Fast counting electronics and multiscaler technique
- Photomultipliers
Optical Diffraction and Interference: Tasks and Goals

- Get familiar with principal optical set-ups, aligning, adjusting
- Regards laser safety rules
- Start with the preparation of light source and alignment for a single and a double slit, the light beam must be parallel and “clean”.
- The diffraction and interference pattern must be clearly visible on the paper screen!
- Align the slit vertically that the end of the optical fiber (core) stays at the center of the pattern during the whole scan; the slit can also be rotated to achieve that.

- Prepare the photon counter
- HV = -2000 Volts; threshold for pulses set at -50 mV software selectable
- Get familiar with the two programs for scanning (ORTEC multiscaler and LINOS stepper drive)
- Take several scans, duration about 10 – 30 min each
- Compare at least one pattern with theory quantitatively, the slit widths and distance are fit-parameters!
- Produce diffraction pattern using the green and the red laser and compare both results
Optical Diffraction and Interference: Tasks and Goals continued

- Produce diffraction pattern of a razor blade and a round disk
- Get a clear scan of the so-called Poisson point alternatively the razor blade
- Proper graphical documentation of all scans and calculations
Single Slit  0.04 mm
Single Slit 0.08 mm
Double Slit 0.04mm width 0.5mm sep
\[ F_{\text{total}} = (F_d)(F_i) \]
\[ F_d = \frac{\sin(\frac{\delta_a}{2})^2}{(a)^2} \]
\[ \delta_a = 2\pi \left(\frac{a}{\lambda}\right) \sin \theta \]
\[ F_i = \frac{\sin(\frac{N\delta_d}{2})^2}{\sin(\frac{d}{2})^2} \]
\[ \delta_d = 2\pi \left(\frac{d}{\lambda}\right) \sin \theta \]

\[ \sin \theta = \frac{(x - x_0)}{r} \]
\[ \tan \theta = \frac{(x - x_0)}{L} \]

\[ r = \sqrt{(x - x_0)^2 + L^2} \]

\[ N \quad \text{number of slits} \]
\[ a \quad \text{slit width} \]
\[ d \quad \text{slit separation} \]
\[ \lambda \quad \text{laser wavelength} \]
\[ x_0 \quad \text{position of global maximum on stepper motor path} \]
\[ L \quad \text{distance from slits to detector fiber} \]
Double slit: black expt red Math Simulation
Five Slits 0.04mm, 0.125mm sep