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исследований
дубна

E13-84-310

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MESOOPTICS AND HIGH ENERGY PHYSICS

Submitted to ICO-13 Congress,
Sapporo, 1984.

1984

1. INTRODUCTION

The problem of track chamber vertex detector of high spatial resolution has arisen after the discovery of particles with very small lifetime 10^{-12}–10^{-15} s. To detect the decay of such shortlived particles with high efficiency the spatial resolution Δx must be smaller than 5 μm. Until very recently only the nuclear research emulsion technique with observation through optical microscope met this condition. The main obstacle of using the classical imaging optics in the chamber of high spatial resolution is the universal relation $\sqrt{\lambda \Delta Z} = 2\Delta x$, where λ is the wave length of the light, and ΔZ – the depth of field attained by classical imaging optics. For $\Delta x = 5\ \mu$m, $\lambda = 0.5\ \mu$m we have $\Delta Z = 200\ \mu$m. The depth of field can be considerably extended with the help of holography and mesooptics [1].

2. DEFINITION OF MESOOPTICS

The imaging system is called a mesooptical one if in the geometrical optics approximation the point in the object space is transformed into the straight or curved line of finite dimensions in the image space. The geometrical transformations performed by the mesooptical imaging system can be written as: $0D \to 1D$, $1D \to 2D$, $2D \to 3D$. In general case the n-dimensioal object goes into an $(n+1)$ – or $(n+2)$-dimensional images. There are two main types of mesooptical imaging systems: with longitudinal or with transversal properties. An example of the mesooptical imaging system is an axicon with conical surfaces or a circular diffraction grating [2]. The second example is mesooptical mirror in the Mesooptical Fourier-Transform Microscope (MFTM) for nuclear research emulsion [3]. The mesooptics has many advantages over the classical imaging optics only for point-like and straight-like objects.

3. MESOOPTICS IN THE TRACK CHAMBER VERTEX DETECTOR

Let the nuclear event in the track chamber vertex detector has been picked up by means of pulse holography [4]. On the stage of reconstruction the virtual image is observed and scanned by the concentrical mesooptical objective as is shown in Fig. 1.

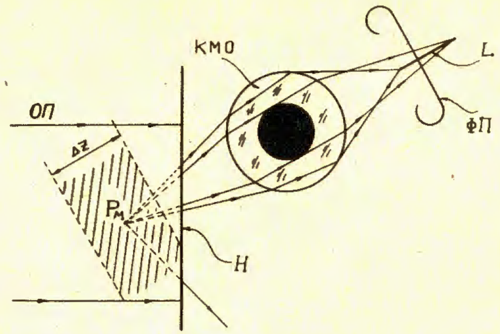

Fig.1

The tracing of rays shown in Fig.1 corresponds to formation of only one of two or more central projections.

The depth of field of the mesooptical objective can be chosen either equal to full depth of track chamber or, if the track density on the hologram is very high, the scanning depth can be diminished untill the reasonable observation is reached. The main problem of such mesooptical objective is the intensive side-lobes in the point spread function. The same problems have been successfully solved in acoustical imaging systems [5].

4. MESOOPTICAL FOURIER-TRANSFORM MICROSCOPE FOR NUCLEAR RESEARCH EMULSION

A new optical instrument called Mesooptical Fourier-Transform Microscope (MFTM) has recently been proposed for observation of nuclear events in the nuclear research emulsion used in high energy physics experiments [3]. The (meso)optical part of the MFTM is shown principally in Fig.2.

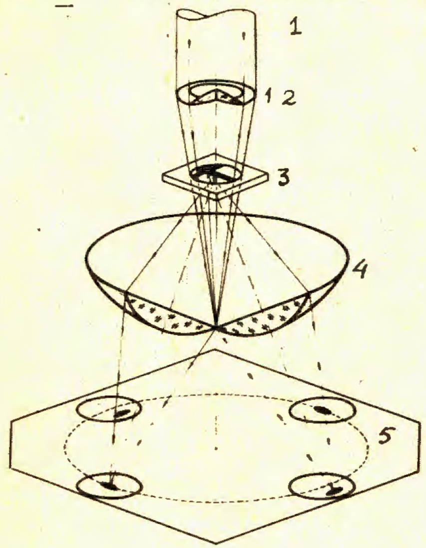

Fig. 2

The nuclear research emulsion is illuminated by the convergent beam of light, the cross-over of which is near the mesooptical objective. The light diffracted by the chain of silver grains in the straight line track is transformed by the mesooptical objective into two small spots of light at the output plane of the MFTM. These two spots do contain all the information about geometrical characteristics of the observed track including Z-coordinate of the track.

In Fig.2 the principal scheme of the MFTM with the mesooptical objective is given: 1 - the convergent beam of light from He-Ne laser, 2 - Fourier transform objective, 3 - nuclear research emulsion, 4 - the mesooptical objective, 5 - the output plane of the MFTM.

The theory of the MFTM in terms of Fourier- and Hilbert-optics [6,7] has been constructed. The Foucault-Hilbert-knife and the high spatial frequency filter accomplish quasi-differentiation of the optical field in the MFTM. The optical signals at the output plane of the MFTM from two heavy relativistic ions accelerated by synchrophasotron in JINR are shown in Fig.3. It is important to stress that stereo-mesooptical microscope can indeed be constracted. Such device containing only classical optical imaging elements cannot be made at all.

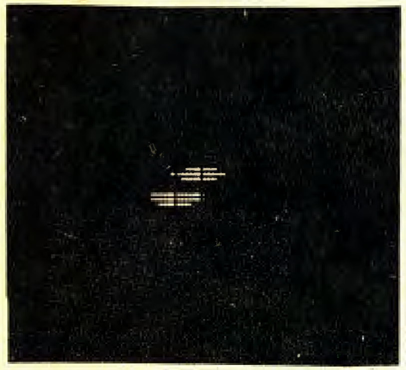

Fig. 3

5. THE DATA PROCESSING ALGORITHMS IN MFTM

The concentration of geometrical information about straight-like particle tracks into small spots of light in the MFTM opens new scopes for speeding up the searching process of the nuclear events in the nuclear research emulsion. The spots of the particle tracks issued from the common centre are laying on the "sinogram" in the case when the vertex of star is inside the field of view of the MFTM or practically on the straight line when the vertex of the star is out of field of view. In the MFTM there are no problems of depth of view inherent to classical optical microscope.

6. CONCLUSIONS

It has been demonstrated that mesooptics gives many advantages over the classical optical imaging systems especially for point-like and (or) straight-like, objects. Just these objects are found wide in the high energy physics.

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Received by Publishing Department
on May 3,1984.

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Мезооптика и физика высоких энергий

Дано определение термина "мезооптика". Приведен пример использования мезооптики в физике высоких энергий. Описаны конструкция и принцип действия Мезооптического Фурье-Микроскопа /МФМ/ для поиска ядерных взаимодействий в ядерной фотоэмульсии. Коротко обсуждены некоторые возможные алгоритмы обработки данных в МФМ.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1984

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Mesooptics and High Energy Physics

The definition of term "mesooptics" is presented. An example of using mesooptics in high energy physics is given. The design and principle of the Mesooptical Fourier-Transform Microscope (MFTM) for searching nuclear events in the nuclear research emulsion are described. Some possible data processing algorithms for MFTM are briefly discussed.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1984