Photon-Absorption Enhancement Factor

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two Advanced Detector Awards, Office of Science, DOE

ENCLOSURE:

FLAT-PANEL TV

3 existing

mass-production technologies

PHOTON→ELECTRON CONVERSION:

CLASSICAL PHOTOCATHODE

ELECTRON DETECTION:

SEMICONDUCTOR

Scintillator + Geiger-MODE AVALANCHE DIODE

'Light Amplifier'

ENCLOSURE:
FLAT-PANEL TV

MAJOR MODIFICATIONS (will show tomorrow)

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ALREADY VERY GOOD

ELECTRON DETECTION:
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Scintillator + Geiger-MODE AVALANCHE DIODE
'Light Amplifier'

ENCLOSURE:
FLAT-PANEL TV

MAJOR MODIFICATIONS (will show tomorrow)

LOOKIN FORWARD FOR IMPROVEMENTS

3 existing mass-production technologies

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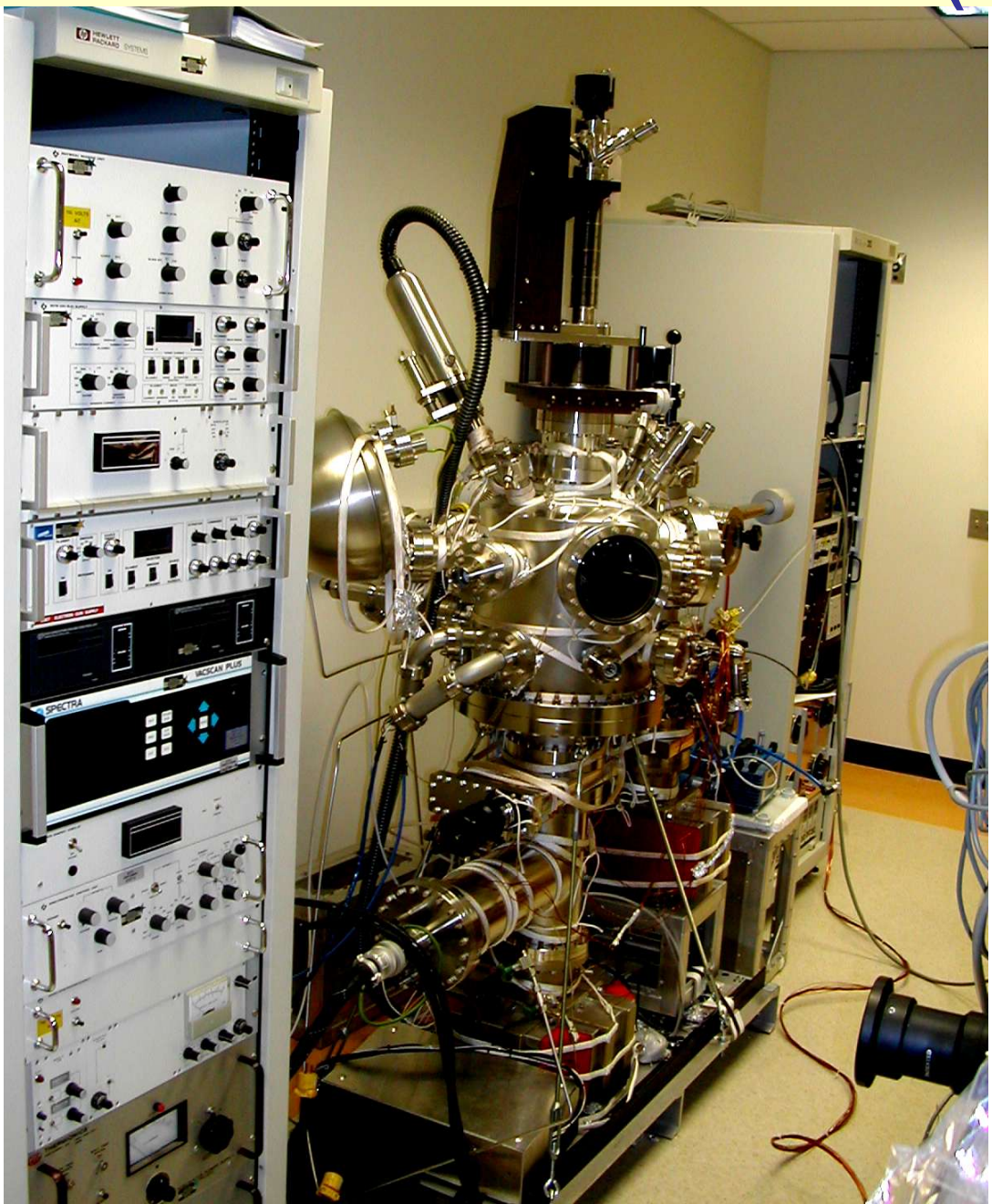
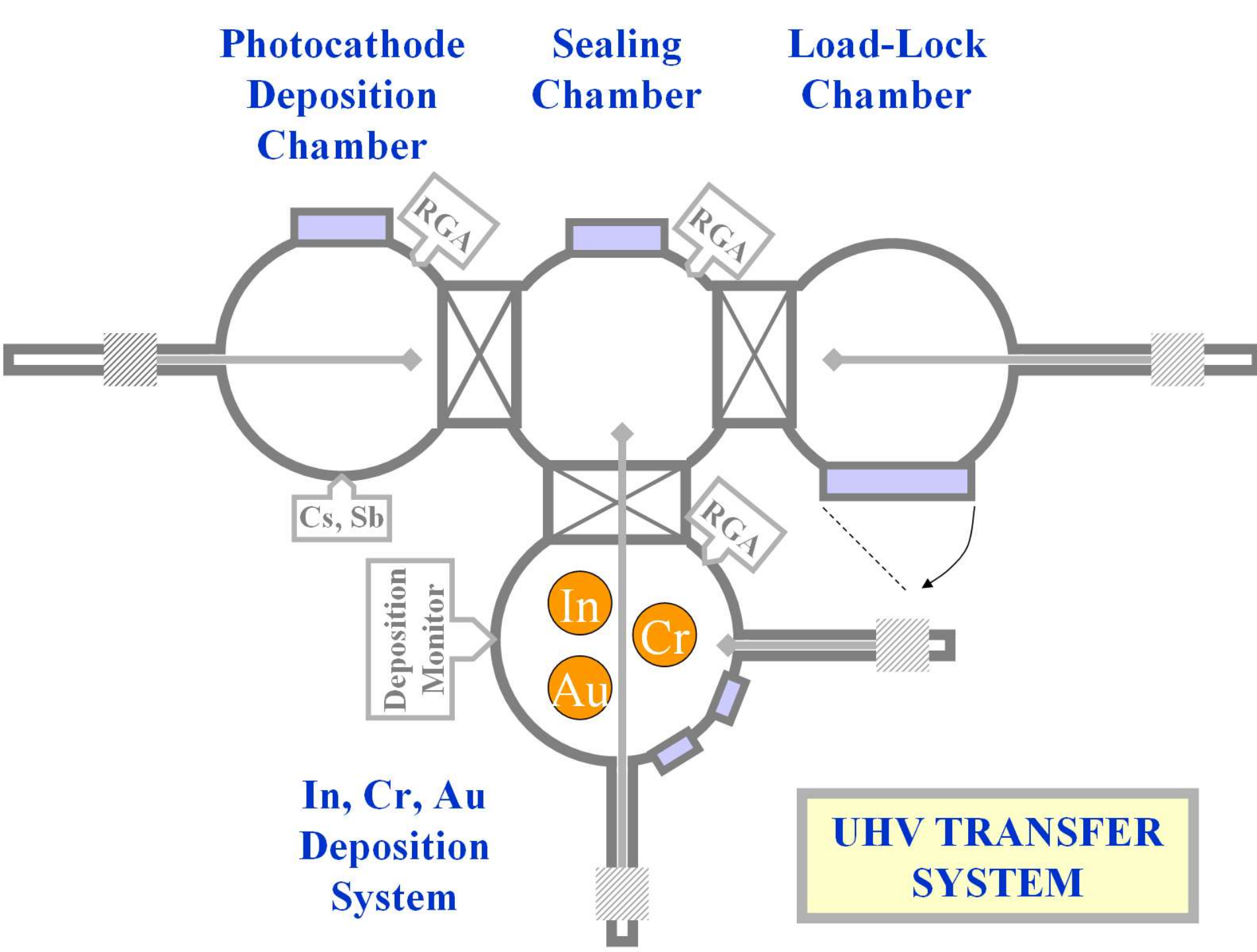
CLASSICAL PHOTOCATHODE ALREADY VERY GOOD

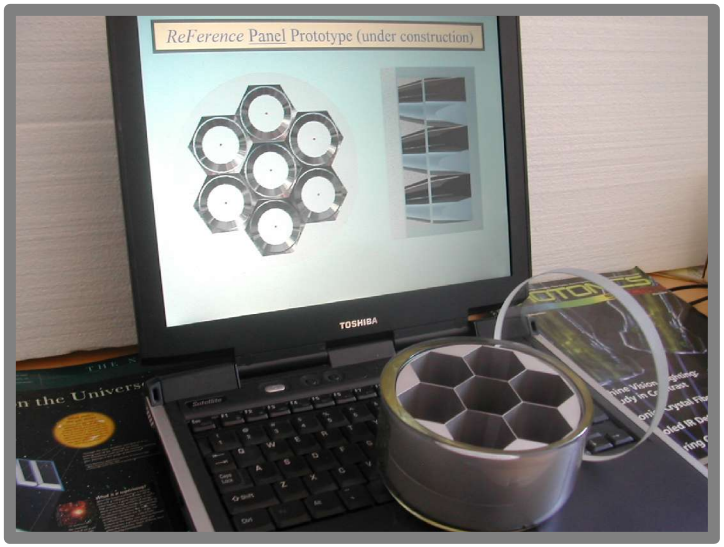
ELECTRON DETECTION:
SEMICONDUCTOR
Scintillator + Geiger-MODE AVALANCHE DIODE
'Light Amplifier'

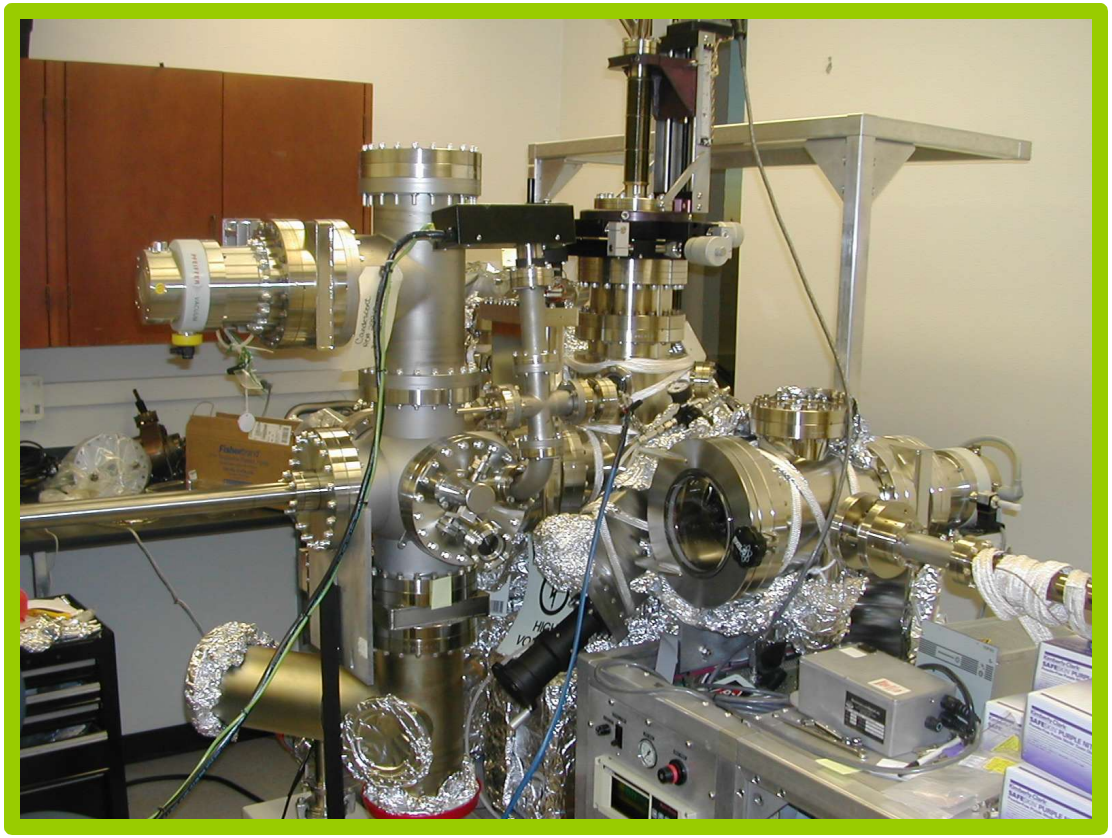
DIAGNOSTIC TOOL – NOT USED (YET)




Photocathode Deposition Chamber
Sealing Chamber
Load-Lock Chamber
RGA
RGA
RGA
Cs, Sb
Deposition Monitor
In
Cr
Au
In, Cr, Au Deposition System
UHV TRANSFER SYSTEM

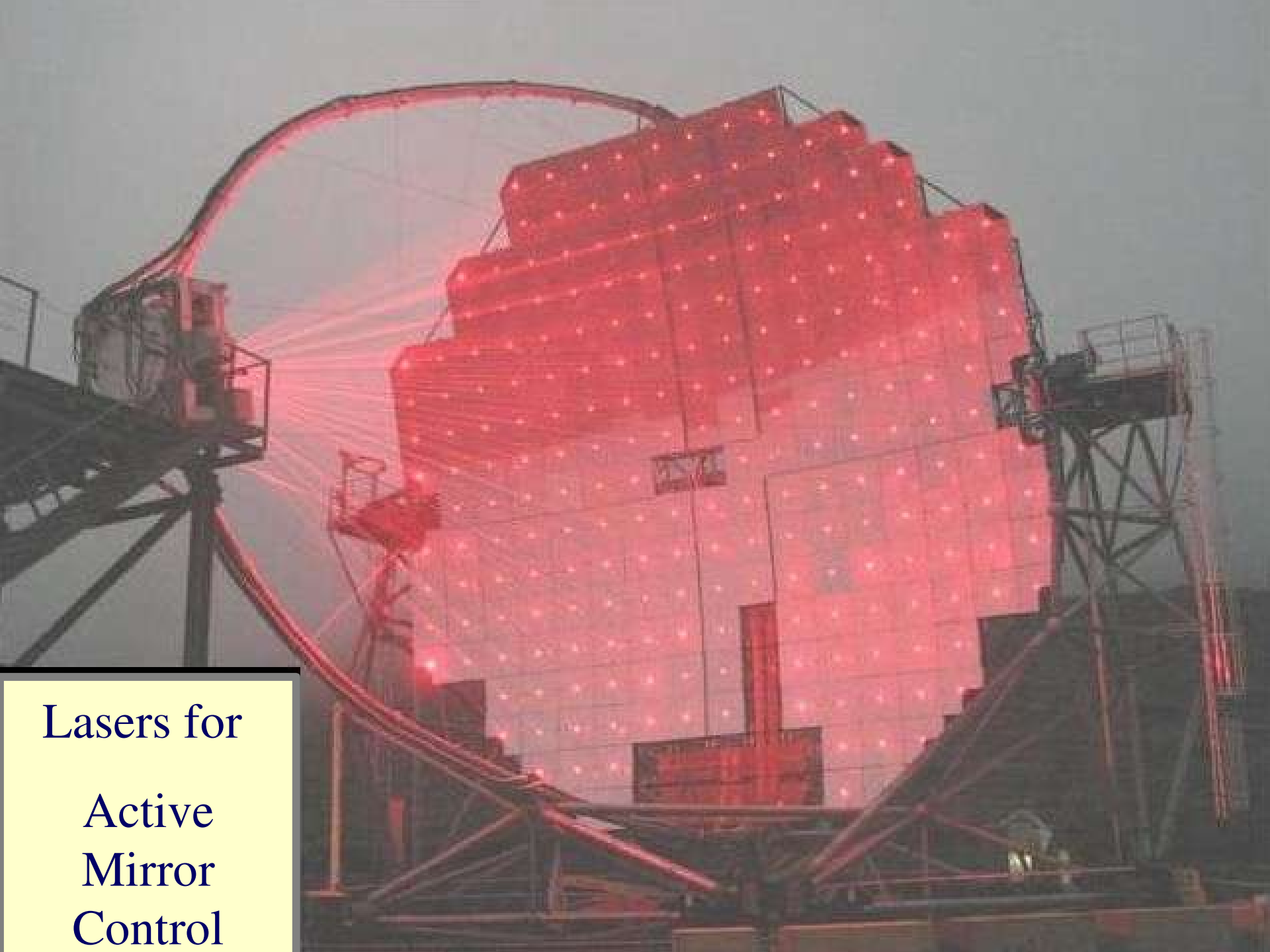
7-pixel 5-inch ReFerence Flat-Panel Prototype





UHV Transfer System :

- **Photocathode deposition**
- **Indium/Au/Cr deposition**
- **Vacuum sealing**



Lasers for

Active
Mirror
Control

SUPER-EFFICIENT CAMERA

A METHOD TO INCREAS E THE QE:COAT WINDOW WITH A LAQUER LOADED WITH WLS AND USING A FAST EVAPORATING SOLVENT -> FORMS FROSTED WINDOW SURFACE LAYER

◆ Simple way of producing a scattering layer

- Increase the quantity of Paraloid B-72 by a factor 2-3
- Dip the PMT 2-3 times (waiting 5 min.)

→ Milky layer easy to be removed

The camera

- Matrix of 577 PMTs
- Two sections:
  - Inner part: 0.1° PMTs
  - Outer part: 0.2° PMTs

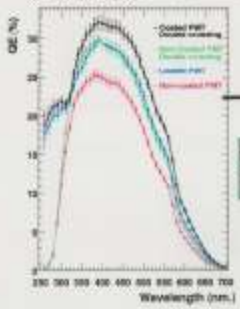
Plate of Winston cones ⇒
Active camera area ~100%

4- INCREASE IN THE QE BY ALLOWING LIGHT TO CROSS THE PhC TWICE IN A HEMISPHERICAL PMT

◆ Light Collectors (LC) are needed in IACT telescopes

◆ LC+PMT with hemispherical PhC allows photon trajectories to pass the photocathode twice

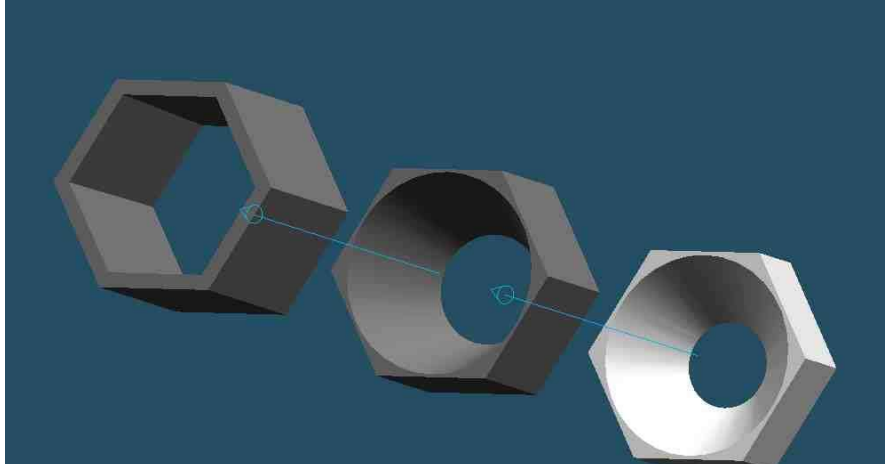
◆ Estimation of this effect has been measured

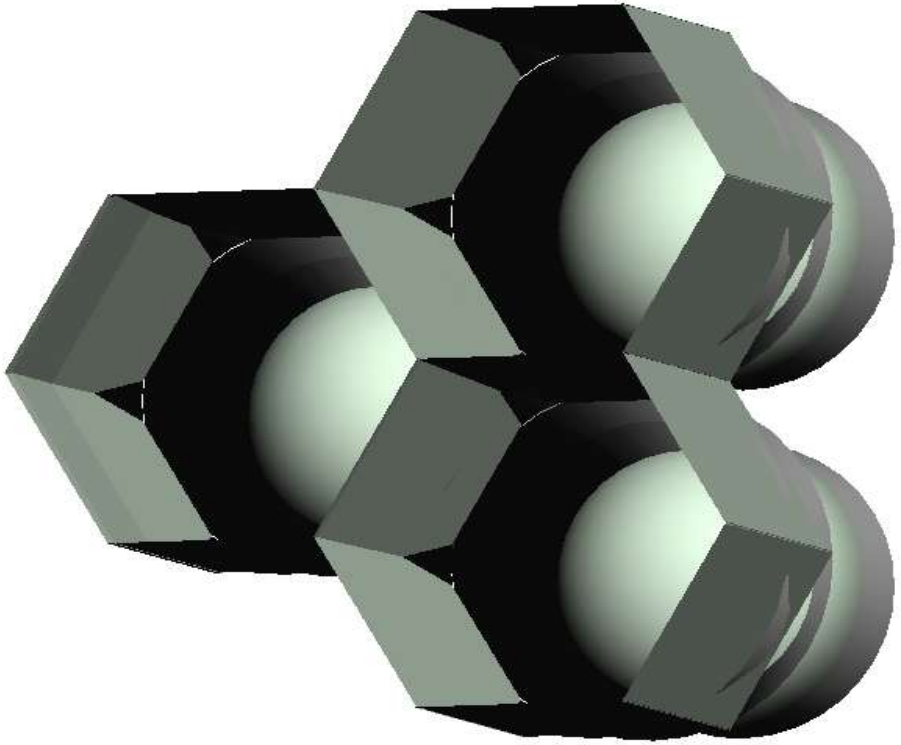


Double cross coated PMT...

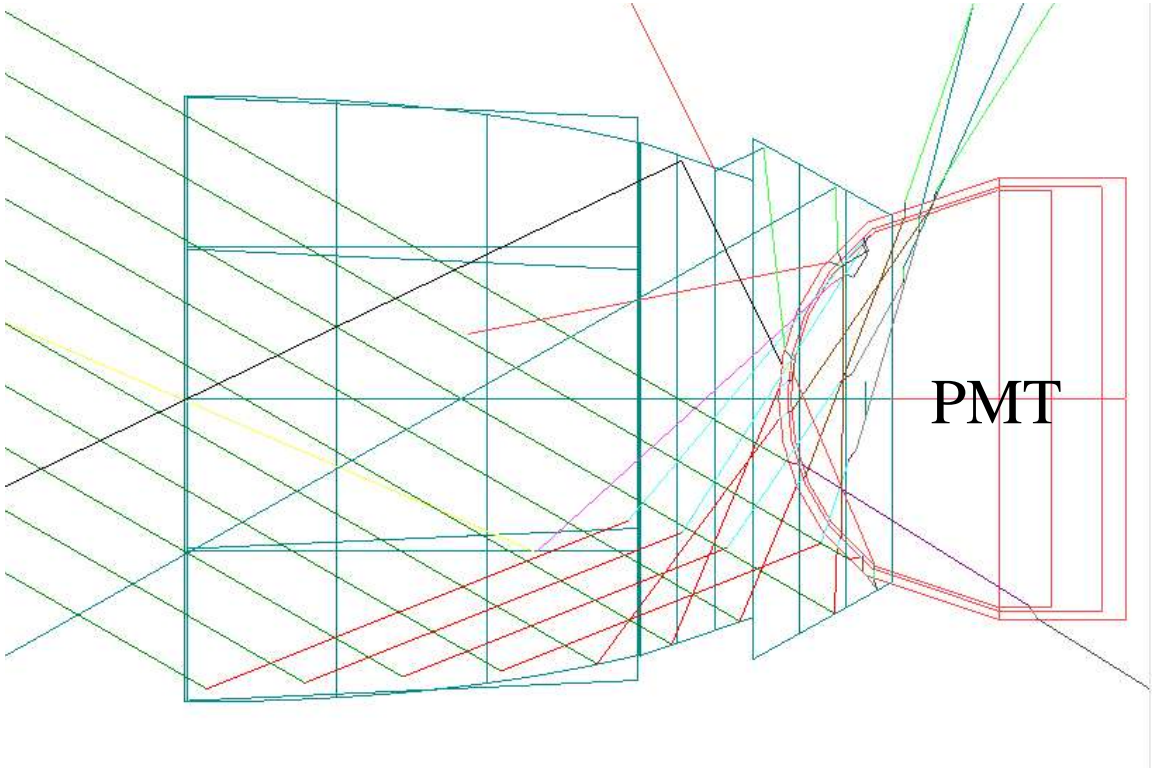
at 400 nm

$$\frac{QE^{Double\ cross\ Coated}}{QE} \approx 1.30$$





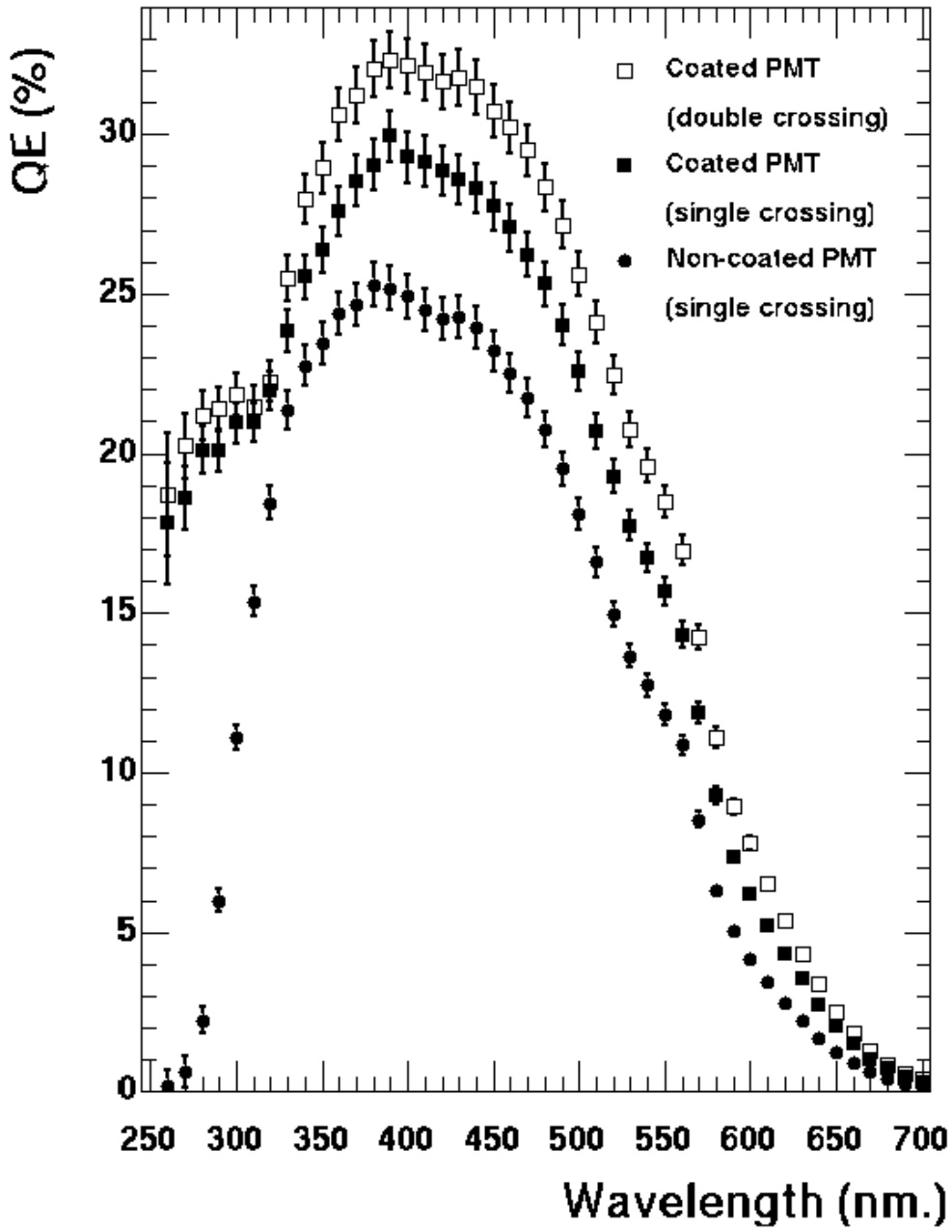
Maximizing Double-Hits in a PMT



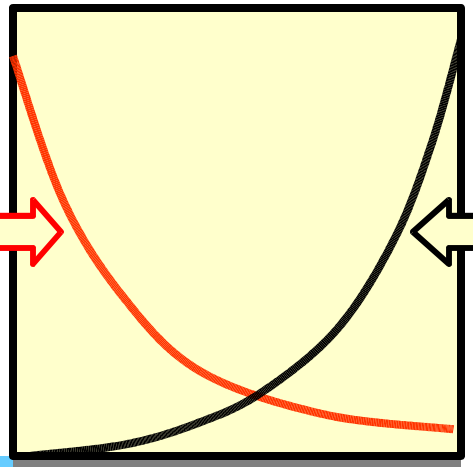
Not yet optimized for the milky PMT coating

➔

Significant additional improvements to come


QE (%)
0
5
10
15
20
25
30
250
300
350
400
450
500
550
600
650
700
Wavelength (nm.)
Coated PMT
(double crossing)
Coated PMT
(single crossing)
Non-coated PMT
(single crossing)

Photon Absorption
(Electron 'Creation')
e.g. in S-20
40% ph. (400 nm) are absorbed
in a **30 nm** thick
photocathode



Probability for an electron to reach the vacuum surface
Random Walk - mainly electron-imperfection scattering
(less e-e and e-phonon)

e.g. scattering length in S-20 ~25 nm

Photon

Photo-Electron

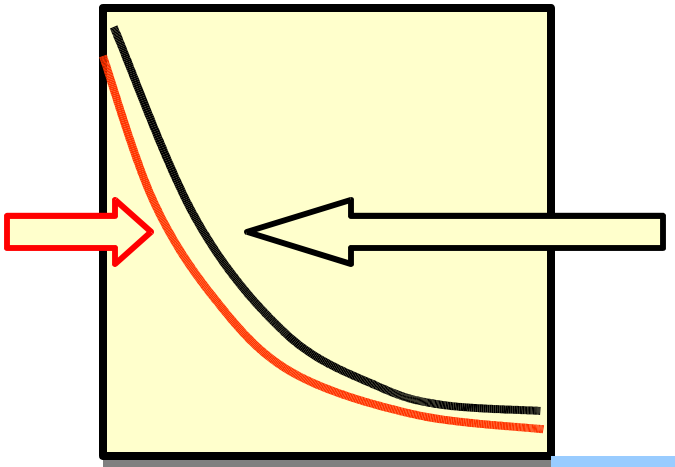
Therefore:
QE ~ 10-20%

Glass Window

Photocathode

Vacuum

Photon Absorption (Electron Creation)



Probability for an Electron to Reach the Vacuum Surface (Random Walk)

Photon

Photo-Electron

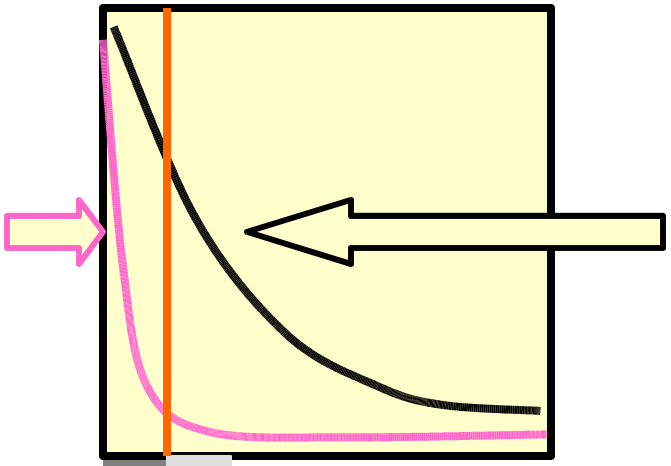
*(e.g. Substrate, **Reflector**,…)*

& LOWER PRODUCTION COST !

Vacuum

Photocathode

UV
Photon Absorption
(Electron Creation)
Mostly @ Surface



Probability for an Electron to Reach the Vacuum Surface (Random Walk)

UV Photon

Photo-Electron

Vacuum

Photocathode

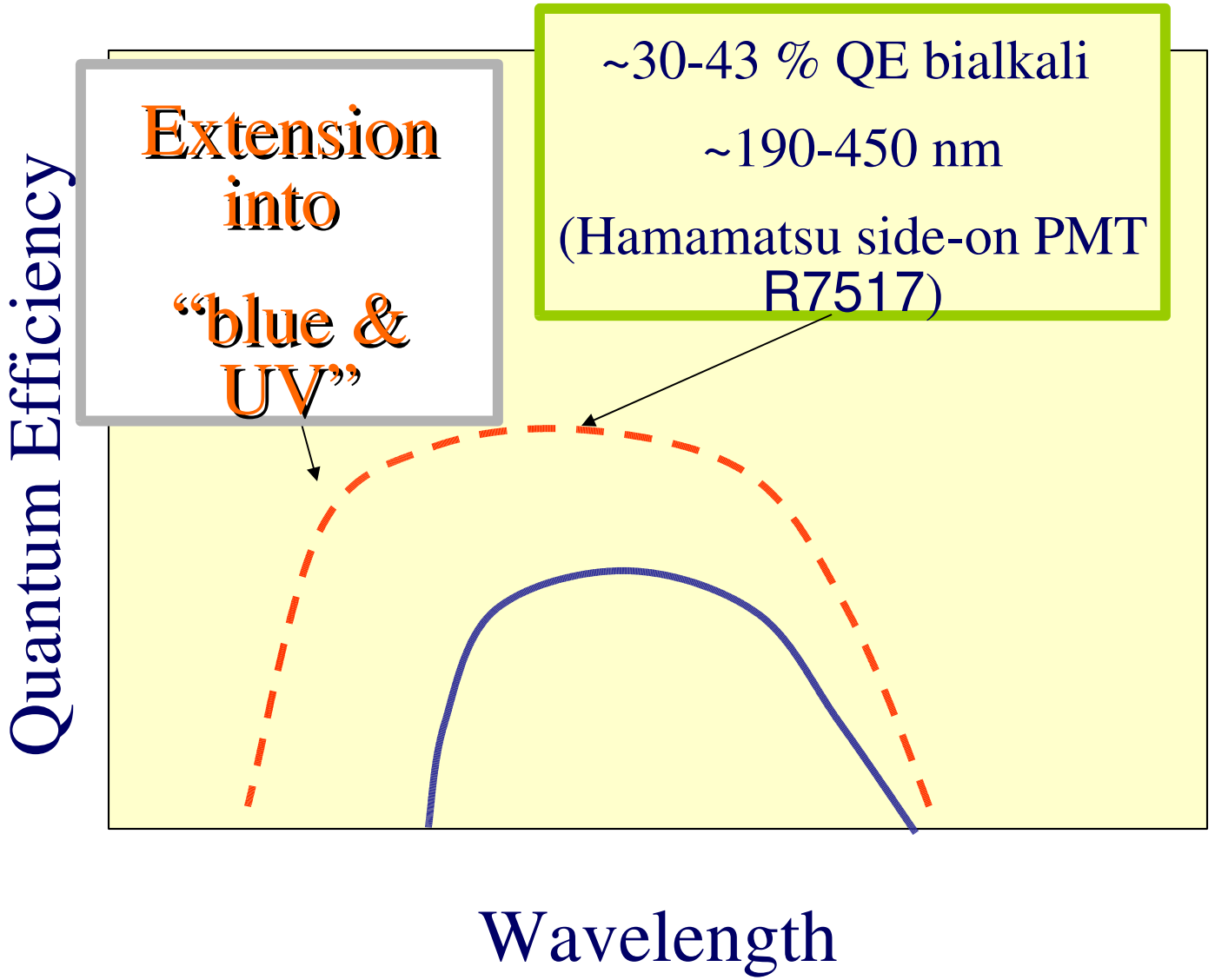
Thin Photocathode on a Reflector,

Interference, Multi-layer Systems

Westinghouse, RCA, ITT

~1963-1975

Reflection Mode vs. Transmission Mode



HAMAMATSU

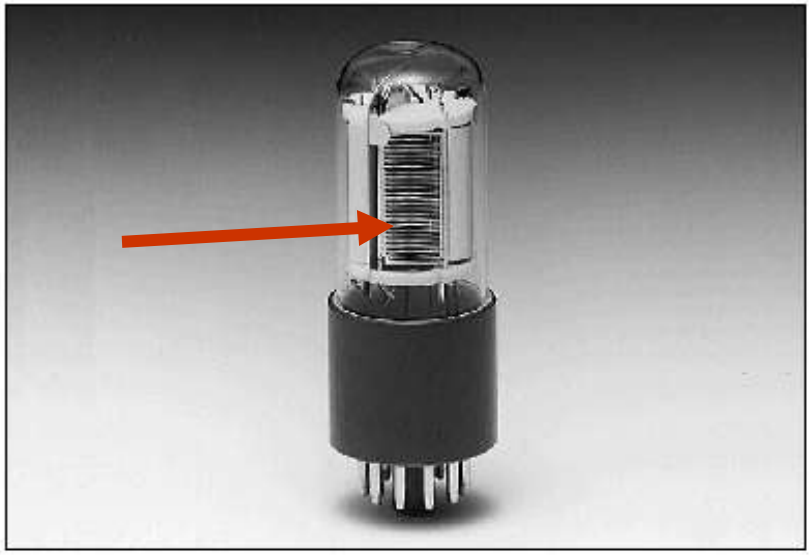
PRELIMINARY DATA
NOV. 1998

PHOTOMULTIPLIER TUBE
R7517

High Q.E., Bialkali Photocathode
28mm (1-1/8 Inch) Diameter, 9-Stage, Side-On Type

FEATURES

- Spectral Response..... 185 to 760 nm
- High Cathode Sensitivity
  - Luminous ..... 160 μA/lm Typ.
  - Radiant at 420nm ..... 105 mA/W Typ.
  - Quantum Efficiency at 220nm ..... 40% Typ.
- High Anode Sensitivity (at 1000V)
  - Luminous ..... 1600A/lm Typ.
  - Radiant at 420nm ..... 10.5×10^5 A/W Typ.



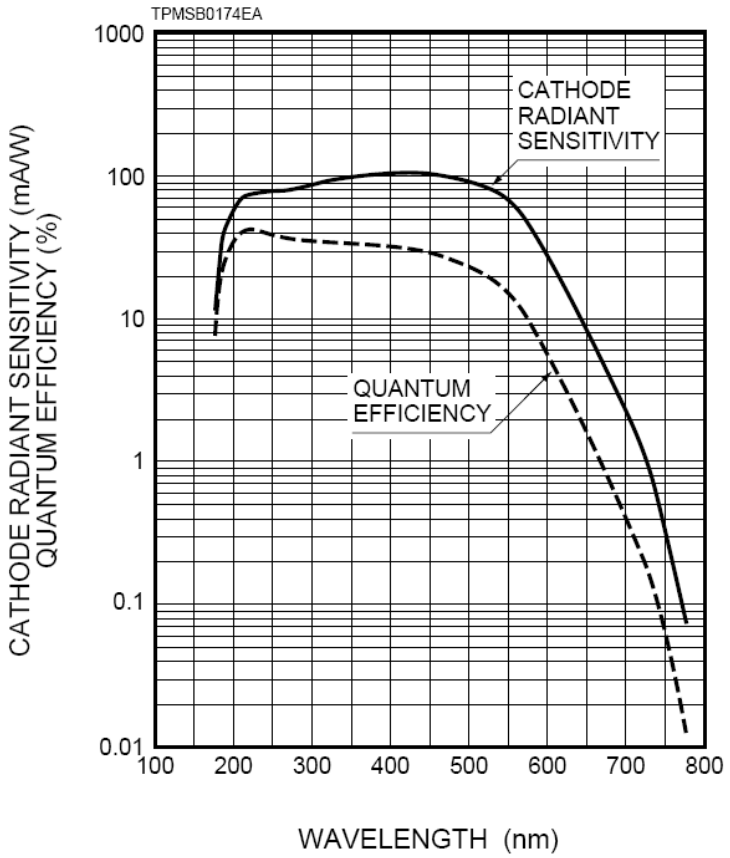
APPLICATIONS

- Fluorescence Spectrophotometers
- Fluorescence Immuno Assay
- SO_2 Monitor (UV Fluorescence)

GENERAL

Parameter	Description	Unit
Spectral Response	185 to 760	nm
Wavelength of Maximum Response	420	nm
Photocathode		
Material	Bialkali	—
Minimum Effective Area	8 × 24	mm
Window Material	UV glass	—
Dynode		
Secondary Emitting Surface	Bialkali	—
Structure	Circular-cage	—
Number of Stages	9	—
Direct Interelectrode Capacitances		
Anode to Last Dynode	4	pF
Anode to All Other Electrodes	6	pF
Base	11-pin base JEDEC No. B11-88	—
Weight	45	g
Suitable Socket	E678–11A (option)	—
Suitable Socket Assembly	E717–21(option)	—

Figure 1: Typical Spectral Response



TRANSMISSION PC

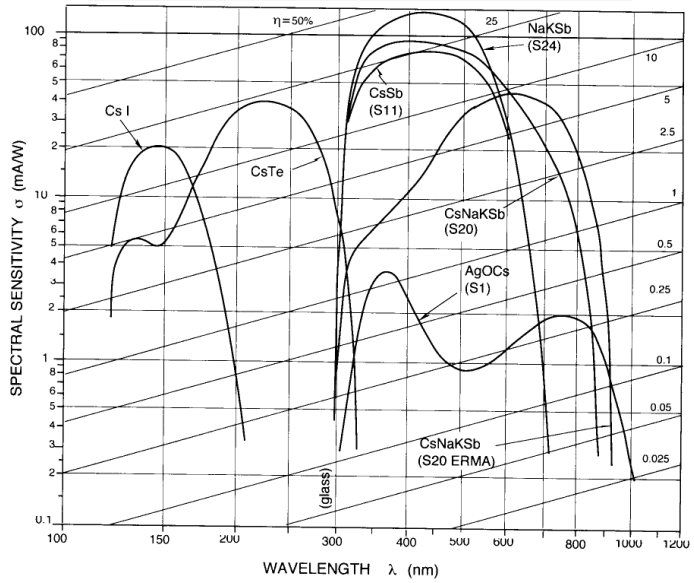


Figure 2-7 Spectral sensitivity vs. wavelength of transmission photocathodes (left, solar-blind responses with magnesium fluoride window; right, common photocathodes with glass window). In parentheses, the standard international EIA designation is shown

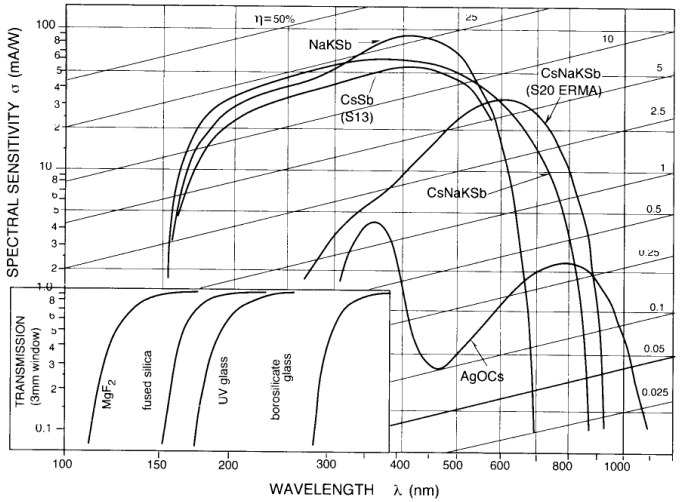


Figure 2-8 Spectral sensitivity vs. wavelength of transmission photocathodes with several UV-grade windows. Insert shows the transmission of a 3-mm thick window

REFLECTION PC

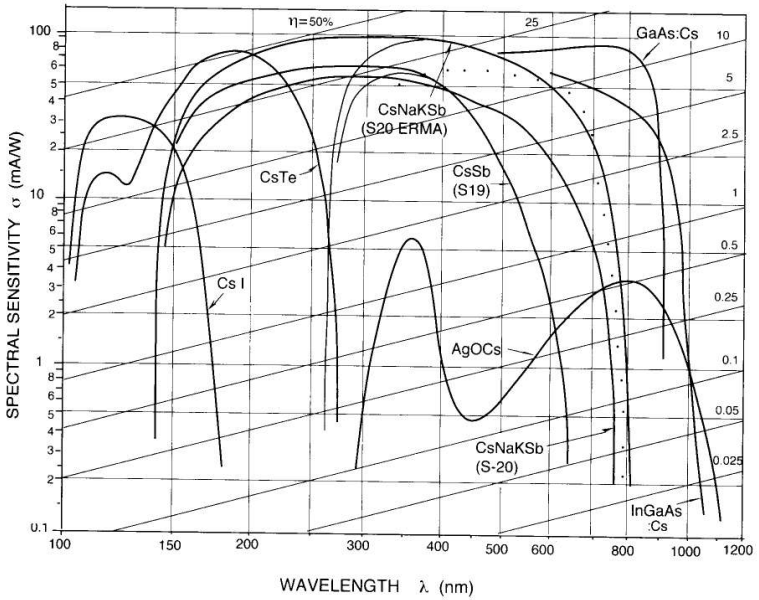


Figure 2-9 Spectral sensitivity vs. wavelength of typical reflection photocathodes, Note that σ is consistently lager than in corresponding transmission photocathodes. Points are simulation results for CsNaKSb, following Eq.(2.13)

Source: Silvano Donati, Phosotosensors

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Absorption of optical power in an S-20 photocathode

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Abstract

By considering a monochromatic plane wave obliquely incident upon a planar layer of S-20 photocathode material, deposited upon a non-absorbing glass substrate, the distribution of optical power absorbed within the layer can be resolved. This is important to the question of photocathode efficiency, as the absorbed light excites photoelectrons within the photocathode which then may pass from the photocathode into the vacuum of the photomultiplier tube and be collected and multiplied. The calculation uses the measured complex permittivity of an extended red S-20 photocathode in the wavelength range, 375–900 nm. The results show that thin film effects are important within the photocathode, as they give rise to interesting power absorption profiles. This information is invaluable in predicting optimum photocathode thickness for wavelength selective applications. Electromagnetic waves that are obliquely incident upon the photocathode are also considered in both transverse electric and transverse magnetic polarizations.

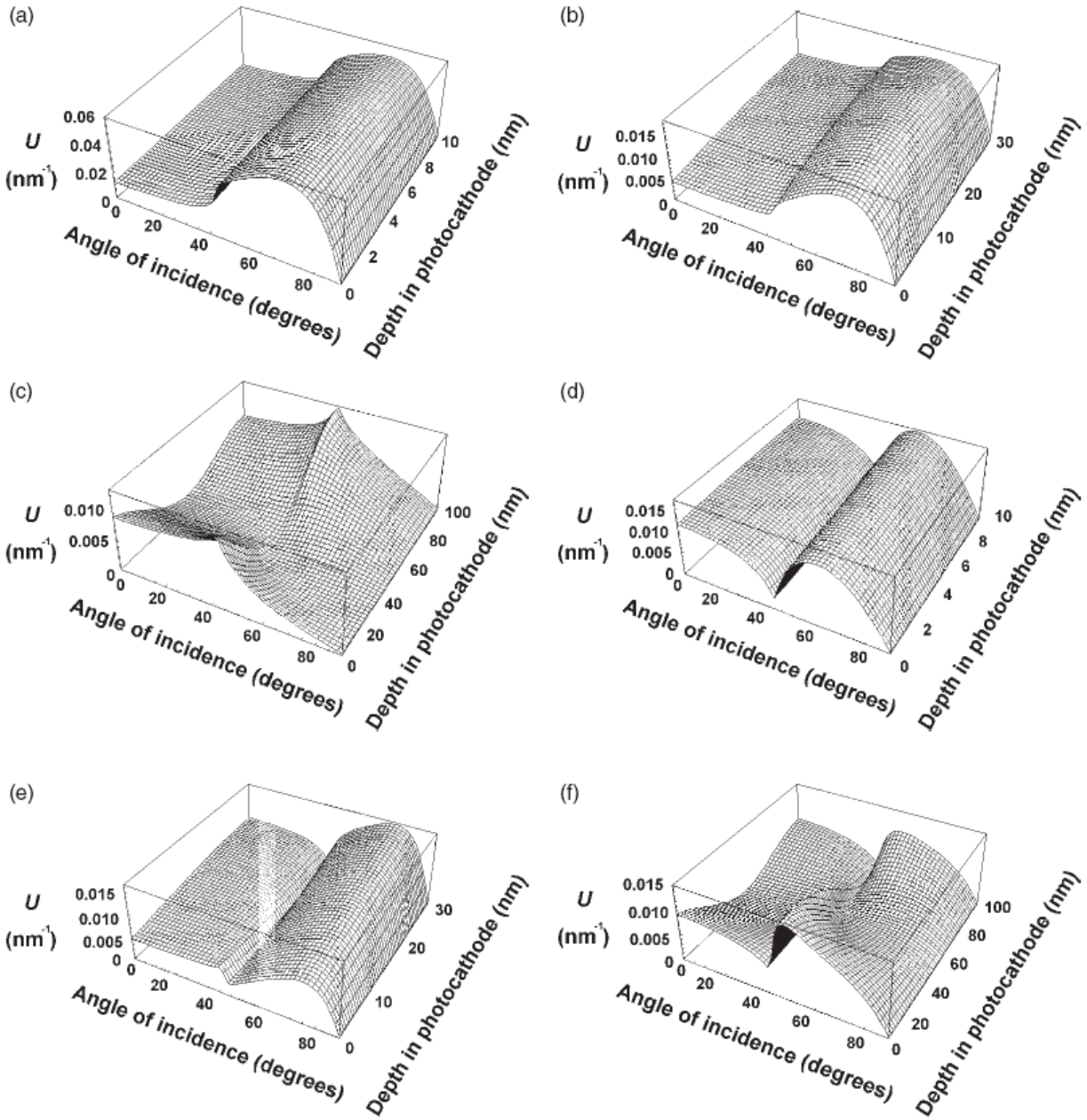
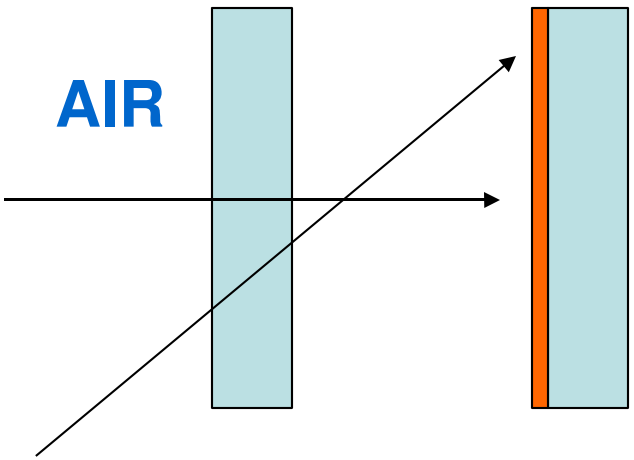


Figure 6. Power profile versus angle of incidence and depth in photocathode. The S-20 photocathode is (*a*) 10 nm, (*b*) 30 nm and (*c*) 100 nm thick and is illuminated by 600 nm TE polarized light. The S-20 photocathode is (*d*) 10 nm, (*e*) 30 nm and (*f*) 100 nm thick and is illuminated by 600 nm TM polarized light.

REFLECTION-MODE PHOTOCATHODES

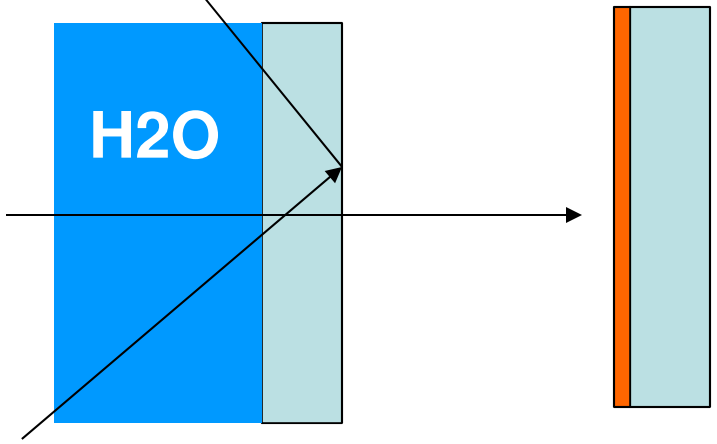
GOOD - air



Gamma-ray astronmy – Atmospheric Cherenkov Telescopes

WORSE – dense media

for larger incidence angles



- Water Cheenkov – neutrinos etc.
- Liquid scintillator
- Plastic, crystal scintillator

Mr. ◯ & Mrs. ▭

Mass production

High performance