Testing the Universal Hologram Scanner*

A picture can speak a thousand words

Rudolf L. van Renesse

In addition to exposing fake DOVIDs –if visually deceptive– diffractive signatures reveal information about the production techniques used by their creators, thus allowing counterfeits to be categorized efficiently. Unfortunately, a microscopic examination (mapping) of a complete DOVID is extremely time consuming. A problem that is successfully overcome by the Universal Hologram Scanner, which projects, records and analyses DOVID diffractive patterns in a fraction of the time. Rudolf van Renesse tests a Universal Hologram Scanner and discusses its functionality and potential.

Introduction

These days, the term “hologram” appears to be loosely used for all optically variable devices that are based on the diffraction of light by gratings. However, the term literally means “complete recording” and it was introduced in 1947 by the inventor of holography Dennis Gabor (1900-1979), specifically for those recordings that contained phase and amplitude information of a wavefront and allowed the three-dimensional reconstruction of an object emitting this wavefront. In this sense, the majority of current diffractive devices are not holograms at all, and calling them that does no justice to the “father of holography”.

This is why Ian Lancaster of Reconnaissance International in 1995 introduced the generic term *diffractive optically variable image device* (DOVID), which comprises all security devices that are based on the diffraction of light by fine gratings. Examples are true holograms –which by definition display three-dimensional images– and numerous types of flat diffractive artwork. A well-known example of a true hologram is the three-dimensional dove on VISA cards, while examples of flat artwork are the Kinegram® strips (OVD Kinegram Corp., Switzerland) on the lower denomination euro notes and the Alphagram® patches (Hologram Industries, France) on the higher euro denominations.

The fringe frequency of DOVID diffraction gratings generally ranges from about 800 to 1900 fringes per millimeter and such fine fringes can only be observed under a good optical microscope. All optical effects displayed by DOVIDs are based on the spatial distribution of fringe frequency and fringe orientation of its gratings. It is this particular spatial distribution of fringe parameters over the various image elements of a DOVID that forms a specific “signature” of the DOVID, and re-originated counterfeits and imitations tend to have markedly different signatures.

Although fake DOVIDs can sometimes be visually deceptive, their diffractive signatures not only expose them as a counterfeits, but they also reveal information on their production method and show potential to adequately categorize counterfeits.

Rudolf L. van Renesse (1940) worked as a senior research engineer for TNO Institute of Applied Physics, Delft (The Netherlands), between 1966 and 2002. He subsequently founded VanRenesse Consulting, established in The Hague (The Netherlands). Van Renesse is involved in document security projects for government departments, financial institutions and industrial companies both in the Netherlands and abroad. He is the author of the textbook ‘Optical Document Security’ and organizes the biannual conferences on ‘Optical Security and Counterfeit Deterrence Techniques’ in San José, CA, USA.

* Published in the Keesing Journal of Documents & Identity, Issue 12, 2005, pp. 7-10 (authorized text version).

The mapping by microscopic analysis of the distribution of grating parameters over the complete DOVID area would obviously be extremely time-consuming. However, by projecting and recording the diffraction patterns of a DOVID, this mapping can be done very fast. In 1998 Steve McGrew of New Light Industries (NLI, USA) announced the development of dedicated hologram scanning equipment for this purpose: the Universal Hologram Scanner (UHS). Since 2000 the UHS is in use for forensic investigations at the Counterfeiting Intelligence Bureau, part of the Commercial Crime Services division of the International Chamber of Commerce (ICC) in London (Holography News, Volume 15, No. 5/6, August 2001, pp. 8/9). I recently carried out extended experiments with the UHS at the ICC and in the following I report on its basics and its potentials. A few of my experimental findings are reported in Holography News, Vol. 18, No. 9, October 2004, pp.3-4.

Diffraction of light

As an introduction to the UHS, a brief discussion of light diffraction by fine line gratings may serve. The phenomenon of light diffraction is abundant; daily life examples are the colorful patterns that we see when looking at a point source through fine lace or the minute barbule arrangement of a bird's feather, and the colorful reflections of CD-ROMs with their microscopically fine, regular traces of digital information. Figure 1 shows a simple line grating that diffracts a monochromatic light beam into a set of diffraction orders symmetrically about the undiffracted part of the light beam: the zero order. The orientation of the plane of diffracted beams is perpendicular to that of the grating fringes. The angle of diffraction increases with the fringe frequency and, as Figure 2 shows, with the wavelength. To further illustrate these principles, Figure 3 gives a few specific examples of gratings and their diffraction patterns. The distance from the center of the diffraction pattern (the zero order) is a measure of the fringe frequency, while the angular orientation of the diffraction orders is a measure of the fringe orientation. Experimenting with the beam of a laser pointer and fine regular structures, such as silk screen, fine metal mesh and bird's feathers, will further assist the reader to comprehend the discussion of diffraction patterns presented here. The multiple diffractions of a laser pointer beam off holograms on ID-cards can sometimes have a right out stunning complexity.

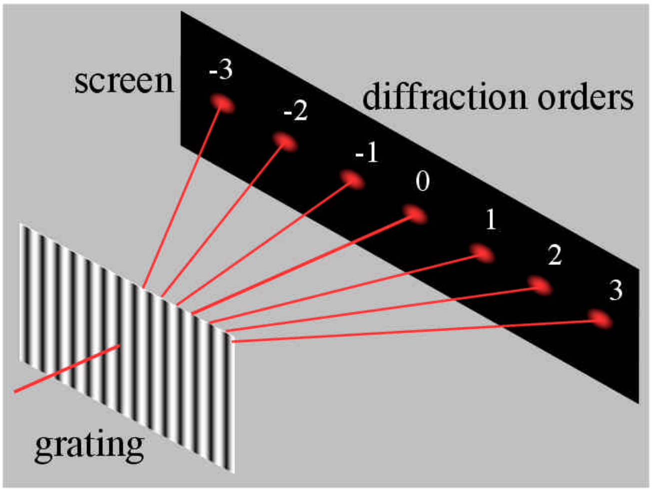

Figure 1 – Schematic illustration of the diffraction of a monochromatic light beam by a grating into a zero order and higher orders. The fringe frequency is not to scale but amounts hundreds to thousands of fringes per mm.

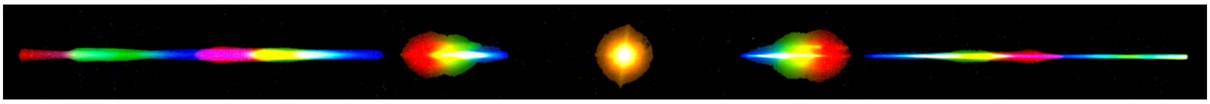

Figure 2 – Three orders of the diffraction pattern of a line grating illuminated with a white light beam, showing the larger diffraction angle of longer wavelengths. The red of the 2nd order overlaps the violet of the 3rd order, to render magenta.

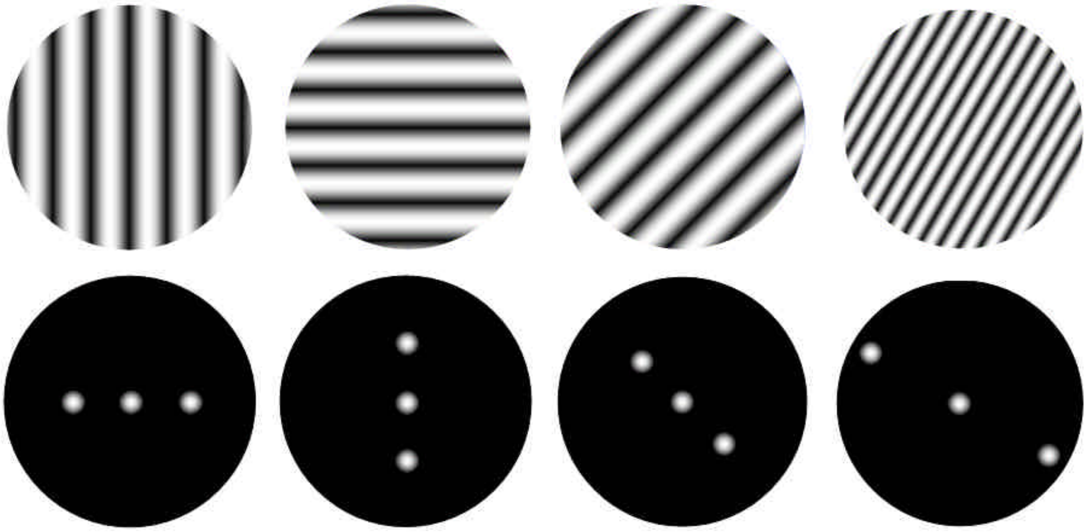

Figure 3 – The relation between grating parameters (top) and the pattern of the diffracted orders (bottom). Only the zero order and both first orders are shown. The light source is monochromatic.

Imagine a DOVID of which the various image elements are composed of the gratings depicted in Figure 3. Scanning its total surface by a monochromatic light beam, and sampling all resulting diffraction patterns, results in the integrated diffraction pattern shown in Figure 4. In order to identify the various diffraction orders, these have been connected by colored lines, while a circle of constant frequency is drawn through the low frequency orders. To a good approximation this diffraction pattern represents the spatial frequency domain (the Fourier plane for intimates) of the DOVID. The beauty of this approach is that, without lengthy microscopic analysis, this pattern immediately reveals the distribution of fringe orientations and frequencies of the DOVID. And because all optical parameters of the scanning system are known, the sampled diffraction pattern can be unwrapped by conversion from polar to rectangular coordinates and fringe orientation versus fringe frequency can be plotted.
Figure 5 shows the result of the conversion of the diffraction pattern in Figure 4 into an orientation-frequency diagram (OF-diagram), the signature of the DOVID. The zero order comprises all possible orientations and forms a band at low frequencies, without particular significance. The colored lines connecting the various orders are transformed to horizontal lines of constant fringe orientation in the OF-diagram, while the circle of constant frequency, of course, becomes a straight vertical line in the OF-diagram.

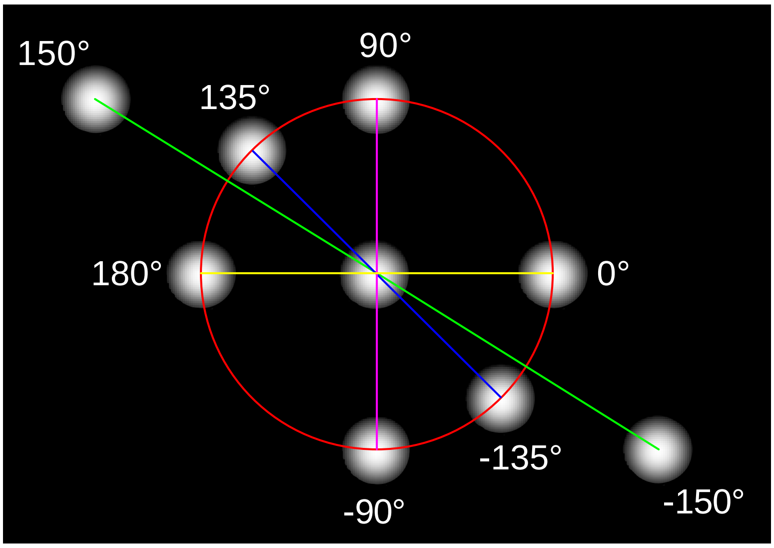

Figure 4 – Combined diffraction pattern of a DOVID composed of the gratings shown in Figure 3.

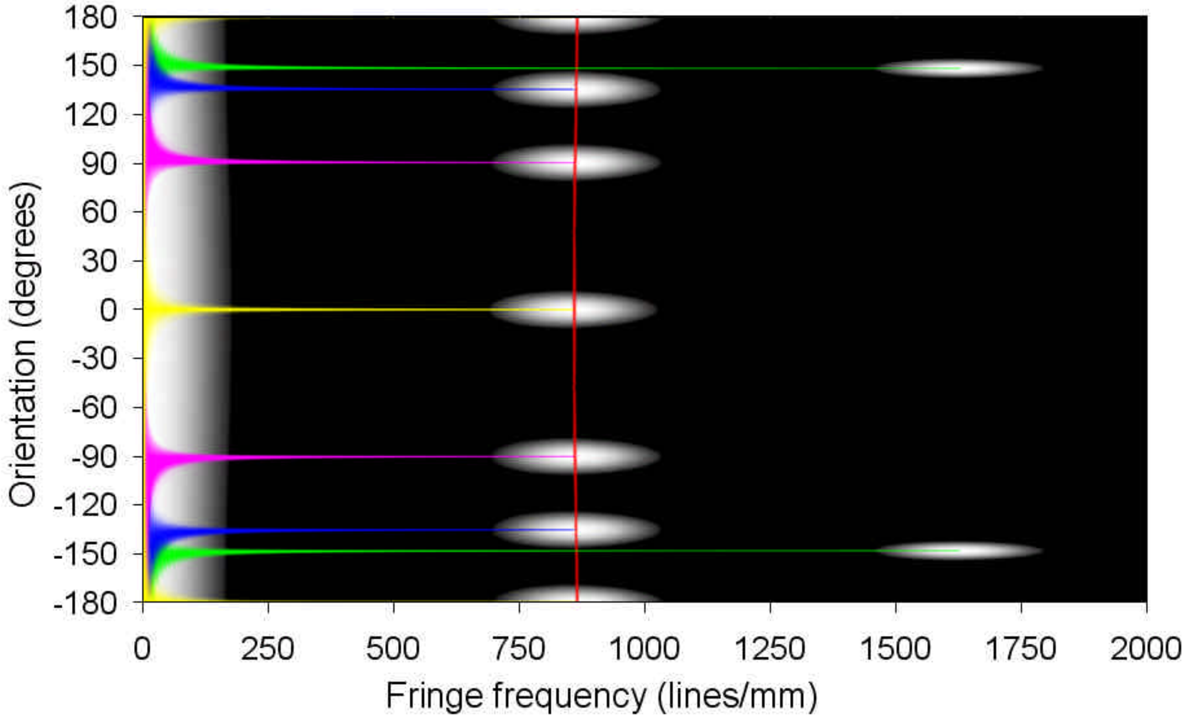

Figure 5 – Orientation-frequency analysis (OF-diagram): orientation versus fringe frequency by unwrapping the diffraction pattern of Figure 4.

The Universal Hologram Scanner

The above describes the optical principle of the UHS. Because DOVIDs are reflective devices almost without exception, the UHS operates in reflection and not in transmission and a possible UHS optical set-up is sketched in Figure 6. A laser diode beam is focused onto the DOVID through a hole in a screen and the diffracted light is projected onto this screen. Via the beam-splitter the screen is then imaged onto an image sensor, which integrates the successive diffraction patterns that result during scanning of a predefined area of the DOVID by means of an XY-stage.

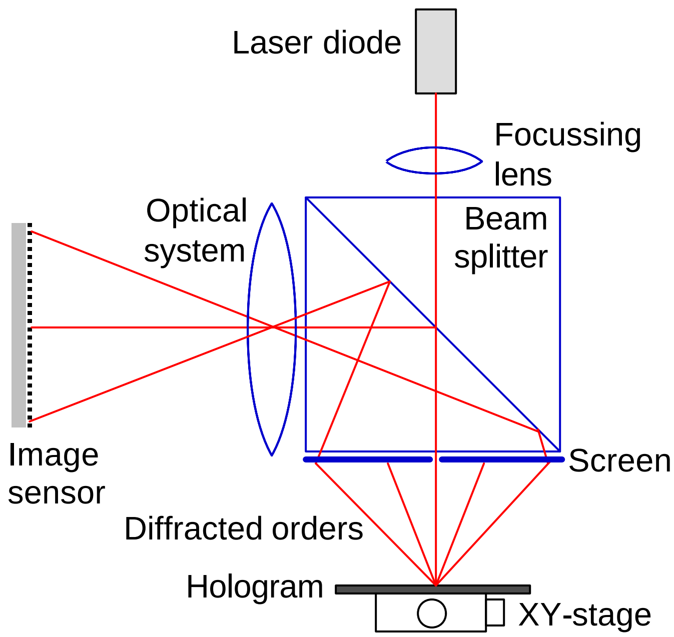

Figure 6 – Possible optical set-up of the laser scanning unit of a Universal Hologram Scanner.

Additionally to this laser scanning unit, the UHS is equipped with a color video camera with macro-zoom lens. The color camera station is used for defining the scan area, and for visual analysis and overlay comparison of DOVID artwork in fine detail. In this way dfferences in size, fonts, position of image elements and image details can be revealed by comparing a suspect DOVID to a previously stored image from the UHS database.

With the use of the UHS at the ICC in London numerous analyses were made of DOVIDs and their counterfeits, amongst others by comparing OF-diagrams of questioned DOVIDs with those of genuine samples. The scanner uses a parallel processing chip and proprietary software to carry out the comparisons. For example, the UHS has revealed beyond doubt that certain suspected counterfeit DOVIDs in Eastern Europe were actually made from an original embossing shim, which lead to the discovery that a shim had been stolen rather than having been remastered. (Holography News, Vol. 16, No. 8, November 2002, p. 8). But falsifying and verifying DOVIDs is not the main potential of the UHS; after all, every expert claims to be able to perform that task with the use of a microscope, if not with the naked eye. Its strength is the presentation of irrefutable evidence of differences or the lack of these between DOVIDs, which evidence can be presented in court in a standardized and comprehensible manner, without requiring a haphazard stipulation of numerous expert details.

The OF-diagram also allows determining differences in laser wavelength, holographic technique, holography table layout, and dot-matrix printer signatures. Further, a most significant application of the UHS can be to help forensic experts worldwide in categorizing DOVIDs according to their diffractive signatures. Rather than using circumstantial and non-standardized descriptions derived of the spatial domain, the OF-diagram provides a coherent and standardized representation in the frequency domain of the essential DOVID characteristics. Storing categorized OF-diagrams in databases of DOVIDs and their counterfeits will aid in efficiently finding similar counterfeits and recognizing the hand of individual counterfeiters and their equipment. It is said that a picture is worth a thousand words!

Examples of UHS investigations

Unfortunately, not all UHS investigations, however interesting, appear suitable for publication because of their confidential nature. A few examples are given below as a demonstration of the potential of the UHS.

The UHS has revealed the existence of three distinct, genuine VISA dove originations, two of which are presented in Figure 7. The banana shaped diffraction patterns are typical for rainbow holograms and represent a distorted view of the slit shaped hologram (the “H1”) that is the starting point for producing rainbow holograms and an essential part of the rainbow holographic set-up. Although the original dove models only differ in minute details, the OF-diagrams reveal that the slits had a significantly different angular width. This is an example where details of the holographic set-up have been exposed.

Another example is the “coffeepot” rainbow hologram used on *Head and Shoulders* shampoo packing. Figure 8 shows the original hologram and a fake. In this case the fake hologram had quite unusual diffraction angles, so that at normal incidence illumination no first orders were diffracted and only zero order noise was returned. The fake hologram was traced to its source by the CIB, which in turn led to the producers of the fake shampoo (Holography News, Volume 15, No. 5/6, August 2001, pp. 8/9).

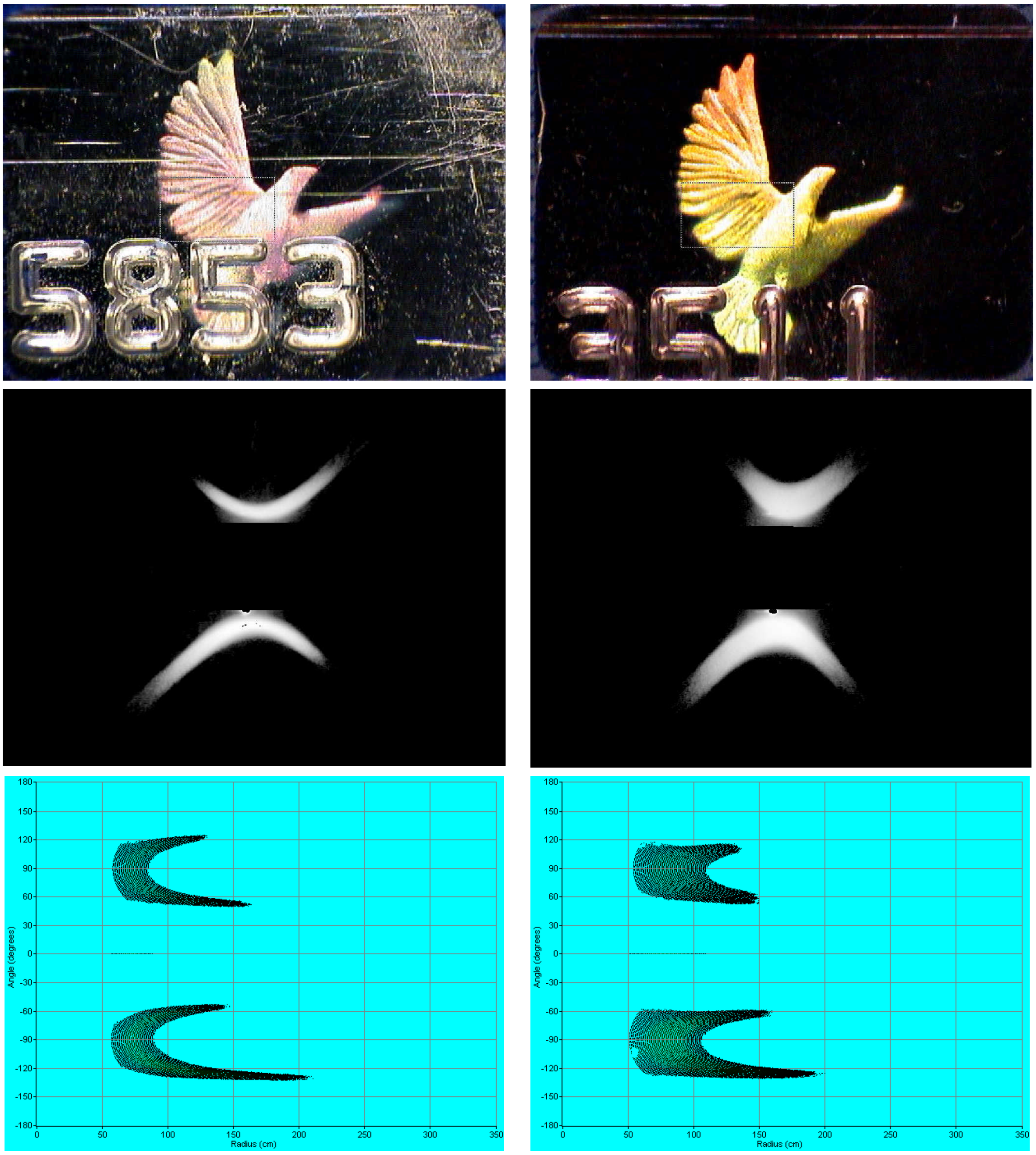

Figure 7 – Two distinct, genuine VISA dove originations (top), their diffraction patterns with zero order noise eliminated (center) and their OF-diagrams (bottom). Courtesy of Steve McGrew (NLI, USA).

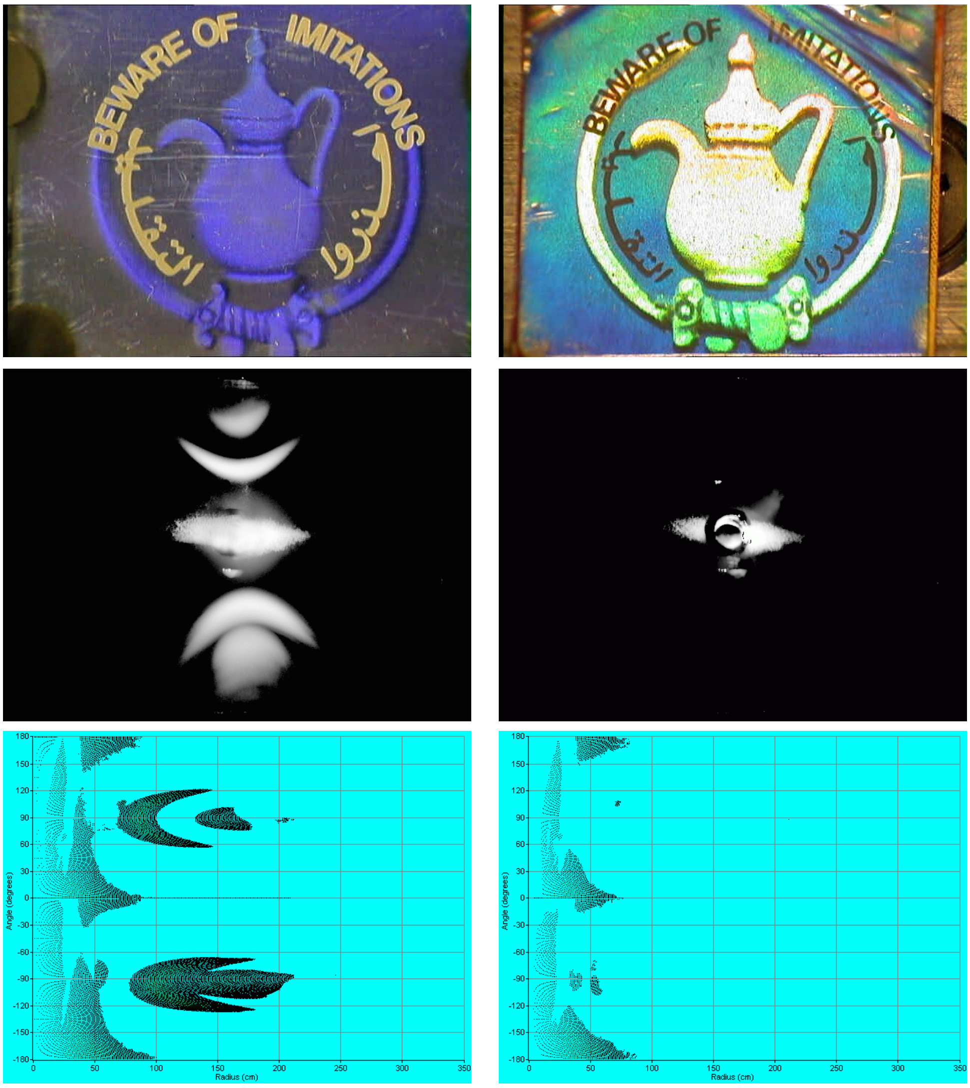

Figure 8 – “Coffeepot” holograms: original (top left) and counterfeit (top right), their diffraction patterns inclusive zero order noise (center) and their OF-diagrams (bottom).

Discussion

An important feature of the UHS is that it provides orientation versus frequency data of any selected area of any type of DOVID without requiring the operator to make numerous angular adjustments and readings of light source and photoreceptor and without the need for special optical features such as machine readable bar codes or hidden images. The UHS automatically scans the selected DOVID area and returns images of diffraction patterns and OF-diagrams. According to McGrew it has also appeared feasible to analyze semi-transparent overlay DOVIDs.

Considering the fact that current security holograms are generally far too complex to allow reliable first-line inspection, it is unreasonable to expect clerks or untrained consumers to distinguish between genuine and fake. Therefore, NLI is developing a Universal Hologram Reader (UHR) – derived of the UHS– that allows fast at the counter verification and falsification of any type of DOVID, independent of dedicated machine readable features. NLI proposes to incorporate a UHR into magnetic card swipe readers used in processing credit- or debit-card transactions. In the many countries where the currency carries a DOVID, another version of such a reader might be used for fast detection of counterfeit notes. NLI has built several test prototypes of the UHR driven by very high-speed computer chips, but commercial versions are still in the development stage. It will be extremely interesting to see how this development matures.