# THE RAPID-CYCLING HYDROGEN BUBBLE CHAMBER HOLEBC

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Since three years we have been designing, constructing, and operating hydrogen bubble chambers as vertex detectors for charm physics in hadron beams. Experience tells us that this kind of physics requires

- a visual detector technique with spatial resolution well below 50 µm in order to detect charm decays;
- a detection sensitivity in the nanobarn range;
- unambiguous discrimination between secondary interactions and particle decays.

The best compromise for such a vertex detector is provided by a rapid-cycling (to achieve the required sensitivity) hydrogen (no topological ambiguities) bubble chamber with high spatial resolution. Therefore, the principal design considerations must take into account the formation of small bubbles of correspondingly high density along the tracks. This asks for expansion cycles which are close to the foam limit of hydrogen. To achieve this goal, we need a clean bubble chamber without any seals, which could favour parasitic boiling.

To realize such a clean hydrogen chamber, we decided to construct its body entirely from plastic material. For photography this material must be transparent to visible light. and in order to perform several tens of millions of short expansion cycles it must possess high impact strength to resist the severe shocks caused by the high-expansion accelerations. From all plastic materials available, only the thermoplastic polycarbonate Lexan offers such properties and it is therefore used for the construction of the chamber body. The different parts of the body (optics windows, expansion membrane) are glued together by applying a solvent cementing technique, which provides the required vacuum-tight joints of high structural integrity with smooth edges.

After the first type of chamber, called LEBC, which used one optics window and retrodirective bright-field illumination, a second type of clean chamber, called HOLEBC, was designed in the autumn of 1980. The principal new design features are as follows (see Figs. 1a and 1b):

- Two optics windows for straight-through exposures, which allow for holography as well as for classical bright-field or dark-field optics.
- Consequently, the expansion membrane is now located at the bottom of the chamber. It is driven by a vertically moving piston, which is cooled by liquid hydrogen to prevent any heat input via the piston rod.

After a few preliminary tests at the CERN Proton Synchrotron (PS) we operated such a chamber at the Super Proton Synchrotron (SPS) between 24 October and 2 November 1981.

Chamber operating conditions

| | |
|---|---|
| Hydrogen temperature | 29.3 K |
| Hydrogen static pressure | 8.3 bar |
| Expansion pressure minimum | 4.0 bar |
| Piston stroke | 0.7 mm |
| Duration of expansion cycle | 4 ms |
| Expansion cycling rate | 30 $s^{-1}$ |

During this test run, pictures were taken in different optical arrangements:

- Classical optics:
  - Bright field
  - Dark field
- Holography:
  - In line (Gabor type)
  - Separated reference beam

The holographic exposures are described in detail by Sekulin$^{1)}$ in these proceedings. Examples of classical bright-field and dark-field photographs are presented in Figs. 2 and 3, respectively. Bubble densities between 120 $cm^{-1}$ and 160 $cm^{-1}$ were achieved. To determine the resolved bubble diameters, we scanned across the bubble images on bright-field film with a microdensitometer. A typical scan along a track is displayed in Fig. 4. It shows the excellent contrast with density variations of about one between bubbles and background. The measured full width at half maximum across the bubble images is around 20 µm, and two bubbles, with 23 µm distance between their centres, are clearly resolved.

Parameters for classical optics

| | | | |
|---|---|---|---|
| Objective lenses | Schneider Componon S | | |
| Focal length | 350 mm | | |
| Demagnification (m) | 1:1 | | |
| Wavelength ($\lambda$) of flash illumination | 515 ± 10 nm | | |
| Lens apertures | F/11 | F/13 | F/16 |
| Nominal spatial resolutions | 14 | 17 | 21 µm |
| Nominal depth of focus | 1.0 | 1.5 | 2.2 mm |
| Flash delay or bubble growth time | 70 | 120 | 170 µm |
| Corresponding bubble diameters | 17 | 22 | 27 µm |

During this test-run, we experienced some unpleasant optical distortions caused by turbulences in the liquid hydrogen of the bubble chamber. In general, the chamber liquid is the main source of trouble for any optical system. Consequently, the operation of the bubble chamber and its design concept are crucial for the achievement of decent pictures of events, and this is particularly true for holographic exposures. It might therefore be worth while to recall some basic aspects of this problem.

All bubble chambers suffer from static (via thermal conduction and radiation) or dynamic (parasitic boiling during the expansion cycles) heat loads. In HOLEBC we succeeded in reducing the dynamic heat load as well as the conductive heat flux to a negligible amount. Nevertheless, we are still left with the heat, which is radiated via the optical channels, absorbed in the chamber windows, and finally transferred to the liquid hydrogen.

In hydrogen, heat transport by thermal conduction is too small by several orders of magnitude to maintain an equilibrium between heat input and consecutive cooling. Therefore we are left with turbulent convections, to transport the absorbed heat to the heat exchanger at the top of the chamber volume. Consequently, small volumes of liquid (so-called eddies), with temperatures slightly different from the temperature of the bulk liquid, will move up or down because of the resulting buoyancy. These eddies, with linear dimensions between 1 and 3 mm, deviate light-rays by an angle $\alpha$, which is proportional to

$$\alpha \propto \frac{\Delta n}{n} \Delta\theta \sqrt{\frac{L}{\ell}} ,$$

where L is the distance from the bubble to the wet side of the optics window, $\ell$ is the linear eddy dimension, $n = 1.1$ is the refractive index of hydrogen, and $\Delta n = 4.2 \times 10^{-3}$ ($K^{-1}$) is its temperature dependence around 29 K [for comparison: in water at 20 °C, $\Delta n = 9 \times 10^{-5}$ ($K^{-1}$)]. Finally, $\Delta\theta$ is the average temperature variation within the liquid. This angle $\alpha$ causes a linear displacement x at the chamber window, which is proportional to

$$x \propto \frac{\Delta n}{n} \Delta\theta \frac{L^{3/2}}{\sqrt{\ell}} .$$

For hydrogen at 29 K we obtain [see Thomas$^{2)}$ and Reinhard$^{3)}$]

$$x \approx 10^2 \, H^{7/8} \, L^{3/2} \qquad (\mu m) ,$$

with H ($W \cdot cm^{-2}$) being the heat flux density through the bubble chamber.

Now, the heat flux density depends on the geometrical cross-section of the bubble chamber and hence in some way on its surface-to-volume ratio. This ratio is of course extremely unfavourable for a small chamber such as HOLEBC, which contains only two litres of liquid. In order to remain in the region of a few $mW \cdot cm^{-2}$ for the heat flux density H, we must keep the heat load for HOLEBC below 0.5 W. Then the displacement x of the light-ray amounts to about 5 μm.

* * *

## REFERENCES

1) R. Sekulin, these Proceedings, p.

2) D.B. Thomas, Proc. Int. Colloq. on Bubble Chambers, Heidelberg, 1967 (ed. H. Leutz) (CERN 67-26, Geneva, 1967), p. 215.

3) H.P. Reinhard, CERN/TC/BEBC 66-62 (1966).

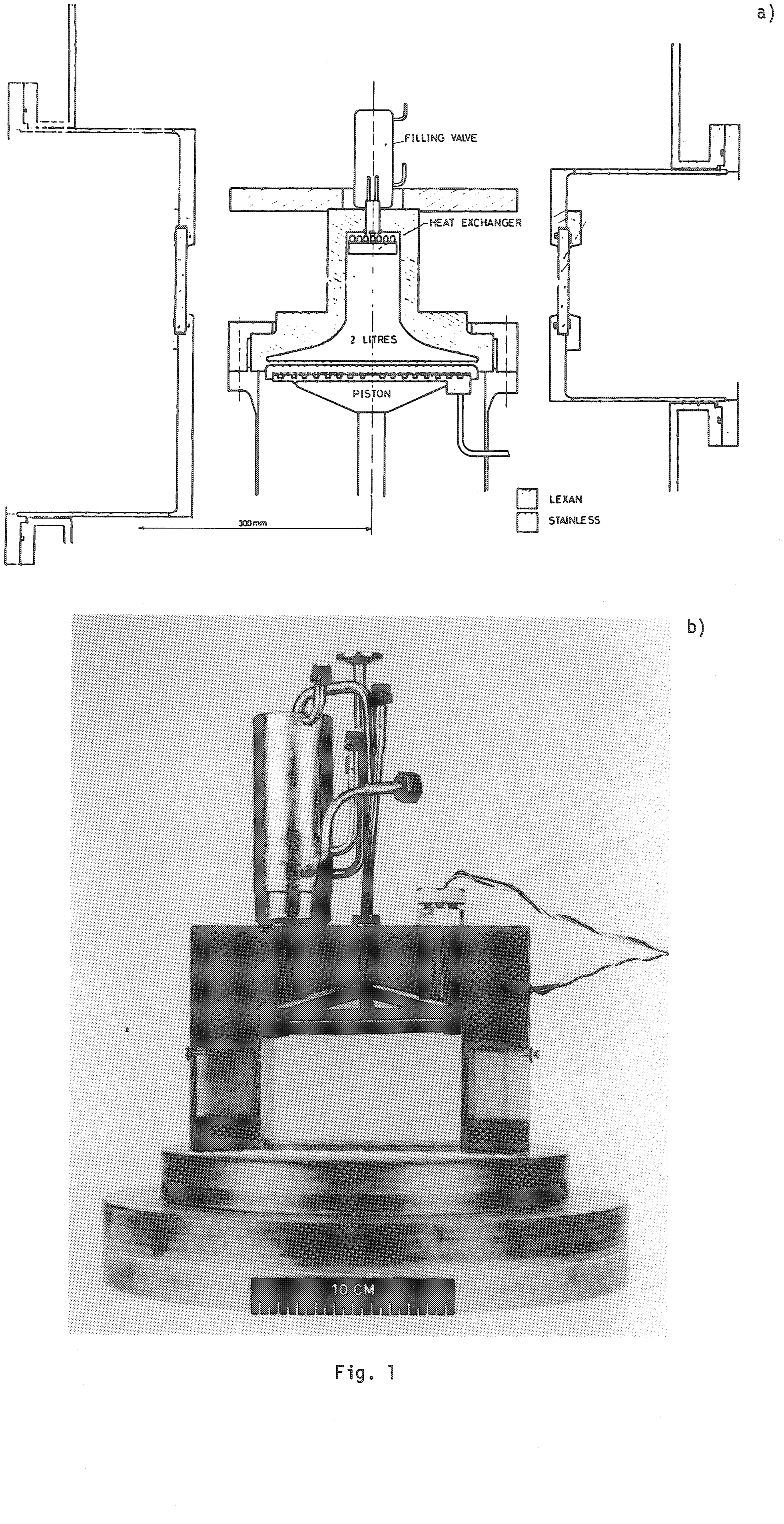
a)
FILLING VALVE
HEAT EXCHANGER
2 LITRES
PISTON
LEXAN
STAINLESS
300mm
b)
10 CM

Fig. 1

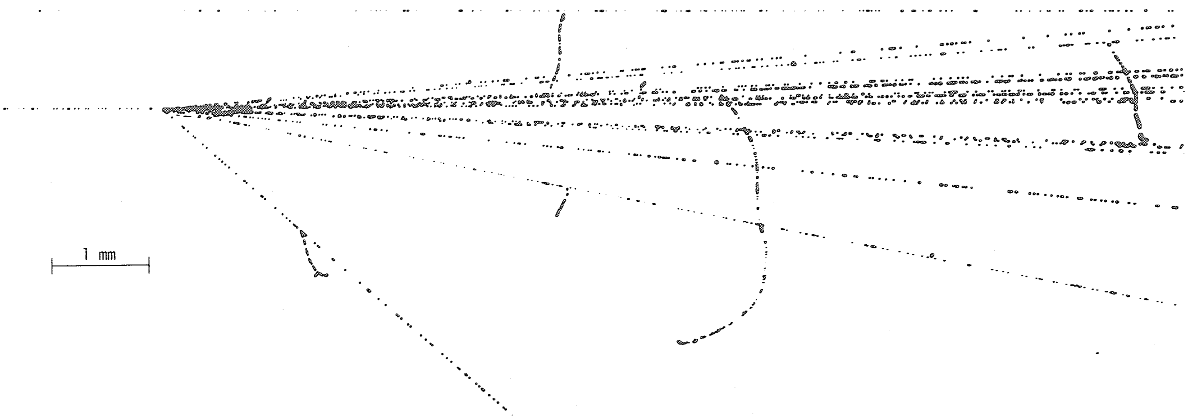

Fig. 2

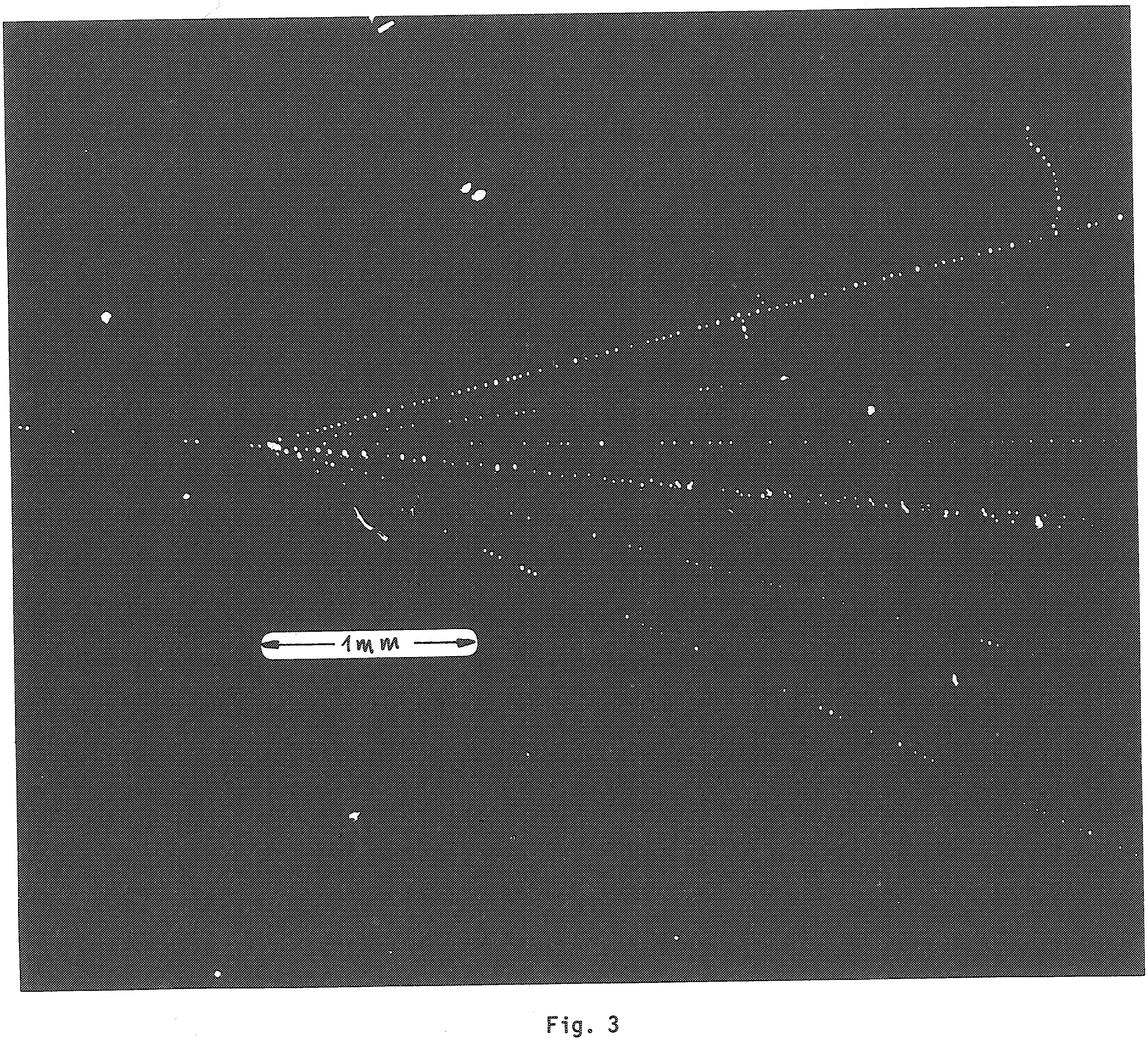

Fig. 3

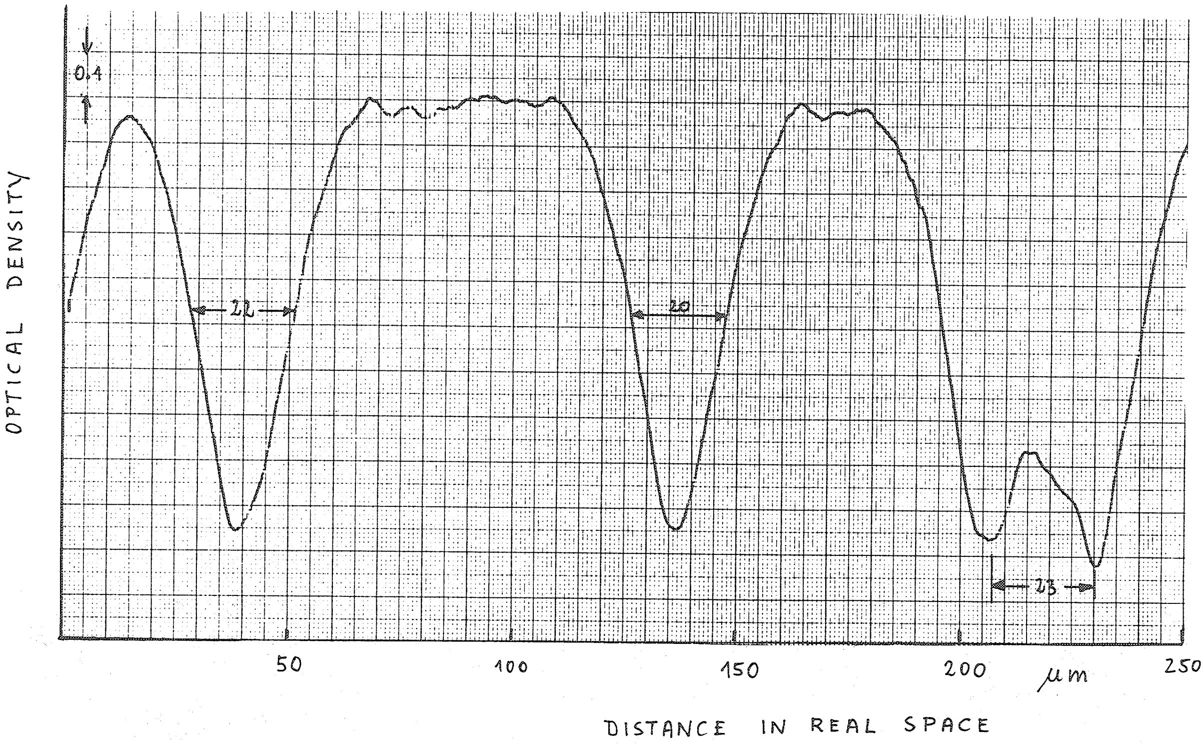
0.4
OPTICAL DENSITY
22
20
23
50
100
150
200
250
$\mu m$
DISTANCE IN REAL SPACE

Fig. 4