Instrumentation Department Forum
Great Malvern - 17/18 September 2001

Day 1

Time	Speaker	Title
12:00	Mike Johnson	Welcome and Introduction
12:30		Lunch
14:00	Nigel Rhodes (ISIS)	Neutron Detectors at ISIS
14:30	Mike Sandford (SSTD/CFI)	Instruments for fundamental physics measurements in space
15:00	Ian Tomalin (PPD)	Introduction to Particle Physics at CMS
15:30		Coffee
16:30	Rob Halsall (ID)	Data Acquisition Strategy
17:00	Frances Quinn (SRD)	Detector requirements for surface science experiments
17:30	Vic Pucknell (SND)	Equipment Control and data acquisition for nuclear physics
18:00	Barry Dobson (ID)	Robots: The way forward for increasing experimental automation
18:30		Session ends
19:15		Dinner

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Day 2

Time	Speaker	Title
9:00	Renato Tuchetta (ID/CFI)	Overview of Monolithic Active Pixel Sensors
9:30	Doug Reading (ID/CFI)	Overview of current Micro Channel Plate
10:00	Richard Stephenson (ID/CFI)	Overview of gas detectors
10:30		Coffee
11:00	Rob Lewis (SRD)	CASIM - an update
11:30	John Simpson (SND)	X-ray Sensors and Instrumentation
12:00	Jon Headspith (ID)	XSTRIP: technology transfer to SR research
12:30		Lunch

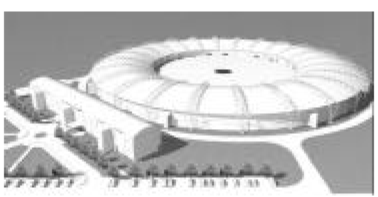
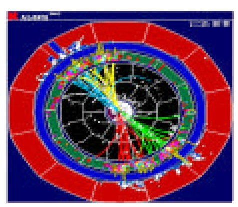
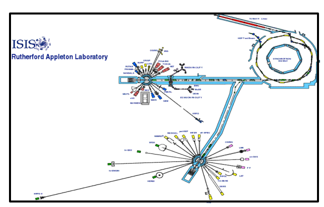
FOR INSTRUMENTATION DEPARTMENT STAFF ONLY

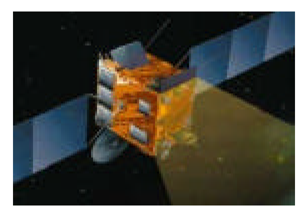
Time	Speaker	Title
14:00	Mr David Hall	"Customer Care"
15:45		Coffee
16:00		Buses depart

Centre for Instrumentation

Instrumentation at CLRC is currently a sum of its parts.

- Create an 'Instrumentation College' with both CLRC and University staff as members
- Develop joint SR and ISIS data acquisition & analysis strategy
- technical workshops
- strategic R&D programmes

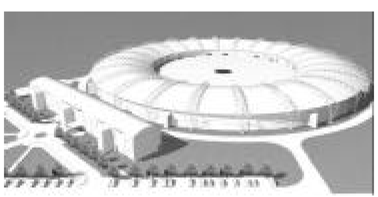


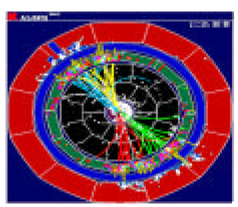
Achieving the goals…

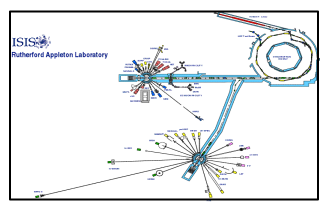
Basic Technology bids - 8

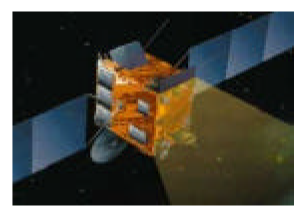
PRIMA (MAPS for science grade sensors)	2.5
Column Parallel CCDs	1.0
HEXT	1.0
IMPRESS -Liverpool	0.8
Parallel electron Detector –Aberystwyth	0.2
Cryo detector –Leicester	0.5
MRI/PET –Cambridge	0.8
QUEST –Manchester	0.5

TOTAL £7.3M (~ £2M pa)









NEUTRON DETECTORS AT ISIS

Neutrons

Provide information on the structure and dynamic of materials on an atomic/molecular scale

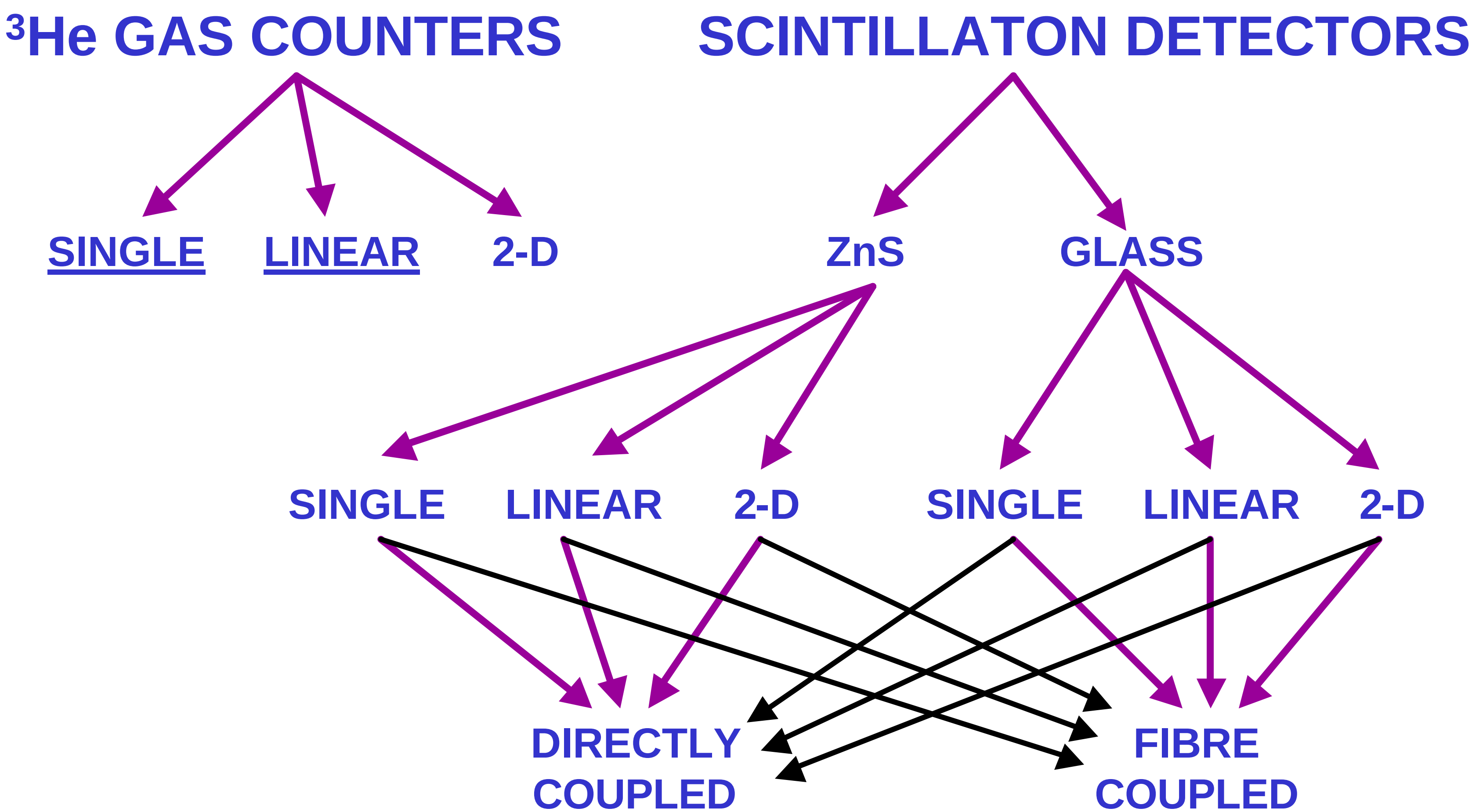
Ideal probes for Condensed Matter Research

- **Zero charge – highly penetrating**
- **Low KE – probe atomic / molecular dynamics**
- **Etc…**

Non idealised particles for detection

- **Zero charge – generally weak interaction**
- **Low KE – generally weak interaction**

Require a nuclear converter


³He GAS COUNTERS
SCINTILLATON DETECTORS
SINGLE
LINEAR
2-D
ZnS
GLASS
SINGLE
LINEAR
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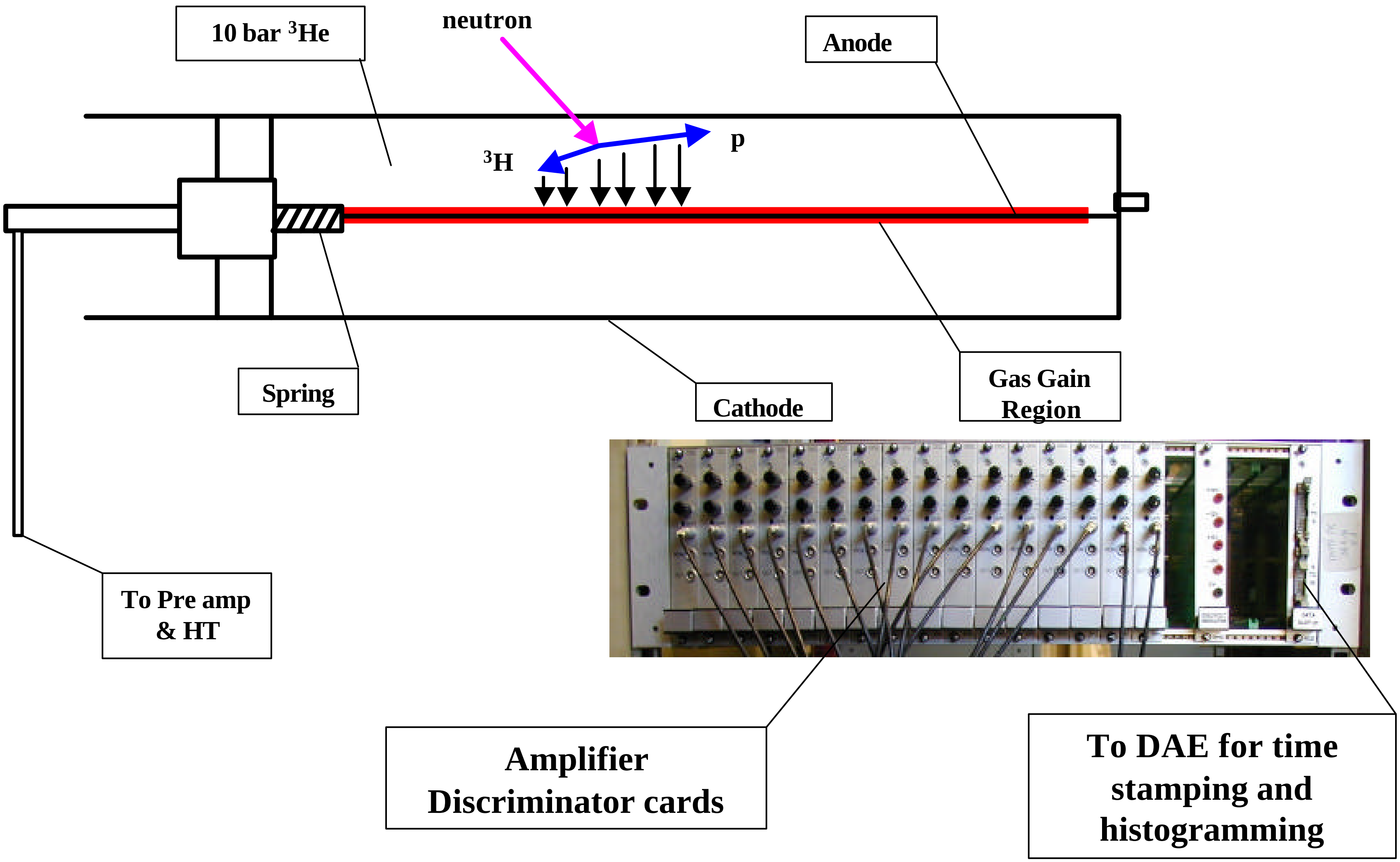
SINGLE
LINEAR
2-D
DIRECTLY COUPLED
FIBRE COUPLED

^{3}He DETECTOR OPERATION



Instruments for Fundamental Physics Measurements in Space

Why go into space for v. high precision measurements at low freqs?

Limit On Earth:

- **Low frequency seismic vibrations < 10Hz**
- **Gravitational coupling (tides, atmosphere…)**

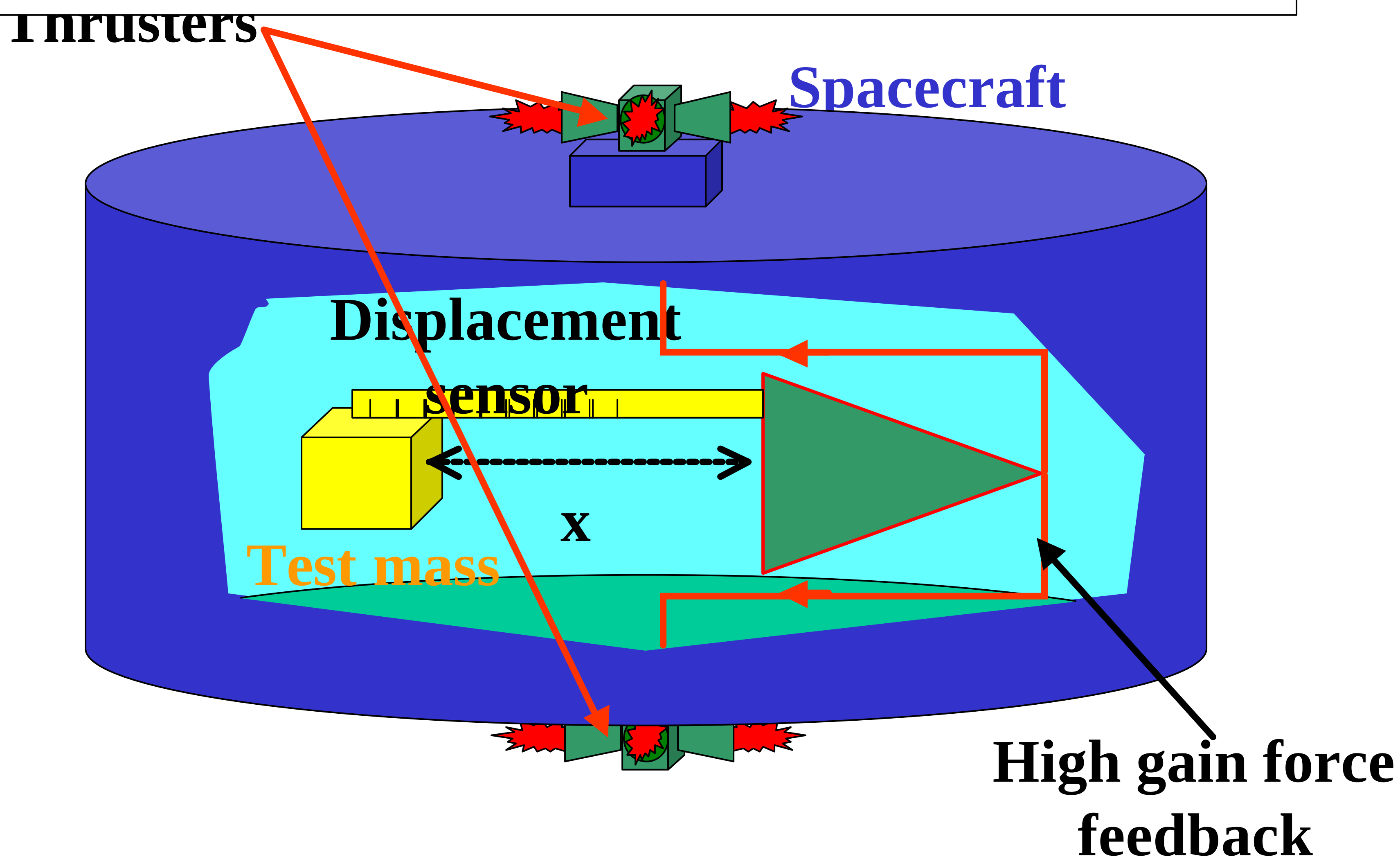
Solution - Drag-free Satellite in Earth or Solar Orbit

- **Gravitational disturbances & atmospheric drag still significant in low Earth orbit**

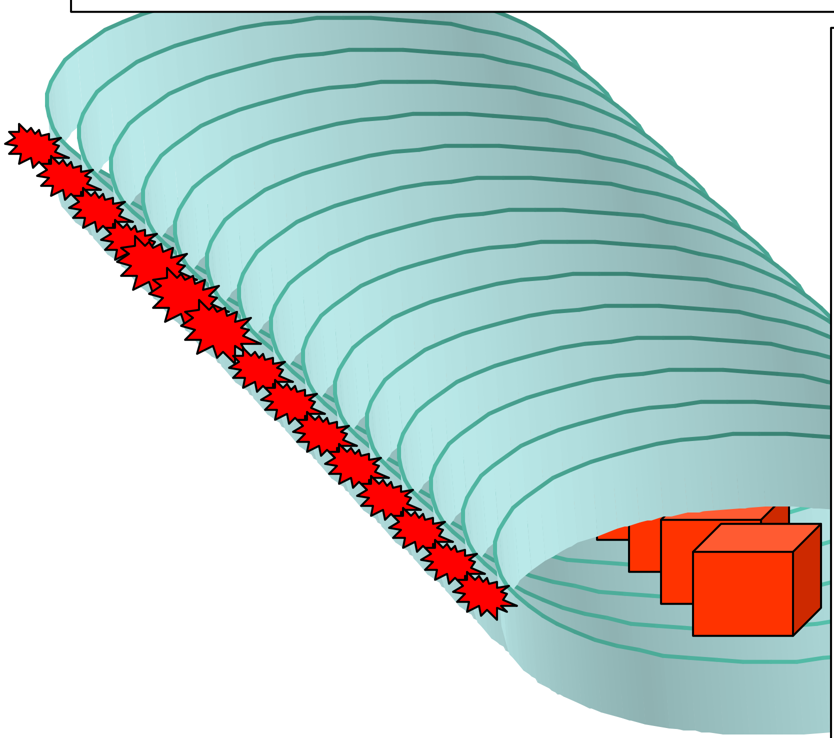
4 Space Experiments:

- **LISA** – **Gravitational Waves (2006/10)**
- **STEP** – **Equivalence Principle (2006?)**
- **HYPER** – **Atom Interferometry (?)**
- **Casimir** – **Zero Point Energy (?)**

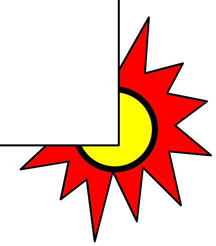
Sensing the Spacecraft Motion



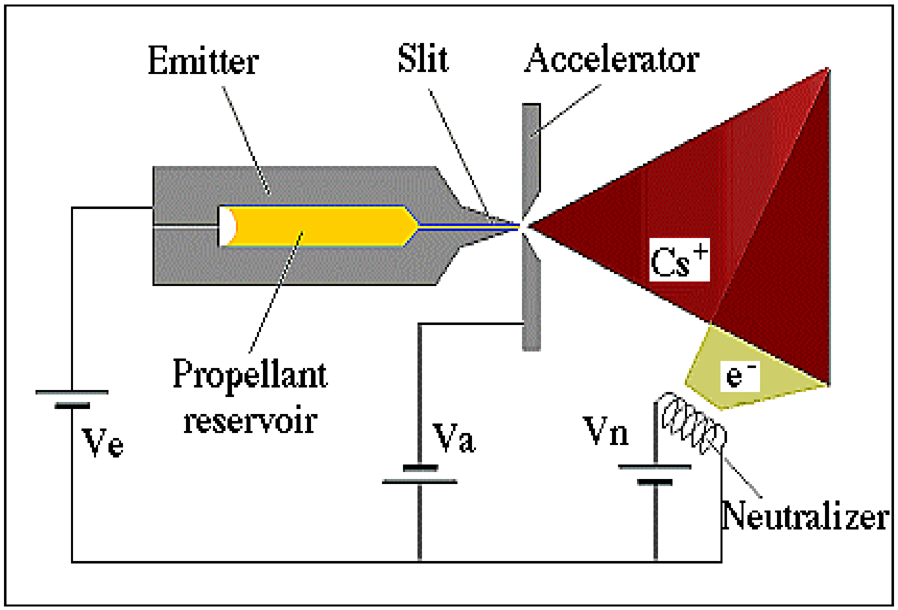
Spacecraft following the proof mass



⇒ **Drag-free control**

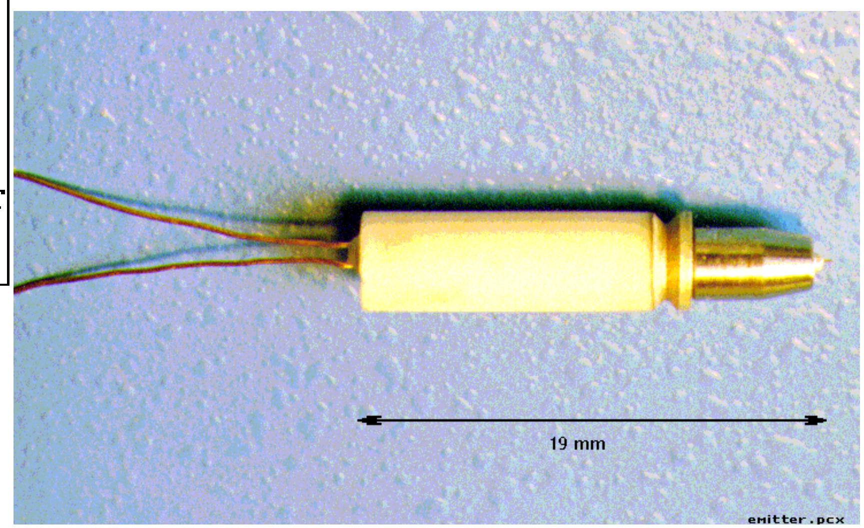


Micro-Newton FEEP Thrusters
(Field Emission Electric Propulsion)



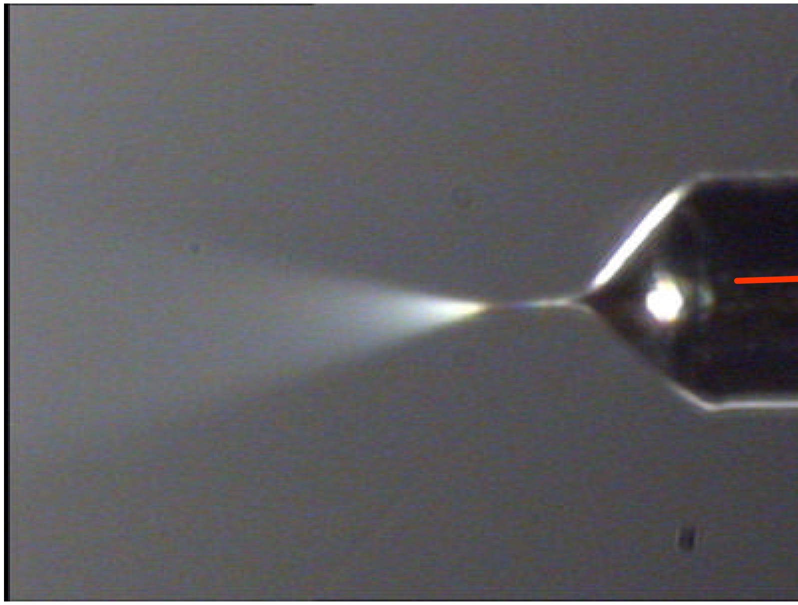
Cesium Slit

Indium Needle

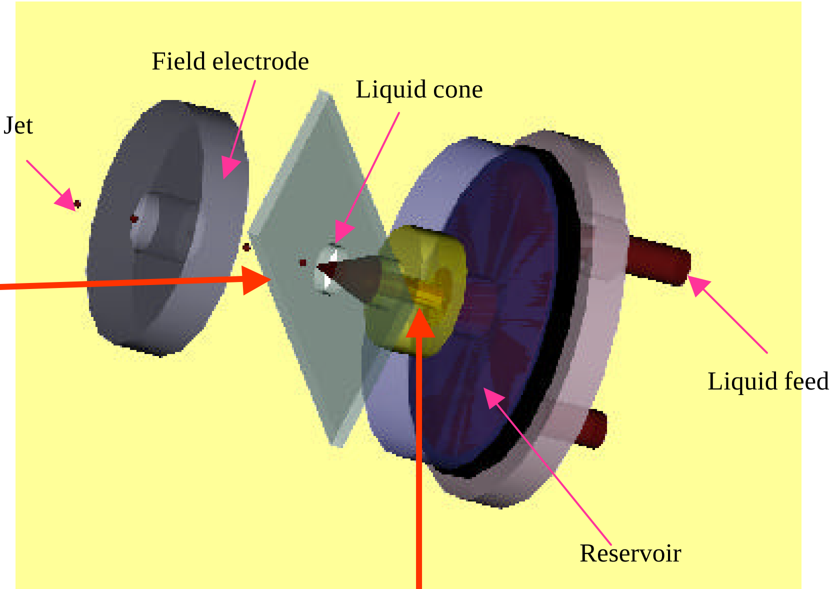


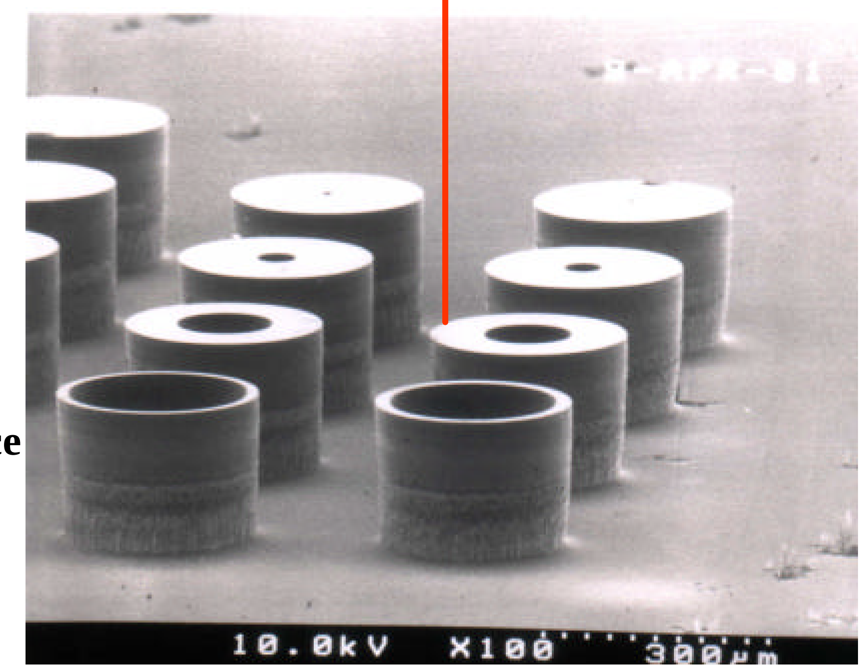
Indium FEEP emitter
Courtesy of Hans-Michael Fehringer Austrian Research Centre Seibersdorf

Electro Thruster - control of "nano" satellite, 10^{-15}g for fundamental physics in space



Electrospray demonstration from a silica capillary



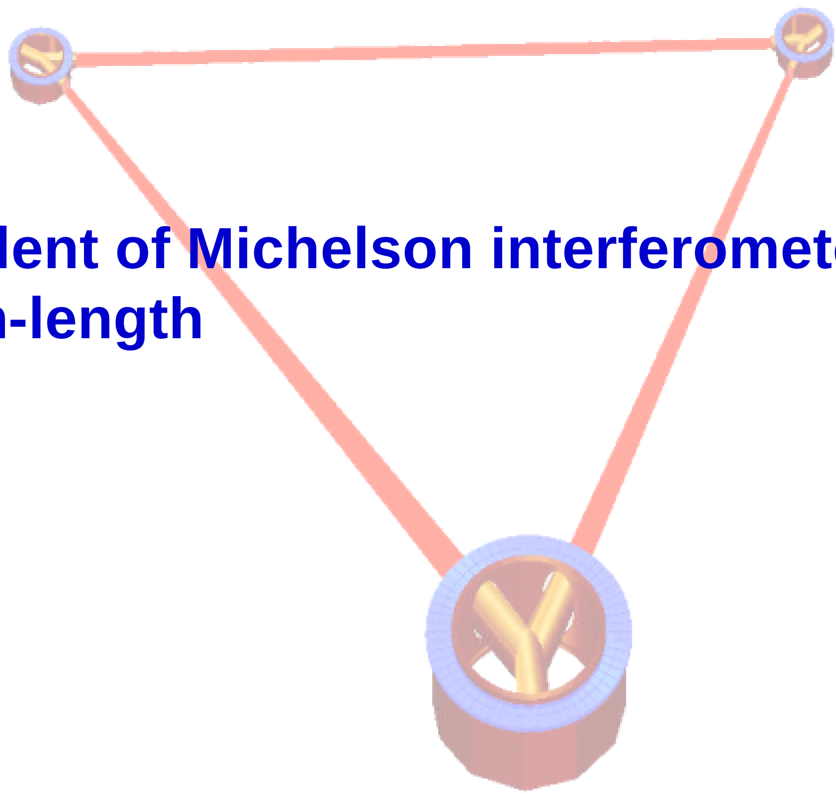


SEM picture of thruster source elements - constructed using

deep etch in silicon.

Laser Interferometer Space Antenna (LISA)

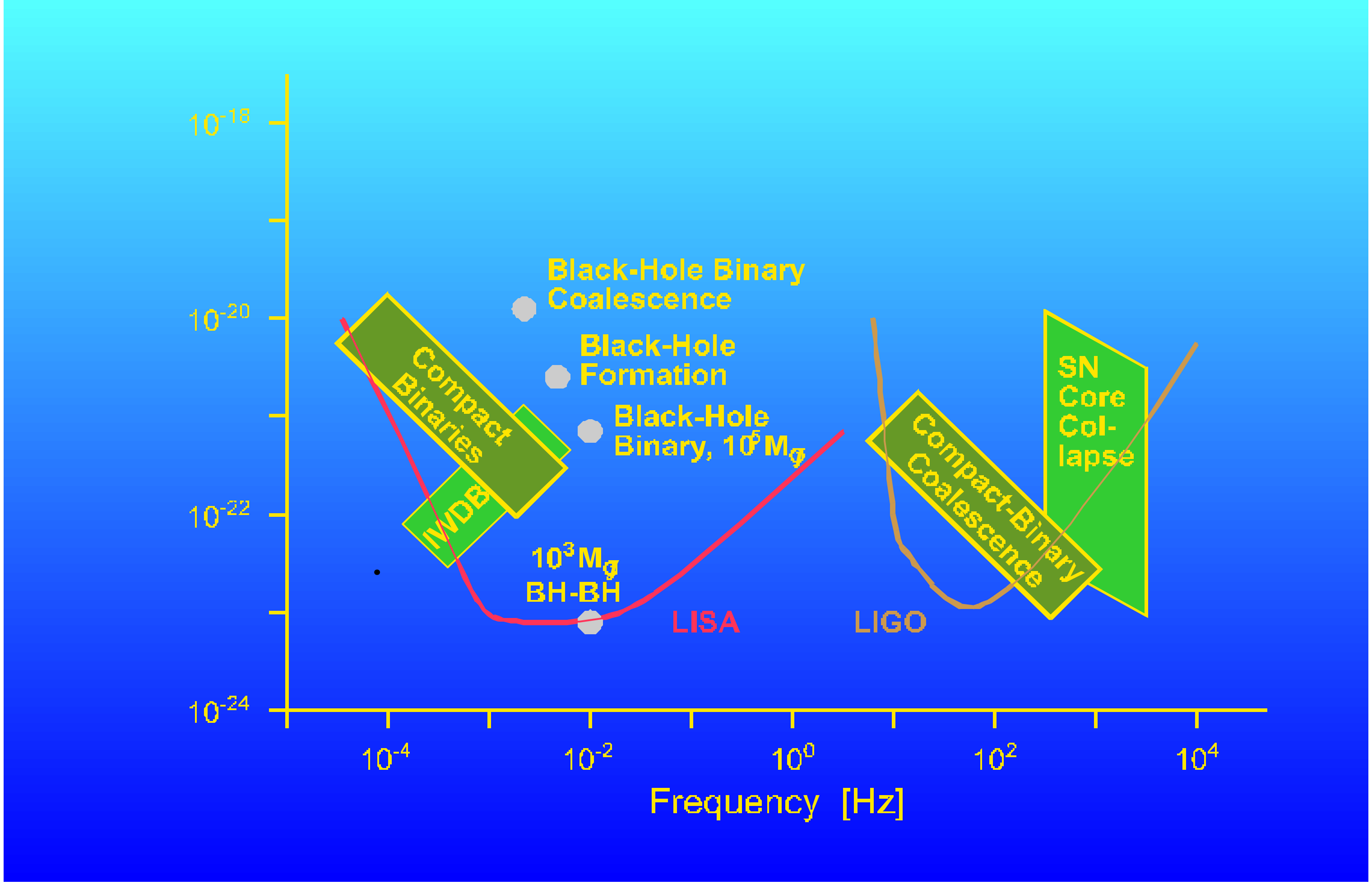
to observe low-frequency gravitational waves



- **Equivalent of Michelson interferometer with 5×10^6 km arm-length**

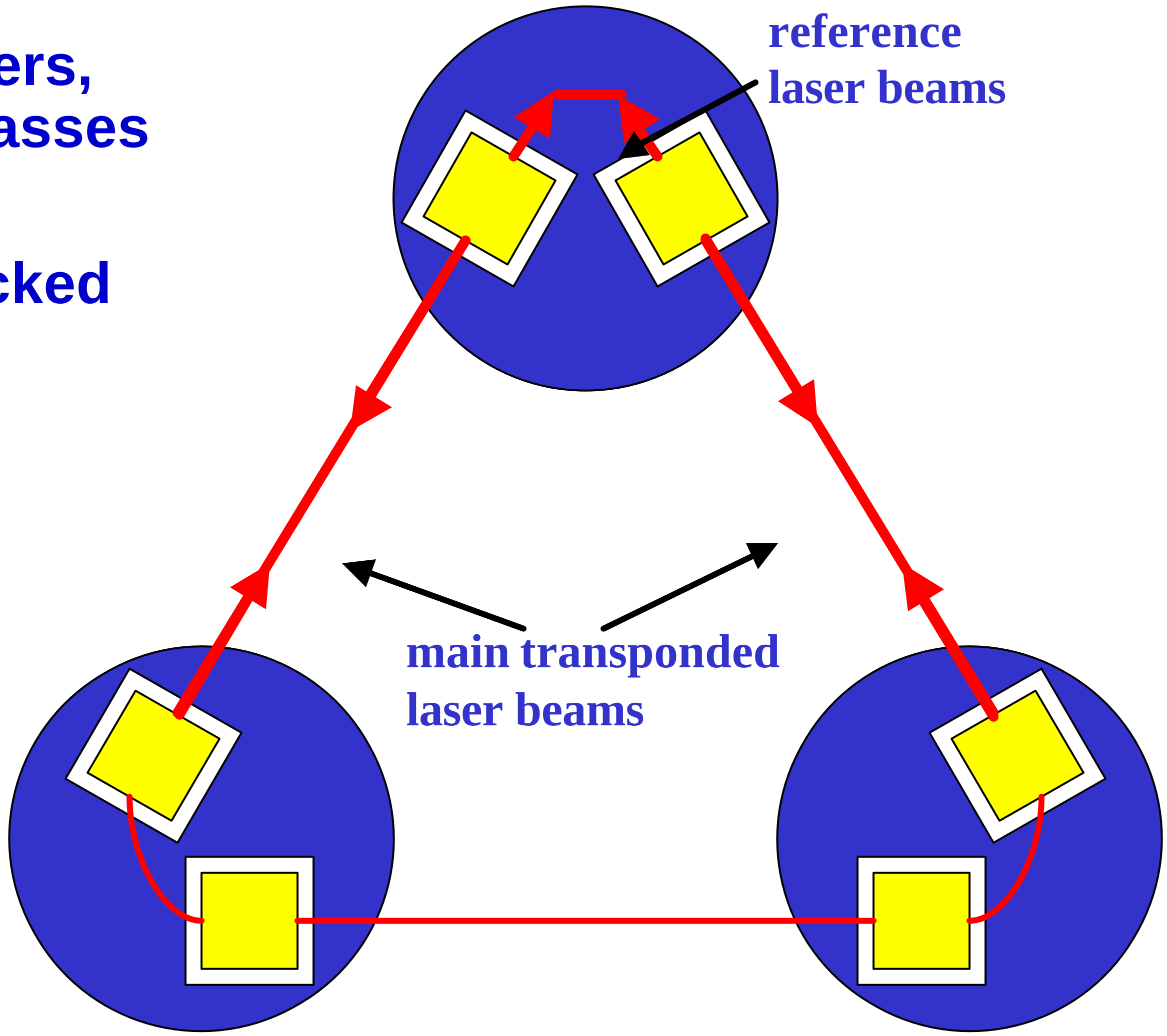
The GW Spectrum Accessible to Detectors

- **Extends over more than 10 decades in frequency**



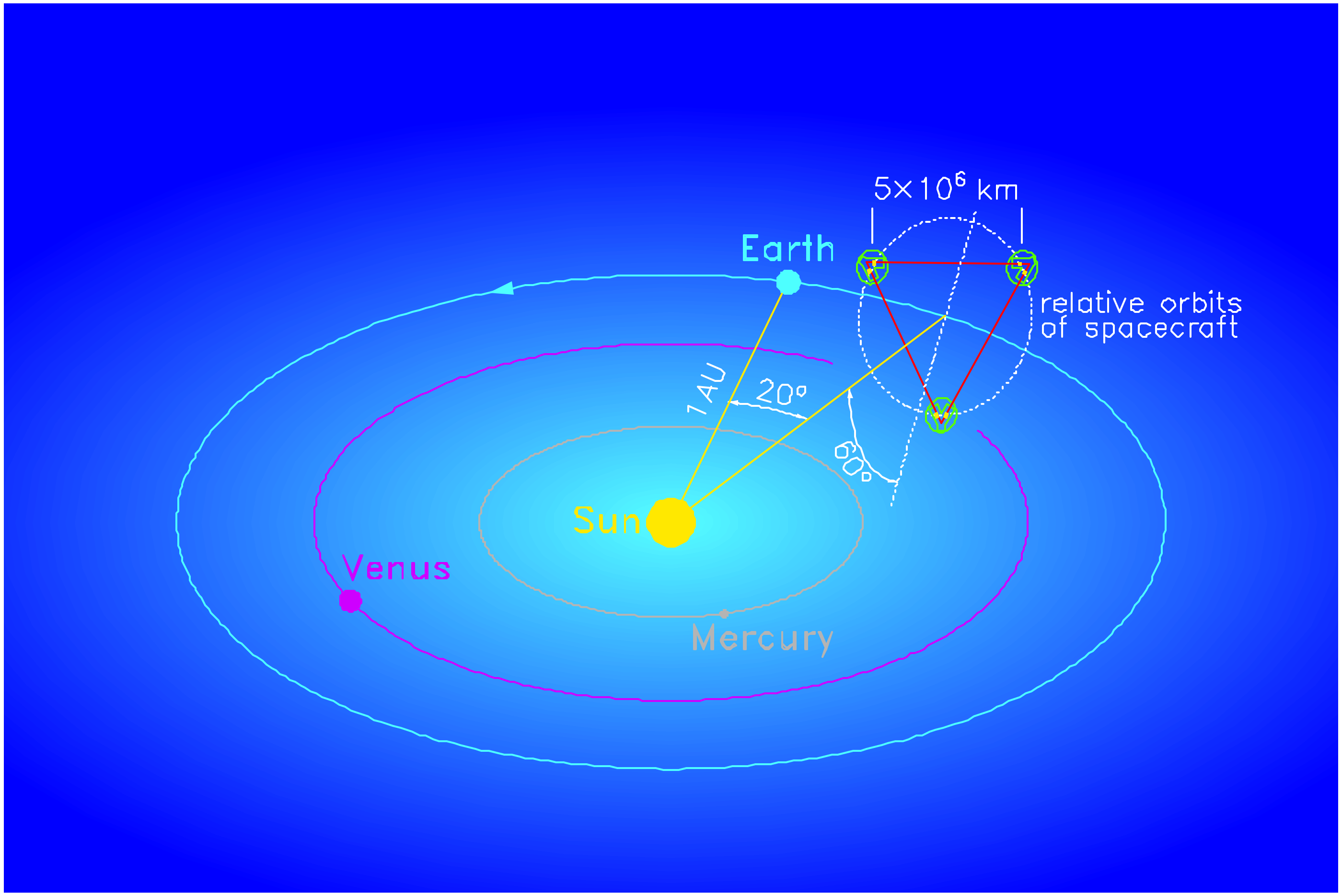
LISA Lay-Out

- **Each S/C carries 2 lasers, 2 telescopes, 2 test masses**
- **Local lasers phase-locked**
- **Lasers on distant S/C phase-locked to incoming light**



LISA Orbit

- Cluster of 3 spacecraft in heliocentric orbit
- Trailing the earth by 20° (50 Mkm)
- Equilateral triangle with 5 Mkm arms
- Inclined to the ecliptic by 60°



RAL-CFP interests in LISA

- **Technology:**
  - Interferometer Optical Bench
  - Inertial Sensor (caging)
  - Thermal Mechanical Design
  - Thruster Neutralisers (Nanotip electron emitters)
  - Miniature HV power supplies
  - Space Electronics

STEP Satellite Test of Equivalence of Inertial & Gravitational Mass

$F = m_i . a$

$F = m_g GM/r^2$

Equivalence: $m_g = m_i$

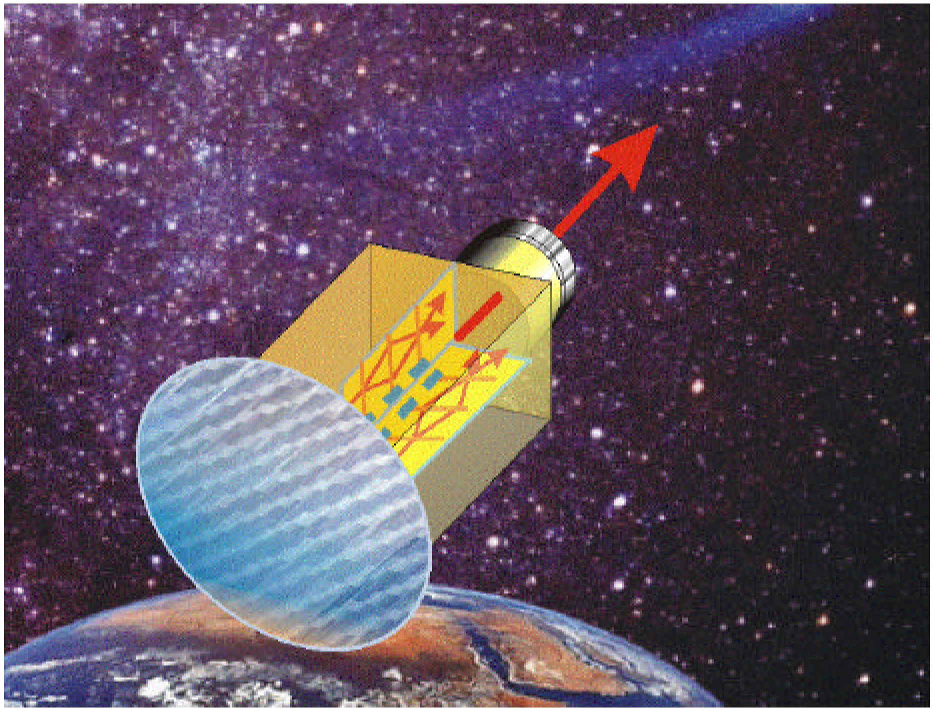
Ground ~ 1 in 10^{-13}

Space ~ 1 in 10^{-18}

Can be upgraded to look for Casimir Effect

RAL interests in STEP

- **Technology:**
  - **Cryogenic Probe**
- **Experiment Operations**
- **European & UK hardware coordination**



HYPER

- precision cold atom interferometry in space

RAL involvement:

Star Tracker Reference
System Design of mission
Subsytems

Measurement of the fine-structure constant improved by one or even two orders of magnitude to test QED

Latitudinal mapping of the general relativistic gravito-magnetic effect of the Earth (Lense-Thirring-effect)

Investigation of decoherence of matter-waves
Þ physics at the Planck scale - quantum gravity

CONCLUSIONS

- **Drag-Free spacecraft enable very small forces to be measured revealing aspects of fundamental physics**
- **LISA technology will be demonstrated ~2006 and will (?) detect gravitational waves ~ 2010**
- **STEP may investigate equivalence in 2006**
- **For the future: matter waves and Casimir force**
- **RAL instrumentation will underpin many aspects of these missions**

Particle Physics at CMS

- LHC collides bunches of protons 40 000 000 times per second ! Why ?

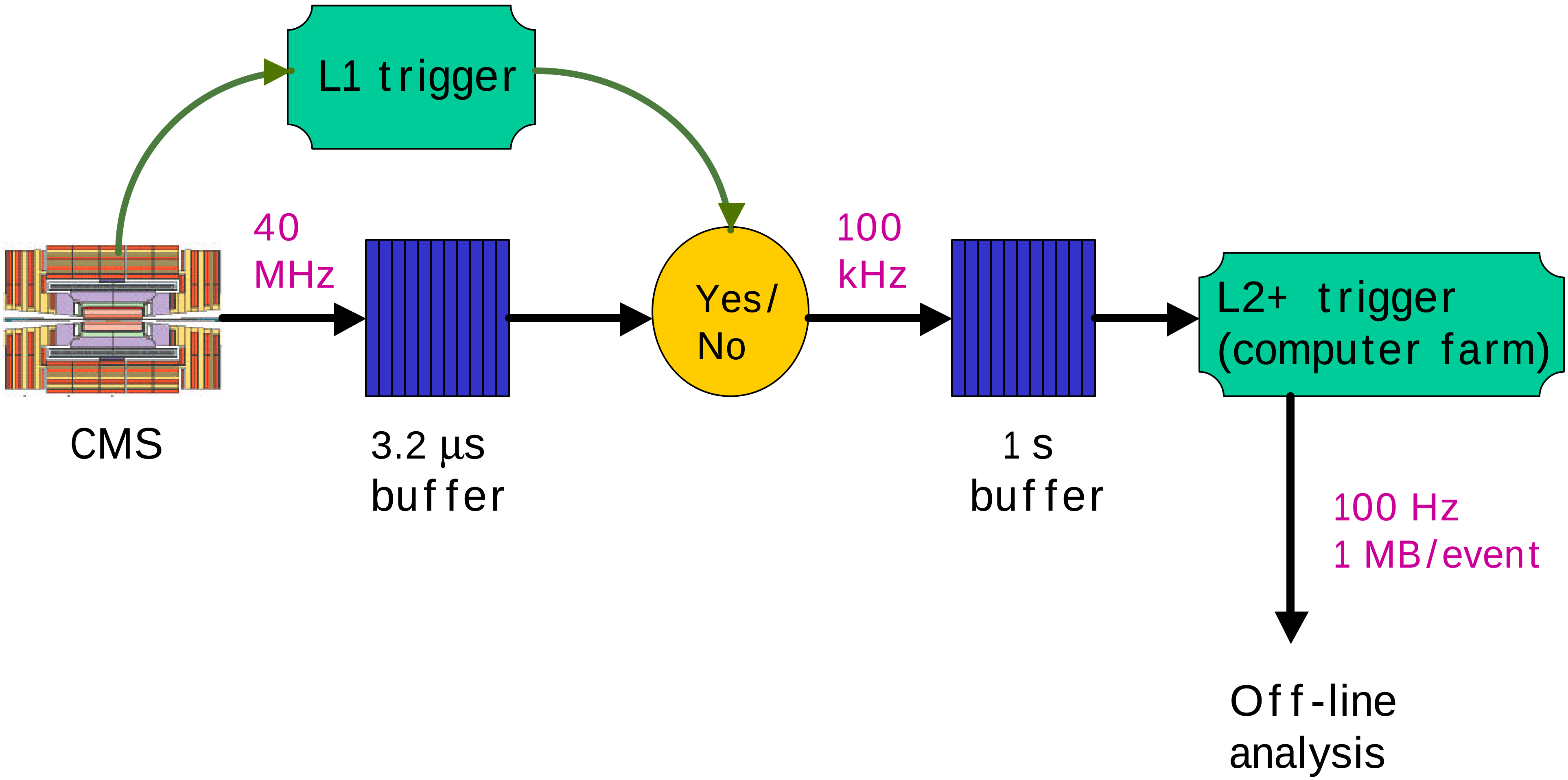
- Even at this rate (10^{16} p-p collisions year), collect only 1000 Higgs ® g g per year.

- How do we find small number of Higgs in large number of p-p collisions ? It's worse that finding a needle in a hay-stack: Needle ~ 5 mm^3 & Hay-stack ~ 50 m^3

So, needle : hay-stack only 1 : 10^{10} !

Particle Physics at CMS

Use triggers and off-line data analysis to find interesting events.



Detectors for Surface Science

- **What is surface science?**
- **Studies of surfaces started as preparation of highly defined systems and had to be studied in UHV**
  - developments were required to build the tools necessary to do the science; surface cleaning protocols, LEED, SEXAFS, surface photoemission
  - work centered around understanding the basics of surfaces, what arrangements were possible, how properties differed from the bulk

- **Developments are recent**
- **seventies; model systems in UHV**
- **eighties; some imaging, the STM (Scanning Tunnelling Microscope) - atomic imaging revolution, spectroscopic imaging on the sub-mm scale**
- **nineties; STM maturity, spectroscopic imaging on the micron scale, some timing**
- **noughties; spectroscopic imaging approaching tens of nm, some timing, some techniques approaching realistic conditions**

Importance of Surface Science

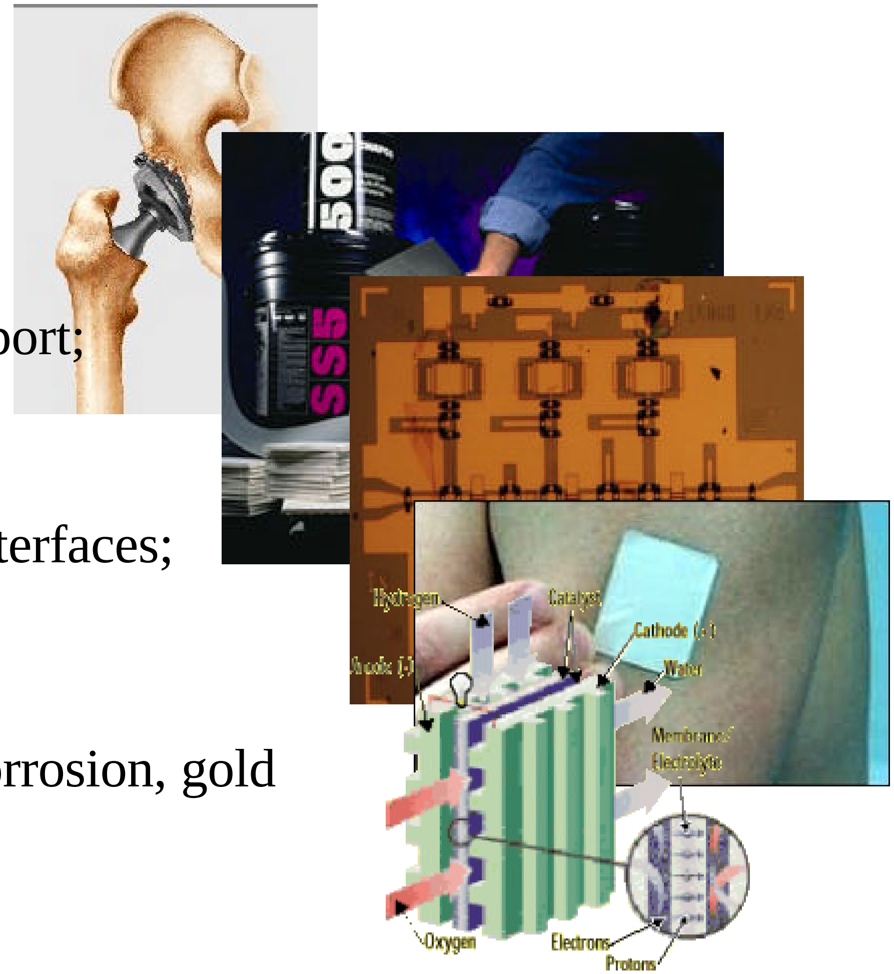
Friction; artificial hips

adhesion; glues

surface electronic transport; nanoelectronics

transport across interfaces; nicotine patches

chemistry; corrosion, gold catalysts



SR Automation: From an Art to a Science or - the robots are coming….

- **Increased demand - Human Genome**
  - Automated protein expression, purification, crystal growth:1000 crystallisations a day!
  - need to screen for good crystals
  - sort, then run good crystals
- **Faster experiments/measurements**
  - screening of large sets of samples
- **More effective use of resources**
  - Automation means we can go & do something more interesting instead!

Targets for Automation

- **Beam Line Optics**
  - increased feedback of actual beam parameters
  - rugged, close-coupled model of optical system
  - novel beam sensors
    - ***monochromator crystal photodiodes***
    - ***grazing incidence UV interferometers***
- **Beam line set-up**
- **Intelligent experimental control**
- **Sample Handling**
  - Large storage/transport cassettes
  - Integrated sample labelling
  - Database management
  - Robotic sample mounting

DL - Proposed system

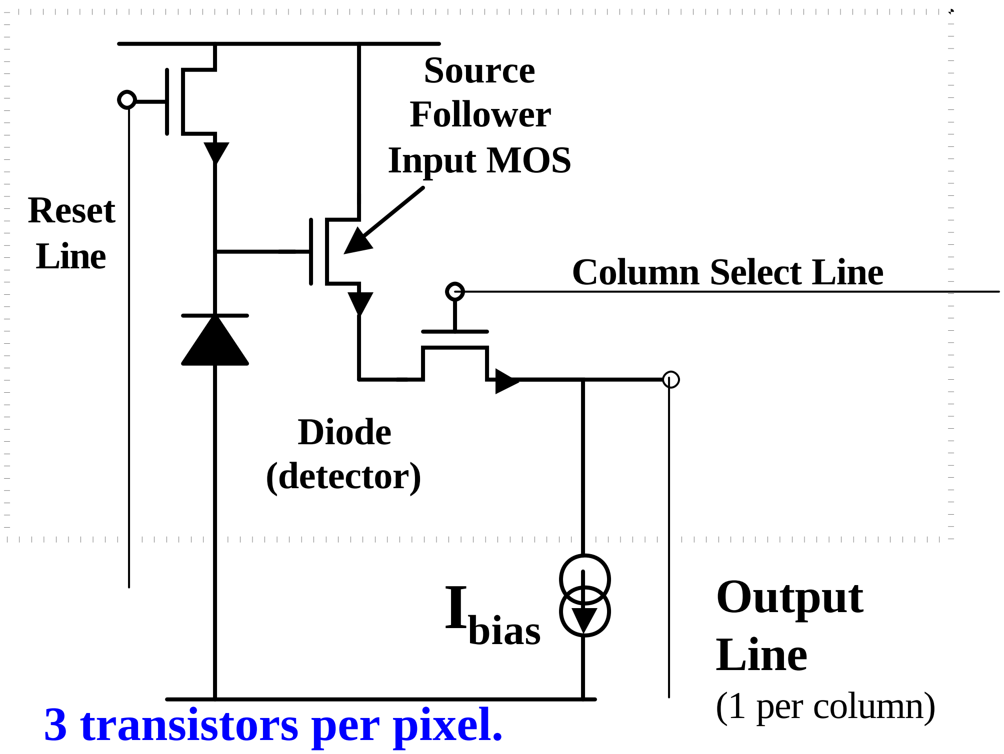
- **Full arm simulator**
  - more flexible
  - applicable to other experiments
- **Specification**
  - 6-axis
  - +/- 40 μm accuracy
  - 2kg load
  - 3.5m/s speed
  - 715mm reach
  - pneumatic hand
  - simple programming

Brief history of Image Sensors

1963 - 1964	Photoconductor (Morrison, IBM)
1965 -1970	Bipolar, MOS photodiodes arrays (Westinghouse, Fairchild-->Reticon, Plessey)
1970	CCD invented at Bell Labs (Boyle & Smith)
1974	320 x 512 CCD imager (RCA)
1980's- 1990's	IR focal-plane CMOS sensors (JPL, Rockwell, …)
1981	CCDs for HEP
1983	First consumer camera (Hitachi & Sony)
1983	First 1 Mpixel CCD (Texas Instruments)
1985-1991	CMOS PPS (Passive Pixel Sensors) developed (Edinburgh ---> VVL)
1987	First HDTV Image Sensor (NEC)
1987	Hybrid Pixel Detectors for HEP
1993 onwards	CMOS APS (Active Pixel Sensors) developed in JPL, IMEC, Stanford, ….
1997	First 5V-only CCD Imager (Sharp)
2001	CMOS sensors for HDTV (Rockwell, ...)

CMOS Active Pixel Sensors.

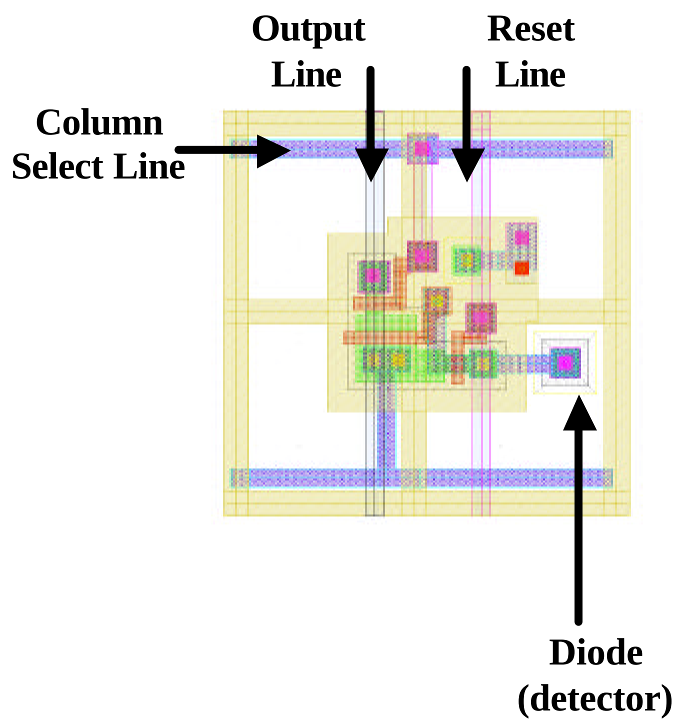
Pixel structure (baseline).



3 transistors per pixel.

Charge to voltage buffer. Only active during readout --> low power

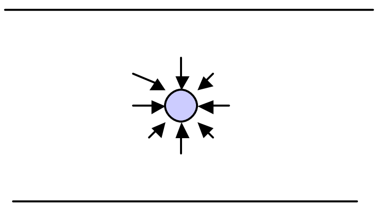
Pixel layout.



CFI Gas Detector Technology programme

How do they work?

- Electron detectors
- Electron multiplication close to anode
- Gain up to 10^5
- Inert gas provides gain, quencher localises
- Can have direct conversion - eg Surface Sc



- Can use gas as converter - eg X-ray detectors
- Can have have solid state convertor - eg Positron camera

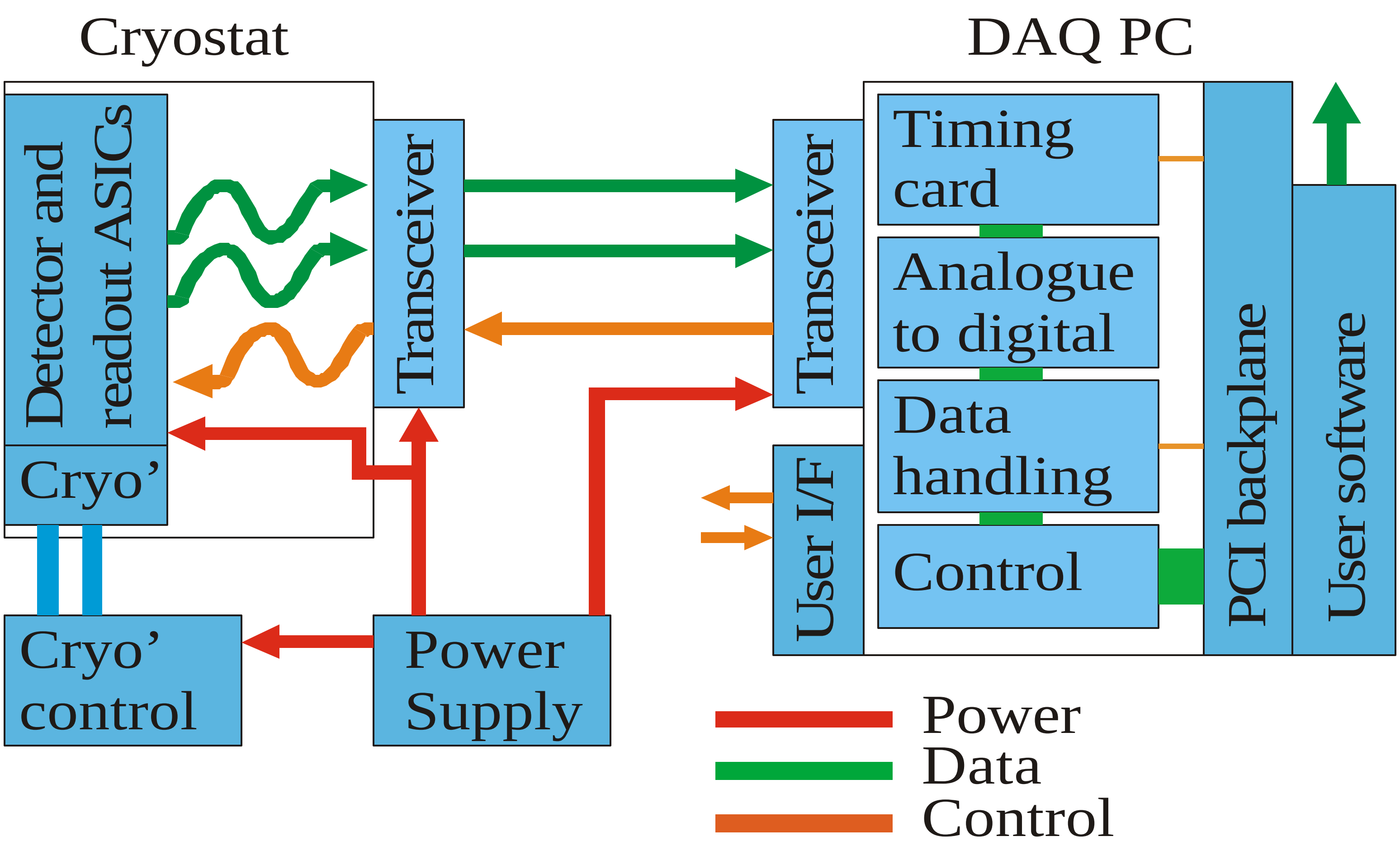
Types of Detector

- Wire counters eg Microgap as used in Rapid, conventional MWPCs as used in PETRRA
- GMSDs eg X-ray or Neutron Detectors
- Pin Arrays eg Neutron pin pixel detector
- GEMs and microwells

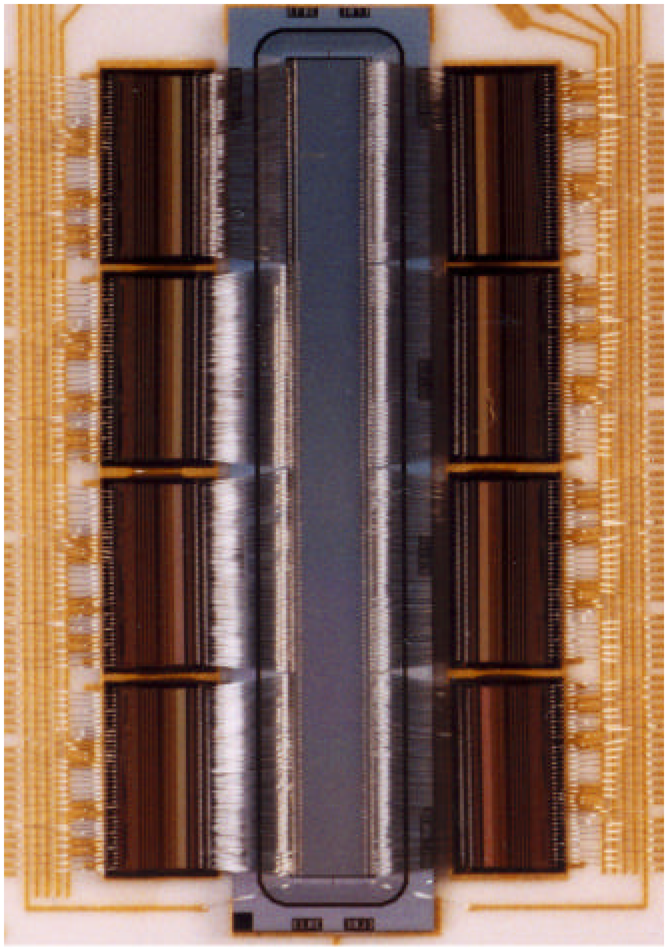
XSTRIP
A new detector for time resolved EXAFS

- **Detector limitations restrict the experiments available on the SRS**
- ***XSTRIP* addresses the need for increased speed of detection in x-ray absorption spectroscopy (XAS)**
- **In XAS ‘quick’ ~ minute (most chemical reactions << minute)**
- **Currently use commercial PDAs or CCDs**
- **But for these the vast majority of chemical reactions lie beyond their capability**

XSTRIP - Block diagram



Detector Head



- **25mm long, 500μm thick Si detector**
- **8 XCHIPs (0.5μm full custom mixed-signal ASIC containing 128 charge integrating pre-amplifiers)**
- **To meet linearity and readout speed specifications the channels are multiplexed down four readout nodes**
- **Ceramic MCM with good thermal properties**