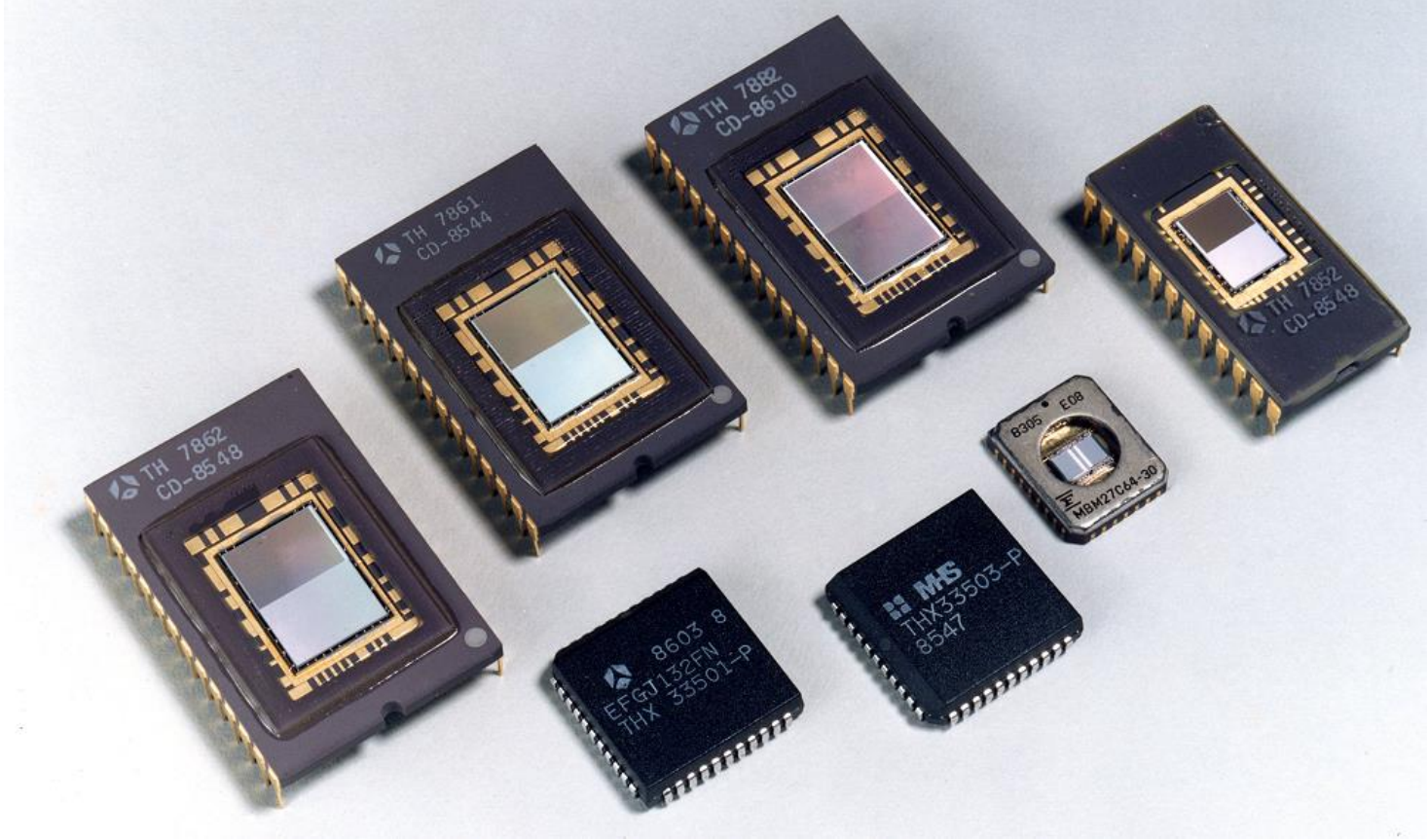
sommaire



Les détecteurs CCD

à Thomson-CSF Saint-Egrève

Années 1970 -1980

TEDIMAGE38

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Avant les CCD

Invention des CCD

Premiers CCD à St Egrève

Inefficacité de transfert

Représentation imagée

Choix technologiques

Transfert en volume

Structure standard en 1975

Technologie années 1970

Du labo vers la prod

1ère barrette photosensible

1er capteur matriciel TH 7852

1er capteur format TV : TH 7864

Performances de capteur CCD

TH7882 Monocoup et aminci

Couplage fibres optiques

Capteur TDL couleur

Capteur 1024 x 1024

Les autres capteurs…

Interligne et CMOS

Annexes

L'image électronique avant les CCD

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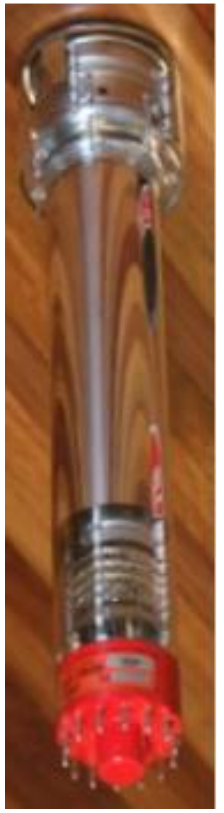
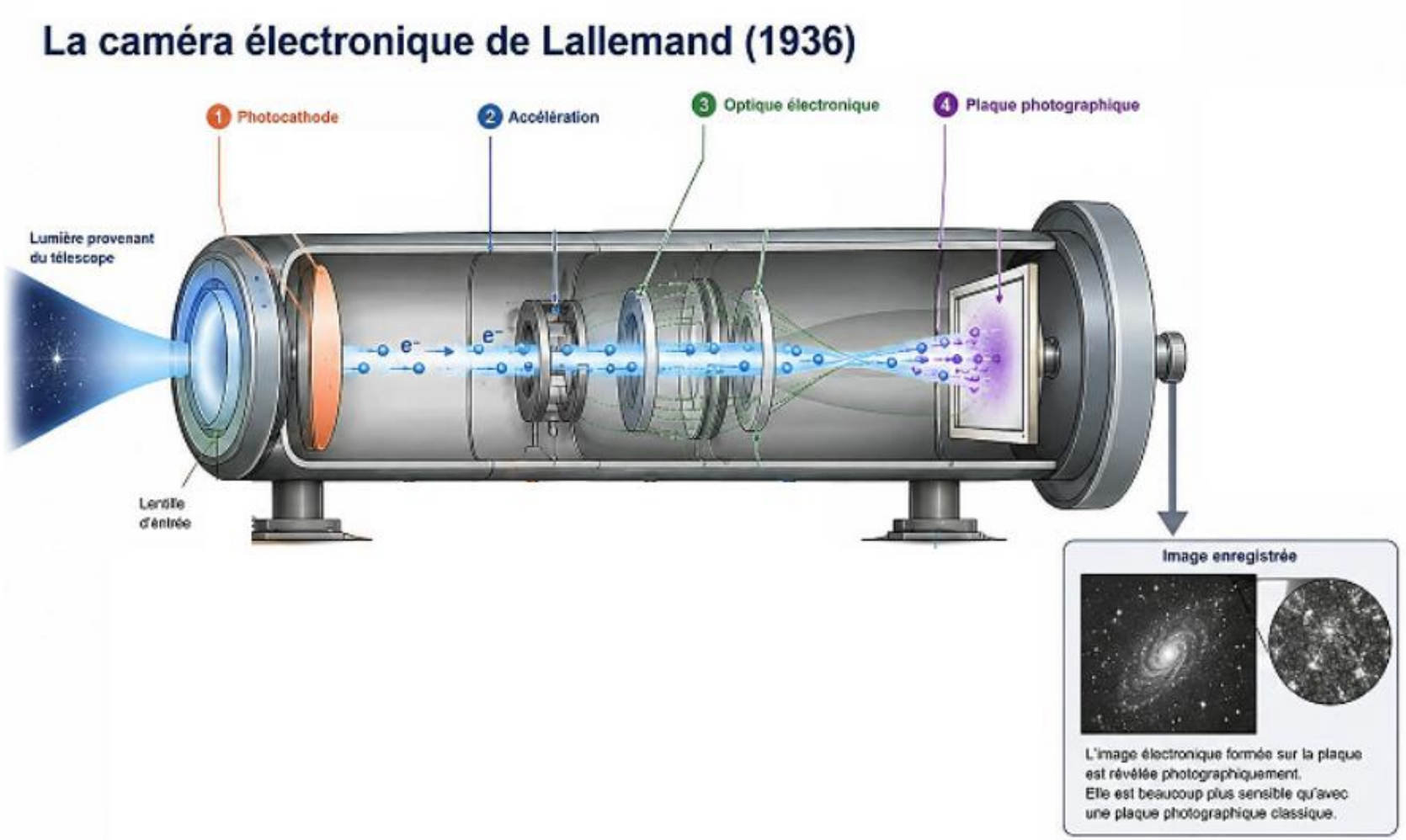


1945
Image Orthicon

L'image électronique avant les CCD – **André Lallemand**

sommaire

André Lallemand
Observatoire de Haute Provence - 1952



https://observatoiredeparis.psl.eu/les-ateliers-lallemand.html

L'image électronique avant les CCD – **Le vidicon**

sommaire

PERFORMANCE OF THE VIDICON, A SMALL DEVELOPMENTAL TELEVISION CAMERA TUBE*

By

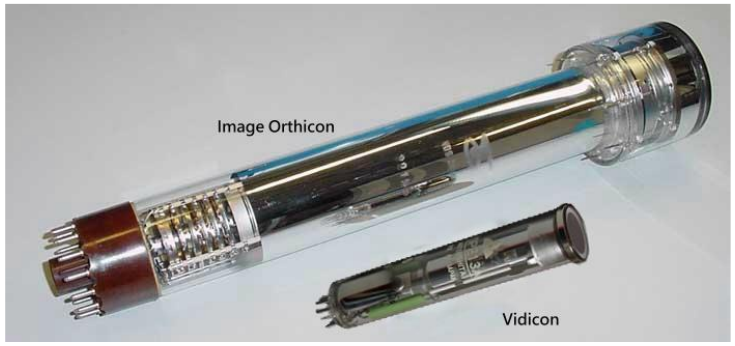
B. H. Vine, R. B. Janes and F. S. Veith

Tube Department, RCA Victor Division,
Lancaster, Pa.

Summary—*The performance of developmental Vidicons utilizing three different developmental types of photoconductive layers is described in this paper. Data is given on gamma, sensitivity, illumination considerations, spectral response, persistence, and life. Vidicon construction and operation as well as signal-to-noise limitations are discussed.*

Introduction

THE Vidicon is a developmental television camera tube employing a thin layer of photoconductive material as its light-sensitive



RCA REVIEW *March 1952*

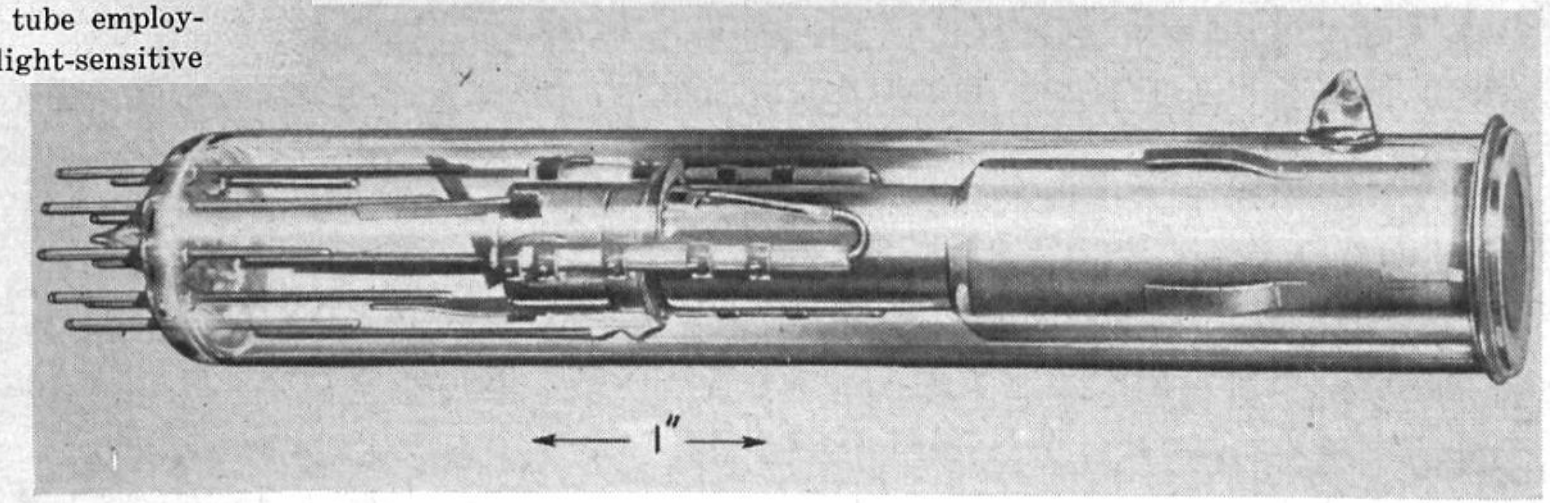


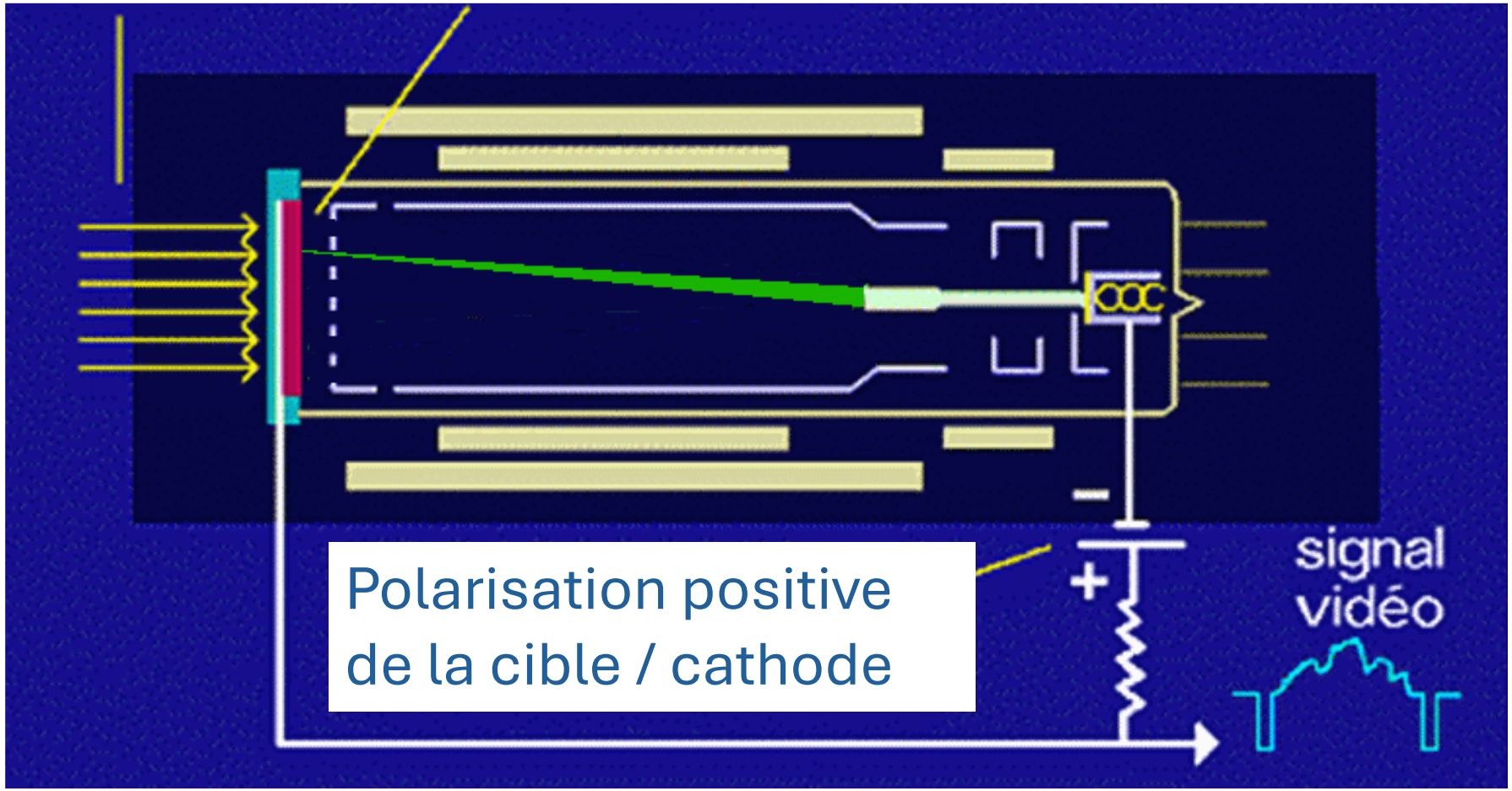
Fig. 3—Photograph of developmental Vidicon.

L'image électronique avant les CCD – **Le vidicon**

sommaire

Image focalisée sur la cible

Balayage de la cible par le faisceau d'électrons



L'image électronique avant les CCD – **Le vidicon**

sommaire

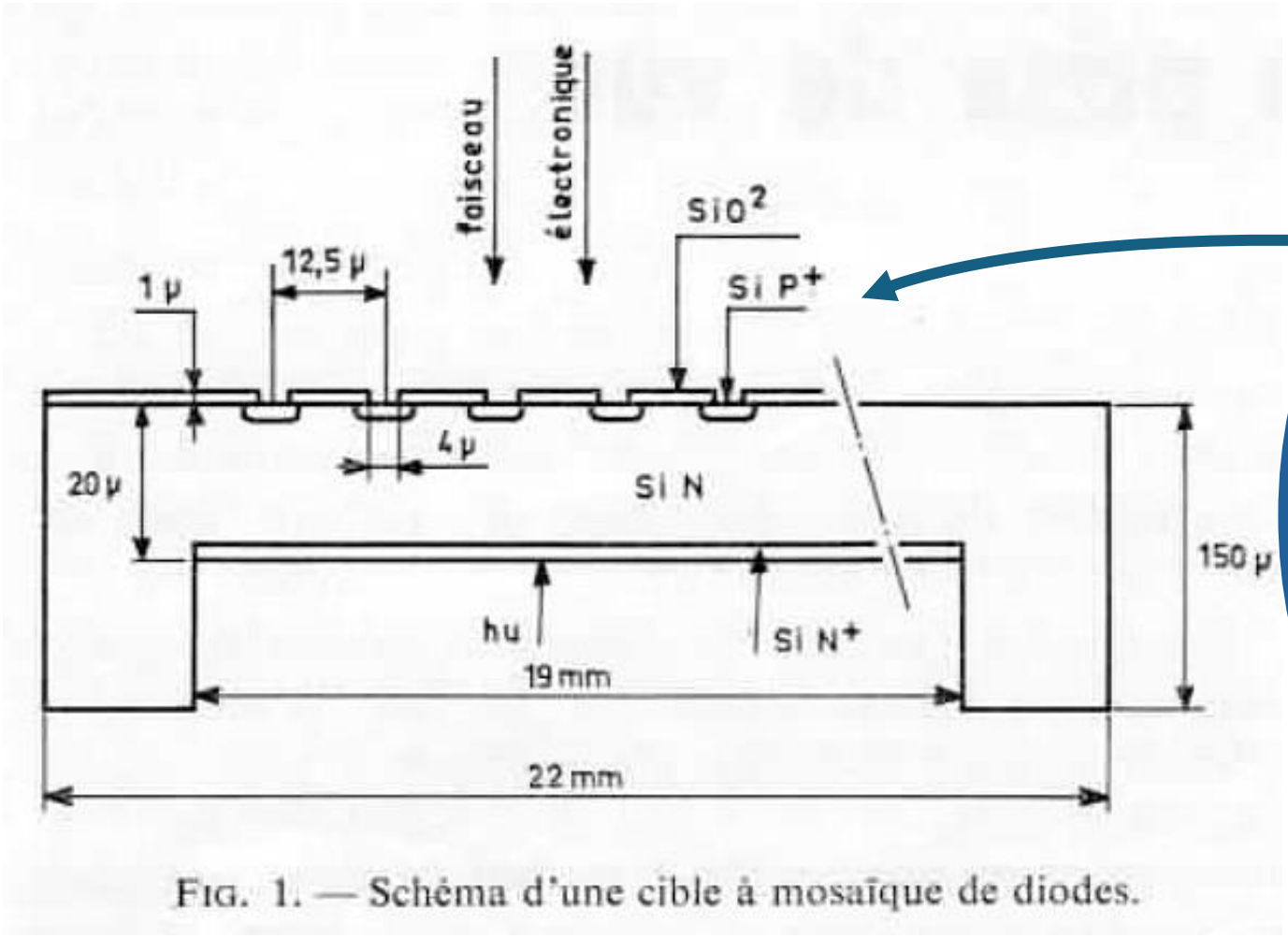
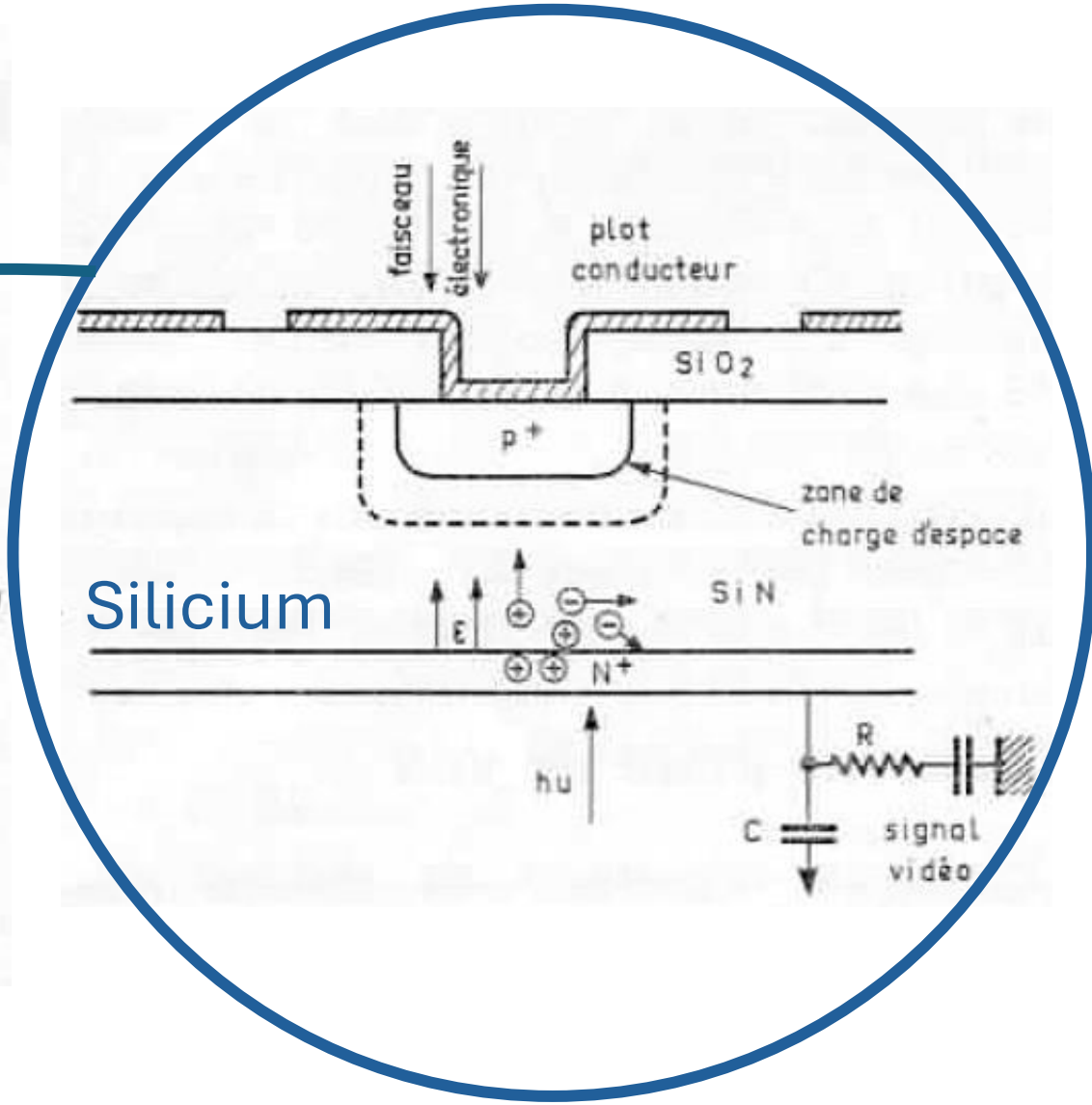
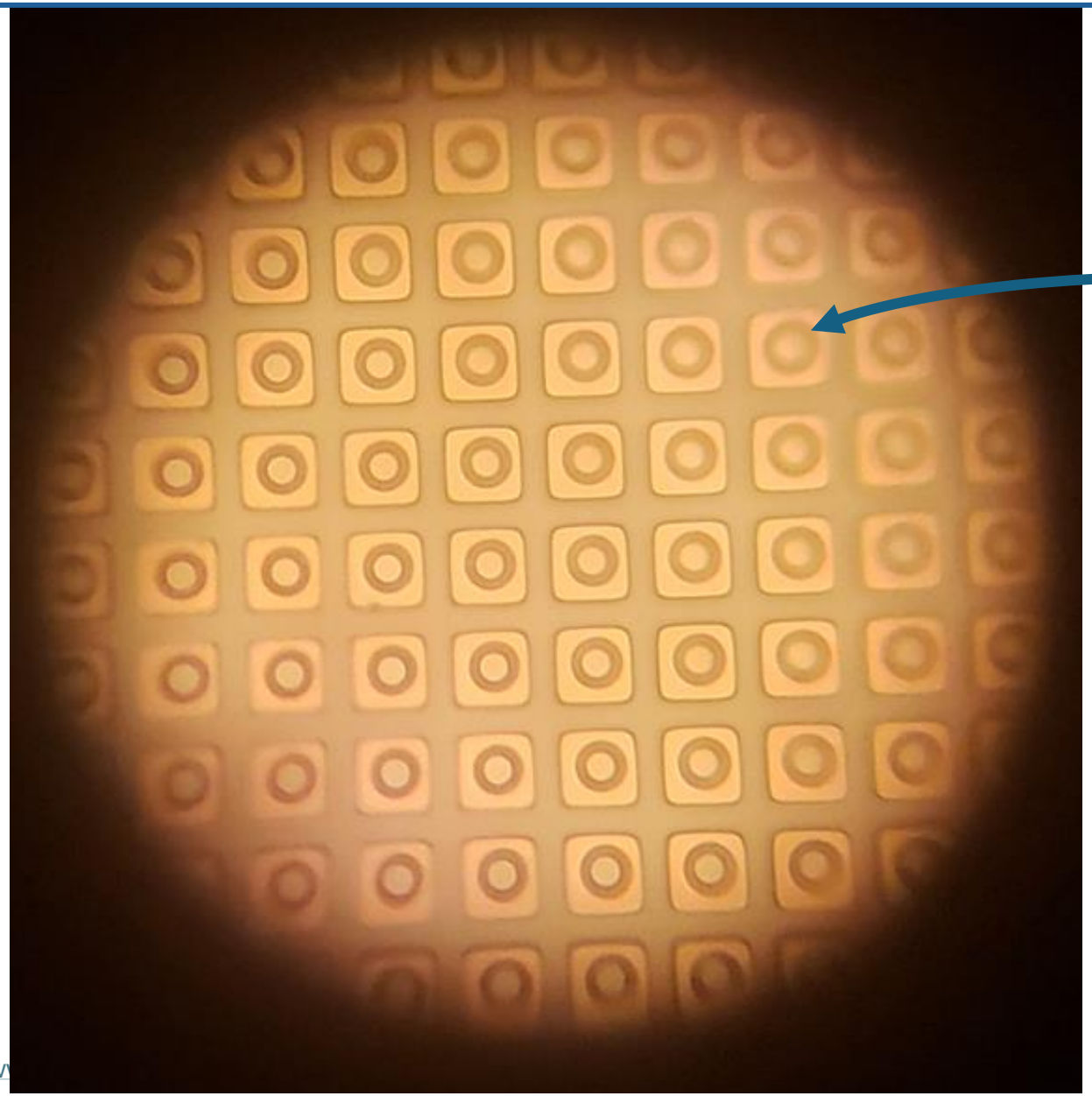


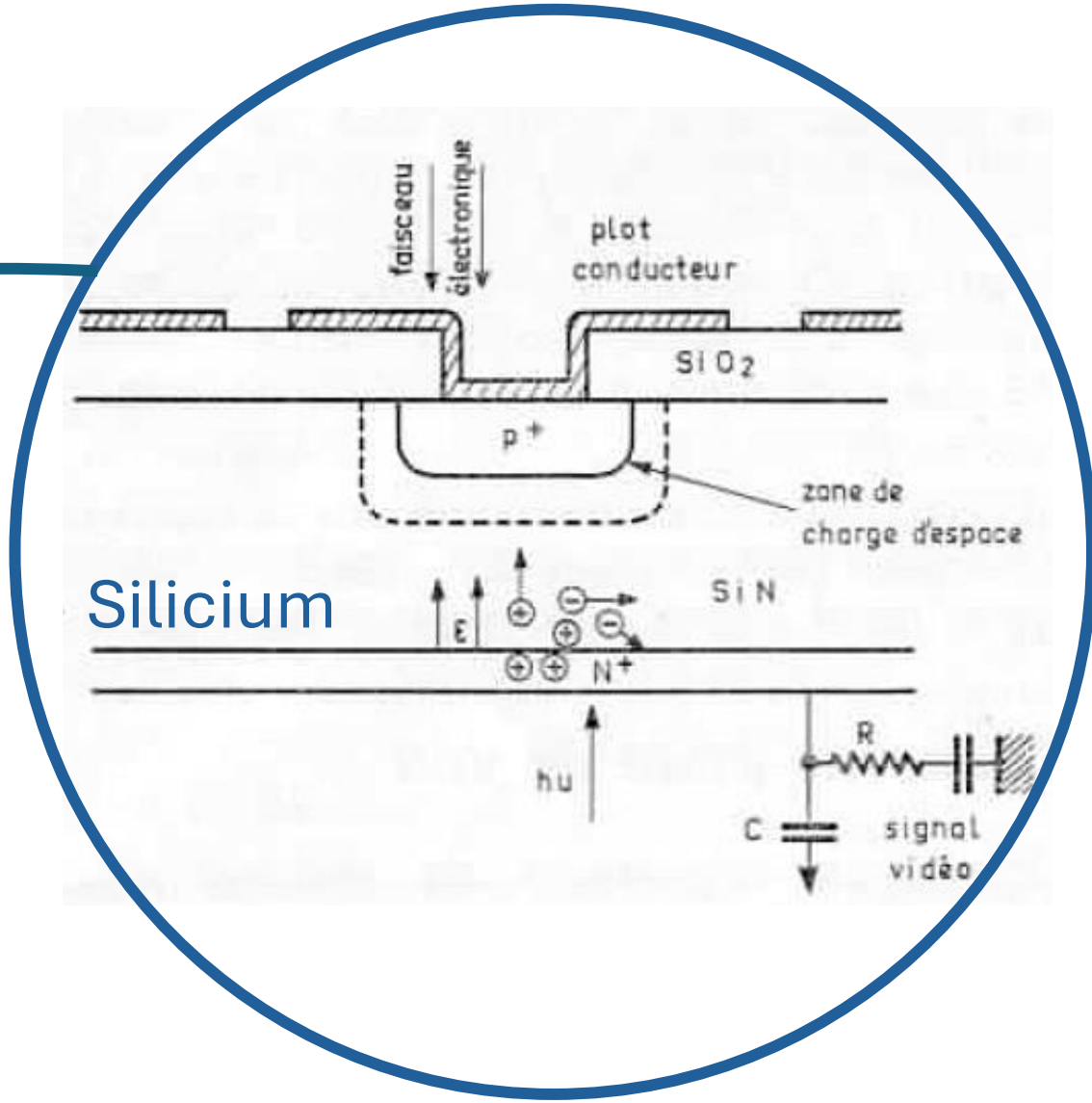
FIG. 1. — Schéma d'une cible à mosaïque de diodes.



L'image électronique avant les CCD – **Le vidicon**

sommaire





1971 à Saint-Egrève

1969 - Invention des CCD

sommaire

Première esquisse d'un CCD
le 18 octobre 1969,
par Willard Boyle et George Smith
aux laboratoires Bell

1969 - Invention des CCD

1er article dans le Bell System Technical Journal

sommaire

B.S.T.J. BRIEFS

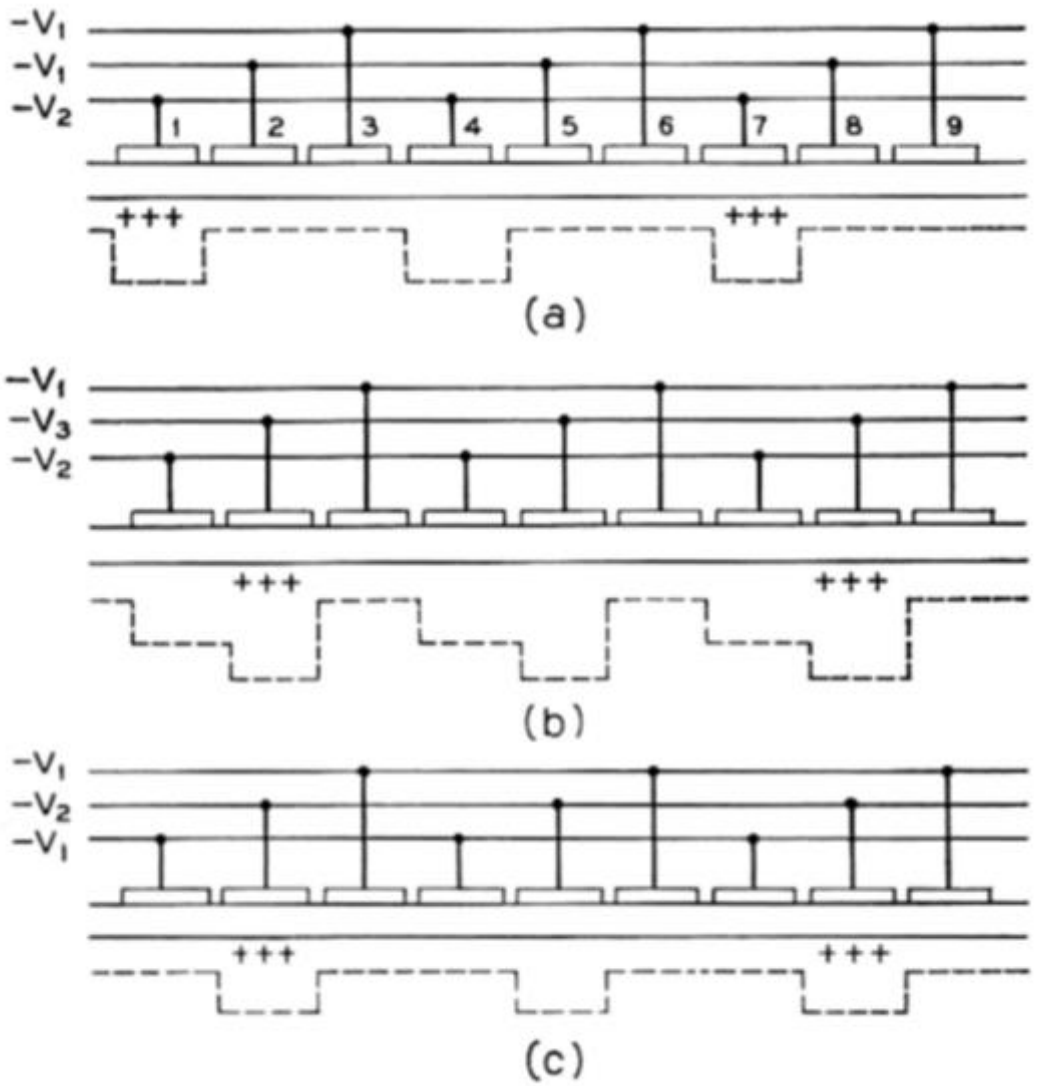
Charge Coupled Semiconductor Devices

By W. S. BOYLE and G. E. SMITH

(Manuscript received January 29, 1970)

In this paper we describe a new semiconductor device concept. Basically, it consists of storing charge in potential wells created at the surface of a semiconductor and moving the charge (representing information) over the surface by moving the potential minima. We discuss schemes for creating, transferring, and detecting the presence or absence of the charge.

In particular, we consider minority carrier charge storage at the Si-SiO_2 interface of a MOS capacitor. This charge may be transferred to a closely adjacent capacitor on the same substrate by appropriate manipulation of electrode potentials. Examples of possible applications are as a shift register, as an imaging device, as a display device, and in performing logic.



https://archive.org/details/bstj49-4-587

Dispositifs à transfert de charge = **C**harge **C**oupled **D**evices

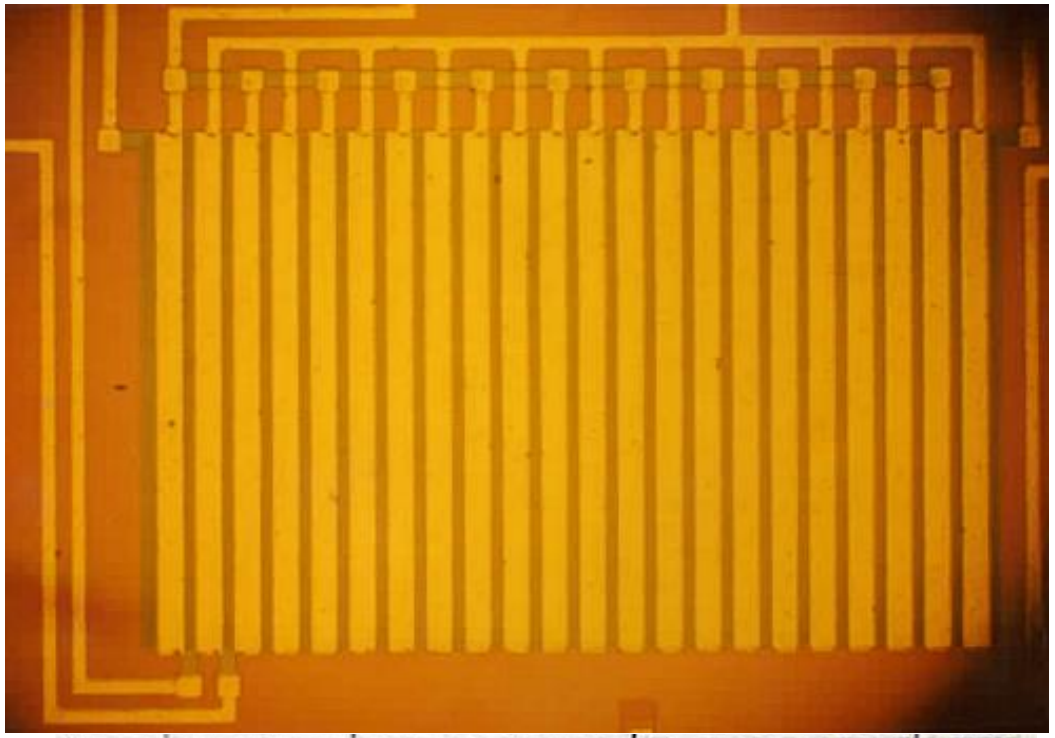
sommaire

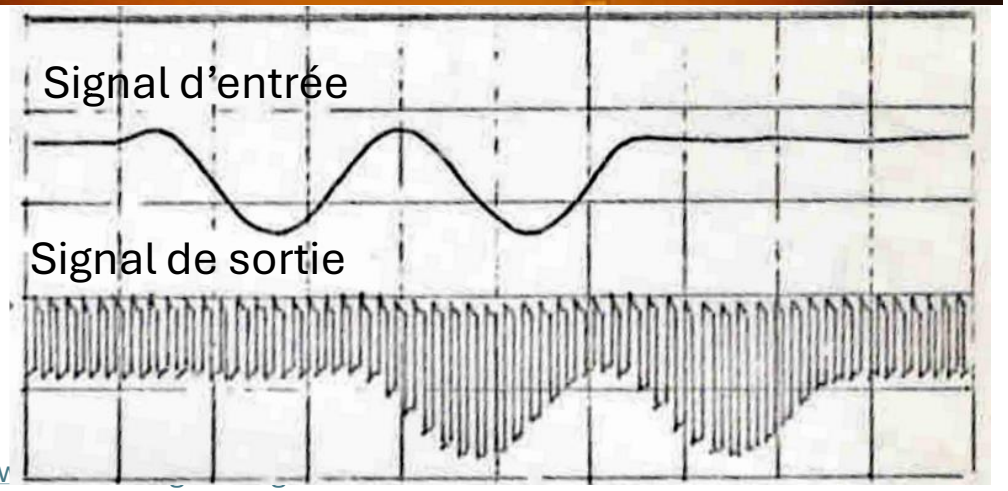
Transfert de charges électriques
d'un puits de potentiel vers un autre
par une suite de capacités MOS
couplées entre elles et
commandées par des potentiels
périodiques

Les CCD
stockent et **déplacent**
une information analogique
échantillonnée
sous forme de paquets
de charges électriques
à l'intérieur d'un substrat semi-conducteur

Début des CCD à TH-CSF Saint-Egrève

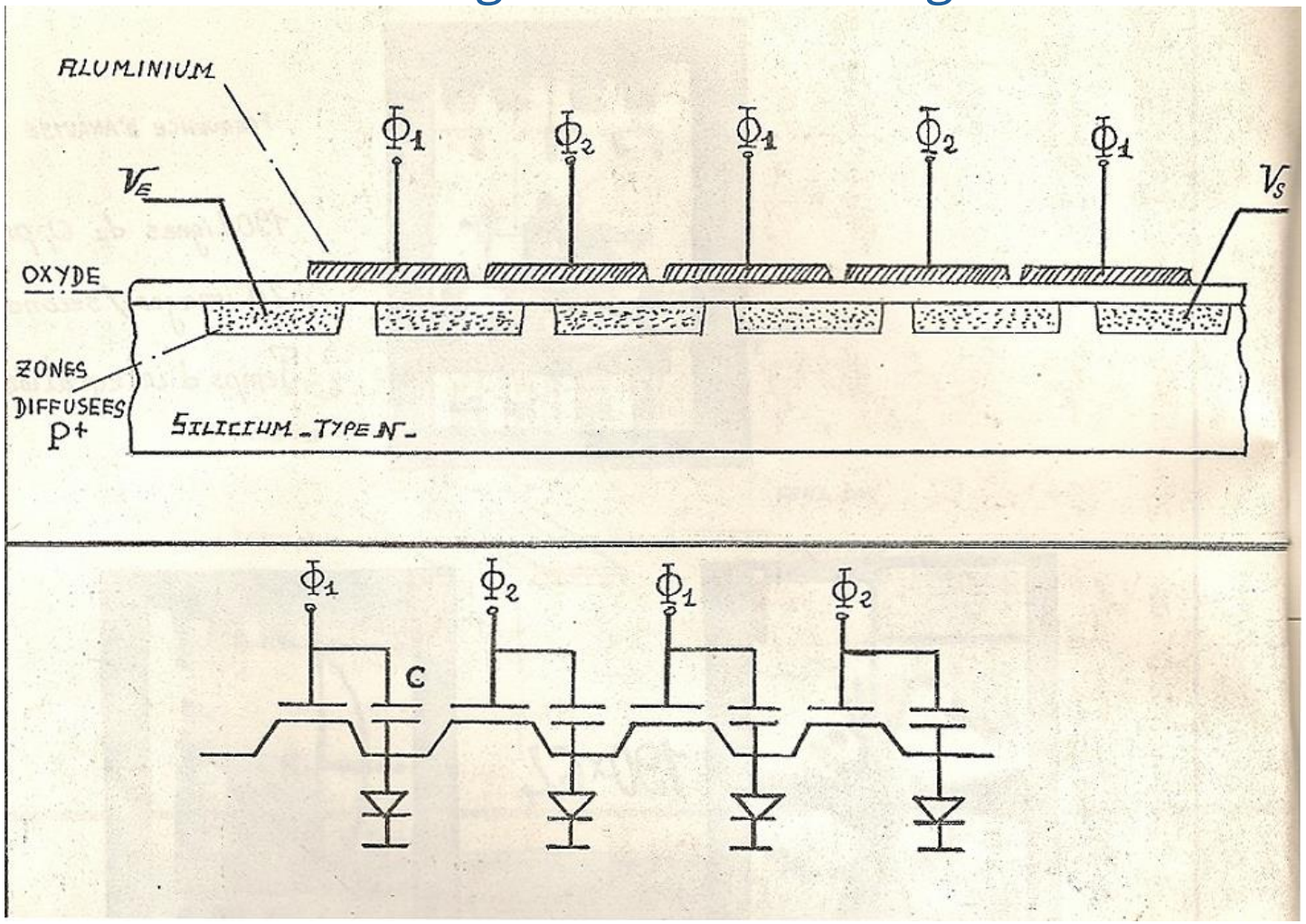
sommaire





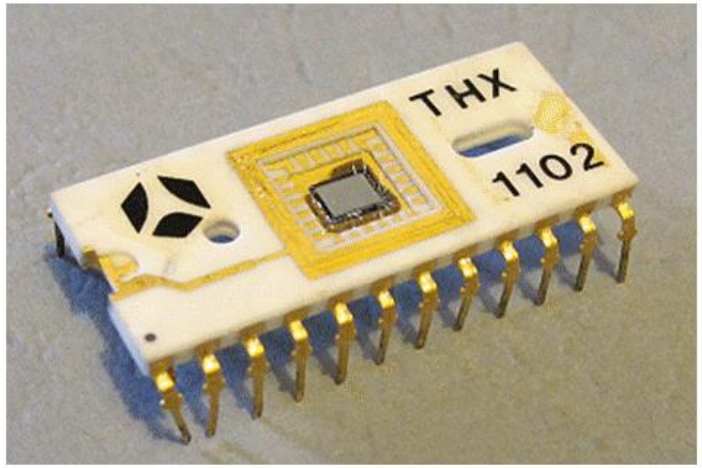
1972 « Bucket Brigade Device » (BBD)

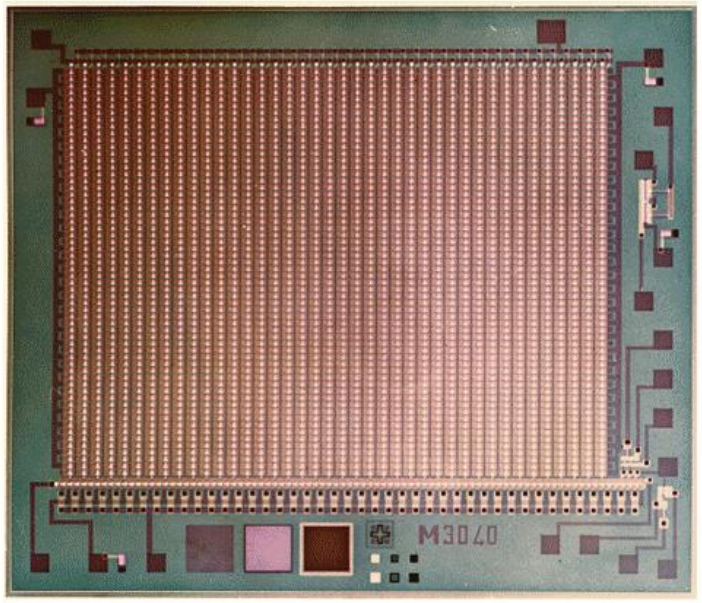
Technologie : métallisation grille alu



Début des CCD à TH-CSF Saint-Egrève

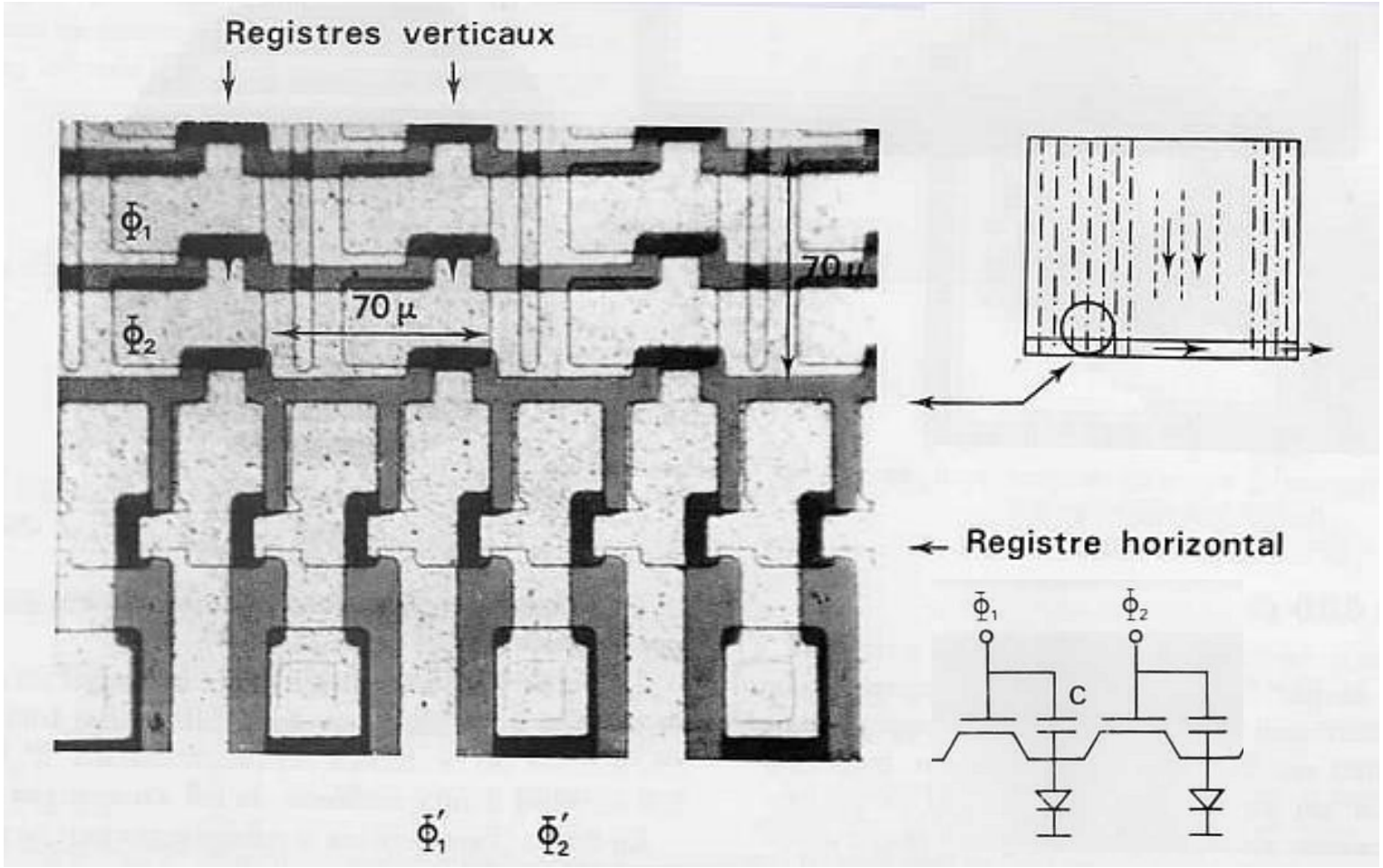
sommaire





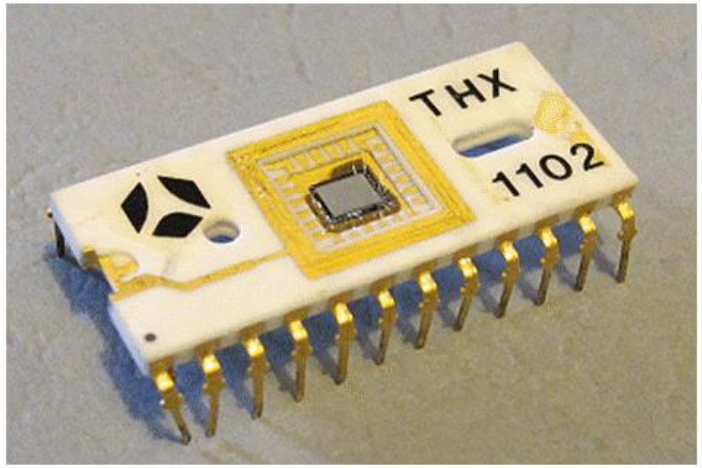
1972 - 73

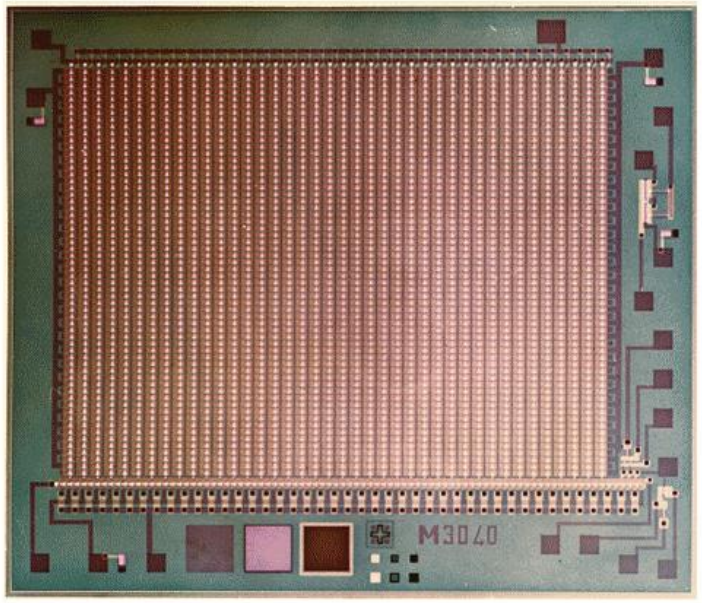
Matrice BBD - 30x40 points – Grille Alu.



Début des CCD à TH-CSF Saint-Egrève

sommaire





1972 - 73

Matrice BBD - 30x40 points – Grille Alu.

Début des CCD à TH-CSF Saint-Egrève

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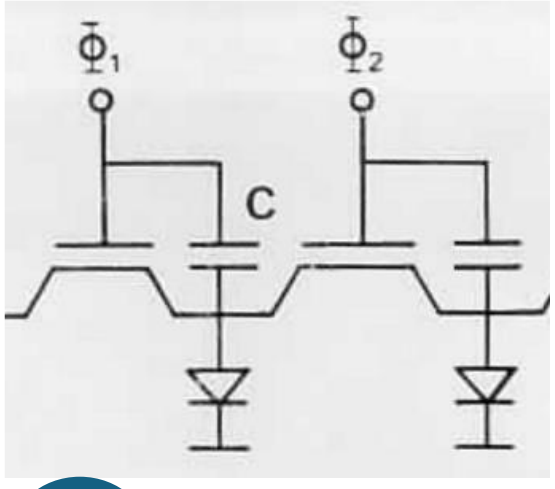
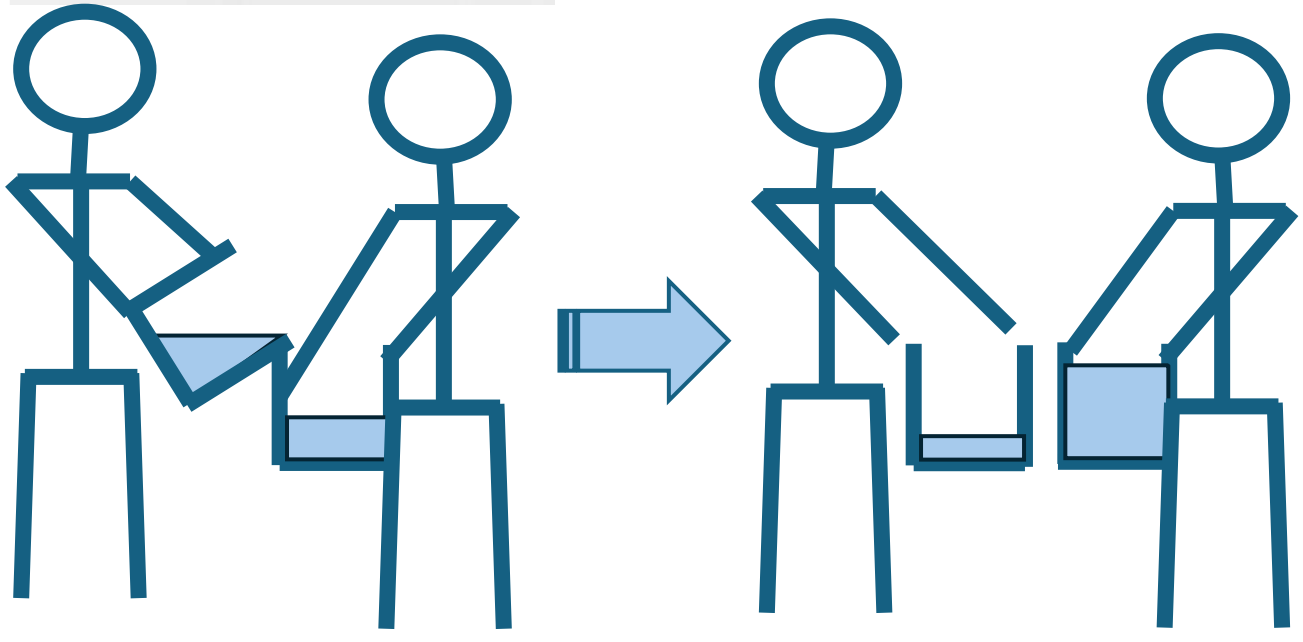
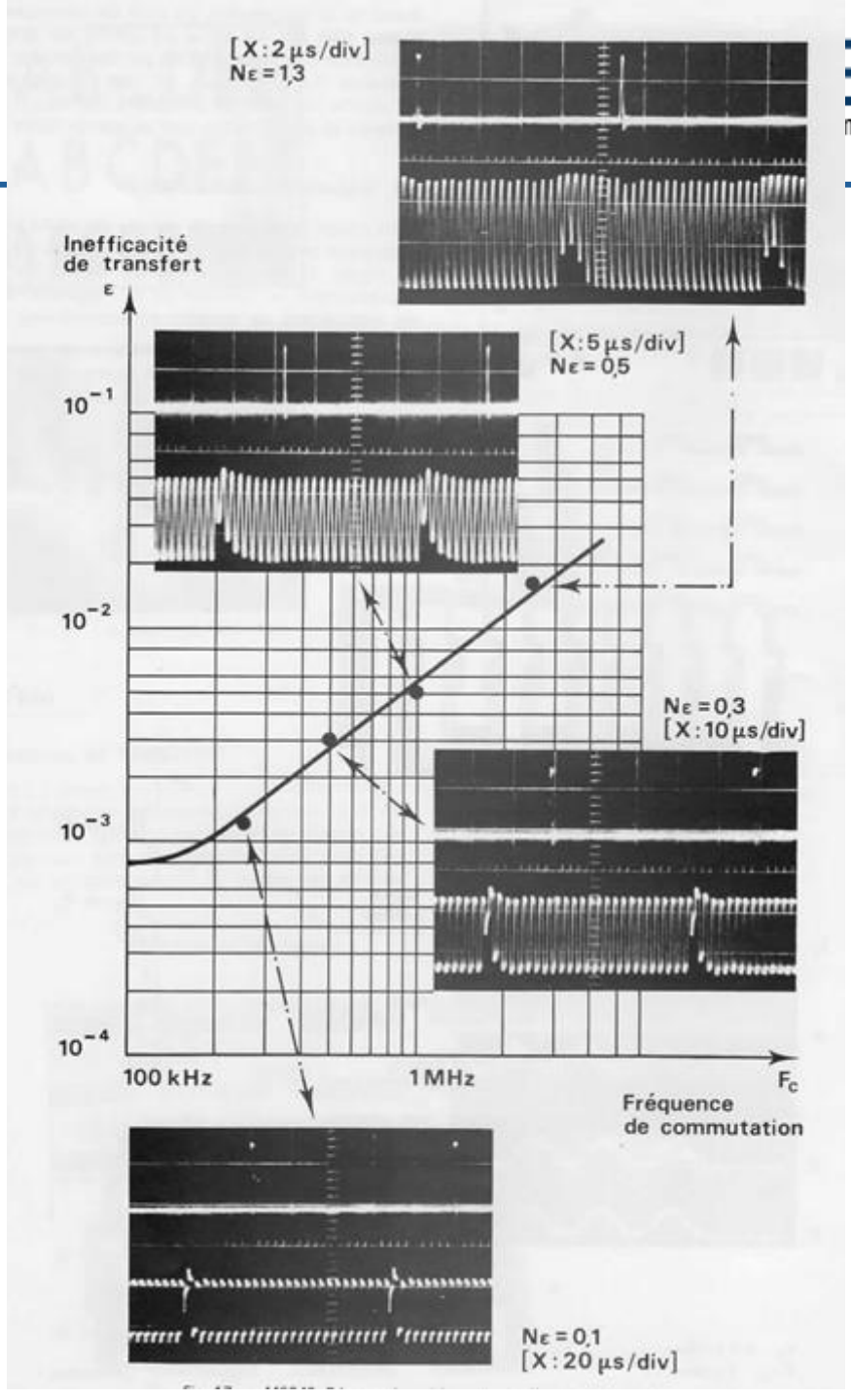


Problème d'inefficacité de transfert !



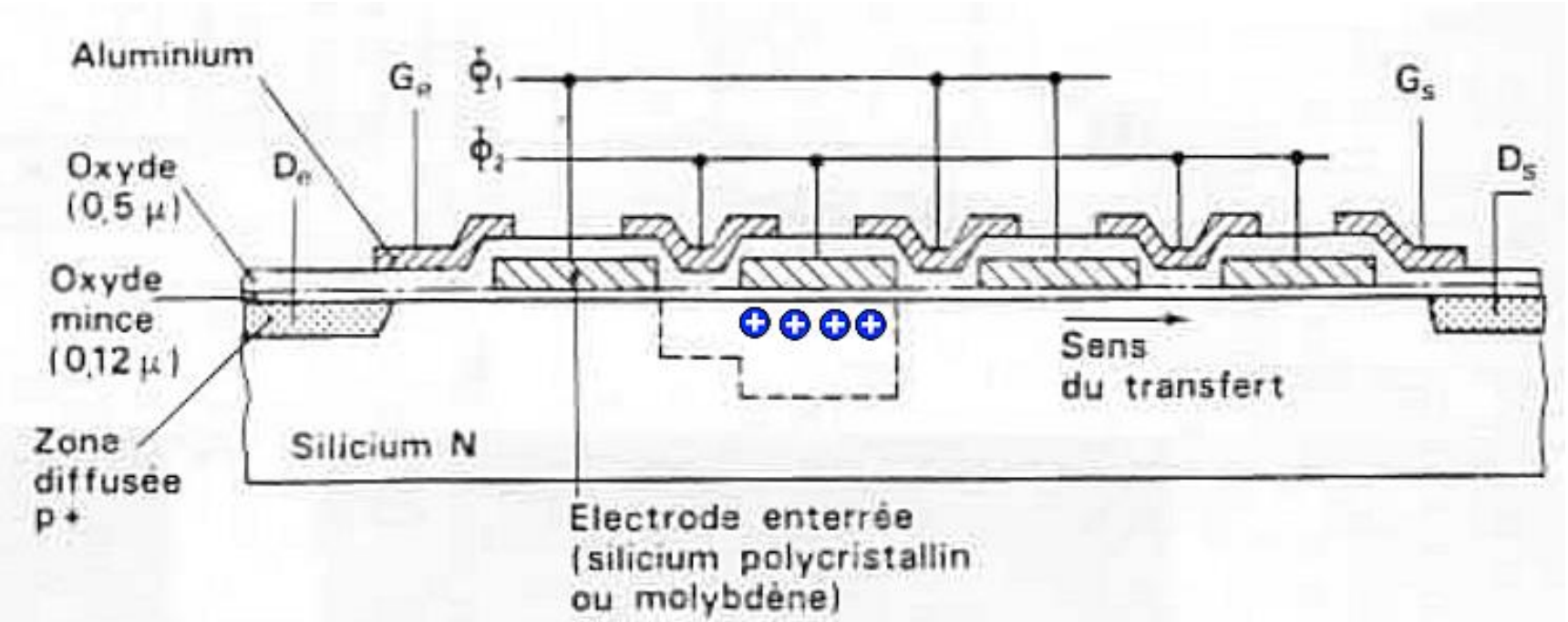


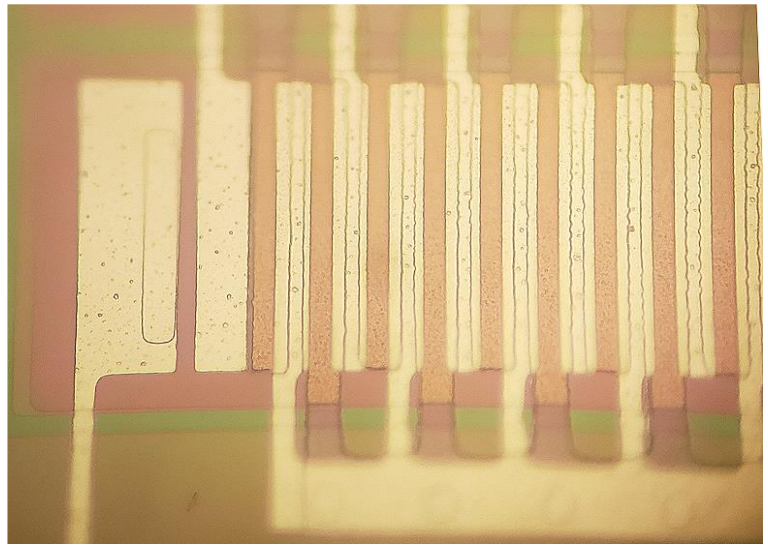
Début des CCD

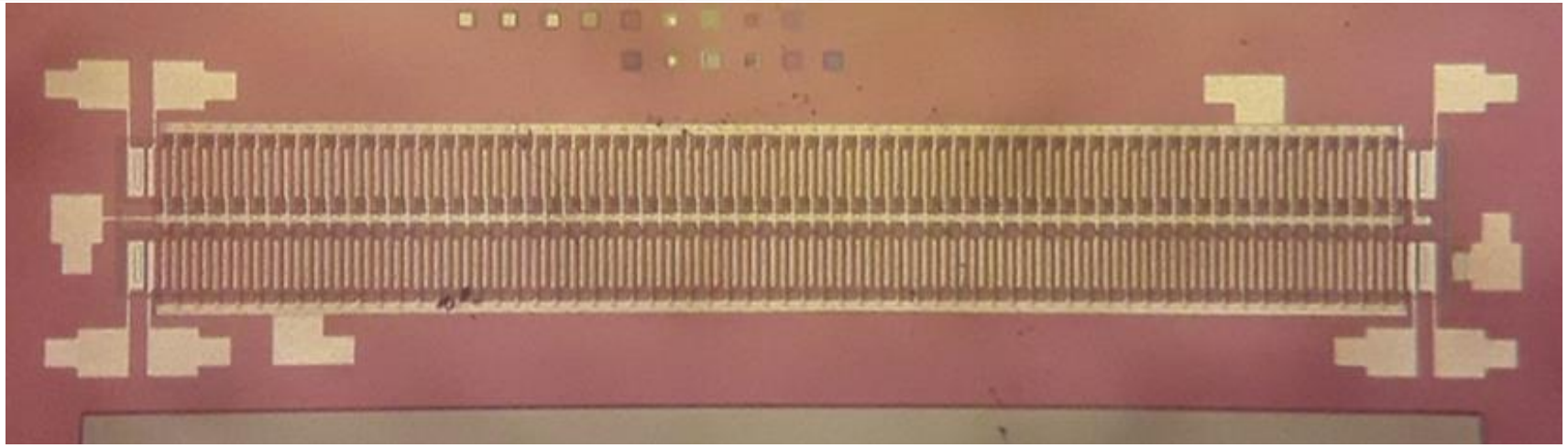
1973 - Barrette CCD 64 étages

Grilles silicium polycristallin et aluminium

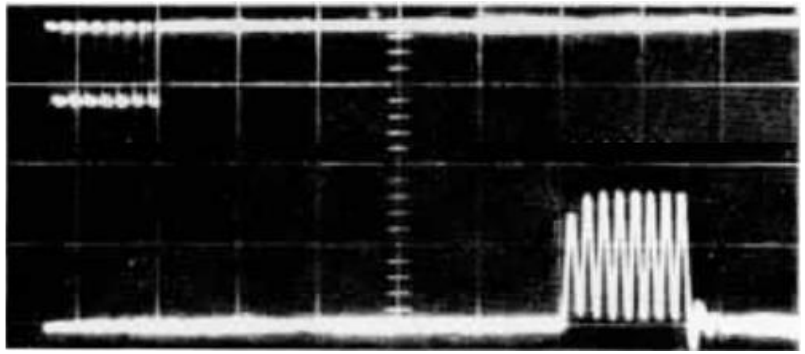
sommaire







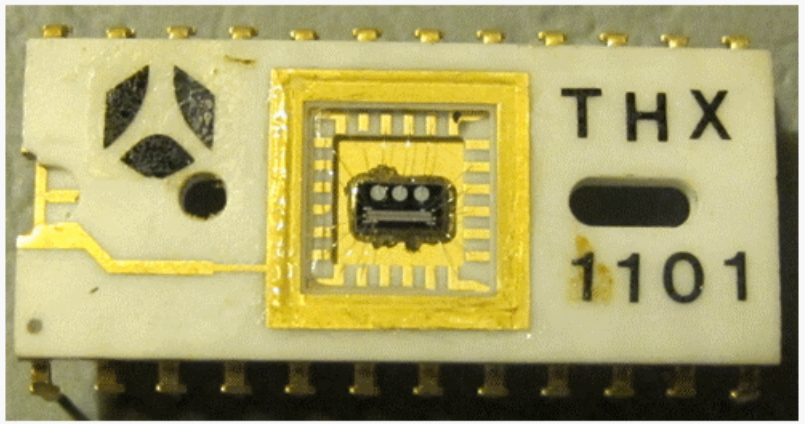
Signal d'entrée



Signal de sortie

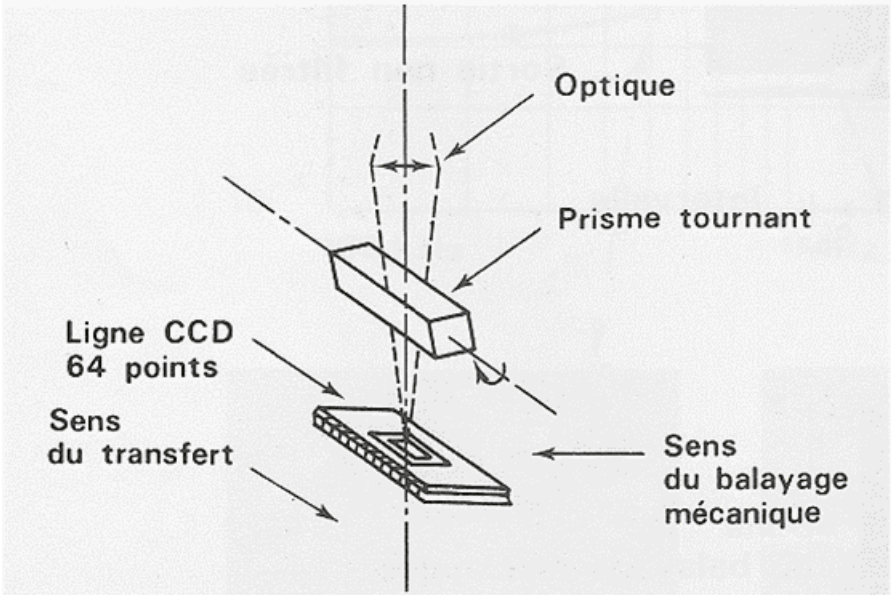
Début des CCD à TH-CSF Saint-Egrève

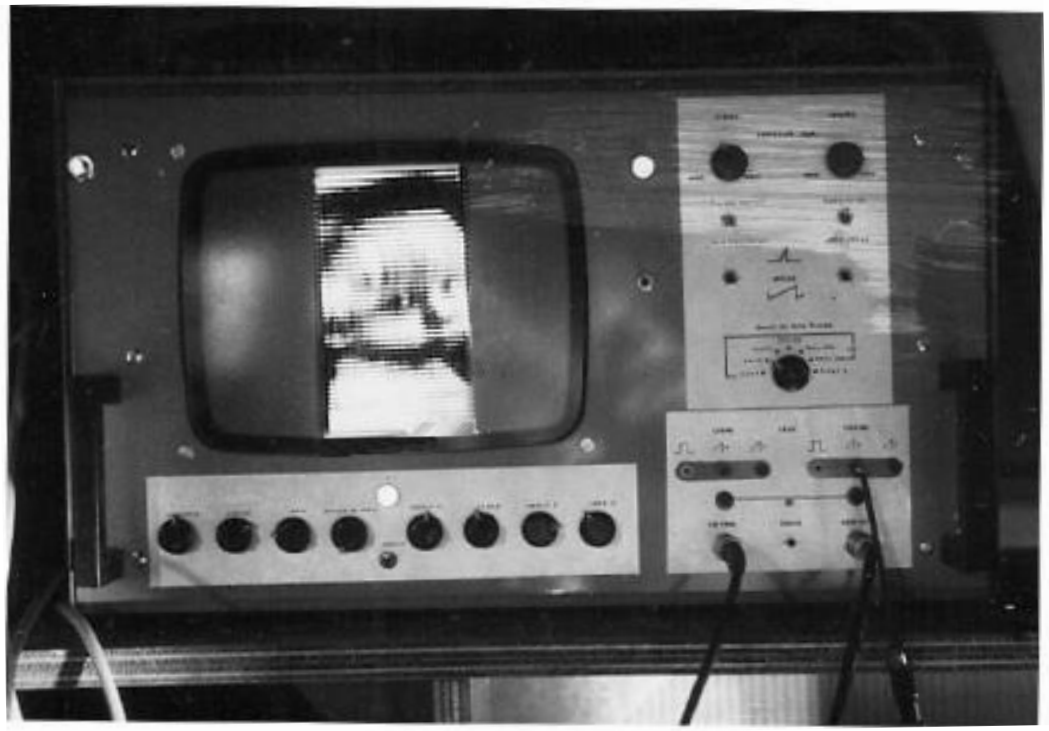
sommaire



1973 - Barrette CCD 64 étages

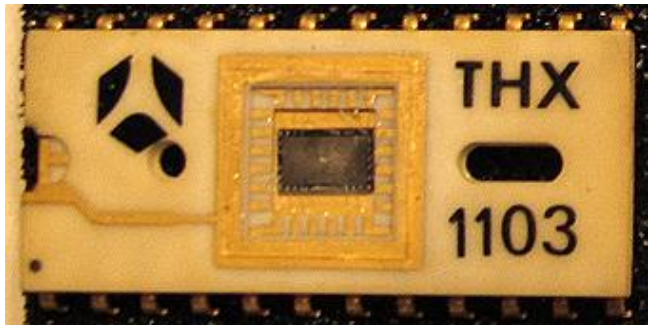
Image avec balayage optique



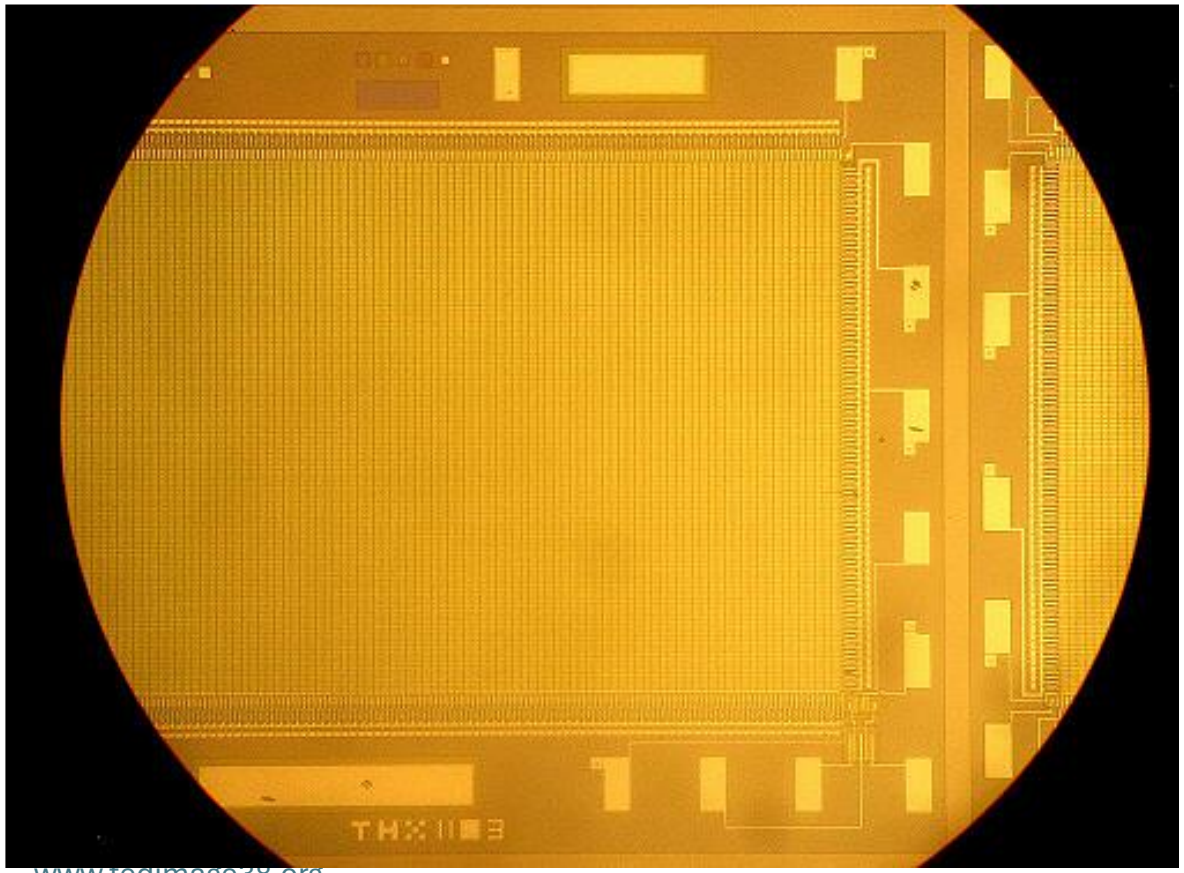


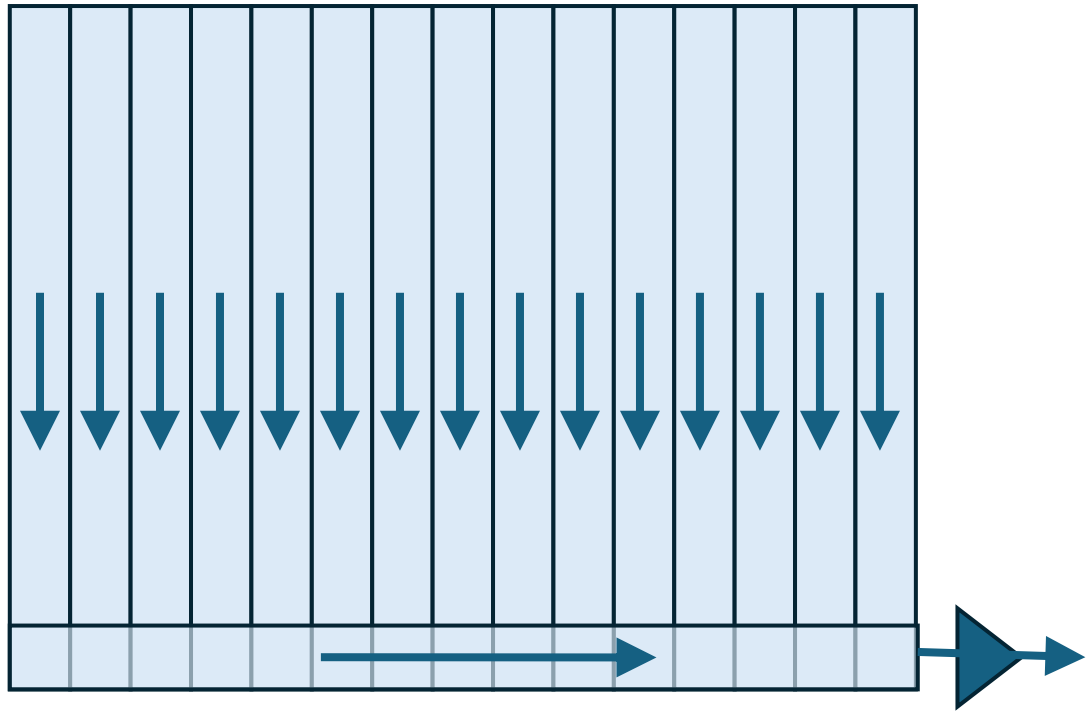
Début des CCD à TH-CSF Saint-Egrève

sommaire



1974 – Première matrice CCD - 64 lignes x 128 points
Grilles silicium polycristallin et aluminium





Début des CCD à TH-CSF Saint-Egrève

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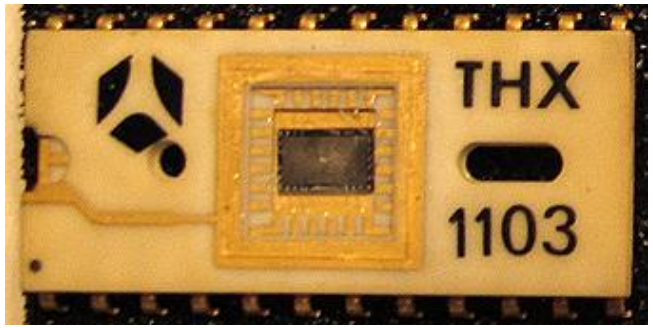
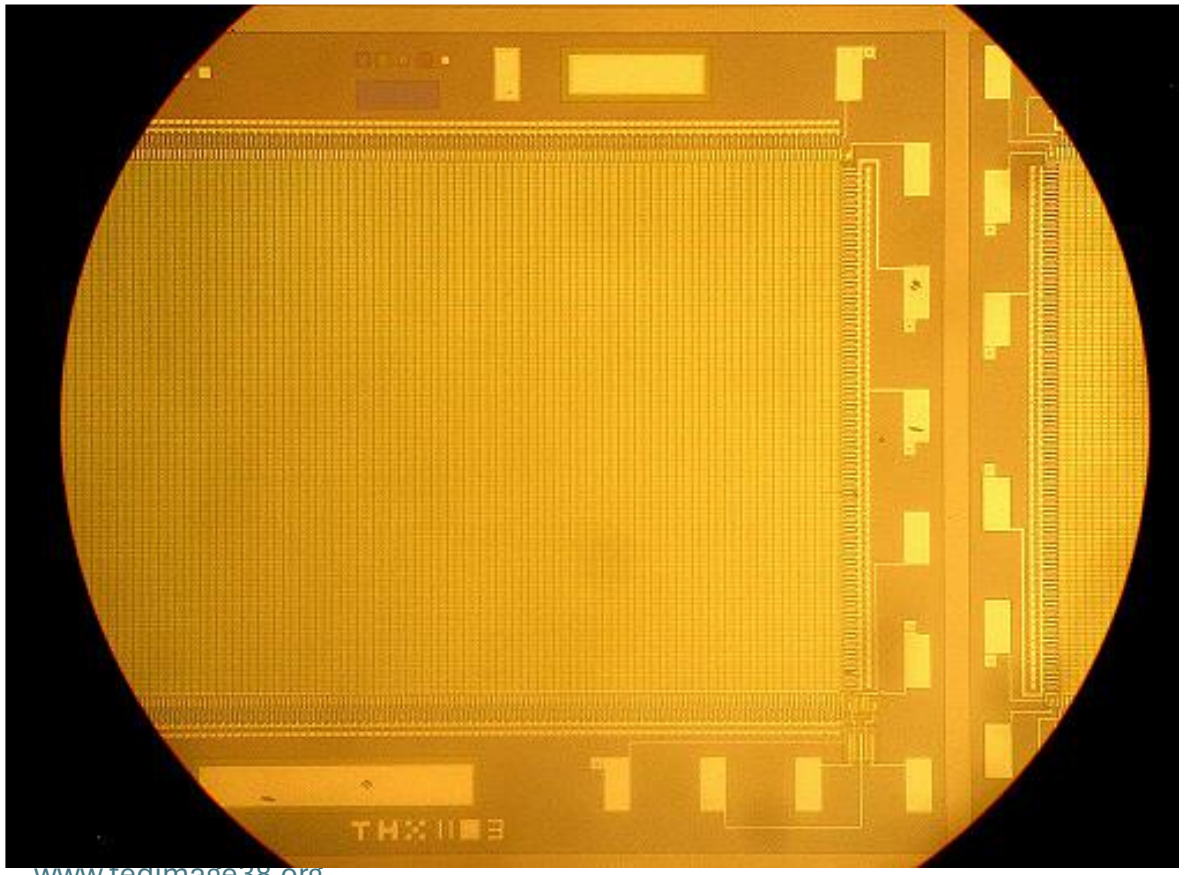


1974 – Première matrice CCD - 64 lignes x 128 points

Grilles silicium polycristallin et aluminium



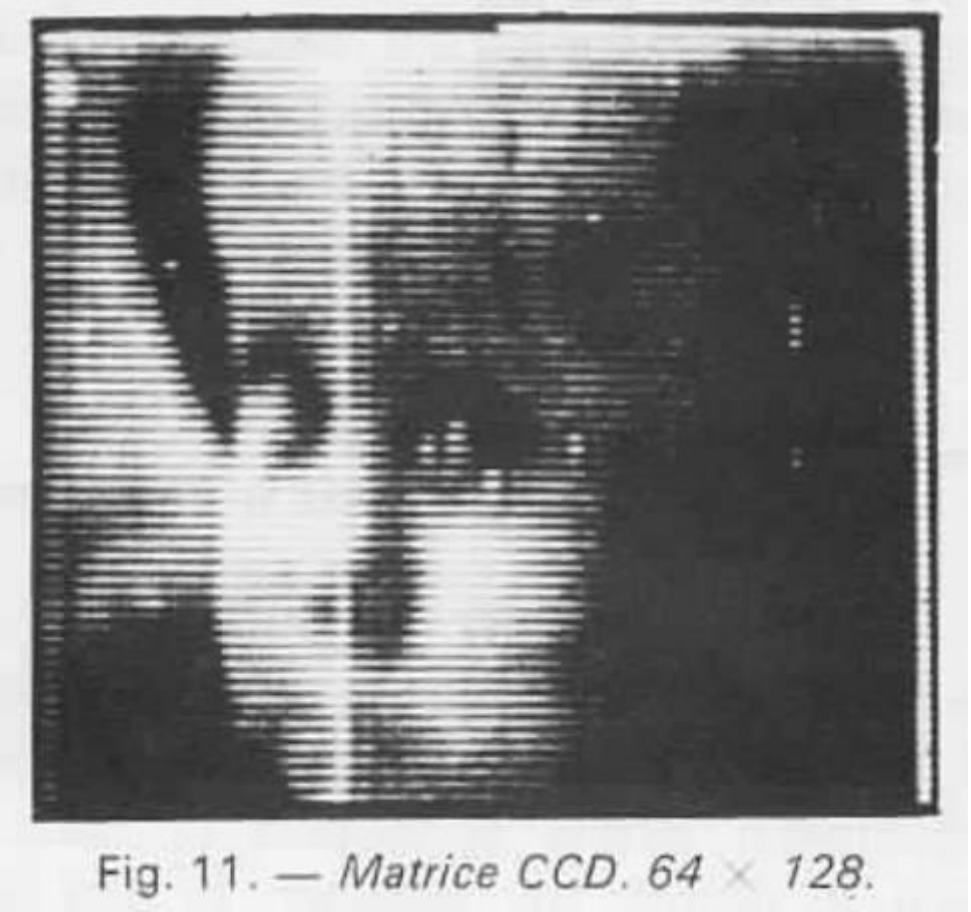


Fig. 11. — *Matrice CCD. 64 × 128.*

Le problème de l'inefficacité de transfert

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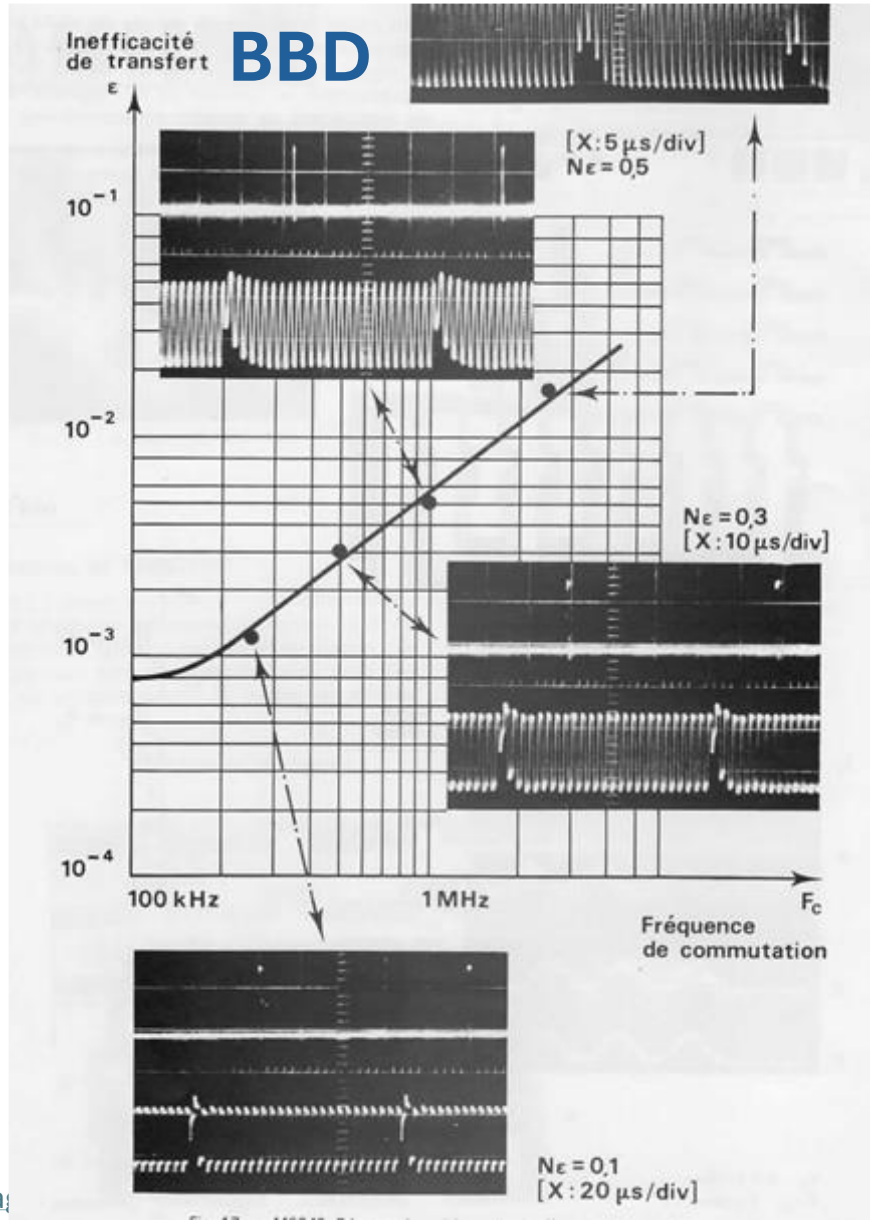
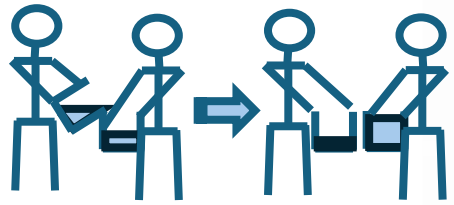
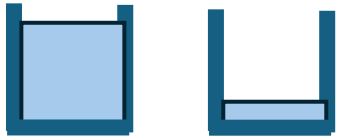
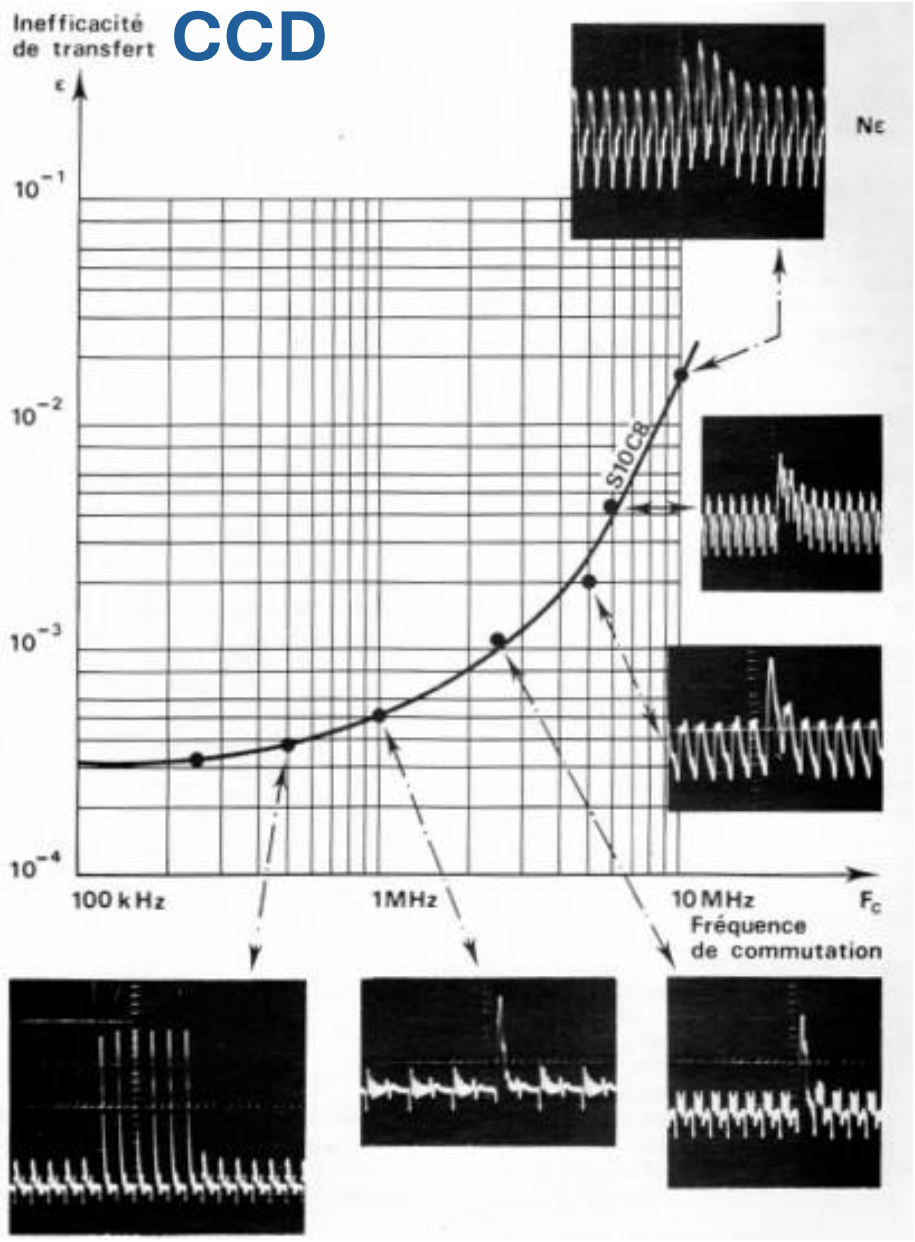




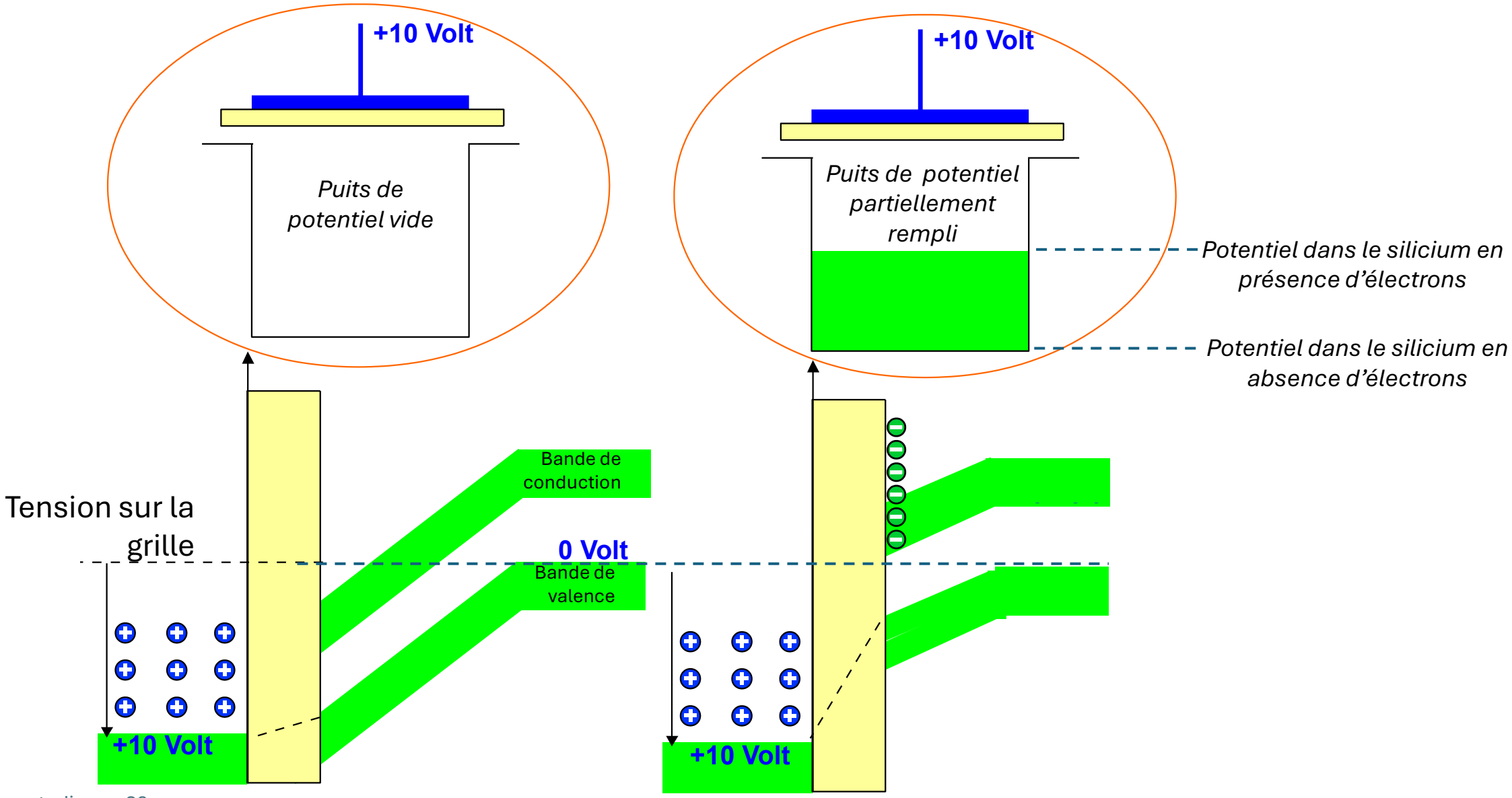


$$\text{Inefficacité} = \frac{Qr}{Q0}$$



Une image utile pour expliquer les CCD…

sommaire



Choix technologiques en 1975

sommaire

- BBD ou CCD ?
- Substrat de type N ou P ?
- Transfert en surface ou en volume ?
- Phases de commande : 1 ou 2 ou 3 ou 4 ?
- Transfert unidirectionnel ou bidirectionnel ?

Choix technologiques en 1975

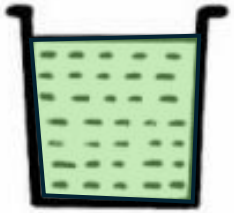
sommaire

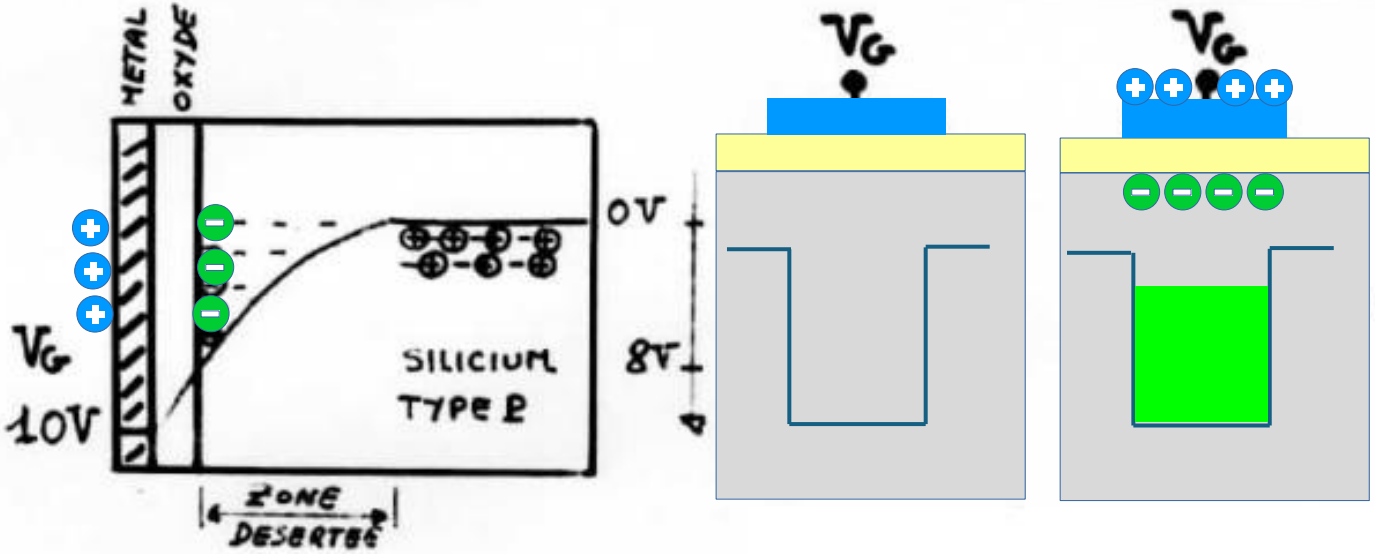
- BBD ou CCD
- Substrat de type N ou P
- Transfert en surface ou en volume
- Phases de commande : 1 ou 2 ou 3 ou 4 → 2 niveaux de silicium polycristallin
- Transfert unidirectionnel ou bidirectionnel

Stockage en surface et en volume

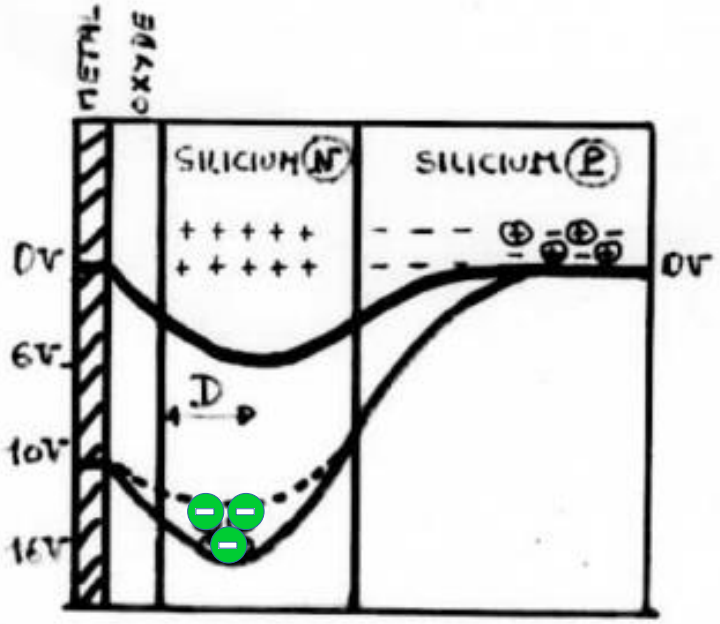
sommaire

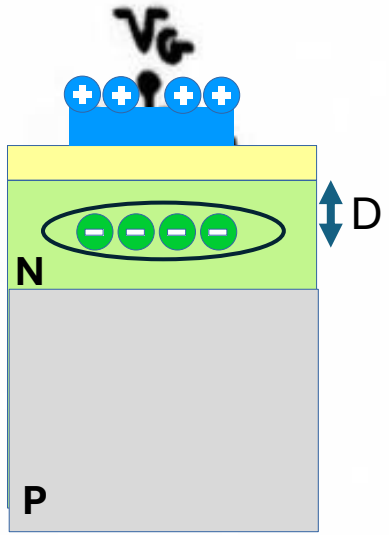
En surface





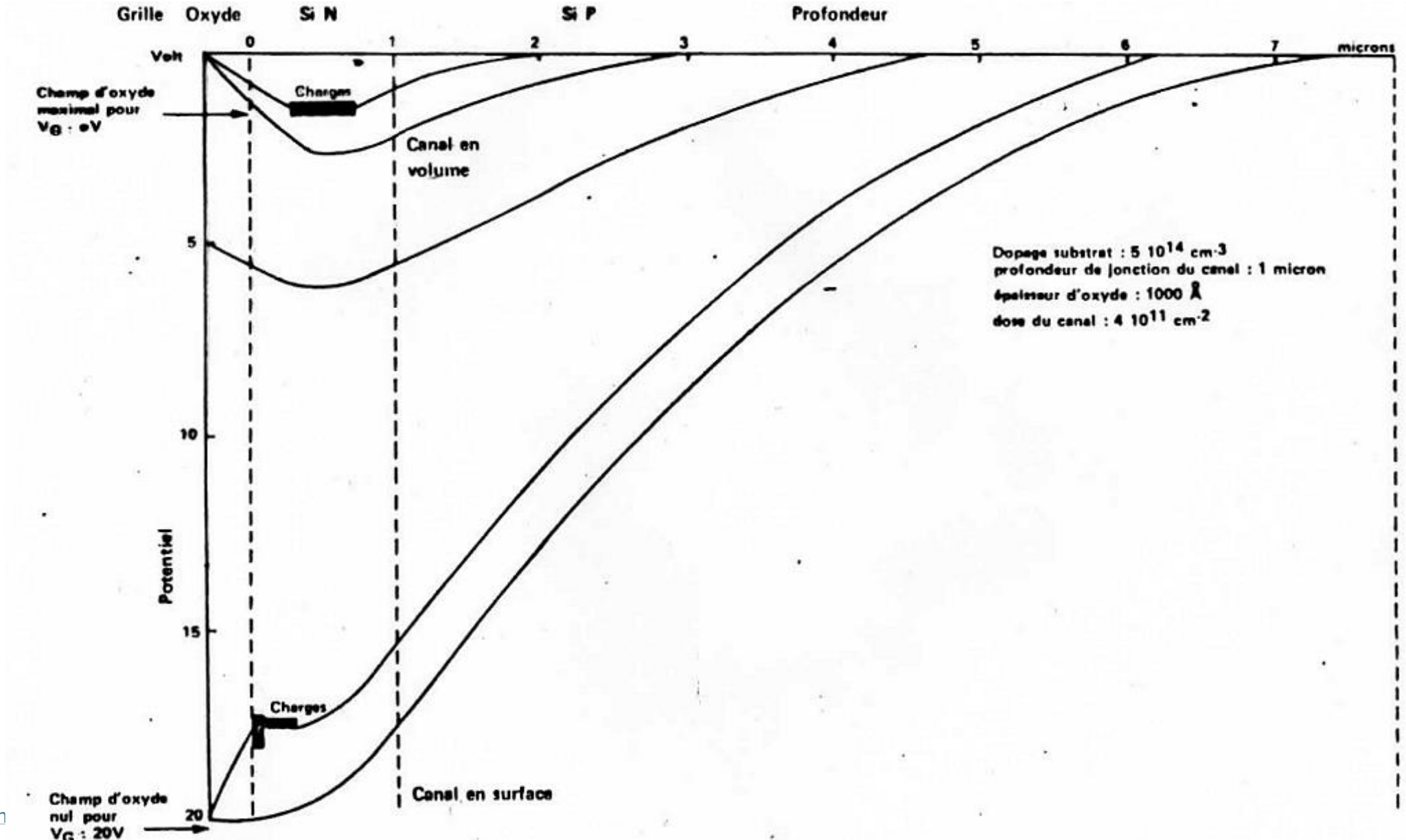
En volume





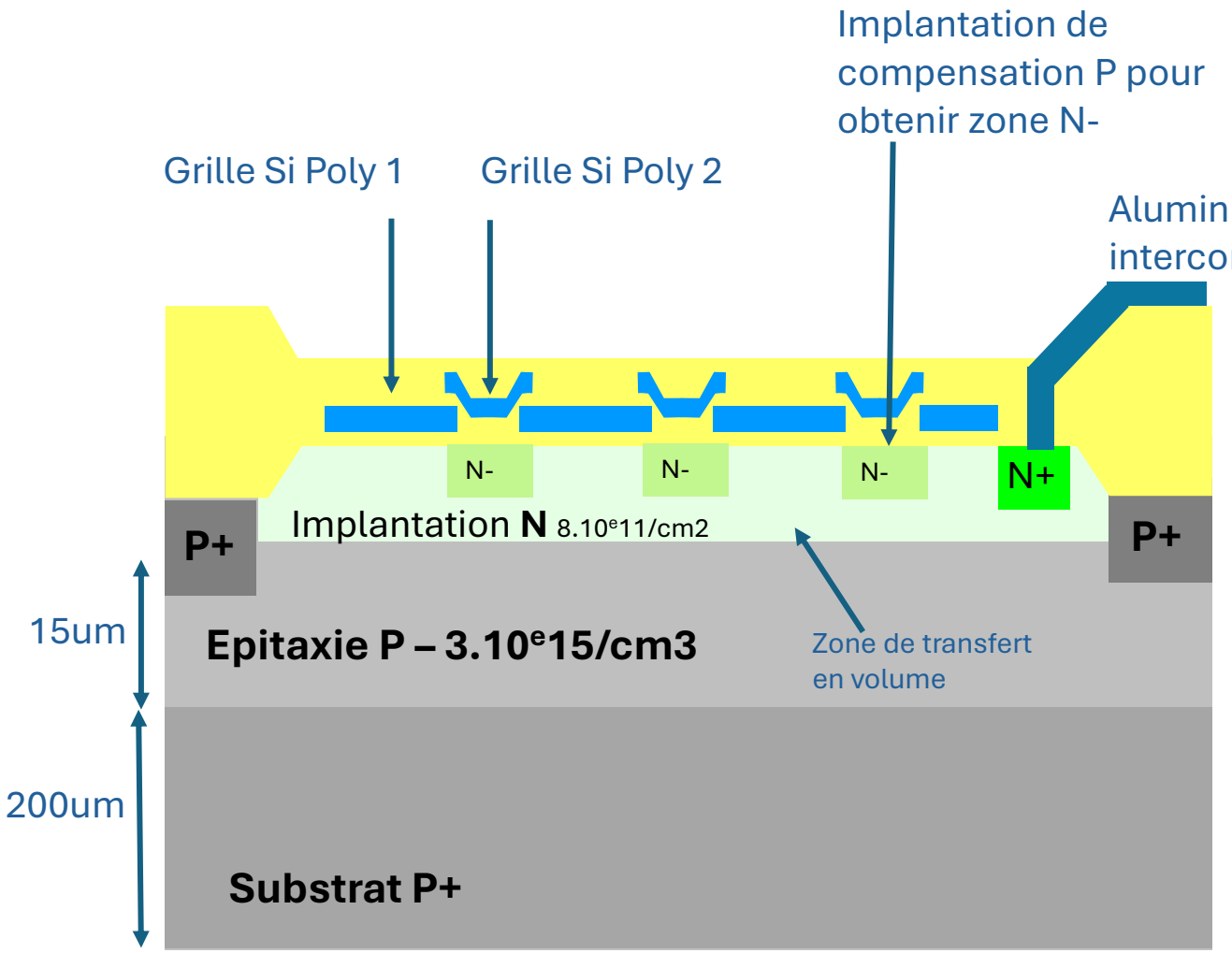
Stockage en surface et en volume

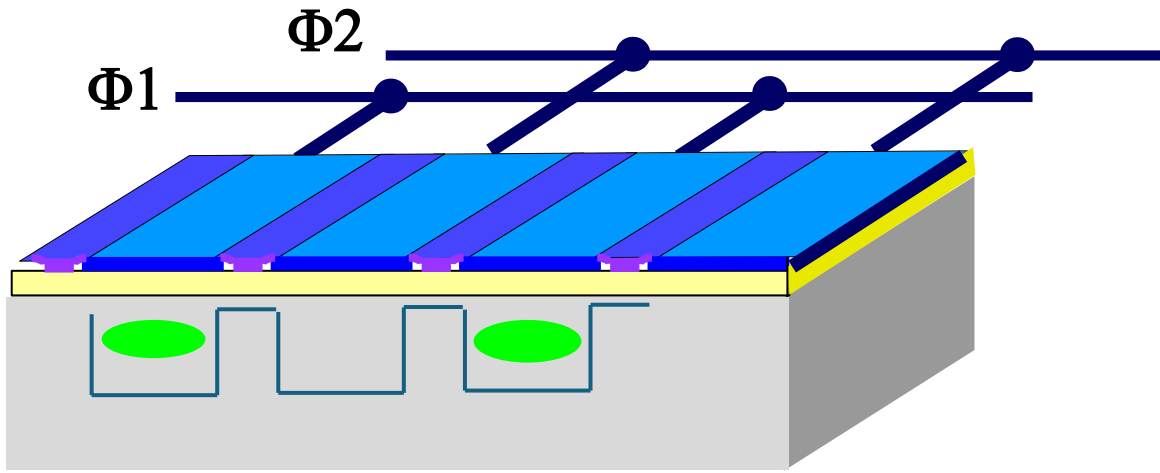
sommaire



Structure standard de 1975 à 1985

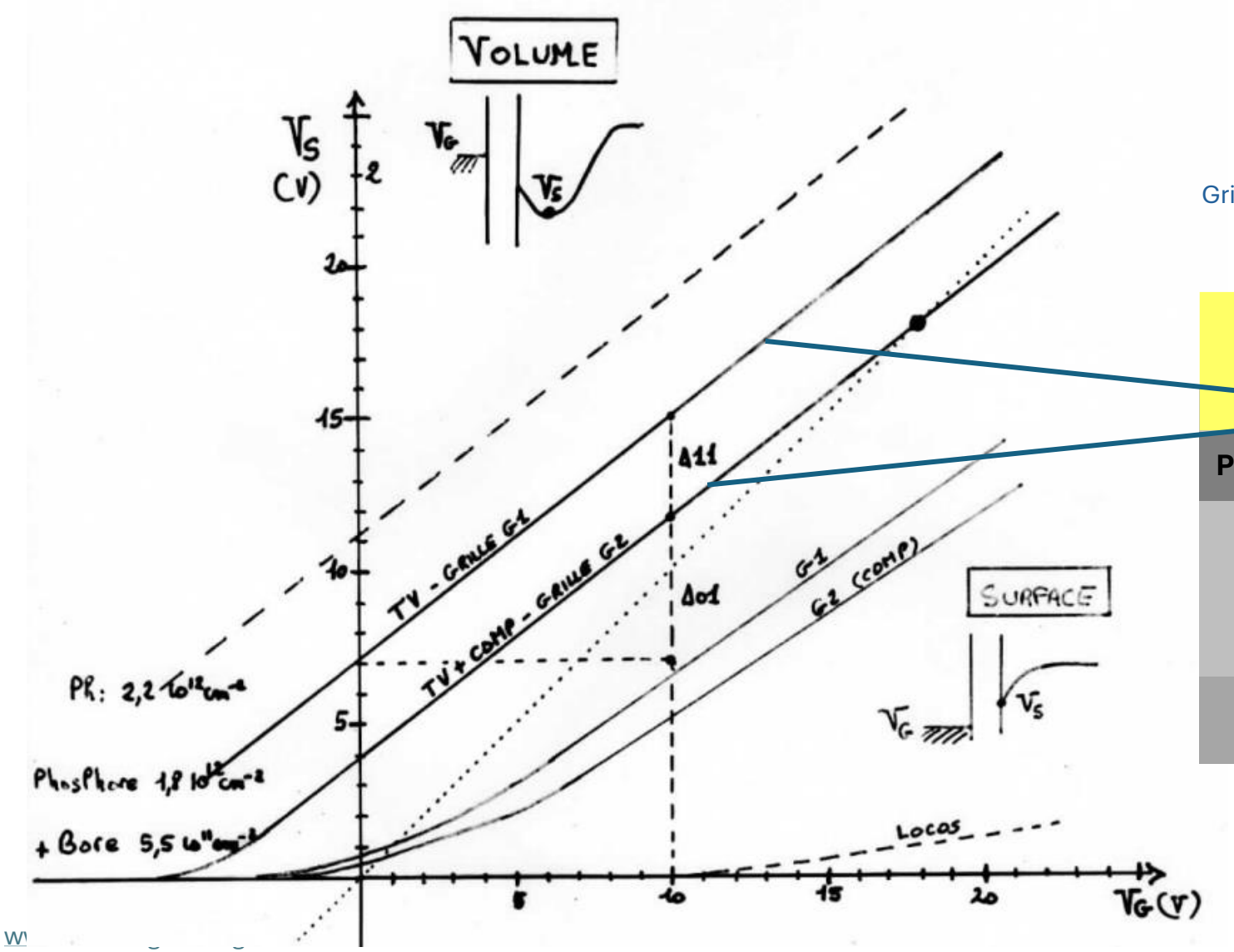
sommaire

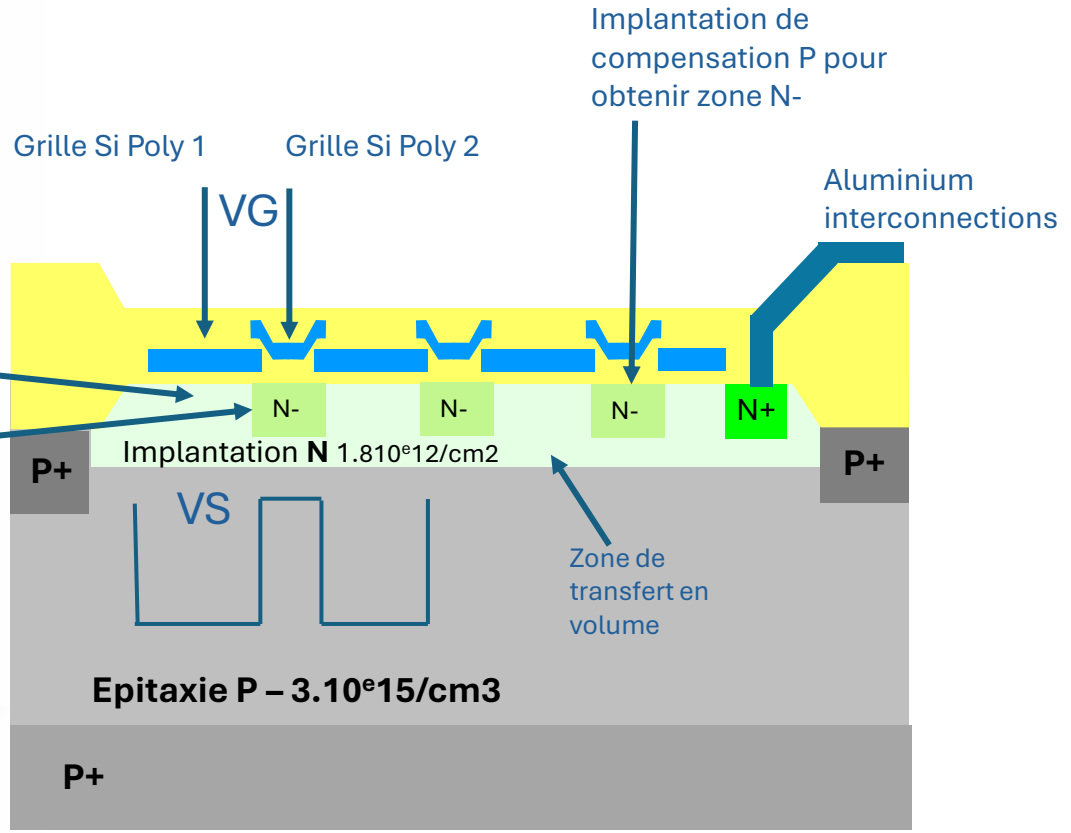




Structure standard de 1975 à 1985

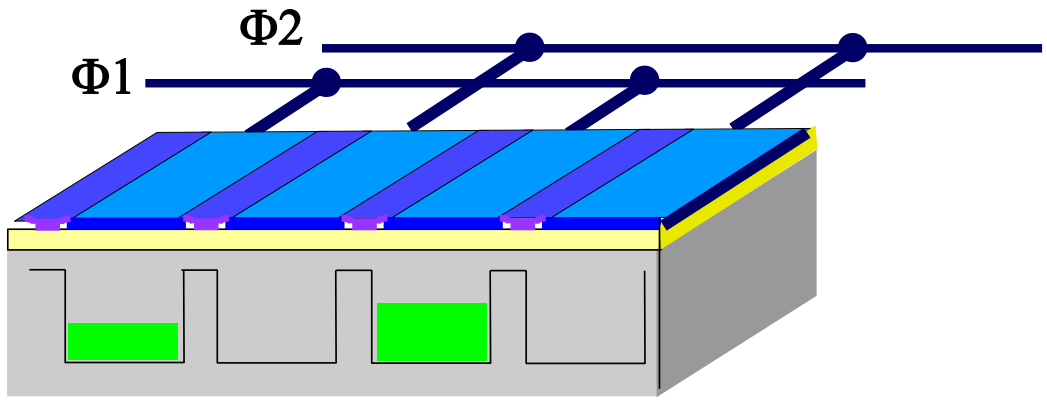
sommaire

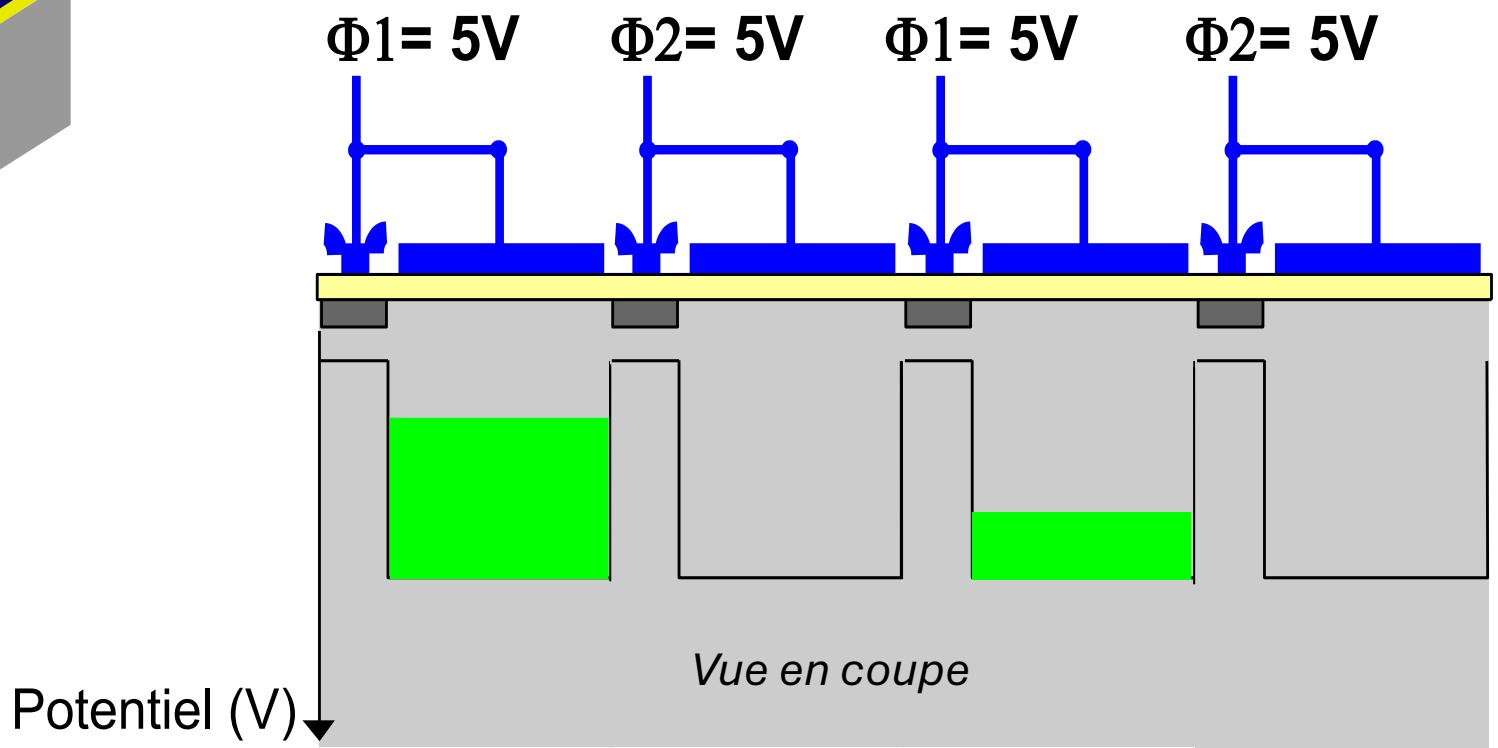




Structure standard de 1975 à 1985

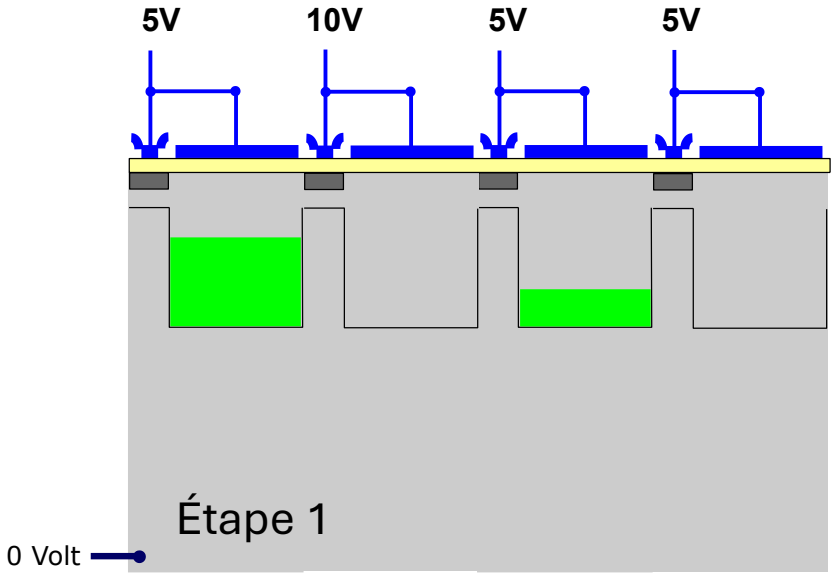
sommaire

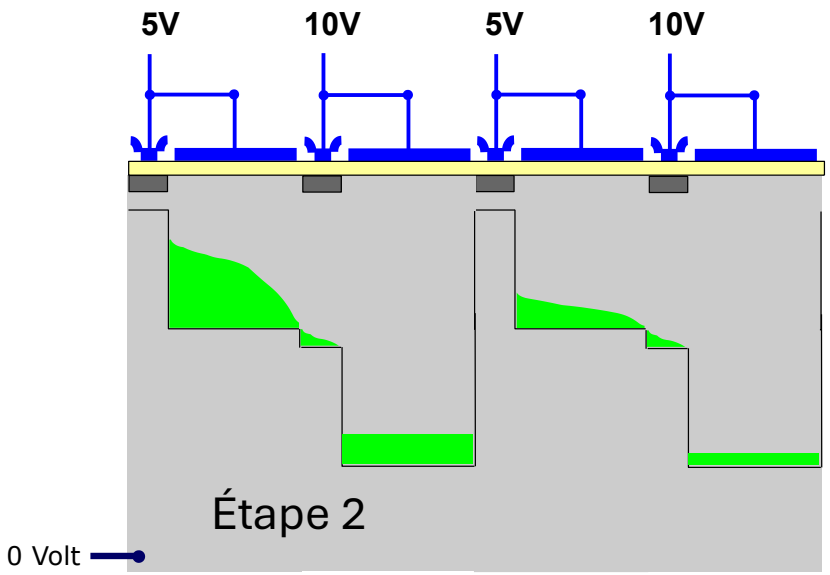


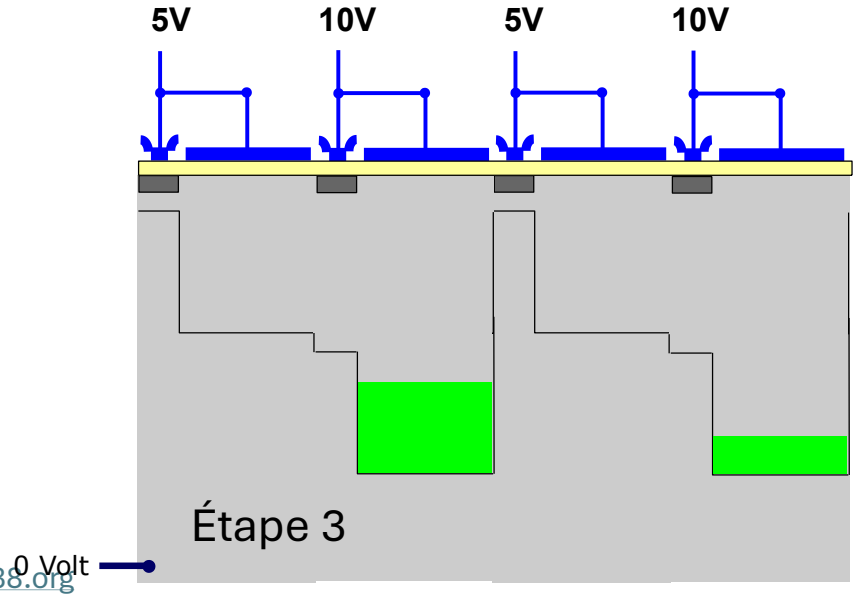


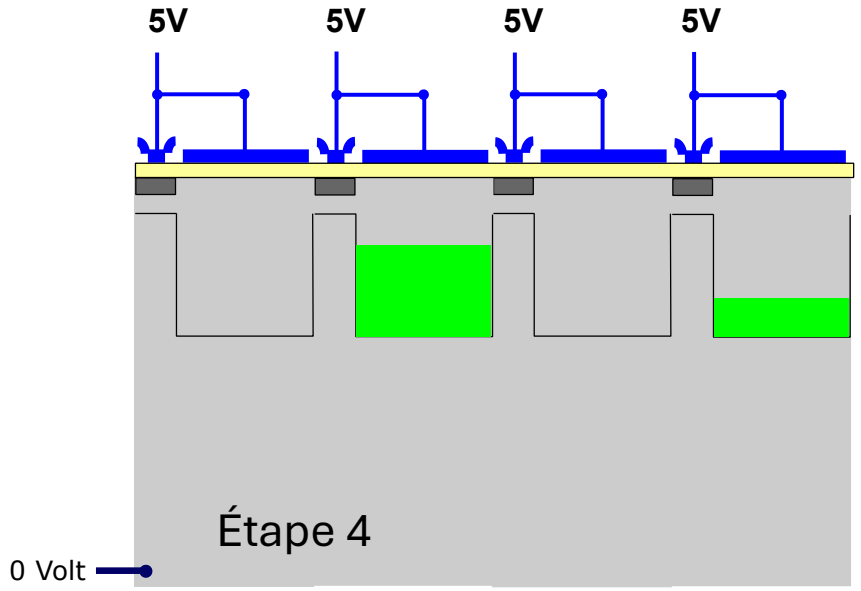
Détail du transfert de charges

sommaire









La technologie à ses débuts

sommaire

Du labo vers la production

sommaire

Catalogue 1988

200 pages

www

Premiers produits commerciaux : Lignes à retard

sommaire

THOMSON-CSF

DIVISION TUBES ELECTRONIQUES

NOTICE TEV 3219

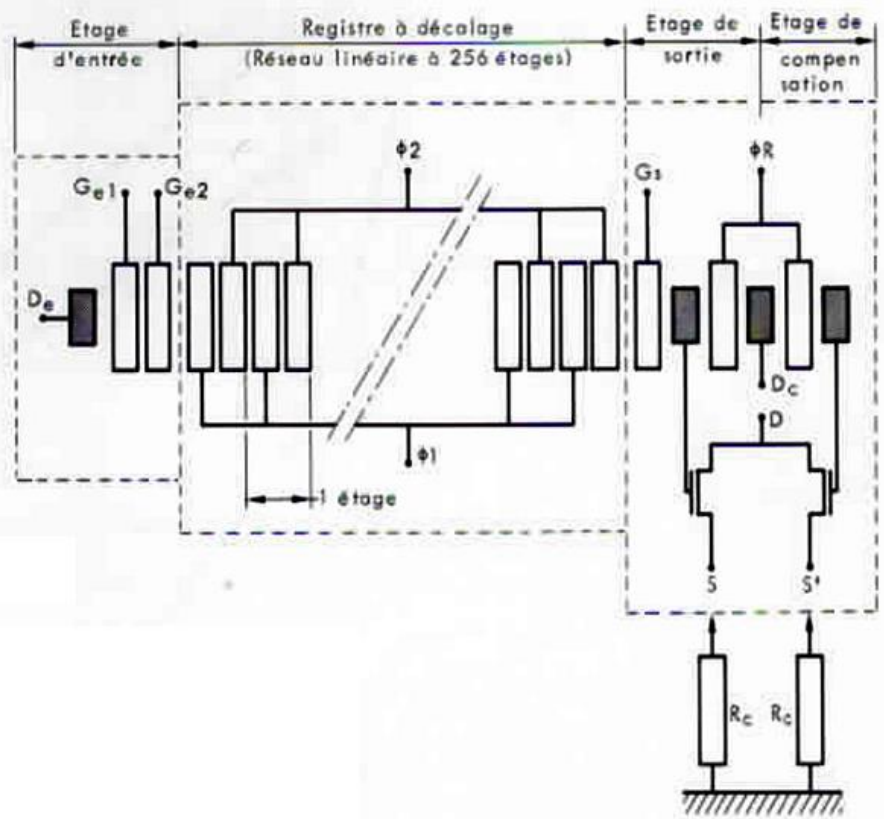
THX 1105

Novembre 1975 - Page 1/7

THX 1105

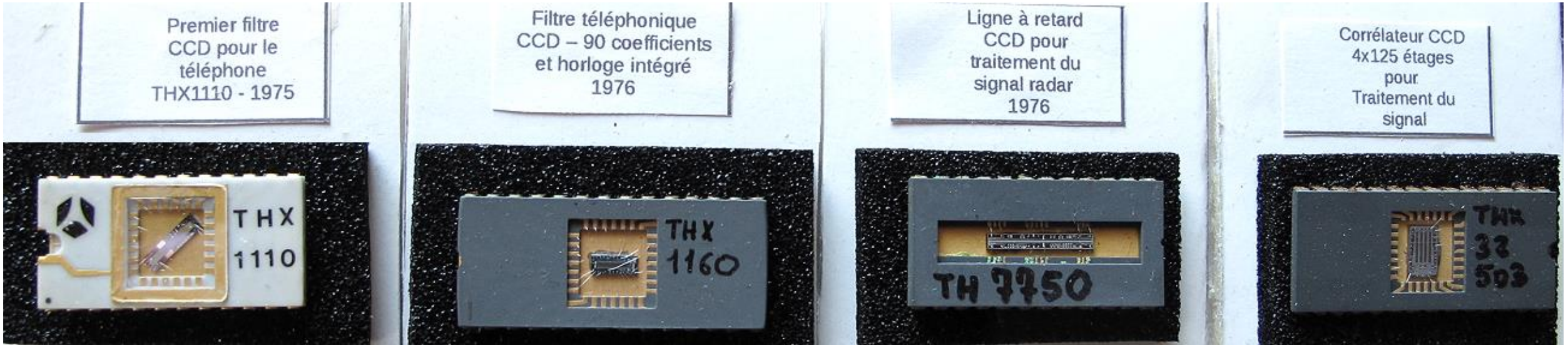
LIGNE A RETARD ANALOGIQUE A TRANSFERT DE CHARGE (DTC) 256 ETAGES

- DYNAMIQUE : 50 dB
- DISTORSION : 1 %
- PRODUIT [RETARD x BANDE PASSANTE] : 128
- BANDE PASSANTE MAXIMALE : 5 MHz
- AMPLIFICATEUR DE SORTIE INTEGRE – SORTIE SUR FAIBLE IMPEDANCE
- COMPENSATION INTERNE DU PARASITE D'HORLOGE



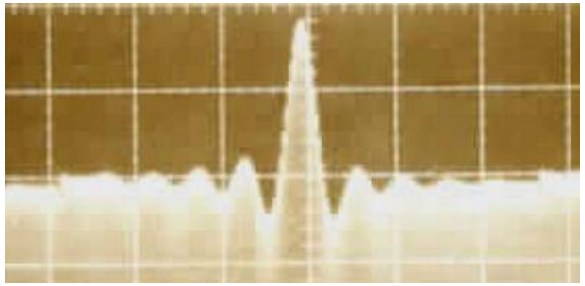
Circuits CCD pour le traitement du signal : 1975 à 1980

sommaire

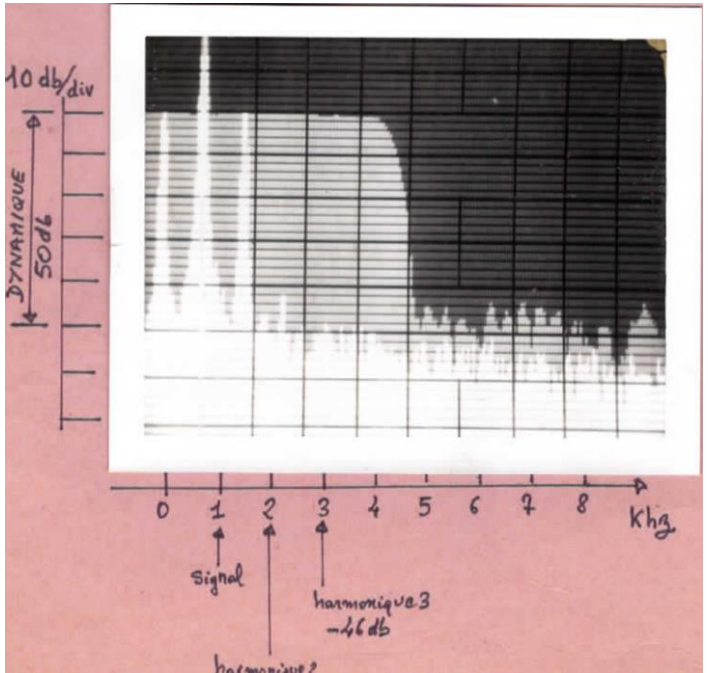


Filtre passe-bas 4kHz pour téléphonie : CCD avec grilles coupées en sinx/x

Réponse impulsionnelle



Réponse en fréquence



Barrettes photosensibles

sommaire

NOTICE TEV 3508

THOMSON-CSF
DIVISION TUBES ELECTRONIQUES

TH 7802

Août 1983

Dispositif photosensible linéaire à transfert de charge (DTC)

- **Haute résolution** : 1024 photodiodes
- **Domaine spectrale étendu** : 300 à 1000 nm
- **Réponse spectrale uniforme**
- **Grande sensibilité**
- **Faible signal d'obscurité**
- **Dynamique 4500:1**
- **Boîtier céramique hermétique**
- **Fenêtre optique en verre**
- **Mise en œuvre simplifiée :**
  - Deux phases de commande externes
  - Echantillonnage et maintien intégrés
  - Référence du niveau d'obscurité disponible

Barrettes photosensibles

sommaire

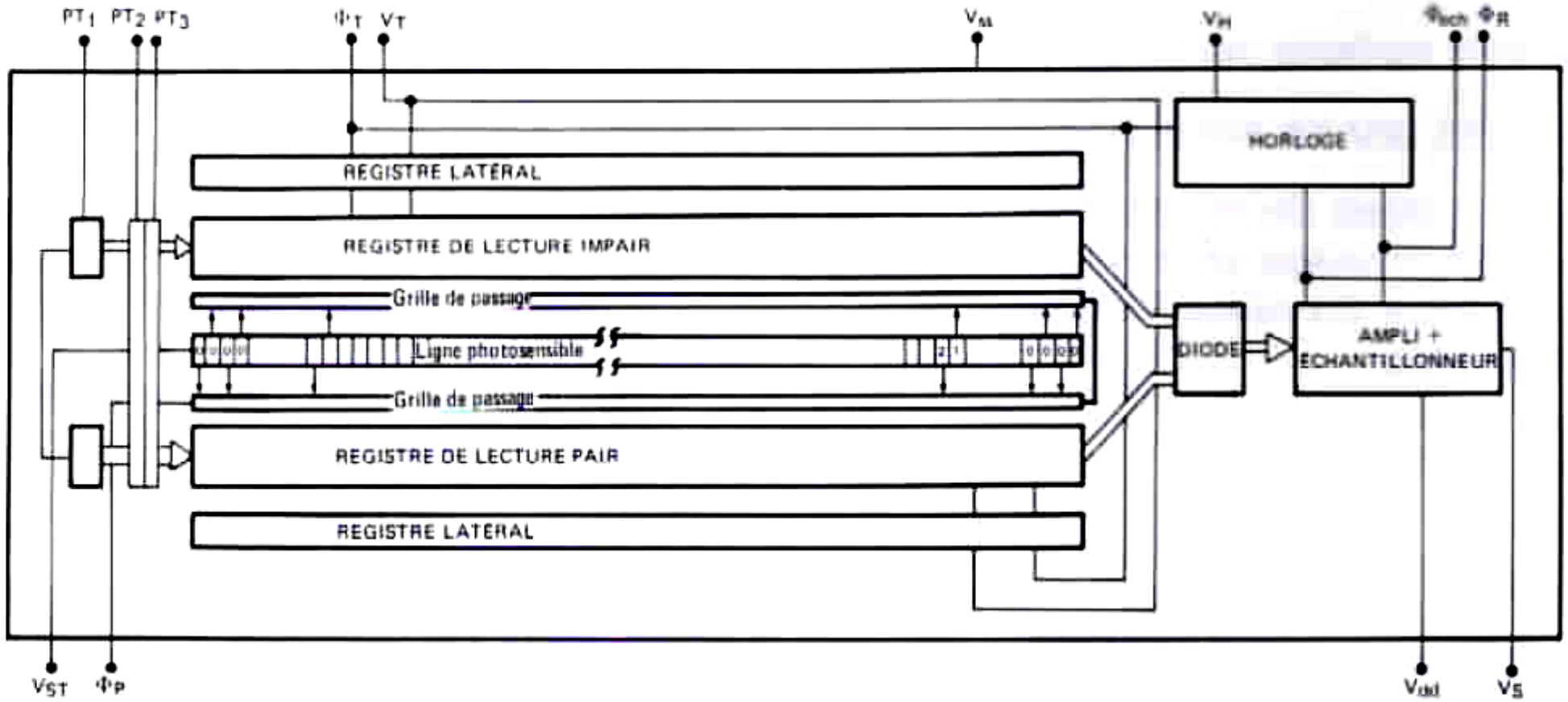
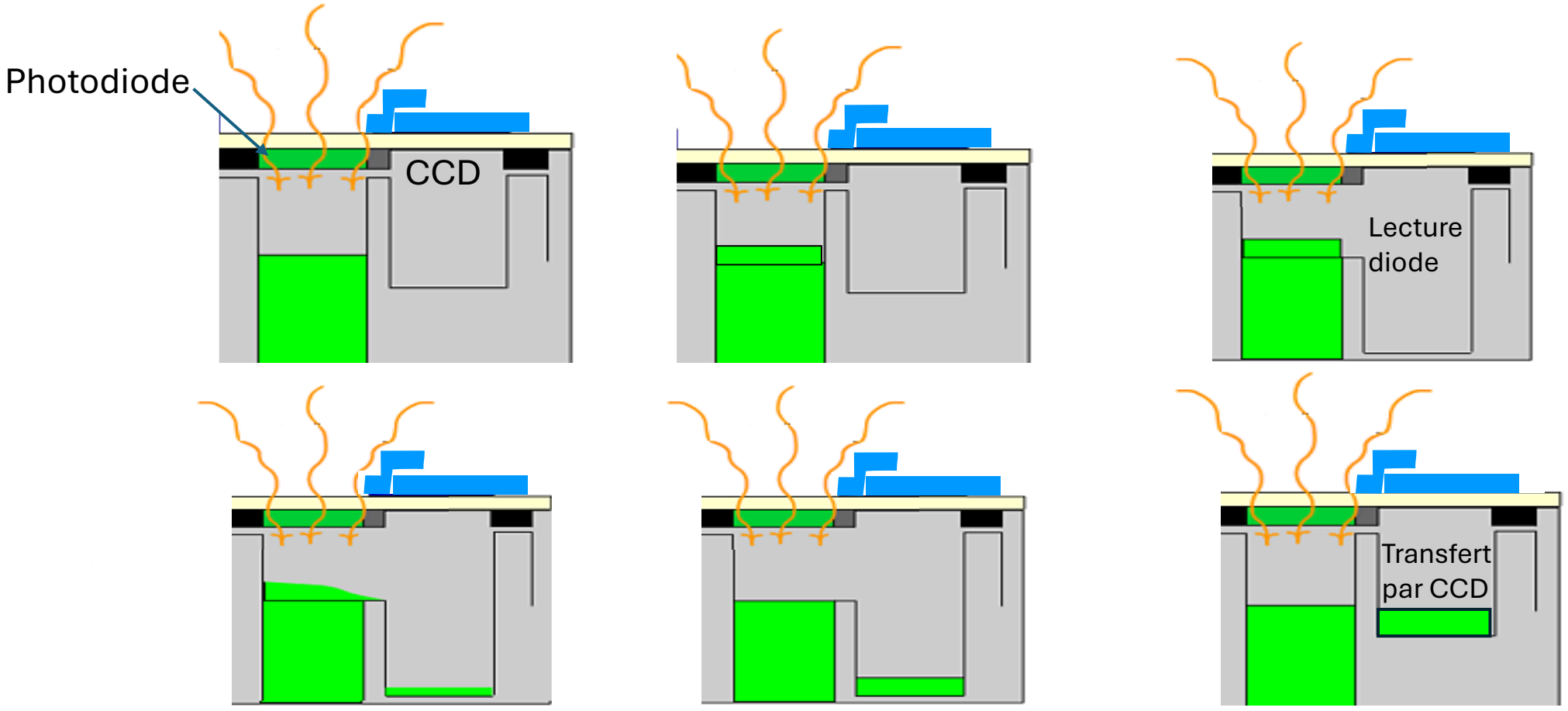


Figure 1 — Schéma fonctionnel du TH 7802

Barrettes photosensibles

sommaire



Capteur surfacique à transfert de trame

sommaire

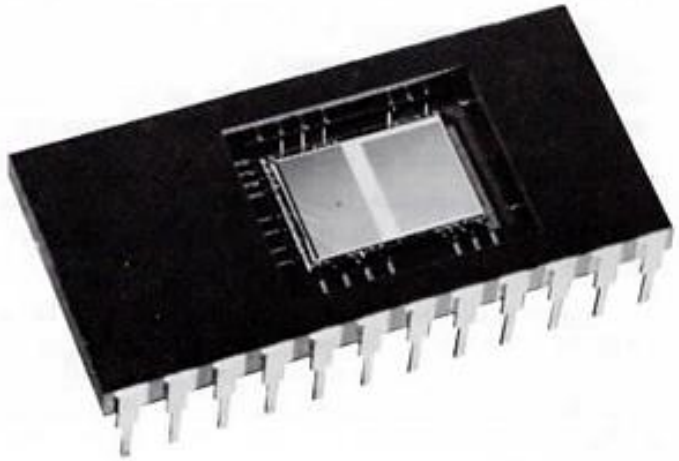
THOMSON-CSF
DIVISION TUBES ELECTRONIQUES

TH 7852
(ex-TH X31138)

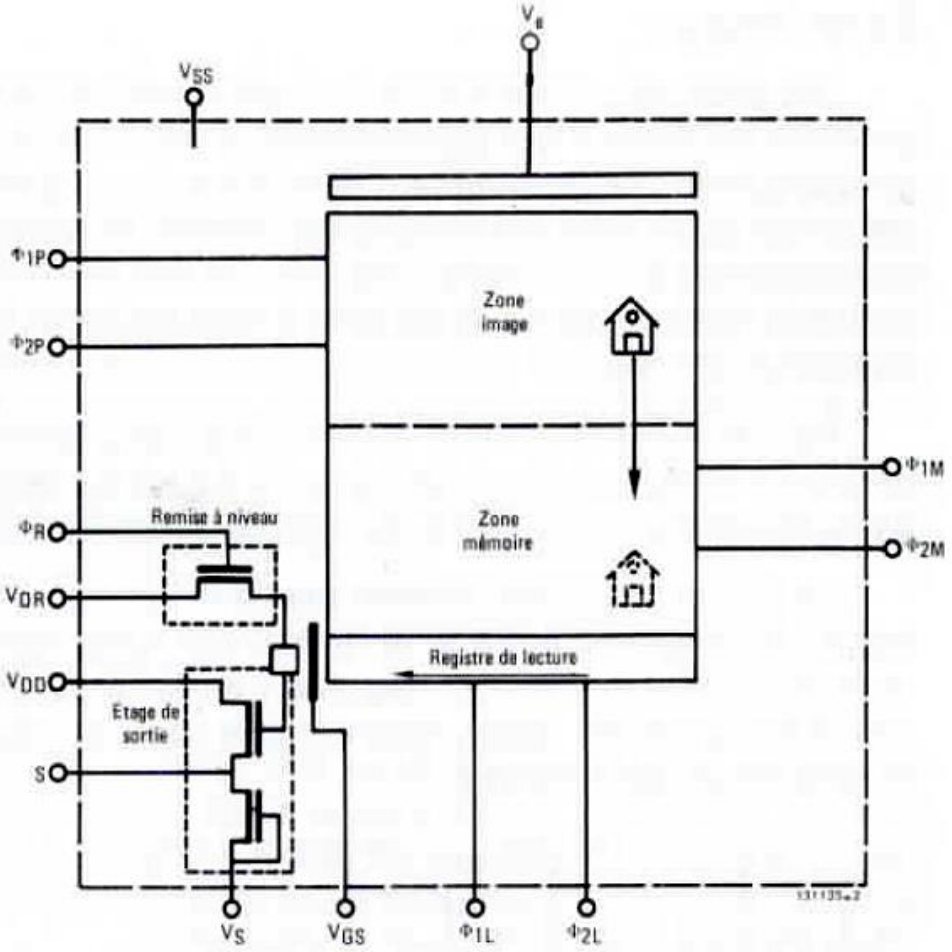
Octobre 1983

Capteur optique matriciel à transfert de charges (DTC)

288 lignes x 208 points élémentaires
Antiéblouissement incorporé

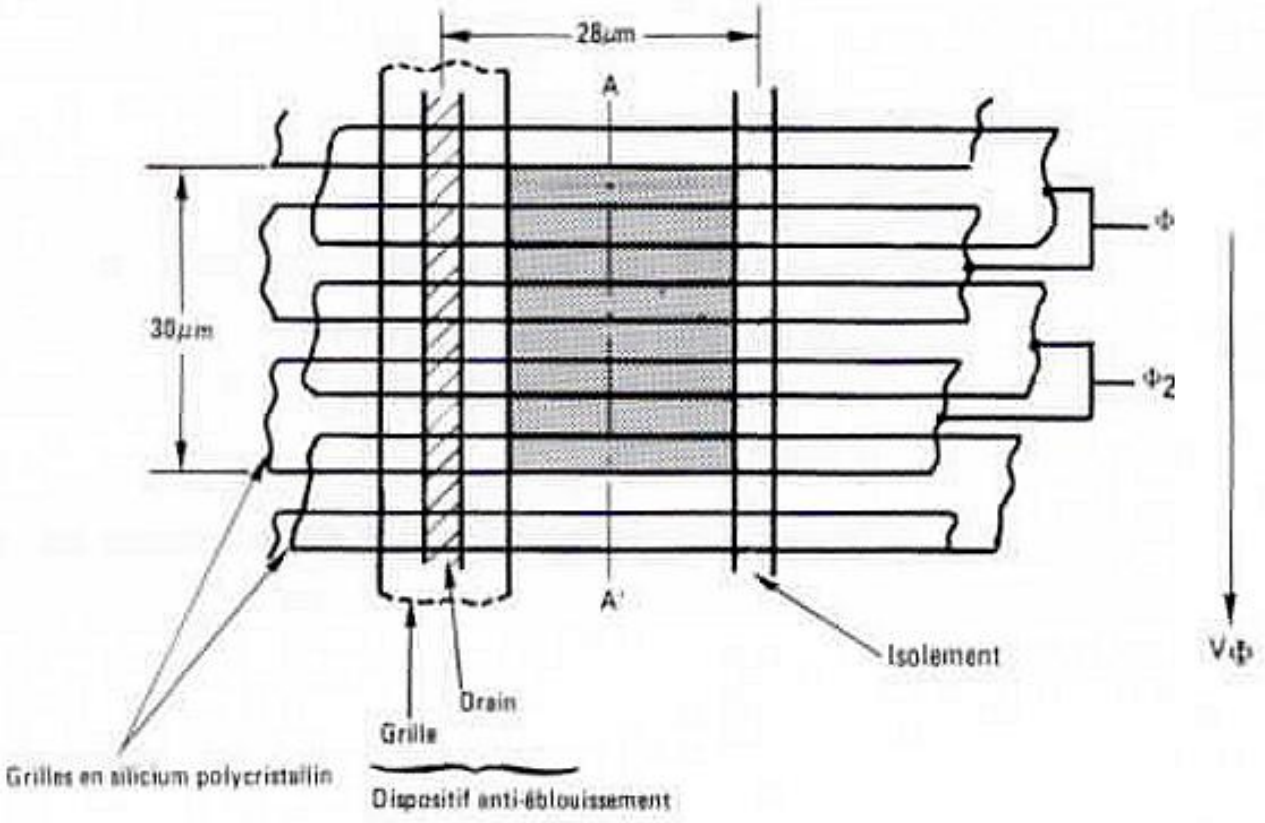


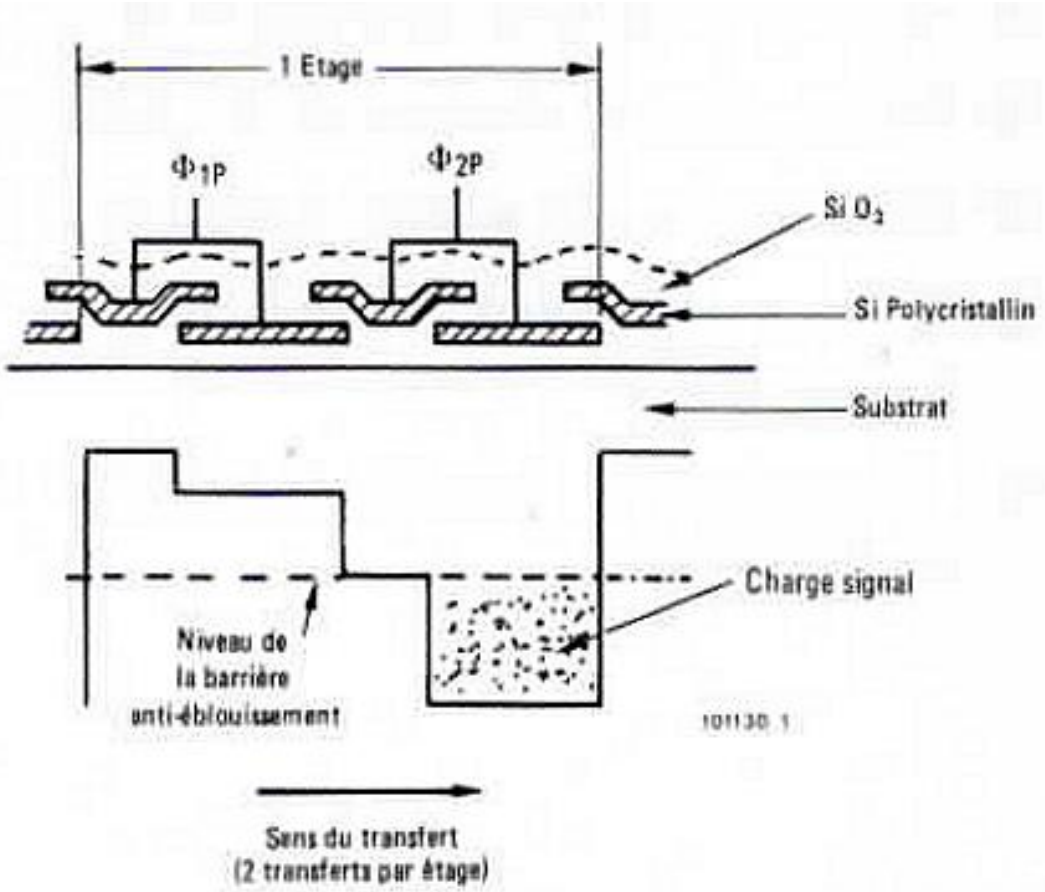
Le TH 7852 (ex-TH X31138) est un capteur optique matriciel à l'état solide qui fournit 288 lignes, comportant chacune 208 points élémentaires (pels), destiné à l'imagerie dans de nombreux domaines industriels et scientifiques.



Capteur surfacique à transfert de trame : TH 7852

sommaire





Capteur surfacique à transfert de trame

sommaire

August 1987

THOMSON-CSF
TUBES ELECTRONIQUES

TH 7864

Area Array CCD* Image Sensor

576 x 550 Pixels
with Antiblooming

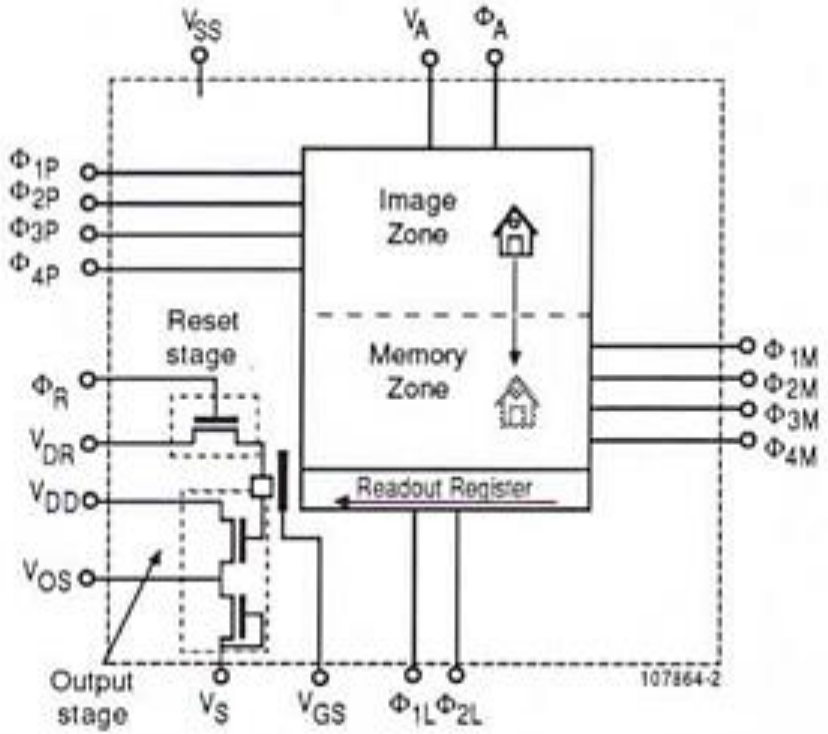


Figure 1 - TH 7864 Organization

- Fully Compatible with CCIR TV Standard
- 2/3" Optics Compatible Image Format (11 mm Diagonal)
- Frame Transfer Organization (Dynamic Range : 4000/1)
- Optimized Resolution and Responsivity in the 400-1100 nm Spectrum (Visible + Near Infrared)
- Antiblooming efficiency : E_{SAT} x 1000
- Sensitivity : 30 dB S/N at 40 milli-lux
- High Contrast : 80 % Modulation at 412 TV Lines
- Low Aliasing (moiré)
- No negative bias needed
- Exposure time reduction capability (iris effect) : 10 times min
- Minimum Field Readout Time:12 ms

Capteur surfacique à transfert de trame : TH7864

sommaire

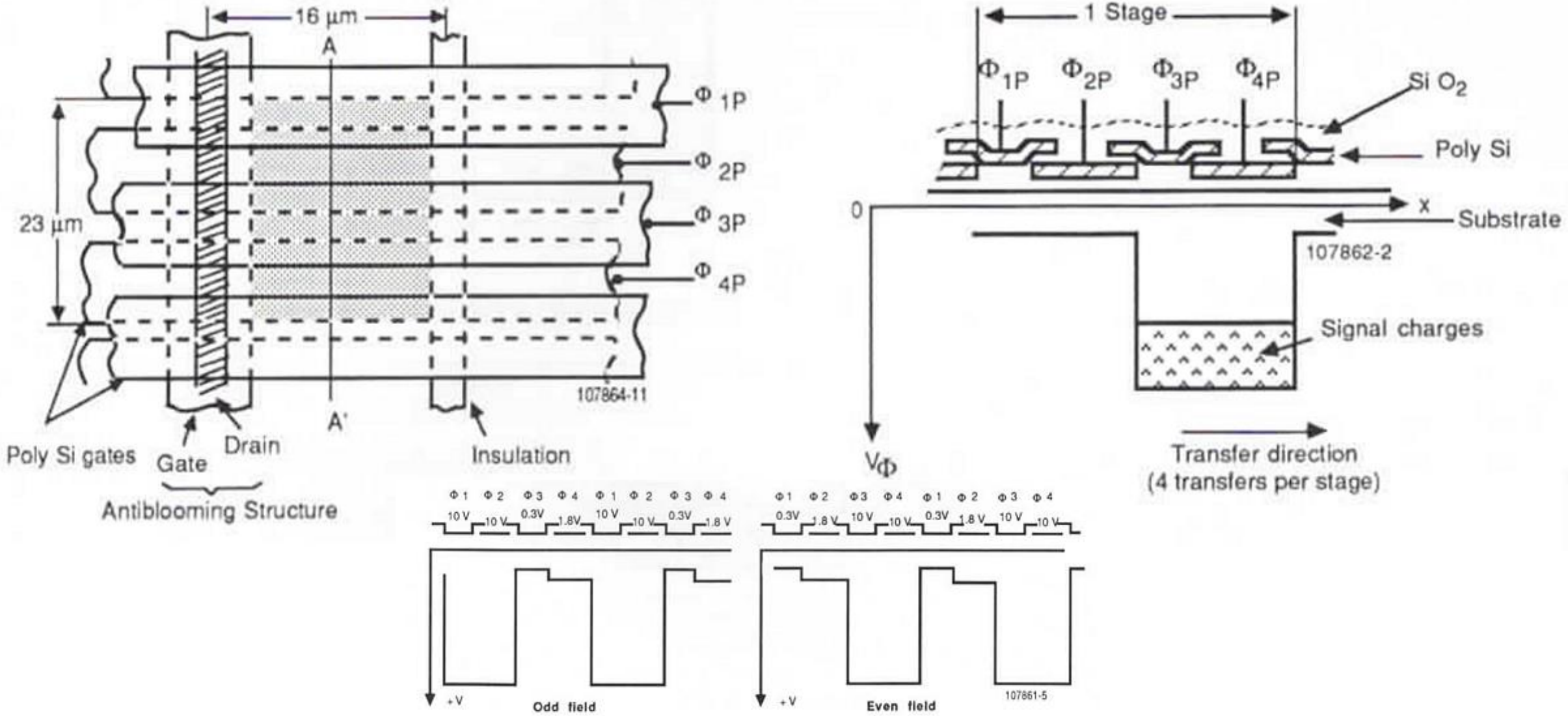
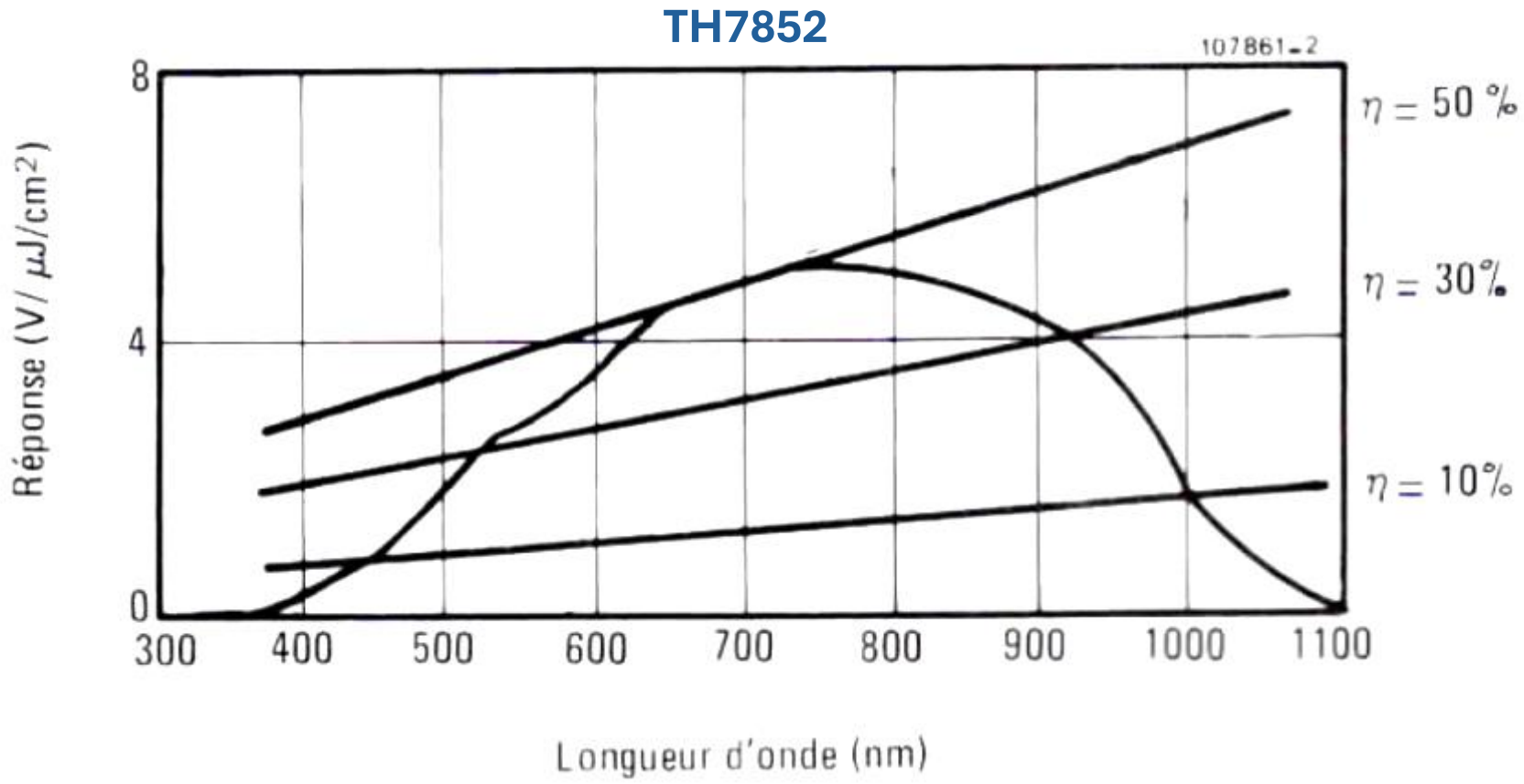


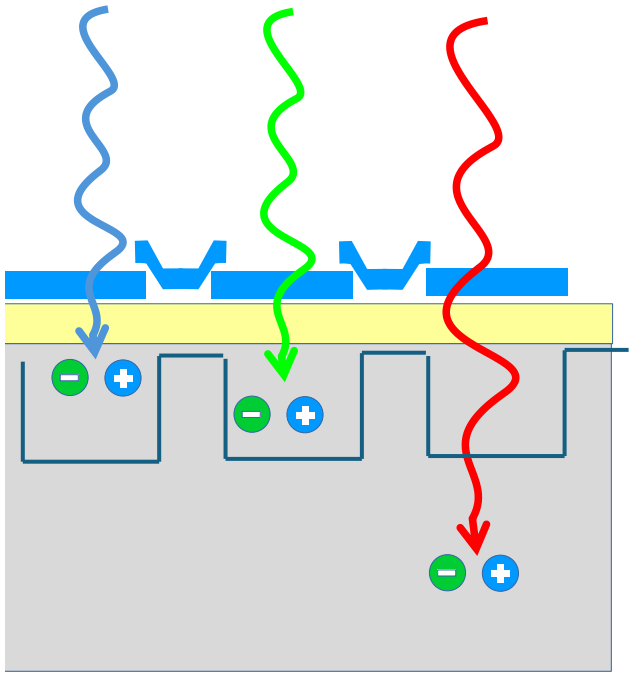
Figure 3 - Image zone potential wells during integration period

Les performances d'un capteur CCD

sommaire

La réponse spectrale d'une matrice



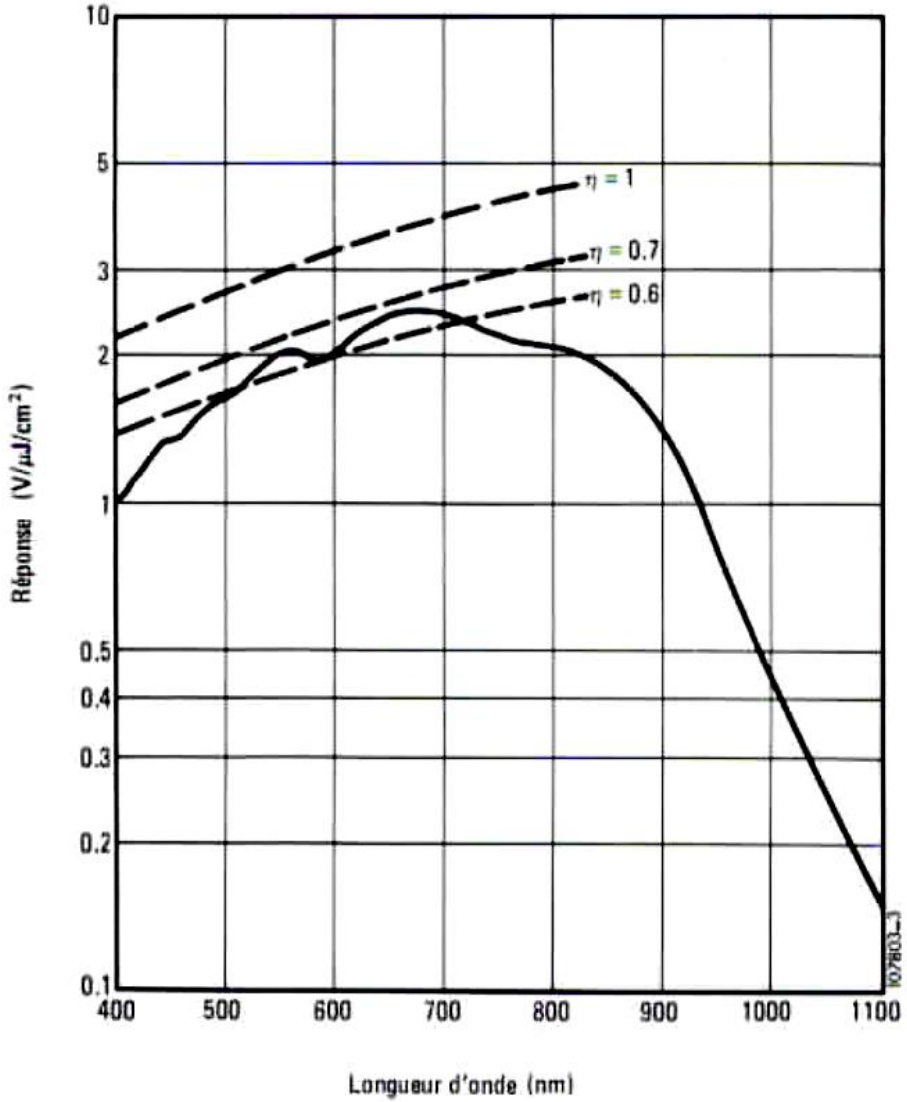


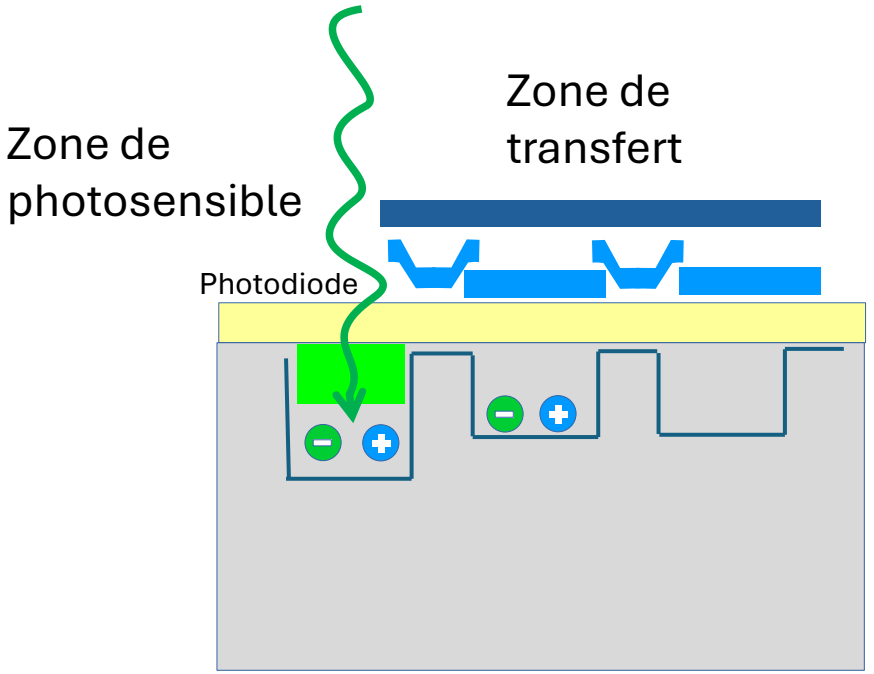
Les performances d'un capteur CCD

sommaire

La réponse spectrale d'une barrette

TH7803



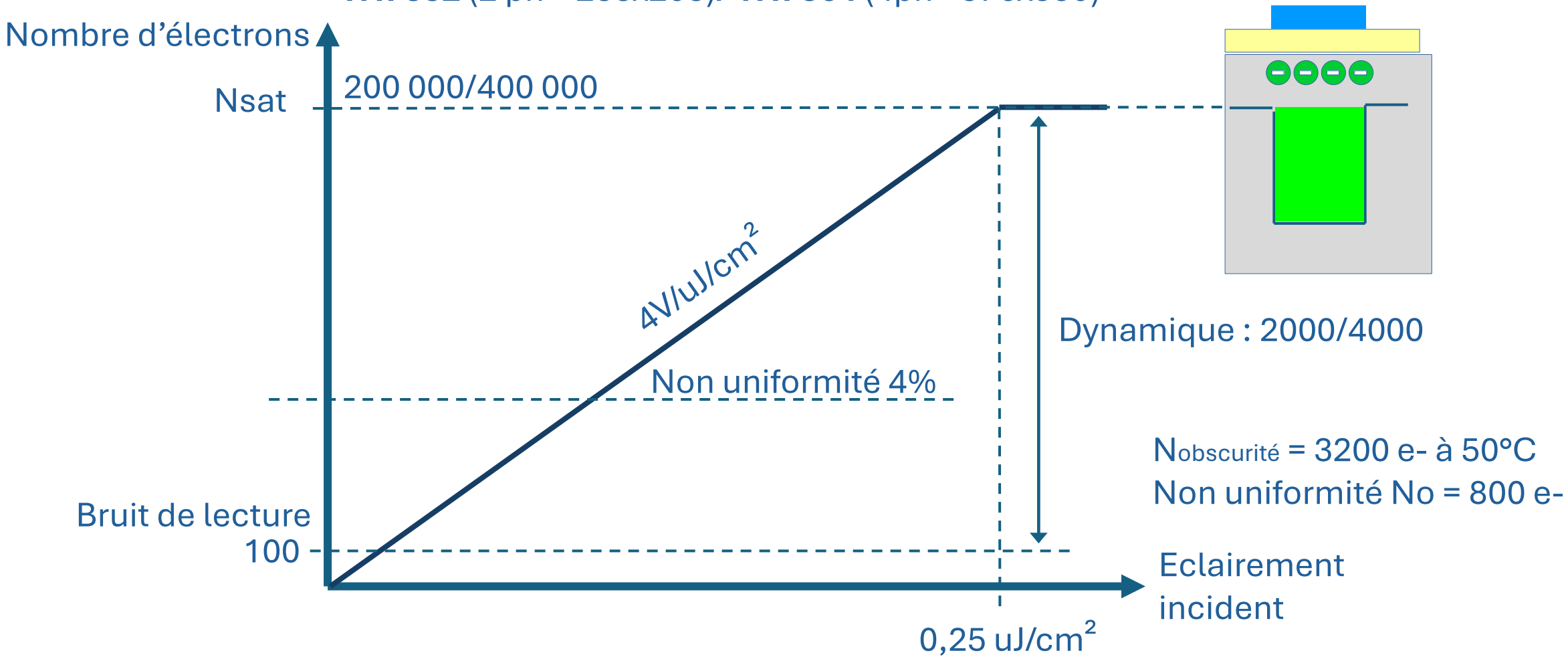


Les performances d'un capteur CCD

sommaire

La dynamique de capteurs surfaciques

TH7852 (2 ph – 288x208)**/ TH7864** (4ph - 576x550)



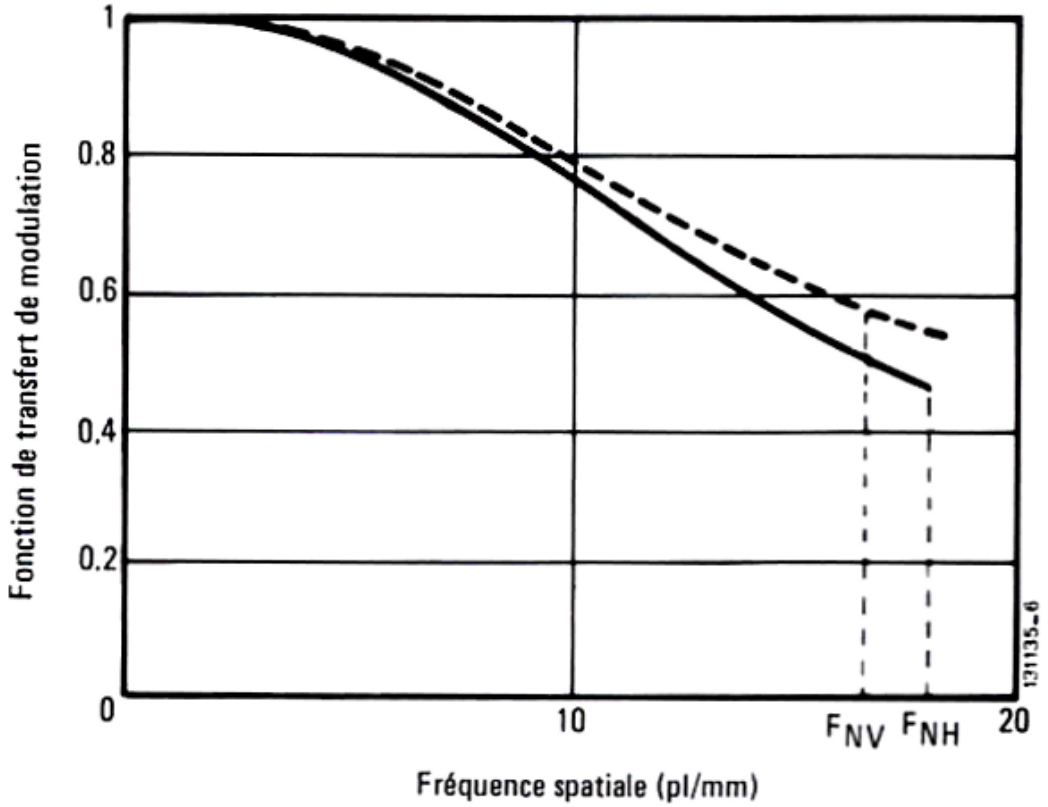
1mV = 410 électrons

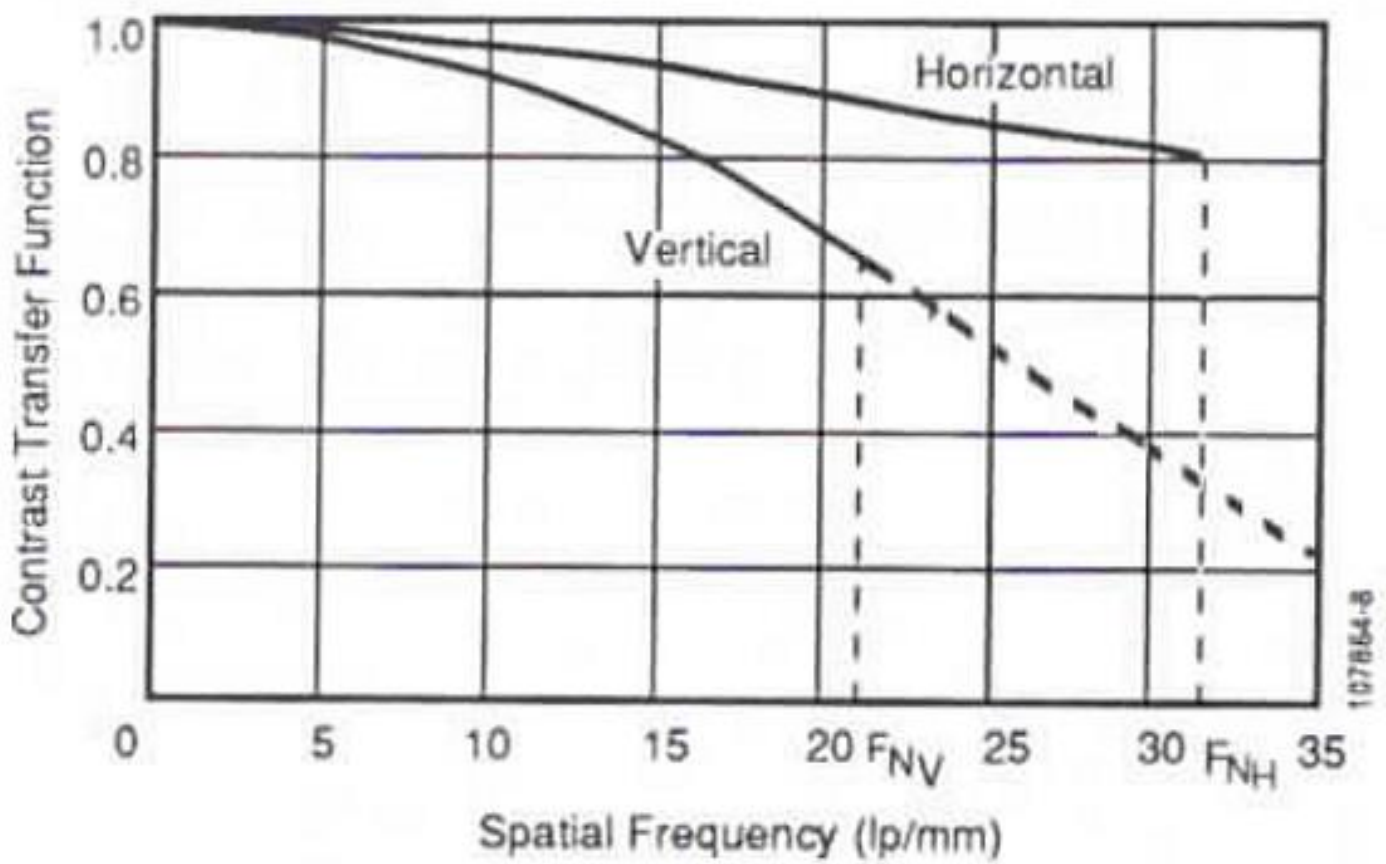
Les performances d'un capteur CCD

sommaire

La résolution de capteurs surfaciques

TH7852 (2 ph – 288/208)**/ TH7864** (4ph - 576x550)

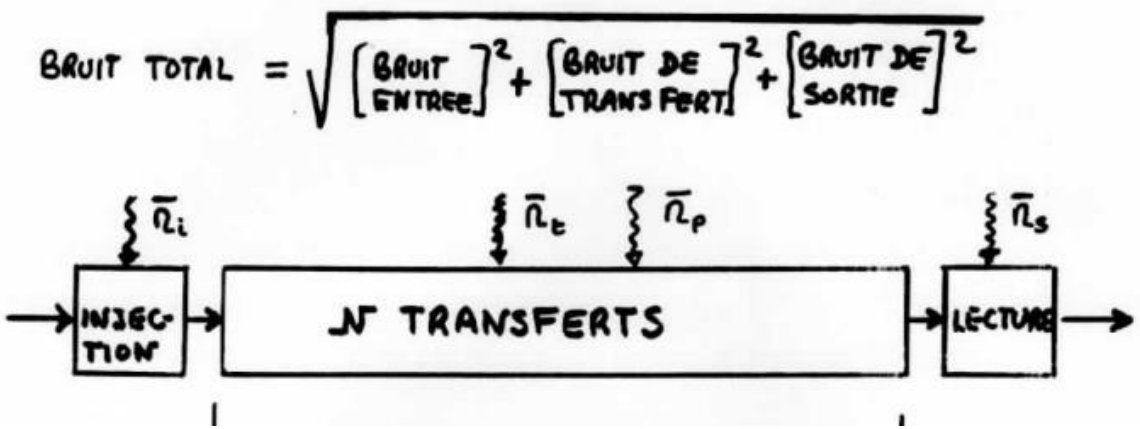




Les performances d'un capteur CCD

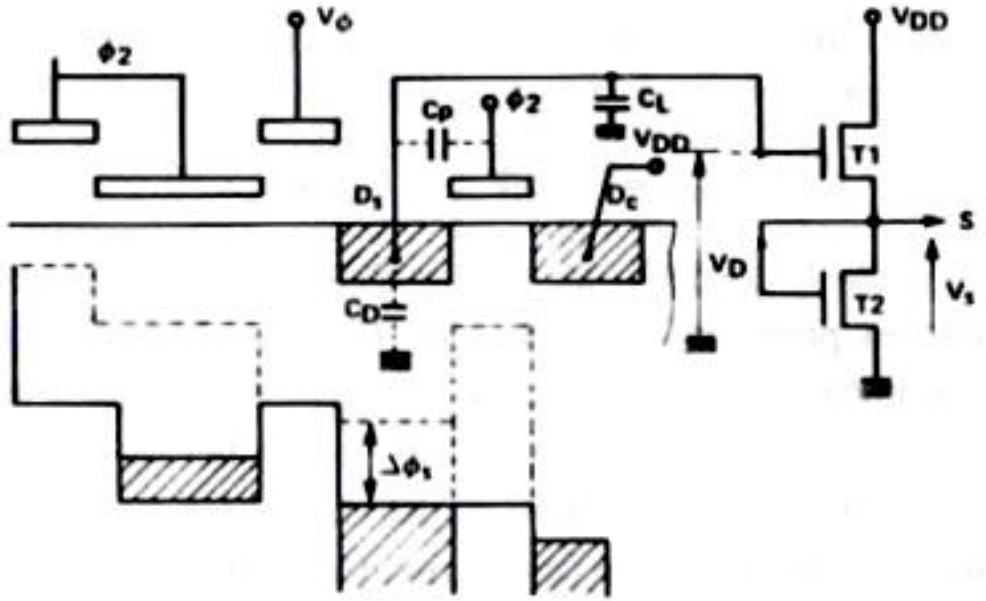
sommaire

Le bruit de lecture d'un CCD



Conversion charge > tension

2 µV /e- - 500e- par mV



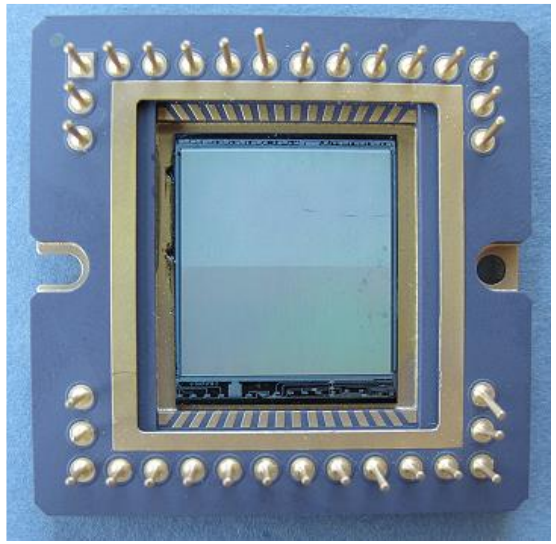
Bruit dominant = bruit de la capacité de lecture

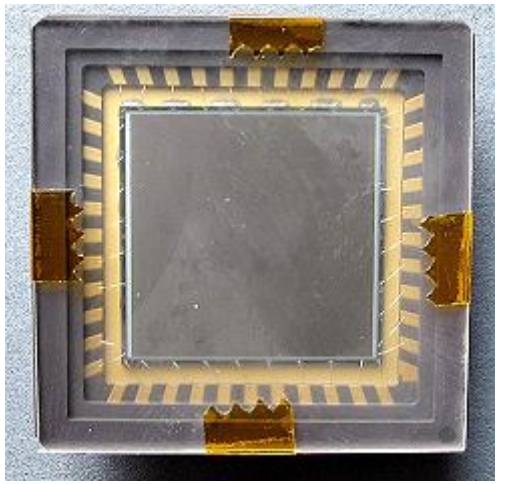
$Ne_n = \sqrt{kTC/q^2} = 400 \sqrt{C\ (pF)}$ à 20°C

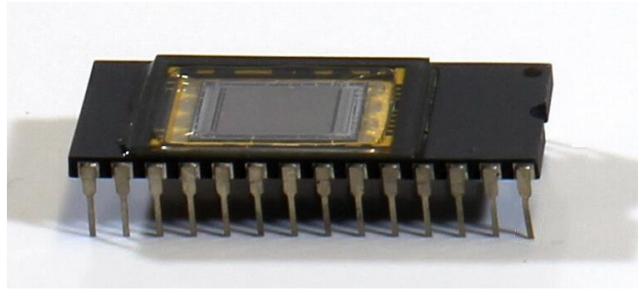
Valeur typique C # 0,05pF → Qn = 90 à 100 e-

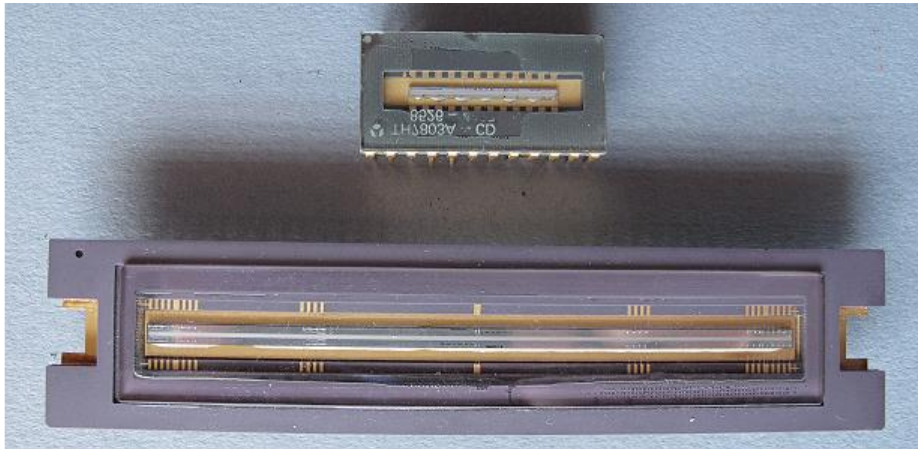
Quelques capteurs remarquables

sommaire







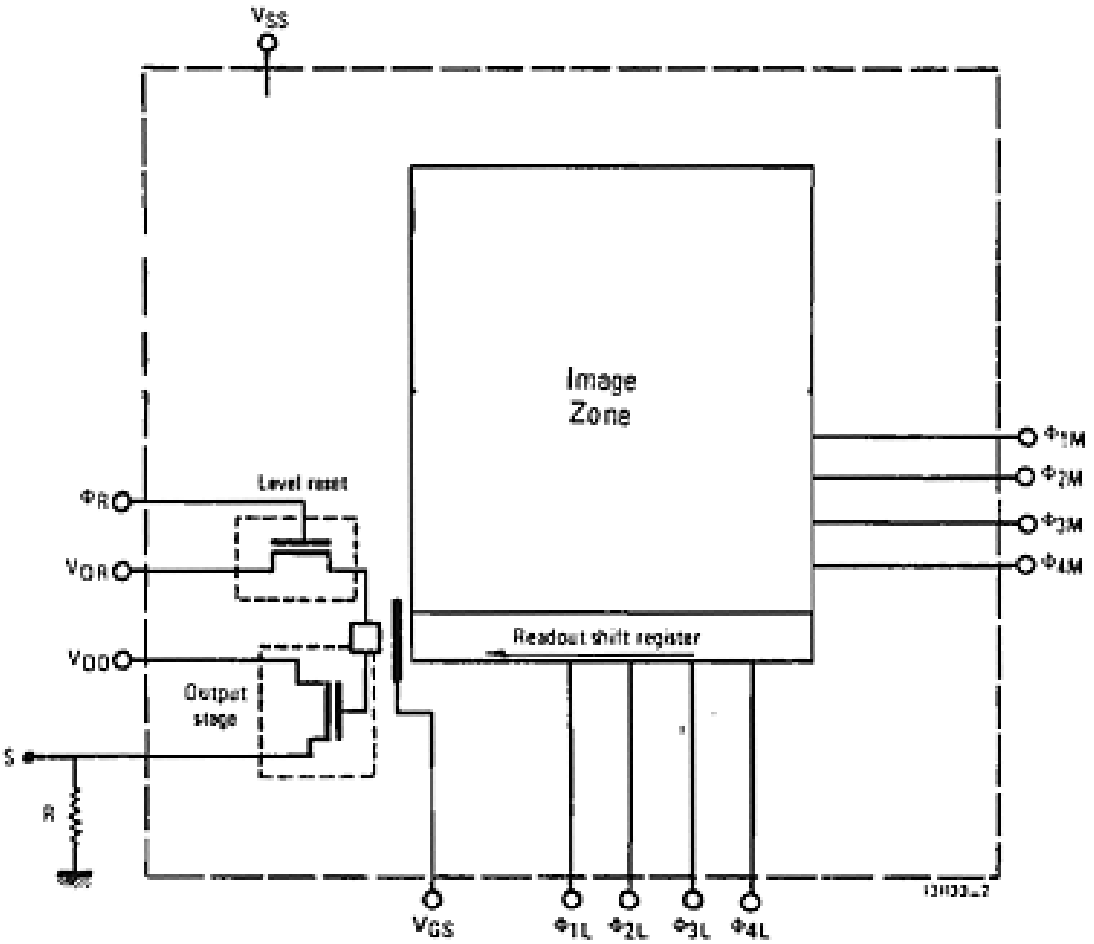


Matrice « monocoup » sans mémoire de trame

sommaire

Capteur TH7882

576 x 384



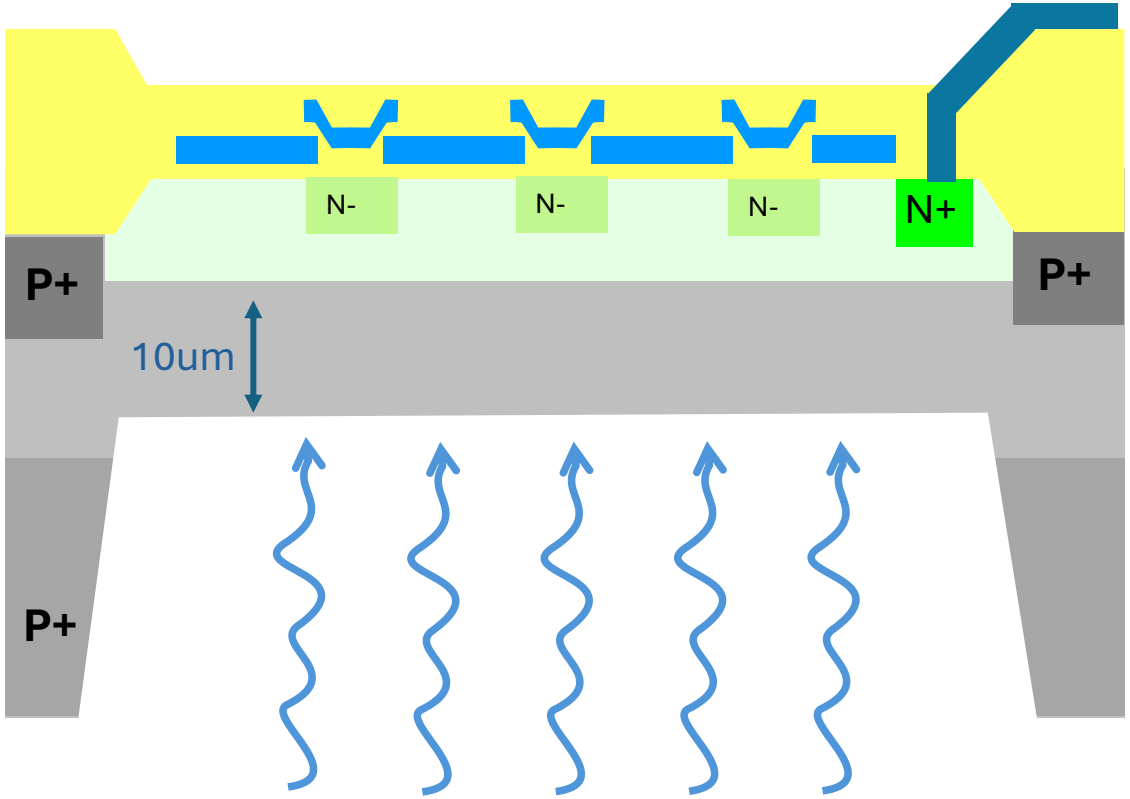
Caractéristiques

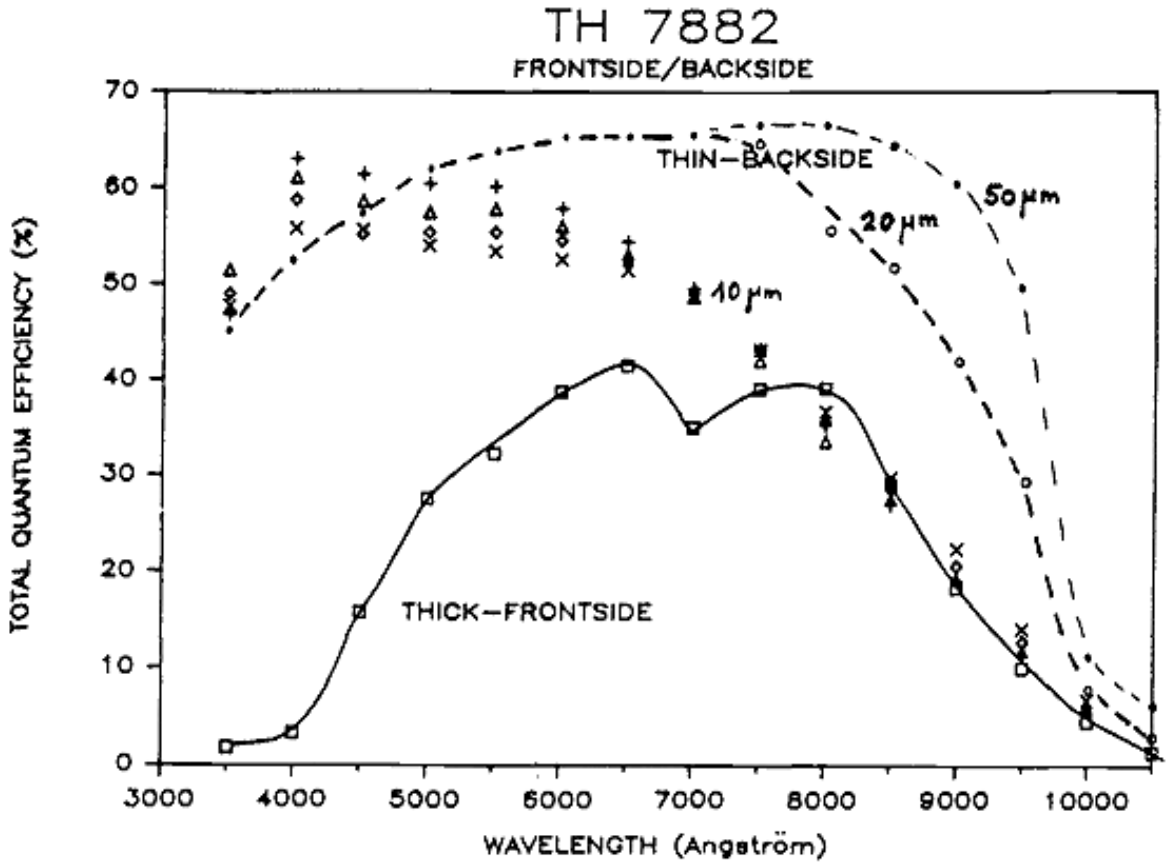
Sensor type. ..... Full-frame, frame transfer
Format ..... 576 V x 384 H
Pixel size ..... 23 p,m x 23 \im
Image area ..... 13.248 mm (V) x 8.832 mm (H)
Drive clock sequencing 4-phase
Full well capacity ..... 6.10 5 e~~
Output sensitivity (RL = 2.2 kq) ..... 0.6 p,V/e~"
Dark current (+ 25 °C) ..... 1 to 2 nA/cm2
Readout noise ..... 5 to 10 e~~ r.m.s.

1986

Matrice TH7882 amincie face arrière (BSI)

sommaire

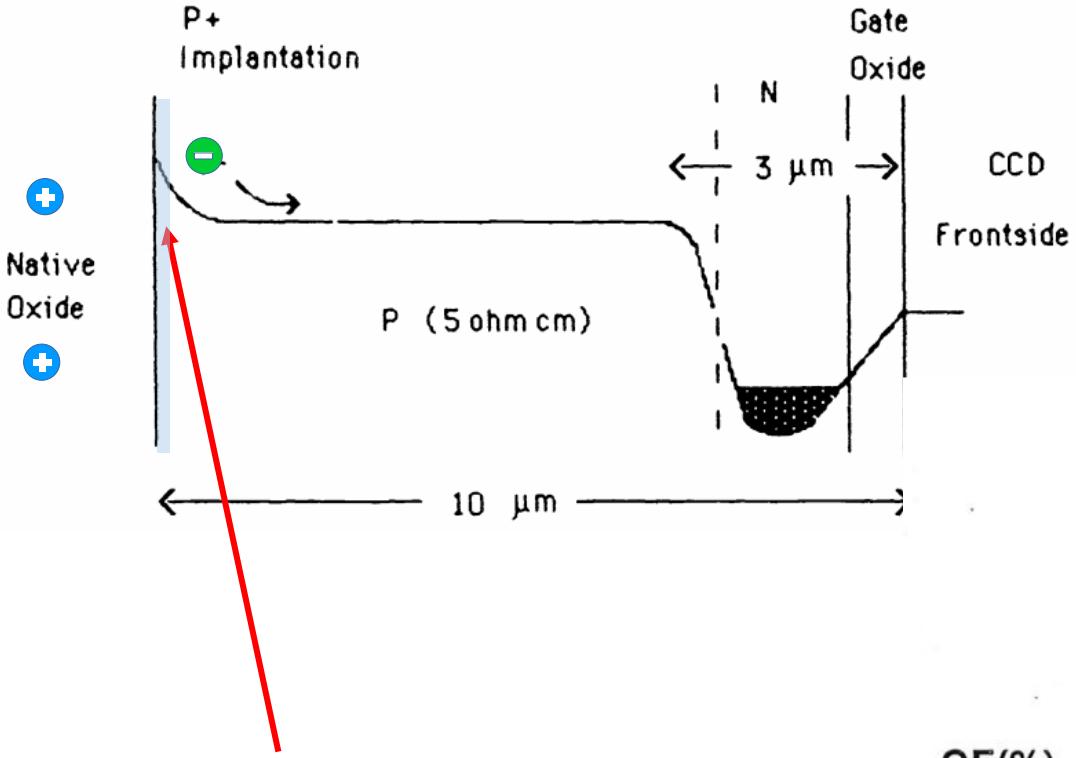




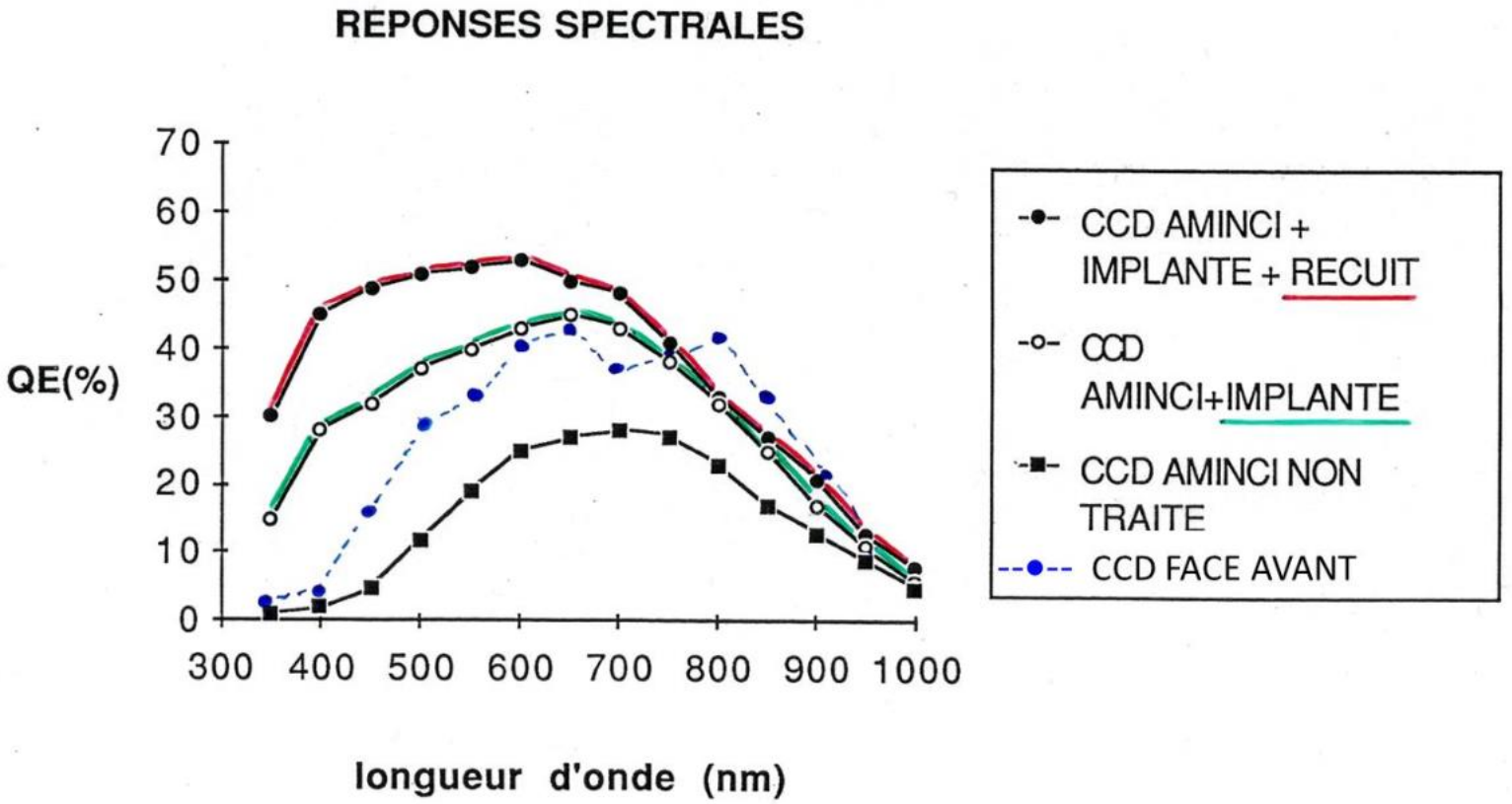
1988

Traitement matrice amincie face arrière (BSI)

sommaire

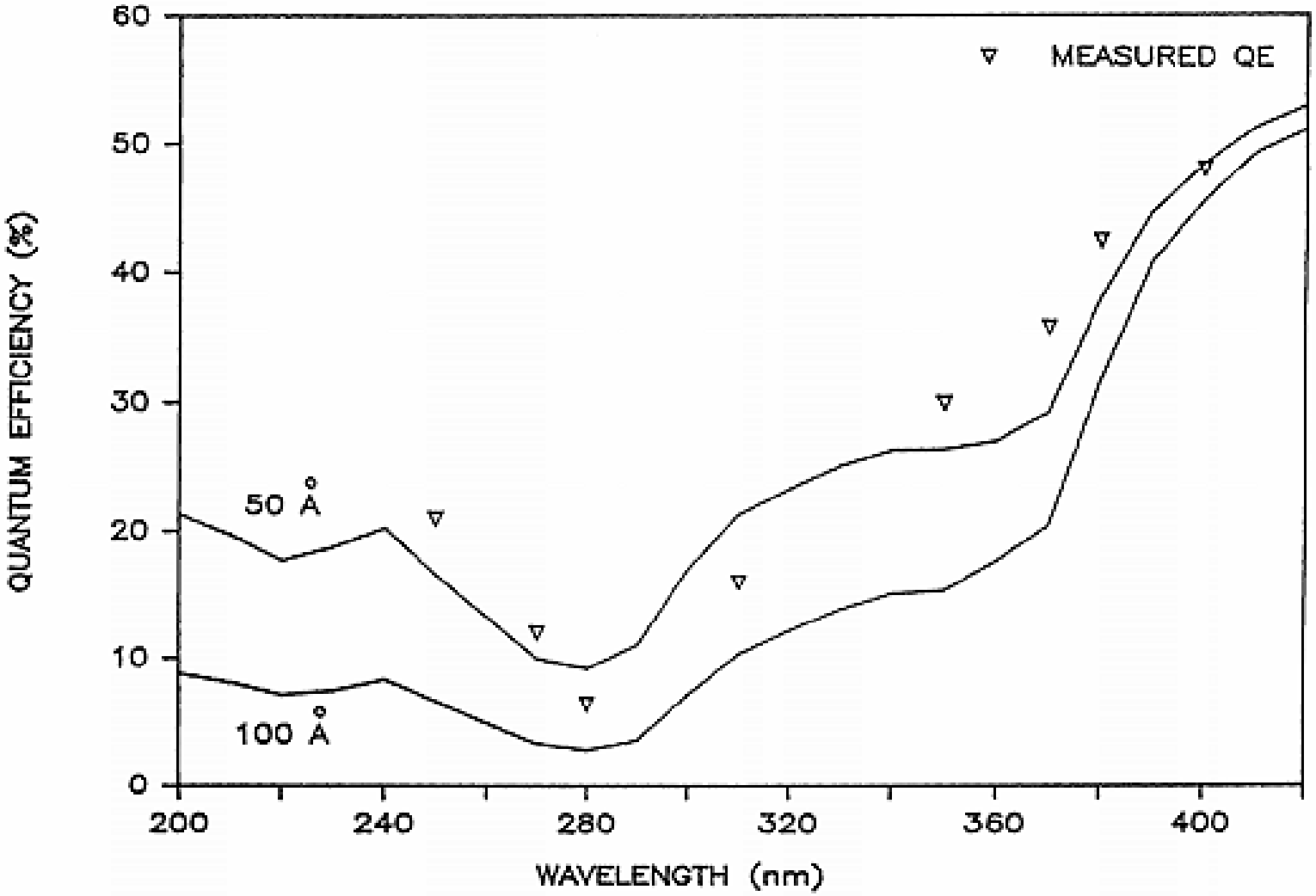


Fine zone implantée P+ permettant de créer un gradient de potentiel favorable à la collecte des photos électrons



Traitement matrice amincie face arrière (BSI)

sommaire



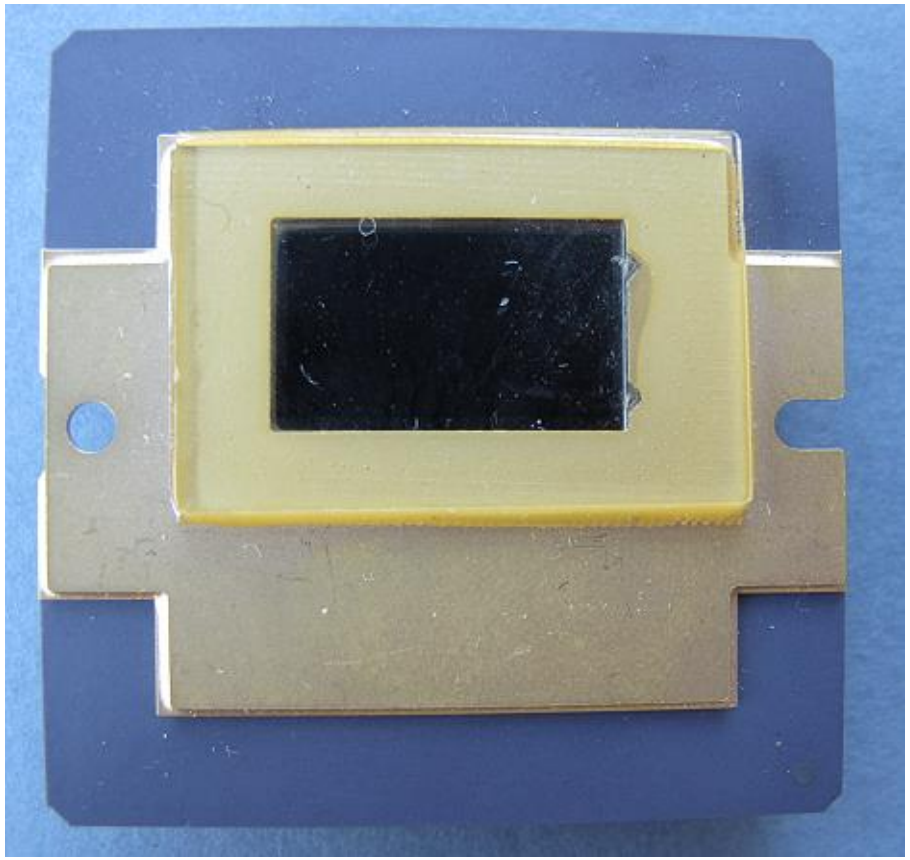
Measured quantum efficiency of implanted and laser annealed 576 x 384 CCD. Calculated QE_s with 50 Å and 100 Å "dead layer" are shown for comparison

C. Tassin, Y. Thenoz, J. Chabbal, "Thinned Backside Illuminated CCDs for Ultra-violet Imaging", Ultraviolet Technology II, SPIE Proc, Vol. 932, pp 305-310, Orlando, 1988.

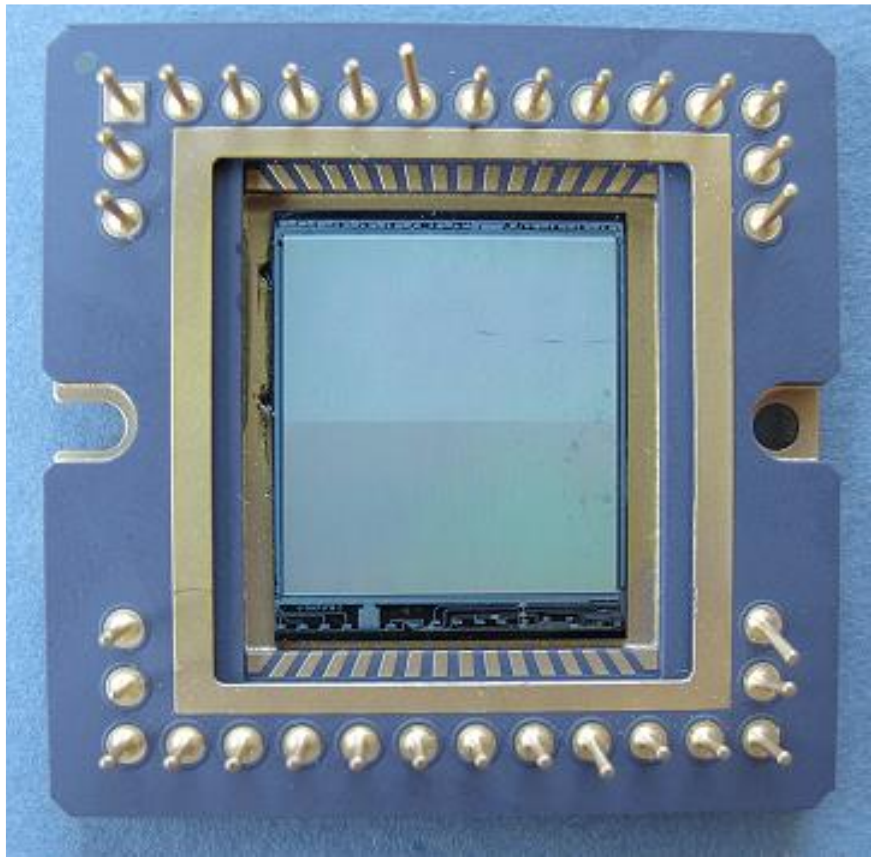
Matrices amincies haute résolution

sommaire

Matrice 1 ’’ THX 31167 (TH 31163 amincie) 1160 x 576 pixels)



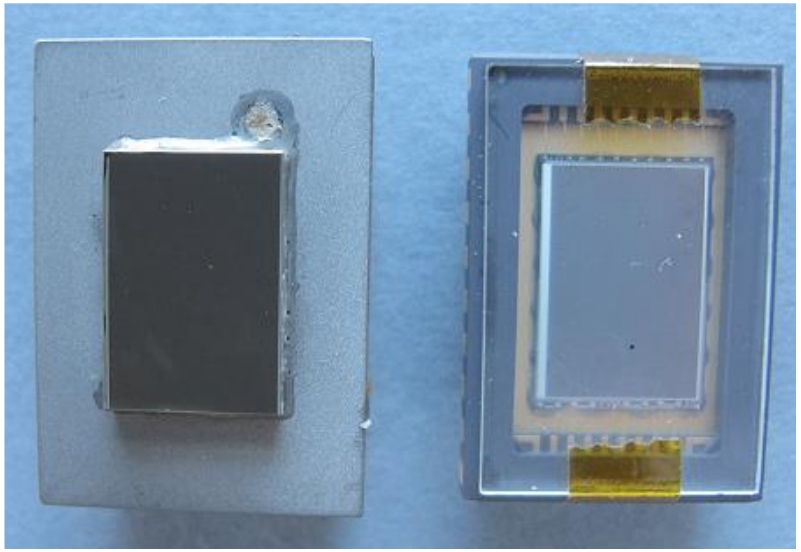
Face d’entrée = face arrière du capteur



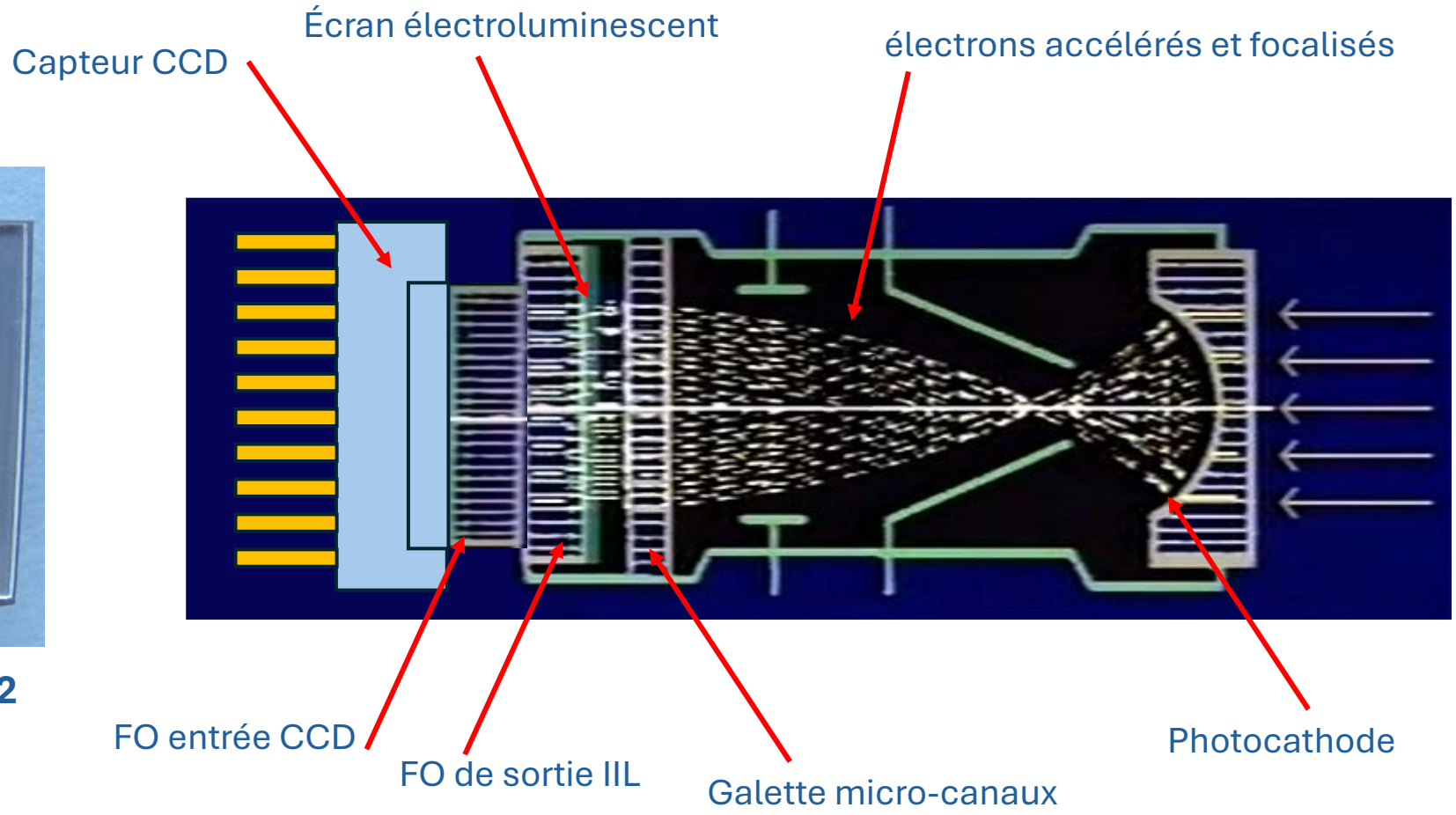
Face avant du capteur

Capteur avec fibre optique – couplage IIL

sommaire



Fenêtre fibre optique sur TH7882



Cf Herpe, G., Boulesteix, J., Marcelin, M., et al. (1991)
"An Intensified CCD Camera for Telescope Guidance"
Experimental Astronomy, **2**, 163–174.

Proxitronic : FiberOpticCouplings.pdf

1989

Capteur à transfert de ligne : 576 x 720 pixels

sommaire

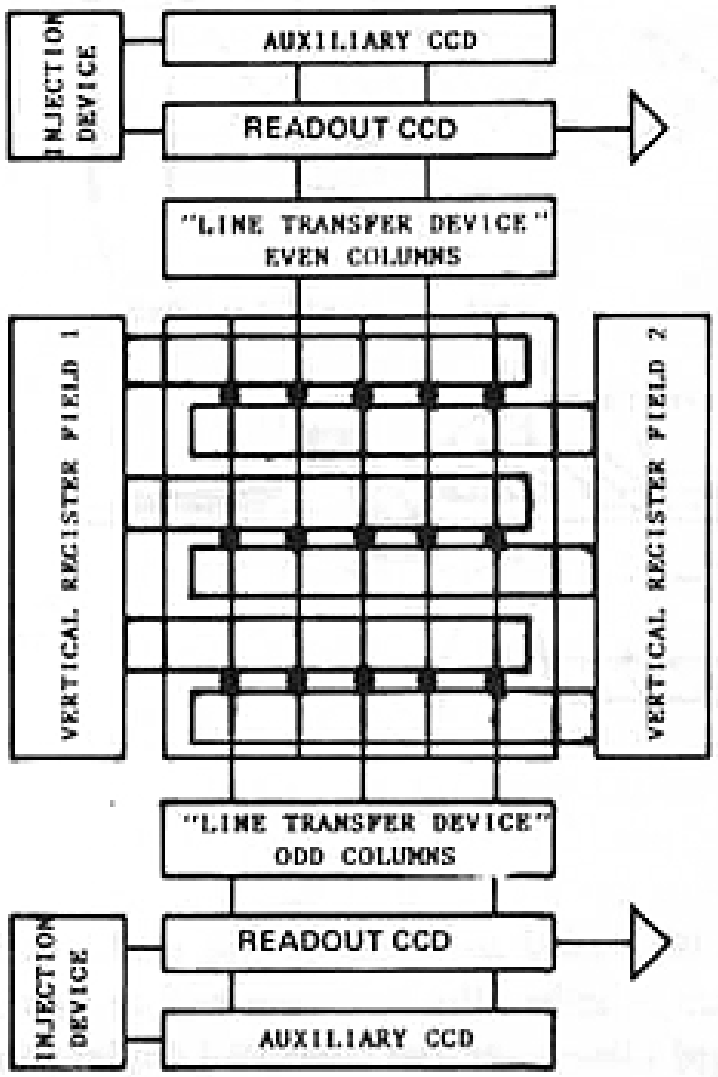


Fig. 1. The line-transfer organization.

THX 1143 – 1145 - 1148

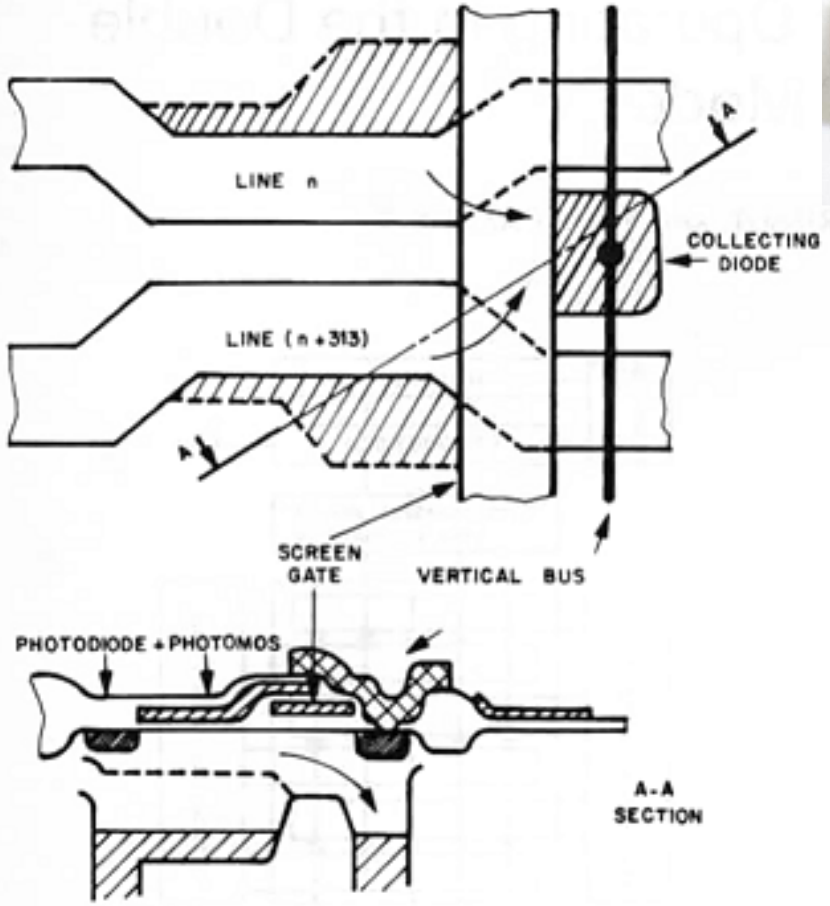
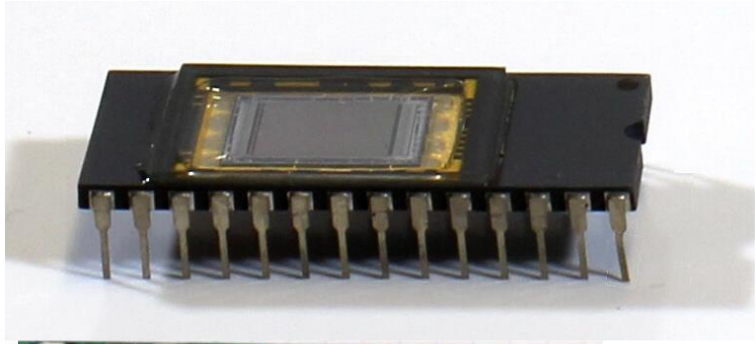
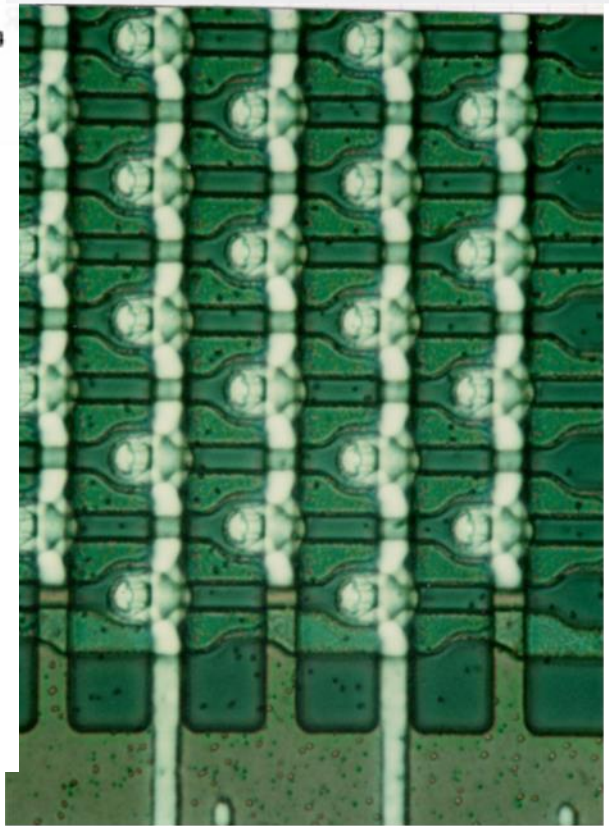


Fig. 2. Detail of photosite.

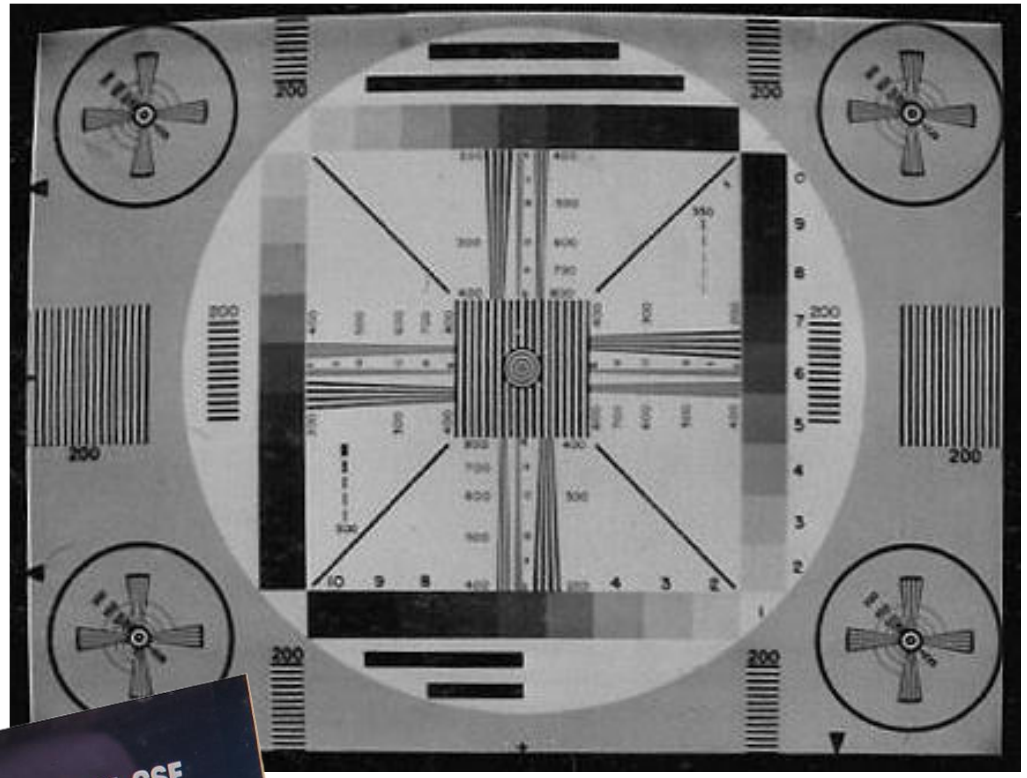




1984-88

Capteur à transfert de ligne monochip couleur : 576 x 702 pixels

sommaire



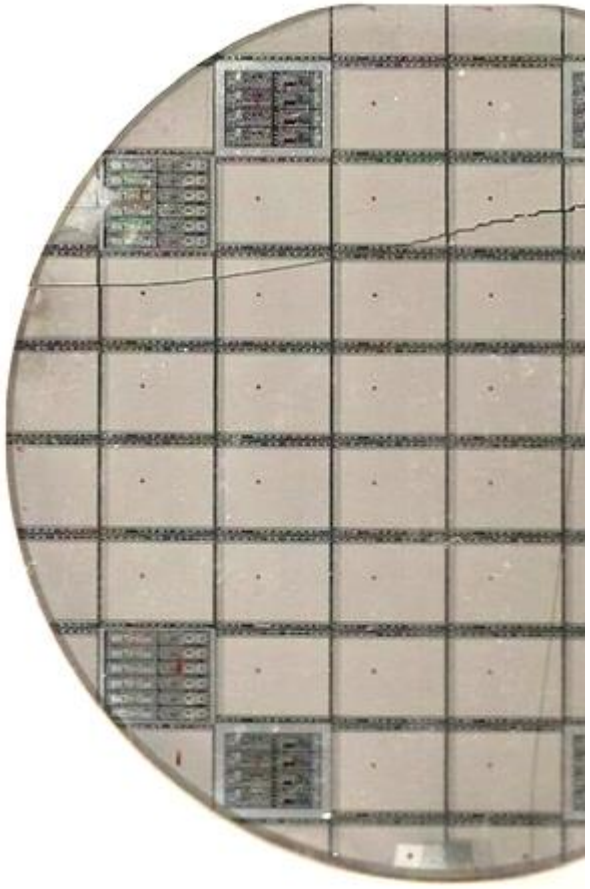
Etude pour visiophone avec caméra numérique couleur

Capteur à transfert de ligne : 576 x 702 pixels

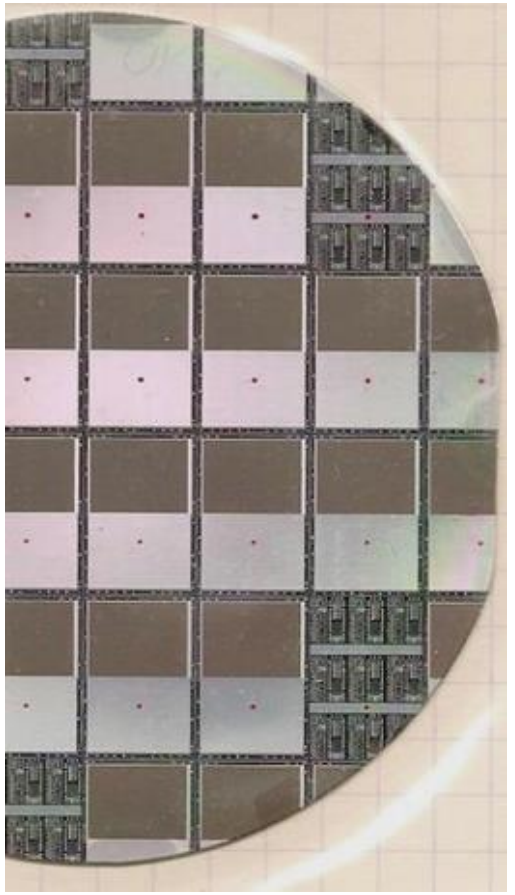
sommaire

CHARACTERISTICS OF LINE-TRANSFER IMAGE SENSOR

NUMBER OF ELEMENTS	576 (V) x 462 (H)		
IMAGING AREA	6.4 (V) x 8.8 (H) mm^2		
PIXEL SIZE	11.5 (V) x 19 (H) μ^2		
• DYNAMIC RANGE AT 30 °C :			
SATURATION CHARGE	8×10^5	electrons	(900 nA)
THERMAL CHARGE	3×10^3	electrons	(3.5 nA)
BIAS CHARGE (Q1, Q2)	2.7×10^5	electrons	(300 nA)
VERTICAL FPN (peak-peak)	250	electrons	(0.28 nA)
TEMPORAL NOISE	700	electrons rms	(0.79 nA)
SMEAR FACTOR	1.2×10^{-5}		
BLOOMING FACTOR	1.5×10^{-4} (30 Ω·cm) to 5×10^{-5} (5 Ω·cm)		
• RESPONSIVITY :			
WHITE LIGHT (*)	1.6×10^4	electrons / Lux**	(QE = 34 %)
(SINGLE CHIP COLOR IMAGER)*** BLUE (λ = 460 nm)	1.9×10^3	electrons / Lux**	(QE = 12 %)
(SINGLE CHIP COLOR IMAGER)*** GREEN (λ = 520 nm)	4.5×10^3	electrons / Lux**	(QE = 22 %)
(SINGLE CHIP COLOR IMAGER)*** RED (λ = 600 nm)	4.5×10^3	electrons / Lux**	(QE = 20 %)
• SPATIAL RESPONSE (MTF) :			
HORIZONTAL	80 % at Nyquist frequency (= 350 TVL)		
VERTICAL	70 % at Nyquist frequency (576 TVL)		
• LAG AND BUILD UP (****)			
1ST frame after increase in illumination	> 95 %		
1ST frame after illumination cut-off	< 5 %		



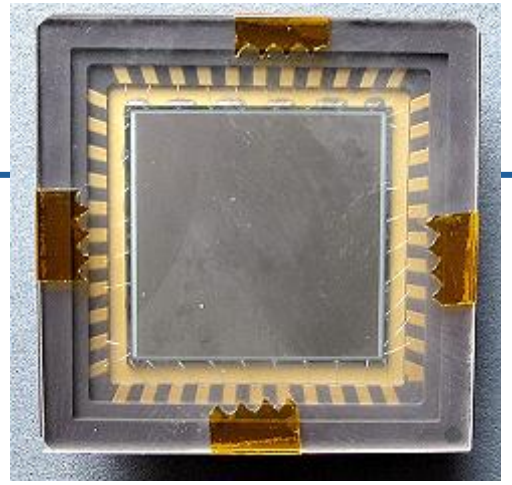
THX 1143 - TDL
576 x 702
36 puces /plaque 3 ’’

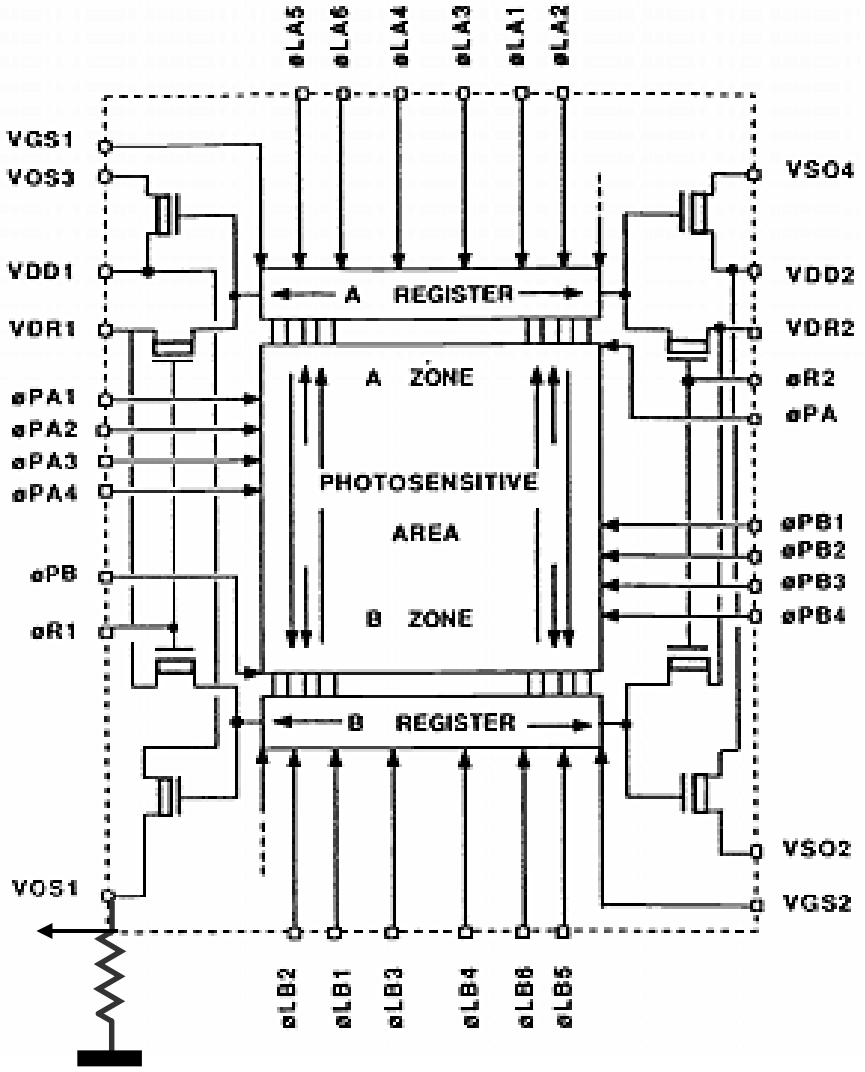


TH 7862 - TDT
576 x 384
20 puces /plaque 3 ’’

Matrice 1024 x 1024 – TH 7896 (THX 31156)

sommaire





Capteur conçu spécialement pour astronomie et applications scientifiques

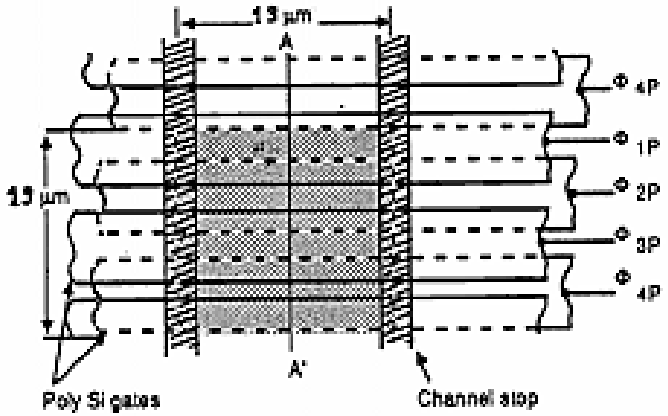
- Optimisé pour une haute sensibilité
- Bruit de sortie 4 e- à -40°C (avec CDS)
- Vsat = 450 000 e-
- Transistor de sortie à canal enterré et résistance externe
- Pixel 19x19um Ouverture 100%
- Réponse spectrale 400nm à 1100nm
- Efficacité de transfert 0,999998
- Courant obscurité 10 e- /pixel/sec à -40°C
- Dispositif de mesure de température intégré
- Pilotage 4 phases

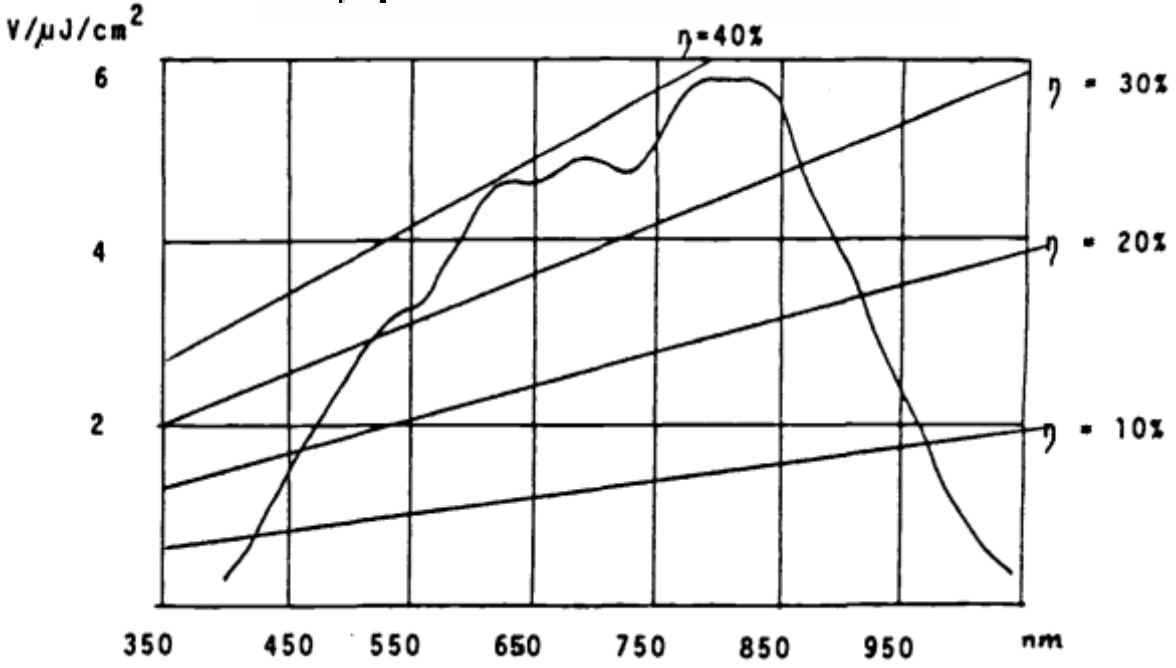
1.5 uV/e- sur R 2,2 kΩ

1989

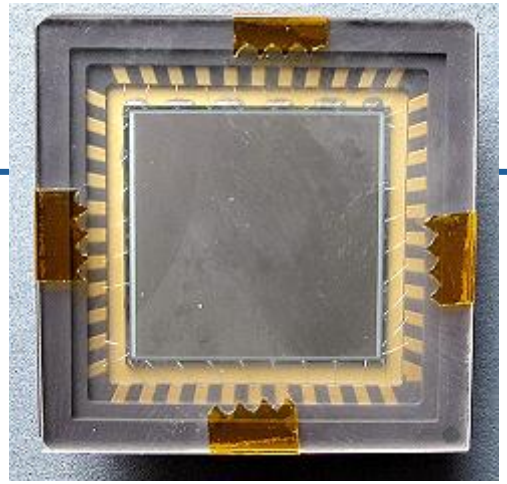
Matrice 1024 x 1024 – THX 31156

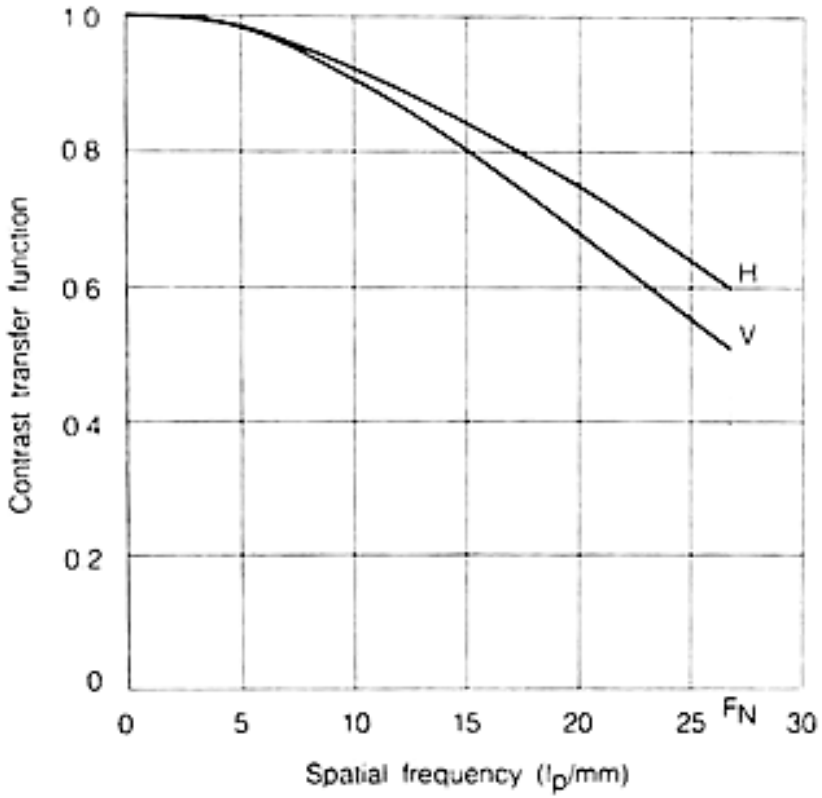
sommaire





Réponse spectrale





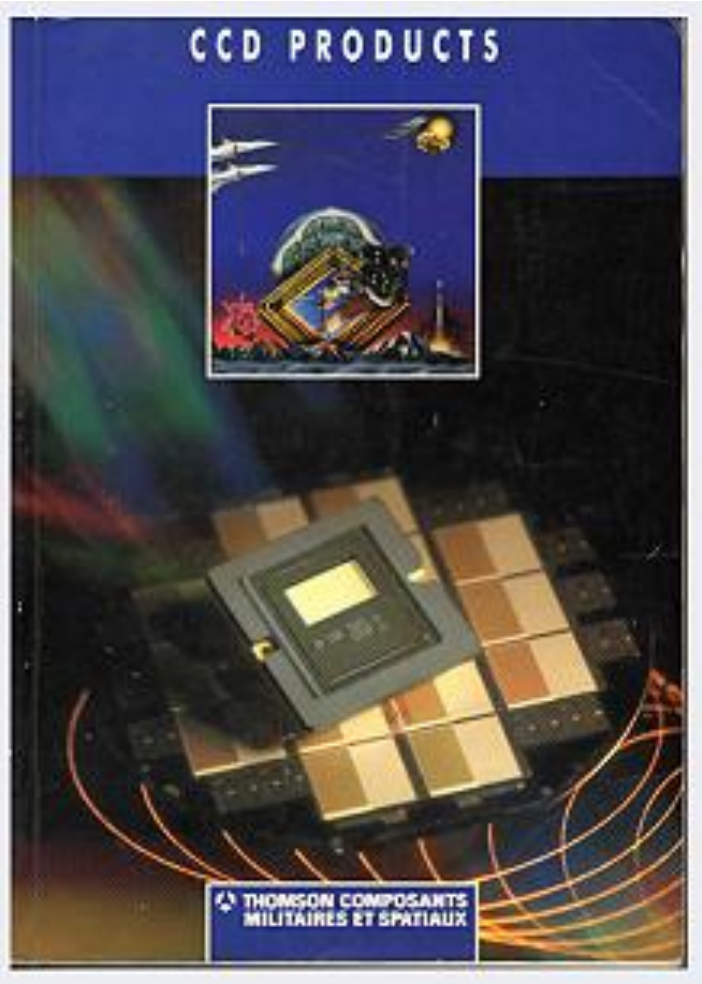
Résolution

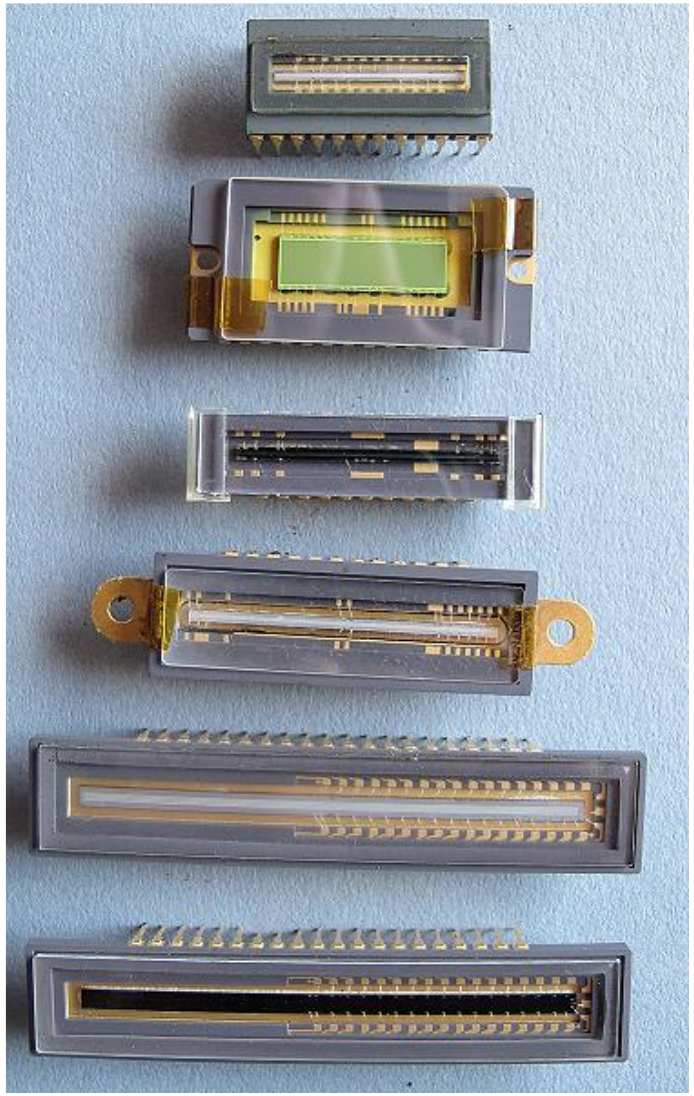
Les autres capteurs CCD fabriqués à St Egrève…

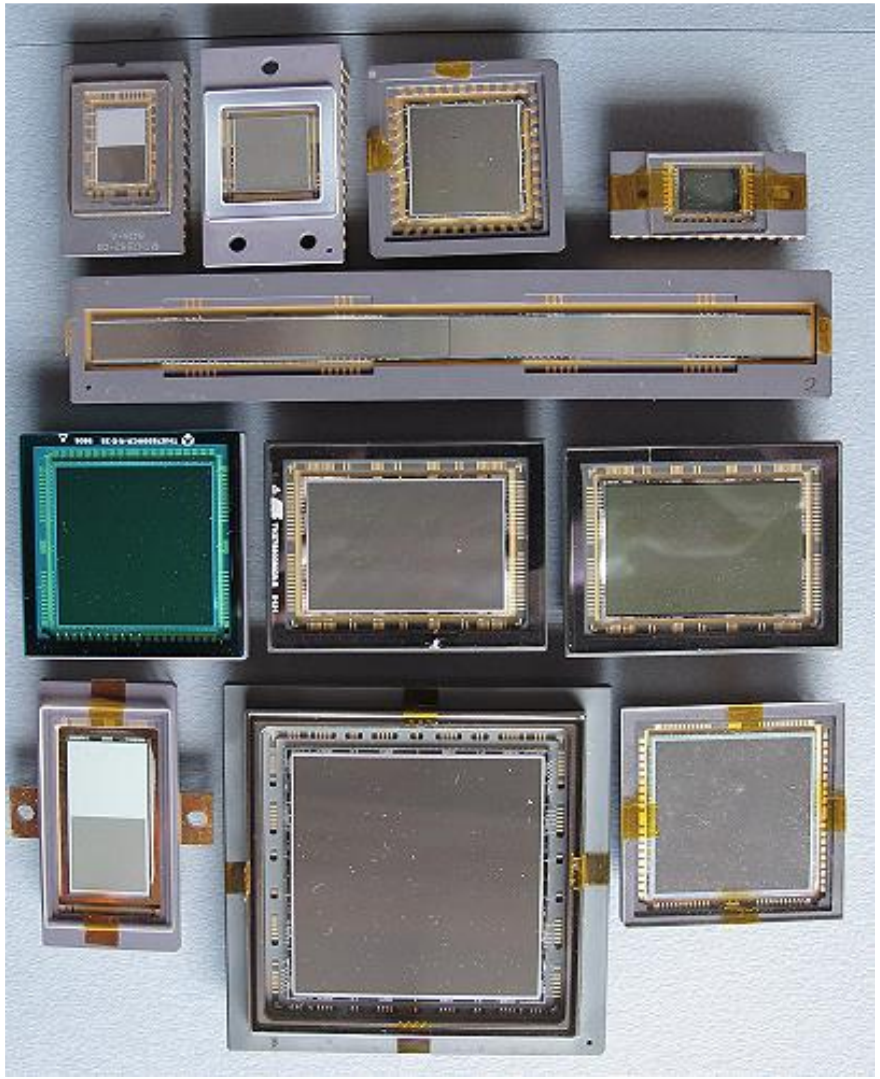
sommaire

Catalogue 1992 – 93

600 pages





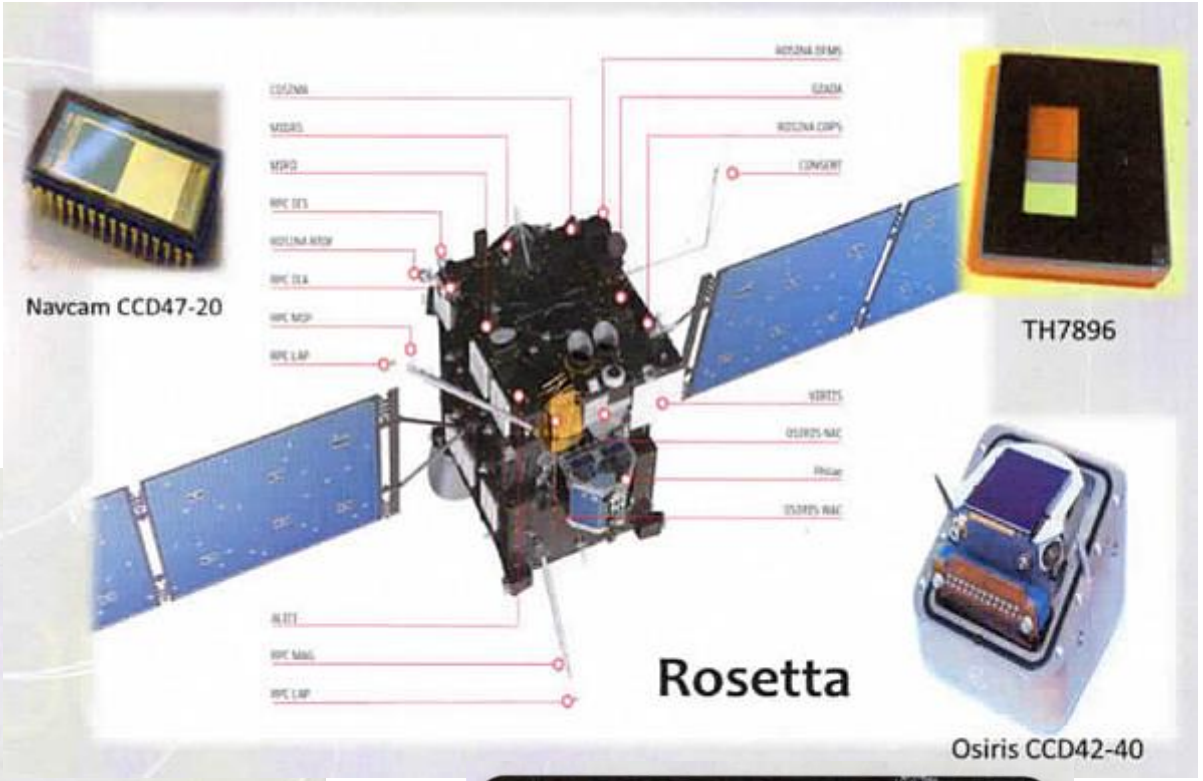


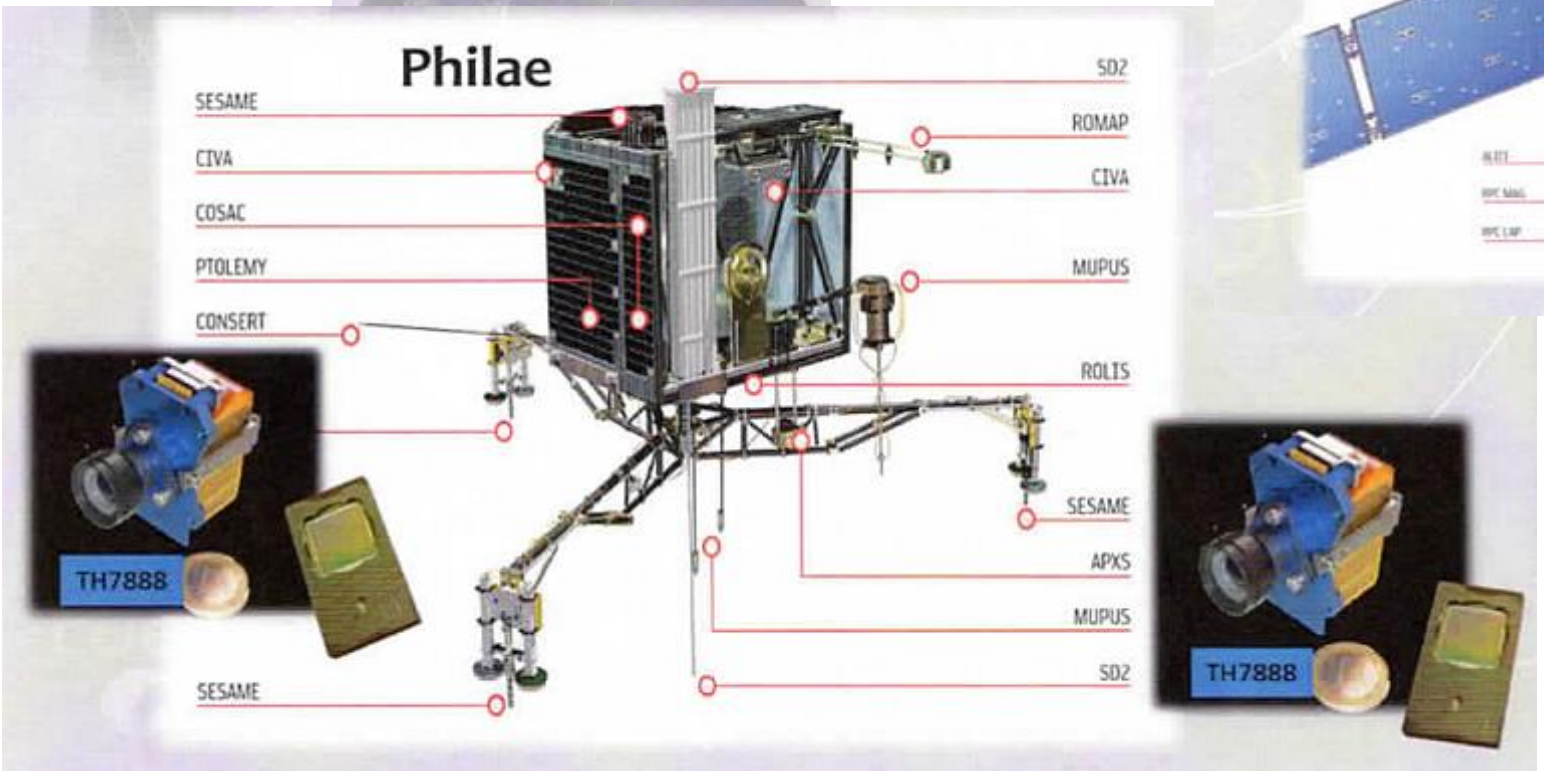
Les autres capteurs CCD fabriqués à St Egrève…

sommaire

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

10 ans de trajet
6,5 milliards de km parcourus

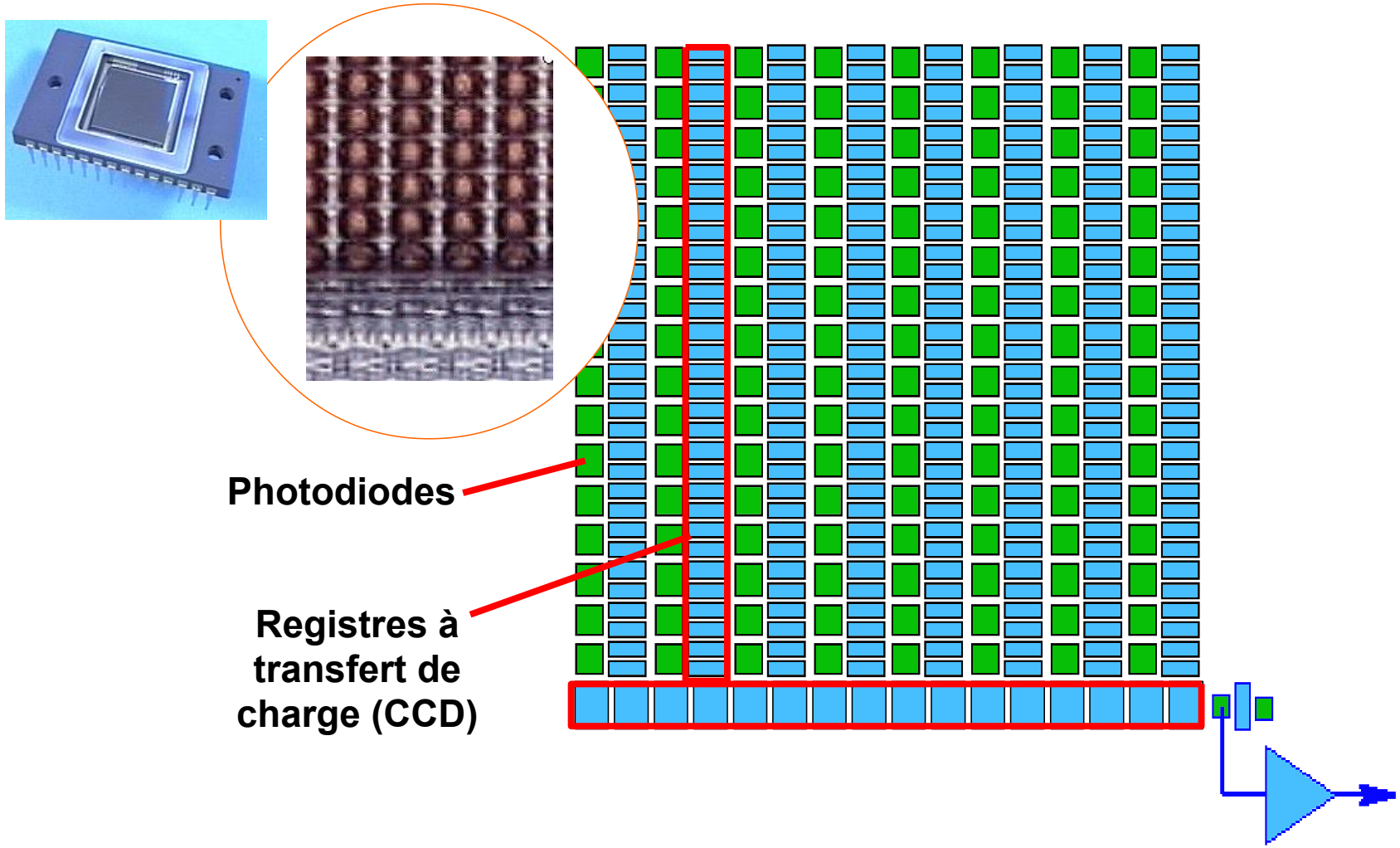




2014

Autres configurations de capteurs - Interligne

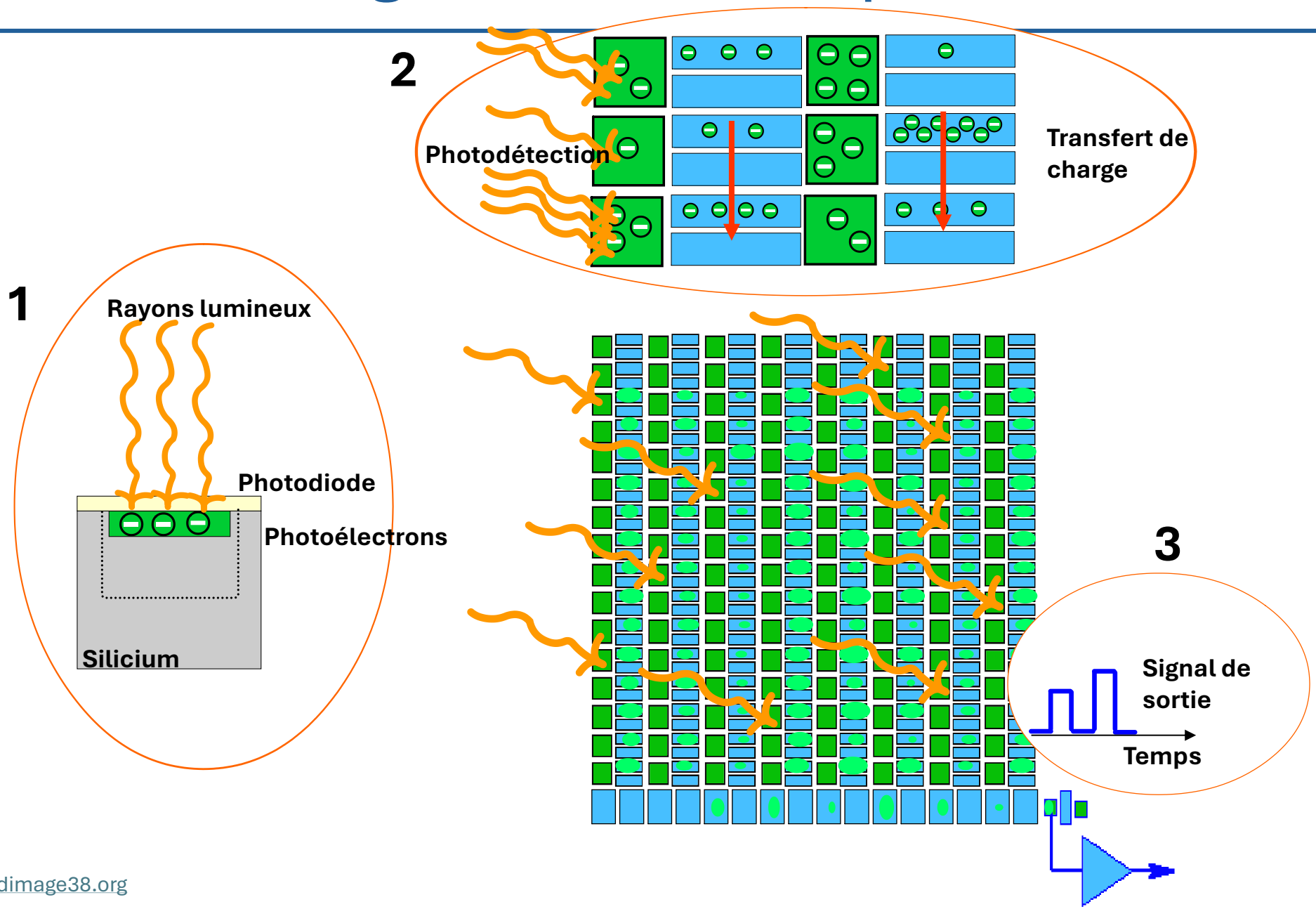
sommaire



Développé à Saint-Egrève sans débouché commercial

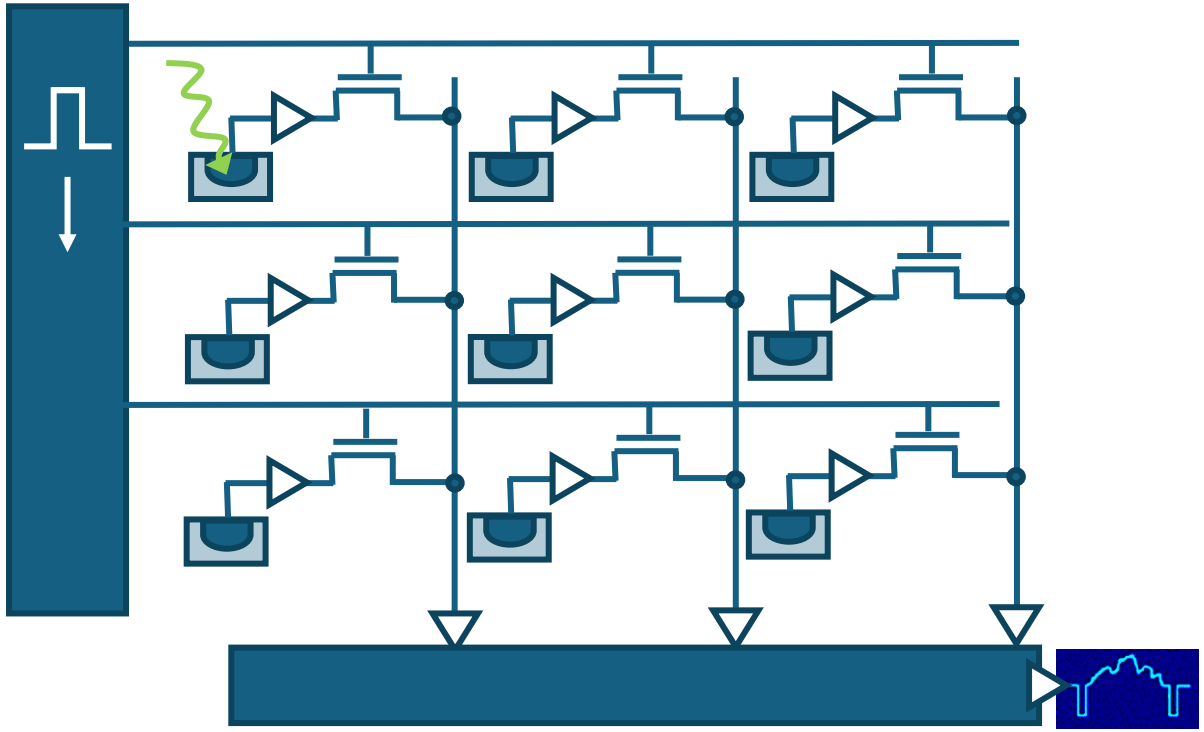
Autres configurations de capteurs - Interligne

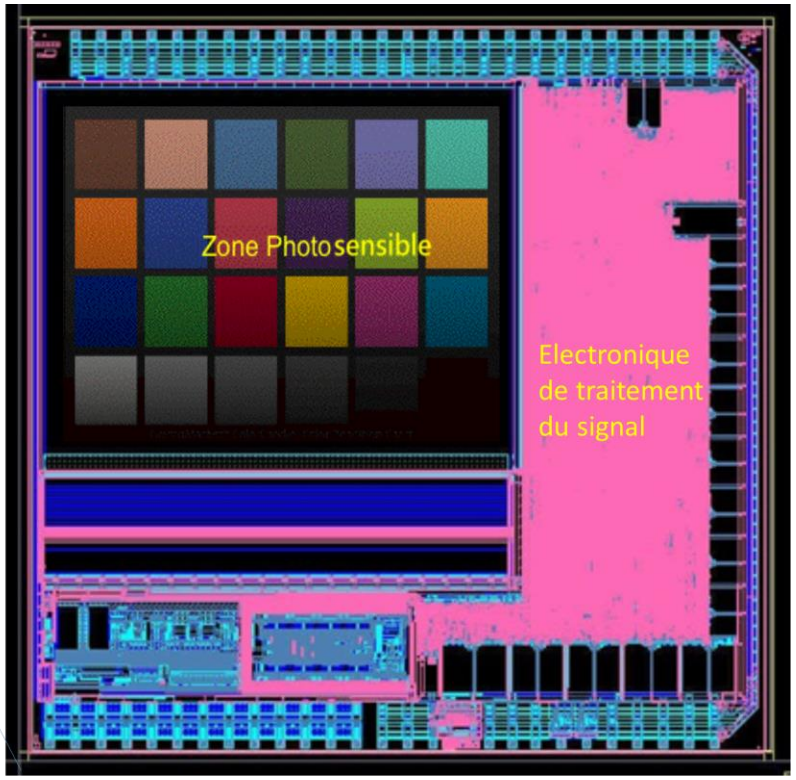
sommaire



Autres configurations de capteurs – Capteur CMOS

sommaire



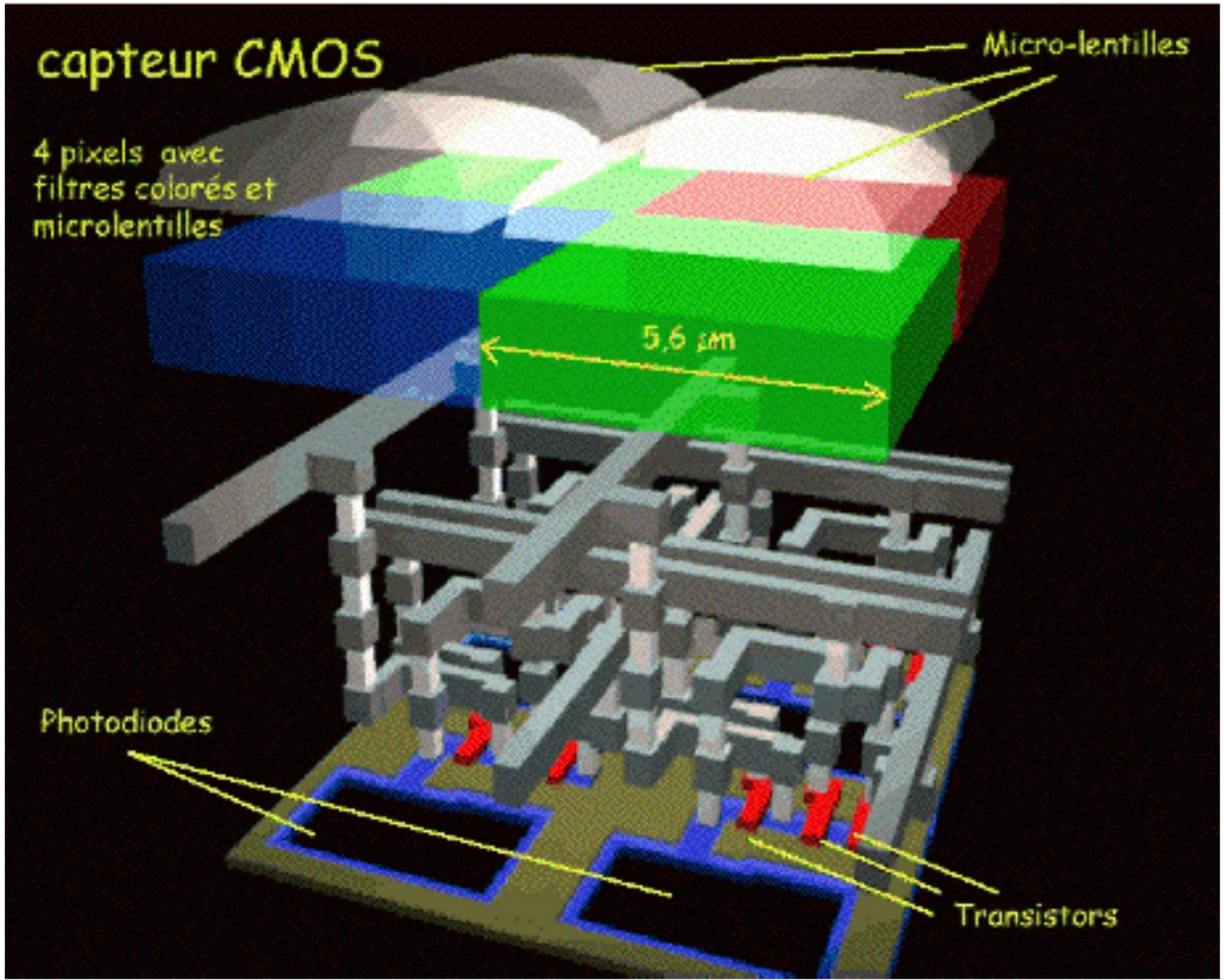


Développé à Saint-Egrève sans débouché commercial

Fabriqué à ST depuis 2000

Capteur CMOS en 3D

sommaire



Annexes et références

sommaire

Table ronde 2024 sur les CCD

https://www.tedimage38.org/histoire/causerie/histoire-des-ccd-et-des-a-saint-egreve/

TH7834 1997-12000_elementsMonolithic_CCD_Linear_Sensor_for_HR.PDF

TH7896 1024_1024_CCD_Array_scientific_application.pdf

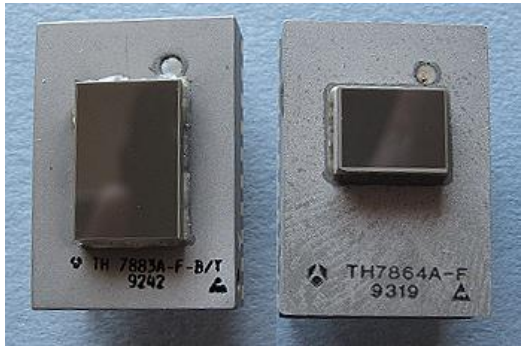
TH7882 backside_illuminated_CCD.pdf

Observations avec TH7883

http://www.observatoire-binou.fr/MISSION%20AU%20PIC%20DU%20MIDI%20EN%201993.html

https://ui.adsabs.harvard.edu/abs/1987OptEn..26..902B/abstract

Couplage fibre optique TH 7883 : https://finesensing.com/iiimaging/doc/FiberOpticCouplings.pdf

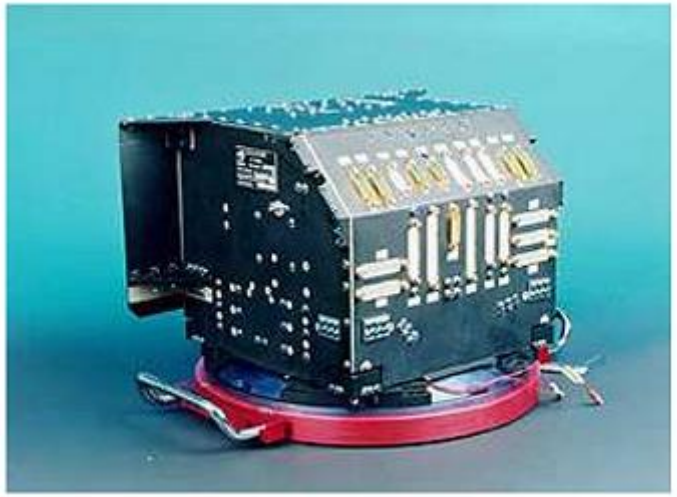


L'historique du site Emile Girardeau du point de vue de ses activités successives

L'évolution des bâtiments du site au fil des âges

TH 7834 – 12000 points pour SPOT 5

sommaire



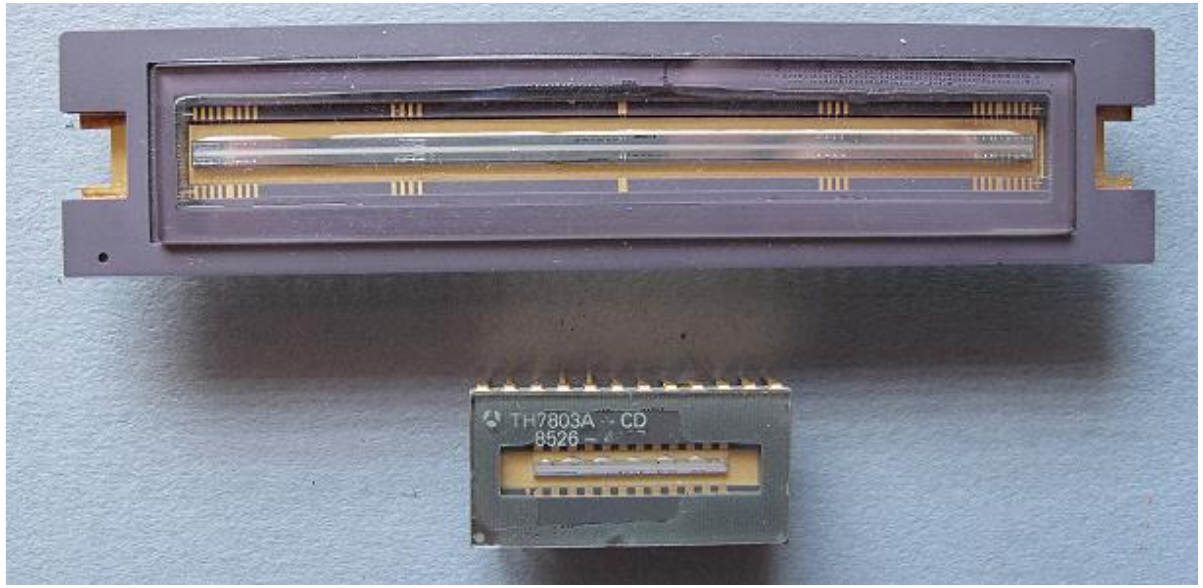
Boitier de détection

Dans le boitier de détection, les détecteurs utilisés sont :

pour la voie PAN, un **détecteur TH7834 (THX31535) de TCS, constitué de deux lignes détectrices de 12000 détecteurs élémentaires utiles au pas de 6.5 µm** ; ces deux lignes étant séparées d'une distance de 3.5 µm au plan focal,

pour chacune des voies B1, B2, B3 on utilise un détecteur TH7834 de TCS constitué d'une ligne détectrice de 12000 détecteurs élémentaires utiles au pas de 6.5 µm,

pour la voir MIR, un détecteur TH31903 de TCS, constitué de 3000 détecteurs élémentaires utiles au pas de 26 µm alignés sur une même ligne géométrique.



TH 7834 – 12000 points pour SPOT 5

sommaire

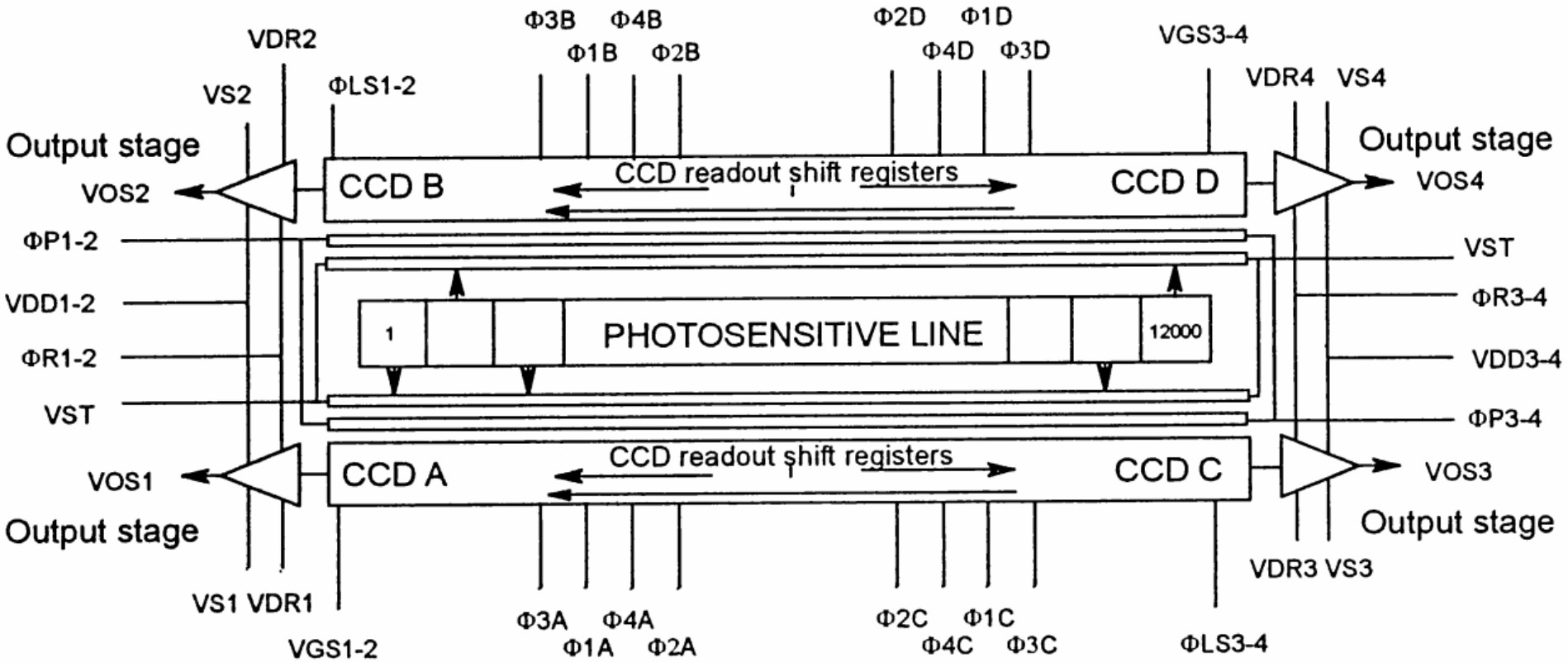


Fig.1 : TH 7834 block diagram.

TH 7834 – 12000 points pour SPOT 5

sommaire

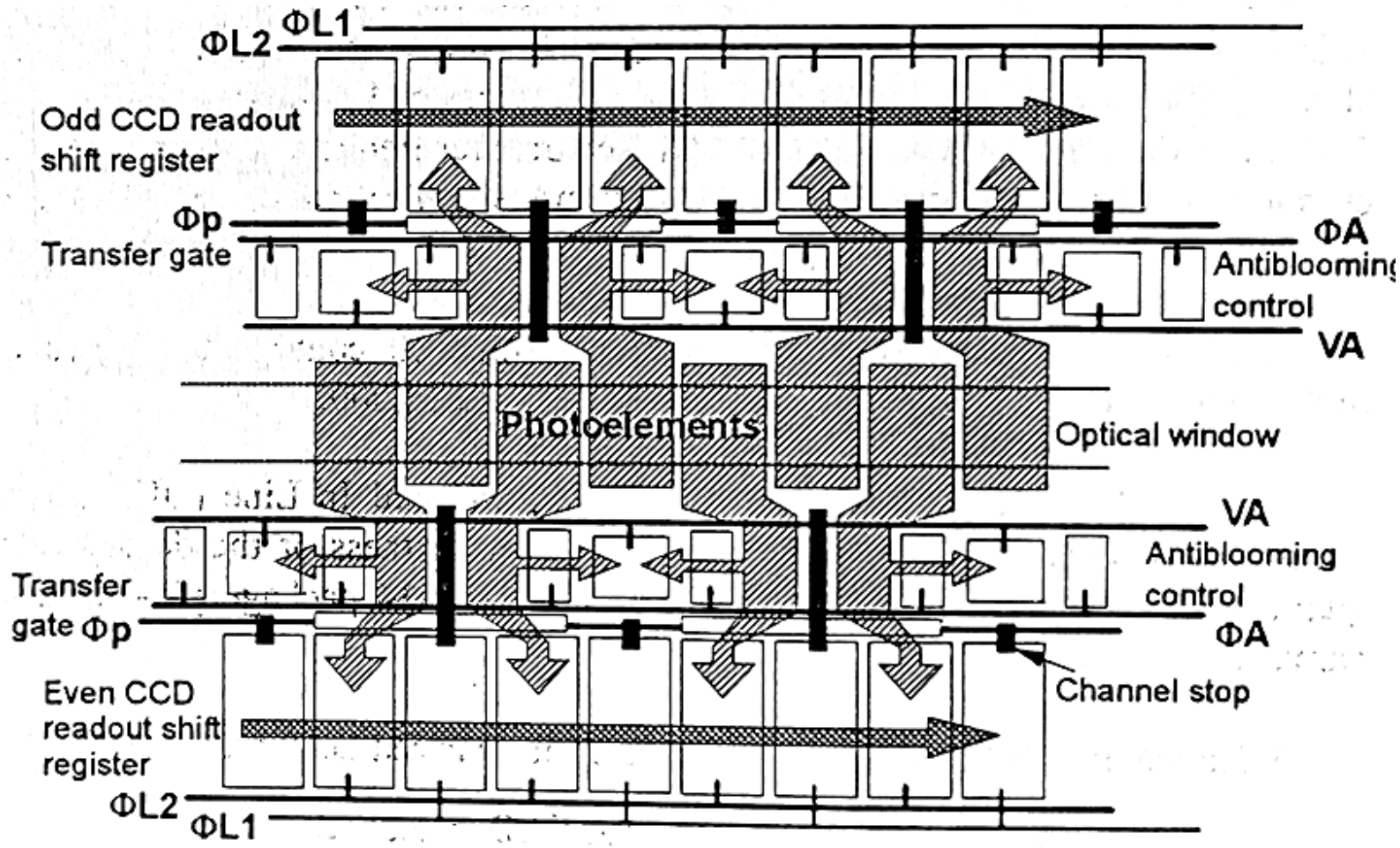


Fig.3. TH 7834 pixel architecture.

TH 7834 – 12000 points pour SPOT 5

sommaire

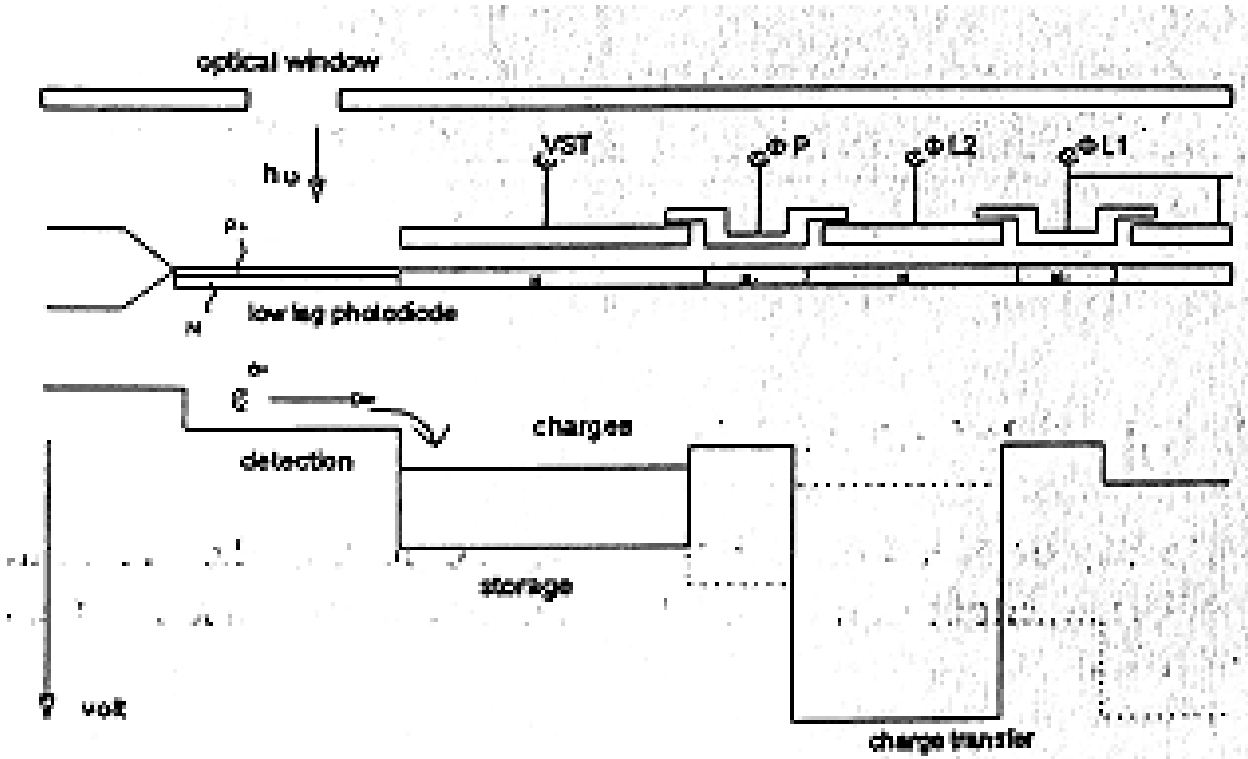


Fig.6. Potential from photodiode to CCD.

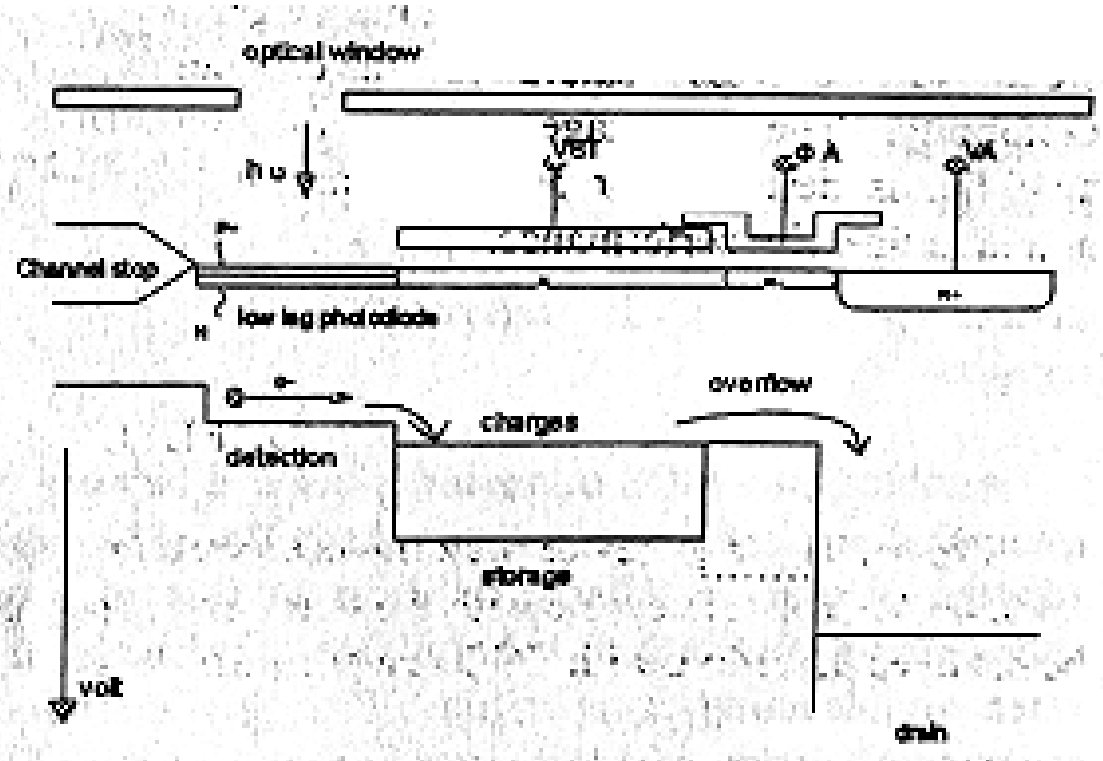


Fig.7. Potential from photodiode to antiblooming drain.

Références

sommaire

Table ronde 2024 sur les CCD

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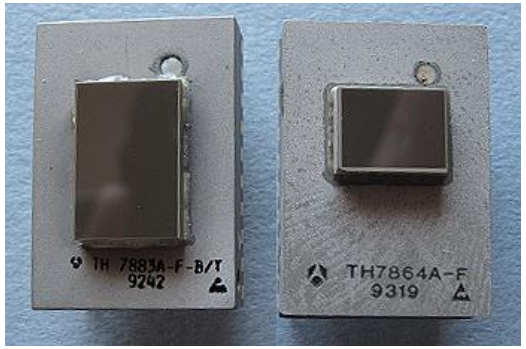

Histoire du site de Saint-Egrève

https://www.tedimage38.org/videos/Histoire_SE_TeledyneV2music3.mp4

https://www.tedimage38.org/videos/survol_historique_site_SE_V3.mp4