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Speckle pattern analysis of security holograms and related foils for quality assessment and authentication.

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2022

Speckle pattern analysis of security holograms and related foils for quality assessment and authentication

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ABSTRACT

A speckle pattern is produced by the mutual interference of a set of coherent wavefronts. Speckle patterns typically occur in diffuse reflections of monochromatic light such a laser light. When a rough surface is illuminated by a coherent light is imaged, a speckle pattern is observed in the image plane. This study involves the quality assessment and authentication of security holograms and its related foils by analyzing the speckle pattern generated from the specimen itself. Speckle pattern from various type of security holograms and foils are taken. By processing the image of the speckle pattern, the size of the speckles is analyzed using MATLAB software. By evaluating the size of the speckle generated, the feasibility of analyzing the quality and authenticity of the security hologram is assessed. The paper discusses about the experimental setup, image capturing, and processing method and the result obtained in detail.

Keywords: Holograms, Foils, Speckle pattern, Speckle size, Security, Authentication, Quality assessment.

1. INTRODUCTION

This paper involves the speckle pattern analysis of security holograms and related foils using speckle interferometry. Holography similar to photography, involves imaging an object into a film or photographic plate. In holography, imaging is done by recording the wavefronts [3]. Speckle Interferometry is the method of imaging the speckle pattern of a test object [4]. The paper discusses about the analysis of holograms and related foils by estimating the speckle size, which is the most important parameter of the speckle pattern. The speckle size is measured from the width of the normalized auto covariance function [6].

This paper consists of an approach to study the feasibility of analyzing the quality and authenticity of security holograms by interpreting the speckle patterns generated by the holograms by using a single wavelength light. Why holograms? Holograms are widely used as security authentication device in India since 1990. Holograms are highly safe and durable. The objective of the paper is to analyze the feasibility of its authenticity and develop methods of its quality assessment so that double security can be ensured. Since both holography and speckle interferometry involves the use of light, studying the characteristics of speckle patterns of the holograms could give us a better understanding of feasibility of quality assessment.

2. METHOD

2.1. Speckle Interferometry

Experiments were conducted to obtain the speckle patterns of the holograms and related foils to be studied. The apparatus used was an electronic speckle pattern interferometer (ESPI) [5]. The schematic diagram of the apparatus is shown below in Fig. 2.1. Electronic Speckle Pattern Interferometer (ESPI) is used to study deformations on the surface of a test object. It is a non-destructive method used to image speckle pattern. Instrument consists of a light source which is a linearly polarized He-Ne laser of wavelength 632.8nm having output power of 5mW. The beam splitter having 50/50 R/T ratio splits the input into two beams transmitted beam and a reflected beam. The former falls on the test object through a spatial filter assembly having magnification of 60 and the latter falls on a CCD. The resolution of the CCD camera is selectable (320-1280 pixels). The zoom lens and CCD capture the image of the test object.

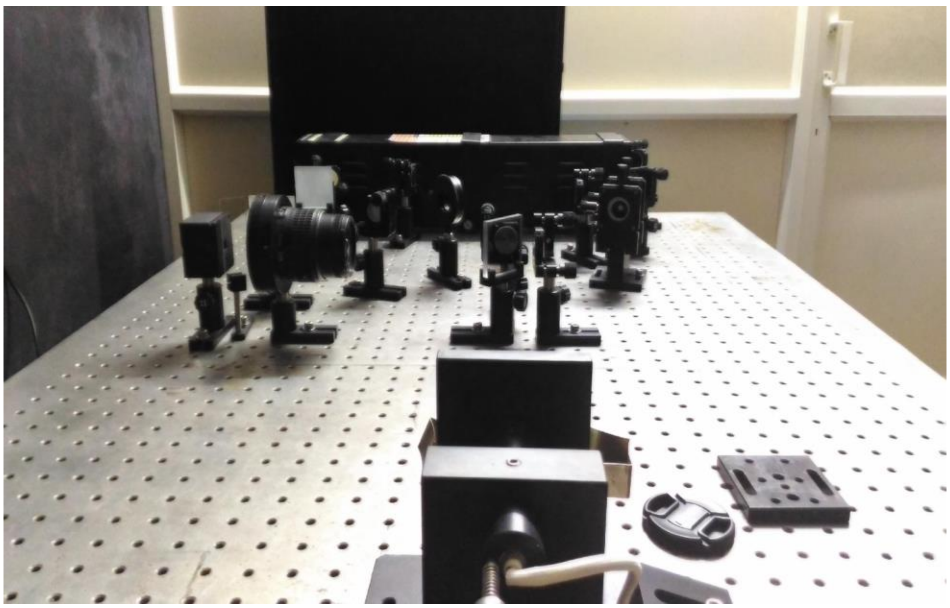


Figure 2.1: Experimental Setup

2.2 Substrate Material of Security Holograms

The current holographic technique used for security applications usually uses mass-produced, identical embossed holograms. For embossing the holographic image, a medium is required. The most commonly used holographic embossing medium uses poly ethylene terephthalate (PET) film as a carrier film having different values of thickness viz. 12 µm, 24 µm and 36 µm coated in different colours. PET is a highly transparent film from the polyester family with a density of 1.44 g/cm^3. It is a solvent inactive film, having temperature resistant property up to a temperature of 250°C. Other than PET, the films of cellulose tri-acetate, biaxially oriented polypropylene, polystyrene, polyethylene or polyvinyl chloride etc. can also be used as carrier films in the embossing media.

There are different types of materials used for manufacturing holograms. They include tamper evident base foils, non-tamper evident base foils, hotstamping foils and cold foils. To manufacture the conventional type tamper evident holographic embossing foils, initially, two-layer coatings namely primer coat and lacquer coat are applied on carrier PET film. The primer coat is a distinctive acrylic resin base coat. The main property of this primer coat is to improve the release property. Primer coating is used to provide the tamper-proof property. Lacquer coat is a colour coat made with special inks and metallic dies. It is an acrylic material or, a copolymer based or a nitrocellulose-based material ((David, 1995). Then the process of metallization is initiated, and a very thin layer of metal is applied on the two-layer coated PET by vacuum metal deposition or sputtering or electron beam deposition. Metals such as aluminium, silver, copper or chromium are used for metallization. To get transparent metallization zinc sulphide is used. It provides nearly 40% reflection. It is used for high security applications. After the metallization, the medium is ready for embossing the hologram. After embossing the hologram, an adhesive is further coated on the film to apply it on the paper or some other substrate. The various adhesives used here are based on water, solvent, and hot melt. The cross-sectional view of a temper evident holographic embossing foil is shown in Fig. 2.2.

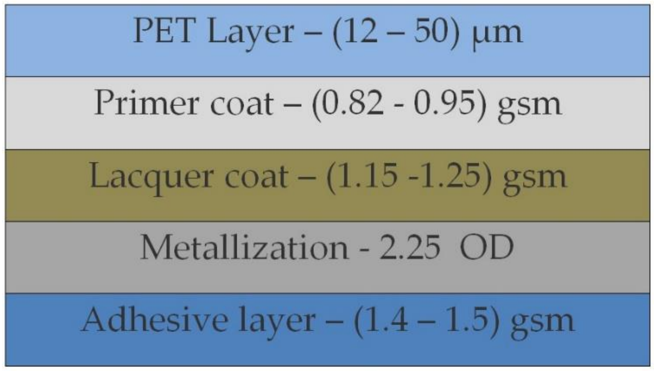


Figure 2.2: General composition of tamper evident holographic foil

The composition of the non-tamper evident base foil is same as temper evident base foil. Two-layer coatings namely primer coat, which is a film surface bonding coat and lacquer coat are applied on carrier PET film. Both coatings are acrylic based coatings. Metallization is same. Metals such as aluminium, silver, copper or chromium are used for metallization. After embossing the hologram, an adhesive is coated on the film to apply it on the paper or some other substrate. Hot stamping holograms are hologram manufactured by dry printing process where heat and pressure is used to apply metallic foil or holograms to substrates such as paper, board, and plastics. Carrier films of thickness 15 m, 19 m and 23 m are used. It is a three layer coating (release coat, lacquer coat and impossible lacquer coat). Then metallization is done. Aluminium metallization is mainly used. An adhesive is coated on the film, after embossing the hologram. Cold foil method includes printing UV glue on the substrate then laminating hologram films on the substrate and UV curing the substrate. It is a three layer coating system.

2.3. Holograms and related foils used for the experiment

This section shows the holograms and related foils used for the experiment. 10 Master holograms, 16 Counterfeit holograms, 10 CDIT Holograms , 8 KP Holograms, 10 silverfoil1, 10 pinkfoils 1 gold foil, 1 silverfoil2, 1 Genuine gold foil, 1 2.5mm Lence, 1 Kurz foil, 5 Kurz holograms, 3 Security Holograms 1 and 5 Security Holograms 2. These holograms and foils were used because they were accessible and the foils were the most common foils used in the manufacturing of security holograms.

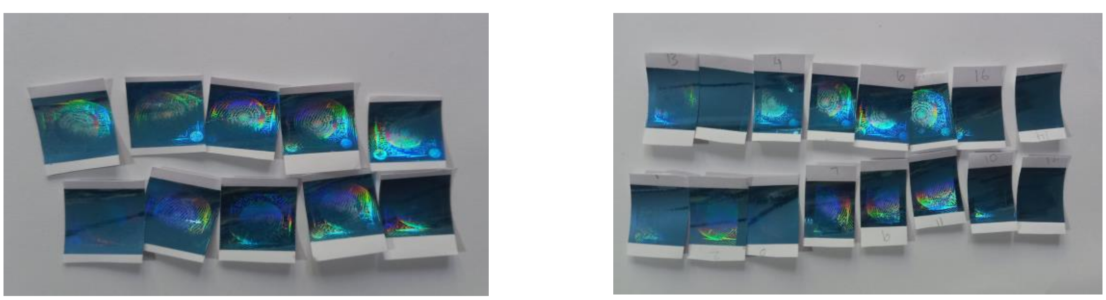


Figure 2.3: (a) Master Holograms (b) Counterfeit Holograms

Figure 2.4: (a) CDIT Holograms (b) KP Holograms

Figure 2.5: (a) Silver Foil 1 (b) Pink Foil

Figure 2.6: (a) Gold Foil (b) Silver Foil 2

Figure 2.7: (a) Genuine Gold Foil (b) 2.5 mm Lence (c) Kurz Foil

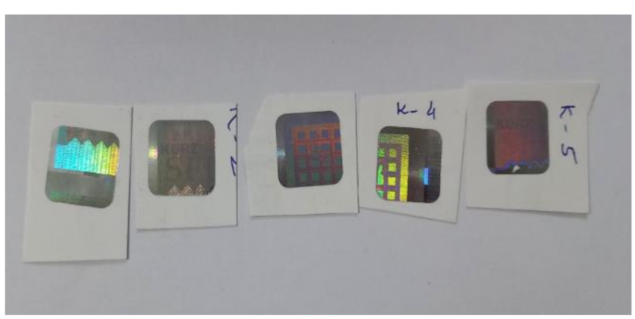


Figure 2.8: Kurz Holograms

2.4. Observations

This section shows the speckle patterns of holograms and related foils obtained from the experiment.

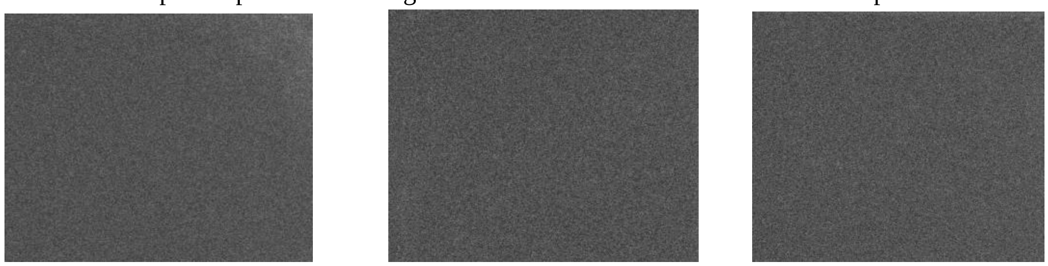


Figure 2.9: Speckle Pattern of (a) Master1 Hologram (b) Master2 Hologram (c) Master Hologram3

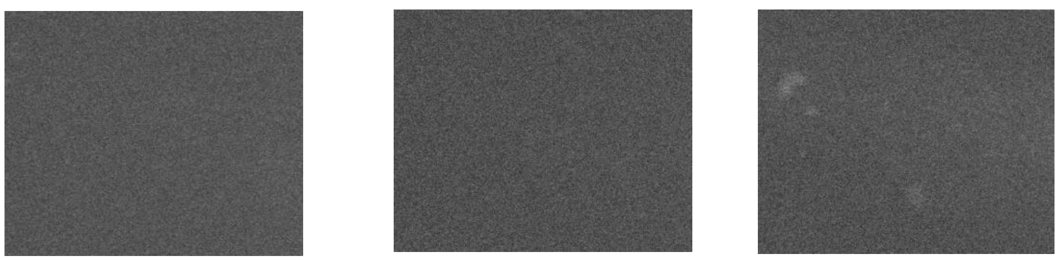


Figure 2.10: Speckle Pattern of (a) Counterfeit1 Hologram1 (b) Counterfeit2 Hologram (c) Counterfeit3 Hologram

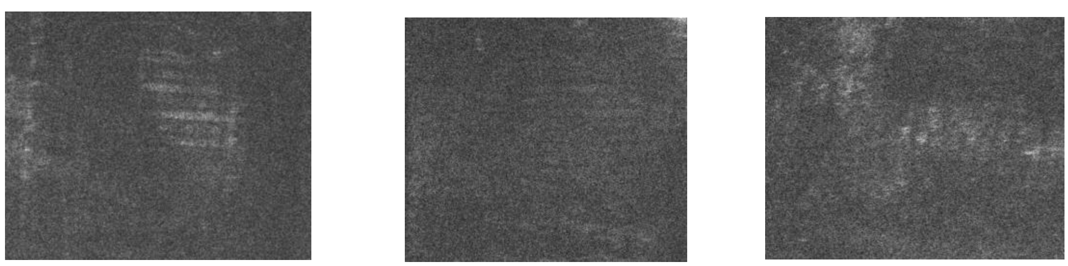


Figure 2.11: Speckle Pattern of (a) CDIT1 Hologram (b) CDIT2 Hologram (c) CDIT3 Hologram

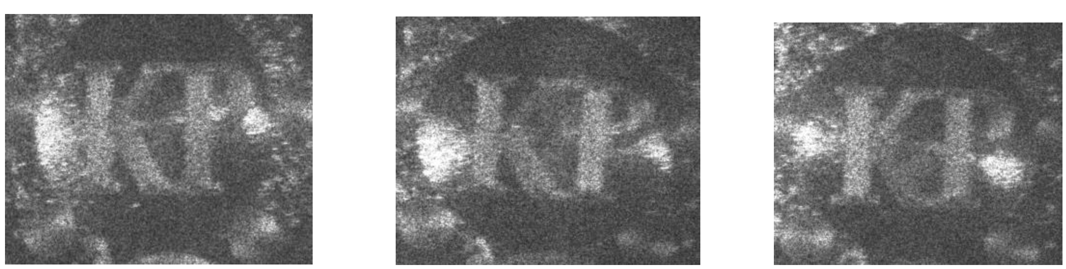


Figure2.12 Speckle Pattern of (a)KP Hologram1 (b) KP Hologram2 (c) KP Hologram3

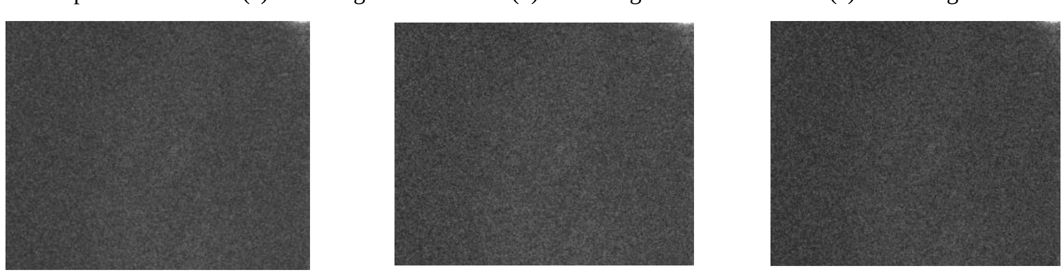


Figure 2.13: Speckle Pattern of (a) Silver Foil 11 (b) Silver Foil 12 (c) Silver Foil 13

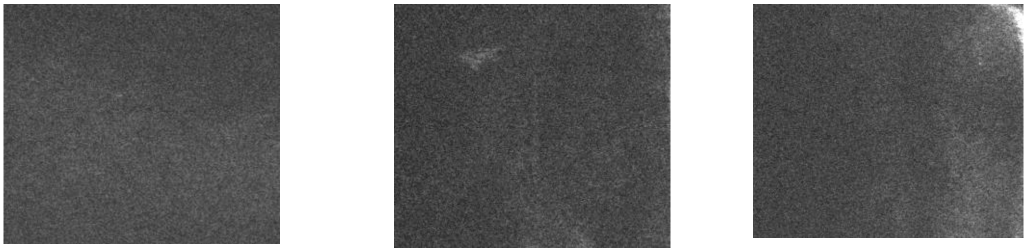


Figure 2.14: Speckle Pattern of (a) Pink Foil1 (b) Pink Foil2 (c) Pink Foil3

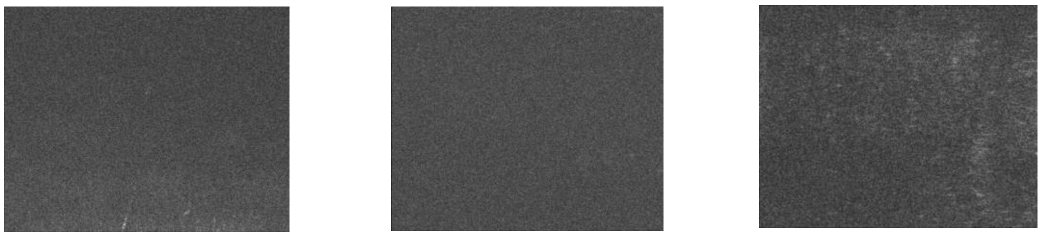


Figure 2.15: Speckle Pattern of (a) Gold foil1 (b) Silver Foil 21 (c) Kurz Hologram1

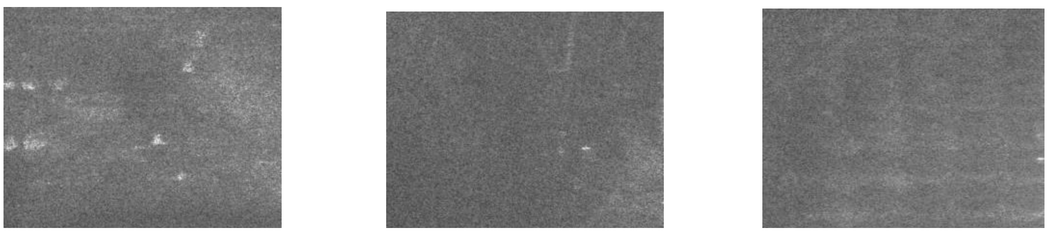
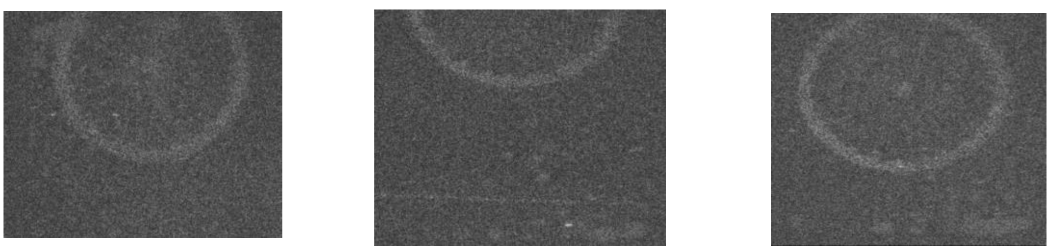
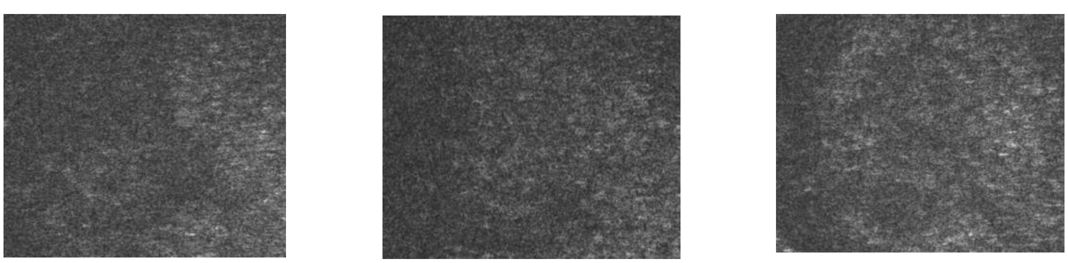


Figure 2.16: Speckle pattern of (a) Genuine Gold foil (b) Kurz Foil (c) 2.5mm Lence



(a) Security Hologram11 (b) Security Hologram12 (c) Security Hologram13

Figure 2.17: Speckle Patterns of Security Holograms 1



(a) Security Hologram21 (b) Security Hologram22 (c) Security Hologram23

Figure 2.18: Speckle Patterns of Security Holograms 2

The speckle patterns of different holograms and foils are different. This is due to their differences in compositions. While examining the master holograms, the speckle patterns are same. The speckle pattern of Counterfeit3 is different from other counterfeits. This may be due to the noises present.

2.5. Calculation of speckle size

Speckle size is the most important statistical property of a speckle pattern. The speckle size is calculated using MATLAB. To estimate the speckle size, the normalized auto covariance function of the intensity speckle pattern is calculated [6]. The sum of auto covariance of all horizontal arrays of the speckle pattern is calculated and normalized. The same is done for vertical arrays. These normalized horizontal and vertical values are fit into a Gaussian curve and the fit is performed. The size can be extracted as both horizontal and vertical size. Its outputs are the FWHM values of Gaussian fits to two arrays generated by the sum of normalized auto covariance of all rows and all columns in the image. The outputs are actually values at which Gaussian fall to 0.5 [7].

3. RESULTS AND DISCUSSIONS

3.1 AFM Results

The results of samples from Atomic Force Microscopy (AFM) imaging are also shown below. Contact mode AFM was used to image the samples. The samples used were a master hologram, a CDIT hologram, a KP hologram and a pink foil. The AFM of the samples of area 20 μm is shown below.

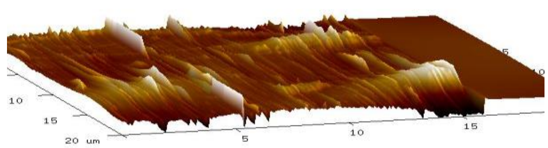


Figure 3.1: AFM image of Master Hologram

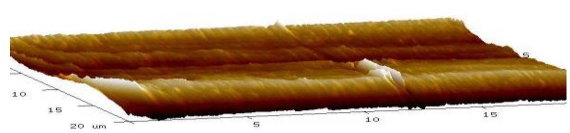


Figure 3.2: AFM image of CDIT Hologram

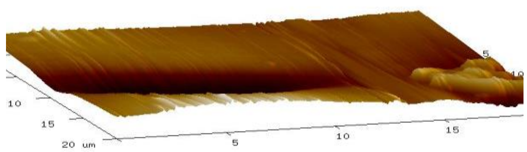


Figure 3.3: AFM image of KP Hologram

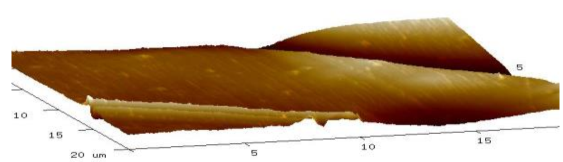


Figure 3.4: AFM image of Pink Foil

The AFM images are different for different samples. This implies that the structural variations and material compositions of the samples are different from one another.

3.2 Speckle size Calculation Results

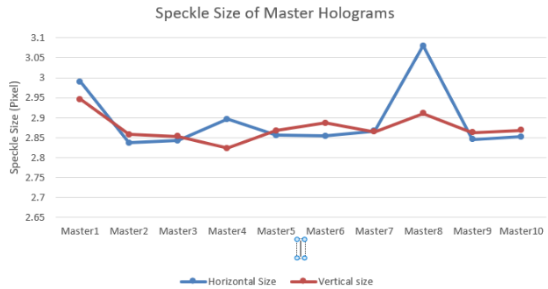


Figure 3.5: Speckle Size of Master Holograms

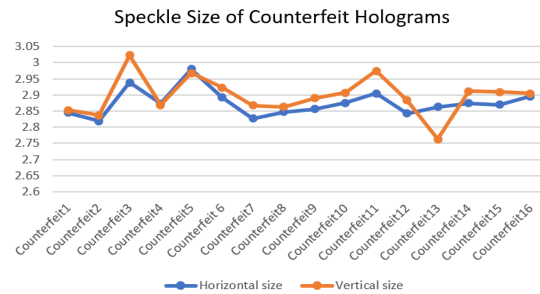


Figure 3.6: Speckle Size of Counterfeit Holograms

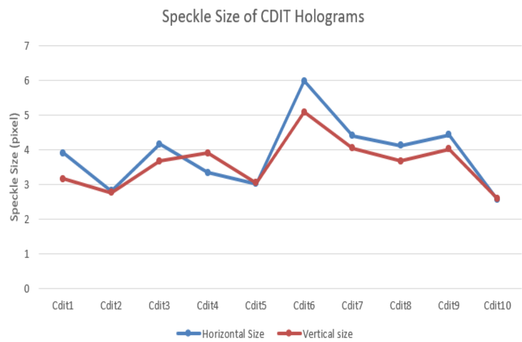


Figure 3.7: Speckle Size of CDIT Holograms

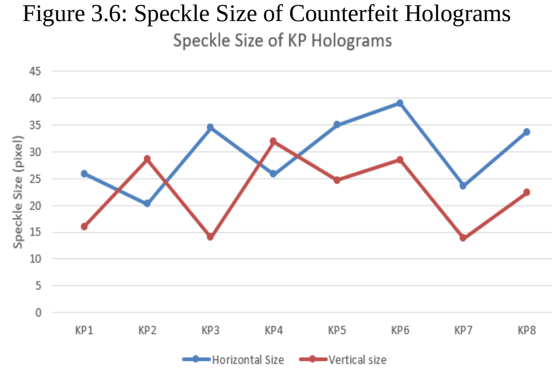


Figure 3.8: Speckle Size of KP Holograms

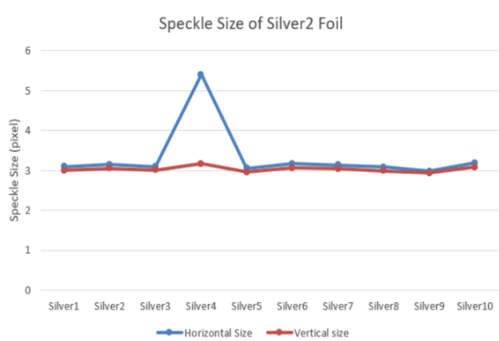


Figure 3.9: Speckle Size of Silverfoils

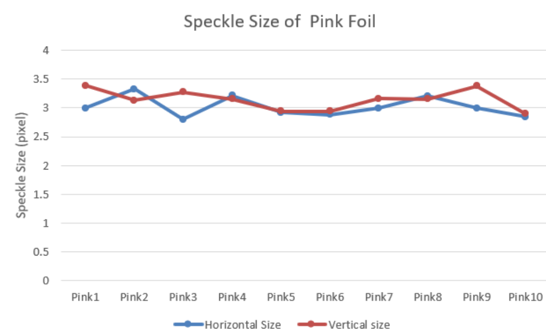


Figure 3.10: Speckle Size of Pink Foils

Figure 3.11: Speckle Size from various foils

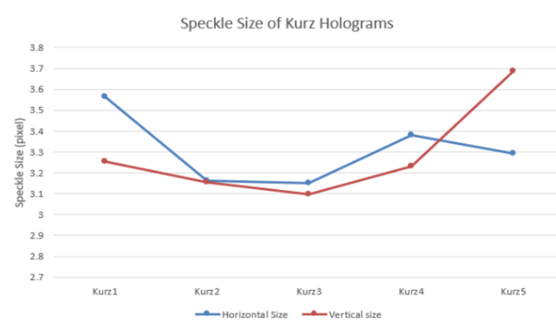


Figure 3.12: Speckle Size of Kurz Holograms

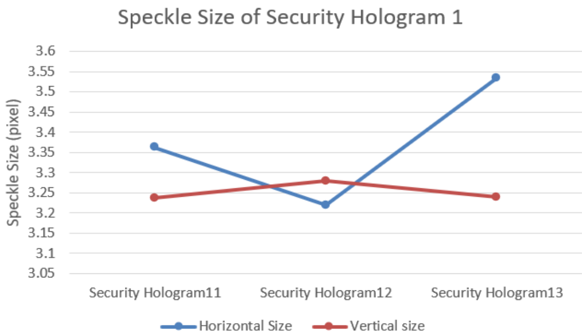


Figure 3.13: Speckle Size of Security Holograms 1

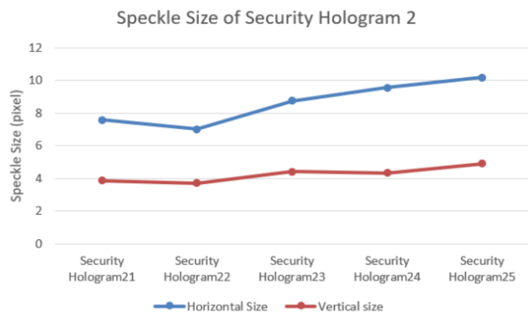


Figure 3.14: Speckle Size of Security Holograms 2

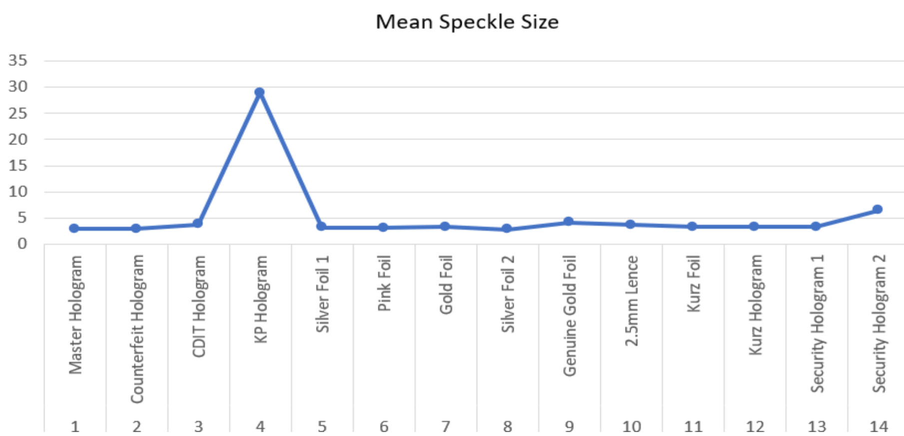


Figure 3.15: Mean speckle Size of Security Holograms and related foils

Table 1. Mean Speckle size of Holograms and related foils

Sl. No.	Name	Mean Speckle Size
1	Master Hologram	2.882757
2	Counterfeit Hologram	2.885886
3	CDIT Hologram	3.743119
4	KP Hologram	28.95802
5	Silver Foil 1	3.182074
6	Pink Foil	3.078693
7	Gold Foil	3.290697
8	Silver Foil 2	2.828532
9	Genuine Gold Foil	4.097158
10	2.5mm Lence	3.697901
11	Kurz Foil	3.267125
12	Kurz Hologram	3.297915
13	Security Hologram 1	3.311729
14	Security Hologram 2	6.438651

The above figures show the speckle size of holograms from the various foils calculated by using the Matlab. Both horizontal and vertical sizes of speckles are calculated, which gives an accurate measure of the speckle size. Since there are a large number of values for speckle size, it is better to take the mean speckle size for the inference of the study. The table 1 shows the mean speckle size of security holograms and related foils obtained by calculating the mean of both horizontal and vertical sizes of them.

From the above figures, it can be concluded that the speckle size of master holograms, counterfeit holograms, CDIT holograms, Security hologram 1, silver foil1, pink foil, gold foil and silver foil 2 are in the range of 2-4 pixels. On the other hand the speckle size of Genuine Gold foil and 2.5 mm Lence foil are in the range of 3-4 pixel. Kurz hologram and Kurz foil have speckle size in the range of 3 pixel. KP holograms and Security Holograms 2 have speckle size in the range of 28 pixels and of 6 pixels respectively.

4. CONCLUSIONS

The speckle size of speckle patterns of holograms and related foils are calculated using MATLAB. By studying the speckle size of the holograms and related foils it can be concluded that the speckle patterns of holograms and related foils are generated from the structural variations and material composition of the samples rather than from the holographic thickness variations in the nanoscopic levels. It is confirmed from the speckle size parameters of the samples. The master holograms, counterfeit holograms, CDIT holograms and Security hologram 1 are rasik foil based and they have speckle size in the same range of 2-4 pixels. The silver foil1, pink foil, gold foil and silver foil 2 are also rasik foil based and they also have speckle size in the range of 2-4 pixels. Genuine Gold foil and 2.5 mm Lence foil are security foil UK based and have speckle size in the range 3-4 pixels. Kurz hologram and Kurz foil based on Kurz foil and have speckle size in the range 3 pixels. All the holograms that are mentioned above are sticker-based tamper evident holograms. The KP Hologram and Security hologram 2 are applied on paper by hot stamping method. Thus, the speckle size varies from the sticker-based tamper evident holograms. KP holograms have speckle size in the range of 28 pixels. Security Holograms 2 have speckle size in the range of 6 pixels. From the results, the speckle size of the same kind of holograms and foils are in the same range. Thus by categorizing them based on their speckle size the feasibility of analyzing the quality and authenticity of the security holograms and related foils can be assured. A more realistic approach can be done by calculating the speckle sizes for light of different wavelengths.

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