

# **Termografia**

# Temperatura del corpo

## Sintomo della salute del paziente

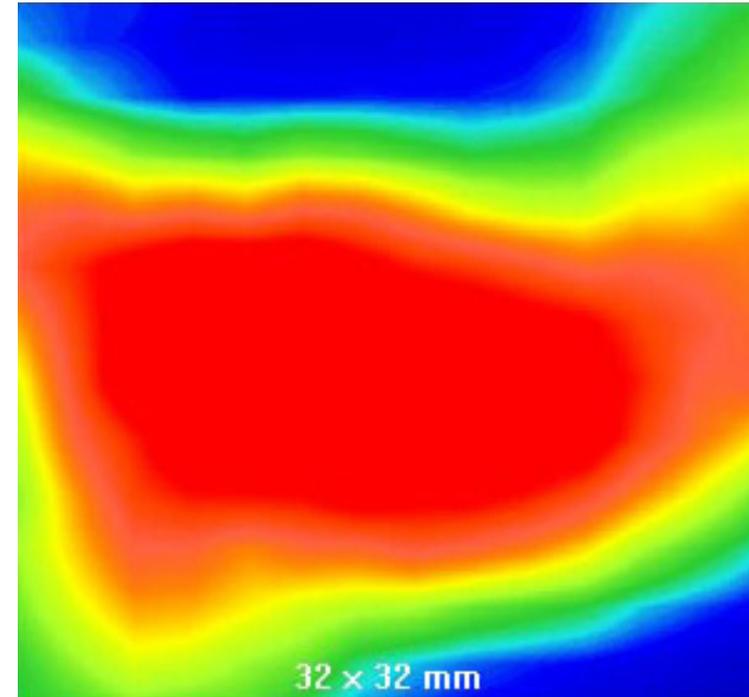
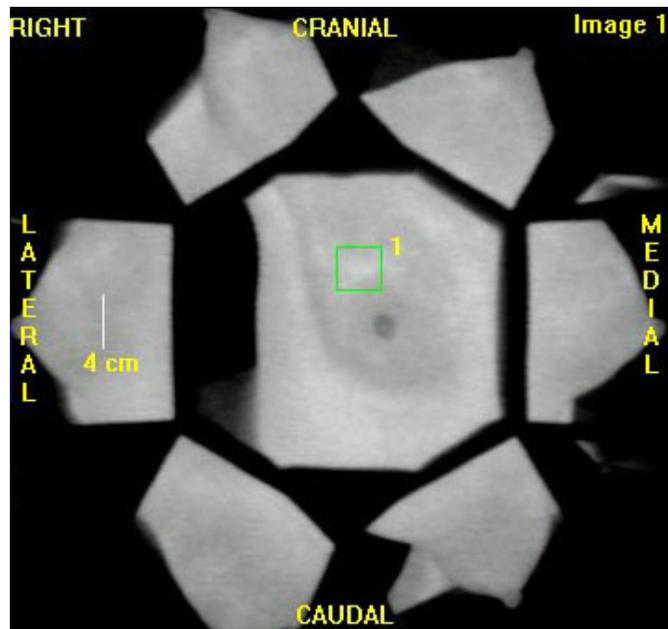
- ridotta pressione sanguigna in una persona con shock circolatorio implica un basso flusso di sangue alla periferia del corpo
- infezione aumento di temperatura
- anestesia diminuzione di temperatura perché deprime i centri regolazione termica
- incubatrici stabilizzano la temperatura del corpo del neonato
- artriti temperatura delle giunture è legata alla quantità di infiammazione

# Termografia medica

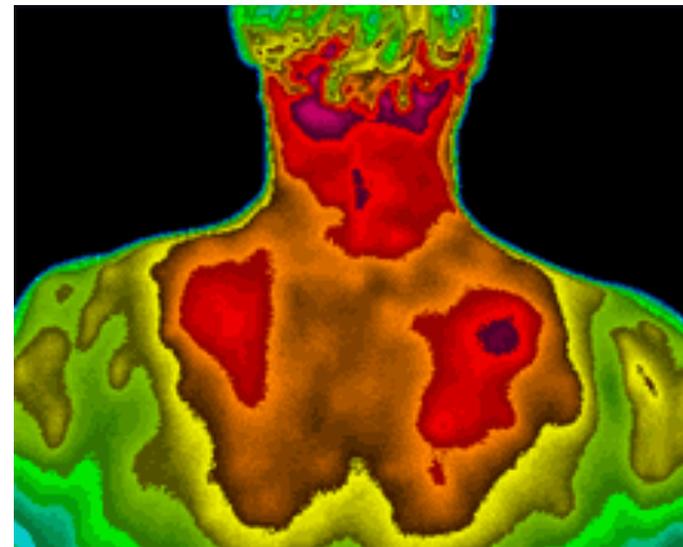
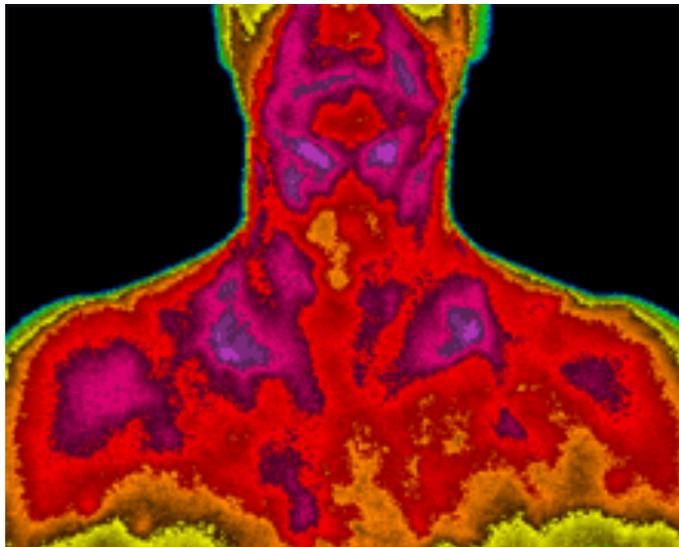
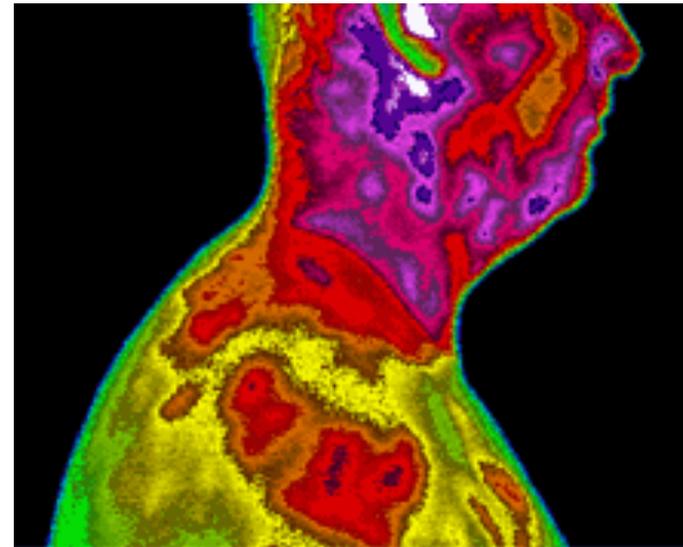
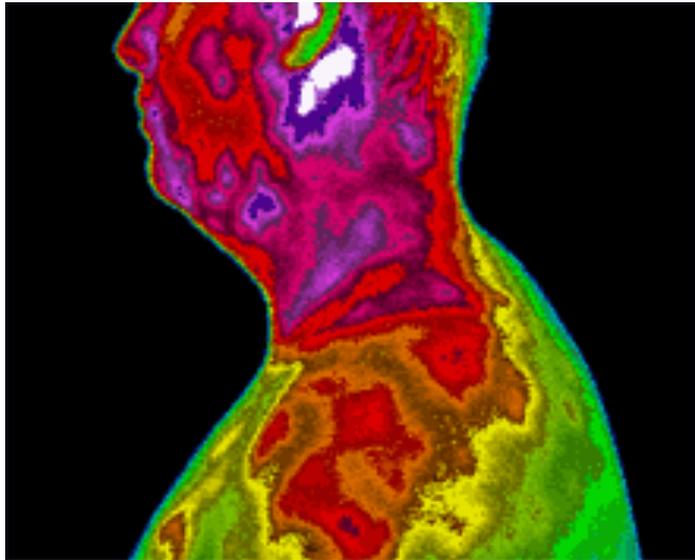
Si basa sulla relazione tra la temperatura superficiale di un corpo e la sua potenza radiante; la temperatura delle varie zone dipende dai processi circolatori o cellulari che si hanno in un particolare punto; mappa della distribuzione della temperatura di un corpo con sensibilità di pochi decimi di grado ° C

## Applicazioni:

- tumore al seno
- disturbi artritici
- disturbi circolatori



# Immagini



# Radiazione termica

## Corpo nero:

assorbe tutta la radiazione incidente ed emette la massima radiazione termica possibile

## Legge di Planck

$$W(\lambda) = \frac{\varepsilon C_1}{\lambda^5} \left[ \exp(C_2 / \lambda T) - 1 \right]^{-1}$$

W potenza radiante (W/cm<sup>2</sup> μm)

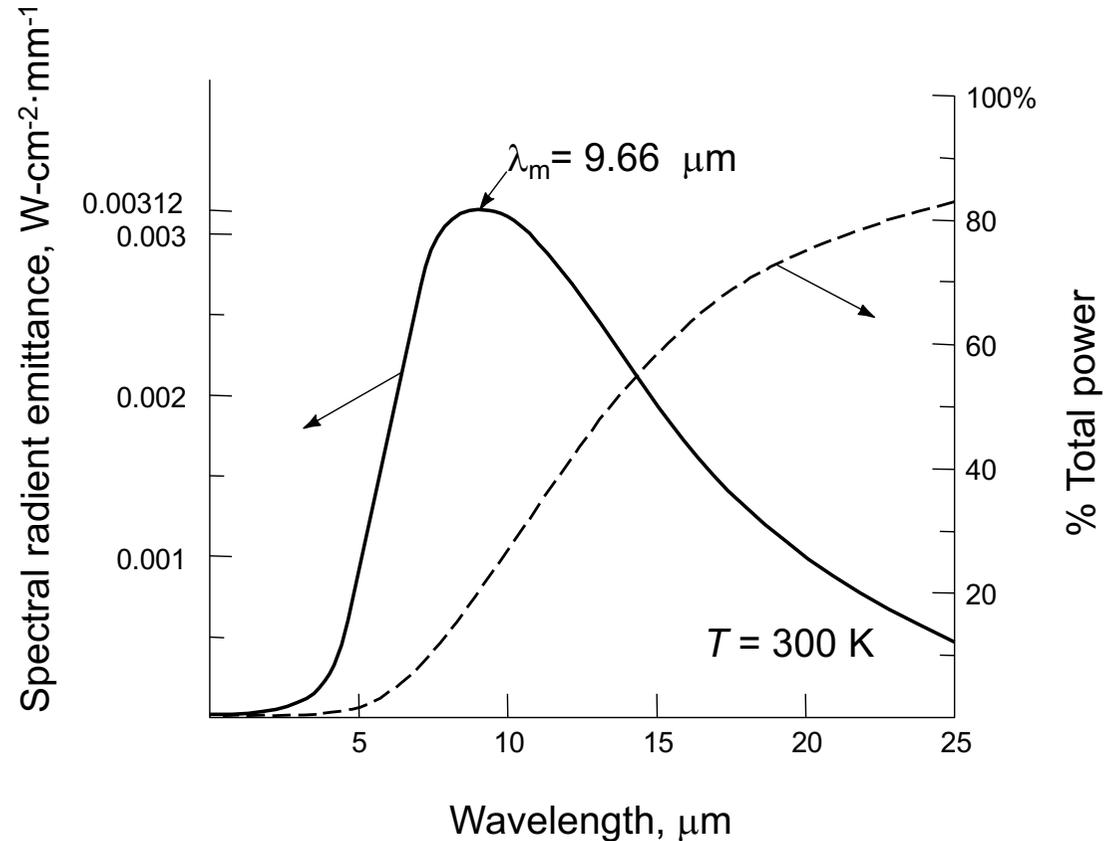
λ lunghezza d' onda (μm)

C<sub>1</sub>=3.74 10<sup>4</sup> (W μm<sup>4</sup>/cm<sup>2</sup>)

C<sub>2</sub>=1.44 10<sup>4</sup> (μm K)

T temperatura

ε emissività, (corpo nero ε=1)



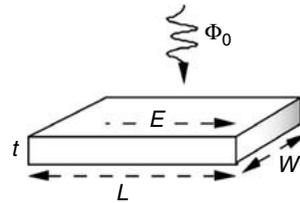
Massimo della potenza radiante  $\lambda_m = 2898/T$  (μm)

**Spettro della radiazione a temperatura ambiente:** 80% della potenza totale si trova nel lontano-molto lontano IR (4 ÷ 25 μm)

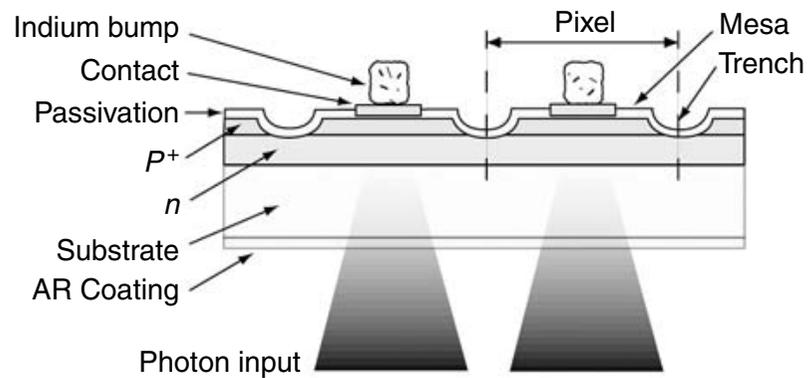
**Legge di Stefan-Boltzmann:** la potenza radiante totale  $W_t = \varepsilon \sigma T^4$  (W/m<sup>2</sup>)  $\sigma = 5.67 \cdot 10^{-12}$  W/cm<sup>2</sup>K<sup>4</sup>

# Sensori di radiazione termica

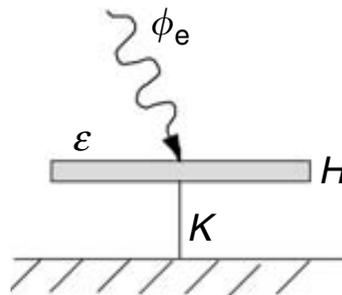
- Fotoconduttori



- Fotodiodi



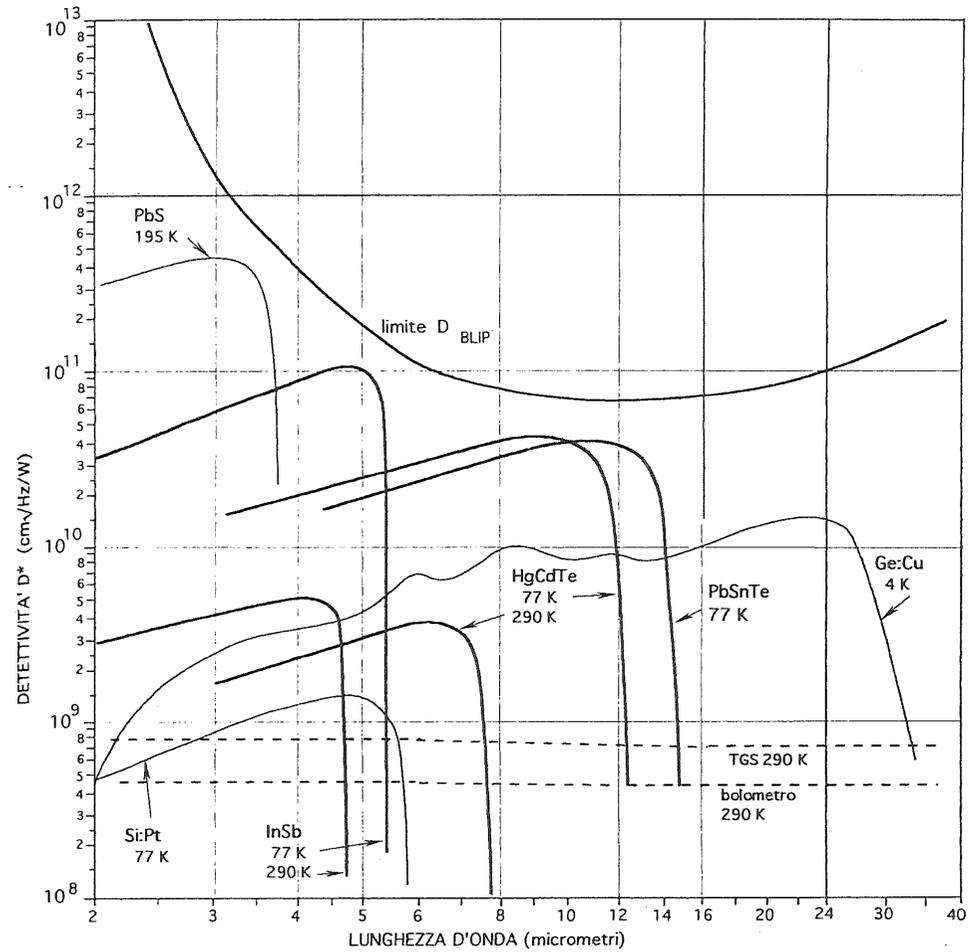
- Bolometri



# Parametri di un rivelatore IR

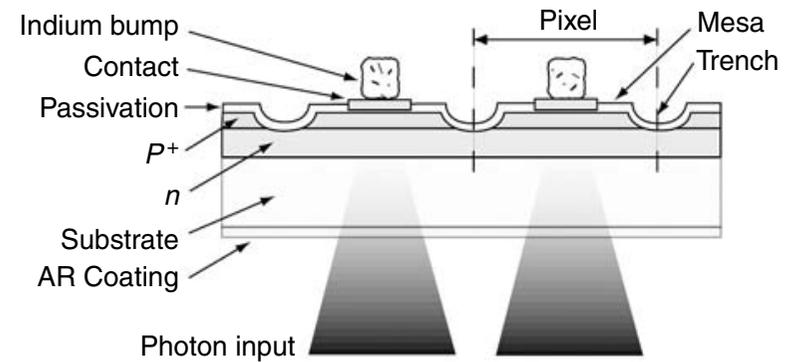
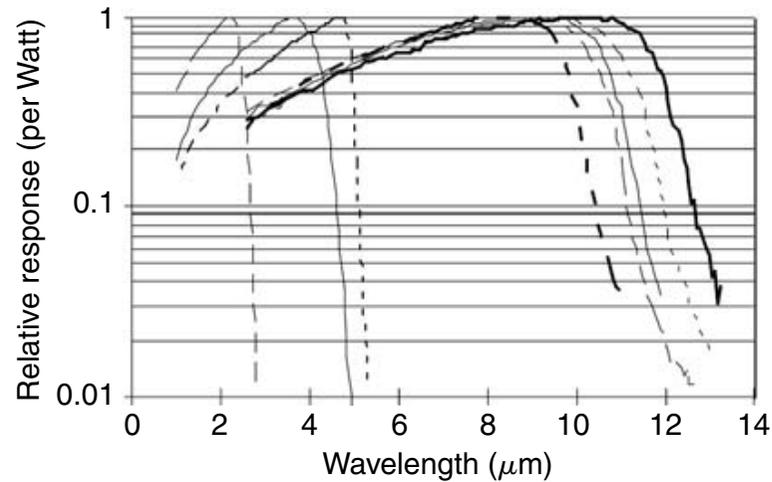
- NEP
- Detectivity
- $D_{\text{BLIP}}$
- NEDT

# Background Limited Infrared Photodetector

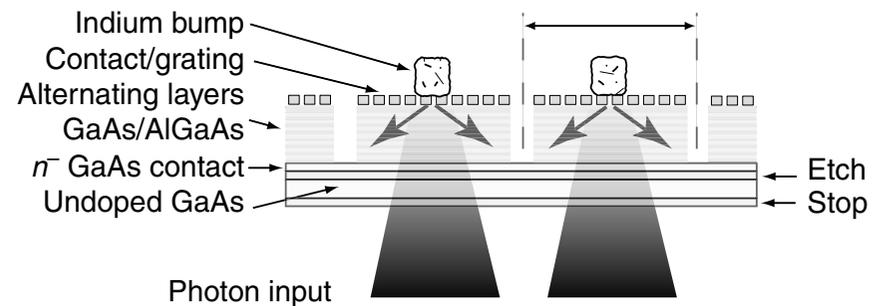
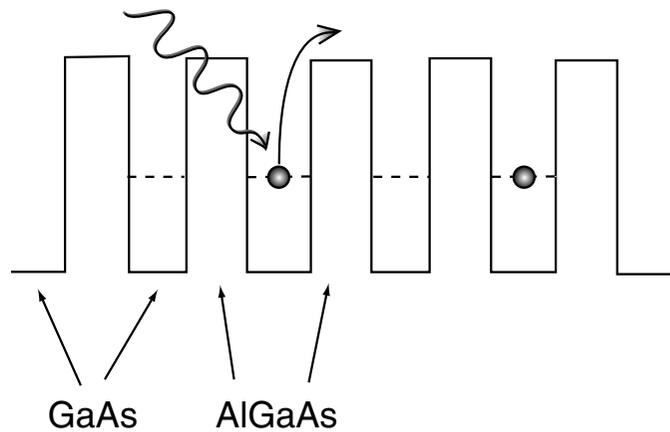


# Materiali per rivelatore IR

- CdHgTe (fotodiodi)



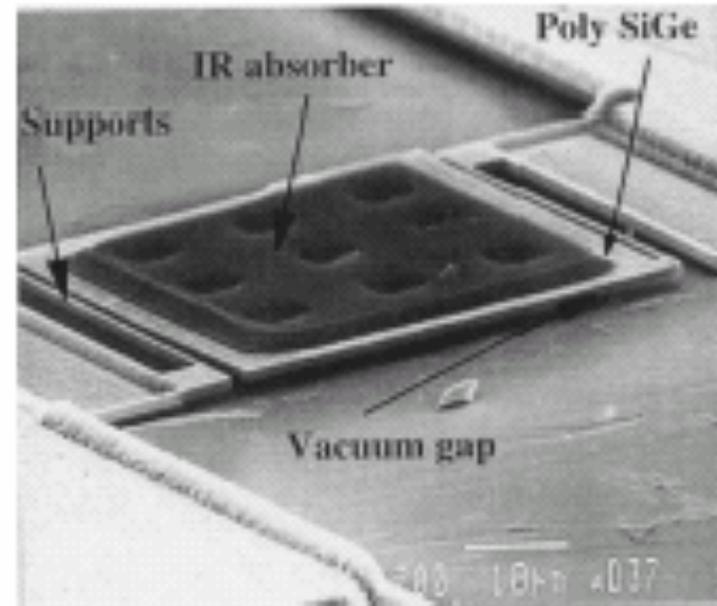
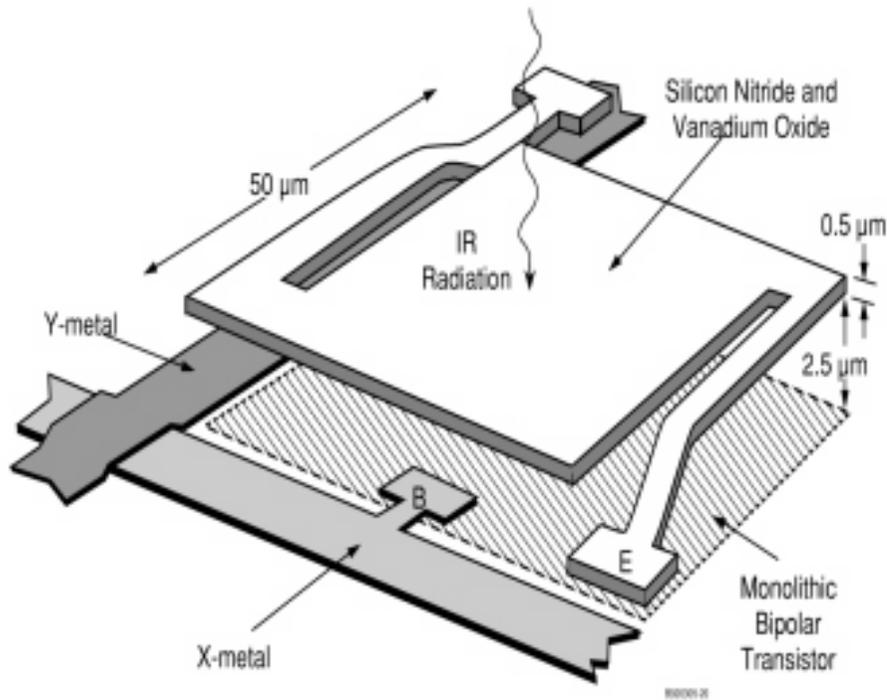
- QWIP (fotoconduttori)



# Microbolometer

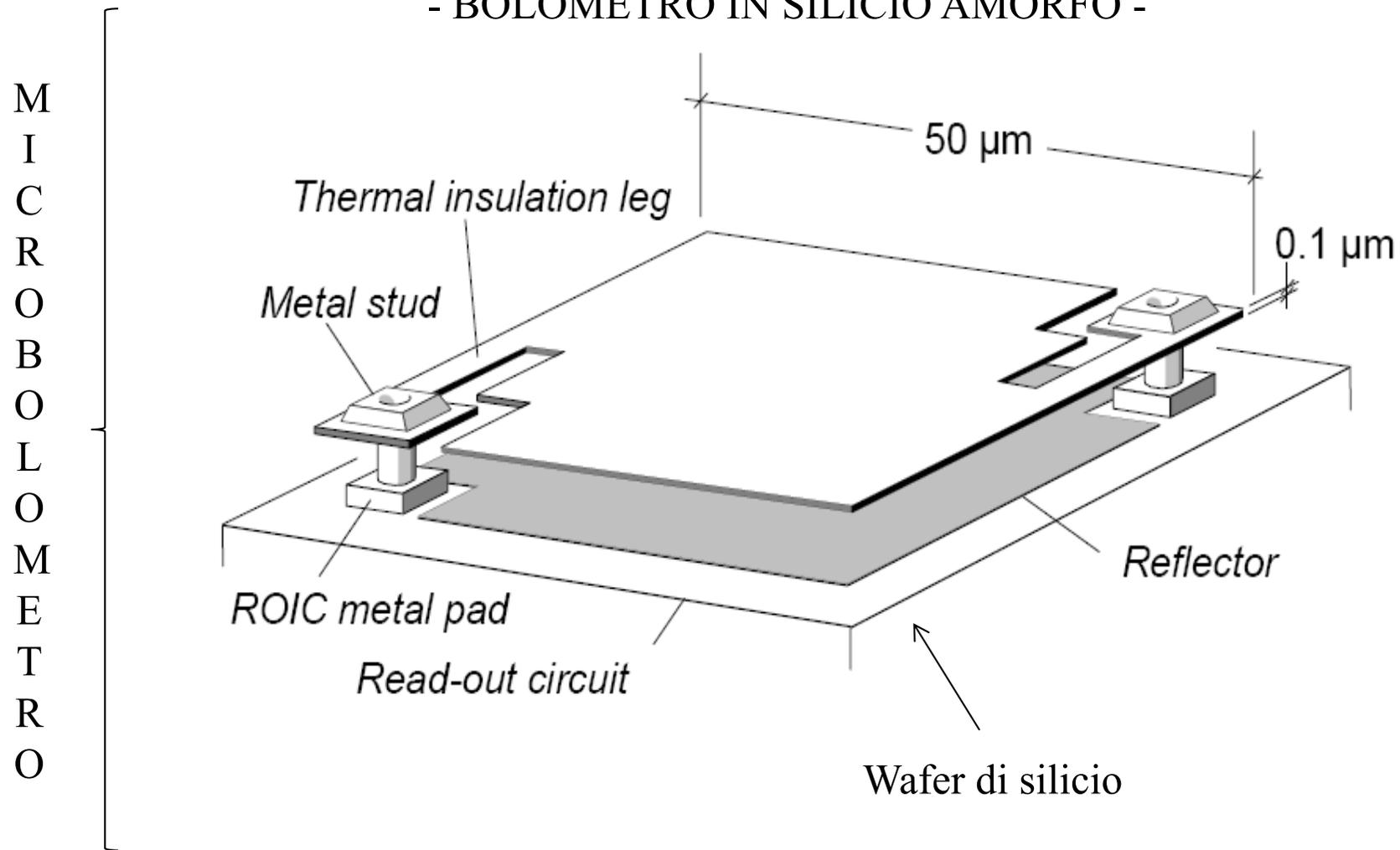
$$\alpha = \frac{1}{R} \frac{dR}{dT}$$

$$\tau = K_t C_t$$

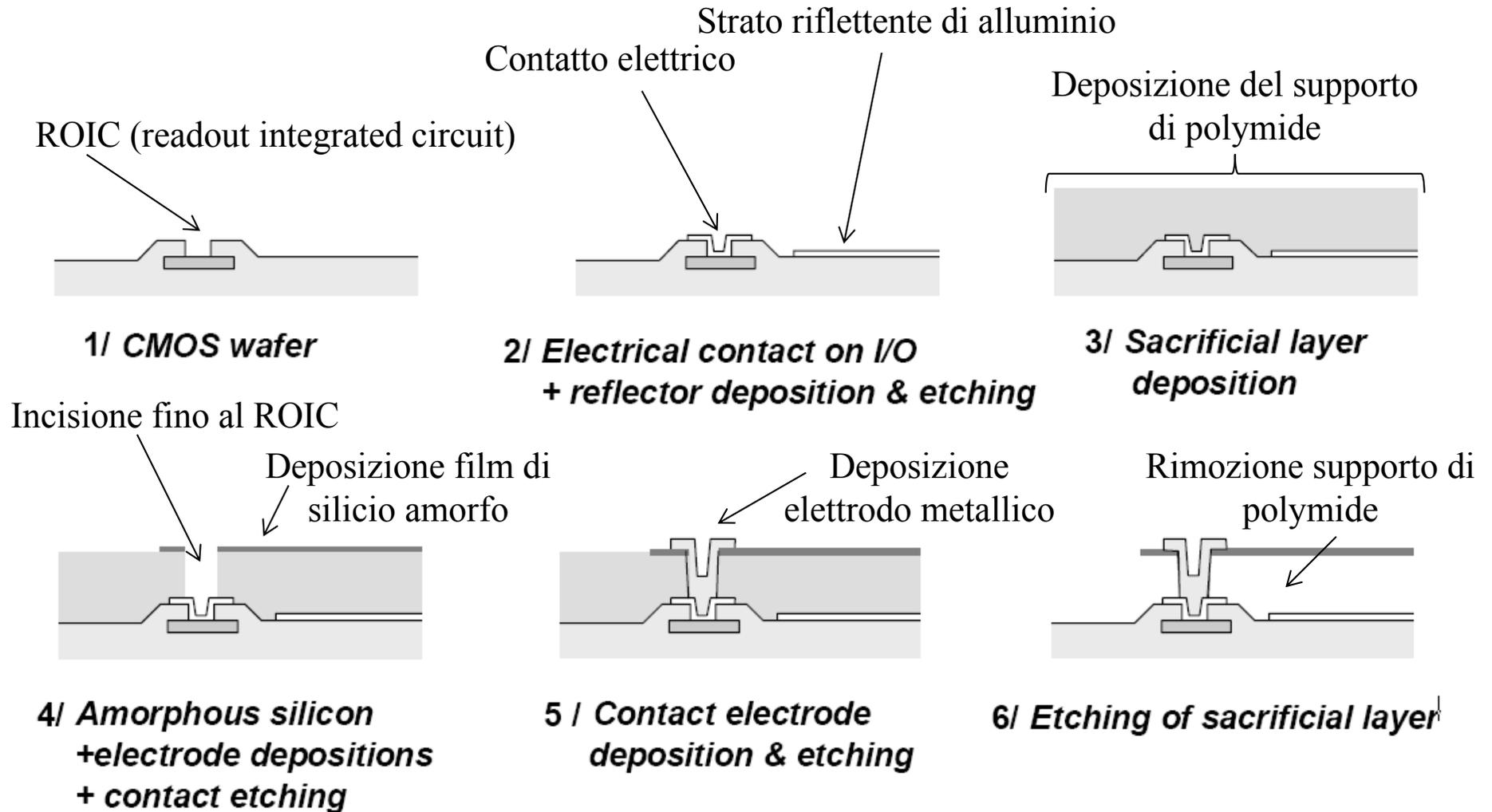


Sensors are either 160 x 120 pixels or 320 x 240.

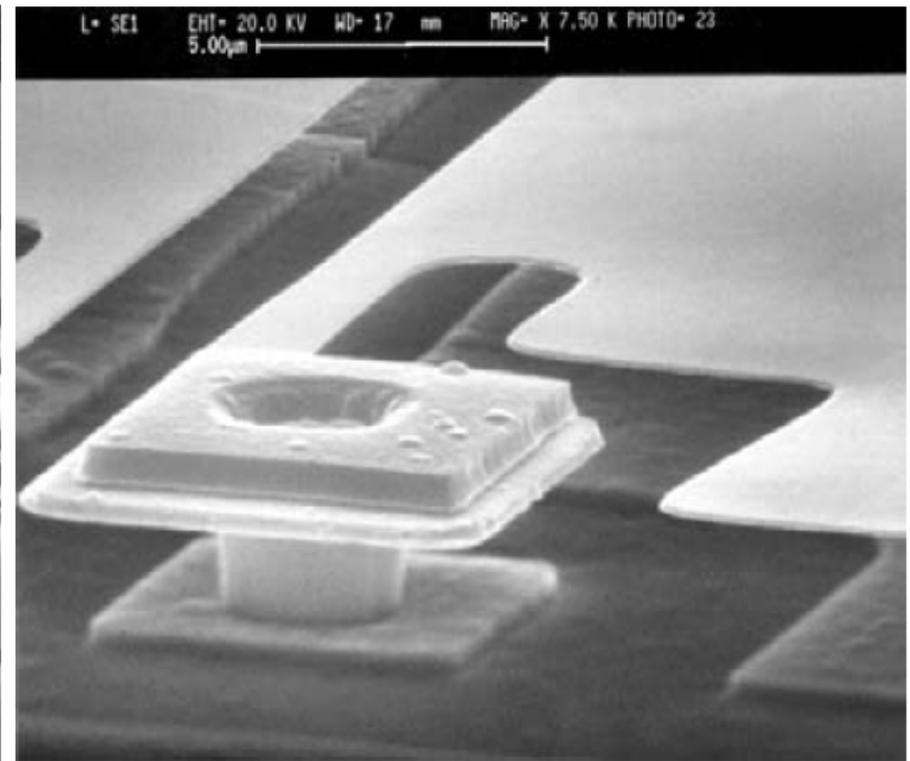
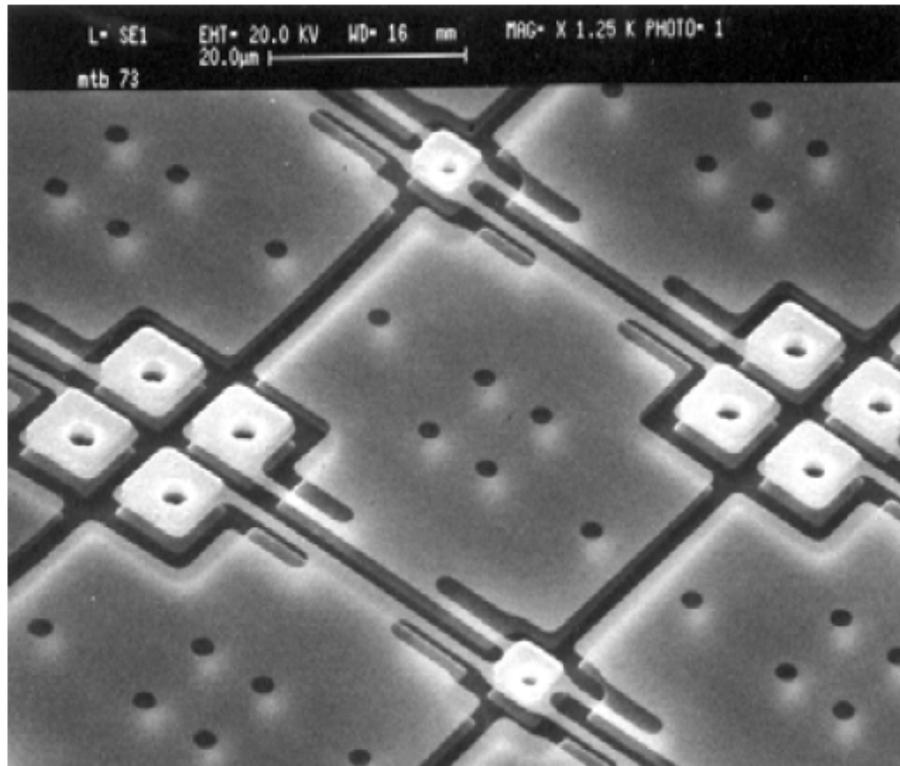
- BOLOMETRO IN SILICIO AMORFO -



# Processo di fabbricazione direttamente su silicio



# Processo di fabbricazione direttamente su silicio

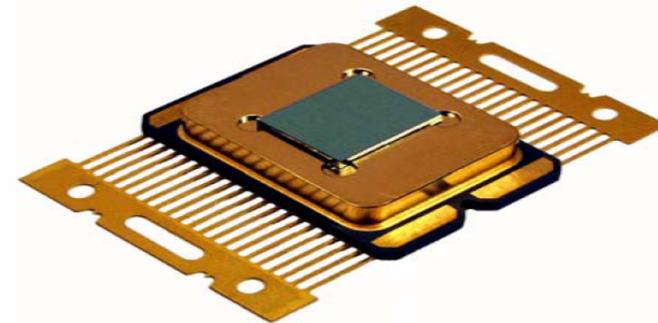


# Esempi di chip microbolometrici

- Prima generazione: *pacchetti metallici* (dimensioni inferiori)

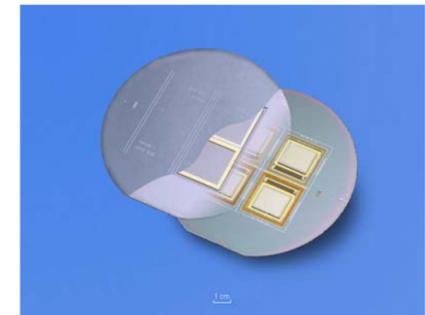
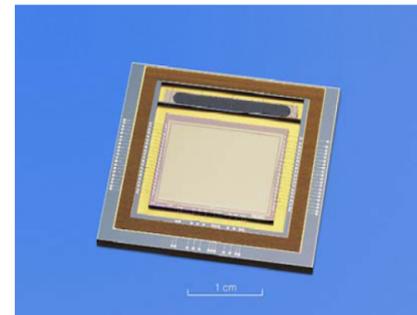


- Seconda generazione: *pacchetti in ceramica* (attualmente molto usati)



- Ultima generazione: *pacchetti a wafer*

- ✓ Due wafer di Si usati per realizzare finestra ad infrarossi
- ✓ Microbolometri chiusi sotto vuoto nelle cavità di silicio
- ✓ Riduzione costi



## - SCHEDE TECNICHE DI MICROBOLOMETRI -

25  $\mu\text{m}$  Uncooled Infrared LW Detector

**640 x 480**

UL 04 17 1

Medical imaging

Night vision

Security

Thermography

...on the way to high definition

Printed in France (C)

ISO 9001 : N° 132 663  
ISO 14001 : N° 181 742

### FOCAL PLANE ARRAY

Material: Resistive amorphous silicon

Array format: 640 x 480  
+ windowing capability  
pixel pitch 25  $\mu\text{m}$

Thermal time constant: 7 ms

CMOS multiplexer integrated circuit with ripple imaging operation

One or two video output

Area fill factor 70%

Spectral response: 8 – 14  $\mu\text{m}$

### PERFORMANCE

Typical TEC environmental temperature range (FPA @ 30°C):  
- 30°C to + 60°C

Extended detector operating temperature range: - 40°C to + 85°C

Typical Array operability > 99.9%

Typical signal response: 7 mV/K

Standard deviation  $\leq$  1.5%

### FEATURES

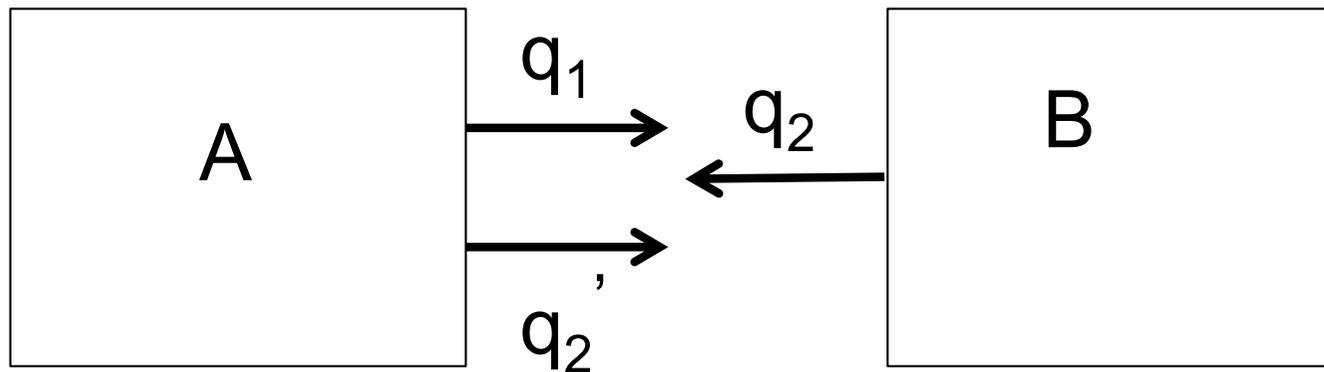
User friendly electrical interface

Integrated TEC for FPA temperature stabilization

Weight  $\leq$  30 g

Overall dimension (mm)  
32 x 23.5 x 7.4 pin out excluded

# Camere Termografica

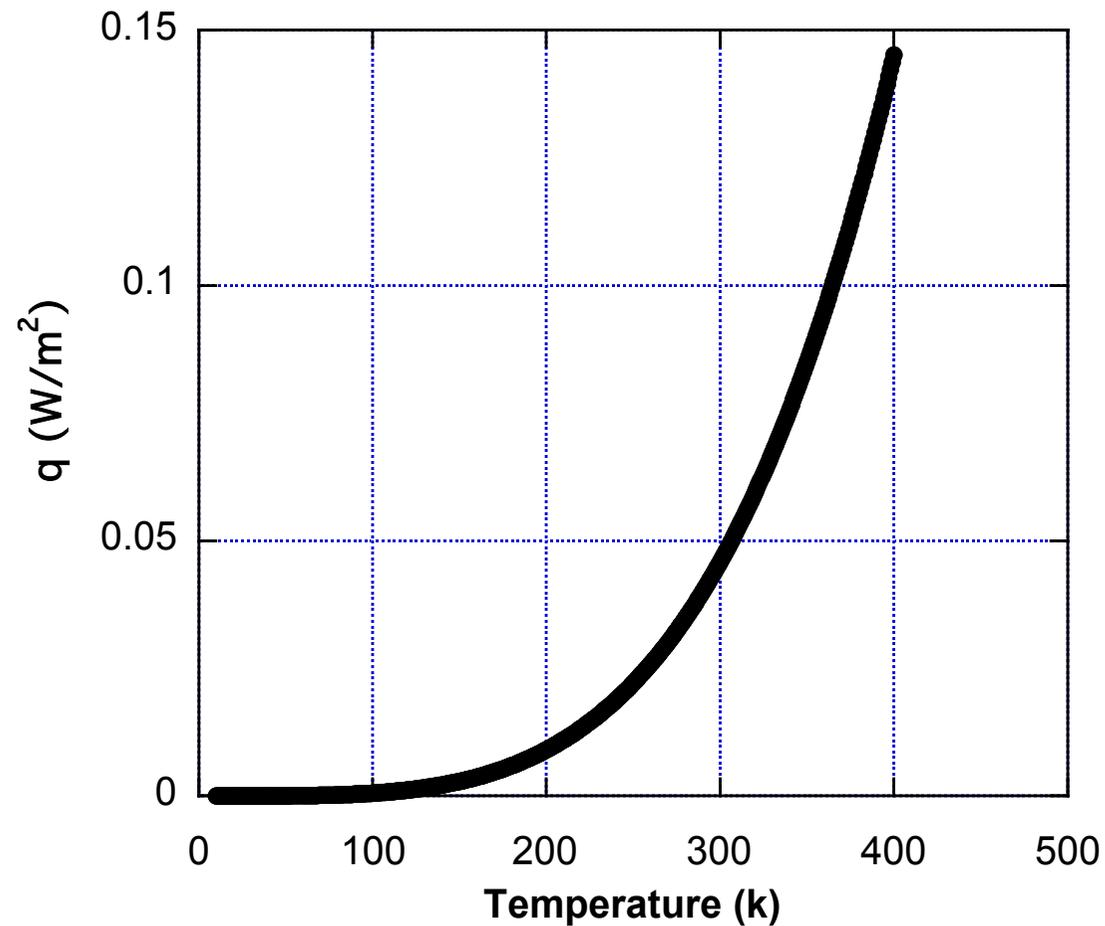


$$q = q_1 + q_2' = q_1 + (1-a)q_2$$

a coefficiente di assorbimento di A

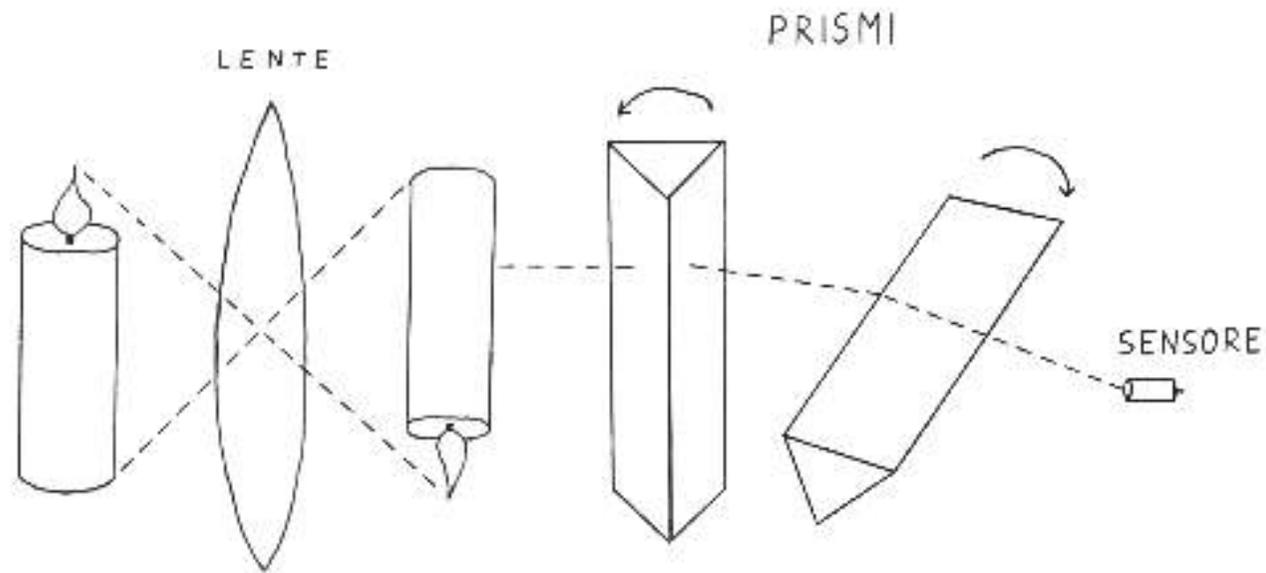
# Camere Termografica

$$q = \sigma T^4$$

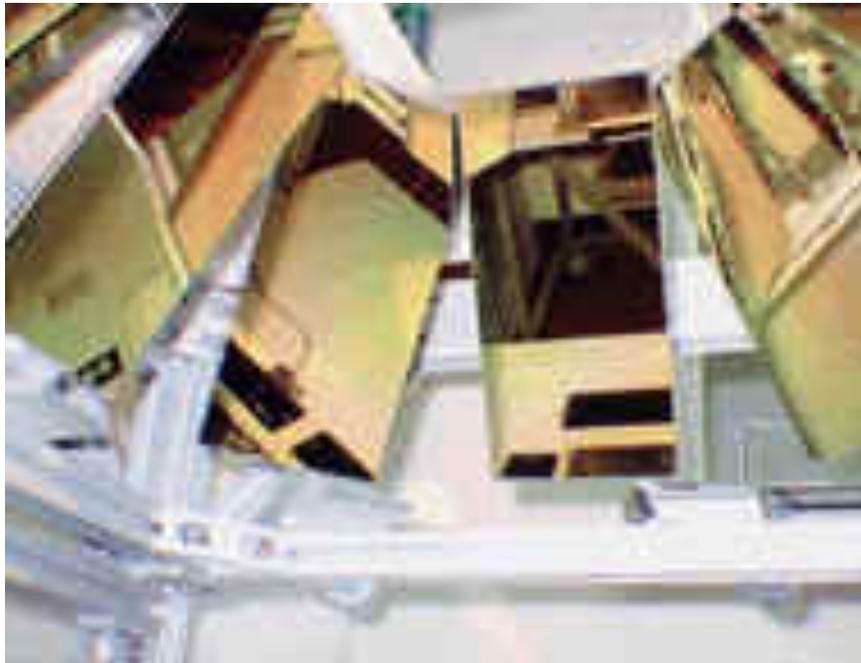


Andamento non lineare e quindi processo di calibrazione

# Camere Termografica a scansione

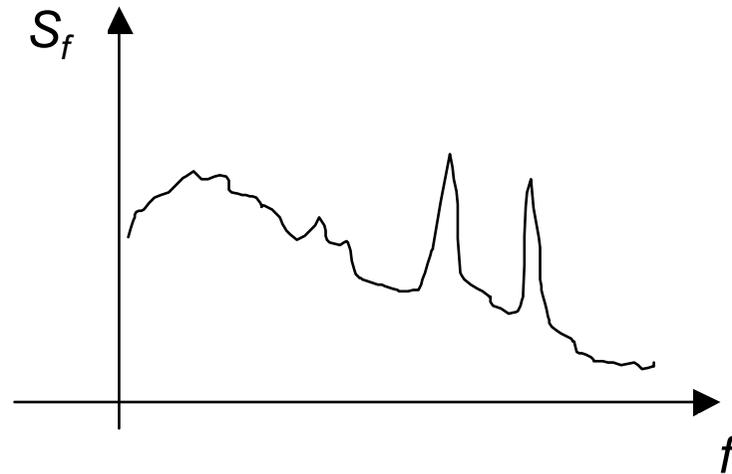


# Camera a sensore singolo



*Inside view of computerized thermal imaging system with mirrors that deflect infrared waves from a patient's breast to a camera below.*

# Svantaggi

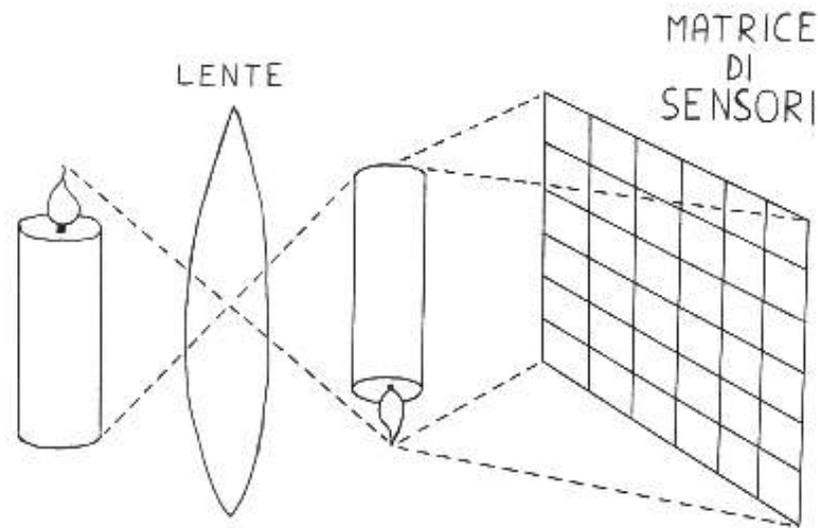


**Soluzione**

**Focal plane array**

# Che cos'è un FPA?

- Image sensing device consisting of an array (typically rectangular) of light-sensing pixels at the focal plane of a lens.



$$NEDT \propto \sqrt{\frac{B}{A}}$$

$$B_{SC} = NB_{FPA}$$

$$A_{SC} = A_{FPA} / N$$

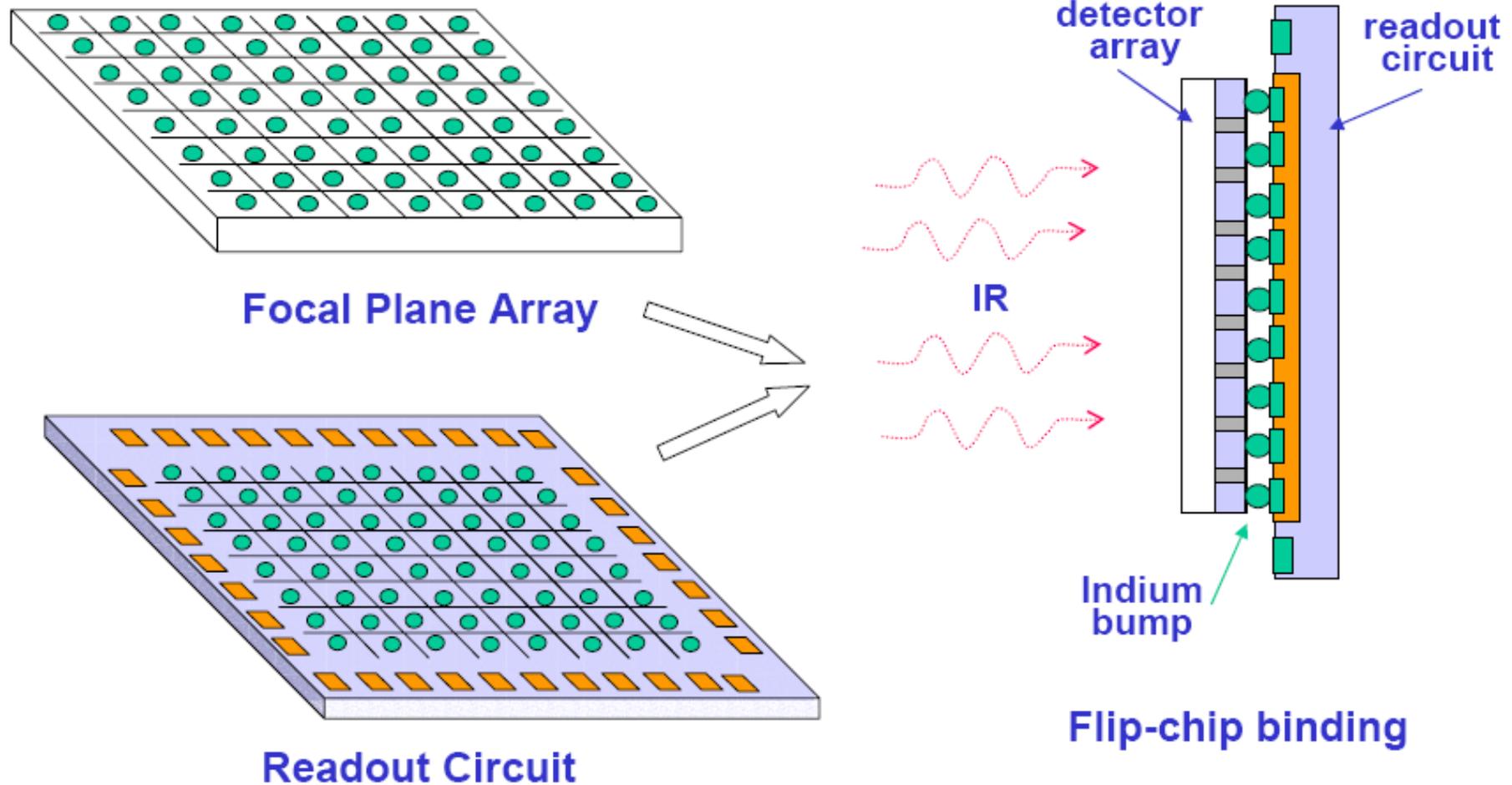
$$NEDT_{SC} \propto \sqrt{\frac{B_{FPA}N}{A_{FPA} / N}} = N \sqrt{\frac{B_{FPA}}{A_{FPA}}}$$

# Focal Plane Array Devices

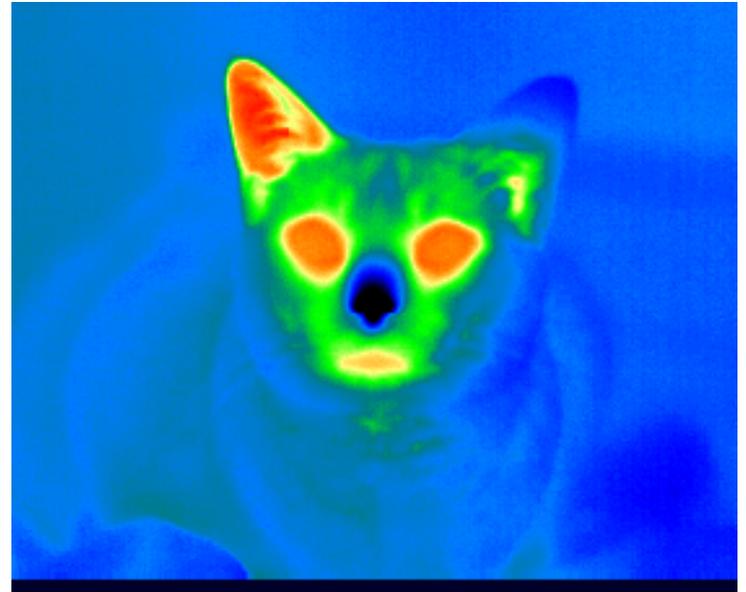
<b>Detector Material</b>	<b>Wavelength[<math>\mu\text{m}</math>]</b>	<b>FPA Size</b>	<b>Sensing</b>	<b>Operability</b>	<b>Cooling</b>
InGaAs	0.9-1.6	320 x 240	Detection	> 99%	Uncooled
InSb	3.0 – 5.0	1024 x 1024	Detection	> 99%	Cooled 70K
QWIP (GaAs/AlGaAs)	8.0 – 9.0	512 x 512	Detection	> 99%	Cooled <70K
HgCdTe	1.0 – 20.0	1024x1024	Detection	85 - 95%	Cooled 60-160K
Microbolometer	7.5-13.5	320 x 240	Absorption	Typical of Si process	Uncooled

Sensibilità termica fino a 30mk, velocità fino a 100frames/s, risoluzione fino a 25micron

# Processo di fabbricazione flip-chip



# Detector - Camera



# Detector



## *MHS 5000 SPECIFICATIONS*

*Coolant: Thermoelectrically Cooled*

*Detector: MCT Detector*

*Automatic Functions: Auto Focus, Auto Ambient*

*Weight: 7.4 lbs*

*Size: 221mm (w) x 147mm (H) x 270 mm (D)*

*Operating Temperatures: 0-70 Degrees Celsius*

*Image Acquisition Temperature Range: 29 to 37 Degrees Celsius*

*Thermal Sensitivity: <0.1 Degree Celsius*

*Field Of View: 21.5 Horizontal And 21.5 Vertical*

*Resolvable Elements: 255 (H) x 233 (V)*

*Pixel Count: 57,000*

*Image Capture Rate: 2 Scans Per Second*

*Emissivity Correction: 96%*

*Image Storage: MHS/MHI/Bitmap Format*

*Image Display:*

*5 x 16 True Color Palettes,*

*1 x 16 Grayscale, 2 x 255 Inverted Grayscale,*

*3 x 16 Step Isotherm*

*Power Options: AC Adaptor/Rechargeable Battery Pack*

# Detector

## *MHS 7000 SPECIFICATIONS*

*Detector: Microbolometer*

*Automatic Functions: Auto Focus, Auto Ambient*

*Weight: 3.0 lbs*

*Size: 3.7 (w) x 4.2 (H) x 6.5 (D)*

*Operating Temperatures: 0-70 Degrees Celsius*

*Image Acquisition Temperature Range: 28 to 36 ° C*

*Thermal Sensitivity: 0.08 Degree Celsius*

*Field Of View: 29.0 Horizontal And 22.0 Vertical*

*Resolvable Elements: 320 (H) x 240 (V)*

*Pixel Count: 76,800*

*Image Capture Rate: 30 Frames/Second*

*60 Frames/Second (Selectable)*

*Emissivity Correction: 98%*

*Image Storage: MHS/MHI/Bitmap/MHV*

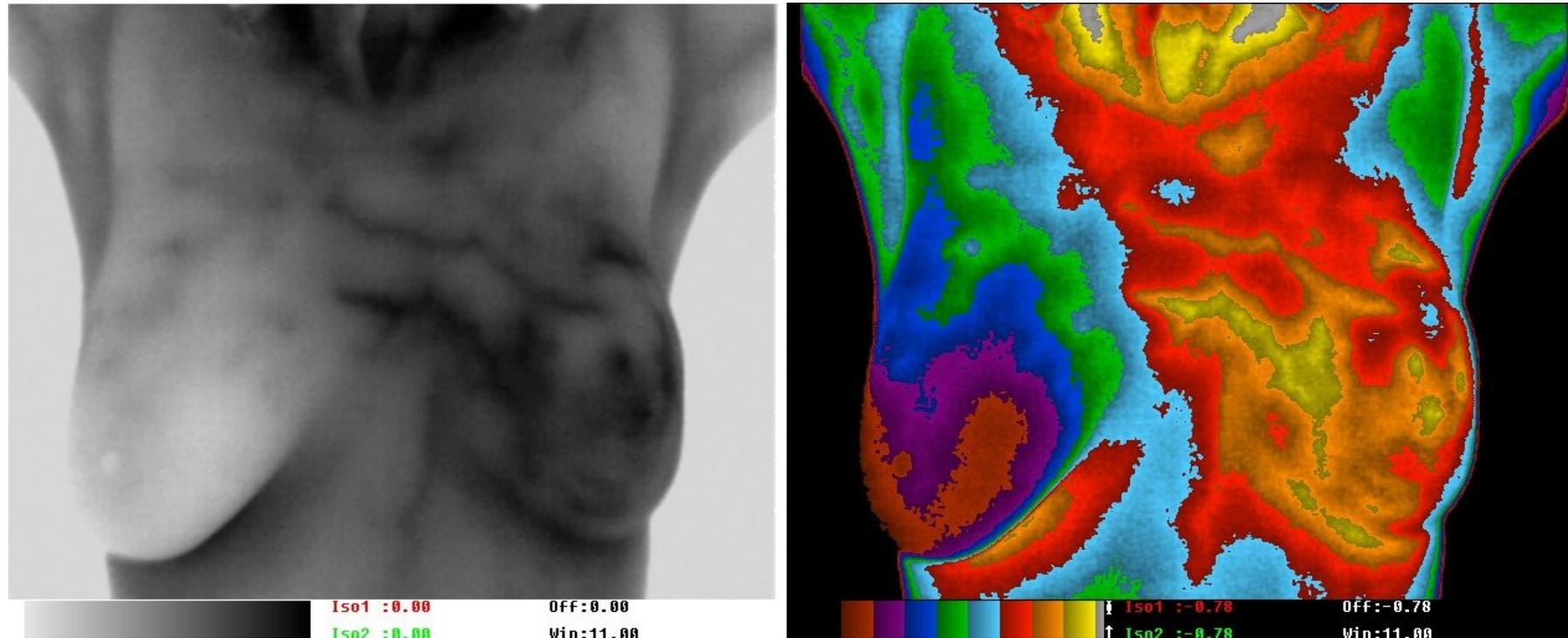
*Image Display:*

- 6 x 16 True Color Palettes,*
- 2 x 256 True Color Palettes*
- 1 x 256 Grayscale,*
- 2 x 256 Inverted Grayscale*
- 3 x 16 Step Isotherm*

*Power Options: AC Adaptor*



# Immagini



While this client's mammogram was normal, her thermogram indicated highest risk, TH5, in the left breast. While initial follow-up by her breast doctor revealed nothing abnormal, her doctor diagnosed breast cancer many months later.

# Immagini

This female's complaint included pain. Thermal imaging revealed a previously undiagnosed right leg arteriovenous malformation over 27mm deep. As a result, the client was spared a sympathectomy. Vascular surgery corrected the problem.

