Talbot’s bands as a refractive-diffractive phenomenon

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An interference experiment described by Talbot in 1837 [1] on the formation of interference fringes in white light has gained relatively little attention so far. In that experiment, Talbot observed the formation of interference fringes (“Talbot bands”) in one of the two first diffraction orders of a grating spectrometer upon inserting a piece of glass of appropriate thickness halfway into the illuminating beam (Figure 1). This observation is somewhat surprising, in particular, the fact that the bands occur only in the +1st order (notation as defined in the figure) and not in the −1st order. The occurrence of the interference fringes in the +1st order can be explained qualitatively in the temporal domain [2]. Here, we have a two-fold interest in the Talbot band experiment: first, we explain it as a refractive-diffractive phenomenon, second, we extend the experimental setup by introducing structured elements.

The delay between the two pulses shown in the figure is given as \( \tau = \tau_r + \tau_d \) where \( \tau_r \) is the “refractive” delay introduced by the glass plate and \( \tau_d \) is the “diffractive” delay due to diffraction. It is

\[
\tau_r(\nu) = \frac{\Delta n(\nu) l}{c} \quad \text{and} \quad \tau_d(\nu) = -m \left( \frac{N}{2} \right) \frac{c}{\nu}
\]

where \( m \) denotes the diffraction order. Fringes are observed if the total delay is approximately zero. Depending on the dispersion behaviour (normal or anomalous for \( \tau_r \), positive or negative sign for \( \tau_d \) depending on \( m \)), one can implement different experimental configurations [2]. Here, we demonstrate an experimental extension of the classical experiment. If, for example, the glass plate is replaced by a staircase-like wedge, one observes a different modulation of the bands (see figure). In particular, they get more pronounced. This situation can be understood as the occurrence of multi-beam interference as compared to two-beam interference in the case of the simple glass plate.

[1] H. F. Talbot, An experiment on the interference of light, Phil. Mag. 10 (1837) 364