Development of New Large-Area Photosensors in the USA

@BURLE – classical PMTs (<u>separate talk</u>)

@UC Davis:

(1) ReFerence Flat Panels for mass production

(2) Light Amplifiers (flat and spherical)

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University of California Davis

Development of Novel Photosensors at UC Davis

Daniel Ferenc

Eckart Lorenz

Daniel Kranich (Feodor Lynen Fellow)

Alvin Laille (Graduate Student)

John Thomson and David Hemmer (UHV technicians)

Physics Department, University of California Davis

1. **The Motivation**
2. **Problem #1: Mr. Liouville → Irreducible Illuminated Area**
3. **Problem #2: Industrial Mass-Production Needs a REAL MARKET (not only physics)**
4. **Solutions**

ReFerence Flat-Panel Photosensor

The Light Amplifier Concept (flat and spherical)

New Markets

SEARCHING FOR EXTREMELY RARE AND WEAK

RADIATION SOURCES

PARTICLE ASTROPHYSICS

(new generation of experiments)

PREVENTION OF NUCLEAR TERROR

Future projects to study very rare phenomena

- **Proton decay, Neutrino Physics and Astrophysics**

  UNO, MEMPHIS, HYPER-K, Kilometer-Cube, also deep-sea Nestor, Nemo, Antares, etc.

- **Gamma-ray Astronomy – a study of faint and/or variable sources requires telescopes with**

  low detection threshold & wide acceptance angle (huge photosensor area)

- **Ultra-high energy cosmic rays ($>10^{19}$ eV)**

- **Double beta decay**

2000-2004:

Advanced Detector Research Award DOE/HEP:

"Novel Highly Sensitive Photosensor Technology for Inexpensive Large Area Cherenkov Detectors"

~$350,000

2002-2003:

Purchased >$2M equipment from the *Candescent FE* flat-panel TV factory

2004:

Purchased a production unit (exhaust station) for 18-mm night-vision image intensifiers (Gen-2), with the MANUAL (Litton Co.)

NEW 2004-2007:

National Nuclear Security Administration (NNSA/DOE),

Office of Nonproliferation Research and Engineering:

"Development of ReFerence Flat-Panel Photosensors for Novel Super-Large-Area Radiation Detectors"

$750,000

Few Remarks on Nuclear Terror

- Explosion of real nuclear weapons in big cities – an expected event
- Leakage of
  - Weapon-grade fissile materials
  - Nuclear bomb technology
- ~1994: a real nuclear bomb may be created from <u>Reactor-Grade Plutonium</u>
- PROBLEM: N-Bombs are only weakly radioactive

➔ **Large-Scale monitoring is needed, with simple, pixelized, <u>mass-produced super-large-area radiation detectors</u>**

(passive detection; neutron-activation; muon tracking)

Sensitivity for the detection of very rare phenomena

Very Large Volumes/Areas

No other choice than

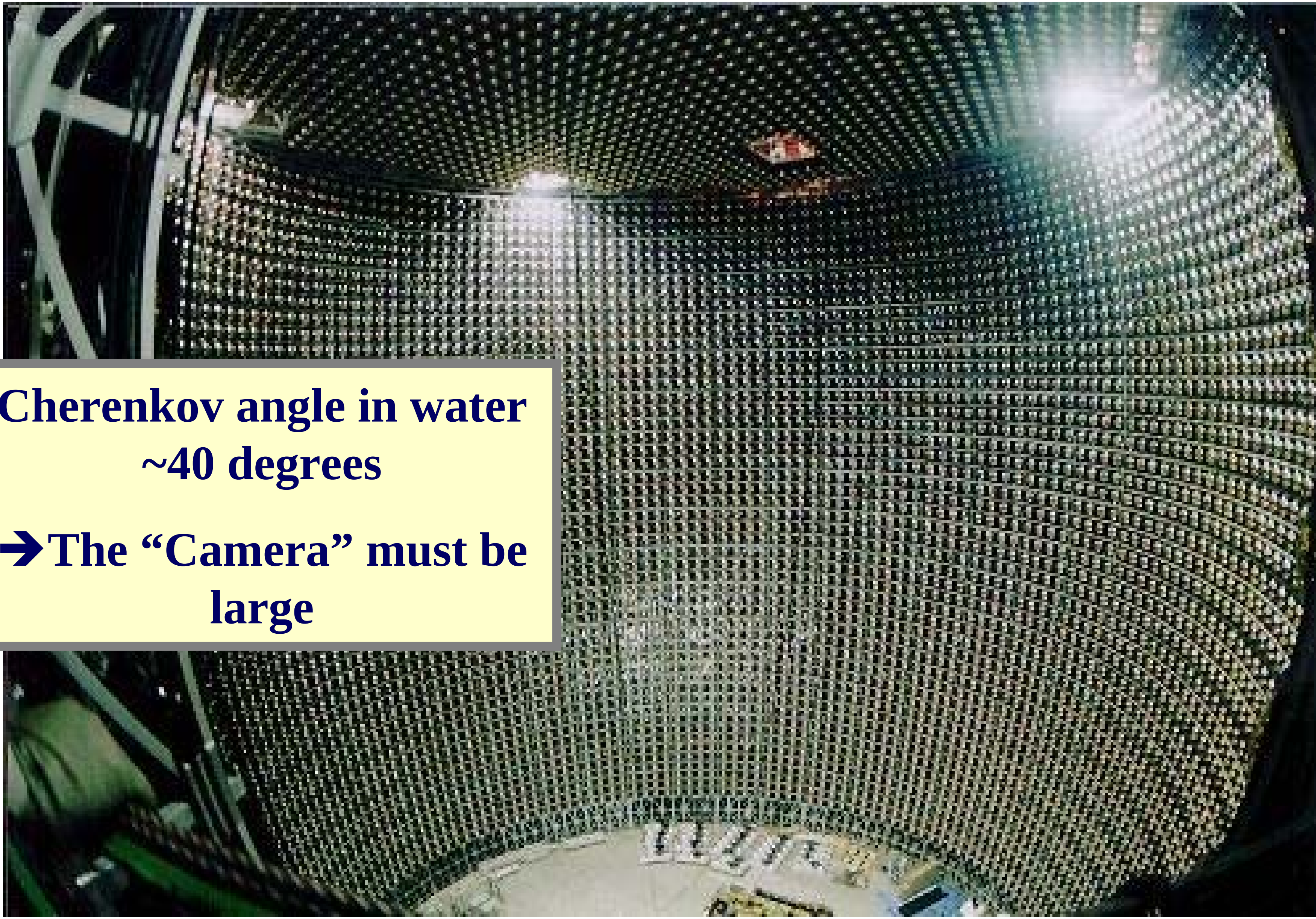
"Natural" **Transparent** Media
(Water, Atmosphere, Ice, +GdCl)

PHOTOSENSORS

Several unconventional photosensor concepts

- **Flat-Panel “*ReFerence*” Camera Concept (Patented)**
- **“*Light Amplifier*” concept, development just started**
  - **SMART PMT (Phillips) → modified configuration**
  - **ReFerence panels → scintillator (fiber) readout**
- **“*SIMPLE*” Imaging Camera Concept, project idling, for EUSO, OWL, but also ground-based applications Patent Pending, project pending**
- **Deep-Sea Photosensor (a new idea, but have no time…)**

The Unbeatable Reality of Mr. Liouville



Cherenkov angle in water ~40 degrees

➔The "Camera" must be large

Irreducibly Large Illuminated Area

Photosensors with

very strong internal information concentration

Vacuum

(photon → photoelectron → no more Liouville)

OBJECTIVES

1. **Large Photosensor Area Coverage**
   - **High Quantity**
   - **High Quality**
   - **Low Price**

   ➔Industrial Mass Production

2. **High Detection Efficiency and S/N**

   (collection and quantum efficiency)

OBJECTIVES

1. Large Photosensor Are...

- High Quantity
- High Quality
- Low Pri...

...ial Mass Production

2. ...igh Detection Efficiency and S/N

WHY NOT ACCOMPLISHED
ALREADY????

Semiconductor Photosensors

→ developed very successfully

(but pixel sizes and areas far too small)

Vacuum Photosensors

(suitable for large-area applications, strong area reduction) did not develop significantly since mid-1960s

Why?

Because of the Vacuum?

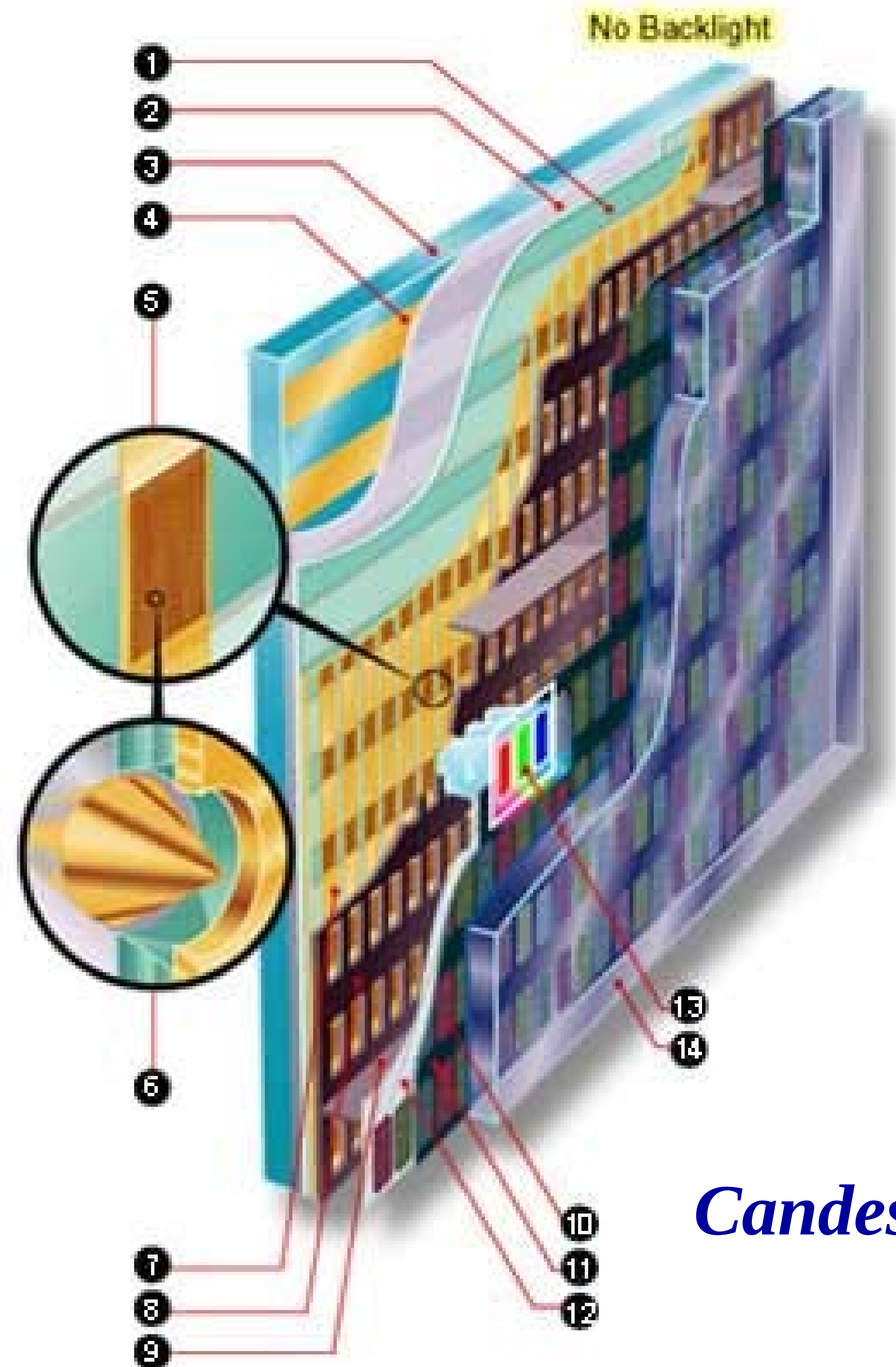
Development of Other Vacuum Devices

~1960

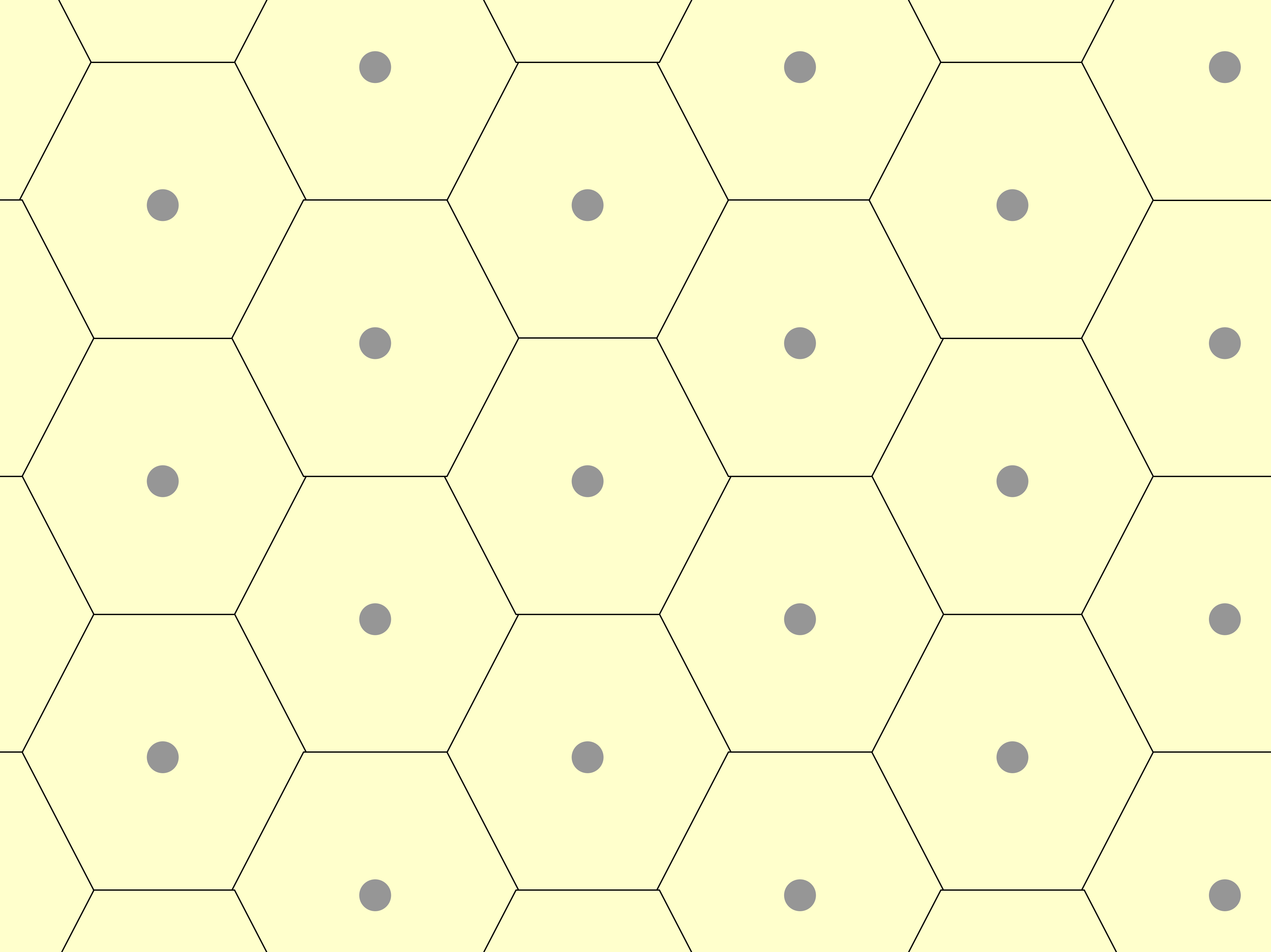
~2000

Price: ~$2,000 per m^2

1. Dielectric
2. Patterned Resister Layer
3. Cathode Glass
4. Row Metal
5. Emitter Array
6. Single Emitter Cone & Gate Hole
7. Column Metal
8. Focusing Grid
9. Wall
10. Phosphor
11. Black Matrix
12. Aluminum Layer
13. Pixel On
14. Faceplate Glass

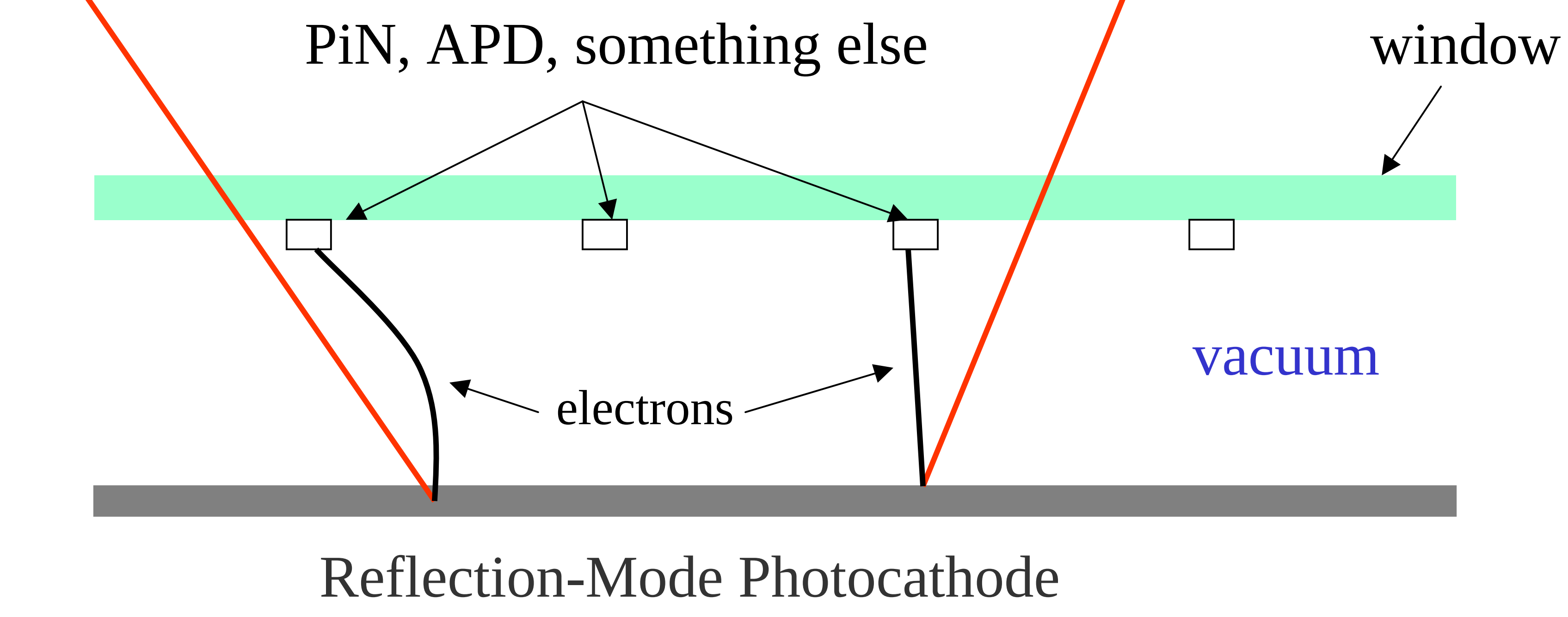


Candescent

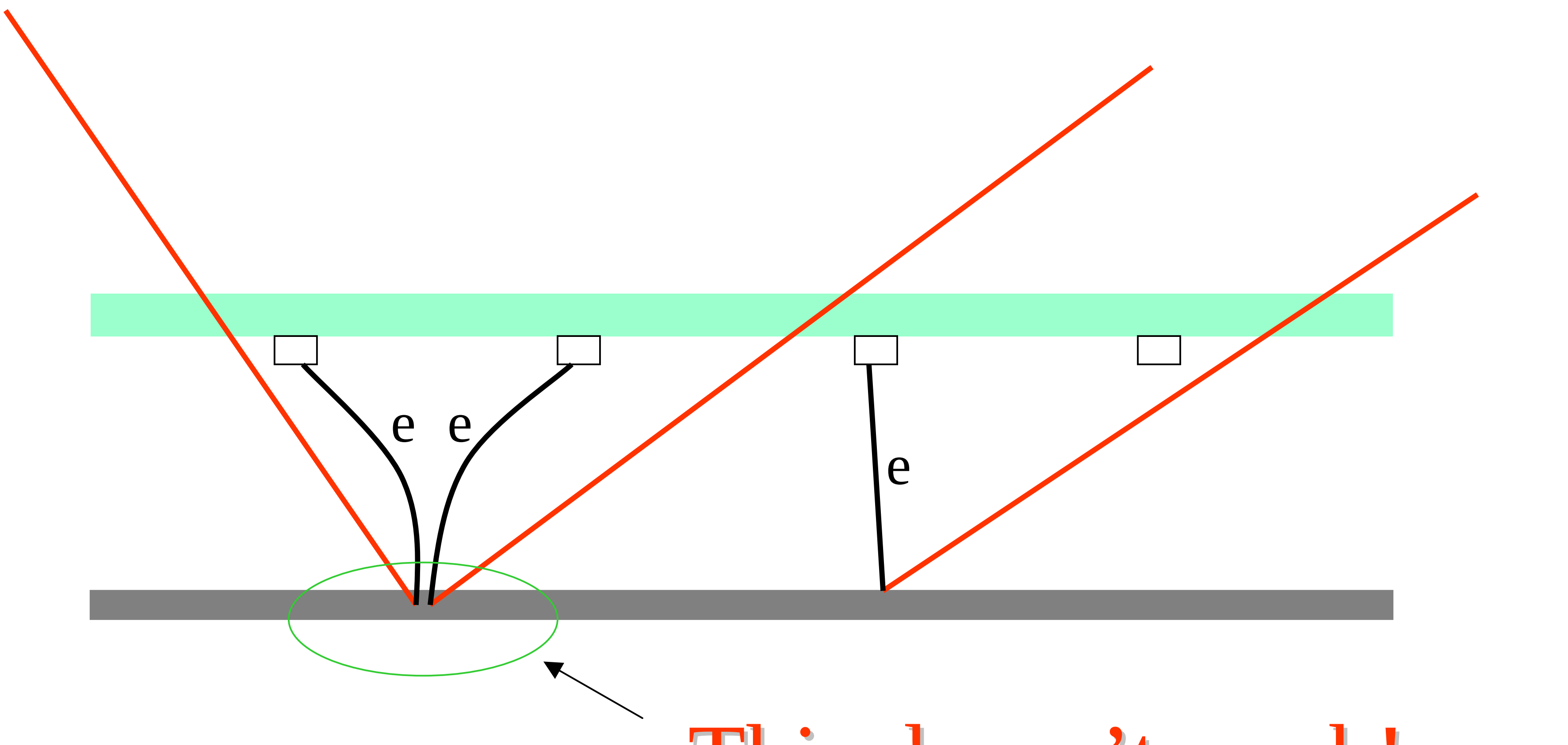


Flat Panel Camera – wishful thinking:

"Continuous" Hybrid Photon Detector (HPD)



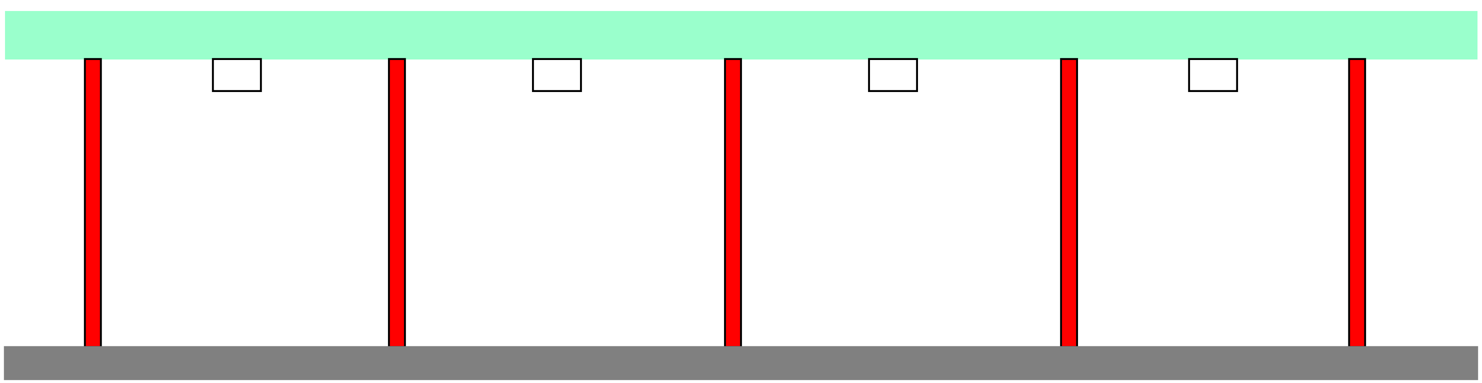
Problem #1 – Electron Optics



This doesn’t work!

Problem #2 – Mechanical Stability

(flat plates need supports)

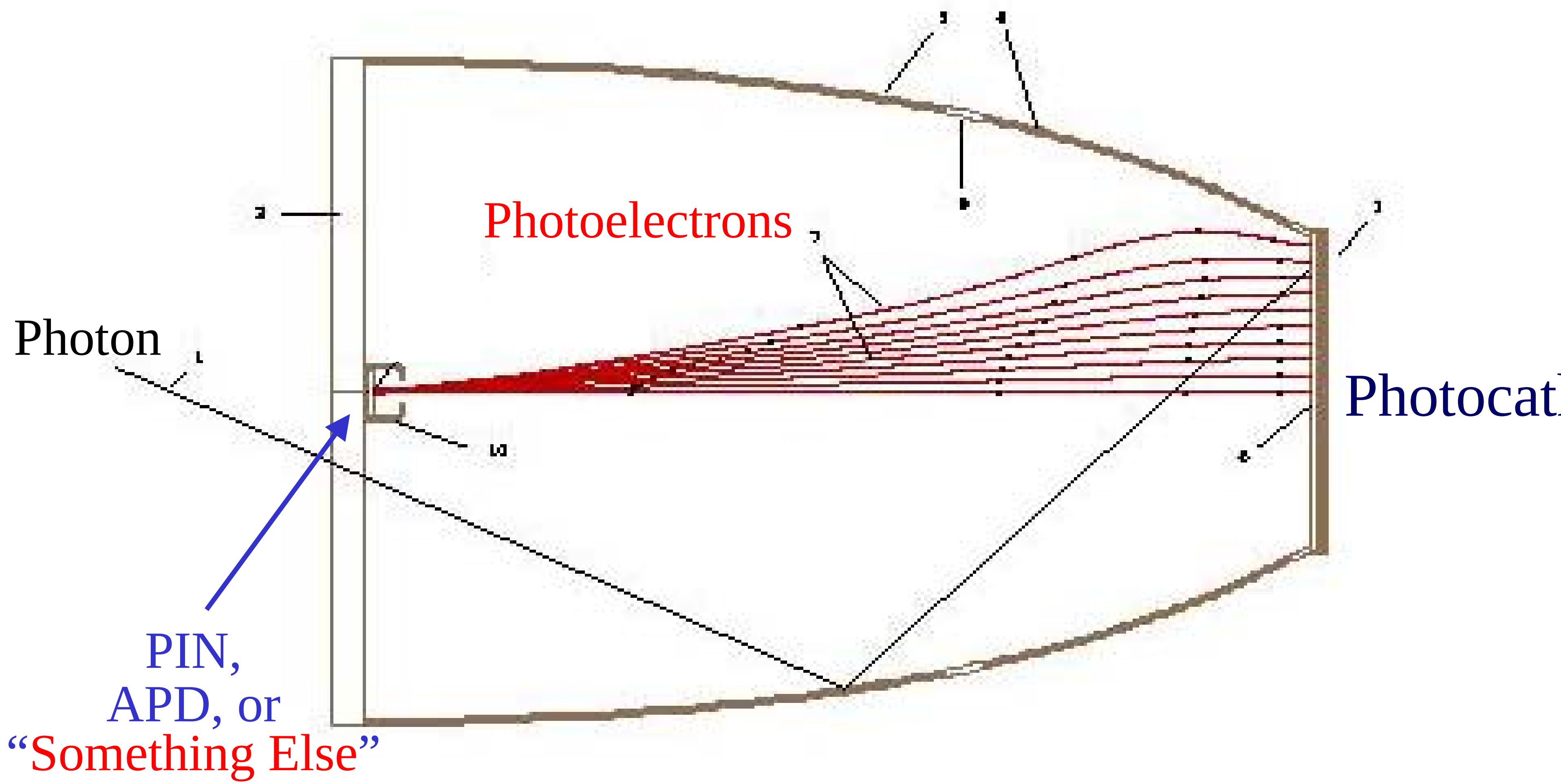


Flat-Panel Pixelized <u>Camera</u> Configuration→

provided by the *ReFerence* Photosensor Concept

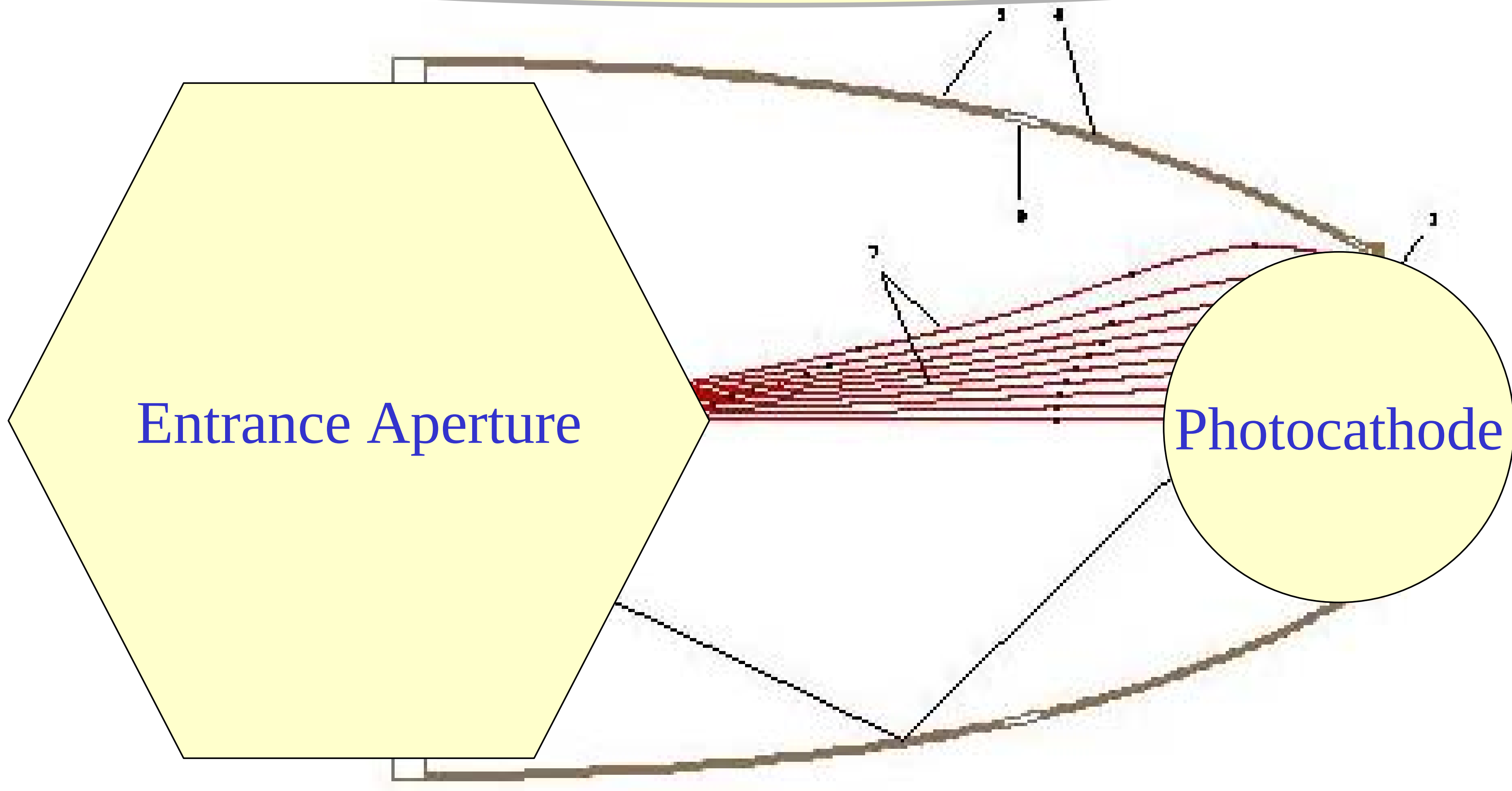
Ideal Light Concentrator

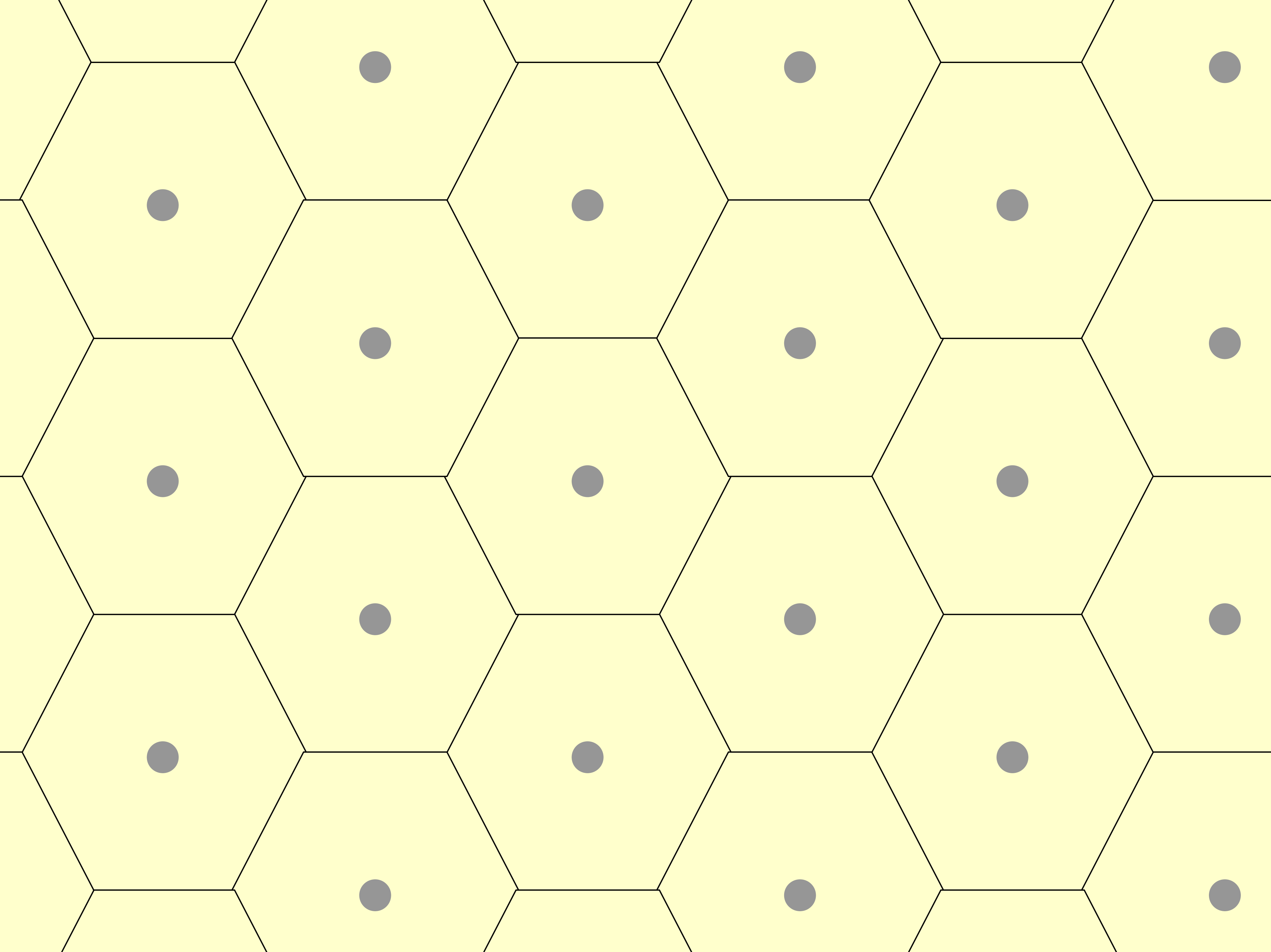
(takes the maximum of Liouville!)



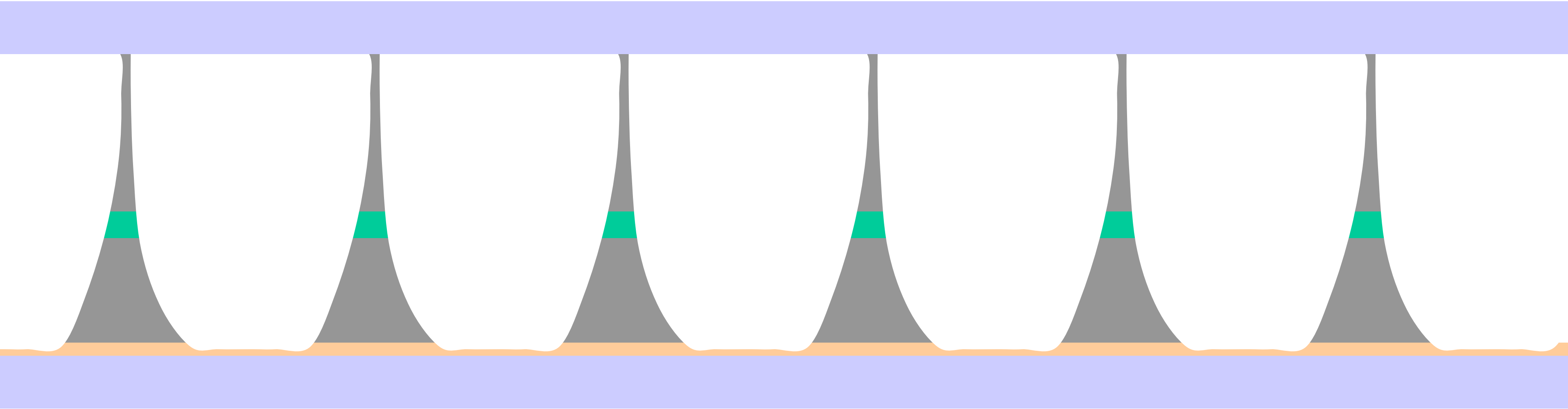
Optimal Electron Lens

Very Important: Hexagonal Packing





Flat-Panel Honeycomb Sandwich Camera Construction



Industrial Production (no glass blowing etc.)

Intrinsic Mechanical Stability, Low Buoyancy,..

PROTOTYPE DEVELOPMENT

UNSEALED 1-PIXEL

CYLINDRIC

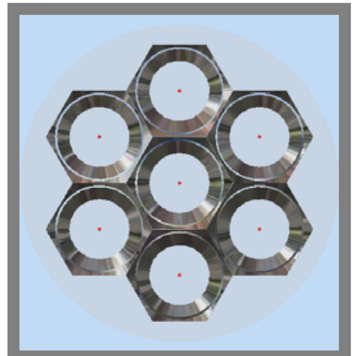
2001-2002

HEXAGONAL

2003

SEALED PANELS

(7 pixels, 5 inch)

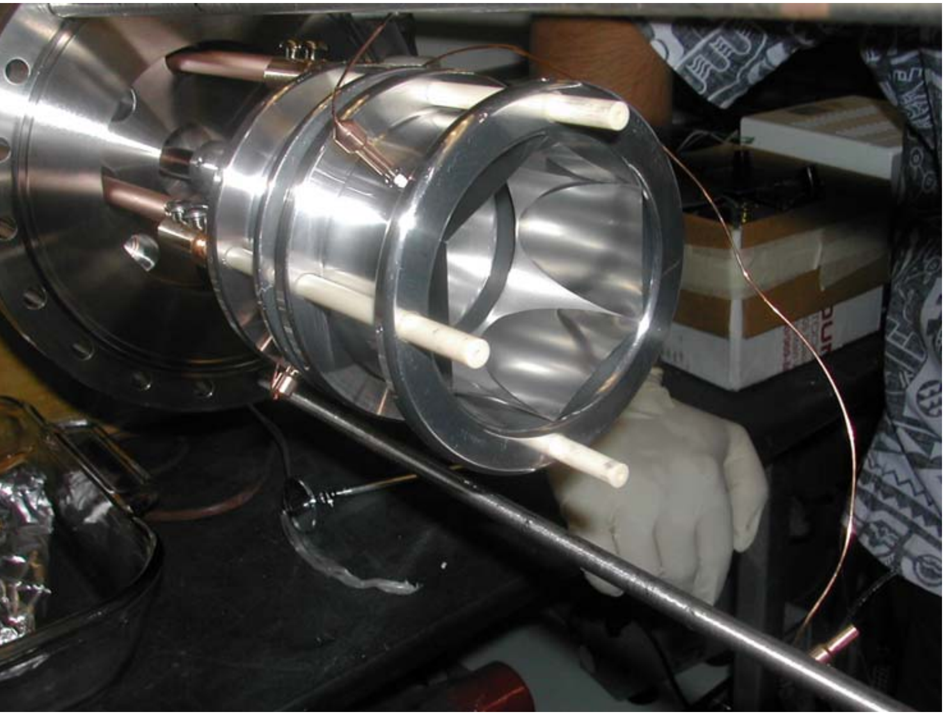


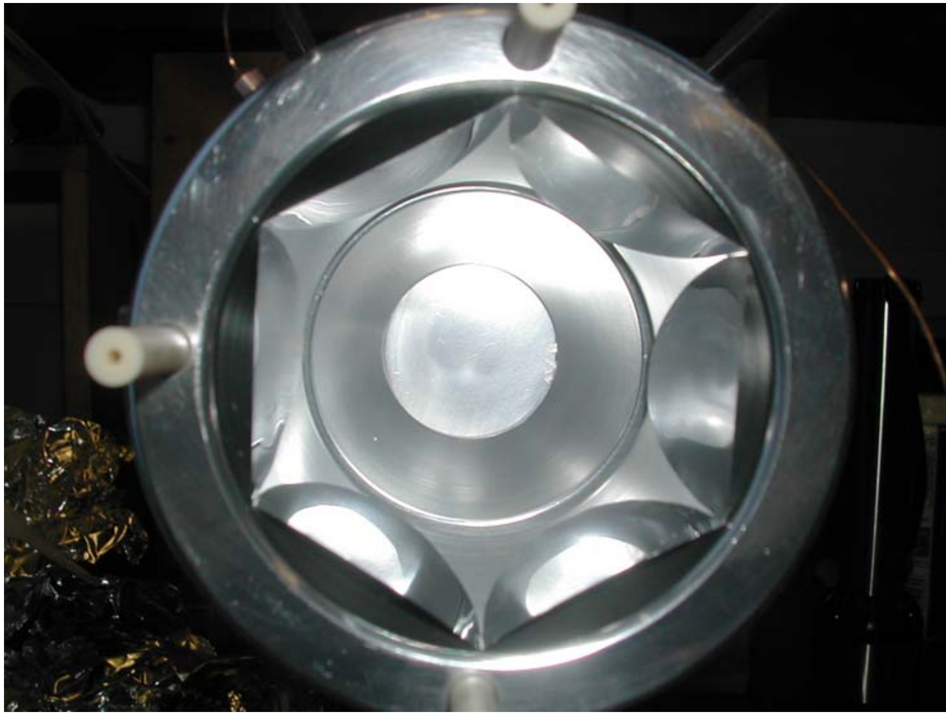
SEALED with In/Au

SEALED with SOLDER GLASS

Equipment (Candescent, Litton Night Vision) ~$2M

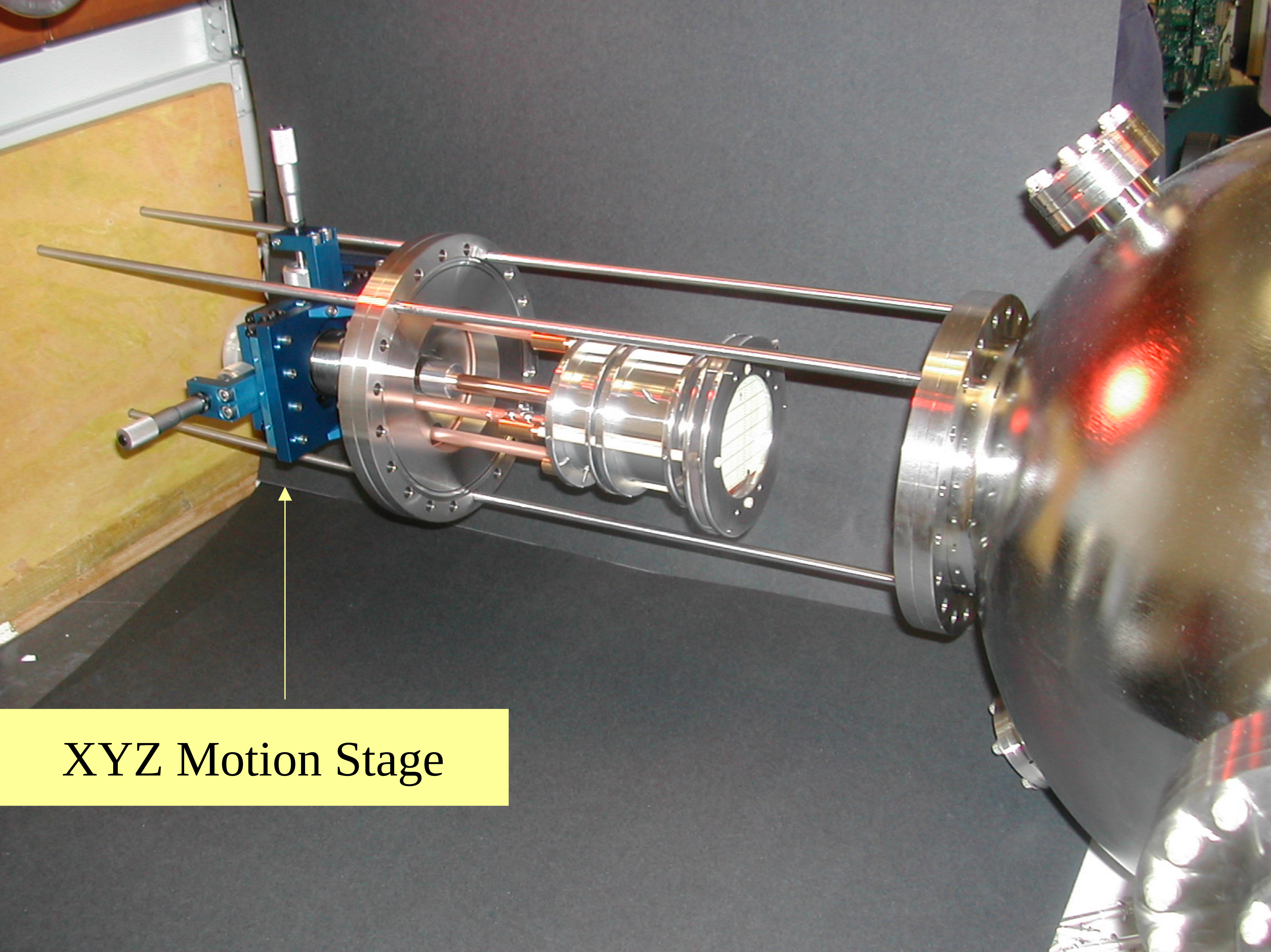
3rd ReFerence Prototype

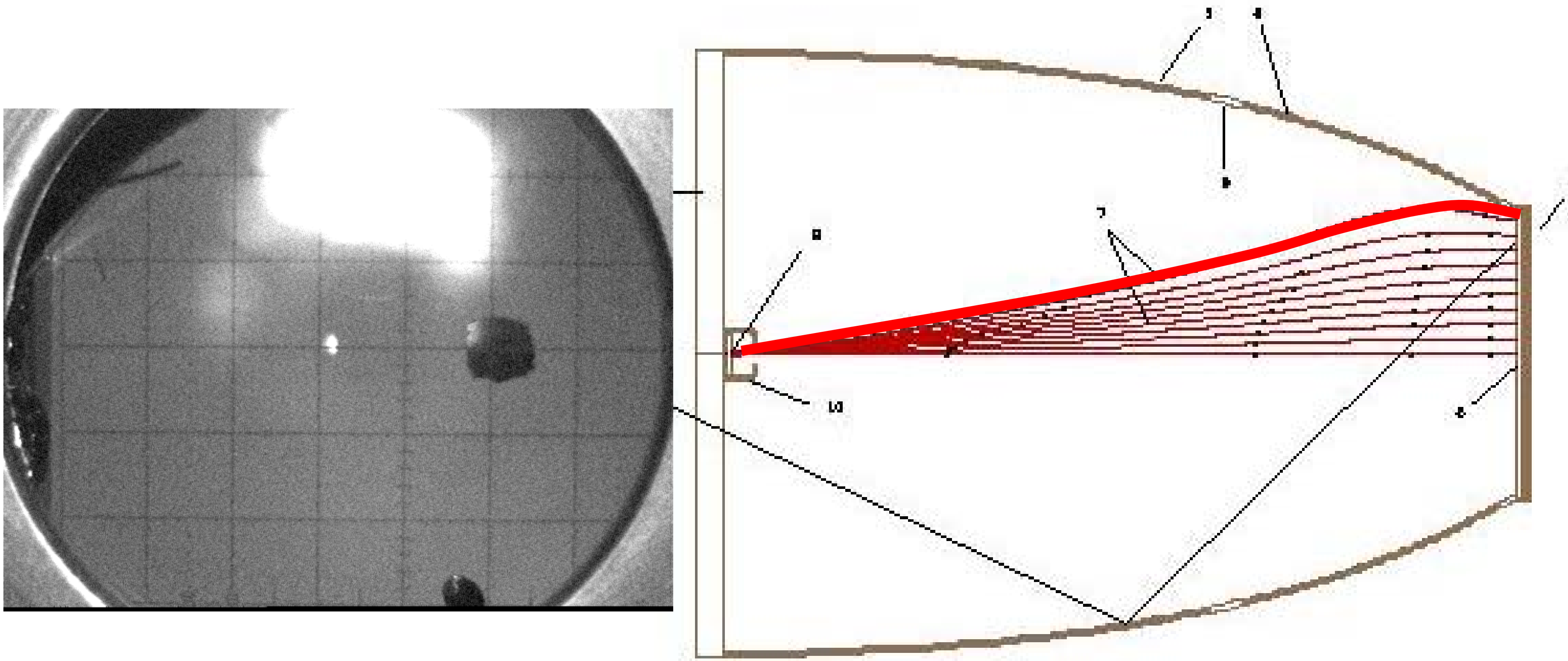


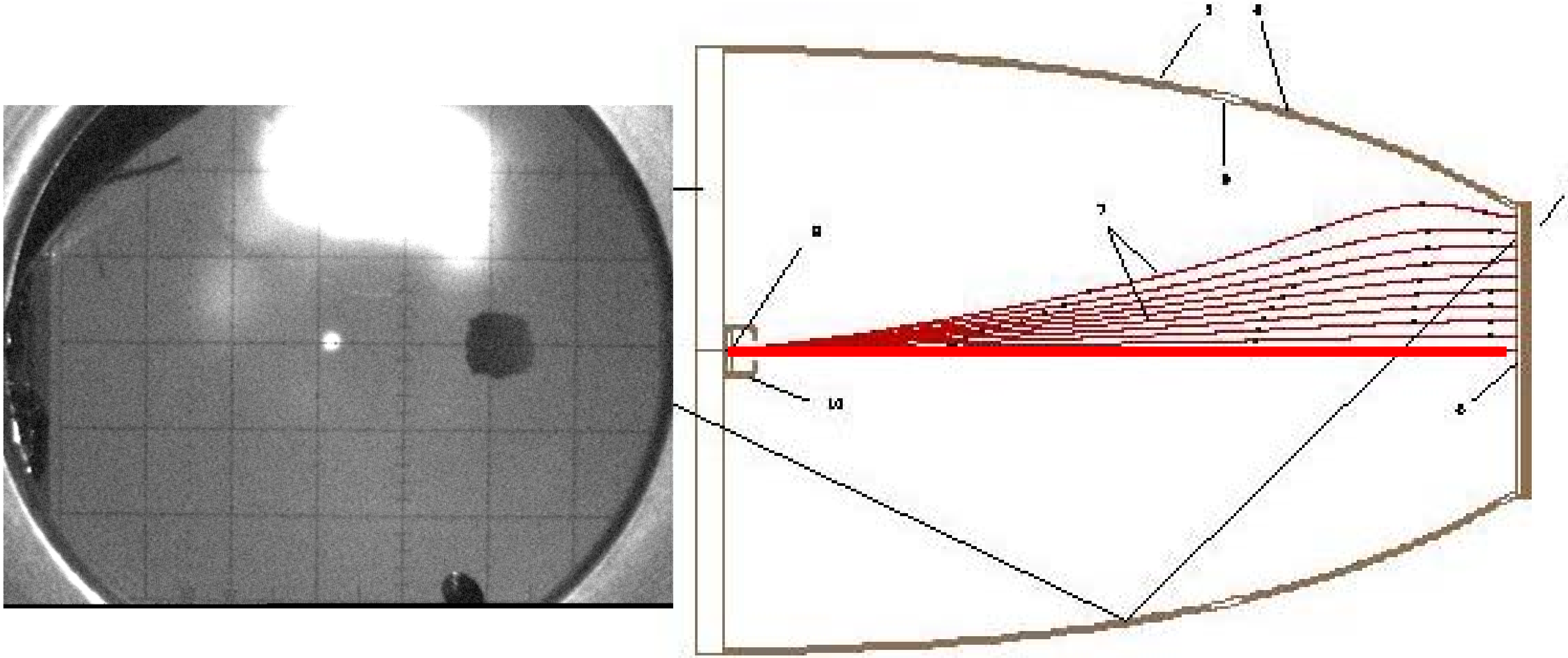


3” diameter, single pixel

(successfully tested – see below)


XYZ Motion Stage





Strong signal concentration, factor ~ 1500

(one of our goals)

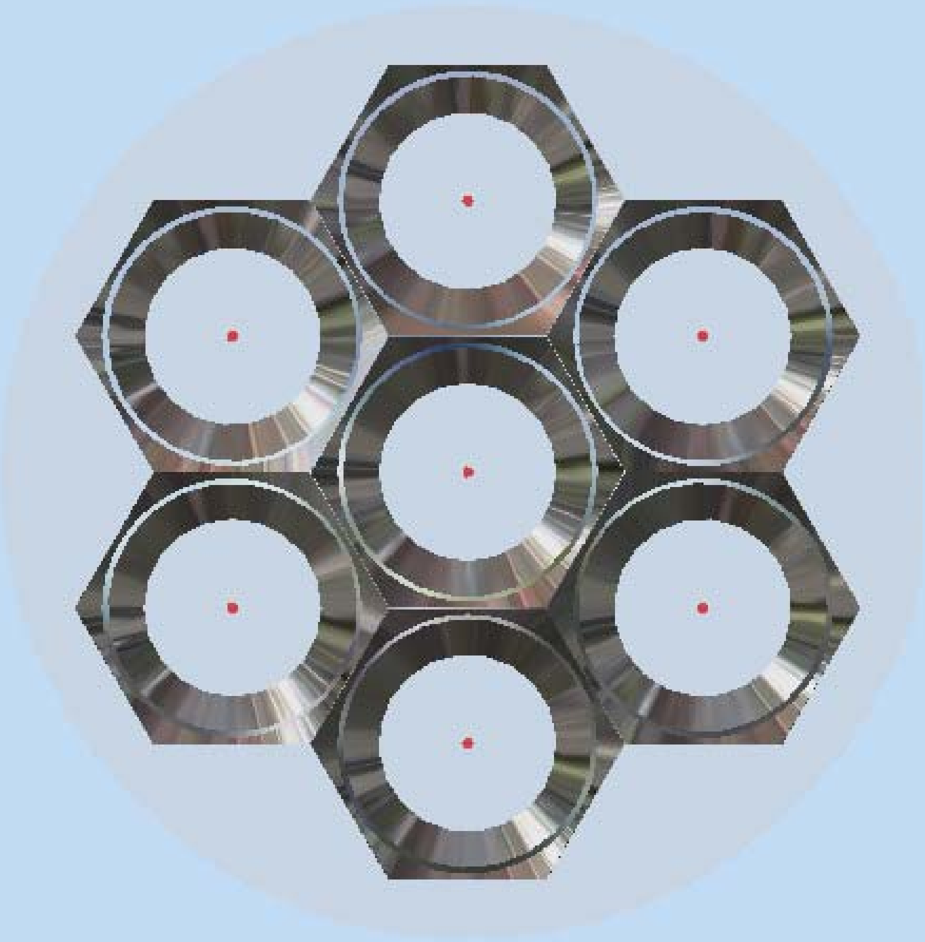
Replaces the entire Dynode Column!

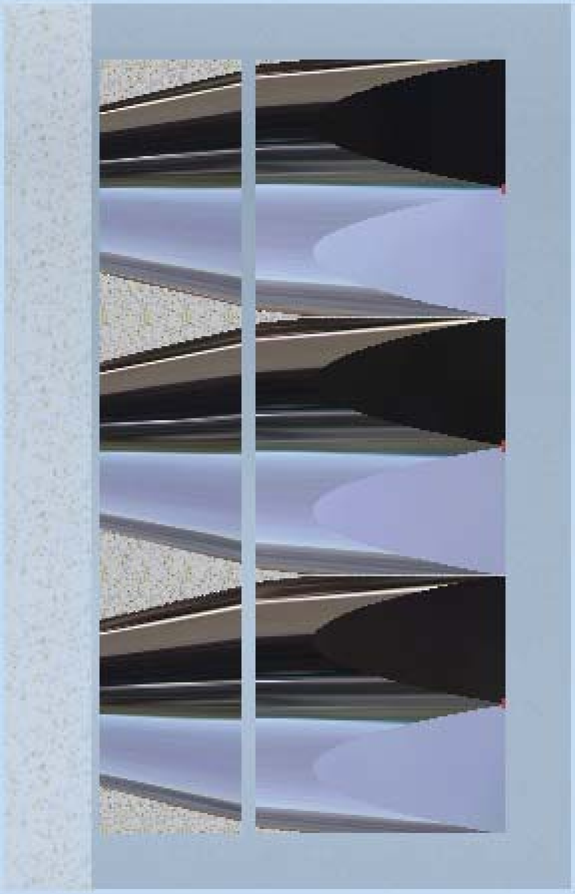
Provides ~100% Collection Efficiency!

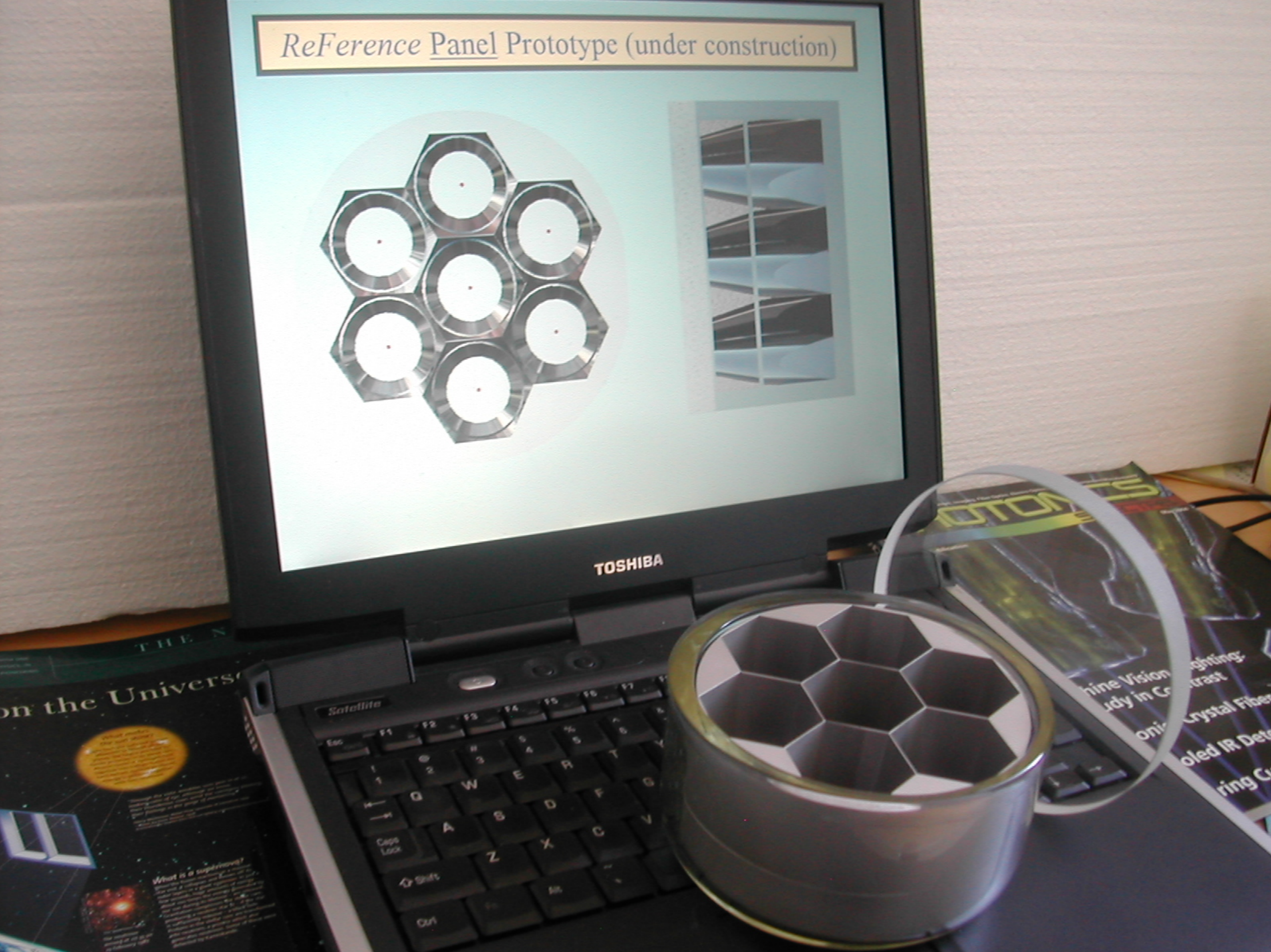
- **APD**
- **Scintillator + Fiber (both of small and comparable diameter – transmission efficiency)**

From Tubes to Large Flat Panels

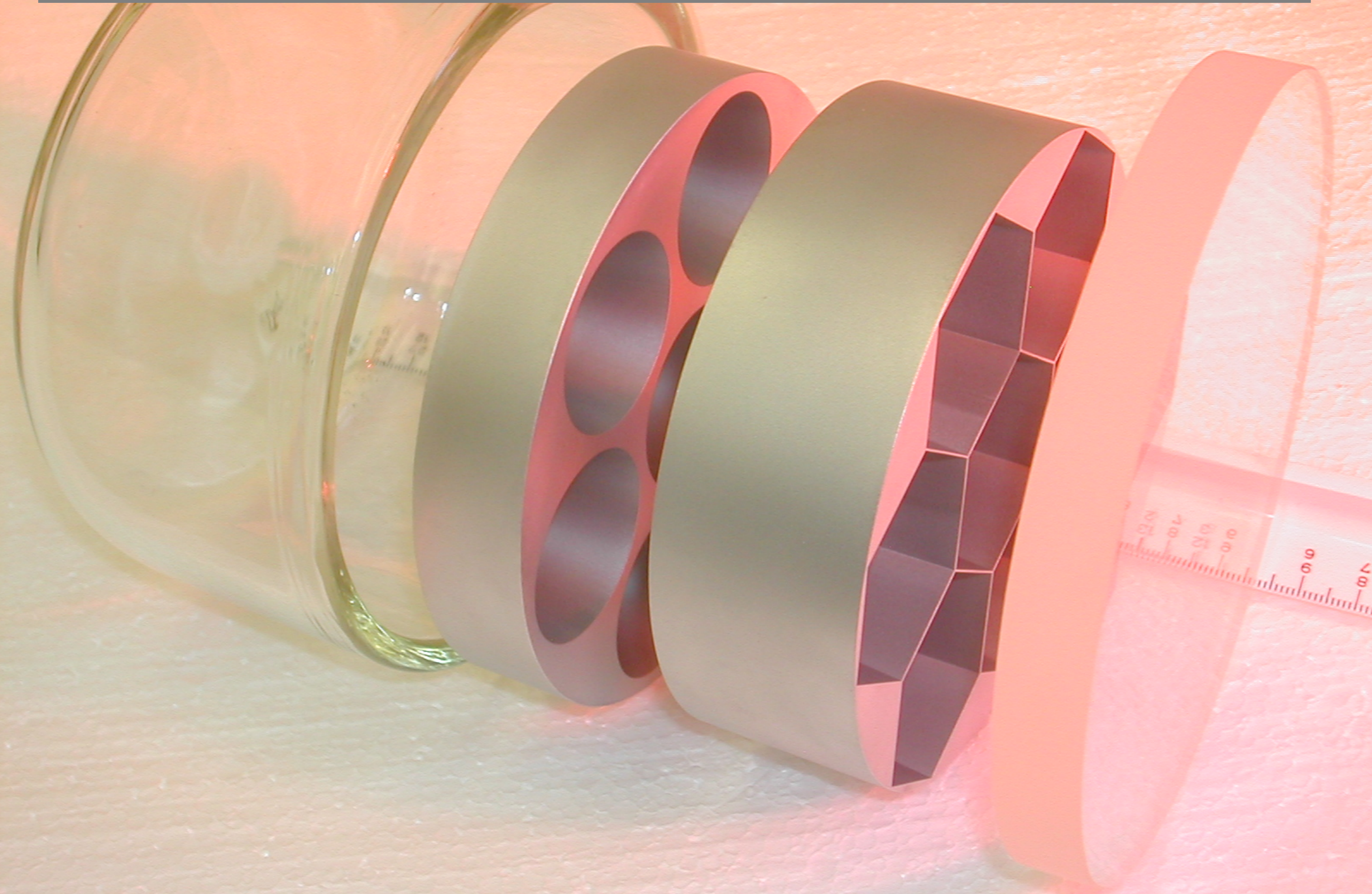
ReFerence Panel Prototype (under construction)

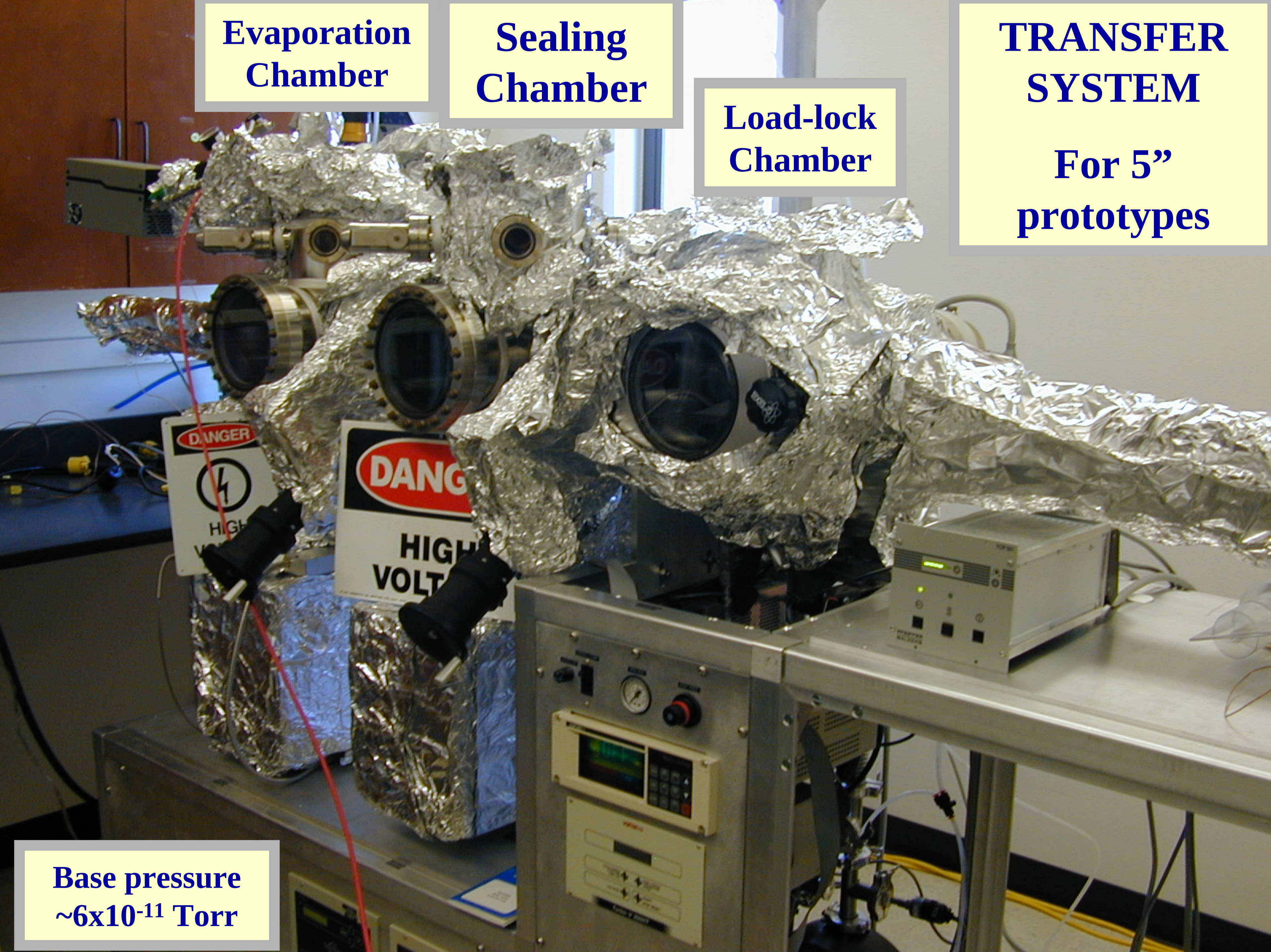


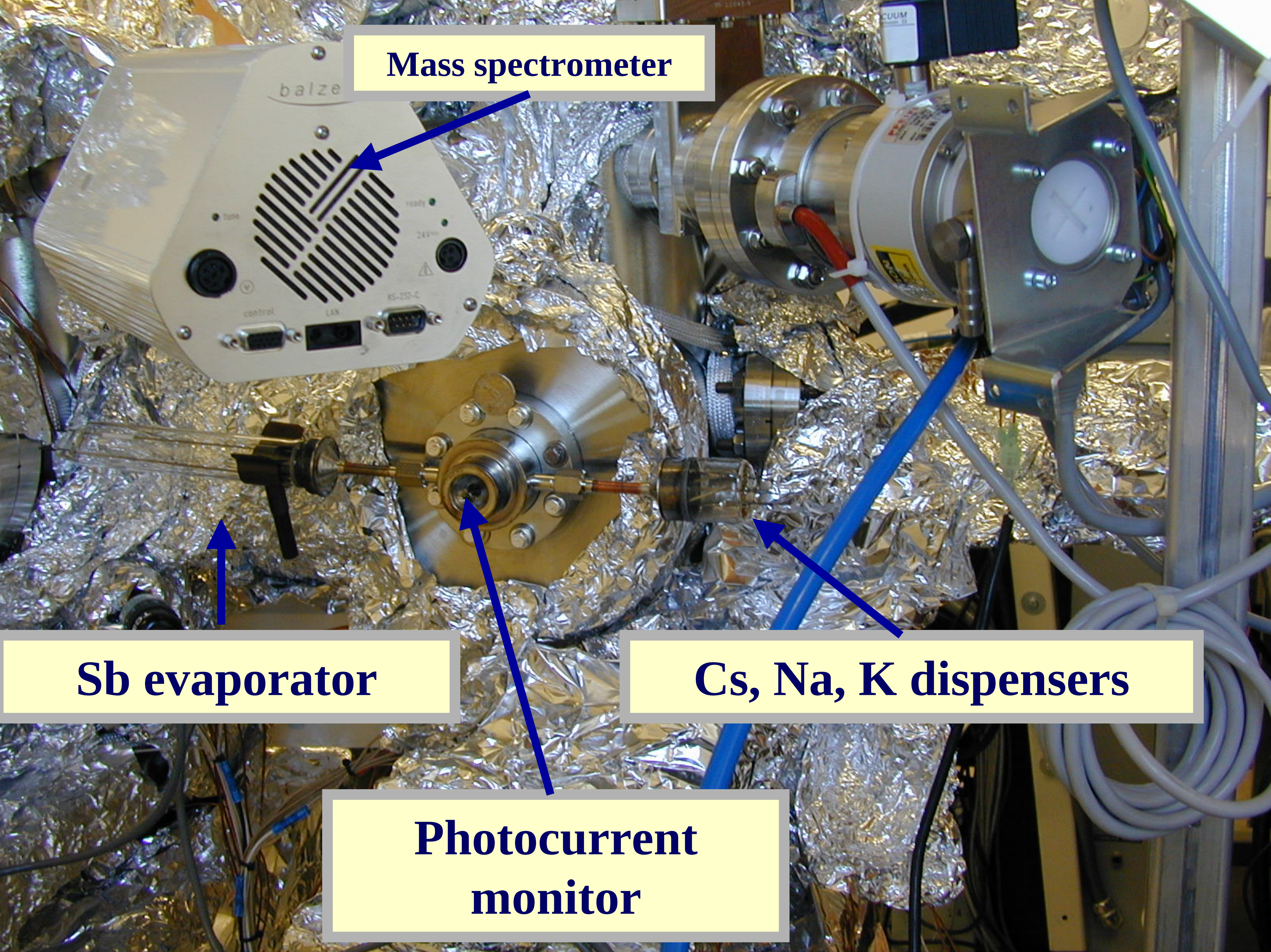


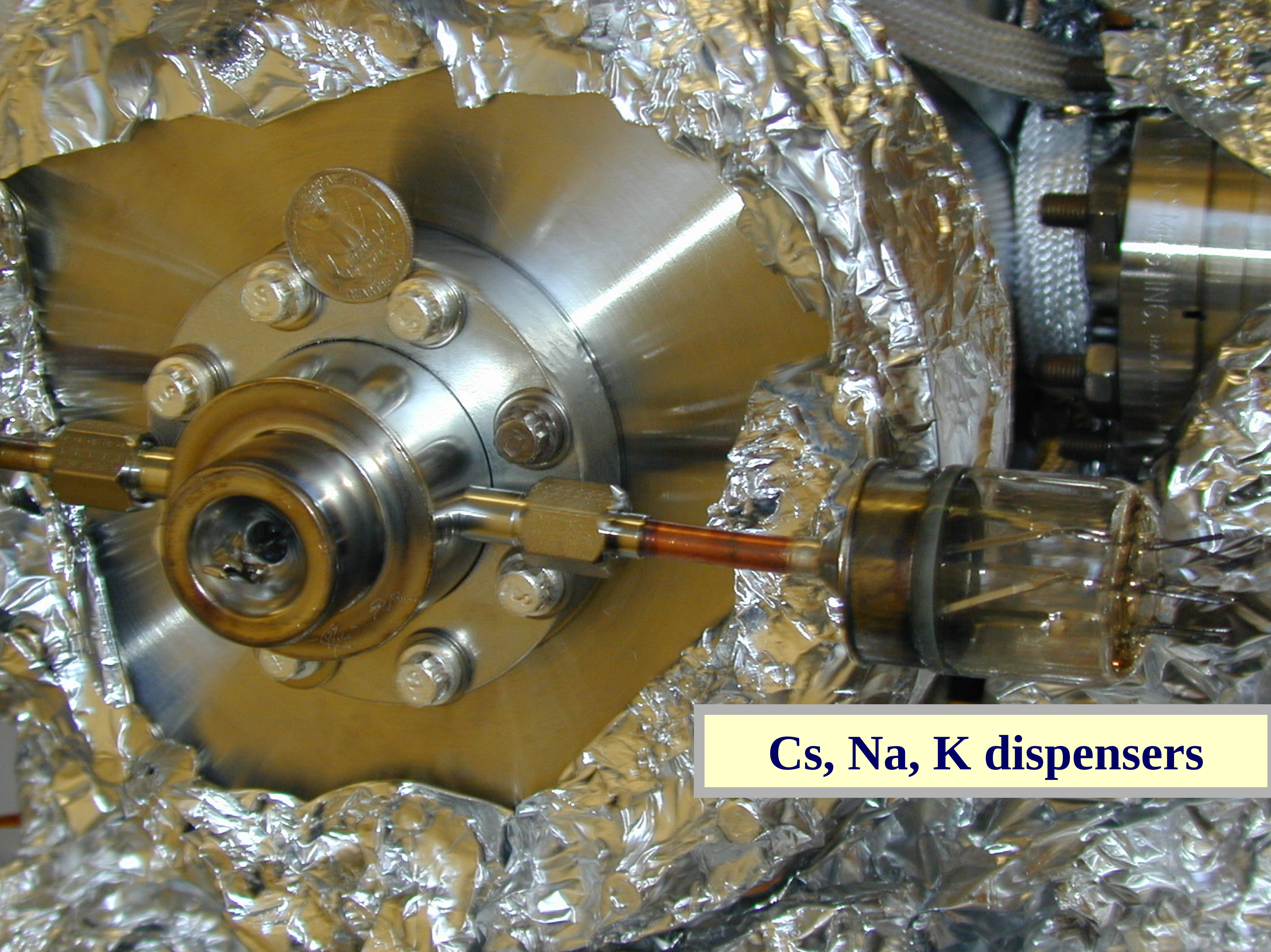

ReFerence Panel Prototype (under construction)
TOSHIBA

Currently Aluminum – ultimately GLASS



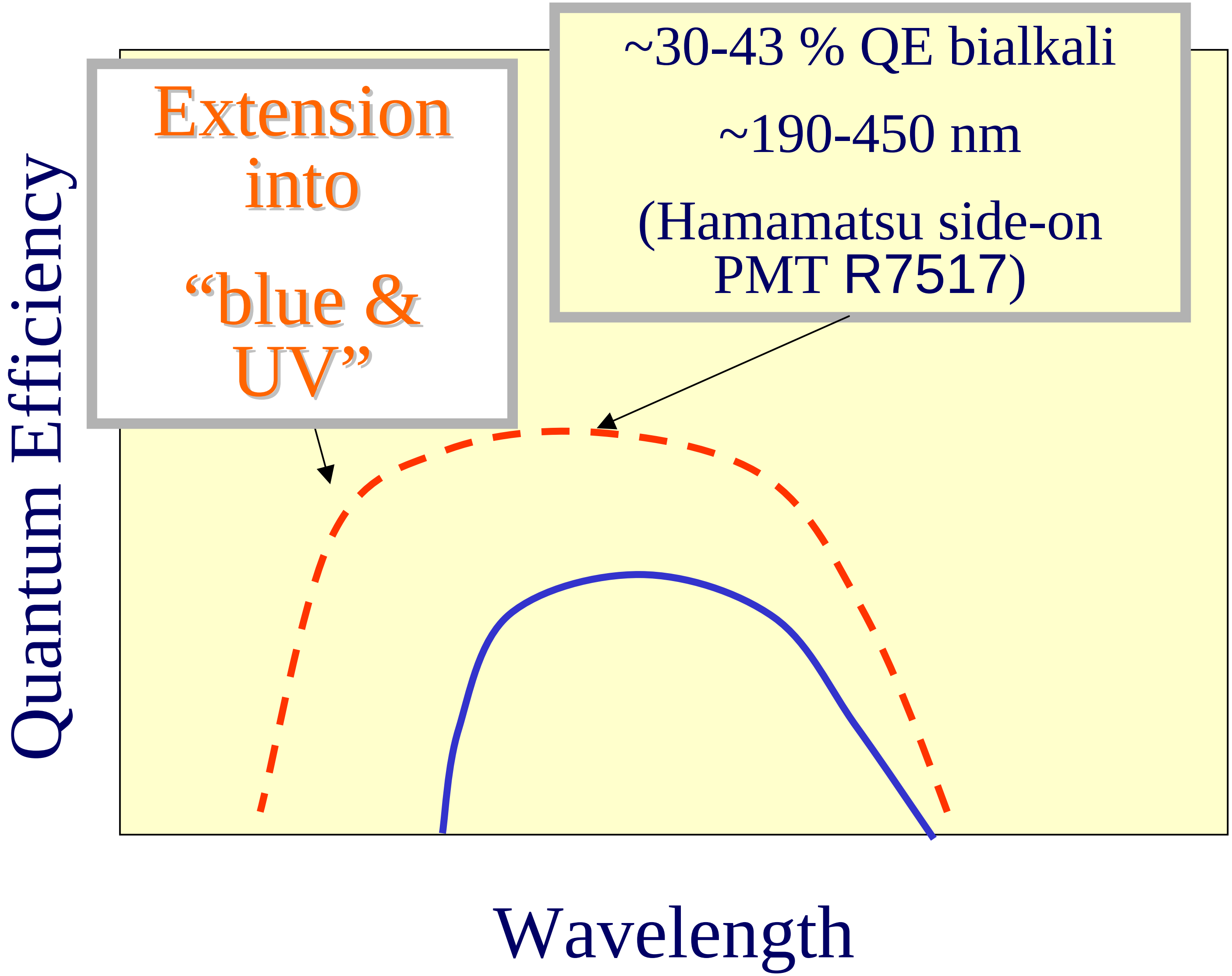

Evaporation Chamber
Sealing Chamber
Load-lock Chamber
TRANSFER SYSTEM
For 5” prototypes
DANGER
Base pressure
~6x10^{-11} Torr


Mass spectrometer
Sb evaporator
Photocurrent monitor
Cs, Na, K dispensers



Cs, Na, K dispensers

Reflection Mode vs. Transmission Mode



HAMAMATSU

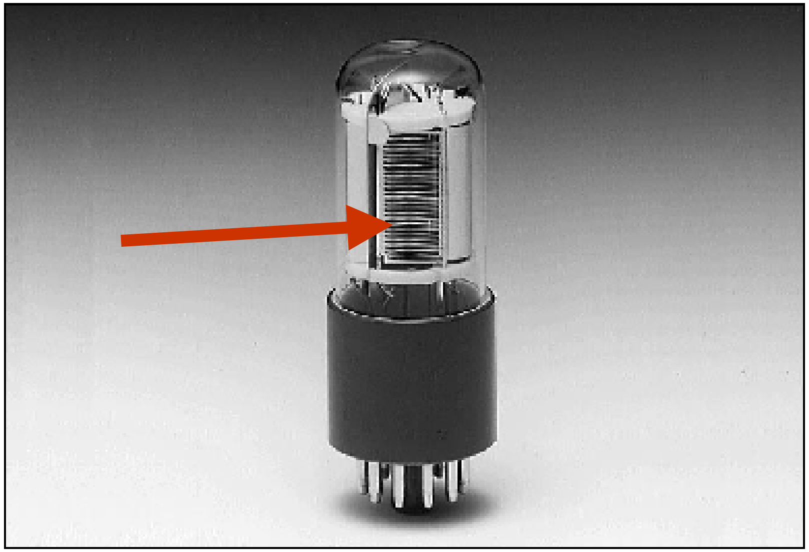
PRELIMINARY DATA
NOV. 1998

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.

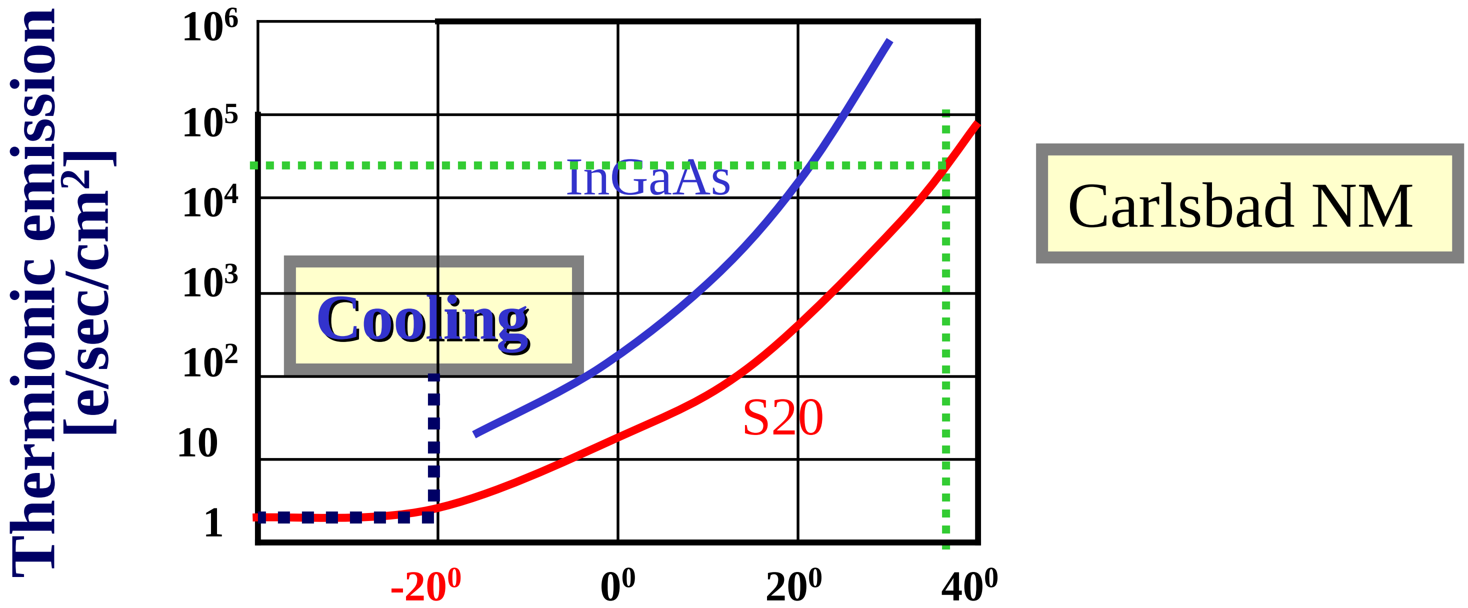


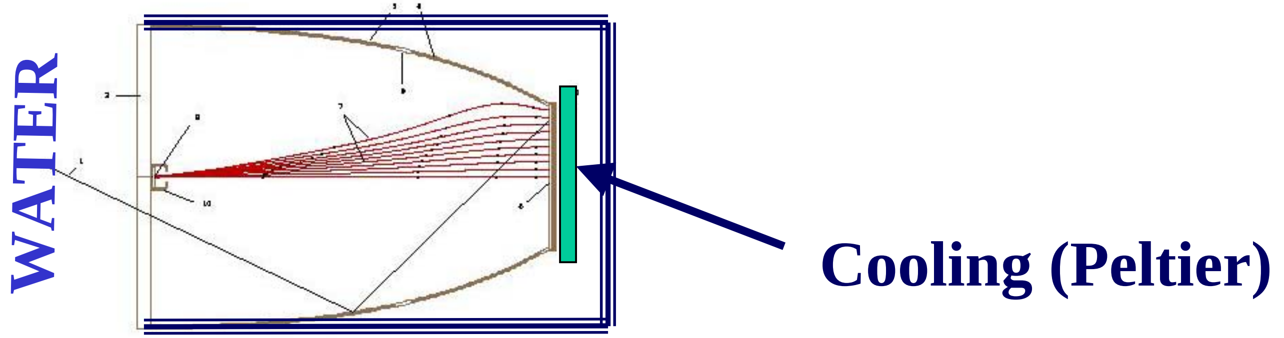
APPLICATIONS

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

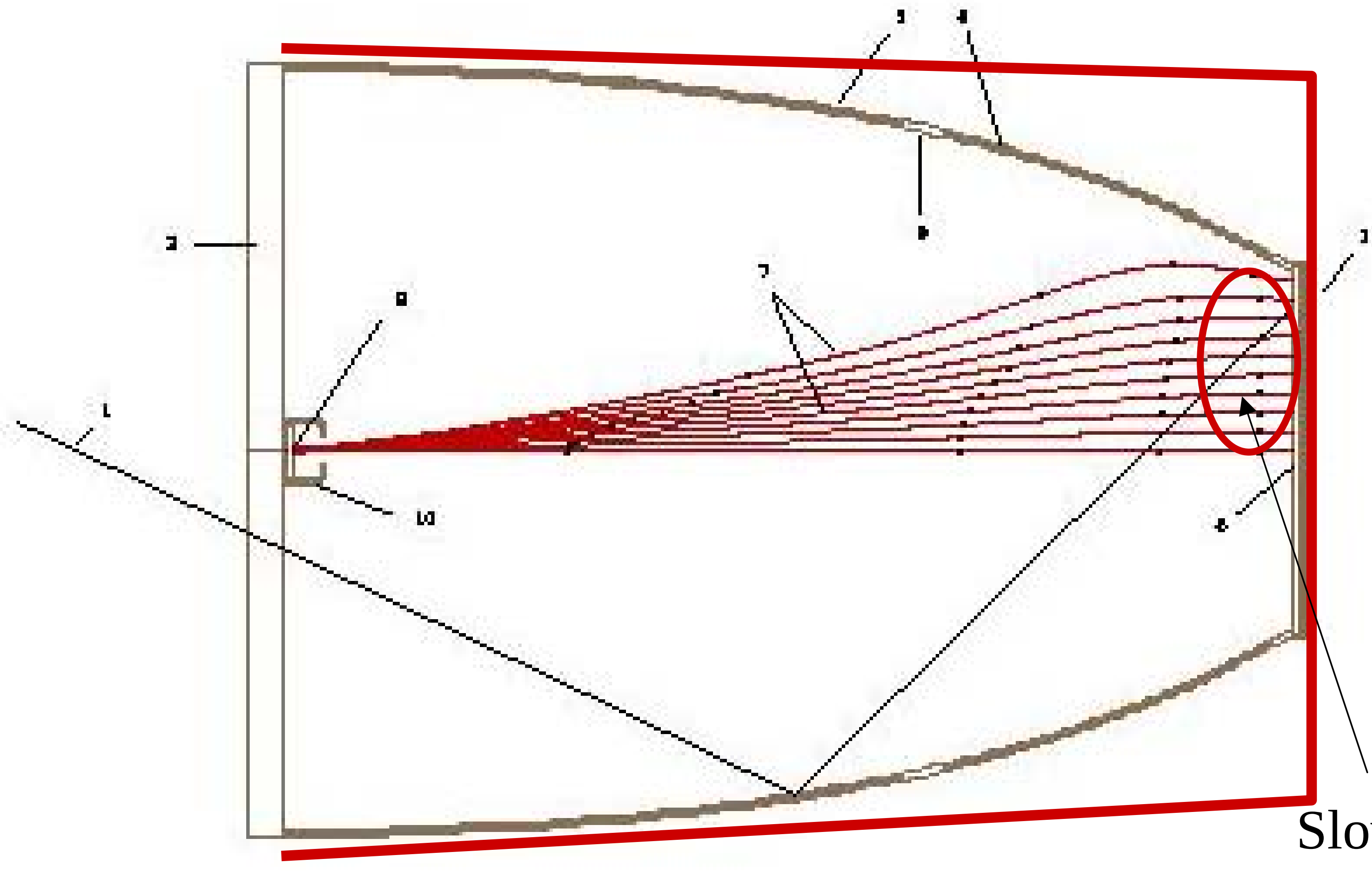
GENERAL

Photocathode Cooling - Diminished Dark Current



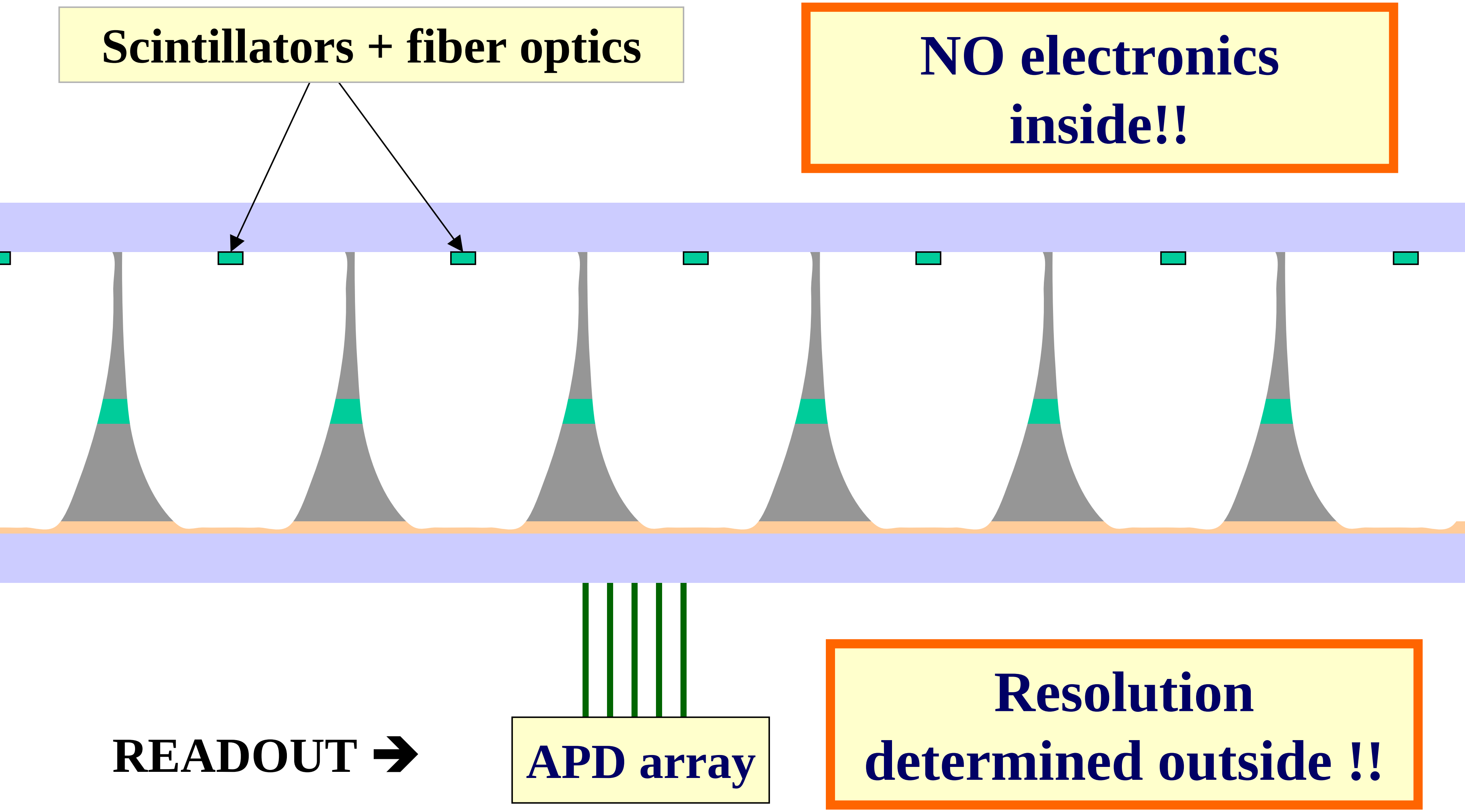


VERY EFFICIENT MAGNETIC SHIELDING

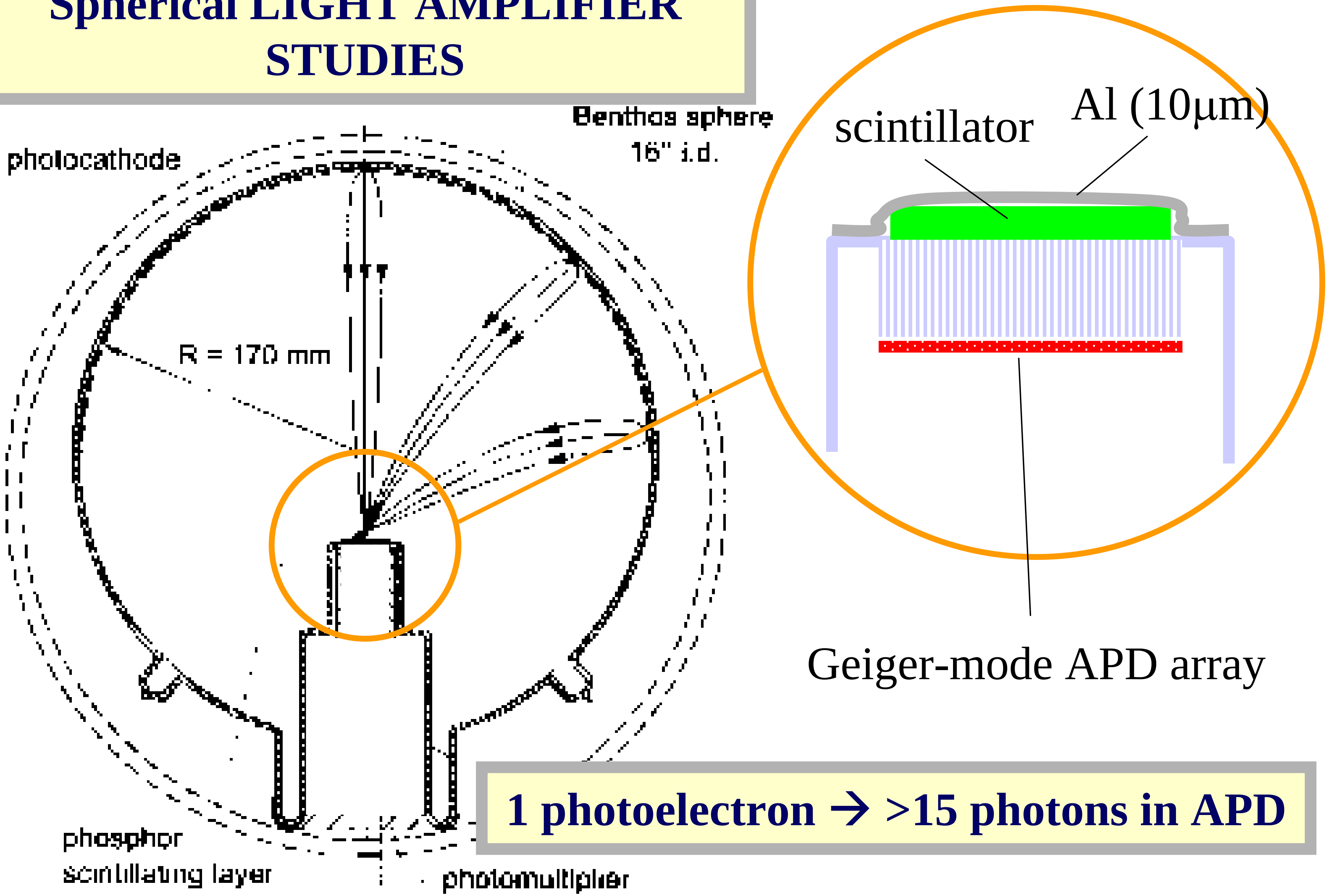


e.g. UNO with Magnetic Field (???)

“*Light Amplifier*” Concept



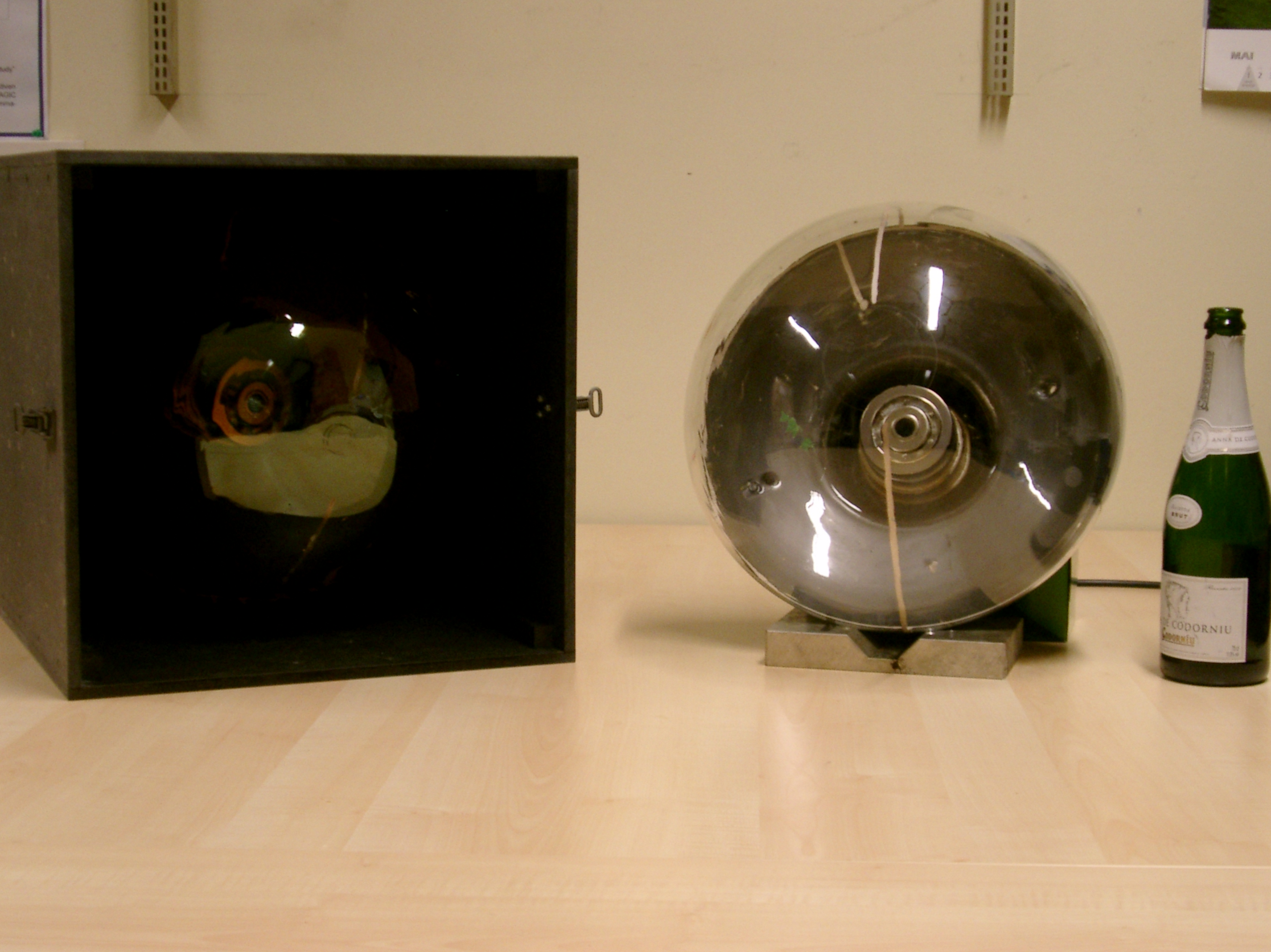
Spherical LIGHT AMPLIFIER STUDIES



1 photoelectron → >15 photons in APD

SMART PMT, QUASAR


2/2
Dauerstrom ohne FI
Kimberly-Clark
KIMWIPES® Lite 200
CODORNIU
Reserva
BRUT
ANNA DE CODORNIU
CODORNIU


MAI
BRUT
CODORNIU

SUMMARY

• The goal: Inexpensive Industrial Mass Production (<$2000 per sq. meter)

• Large New REAL Markets (not physics), we are funded already for/from one of those

• Fully functional 7-pixel prototype in 2-3 months (to demonstrate the panel concept, not yet for excellent performance)

• All-glass industrial prototypes ~by the end of 2005