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A HOLOGRAPHIC HIGH PRESSURE

STREAMER CHAMBER

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ABSTRACT

Tracks in a high pressure streamer chamber were holographically recorded. The chamber was filled with a mixture of helium and methane and operated in a pressure range of 4 to 13 atmospheres. At a pressure of 13 atm a streamer diameter of $\sim 25 \mu\text{m}$ was observed. The influence of electron diffusion and streamer size on the spatial resolution is discussed.

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1. INTRODUCTION

For the study of the properties of charmed or beauty particles it is interesting to use a streamer chamber as a high resolution vertex detector because it is triggerable and has a short memory time which allows high beam intensity. These two advantages result in a high sensitivity which is important for example in the investigation of branching ratios for rare decay channels or mixing parameters.

In order to obtain a high spatial resolution with a streamer chamber, the following three subjects have to be considered:

1. The electrons liberated by the ionizing particle (and representing the streamer centre) diffuse during the time between their liberation and the arrival of the HV pulse at the chamber electrodes. This leads to a displacement of the streamers from the true particle track and therefore to a track broadening.
2. The streamers need to have a certain size in order to emit enough light to be photographed.
3. The streamers normally were photographed with a classical optical system using image intensifiers and high sensitivity film both of which have a limited resolution. The best value for resolution which can be reached is about 40 μm . With such a system in a neon-helium mixture (70% - 30%) at 20 atm a streamer diameter of $\sim 70 \mu\text{m}$ was observed¹⁾.

Even if it were possible to reduce the streamer diameter to about 20 μm and to resolve such a distance with a classical optical system, the problem of the coupling of resolution with depth of field remains. In the case of 20 μm resolution, the depth of field is restricted to 2 - 3 mm.

The use of holographical recording solves the depth of field problem and could improve the optical resolution. The aim of this

work, therefore, was to find out whether streamer chamber tracks can be holographically recorded with a satisfying contrast of the reconstructed image and whether the streamer diameter observed is smaller than with classical recording.

2. EXPERIMENTAL SET-UP

Fig. 1 shows a schematic drawing of the experimental set-up, from which it is evident that all the holograms were made in the in-line mode. A brief description of the various components is given below.

Fig. 1 : Experimental set-up: 1. beam splitter; 2. joule meter; 3. beam expander; 4. optic fiber and photomultiplier used to pick up the laser light pulse; 5. HV pulse pick-up; 6. collimator for nitrogen laser; 7. delay units.

2.1 The streamer chamber

The streamer chamber has a track sensitive volume of 50 mm diameter and 23 mm depth (see fig. 2 and ref. 1). It was filled with helium plus 10% (or 5%) methane (CH_4) and operated between 4 and 13 atm.

Fig. 2 : Holographic high pressure streamer chamber.

Methane was chosen because of its relatively high index of refraction. The two transparent electrodes needed to do holography are 15 mm thick glass windows of optical quality, which have a conducting gold layer (Aurell - A3 from Balzers) with a resistance of $10 \Omega/\text{cm}^2$. A 1.5 mm thick glass plate is glued on this layer to protect it against destruction due to sparking. This whole structure is furthermore covered on both sides with an antireflecting coating. The electrodes have a transparency of 75% and allow a recording without the disturbing background structure of wires.

The HV pulse is delivered by a 400 kV Marx generator and shaped in a Blumlein pulseformer to 10 nsec FWHM (see ref. 1 for more details). The highest possible field strength in the streamer chamber is $\sim 160 \text{ kV/cm}$ (at 13 atm).

The tracks were produced by a 20 μJ nitrogen laser, the beam of which was focused in the middle of the chamber to a width of $\sim 100 \mu\text{m}$. In order to give a standard trigger condition the laser was fired 1 μsec before the HV pulse.

2.2 The holography laser

The laser for the holographical recording was the excimer-dye laser system used to do holography in the "Holographic Bubble Chamber" (HOBC) (see ref. 2 for further details). It was operated at a power of 5 mJ and at a wavelength of 514 nm fitting the argon line for the replay system. Its beam was expanded to a diameter of 10 cm and the holograms were taken about 150 ns after the arrival of the high voltage pulse at the chamber (i.e. streamer formation).

The holograms were recorded on photographic emulsion plates (type 10E56 from Agfa), which have a sensitivity of $\sim 5 \mu\text{J}/\text{cm}^2$.

3. EXPERIMENTAL RESULTS

3.1 Reduction of electron diffusion

The reduction of the track broadening, due to the diffusion of the electrons, by increasing the pressure in the streamer chamber was investigated in a previous study¹⁾. The result was that the mean displacement σ , i.e. half the track width, shrinks proportionally to $1/\sqrt{p}$ (fig. 3). In a neon-helium mixture (70% - 30%) at 20 atm a σ of 70 μm was observed.

Fig. 3 : Mean displacement σ of the streamer centre from the "true" track vs chamber pressure p . The curve is proportional to $1/\sqrt{p}$.

There are two other possibilities under study to further reduce the track broadening. First to use electrons in metastable states and secondly to use electrons attached to ions for the storage of the track information. In both cases the electrons have to be liberated by a laser pulse just before the arrival of the HV pulse at the chamber. For more details and first results in this field see the contribution of R. Majka elsewhere in the same proceedings.

3.2 Holographical recording

3.2.1. General results and tendencies

Concerning the holographical recording of tracks in the high pressure streamer chamber the following qualitative observations were made:

- Hologram taking: The hologram has to be taken in the so-called far field because in the near field only the shadow of the streamer is recorded and not the interference pattern needed to reconstruct the streamer³⁾. In our case the distance between the photographic emulsion plate and the track was ~ 30 cm at 4 atm and ~ 20 cm at 13 atm.
- Delay time: The delay time between the streamer formation and the hologram taking was varied between 50 and 300 ns. In this range no striking influence of the delay time on the quality of the holograms and the reconstructed images was observed.
- Gas mixtures: The chamber was filled either with helium plus 10% CH₄ or with helium plus 5% CH₄. In the whole pressure range (4 - 13 atm) the reconstructed images show a better contrast with the higher CH₄ concentration.
- Pressure dependence: At a pressure of 10 and 13 atm (He + 10% CH₄) holographical recording gives a satisfying contrast of the reconstructed images; at pressures smaller than 10 atm the contrast of the reconstructed images decreases rapidly.

3.2.2 Streamer diameter

At 13 atm and the chamber filled with helium plus 10% methane a streamer diameter of $\sim 25 \mu\text{m}$ was observed. This result was independently obtained with two different measuring methods:

- Microscope measurement: By looking with a microscope at the reconstructed image a streamer diameter of $26 \pm 4 \mu\text{m}$ was observed. Fig. 4 shows a reconstructed 1.5 cm long track and fig. 5 three reconstructed streamers.

Fig. 4 : Reconstructed track (13 atm, He + 10% CH₄) photographed through a microscope.

Fig. 5 : Three reconstructed streamers (13 atm, He + 10% CH₄). A scale is added and the numbers indicate the line pairs per millimeter. For instance 35.9 means 35.9 line-pairs/mm, so a black white line pair is $\sim 27 \mu\text{m}$.

- HOLMES measurement: A more precise measurement was performed with the measuring machine HOLMES, described in detail by H. Drevermann elsewhere in the same proceedings. This machine is connected to a digital image processing system giving the intensity distribution of the reconstructed image over 512 channels horizontally and vertically. The intensity-scale is related to a colour-scale and the image is monitored on a colour display (fig. 6).

Fig. 6 : Two dimensional intensity distribution of a reconstructed image replayed on HOLMES. (The original is coloured, see text).

The intensity distribution along one horizontal line through the centre of a streamer is shown in fig. 6. To this distribution a gaussian was fitted (as expected from ref. 4) and the full width at half maximum

Fig. 7 : Streamer intensity distribution (averaged over 3 horizontal lines) with the fitted gaussian. The scale is 1.5 μm per channel.

was defined as the streamer diameter (fig. 7). The measurement of ~ 80 streamers belonging to two different tracks gave a mean streamer diameter of $25 \pm 2 \mu\text{m}$.

4. SUMMARY AND CONCLUSIONS

Tracks in a high pressure streamer chamber were holographically recorded. It has been shown that the reconstructed image has a very good contrast even if the streamers are very small. The important operating conditions are the far field for the recording, the percentage of CH_4 which has to be added to the helium, and the chamber pressure. A delay time of 50 - 300 nsec between the HV pulse at the chamber and the holography laser has no influence on the quality of the hologram.

In helium + 10% CH_4 at 13 atm a streamer diameter of 25 μm was observed. This value is a factor 3 smaller than the one observed with a classical optical system at 20 atm in Ne-He and only a factor 2 larger than the bubble diameter in the Holographic Bubble Chamber (HOBCh)⁵⁾.

Because of the large coherence length of the laser light a depth of field problem as in classical optics does not exist. Therefore chambers with a depth of a few tens of centimetres surrounding a storage ring pipe are feasible.

In a next series of tests it is planned to concentrate on the diffusion problem. If the track broadening by diffusion can be reduced to the same order of magnitude as the streamer diameter, the holographic high pressure streamer chamber would be very suitable for doing charm and beauty studies.

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