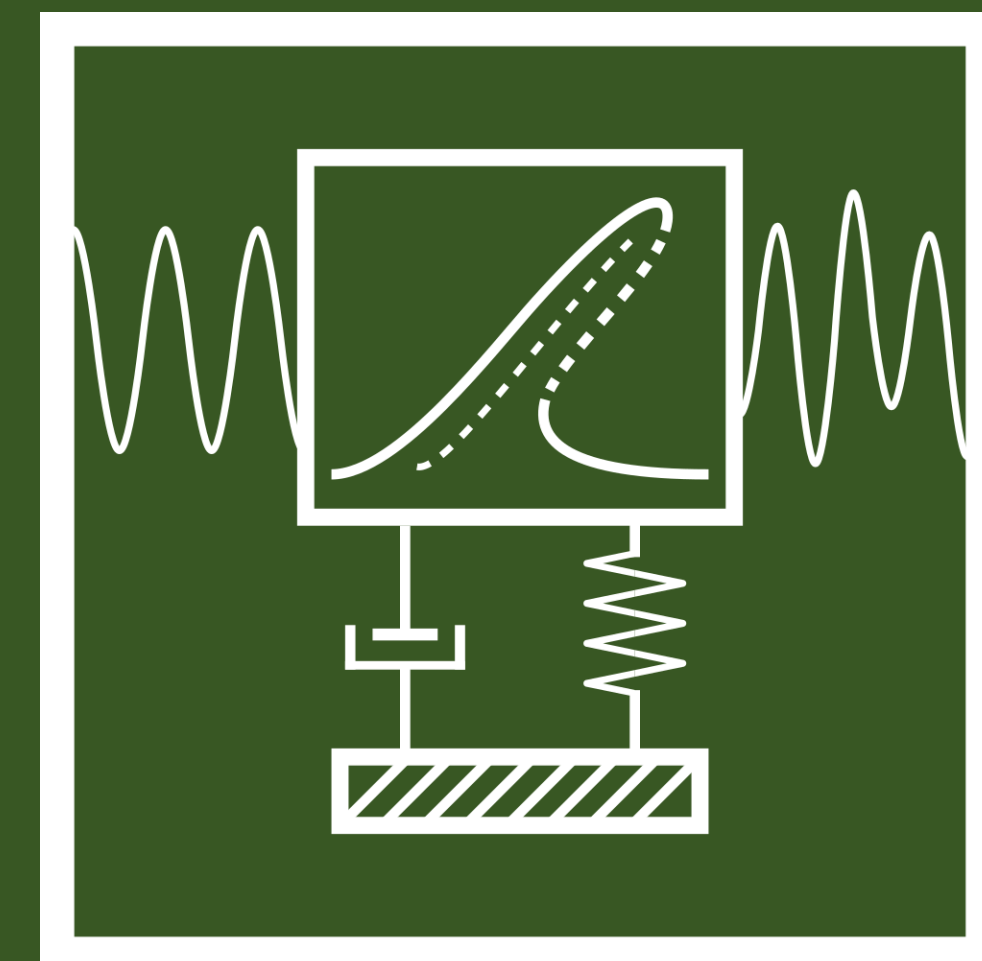


Optimal Implementation of Dynamic Visual Cryptography on Digital Displays

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A

Abstract

Dynamic visual cryptography (DVC) hides a secret image in a single moiré cover image and reconstructs it through time-averaged fringes generated by controlled oscillation. This work investigates the optimal parameters for implementing DVC on digital displays under finite refresh-rate constraints.

01

Methods

- DVC is a single-share optical technique for hiding visual information in a moiré grating and revealing it through oscillation and temporal averaging [1].
- Decoding relies on temporal integration by the human visual system and can be implemented using either mechanical shakers or digital displays [2–3].
- Digital displays offer a portable alternative, but hardware limitations constrain real-time oscillations, motivating the investigation of optimal parameters for reliable DVC implementation (Figs. 1–3) [3].

02

Results

Grating	Harmonic	Ronchi
	$M(x) = \frac{1}{2} + \frac{1}{2} \cos\left(\frac{2\pi x}{\lambda}\right)$	$M(x) = \frac{a_0}{2} + \sum_{n=1}^{+\infty} \left(a_n \cos \frac{2n\pi x}{\lambda} + b_n \sin \frac{2n\pi x}{\lambda} \right)$ $a_0 = 2(1-a), a_n = \frac{\sin(n\pi(1-a)) - \sin(n\pi(1+a))}{n\pi},$ $b_n = \frac{\cos(n\pi(1+a)) - \cos(n\pi(1-a))}{n\pi}, n = 1, 2, \dots$
Oscillations		
Harmonic $a \sin(\omega t + \varphi)$	$\bar{M}(x, a) = \frac{1}{2} + \frac{1}{2} \cos\left(\frac{2\pi x}{\lambda}\right) J_0\left(\frac{2\pi a}{\lambda}\right)$	$\bar{M}(x, a) = \frac{a_0}{2} + \sum_{n=1}^{+\infty} \left(a_n \cos \frac{2n\pi x}{\lambda} + b_n \sin \frac{2n\pi x}{\lambda} \right) J_0\left(\frac{2\pi n}{\lambda} a\right)$
Stochastic $N(0, \sigma^2)$	$\bar{M}(x, \sigma) = \frac{1}{2} + \frac{1}{2} \cos\left(\frac{2\pi x}{\lambda}\right) \exp\left(-\frac{1}{2} \left(\frac{2\pi \sigma}{\lambda}\right)^2\right)$	$\bar{M}(x, \sigma) = \frac{a_0}{2} + \sum_{n=1}^{+\infty} \left(a_n \cos \frac{2n\pi x}{\lambda} + b_n \sin \frac{2n\pi x}{\lambda} \right) \exp\left(-\frac{1}{2} \left(\frac{2\pi n}{\lambda} \sigma\right)^2\right)$
Rectangular	$\bar{M}(x, a) = \frac{1}{2} + \frac{1}{2} \cos\left(\frac{2\pi x}{\lambda}\right) \cos\left(\frac{2\pi a}{\lambda}\right)$	$\bar{M}(x, a) = \frac{a_0}{2} + \sum_{n=1}^{+\infty} \left(a_n \cos \frac{2n\pi x}{\lambda} + b_n \sin \frac{2n\pi x}{\lambda} \right) \cos\left(\frac{2\pi n}{\lambda} a\right)$

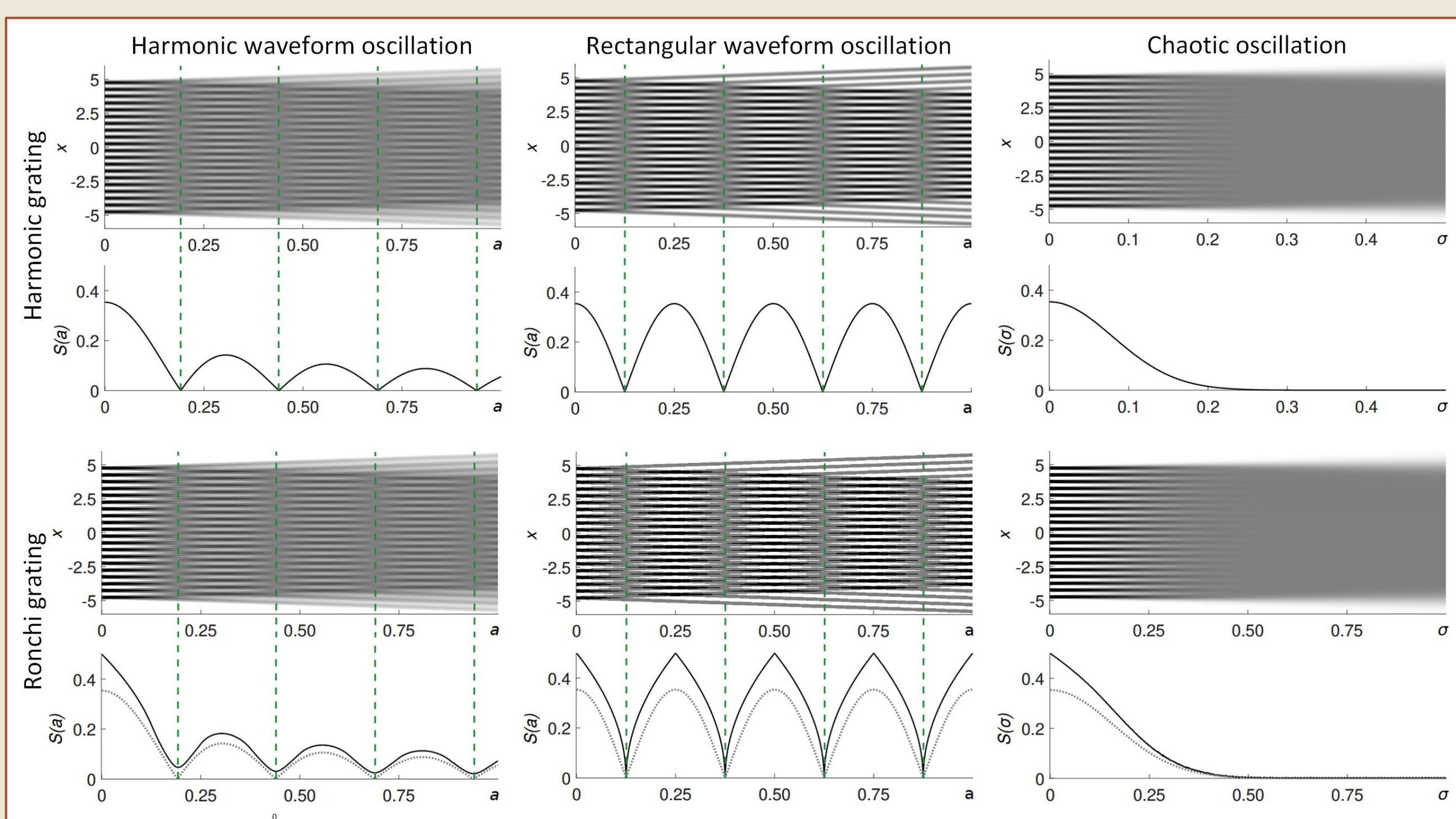


Fig 1. Optical blur effects induced by harmonic and rectangular waveform oscillations produce time-averaged fringes in time-averaged images of the one-dimensional harmonic moiré grating and the Ronchi grating. Stochastic oscillations do not produce time-averaged fringes in time-averaged images of both gratings. The standard deviations $S(a)$ and $S(\sigma)$ of pixels in time-averaged images characterize the optical blur effects induced by different oscillations. The pitch of the harmonic and Ronchi gratings is set to $\lambda = 0.5$.

03

Discussion

The oscillation frequency of the cover image does not affect the formation of time-averaged moiré fringes, but it determines whether the human visual system can perceive them. Previous studies [2] indicate that the secret can be decoded at oscillation frequencies of at least 25 Hz, whereas at lower frequencies the visual system tracks the oscillating image instead of performing temporal integration.

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Conclusions

Limited display refresh rates restrict higher-order fringe reconstruction with harmonic oscillations. Rectangular waveforms require only two frames per period, enabling reliable reconstruction and providing a basis for investigating temporal integration in the human visual system, with potential applications in studying visual processing, attention, and fatigue.

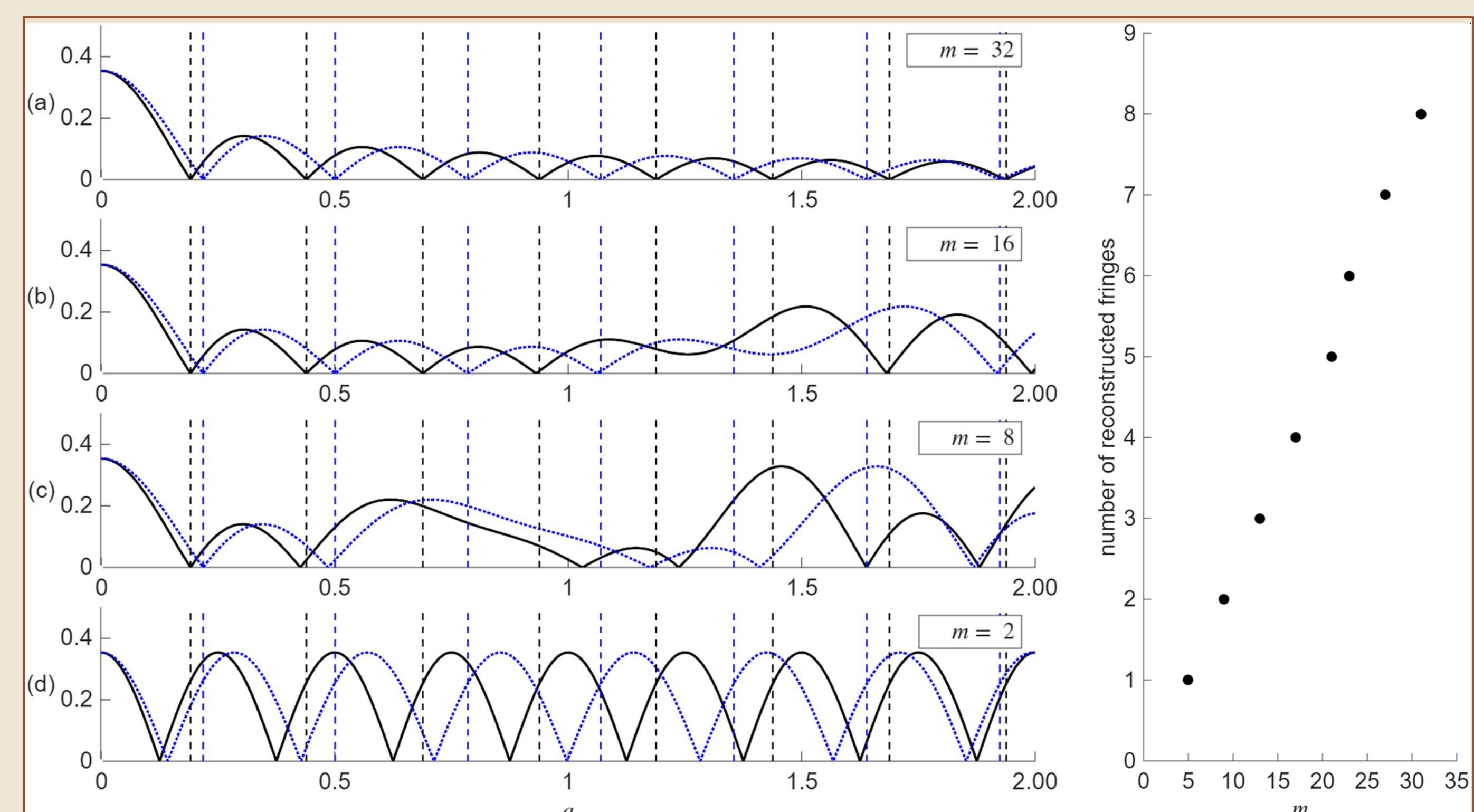


Fig 2. Computational reconstruction of the standard deviation $S_1(a)$ (black solid line) and $S_2(a)$ (blue dotted line). The first seven time-averaged fringes are reconstructed according to the predefined accuracy $\varepsilon = 0.01 \cdot \lambda$ with $m = 32$ frames per period.

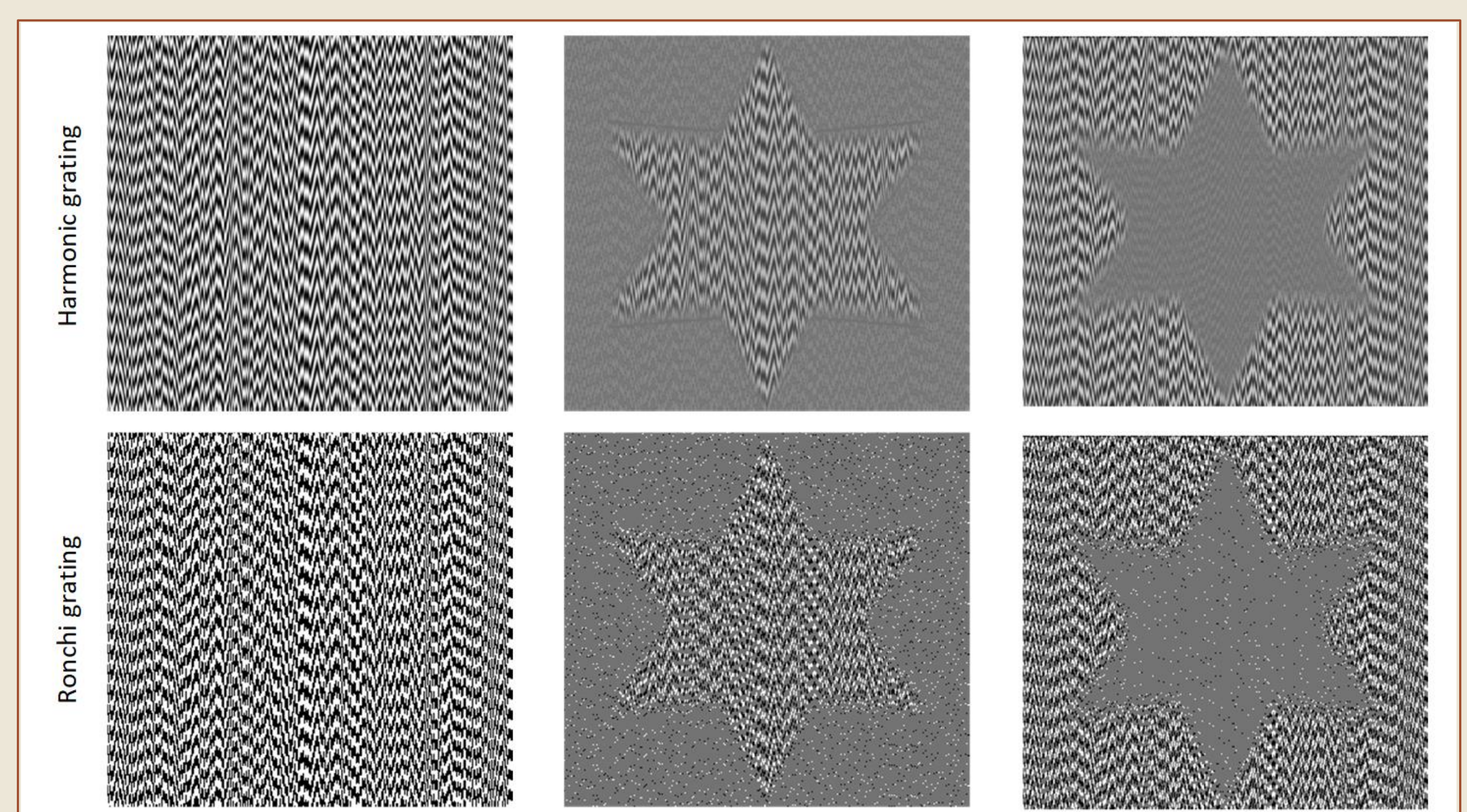


Fig 3. The secret image is encoded into the harmonic grating and Ronchi grating (the left column). Harmonic and Ronchi moiré gratings with pitches $\lambda_1 = 0.5$ and $\lambda_2 = 0.57$ are used to encode the background and the secret image respectively. Rectangular waveform oscillations are used to decode the secret: the background becomes blurred when the amplitude of oscillations is equal to $a = 0.375$ (the middle column); the secret becomes blurred when $a = 0.4275$ (the right column).

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