Phosphors and Scintillators in Radiation Imaging Detectors
……incorporated into real world detectors

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Fluorescent & Scintillation Products
for Industry, Science & Medicine

Outline and objectives

- Luminescence
  - Introduction

- An overview of radiation imaging innovation at AST with reference to synergy of materials science with physics.

- X-ray imaging and detection
  - Commercial applications
  - New imaging intensifying screens
  - New detectors (3D-RID)

- Neutron imaging and detection
  - Fast detectors at RAL
  - Applications

- UV and infrared imaging
  - Cost effective spectral enhancement of linear arrays and coated CCDs for instrumentation

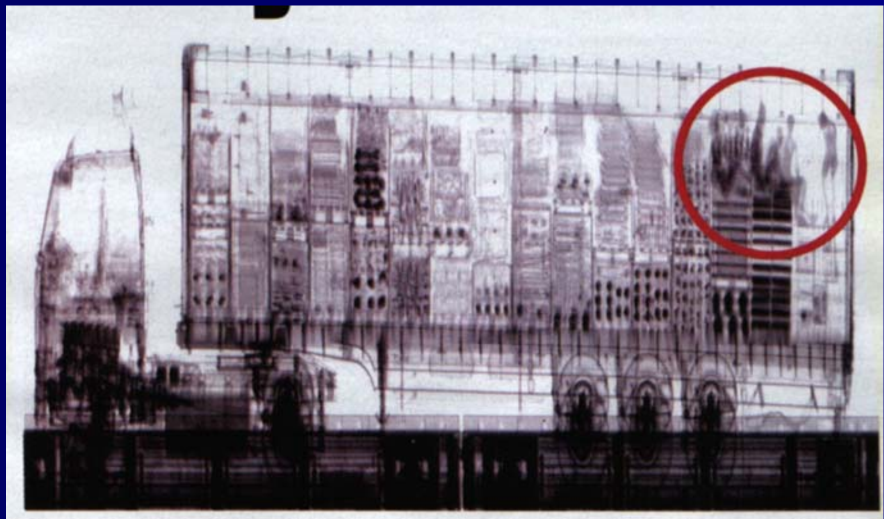
The single viewgraph acknowledgement to the great luminescence pioneers

- Early history
  - 10th century Japan and China
  - 17th century Sir Isaac Newton – Thermoluminescence from diamond
  - 17th century Vincentinus Casciarolo (Bologna) coined the term phosphor Phosphor – “gk. Light bearer”– “Bolognian Stone” (BaSO4)
  - 19th century -Eilhardt Wiedemann (German Physicist) – coined word luminescence in 1888.
- Recent history
  - Lenard (1862-1947) – alkaline earth sulfides
  - Pohl (1920s and 1930s) Tl activated alkali halides
  - Humboldt Leverenz (1940s and 1950s) ZnS
  - Ginther (1960s) – neutron detection glasses

Major applications of phosphors

- Displays
  - Cathode ray tube
  - Plasma displays, Electroluminescence,
  - Oscilloscopes –
- Lighting
  - Fluorescent lighting
  - White LEDs
  - UV Therapy lamps
- Printing
  - Security inks, etc for banknotes and credit cards
- Safety signs and strips
- X-ray intensifying screens
- Novelty goods – luminescent toys

….and how they can be applied to niche applications I



Security

• Fast decay x-ray phosphors for x-ray backscatter detection

• High efficiency and low γ sensitivity detectors for radiation threat monitors

• High efficiency screens for baggage scanning and postal imaging systems

• Image storage panels for rapid response terrorist threats

….and how they can be applied to niche applications II

Therapeutic X-ray medical imaging system using Levy Hill X-ray Screens. Courtesy of Philips Medical Systems.

Medical

• High thickness phosphors for MeV radiotherapy systems

• Intensifying screens for medical imaging

• High efficiency screens for baggage scanning and postal imaging systems

• Image storage panels for rapid response terrorist threats

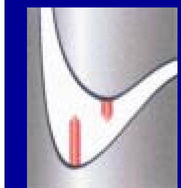
….and how they can be applied to niche applications III

Instrumentation

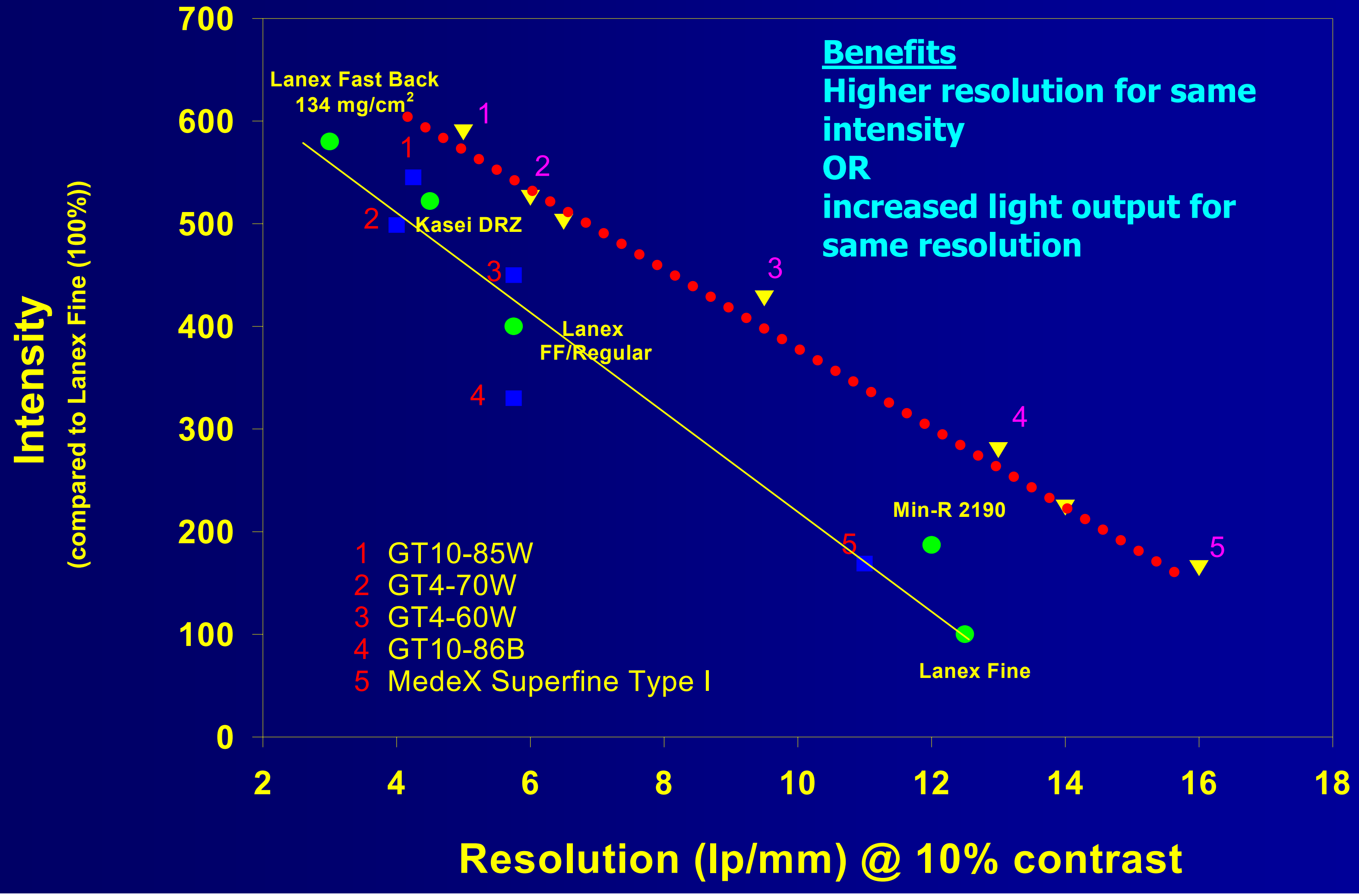
- Neutron scintillators for MWD oil well logging
- High resolution for state of the art TEM digital imaging systems
- CsI:Tl for dental x-ray applications and oxysulfide phosphors for panoramic imagers
- Alpha/beta detectors for health physics
- Y_2SiO_5:Ce, Gd_2SiO_5:Ce, YAP:Ce, YGG:Ce, YAG:Ce for mass spectrometry
- CdS:In, ZnO:Ga fast scintillators (2ns) for TOF mass spectrometry

X-ray scintillators

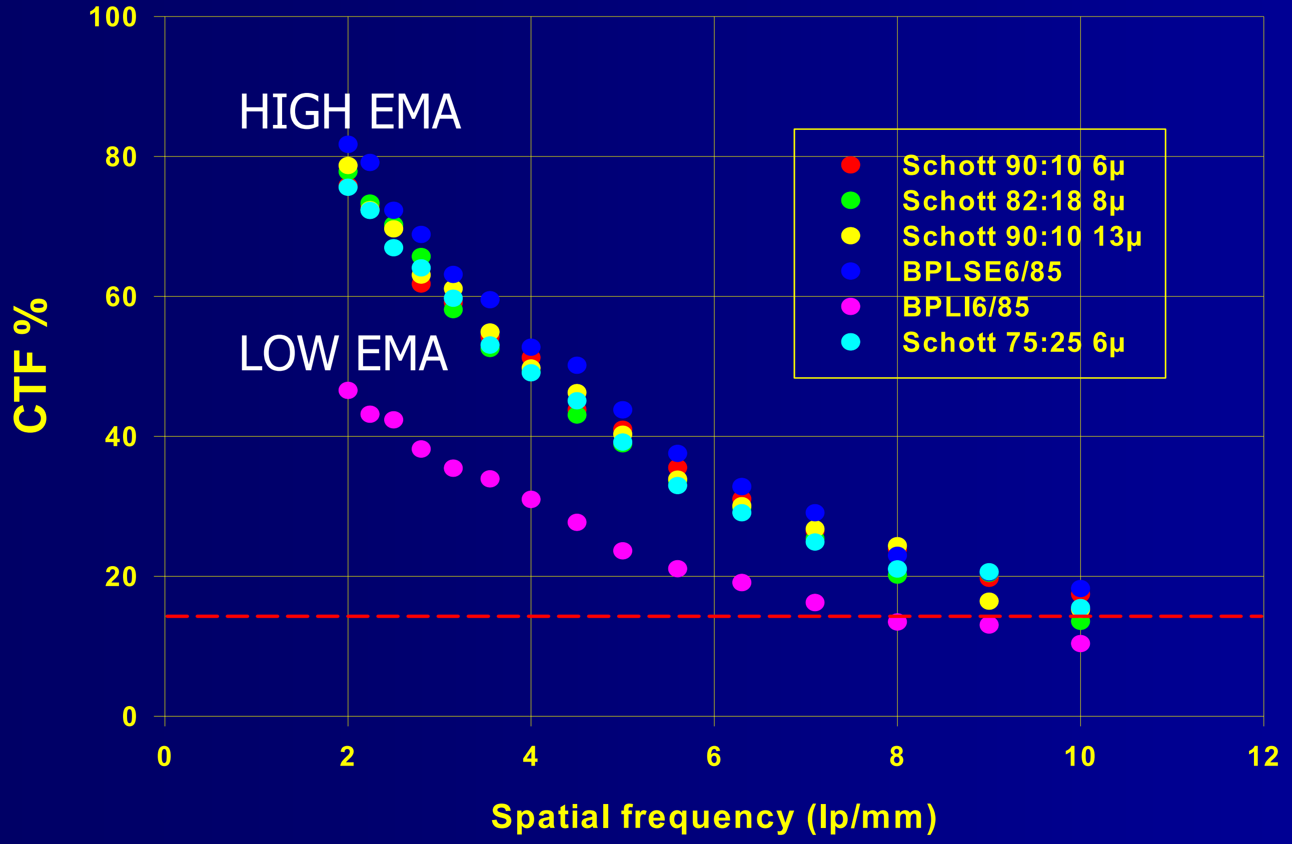
- X-ray Intensifying Screens – A launch of a new series of oxysulfide screens with world class imaging performance.
- CsI:Tl on fiber optics – Xio range incorporated into digital dental x-ray systems
- Fast decay phosphors for security – Pr doped
- High gain screens for MeV imaging
- 3D-RID – melt detectors in silicon and glass devices. Depression of melt point to converge technologies.



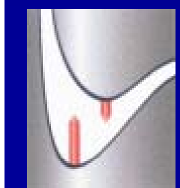
S-type scintillators



CTF measurements of different fibre optic types with CsI coating

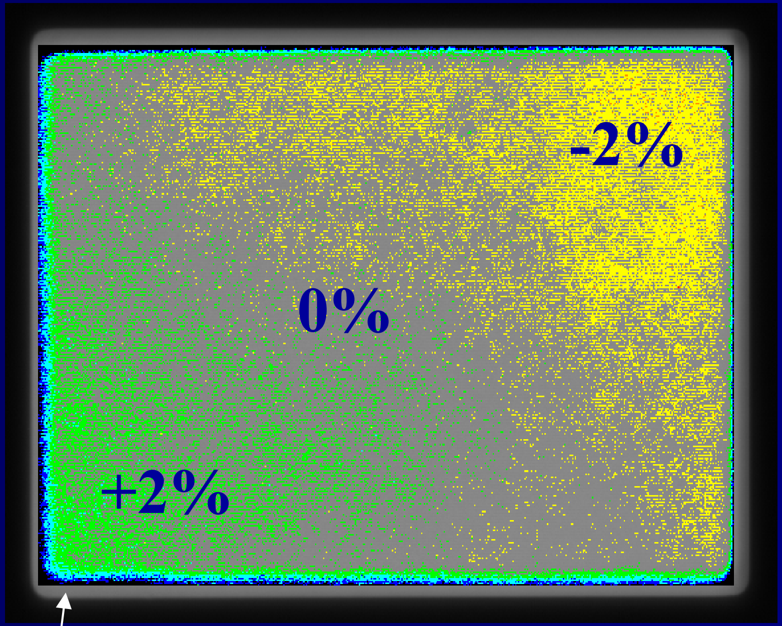


Schott 90:10 (6)
Incom BPLSE 6/85
Schott 75:25 (6)
Schott 82:18 (8)
Incom BPLI 6/85
(very poor low spatial Frequency)



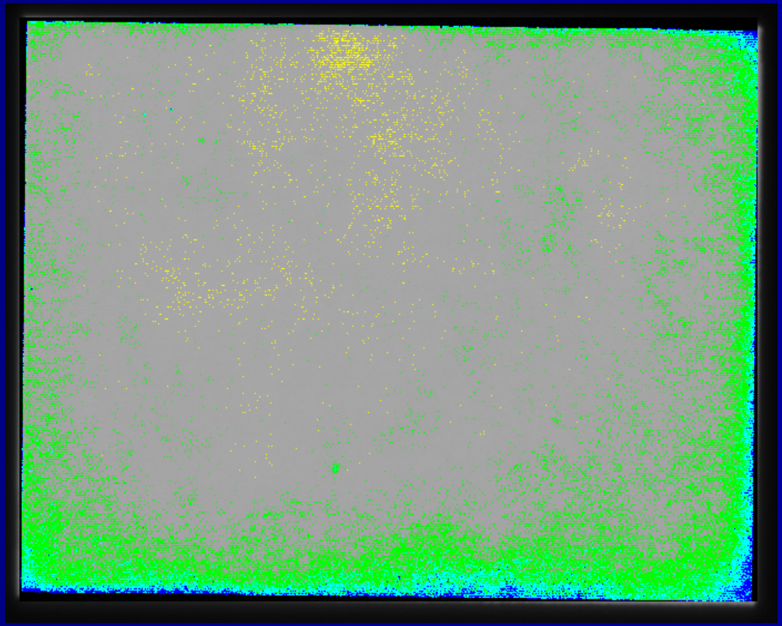
High uniformity CsI with excellent edge characteristics

Hamamatsu
HR

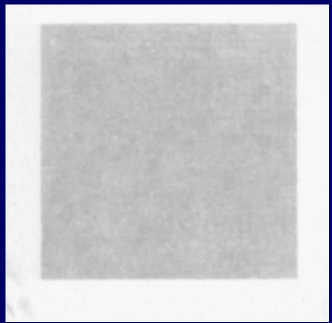


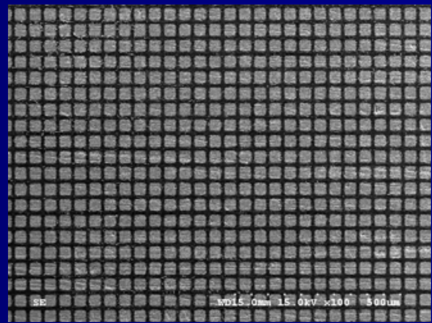
Significant inactive
Edge area

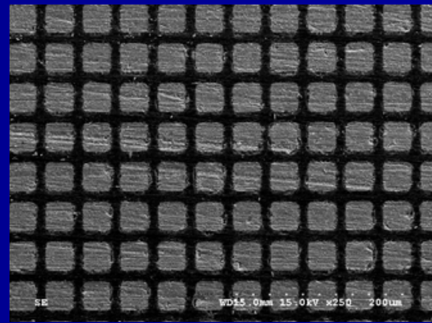
Applied Scintillation
Xio F1



CsI:Tl Filled pores



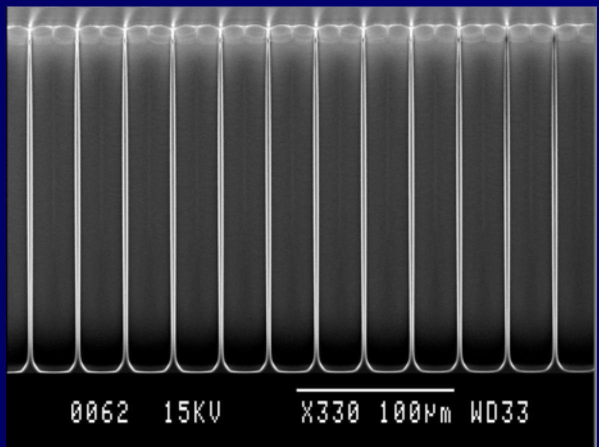




20mm

1.25 mm

500µm



Etched structures courtesy:
Jan Linnros/Xavier Badel –
KTH Stockholm

Neutron imaging and detection

- Commercial applications
  - MWD Oil well logging
  - Gemstone detection and imaging
  - NDT (hydrogen inclusions in complex metal casts)
- Fundamental and applied physics
  - Detectors for neutron spallation sources
  - Neutron radiography
  - Planetary studies

Neutron reaction in screen and glass

The process for neutron capture in a $^6LiF/ZnS:Ag$/polymer screen is by reaction of a thermal neutron with ^6Li atom.

$$^6Li + n \rightarrow {}^3H + {}^4He + 4.71\ MeV$$

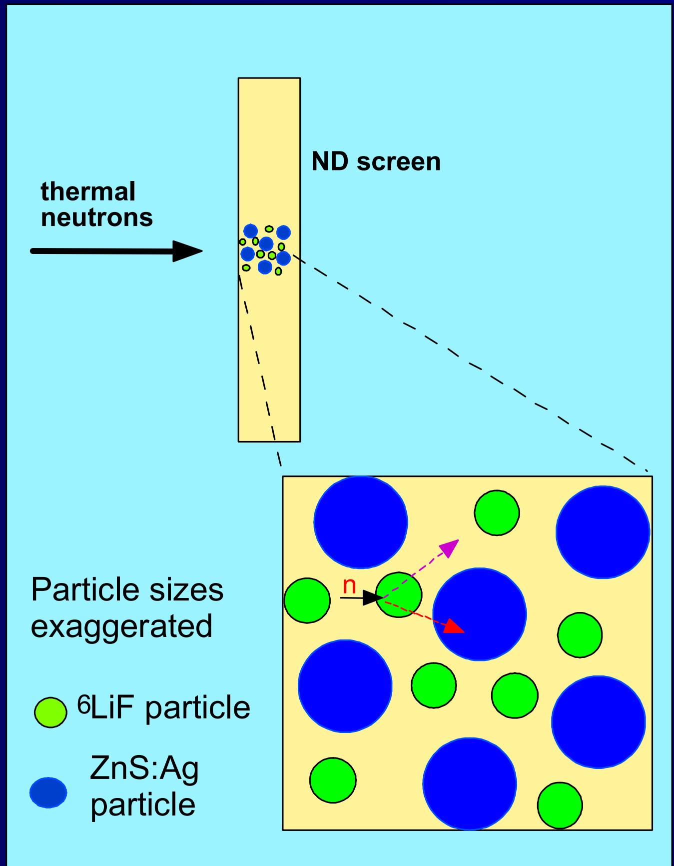
The probability of interaction of a thermal neutron with a screen is dependent upon the number of ^6Li atoms in a fixed volume.

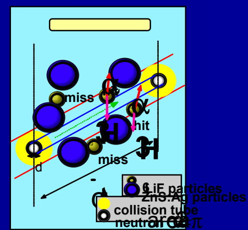
The neutron attenuation coefficients of any material can be determined using the following relation,

$$I = I_o \exp(-N\sigma t)$$

where
- t is the thickness of the material
- σ is the atomic cross section in barns
- N is the number of ^6Li atoms per cm^3
- I_o is the incident neutron flux
- I is the transmitted neutron flux

Diagrammatic representations of physical processes occurring in a Li^{6}F/ZnS neutron detection screen





Benefits of neutron screen

Benefits

- High n/γ sensitivity 10^{-7} -10^{-8} in ISIS detectors at RAL: due to improved phosphor purity.
- ^{6}Li reaction gives approx 68 times more energy per event than ^{157}Gd and couples efficiently into luminescent process.
- Intrinsic efficiency of phosphor is high.
  (Gd_20_2S ~14%; ZnS:Ag ~23%)
- λ_{em} at 460nm gives matched spectral output for standard bialkali and many other PMTs
- Excellent imaging performance – 6 lp/mm at 10% MTF

Drawbacks

- Reduced neutron absorption compared to Gd screens
- Escape of light more difficult from thicker screens, may require angular use to neutron increase path length.

Neutron detection

GEM module from ISIS: courtesy N.J. Rhodes

Applied Scintillation Technologies ND scintillators ($^6LiF/ZnS$) populate significant number of detector modules at the ISIS pulsed spallation source at the Rutherford Appleton Laboratories,

e.g. SANDALS:
GEM:
HRPD:
ENGIN-X:

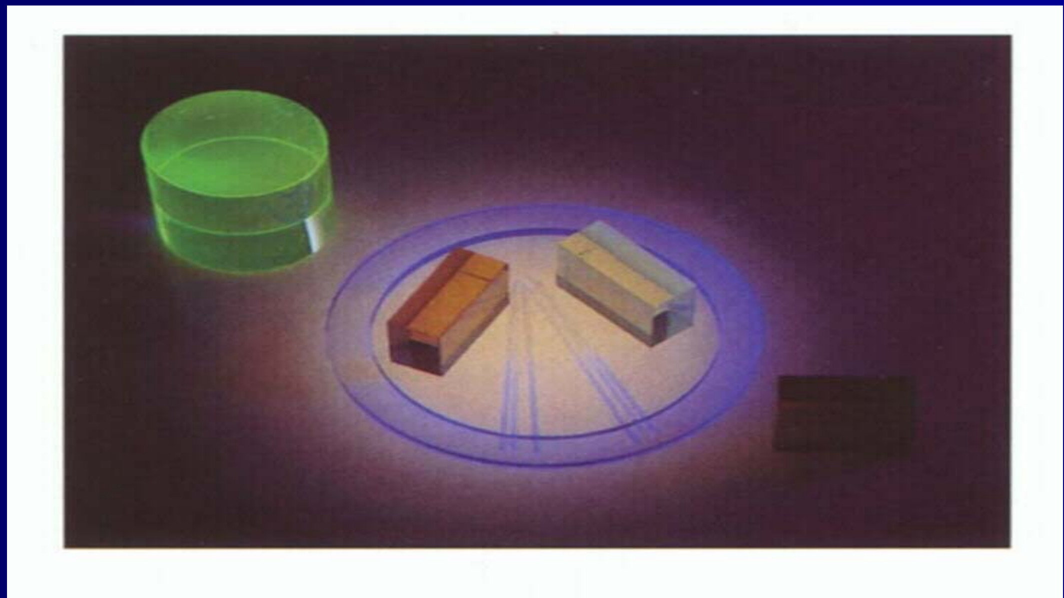
2nd Target station detectors for 2008
WISH?
NIMROD?

Ce- doped Scintillation Glass

- extremely robust
- resistant to all organic and inorganic chemicals except hydrofluoric acid
- can easily operate in temperatures ranging from -200°C to 250°C.
- allows them to be used in conditions which prohibit the use of many other scintillation materials.

Fabrication of complex glass components

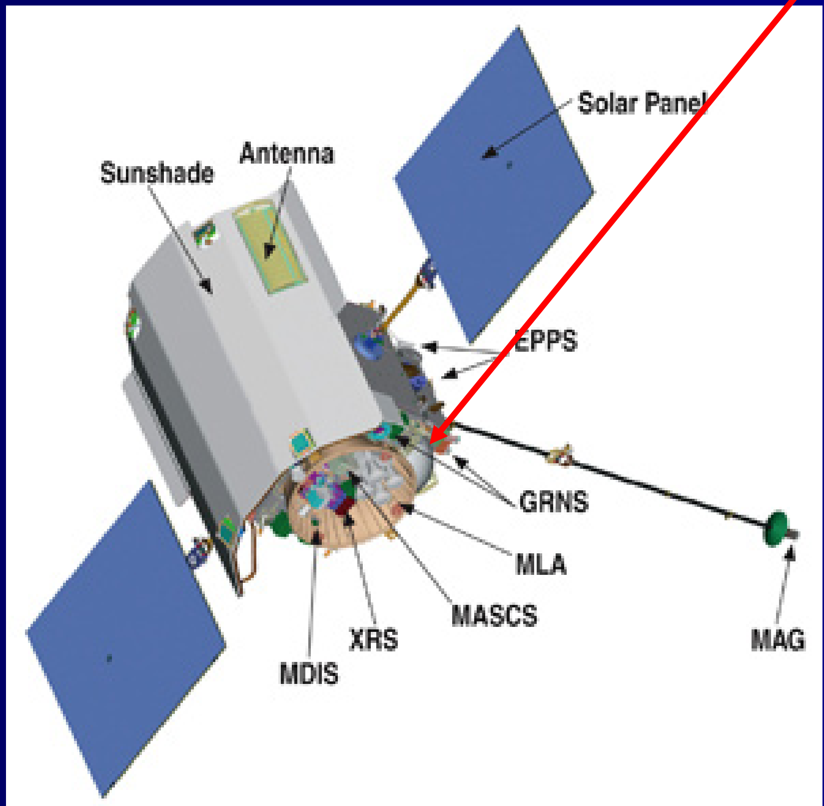
- Luminescent glass is difficult to manufacture in complex shapes
- Variety of complex detector configurations can be manufactured to a variety of finishes



MEcury Space, Space ENvironment, GEochemistry and Ranging

JHU-APL NASA MESSENGER

– Gamma Ray and Neutron Spectrometer (GRNS)



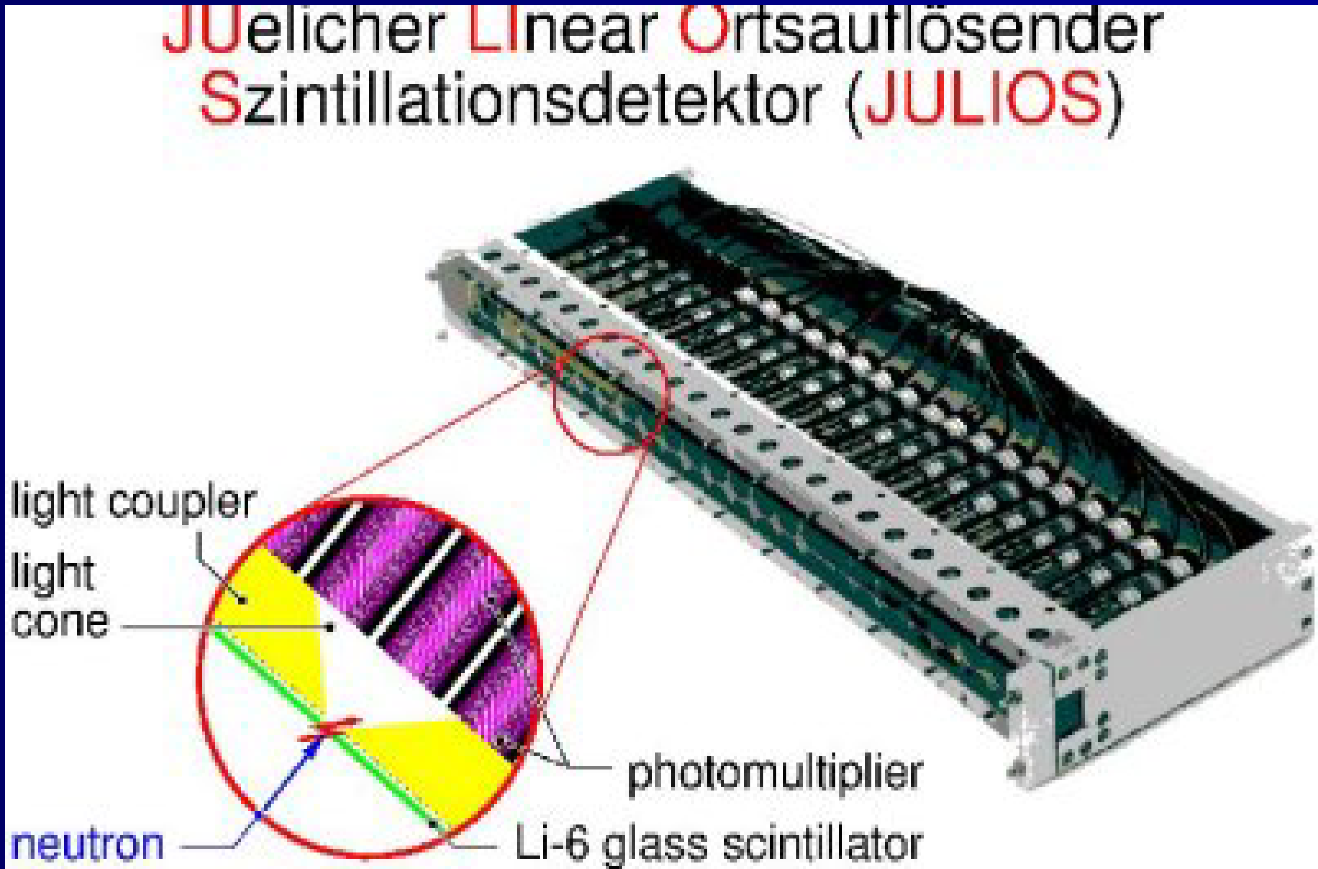
GRNS detector
Ed Rhodes – JHU-APL

GS20 scintillators

+/- 5% pulse height matched

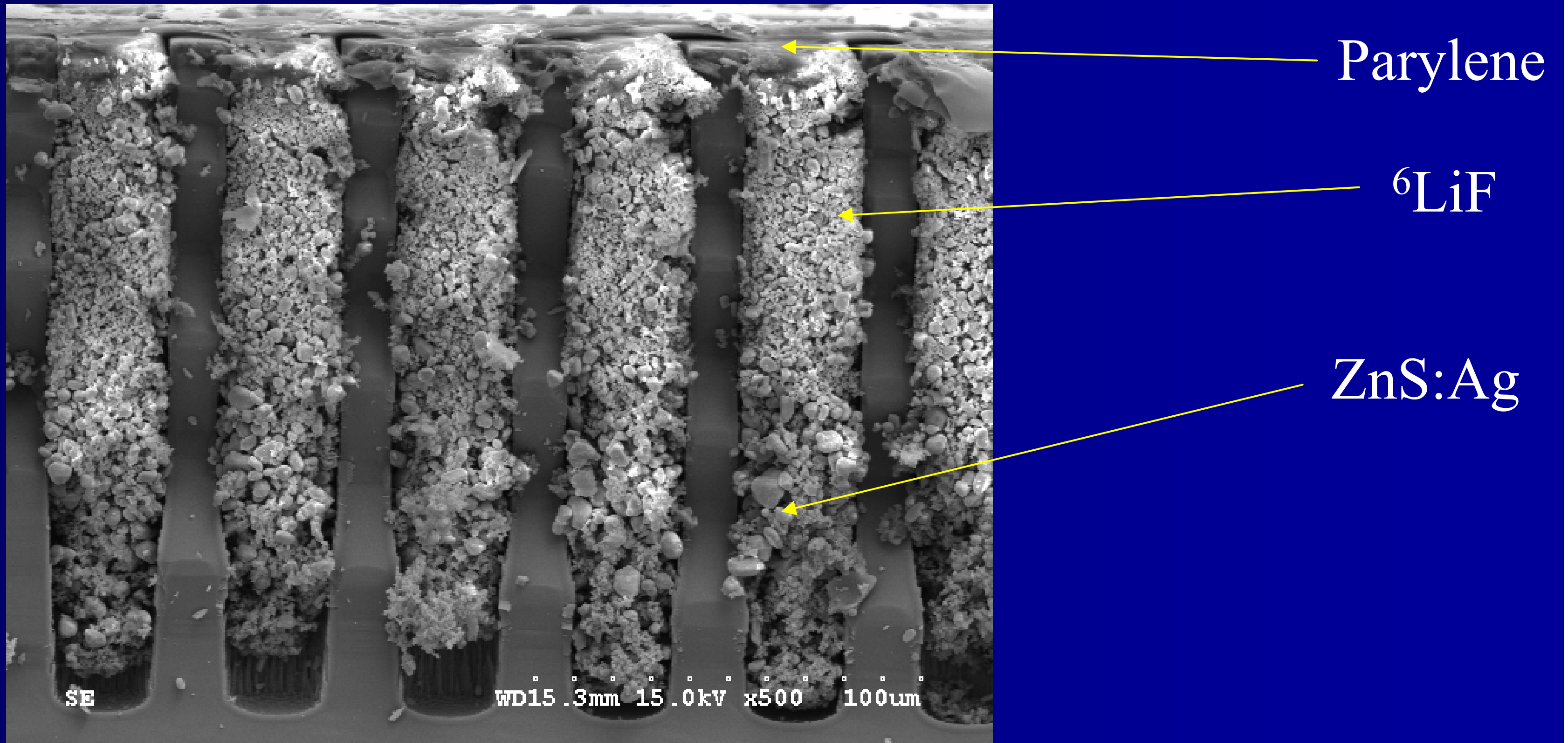
This instrument will detect gamma rays and neutrons that are emitted by radioactive elements on Mercury's surface or by surface elements that have been stimulated by cosmic rays. It will be used to map the relative abundances of different elements and will help to determine if there is ice at Mercury's poles, which are never exposed to direct sunlight.

Applications of lithium scintillator glass - - Positional sensitive detection



Courtesy: Dr. Ralf Engels – KFA Julich

Neutron sensitive 3D scintillation structure

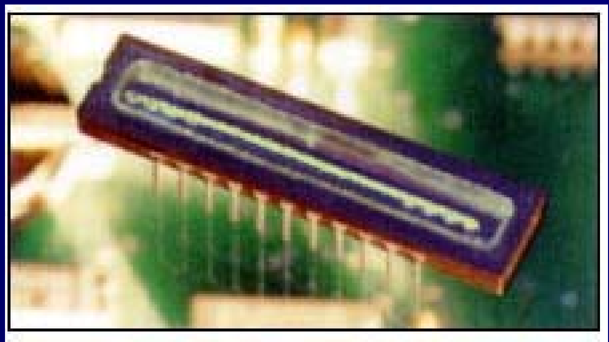


- ^{6}LiF/ZnS:Ag shows compact and complete filling within pore structures.
- Parylene binds the phosphor to the pore and also adds a conformal cap layer to the pore.

UV detectors and imagers

- Enhancement of spectral response of silicon linear diode arrays
- UV passive converters for bioscience applications – Gel documentation
- Wavelength specific applications for specific dyes for proteomic and genomics (e.g. Cy3, Cy5, Alexa, etc)

UV Enhancement of diode arrays



Manufacturer	Description
Sony	ILX 511
Sony	ILX526A
Sony	ILX 554B
Toshiba	TCD1201D

Extension of functionality of silicon devices using inorganic and organic phosphors

human eye sensitivity

standard silicon sensitivity

modified silicon

back-thinned device sensitivity

Sensitivity range of AST’s low cost spectrally extended silicon devices - ExtendUV

150 200 250 300 350 400 450 500 550 600 650 700 750 800 λ (nm)

V-UV	UV-C	UV-B	UV-A	Visible	Near infra red

Vacuum UV

applications:
semi-conductor
metals analysis

Germicidal UV

applications:
curing
bacterial control
EPROM erasing
industrial testing

Solar/sun-tan UV

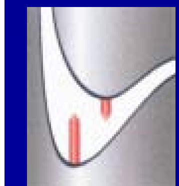
applications:
genetic finger print
bio-sciences
sun tan

Black light

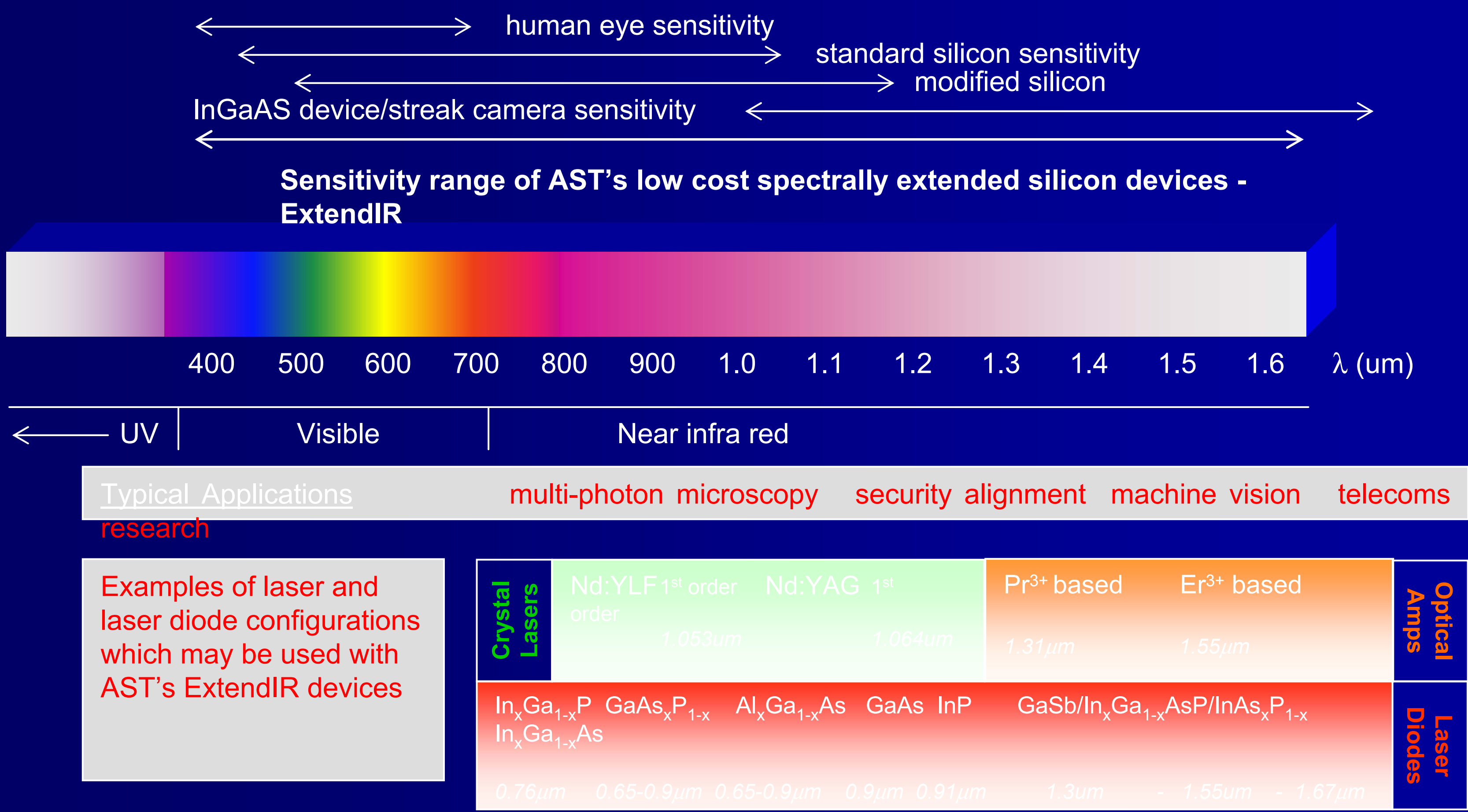
applications:
non destructive test

UV Lasers	ArF (3rd)	KrF	Nd:YAG (4th)	XeCl	HeCd	N2	Nd:YAG
	193nm	248nm	266nm	305nm	325nm	337nm	355nm

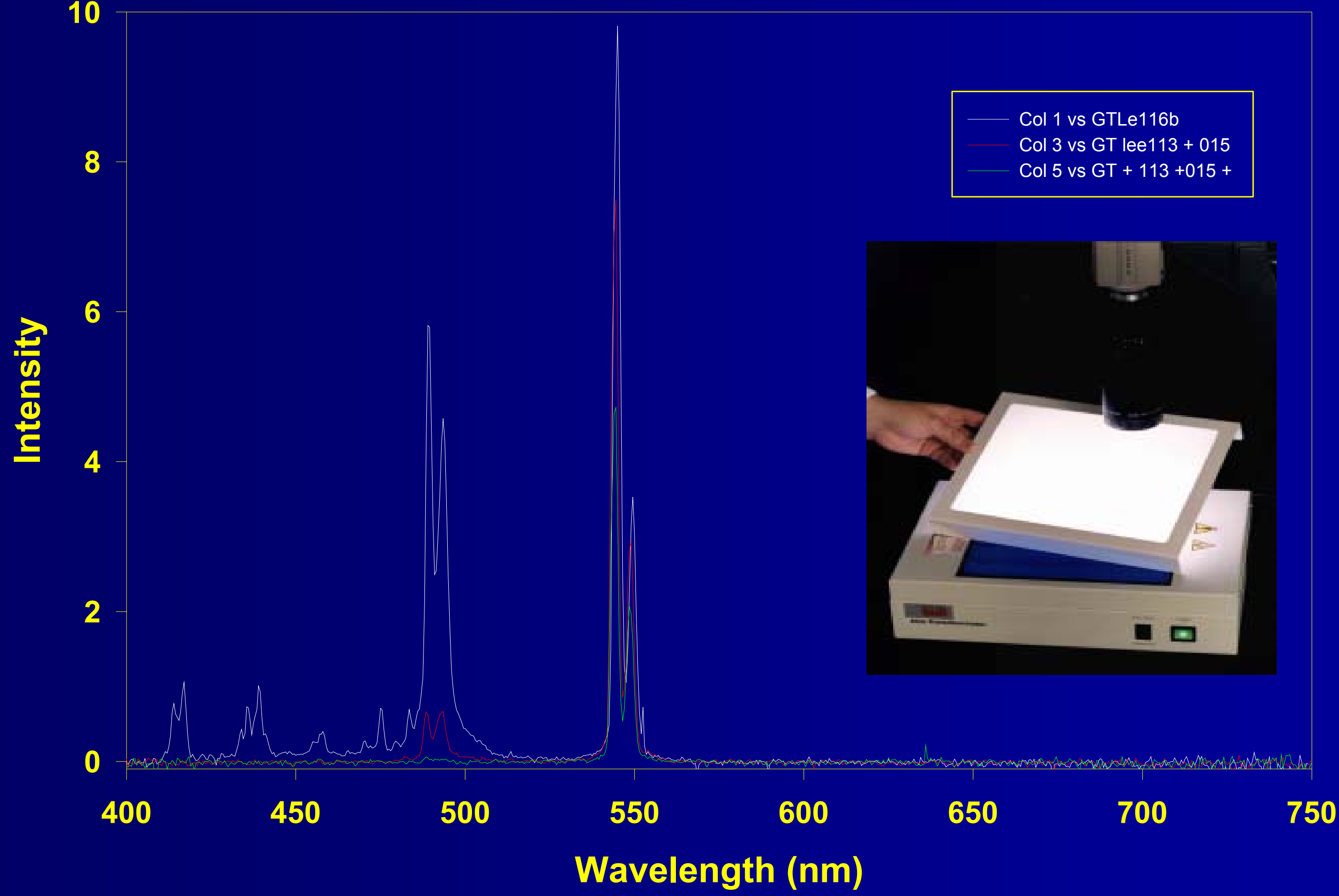
Hg Lines				
	185nm	254nm	302nm 312nm	365nm



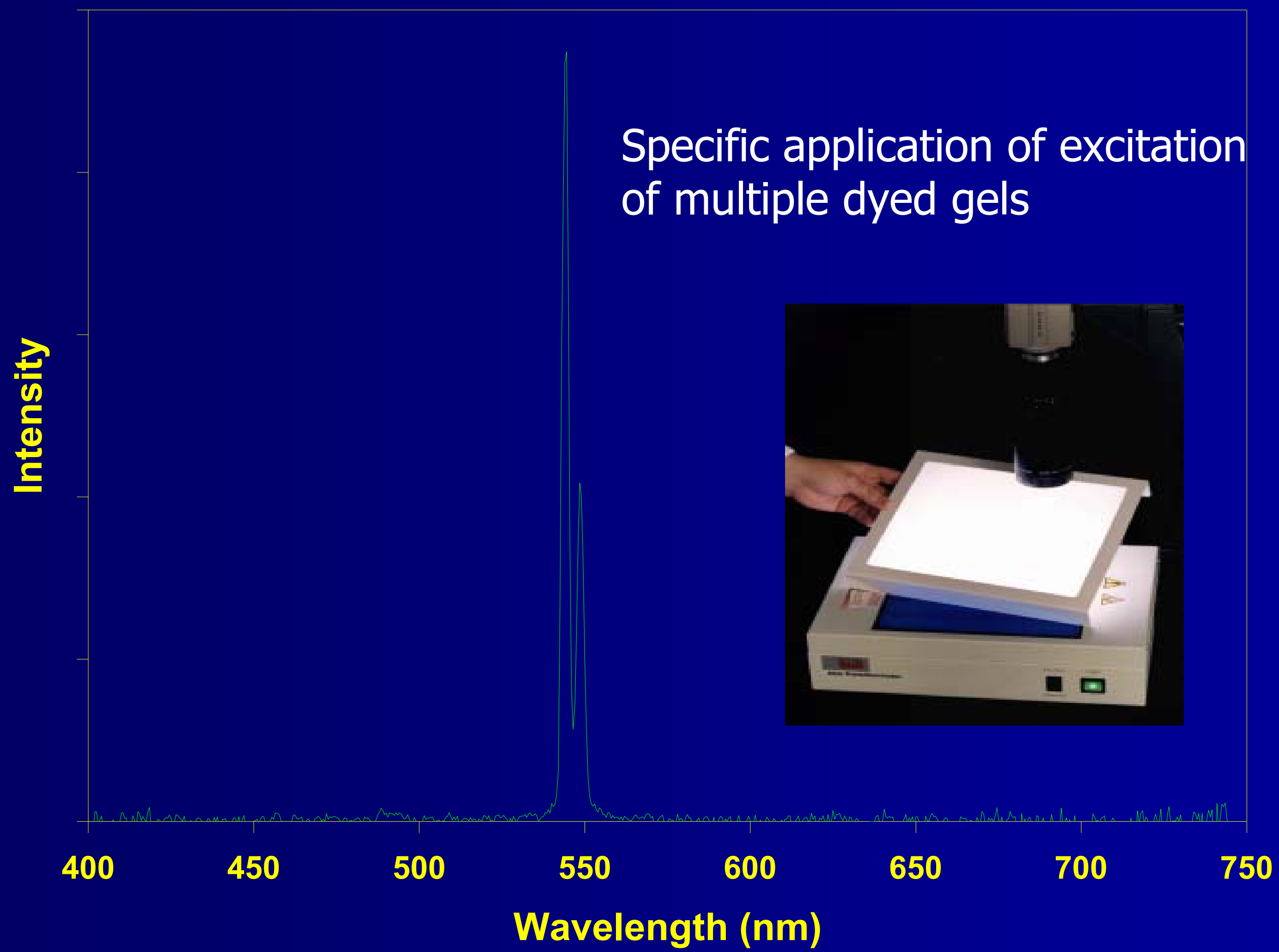
Extension of functionality of silicon devices using inorganic and organic phosphors



Filtration of non-specific wavelengths in $Gd_2O_2S:Tb$



Emission spectrum of Visi-Dye Green following filtration

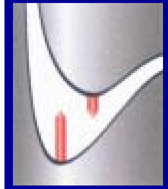


Specific application of excitation of multiple dyed gels

Summary

- Phosphors and scintillators have a very widespread practical application

- There are so many different flavours



Acknowledgements

- Present AST development group members
  - Steve Moody
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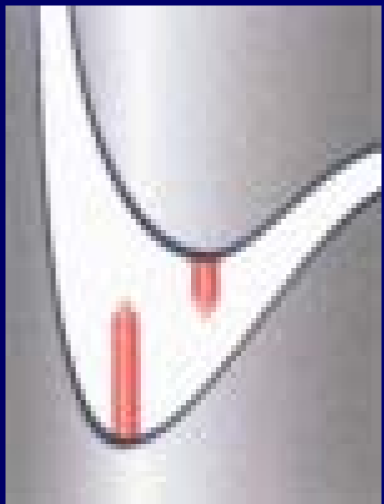
  - Dr Xiangdong Qu
- Partners in 3D-RID consortium
  - University of Glasgow, STS, Metorex, Mitthogskolen, KTH Stockolm, CTU,University of Freiburg
- Other collaborators
  - University College London, Kings College London, RAL,
  - All the unnamed key account partners

Thank you for listening.....any questions?



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