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MESOOPTICAL FOURIER TRANSFORM MICROSCOPE FOR NUCLEAR EMULSION

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I. Introduction

For many years the nuclear emulsion has been the most convenient detector for investigation of a large class of nuclear reactions. The nuclear emulsion detector is a stack consisting of 200-600 μm thick photosensitive layers placed into the accelerator beam. Going through the emulsion, charge particles leave their tracks as a series of dots lying along a straight line. After development the emulsion layers are examined by means of a microscope. As the thickness of tracks is very small (1 μm) and the contrast is rather low, it is a tiresome task to find them. The depth-of-focus problem makes the search even more difficult, for very high magnification must be applied. Thus, it takes days to find the reaction and the probability of the success is low (20-50 %).

To overcome these problems and to automatize the search, a conception of a new apparatus called MFTM was put forward[1]. The MFTM is a coherent optical data processing system which gives an optical output signal only if a straight line appears in the input plane. There is an exact correspondence between the place of the output signals and the location and angular direction of the straight lines in the input plane.

II. The principle of MFTM

To understand how the MFTM works let us first discuss the optical system shown in fig. 1. In fig. 1a) a conventional imaging system supplied with an additional L_A concave conical lens (so-called axicon[2]) is shown. The source of light is a parallel laser beam. The lens L_1 forms a convergent beam focused in the plane of the L_2 lens (P_2 or Fourier transform plane). The object to be imaged is placed in the P_1 optical input plane and imaged by the L_2 lens (if we omit the L_A element) to the P_3 optical output plane. Let the object be a pinhole (fig.1b)). In this case the full aperture of the L_2 lens is illuminated by the diffracted light (fig.1c)). If the object is a narrow slot (fig.1e)) then the Fourier spect-

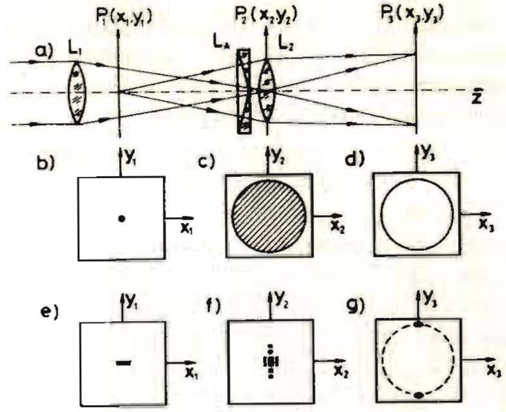

Fig.1

rum is a narrow line-like light distribution perpendicular to the slot (fig.1f)). Let us now modify the Fourier spectrum of the input object adding the L_A concave conical lens which can be treated as a prism with rotational symmetry. In the case of the pinhole we obtain a bright circle in the output plane which we shall call focal circle (fig.1d)), while the image of the slot is doubled: the two images are located in the opposite positions of the circle determined in fig.1d) perpendicularly to the slot (fig.1g)). According to the proposed determination[3] optical systems that produce images with increased dimensionality (e.g. circles from dots) are called mesooptical systems. We will use this nomenclature to stress the difference between a conventional microscope and the MFTM. With adding "Fourier Transform" to the name we would like to express the fact that the functional role of the mesooptical element (the conical lens) is to modify the spatial Fourier spectrum of the input object.

It is important to note that the picture in the output plane P_3 is not an image in the strict meaning of imaging: it is obvious that the circle cannot be considered as the image of the pinhole. The case of a slot is more complicated, because the output "images" (fig.1g)) are really similar to the input object. Actually we would get the same output picture if we replaced the slot with a series of small holes along a straight line. The microstructure of the input object is lost but the information about the arrangement remains.

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As we can see in the case of a dot-like input the energy contained in the dot is spread in a large circle. In the case of a slot considerably bigger energy is concentrated in two spots. Thus the intensity in the output signal is incomparably higher than the noise produced by independent spots, figures of arbitrary shape. Thus, we can say that dot-like input objects, curved lines, spots of arbitrary shape, etc. produce practically no output signals.

Let us now turn to the principal scheme of the MFTM (fig. 2). Instead of the L_2-L_A lens-conical lens combination here we use a lens from which a cone is removed. It is now clear that the straight tracks shown in the picture form their pairs of output signals in the output plane. If the track goes through the optical axis (track No 1) then the output signals appear exactly on the focal circle (signals 1'). If not (track No 2), then the displacement of the output signals is proportional to the displacement of the track (signals 2'). It has also been shown that displacement along the optical axis and declination from the emulsion plane lead to the corresponding displacement of the output signals (see fig. 3).

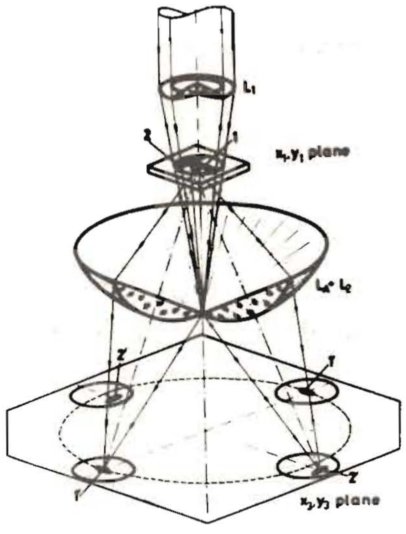

Fig.2

Placing the emulsion into the input plane and scanning over the area to be investigated and observing the bright spot pairs in the surroundings of the output focal circle we can obtain the necessary information about the tracks.

III. The experimental MFTM, results

To avoid the technical difficulties connected with the production of the mesooptical lens, the experimental equipment has a spherically symmetric metallic mirror with an elliptic radial profile, giving the same effect.

The output signals are collected by a rotating CCD-matrix TV-camera. Both output signals of a track are projected into the camera at the same time so we can see two bright spots on the TV-set wherever a track appears in the input plane. This picture is then filtered by a two-level comparator and recorded in a compressed form.

After scanning over the desired emulsion area the collected information is processed and the parameters of the tracks found are given.

Some possible track locations and the corresponding TV-pictures are shown in fig. 3.

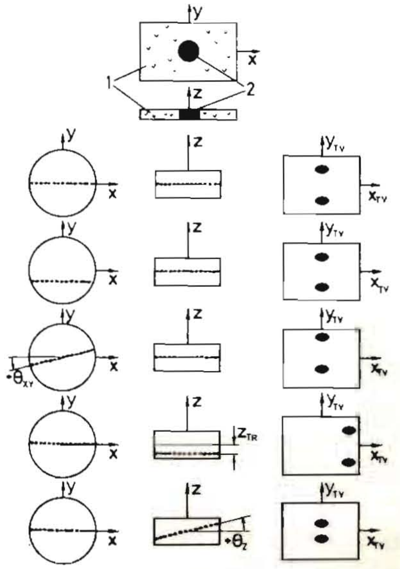

Fig.3

Similar pictures were obtained experimentally by the experimental equipment built in JINR and called MESOSCAN. Experiments have shown that the MFTM can successfully be realized and used in high energy physics. It can also be recommended in other fields to solve similar problems.

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Мезооптический фурье-микроскоп для ядерной фотоэмульсии

Мезооптический фурье-микроскоп /МФМ/ представляет собой когерентную оптическую систему обработки данных, которая дает выходной сигнал только тогда, когда во входной плоскости появляется прямая линия, и может быть использован для поиска прямых линий в сложной входной картине. Показаны принцип работы МФМ и его применение для поиска следов элементарных частиц в ядерной фотоэмульсии.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

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Mesooptical Fourier Transform Microscope for Nuclear Emulsion

Mesooptical Fourier Transform Microscope (MFTM) is a new coherent optical data processing system which gives an optical output signal only if a straight line appears in the input plane and can be used for searching straight lines in a complicated input picture. The principle of operation of the MFTM and its application for searching for tracks of elementary particles in nuclear emulsion are shown.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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