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MECHANO-OPTICAL CAMERA WITH A RECORDING SPEED OF TEN MILLION IM--ETC(U)
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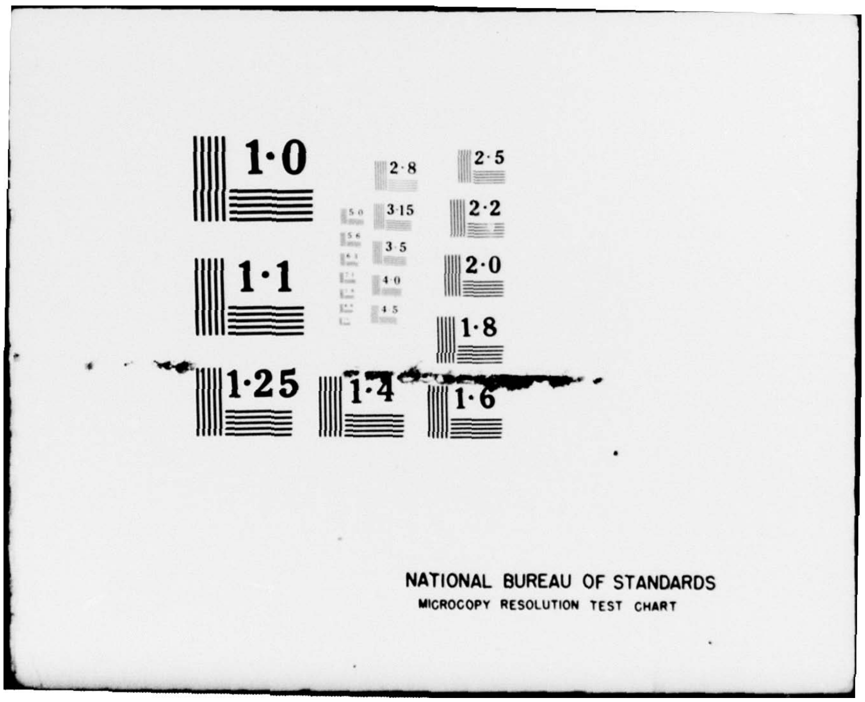
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NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

(Camera mecano-optique a dix millions d'images par seconde).

MECHANO-OPTICAL CAMERA WITH A RECORDING SPEED OF TEN MILLION IMAGES PER SECOND

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Translated by Ted Bear and Louis H. Cohen.

English Language Translation

Text in French and English

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AIR FORCE FLIGHT TEST CENTER

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Abstract

A prototype of a new whole-image, total-activity mechano-optical camera has been developed for the study of ultra-fast luminous phenomena. The camera can record 144 6 x 6.2mm images at the maximum rate of ten million images per second, with a dynamic resolution reaching 50 pairs of lines per millimeter.

This was achieved by the use of an optical speed doubler included in an original design, together with a mirror rotating at 9,000 turns per second which benefits from recent technological progress in this field.

"Mechanical-Optical Camera with a Recording Speed of Ten Million Images per Second", translated from the French by Dr. Louis H. Cohen and Mr. Ted Bear, Air Force Flight Test Center, Edwards Air Force Base, California.

For several years, high-speed photographic devices have been used by the (French) Atomic Energy Commission to study very fast luminous phenomena. The results obtained showed that in order to better understand the physics of the experiments they were conducting, it was necessary to refine their investigative methods.

To do this, the Commission (C.E.A.) came up with the principle of a new whole-image camera (C.I.A.T.). The responsibility for the design of this camera was given to the Central Armament Laboratory (L.C.A.). The prototype, which was developed by the Electrical and Mechanical Optical Society (S.O.P.E.L.E.M.), has the highest recording speed achieved thus far by a total activity/mechano-optical camera. Indeed, the whole-image camera (C.I.A.T.) has the capacity to record 144 images at a maximum rate of 10,000,000/sec. (ten million pictures per second).

One part of the optical design is similar in principle to that of other cameras of the same type such as the CI-1 made by the (French) Armament Lab. The system comprises a common front section, behind which there are four distint but identical image paths.

The front lens O_1 forms, near the field lens C_1, a first image of the phenomenon, which is then reimaged at infinity by the semi-lens V_1. The beam is then split into four beams by the pyramidal mirror. (Fig. 2)

Let us trace one of these image paths. After going through simi-lens V_1' and collector C_2, the rays converge near the revolving mirror, forming a second intermediary image. The beam--after going through a multiplier and then being reflected by the rotating mirror--forms a third image which, after being picked up by a ring assembly of thirty-six secondary lenses, is projected onto the film.

The film is wrapped around a cylinder, the axis of which coincides with the main axis of the camera and with the rotational axis of the revolving mirror.

The high framing rate of the camera results from both the performance of the revolving mirror and the characteristics of the multiplier. The latter (Fig. 3) is made up of a very wide aperture lens O_2 (aperture F:1.4) and a reflecting dihedron, the edge of which is parallel to the rotational axis of the revolving mirror. The focal plane of this lens coincides with the second intermediary image.

Fig. 3 shows how, when the mirror M rotates throughout angle a (alpha), the beam which emerges from lens O_2, after having been reflected twice off the faces of the dihedron, makes an angle equal to 4a (four alpha) with the incident beam (instead of 2a in the absence of a multiplier). Thus the multiplier has the effect of doubling the sweep speed of the right assembly of lenses located in front of the film.

So as not to block the beam propagating toward the secondary lenses, the lens of the multiplier is cut in two, and the half which does not receive light beam is removed.

For this reason, the construction and assembly of this element posed delicate optical and mechanical problems.

The revolving mirror (Fig. 4) is driven by a compressed air turbine which reaches a speed of 9,000 revolutions per second. It is the result of significant technological advances made in recent years. The most important advances came from the development of dry roller and ball bearings, and dynamic leakproof gaskets of a new type.

Furthermore, extensive studies allowed the CA Lab to optimize the shape of the turbine blades.

Keeping in mind the configuration of the camera, it can be shown in order to have the maximum writing time (total activity), the number of mirror faces must be an odd number and at least equal to five. In fact, the mirror design is determined by practical constraints on the multiplier lens aperture and on the dimensions of the mirror itself. A heptagonal cross-section was adopted. The seven faces are 8.7mm wide and 24mm long. The resulting image size is 6 x 6.2mm.

A diamond-shaped aperture is placed in the plane of the semi-lens V_1, as well as at the pupil of each secondary lens V_2. As the mirror rotates, the collector lens C_2 successively projects the image of the first aperture onto the ring array of lenses. The effective exposure time therefore is determined by the auto-correlation function of the diamond. At the maximum frame rate, the exposure time is of the order of 40 nanoseconds.

This shutter process is standard. However, the arrangement generally adopted (first beam aperture in the plane of the entrance pupil) was made very difficult because of the required interchangeability of the front lens which can be selected from among 3 models having focal lengths of 1000, 600, and 200mm (Fig. 5).

One should note that the lenses are mounted on an articulated arm which allows both horizontal and vertical sighting (Fig. 6).

Despite the complexity of the optical system, the dynamic resolution of the camera is between 35 and 50 line pairs per millimeter on the film in the direction perpendicular to the sweep. Diffraction limits resolution to 20 line pairs in the direction of the sweep.

The photometric aperture exceeds f50.

The theoretical image sequence consists of 144 images. At maximum speed, this corresponds to a recording period of about 15 microseconds. In order to avoid double exposure of the film, the main beam must be interrupted before the last image is exposed. This is the role of the ultra-rapid electro-magnetic shutter, the closing of which is triggered as soon as the phenomenon occurs. The shutter closing speed is increased by giving the shutter a conical shape which coincides with the envelope of the beam.

Practically speaking, only about 100 images can be obtained.

Installing the camera does not pose any particular problems. It is mounted on an orientable-type stand. The framing can be done through two reflex viewers; one located behind the entrance lens, the other near the film.

The C.I.A.T. camera has been used for three years under severe environmental conditions. The results obtained have been adjudged to be very satisfactory.

For a comparable image quality, this C.I.A.T. camera has enabled the frame rate to be increased four fold over what the CI-1 could do, a camera which until now, was the fastest of the total activity mechano-optical cameras used by the French Atomic Energy Commission.

Probably the C.I.A.T. (Whole Image Camera) represents the optimum that is achievable for this type of design. A larger photometric opening or a faster frame rate could be obtained by other techniques, but it would be at the expense of camera characteristics such as the total number of recorded images (converter camera) or the spatial resolution (dissection camera).

Practically speaking, there is no universal camera and the recording technique must, to a degree, be adapted to the characteristics of the object being studied. The use of the C.I.A.T. camera for detonation studies or in plasma research is fully justified.

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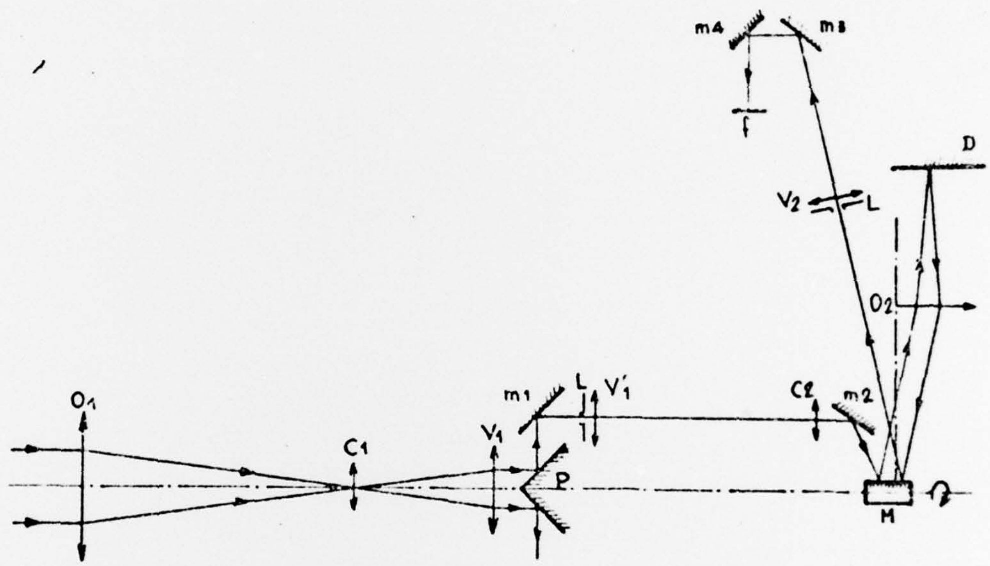

Fig. 1 : Schéma optique de la C.I.A.T.

O_1 : object principal	C_1 : verre de champ	V_1 : demi-véhicule	P : miroir pyramidal
m_1 : miroir	L : diaphragmes losange	V'_1 : demi-véhicule	C_2 : collectrice
m_2 : miroir	M : miroir tournant à 7 faces	O_2 : multiplicateur	D : dièdre
V_2 : demi-véhicule	m_3 et m_4 : miroirs	f : film	

Fig. 1: Optical Schematic of the C.I.A.T. (Whole Image Camera).

O_1 Front Lens	C_1 Field Lens	V_1 Semi-Lens	P. Pyramidal Mirror
M_1 Mirror	L. Diaphram Aperture	V_1 Semi-Lens	C_2 Collector Lens
M_2 Mirror	M Revolving Mirror and 7 Faces	O_2 Multiplier	D Dihedron
V_2 Secondary Lens	M_3 and M_4 Mirrors	f. Film	

Fig. 2 : Dispositif de séparation du faisceau.

Fig. 2: Apparatus for the separation of the Bundle

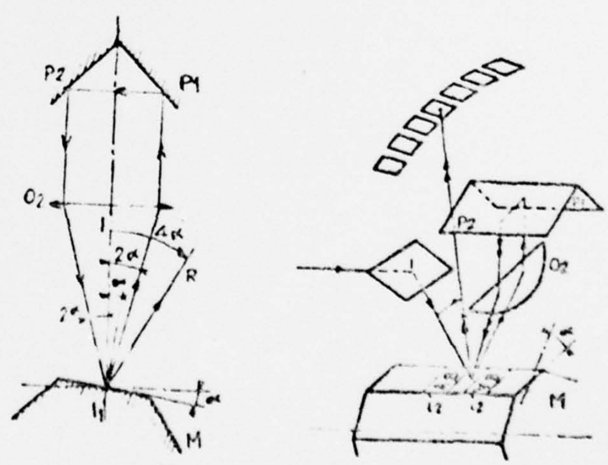

Fig. 3 : Schéma de principe du multiplicateur.

M miroir tournant – 02 objectif

Fig. 3: Schematic of the Caracteristics of the Multiplier.

M. Rotating Mirror -- 02. Wide Aperture Lens

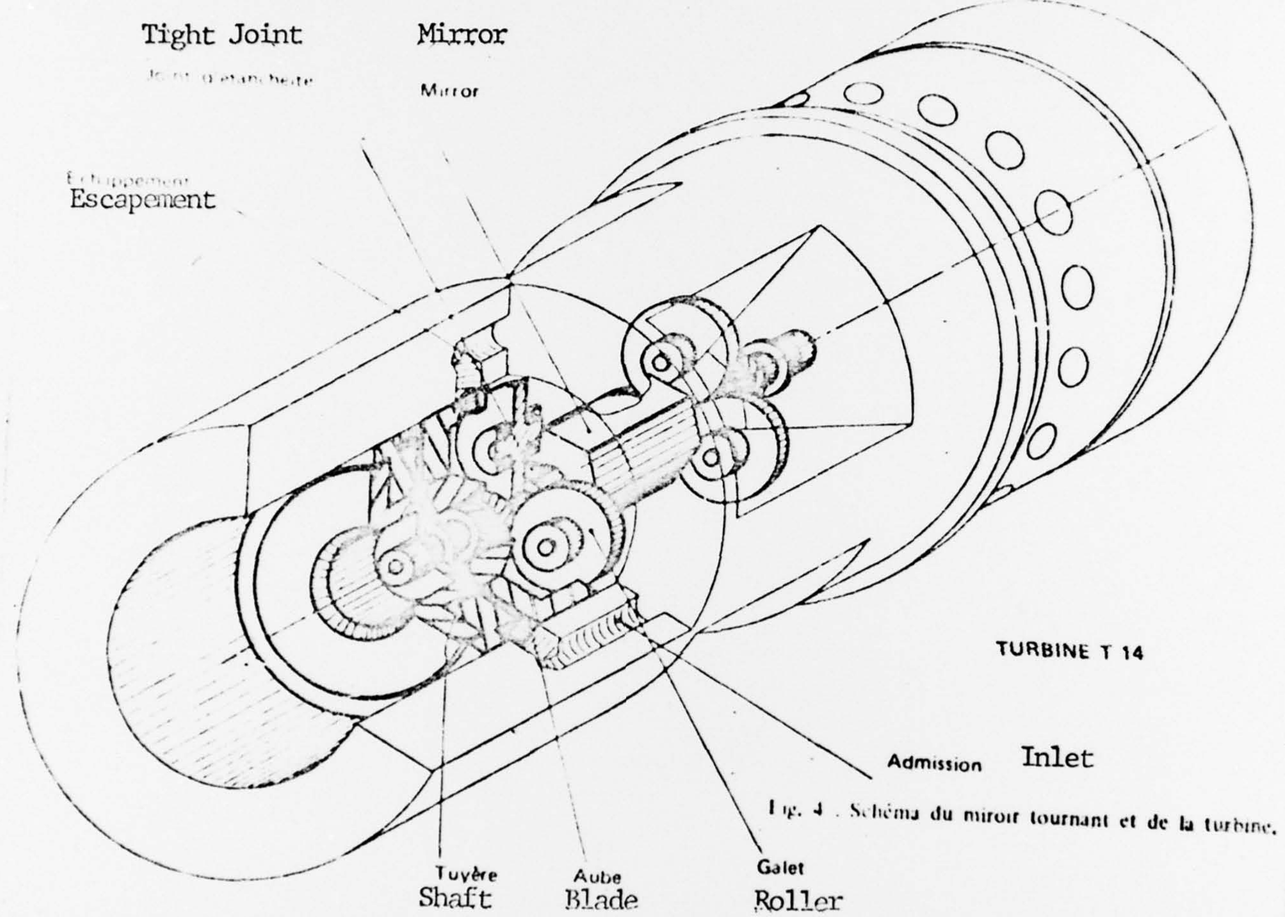

Fig. 4: Schematic of the Revolving Mirror and Turbine.

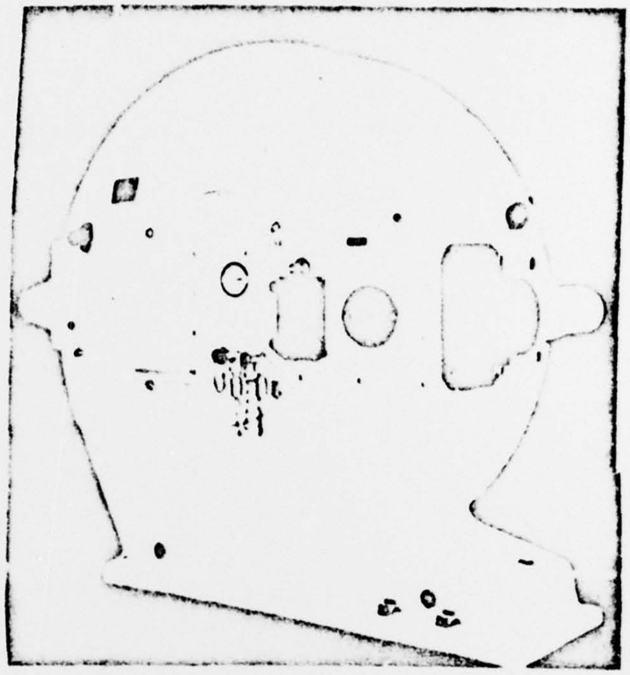

Fig. 5 : Aspect extérieur de la C.I.A.T.

Fig. 5:

Exterior aspect of the C.I.A.T. Whole Image Camera.

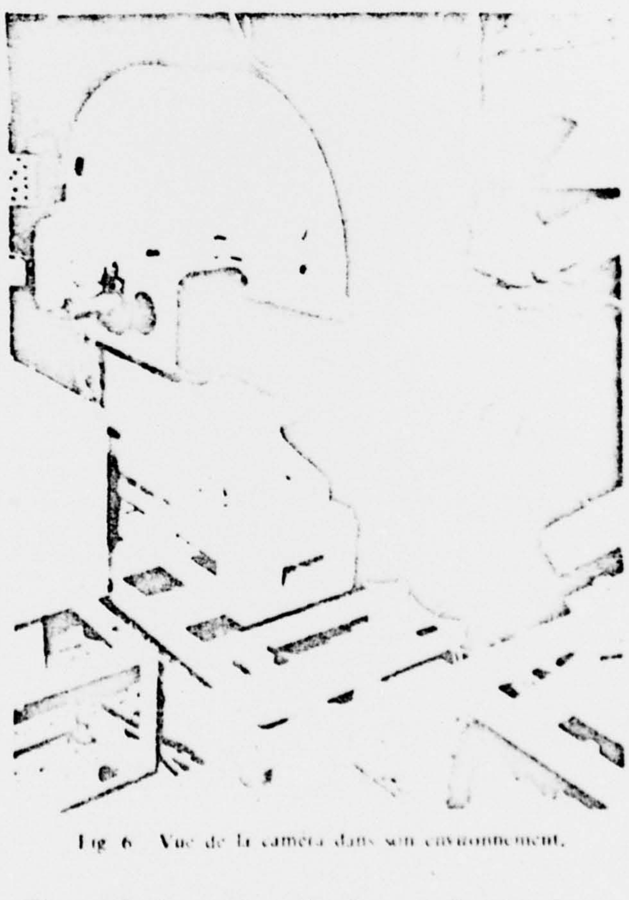

Fig. 6 Vue de la caméra dans son environnement.

Fig. 6:

View of the Camera in its environment