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Visualization and recognition of the particle tracks by methods of coherent laser holography

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Abstract
The present article opens a series of publications related to the application of Photonics to visualize results in experimental physics. This report is devoted to the analysis of experimental results using methods of coherent laser holography for common tasks event detection in the tracking detectors of elementary particles. This paper deals with the possibility of three-dimensional holographic imaging and optical correlators with coherent laser light. It justifies the use of holographic systems for recognition of events recorded by tracking detectors at the stage of primary selection on the form or intensity of the signal correlation. The expediency of both laser radiations coherence transformation and the transition to optical imaging and processing by radiation with partial spatial coherence is justified.

Keywords: Laser Photonics, holography, correlation, coherence.

1. Introduction

Previewing and pre-selecting images from track cameras is one of the most time-consuming and lengthy stages of the results of an experiment processing. Optical and holographic methods of data processing are distinguished by high information capacity of the carrier - light field and holographic memory blocks, naturalness of information representation in two-dimensional form, high speed of direct processing, possibility of multichannel analysis of input data. Therefore, almost immediately after the appearance of one of the most important coherent-optical processing circuits - holographic correlation, an image recognition by the method of spatial frequency filtering [1], there was a rise of interest to its application for images processingfrom bubble chambers [2]. In the joint project of the laboratory FNAL (USA) and the Center for Data Analysis of Track Detectors of Tohoku University (Japan), there are 5.104 holograms of three-dimensional track objects registered on a 30-inch camera. With such data volumes, manual visualization (Fig. 1) becomes so labor-consuming [3] that the search for an informative event is practically unrealizable.

Figure 1 – Laboratory of manual visualization of holograms of track detectors - Tohoku University (Japan)

2. Features of holographic visualization of events in track detectors

The analysis of the data processing problems for tracked detectors for solving optical methods shows that the practical interest may not be the measurement of the

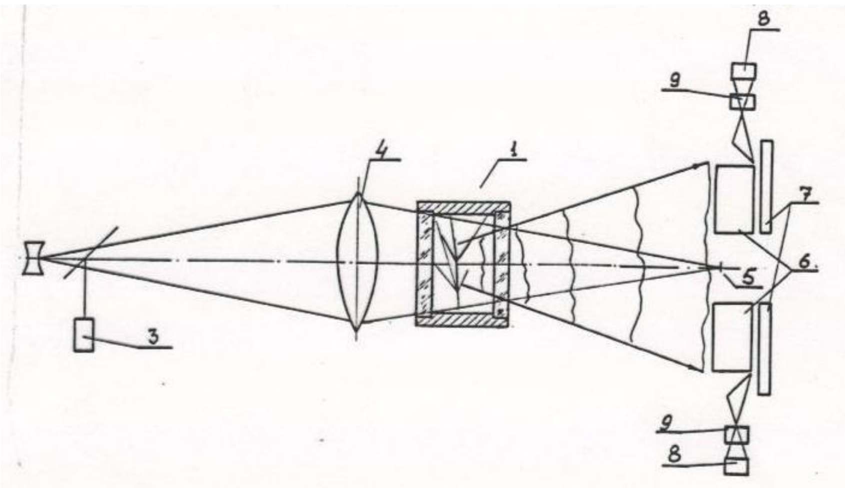

Figure 2 – Scheme of holographic recognition of traces of particles in a track detector

1 – track detector, 2 – pulse laser, 3 – incoherent light source, 4 – condenser, 5 – spatial filter, 6 – Fourier-interferometers, 7 – hologram recorders, 8 – service information slots, 9 – The scheme also shows mirrors, a lens-beam expander and a beam-splitter, but for the sake of simplicity, these elements are omitted.

geometric parameters of events or the search for these features. Primarily the problem of accelerating the viewing of images and recognizing events based on topological features, for example, the presence of stars, the number of tracks in the stars, the end of tracks, the suppression of background tracks.

The introduction of high-efficiency low-volume track cameras as vertex detectors [4,5] into experimental practice and the consequent need for holographic information retrieval from such cameras gave a tangible impulse to closer research into the possibilities of optical data processing from track cameras under new conditions [6 , 7]. The range of such studies includes a rethinking of the methods and schemes proposed earlier for coherent processing systems [8-10], the study of optical methods for recognizing events with non-fixed geometry [11-12], the development and creation of systems of partially coherent photonics [13-15].

Experiments to determine the type of signal correlation and the discrimination selectivity carried out on the models of track events. The experimental setup was a variant of Vander Lugt's holographic correlator, supplemented with a scheme for recording holographic filters and recording equipment. Our system of holographic pattern recognition (Fig. 2.3) allows comparison of two images (banners) - recognizable, installed in the input plane, and a reference image recorded on a holographic filter, by their mutual correlation function. Objects that arise during the track detector data processing are formed, being abstracted from their microstructure, by straight lines, arcs and combinations of their small number. The higher is the efficiency of the recognition system for a given class of objects, the less time-consuming the operations that must be performed on the input signals to establish the difference or identity of the objects to be recognized. In cases the object is formed by a set of elements of different configurations, the operation is the simplest: the presence is established (if the objects coincide) or the absence (in case of a mismatch) of the light point in the output plane. For the objects considered, belonging to the class of objects formed by a small number of simple elements , it is necessary to analyze the features of the form of the correlation signals, that allows to detect events with

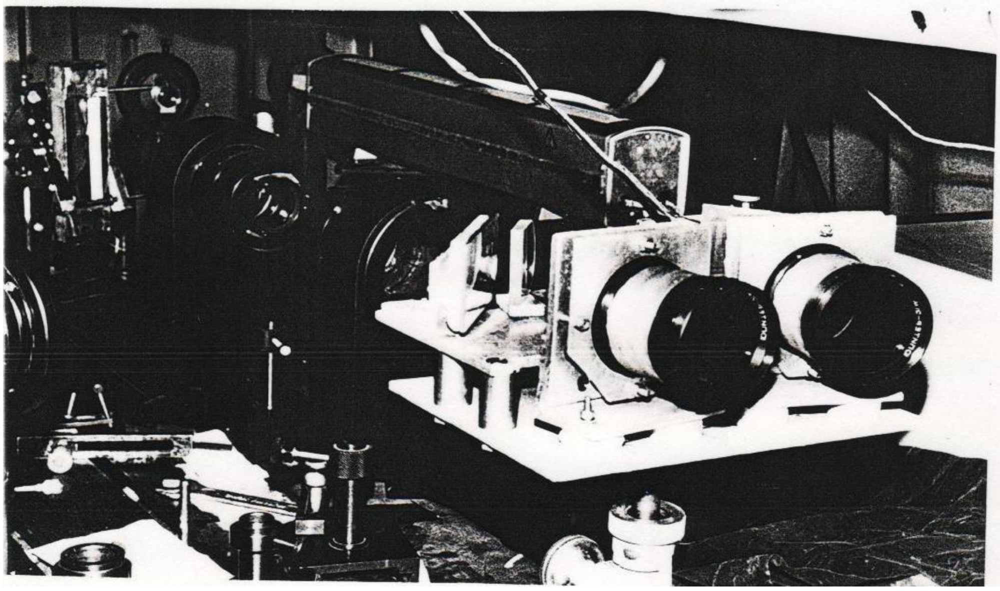

Figure 3 – Device of holographic recognition of traces of particles in a track detector

given parameters among the others. Figure 4 shows an example of the result of recognition of an event in the form of a three-beam star.

3. The main recognition problems solved by the holographic correlator

3.1. Detection of a direct track of a given direction

If the direction of the track does not coincide with the direction of the reference segment, the cross-correlation signal is transformed into a parallelogram. Using this signal sign, you can select all the segments of the given direction. In addition, there is a difference in the intensity of the correlation signals as a function of the angle between the reference and the given segments. By selecting the parameters of the reference segment researcher can control the selectivity of the detection.

3.2. Detection of the preset angle formed by two tracks

The considered objects have the length of the correlation signal comparable to the intrinsic size, so their difference or coincidence most clearly manifested in the form of the signal, while measuring the peak intensity of cross-correlation and autocorrelation signals becomes inconvenient, since it is necessary to set the coordinates of the measurement point on an extended signal. The correlation signals represent the sum of the signals over individual segments. For these objects, it is also possible to detect the shape of the signal if the angles do not coincide in the case of the same orientation of one of the sides of the required and reference angles. It is possible to adjust the selectivity of the detection by choosing the width and length of the segments that form the reference image of the angle recorded on the holographic filter.

3.2. Detection of events formed by curvilinear tracks

In this case, the recognized objects have additional information signs that complicate their structure. The correlation signal localized and recognition reduced to establishing the presence or absence of a localized light response. Compared to objects having an extended correlation signal, it is easy to measure its magnitude, since integral spot measurement is possible, which makes it possible to use the dependence of the values of the correlation signal against the mismatch of the curvature of the recognized and reference arcs.

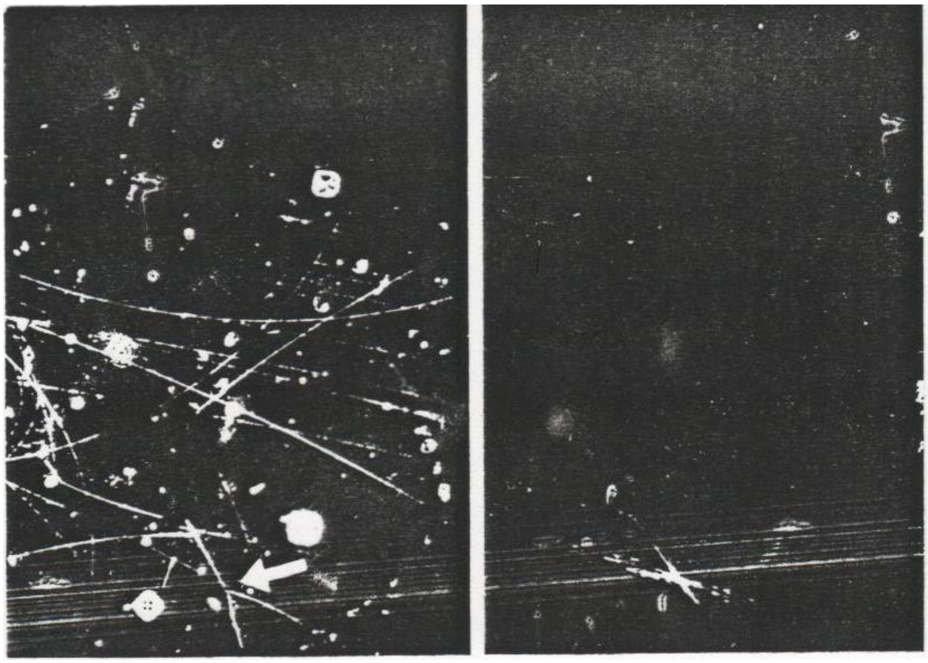

Figure 4 –

Рисунок 1 – Example of holographic recognition of an event in the form of a three-beam star

a - the input object, b - the signal in the correlation plane

4. Quantification of signals and adjustment of recognition modes

When objects recognized in the holographic correlator, the characteristics of the signals close to the calculated ones can obtained, and consequently, a quantitative evaluation of the signals and adjustment of the recognition modes are possible. The events in the pictures detected may appear in a variety of variants due to the limited number of kinematic links and arbitrary orientation. In this case it is necessary either to create a holographic filter that can recognize an event by topological characteristics or use multichannel processing for a set of filters in which a set of standards overlapping the entire range of possible event configurations in pictures is recorded with a step determined by the selectivity of a single reference. The second approach may require a sequential-parallel comparison, i.e. in addition to a parallel in time comparison with a group of standards recorded on a single hologram, the operational replacement of such holograms. A concrete example is the construction of the elastic scattering cross section of π + by He3. Taking into account the arbitrary orientation of the plane in which the scattering fork is located, shows that more than 10^2 standards should use.

Such a number of standards can technically recorded on one hologram, but filters corresponding to other ranges of scattering angles should recorded on other holograms. The task of rapidly changing hologram filters in circuits with coherent illumination becomes difficult to achieve, because is necessary to provide positioning accuracy of about 10μ. This is one of the essential limitations on the use of holography with the emission of high spatial coherence.

Holographic correlation analysis makes it possible to determine the quantitative parameter - the degree of localization of the autocorrelation signal of the object L = δ / D, where D is the largest object size, and δ is the extent of the function of its autocorrelation. For L << 1, recognition objects are "complex", with L ≤ 1 - "simple". In the case of "simple" objects - direct tracks and stars, the spatial structure of autocorrelation signal coincidence that they form is similar to the objects themselves.

However, a small change in the parameter of the object shown drastically changes the shape of the signal, while the difference in the image of the object itself is difficult to detect. This is what determines the appropriateness of using a system of partially coherent recognition, even for objects belonging to the class of "simple" ones.

Recognition of "simple" objects imposes features on the elements of the optical system. The recording of a holographic filter intended for use in coherent illumination is hampered by the narrow spectrum of the spatial frequencies of the reference object and the large dynamic range of the spectrum components. Since real tracks are formed by separate bubbles, it is necessary to ensure undistorted recording of low spatial frequencies of the standard, which results in low diffraction efficiency of the holographic filter (<1%) and high noise level. In part, this difficulty can circumvented by applying the methods of element-by-element and two-step recording.

In spatially coherent illumination, one of the most stringent is the requirement for phase homogeneity of the base of the processed images. The size of the processed image can not significantly exceed the correlation radius of carrier phase noise, because otherwise the magnitude of the signal will be determined not by the useful information, but by the nature of the phase noise. This limitation can also overcome by using a laser radiation with a transformed coherence function in a holographic correlator.

5. Conclusion

- The use of holographic systems for recognition of events recorded in track detectors is possible at the stage of primary selection according to the form or intensity of the correlation signal.
- The use of holographic systems for visualizing events in track detectors has significant merits.
- It is advisable to develop methods for detecting events with non-fixed geometry. Orientation and exact geometry of events are usually unknown in advance, and therefore the number of required holographic filters may be excessively large - more than 10^2.
- Three factors make it necessary to transform the coherence of laser radiation and transition to holographic visualization and processing of information by radiation of partial spatial coherence.

  1. With coherent illumination, the practical realization of the potential capabilities of holographic systems significantly hampered by stringent requirements for phase homogeneities.

  2. With coherent illumination, the sensitivity of the recognition result to the accuracy of the installation of the holographic filter is extremely high.

  3. With coherent illumination, it is practically impossible to recognize "simple" objects due to the lack of localization of the correlation signal in the output plane of the system.

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