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THE QUALITY INSPECTION METHOD OF SECURITY HOLOGRAMS

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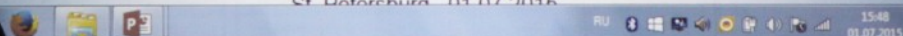
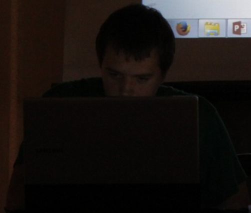
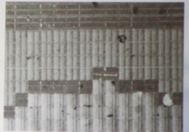




Objective

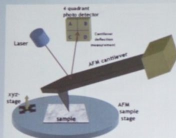
The subject of the work is developing of method, based on objective assessment about the quality of security holograms

The main parameters of the elementary grating:
- spatial frequency ν_x;
- grating depth d;
- number of periods in the grating N;
- grating orientation φ.

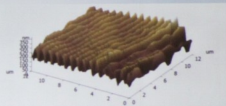


Methods of security hologram quality inspection

1) Method based on directly measurements of the diffraction grating parameters with atomic force microscope.



Disadvantages: time-consuming processing of results, expensive equipment.



2) Method based on indirectly measurements of the diffraction grating parameters.

Known relationships:

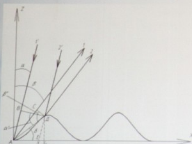
- For a given value of wavelength λ and incidence angle α the intensity distribution I over the diffraction orders of the phase grating depends on the grating depth d;
- For a given value of wavelength λ and incidence angle α the value of diffraction orders angles $\beta_{\pm 1}$ depends on the value of the spatial frequency ν_x;
- The orientation of the plane in which diffraction orders are located depends on the angle orientation diffraction grating φ;
- Angular size $\Delta\beta_{\pm 1}$ of the diffraction orders depends on the number of periods in the grating N.

Assumptions of the mathematical model description:

- elementary phase diffractive gratings are sinusoidal;
- effects caused by secondary re-reflections are negligible;
- the scalar diffraction theory is used.

The equation of the phase grating surface

$$z = A \cdot (1 - \cos\frac{2\pi x}{T}) = 2A\sin^2\frac{\pi x}{T}$$



Wave amplitude distribution

$$U = U_0 \cdot U_1 \cdot U_2$$

$$U_1 = \int_0^T e^{ik\Delta_1 x}\,dx$$

$$U_2 = \sum_{j=0}^{N} e^{ikj\Delta_0}$$

$$\Delta_0 = T(\sin\alpha + \sin\beta)$$

Intensity distribution

$$I = I_0 \cdot I_1 \cdot I_2$$

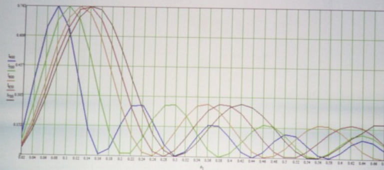
$$I_1 = |U_1|^2$$

$$I_2 = |U_2|^2 = \frac{\sin^2\left(\pi\frac{N\Delta_0}{\lambda}\right)}{\sin^2\left(\frac{\pi\Delta_0}{\lambda}\right)}$$

The results of mathematical modeling

Graphs of the ratio between intensity distribution I in the first order of diffraction and the grating depth d for normal incidence of radiation

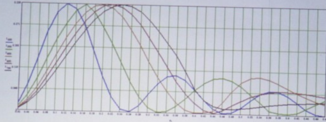
$\alpha=0,\ T_x = 1{,}5\ \mu m,\ \lambda = 400, 500, 600, 650, 700\ nm$



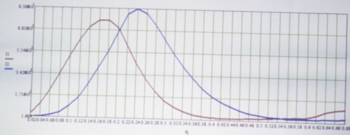
Graphs of the ratio between intensity distribution *I* in the first order of diffraction and the grating depth *d*

$T_x = 1\,\mu m,\ \lambda = 400, 500, 600, 650, 700\ nm$

$\alpha = 0$, $\lambda = 400, 500, 600, 650, 700\ nm$



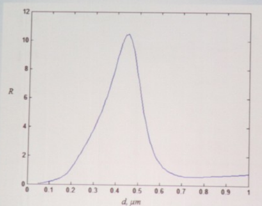
$\alpha = 60^\circ$, $\lambda = 405\ nm$



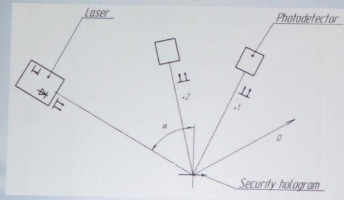
To improve the accuracy of the method, we use the relationship R between intensity distributions of the 1st and 2nd diffraction orders

Graph of the ratio between R and the grating depth d

for $T_x = 1\, \mu m$, $\lambda = 405\, nm$



Functional scheme showing principal of the method



Conclusions

1) The possibility of security holograms quality inspection based on the proposed method of indirect measurement of grating parameters is confirmed.

2) Relations for defining the parameters of the grating are derived.