3-D Image Reconstruction of Nuclear Tracks Induced in CR-39 Detectors by means of Digital Holography

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Digital holography has several features that make it a powerful alternative to conventional microscopy; among them improved focal depth, possibility to generate three-dimensional images and phase contrast images[?]. In this paper we present the 3-D image reconstruction of nuclear tracks in CR-39 detectors. Digital Holographic Microscope experimental set-up is given[?]; designed for transmission imaging with transparent sample. A linearly polarized He-Ne laser (15 mW) is used as light source. The digital hologram (DH) is recorded by CCD camera (PULNIX model TM-9701) and transmitted to a computer via Frame Grabber card. The DH $Ih(k,l)$ is an array of 640x480 8-bit-encoded numbers that results from the two-dimensional sampling of $Ih(k,l)$ by the CCD camera. With DH it is possible to reconstruct the wave field of the object for different reconstruction distances, so that different reconstructed 2-D images can be established and tha is digitally and numerically extracted from the observed hologram pattern using the Fresnel diffraction equation **??**.

$$\phi(x',y',d') = arctan\left(\frac{\Re\left(\Psi(x',y',d')\right)}{\Im\left(\Psi(x',y',d')\right)}\right) \quad (1)$$

The result of calculations is an array of complex numbers called wave front $\Psi(x',y',d')$, which represent the complex amplitude of optical field in the observation plane $0x'y'$. The distance between hologram plane $0\xi,\eta$ and observation plane is defined by the reconstruction distance d'. Since (x',y',d') is an array of complex numbers, a 2-D amplitude-contrast image is obtained by calculating the intensity with equation **??**

$$I(x',y',d') = \Re\left(\Psi(x',y',d')\right)^2 + \Im\left(\Psi(x',y',d')\right)^2 \quad (2)$$

and a 2-D phase-contrast image by equation **??**. Phase values calculated lie in the range $-\pi$ to $+\pi$; this means that calculating the complex map sequence of field $\Psi(x',y',d')$ for various reconstruction distances d', separated by a distance $\Delta d'$, the continuous phase distribution can be determined by equation **??**;

$$\phi(x,y,d'_z) = \sum_{d'=d'_f}^{d'_s} \phi(x,y,d') \quad (3)$$

where d'_f and d'_s are the distances from CCD to the track end and to the upper top of detector surface. These two distances can be determined experimentally using the intensity image reconstruction and auto focus techniques. The distinctive feature of this method is that only one hologram is needed to unwrap the whole 3-D phase field. Figure **??** shows a digital hologram of a selected area in the CR-39 detector, which was irradiated with 5.48 MeV α-particles from ^{241}Am (etched 4 h, 6 N NaOH at 70^{o}C). From the hologram, the reconstructed amplitude-contrast images was determined for d' ranging from 180 mm to 225 mm and with $\Delta d'$=1 mm. The sequence of intensity distribution was combined to obtain the image in figure **??**. It is

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observed that a point shaped intensity pattern is obtained at the reconstruction distances corresponding to the distance from the hologram plane to focusing distance of each track bottom. This example shows that numerical reconstruction of holograms provides an efficient method for visualizing virtual focusing of microscopic sample. Quantitative analysis of geometrical shape and its main parameters rely on the ability of Digital Holographic Microscopy to provide information not only about intensity, but also on the phase distribution of the optical wavefield at different planes from the recorded hologram. Applying the developed 3-D reconstruction method, the continuous phase distribution was obtained (figures **??** and **??**). Height distribution $h(x, y)$ on the sample surface is proportional to the reconstructed phase distribution $\phi(x, y)$[**?**]. It means that phase changes can be measured on the basis of reconstructed phase-contrast image. Accordingly, the reconstructed phase distribution can be used for quantitative measurements as figure **??** and **??** illustrate. Dimensional volume parameters and profile forms of nuclear tracks can be estimated. The volumetric characteristics of tracks induced by normal incidence of alpha particles on detector surface as well as three-dimensional visualization of detector surface irregularities is well evidenced. Surface roughness of CR-39 detector after the etching process can also be evaluated. Through the 3-D representation is possible to determine the fundamental geometric parameters as minor axis a, major axis b, length L and incident angle ϕ. With the determination of these morphometric parameters it is possible to characterize the incident particle and particularities of etching process. It was demostrated that microholographic method constitutes a new an alternative procedure providing high resolution imaging of tracks by DH and it can be a very useful tool to study track formation and etching mechanism of tracks in detectors. The present work was supported by the Brazilian research agencies CAPES and FINEP and by the National Fund of Science, Technology and Innovation (FONACIT), Venezuela, under contract number S1-2001000954.

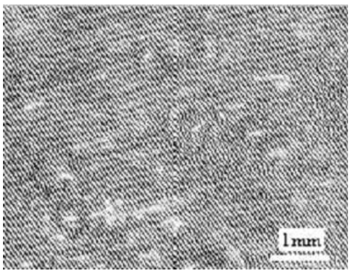

Figure 1: CCD recorded digital hologram.

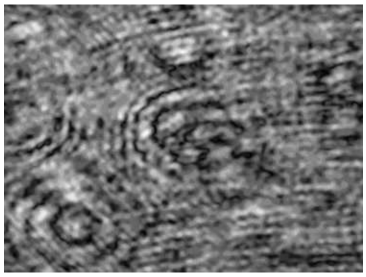

Figure 2: Digitally reconstructed object.

References

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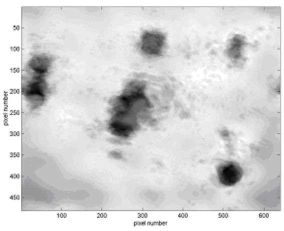

Figure 3: 2D reconstruction of hologram shown in figure **??**.

Figure 4: 3D perspective of hologram shown in figure **??**.

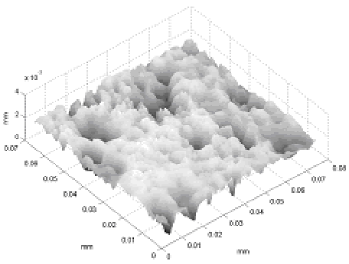

Figure 5: 3D field of view.

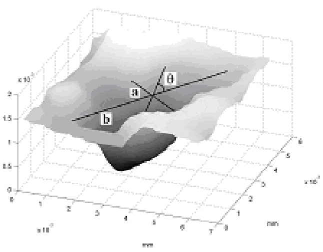

Figure 6: Detail of figure **??**.