Negative Images in Stroboscopy

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Abstract

The effects of varying the duration of a stroboscopic flash are considered.

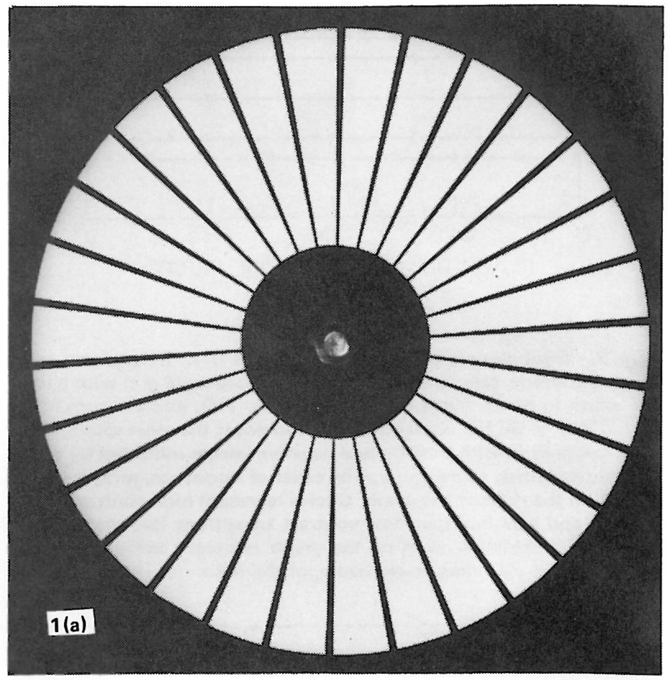
If the disk in Fig. 1(a) is rapidly rotated and viewed under continuous illumination which is periodically interrupted for short intervals, then by adjusting the frequency of the interruptions, the stationary negative image in Fig. 1(b) is produced. Standard texts in stroboscopy[1] and visual perception[2] do not mention this effect,and we have been unable to find anyone who is familiar with it. There is, however, an early paper by Faraday,[3] cited by Helmholtz,[4] which describes related but not identical phenomena.

The observed patterns can be predicted using optical arguments. Two time-varying illumination schemes are called *complementary* if the sum of the intensities of both schemes gives a constant illumination in time. While the disk in Fig. 1(a) is rotating rapidly, it appears a uniform gray under constant illumination, due to time averaging in the visual system.[4] Hence, if the spatial pattern of intensity observed on the rotating disk under some illumination scheme is summed with the pattern observed under the complementary scheme, the result must be a uniform gray. Consequently, since illumination with periodic short light flashes gives a positive image (narrow dark bars on a bright field), illumination by the complement must give a negative image (narrow bright bars on a dark field), Fig. 1(b).

Given any illumination scheme the spatial intensity of illumination can be readily computed. Let us define the *recurrence frequency*, f, of a rotating disk as the inverse of the time required for one dark bar to move the position of the next dark bar. A rapidly rotating disk will appear stationary if

$$mf=n\nu,$$

where ν is the frequency of light flashes, and m and n are integers with no common factor.[1] When this resonance condition holds, the observed spatial frequency is mF, where F is the spatial frequency of the pattern on the disk. Therefore, the illumination pattern can be computed by considering the pattern produced in one period by a single moving bright bar, and superimposing m such patterns separated by a distance 1/mF. The single-bar pattern is a bright bar flanked by two "shoulders" whose illumination drops linearly with distance; i.e., its graph of illumination versus position is a trapezoid. Therefore, the determination of the illumination pattern involves adding m such trapezoids, which may or may not overlap. For a given m, n, transitions between positive and negative image occur as the flash duration is varied while the interflash period is kept constant. Two types of transition occur: a high contrast transition in which bright and dark bars of equal width can be seen at the transition



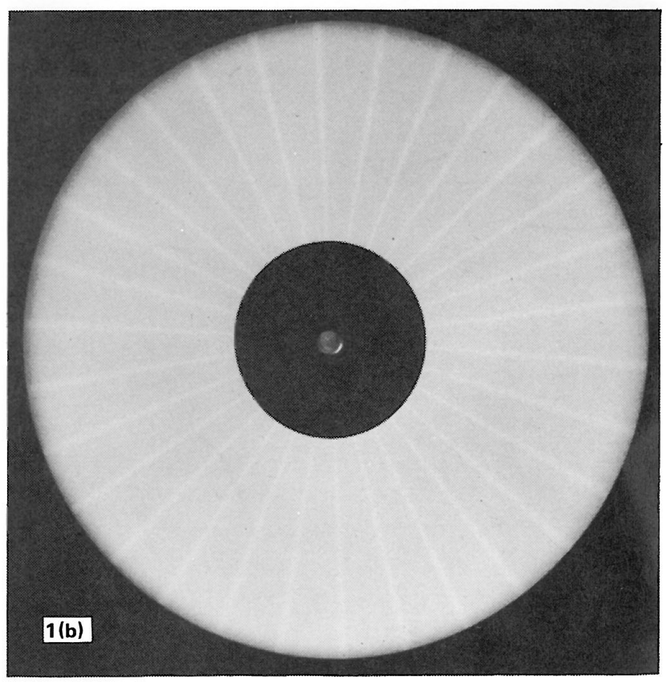


Fig. 1. (a) A disk of 30 black bars on a white background. (b) The disk in Fig. 1(a) as seen under negative image strobing conditions. The disk was rotating with a recurrence frequency of 50 Hz and the view of the disk was obstructed periodically at the same rate (m/n=1/1) for a time equal to 1/12 of the period. The photographic exposure time was 1/8 sec.

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