Far-IR/sub-mm/mm-wave satellite technology

Pete Hargrave, Cardiff University, UK

Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

Outline

- Optics & quasi-optics
- Detectors
- Calibration sources
- Test facilities
- Space instrument design & leadership

Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

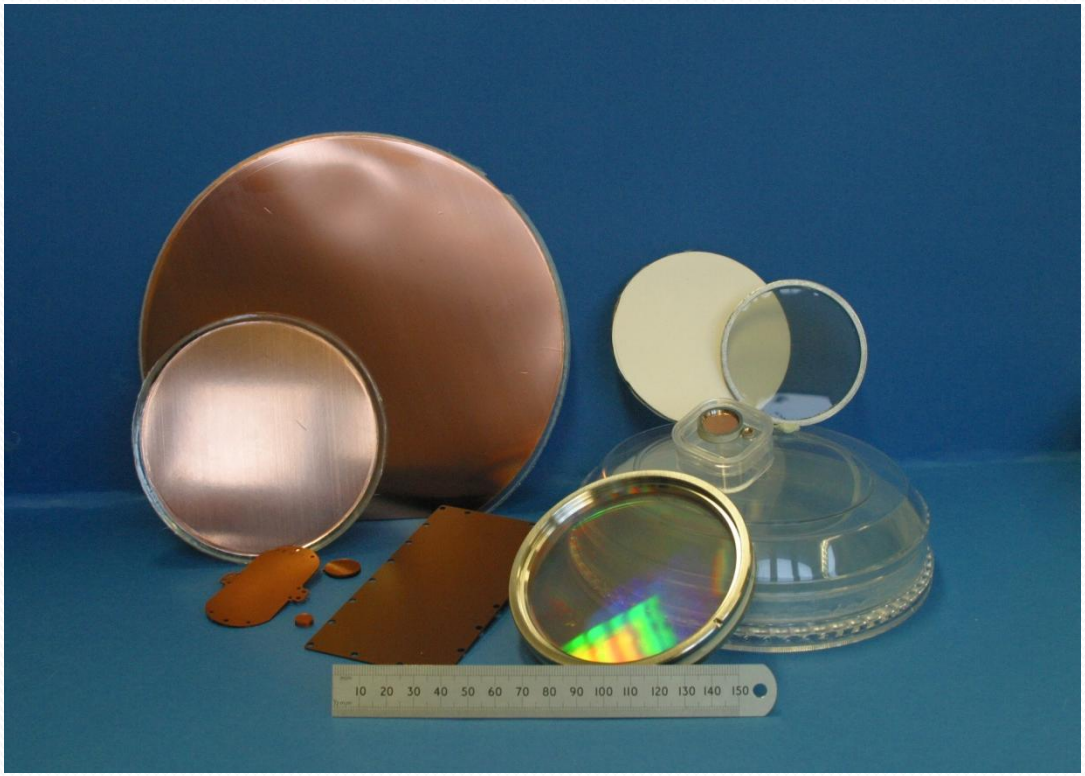
Optics & quasi-optics

- Filters
- Beam dividers
- Dichroics
- Polarizers
- Half-wave plates
- Feedhorn design & testing
- Antenna design & quasi-optical networks
- Fourier transform spectrometers
- Anti-reflection coatings
- Meta-materials

Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

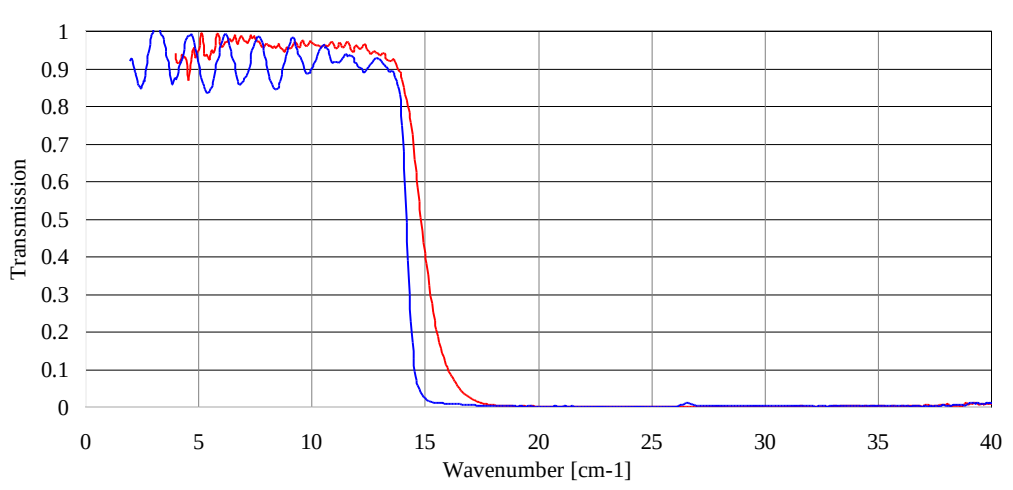
Filters

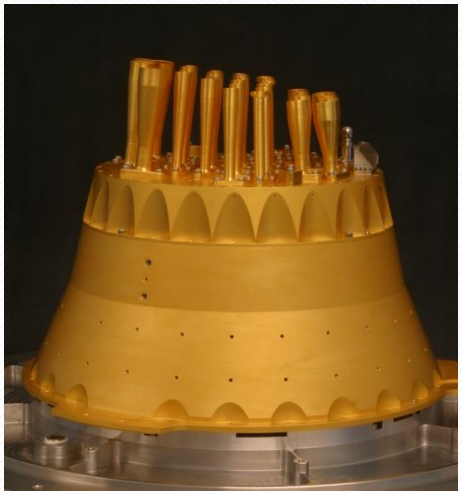
- Metal-mesh technology
- Inductive, capacitive, resonant grids
- Excellent space heritage – flown on many satellite platforms

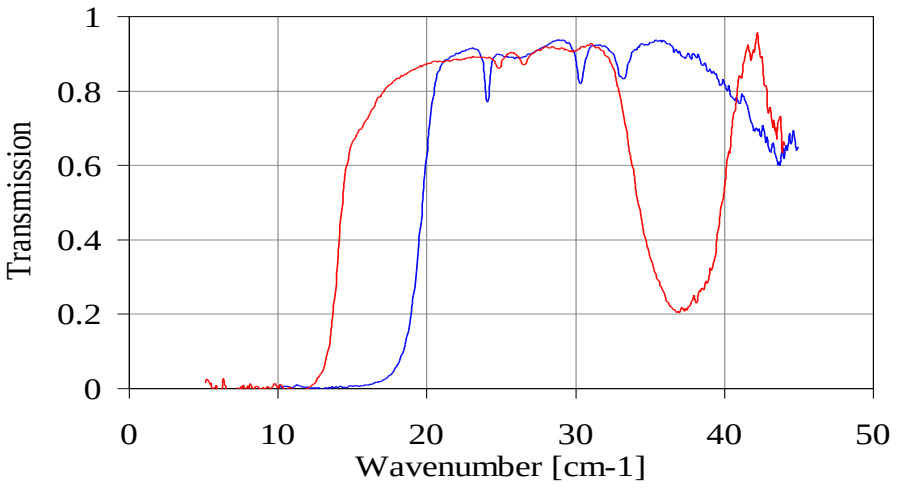


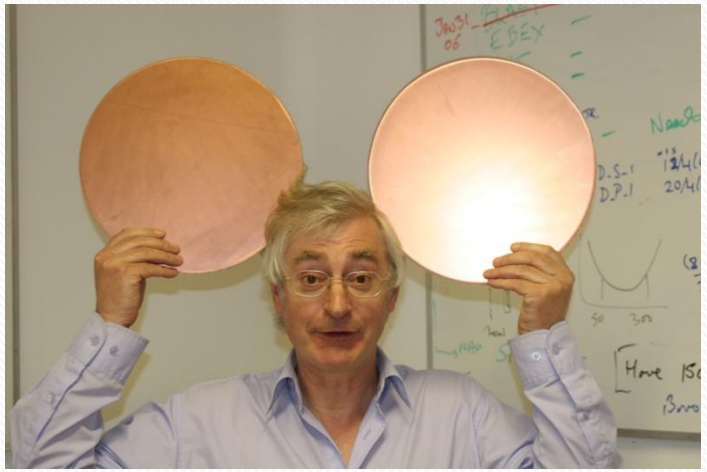
Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

Low-pass & high-pass edge





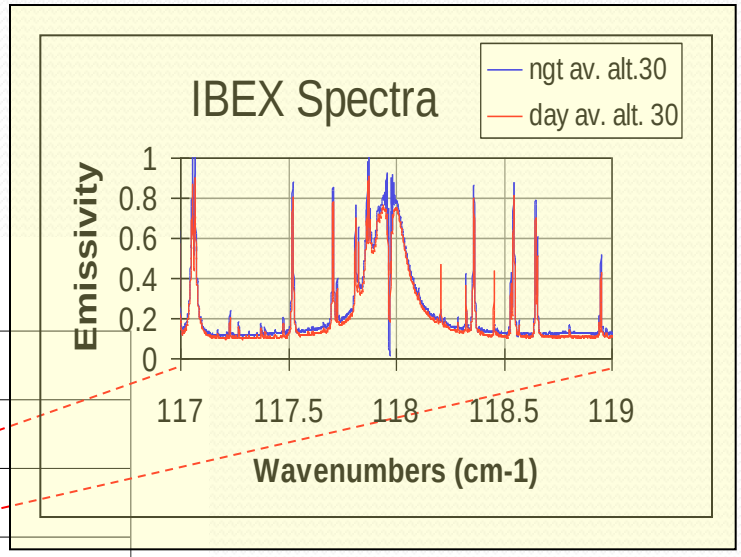


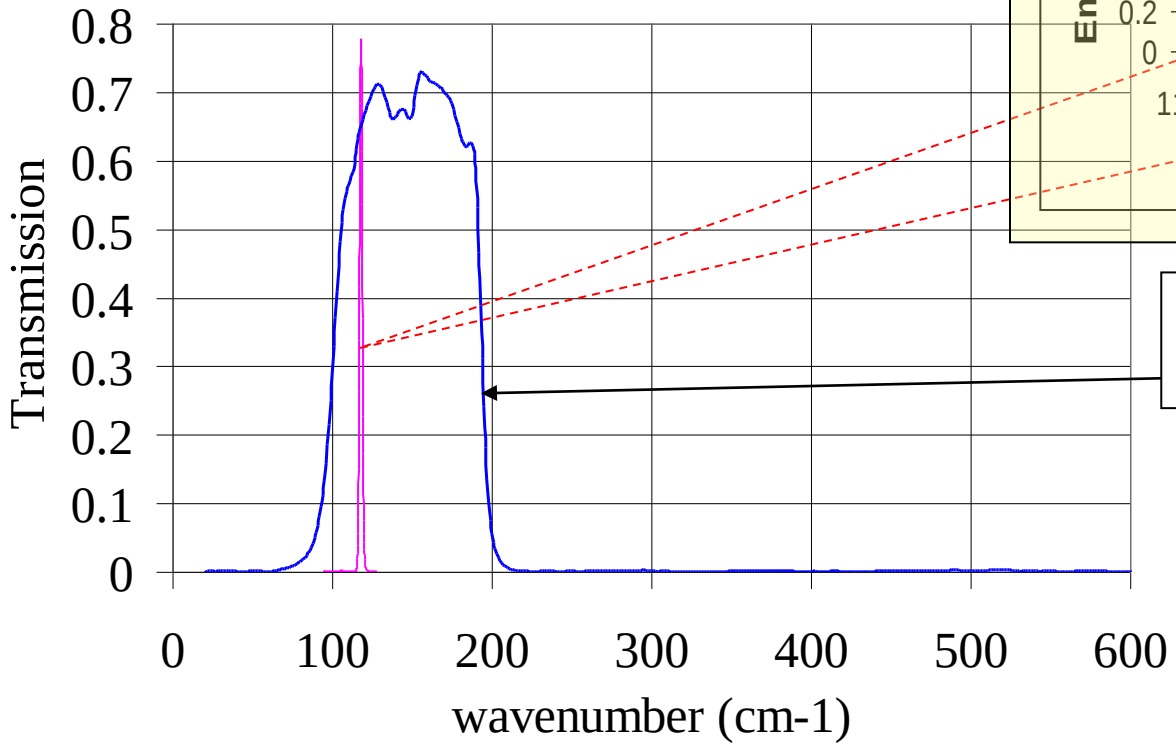


Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

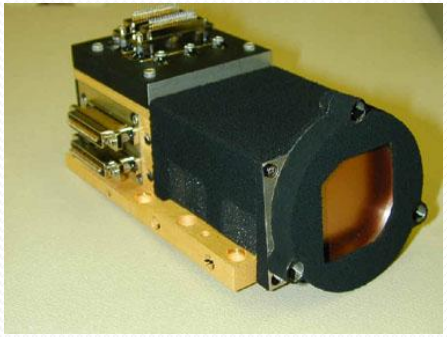
Wide & narrow-bandpass filters

IBEX Balloon-borne FTS with Ge:Ga photodetector and an air-gap DHW 2 cm^{-1} bandpass filter centred near OH lines in upper atmosphere





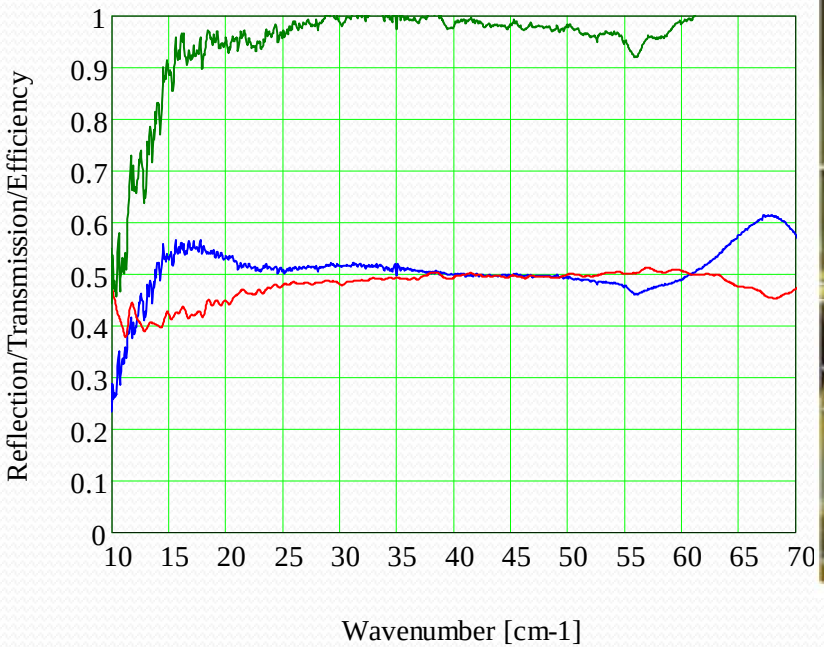
MIPS photometer 70um Bandpass filter on Spitzer

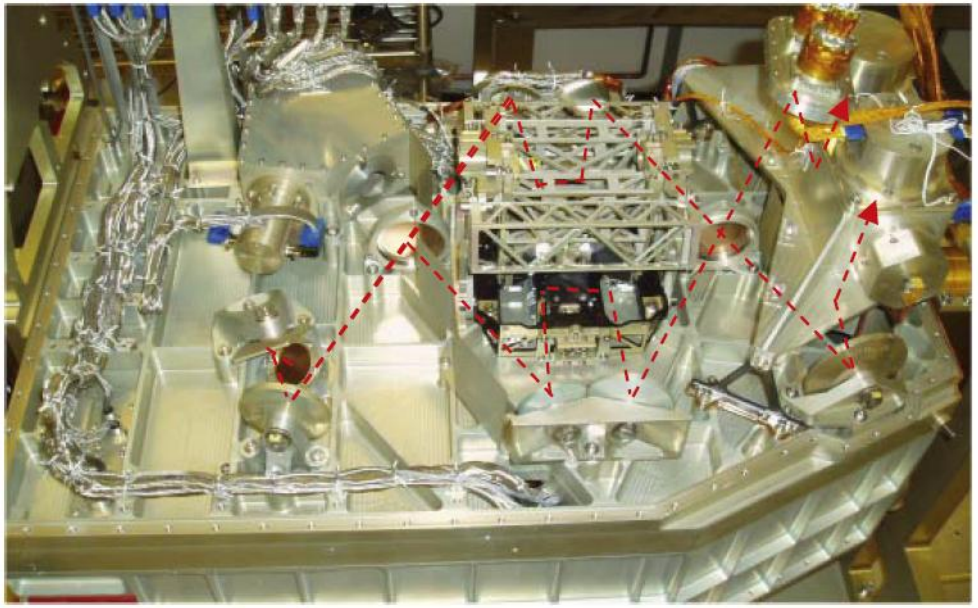


p.nargrave@astro.cr.ac.uk

Metal mesh beam dividers

- Intensity beam dividers for FT spectrometers significantly increase efficiency
- Combinations of capacitive and inductive meshes provide uniform R and T

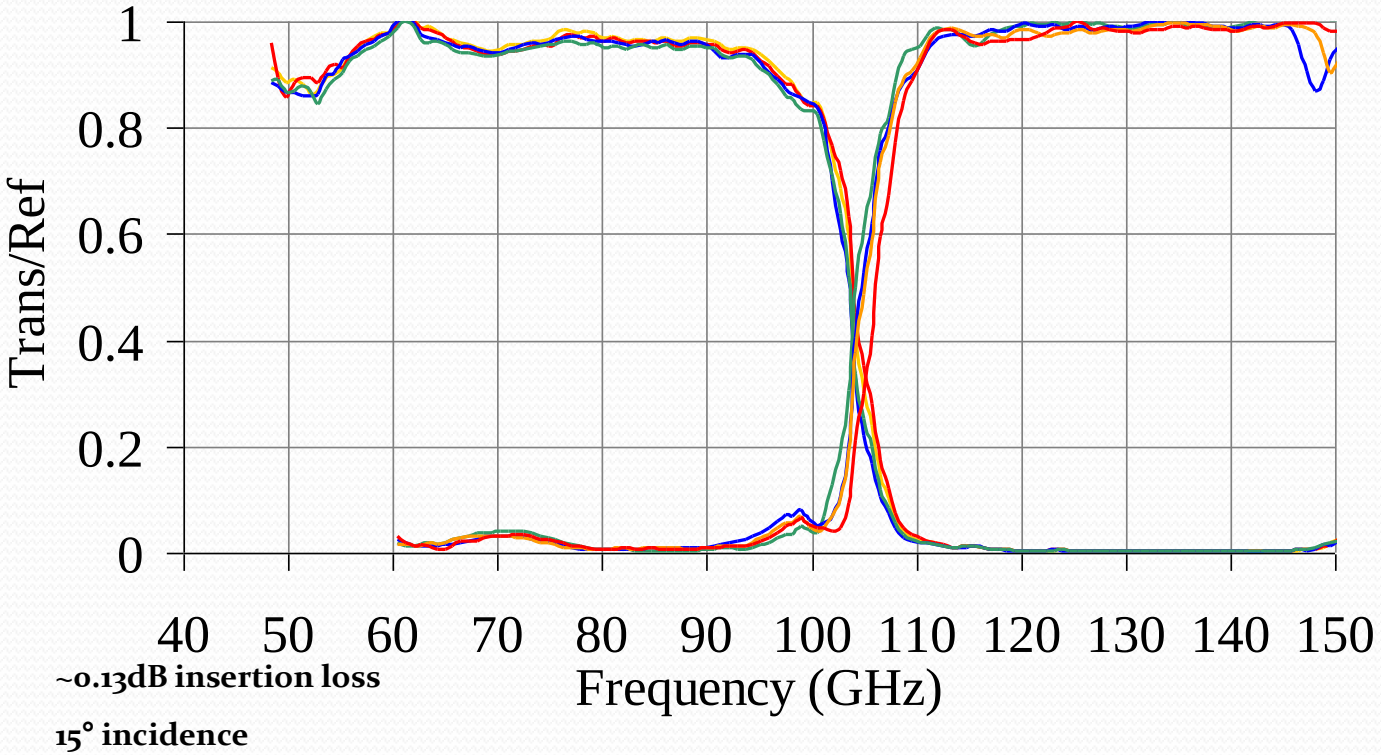




FTS intensity beam divider measured performance with F/4 beam at ~45 degree angle of incidence: blue line transmission, red line reflection and green line efficiency (4RT).

Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

Dichroics

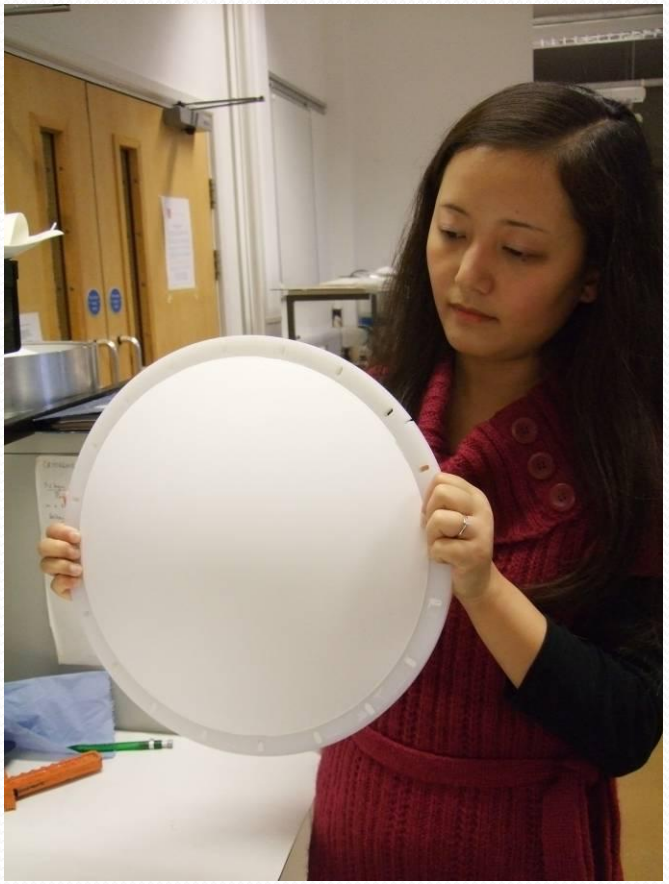


~0.13dB insertion loss

15° incidence

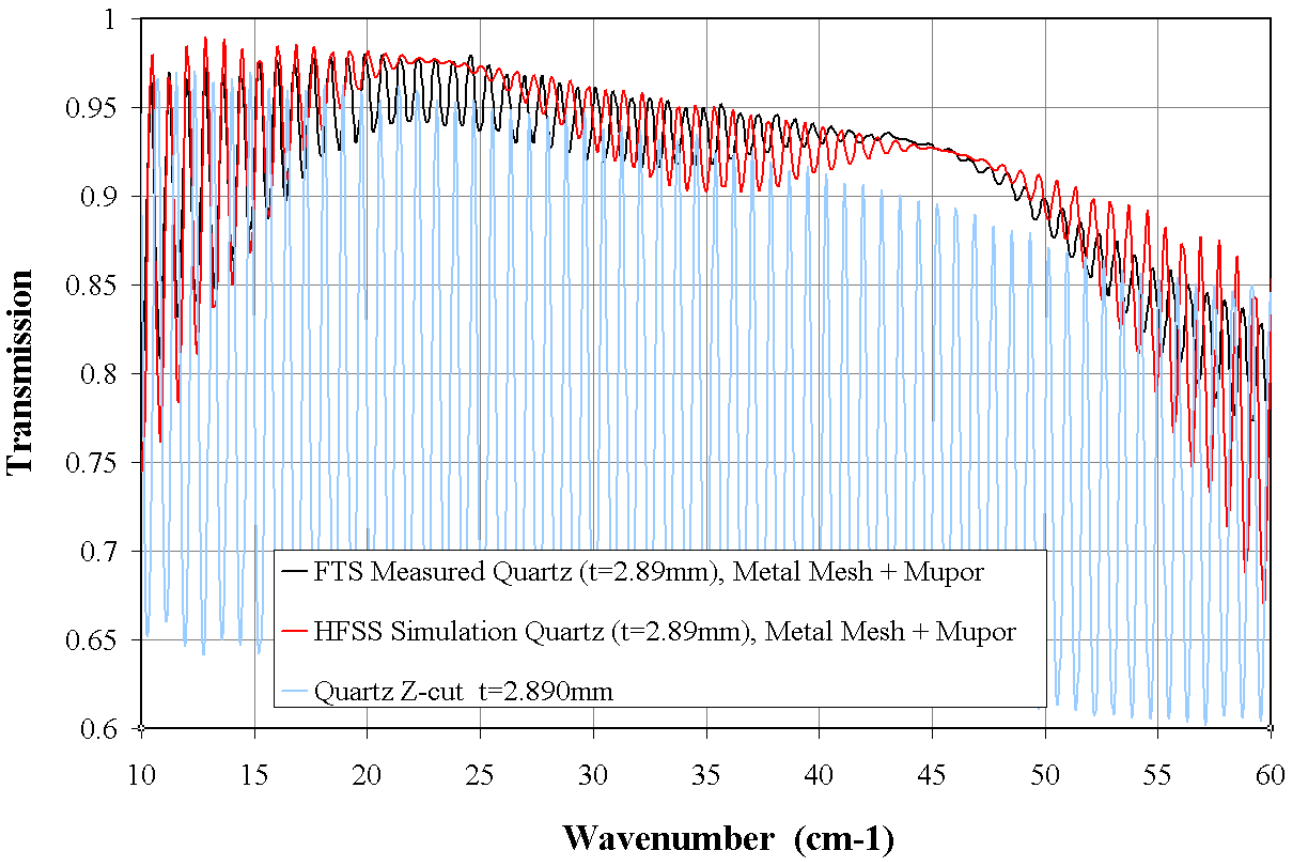
Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

Large anti-reflection coated lenses



Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

Artificial dielectric materials – anti-reflection coating applications



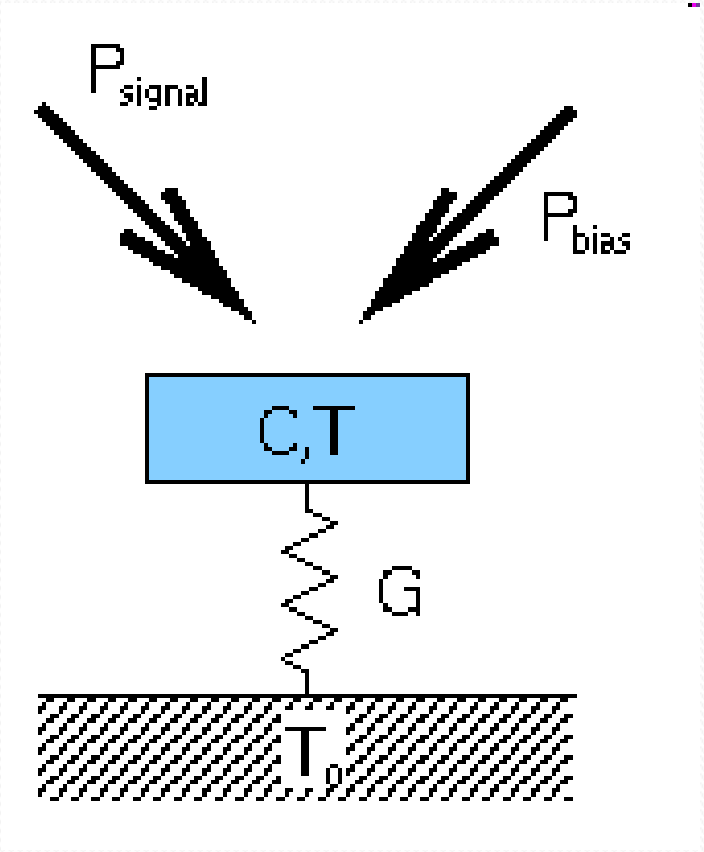
- black line – FTS transmission spectrum of the stack (PPTFE-ADM-QUARTZ-ADM-PPTFE)
- red line – HFSS simulation of the complete ARC quartz plate
- blue line – measured data of the uncoated quartz substrate.

Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

Detectors

Traditional bolometers

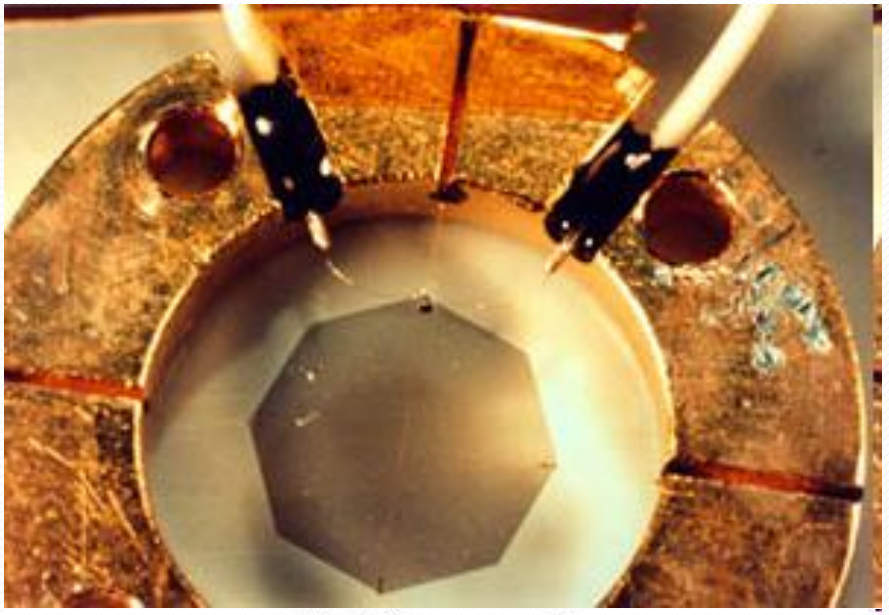
- Time constant: $\tau = C/G$
- Sensitivity proportional to 1/G
- Trade off sensitivity vs speed
- Minimise heat capacity

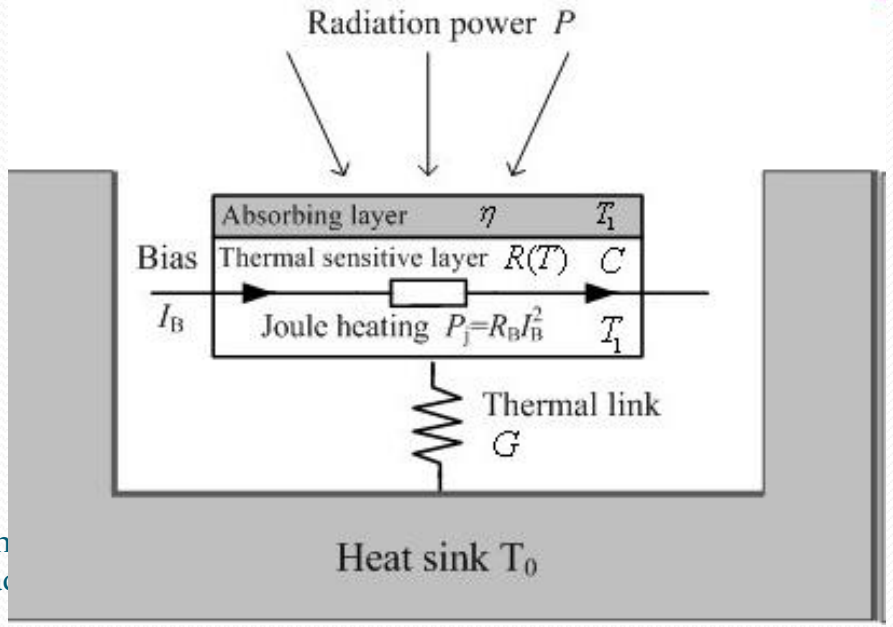


Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

Early bolometers

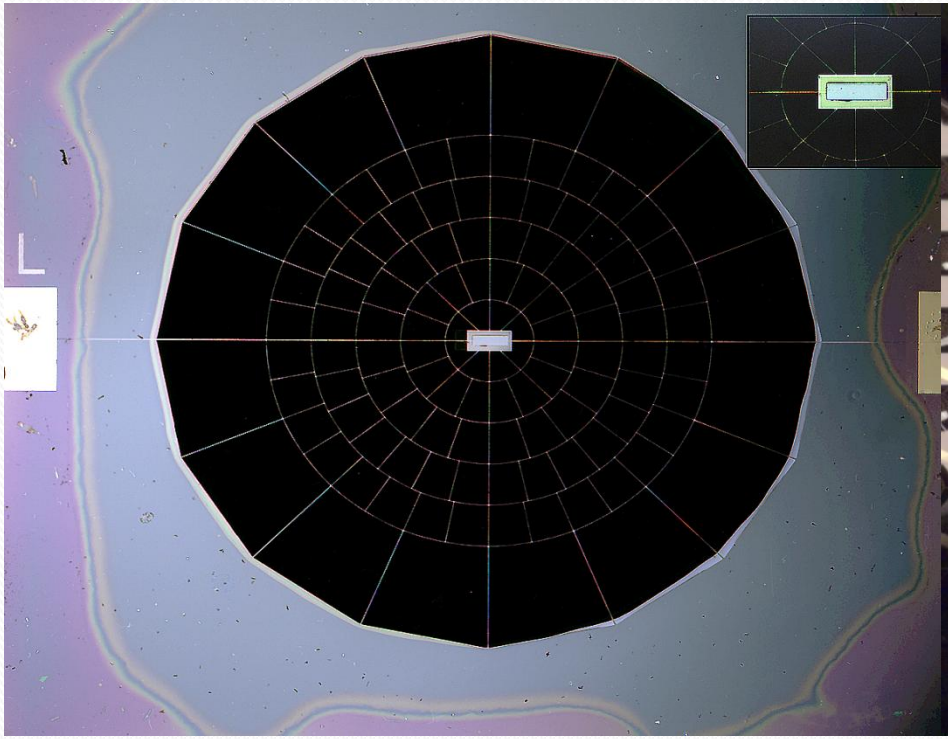
- Composite bolometers
  - Absorber, thermistor, thermal link
  - Single pixels
  - Discrete detectors assembled into arrays e.g.COBE, SCUBA

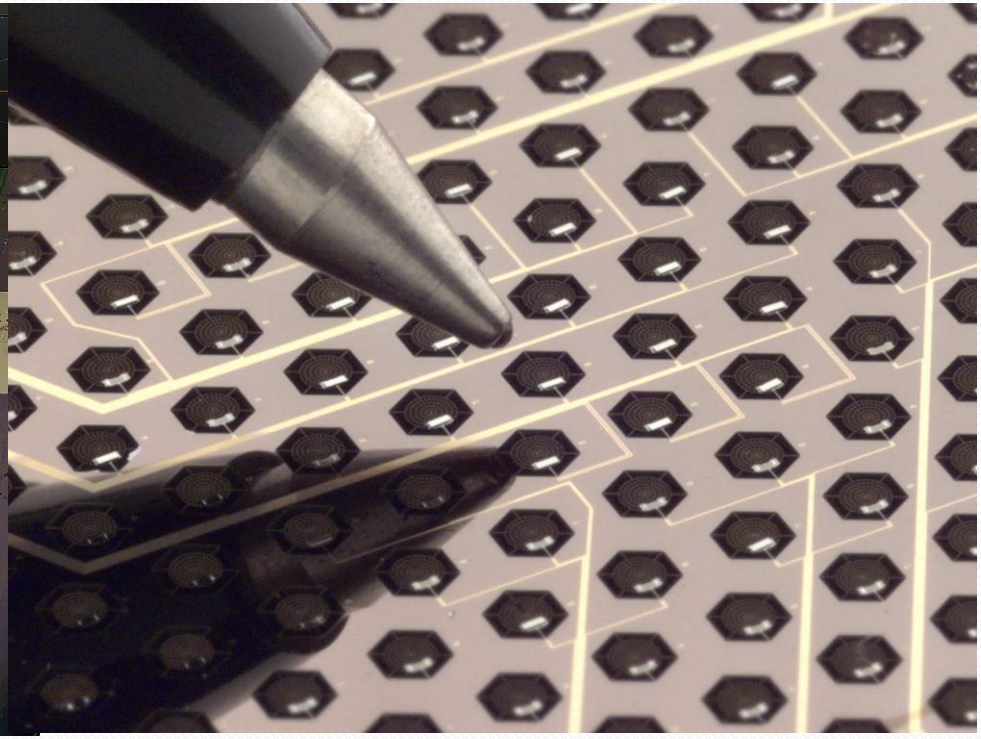




Pete Hargrave, Cardiff Un
p.hargrave@astro.cf.ac

Spider-web bolometers

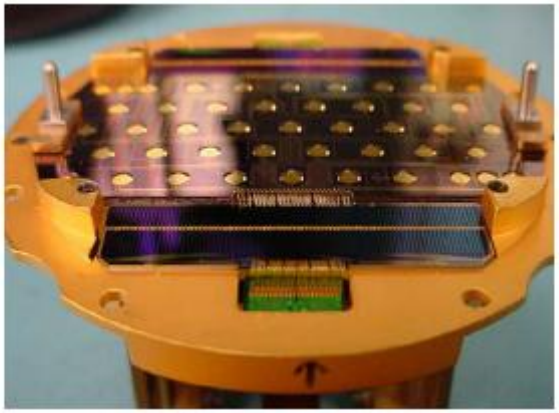


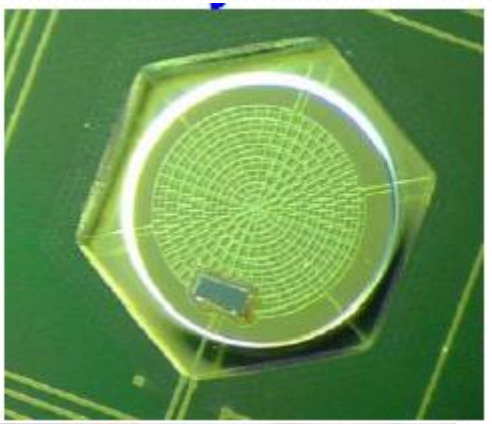


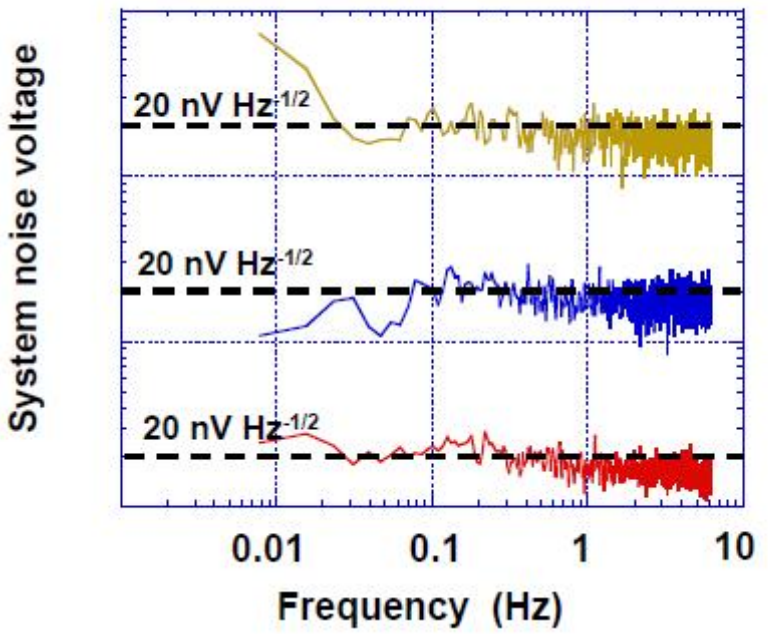
Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

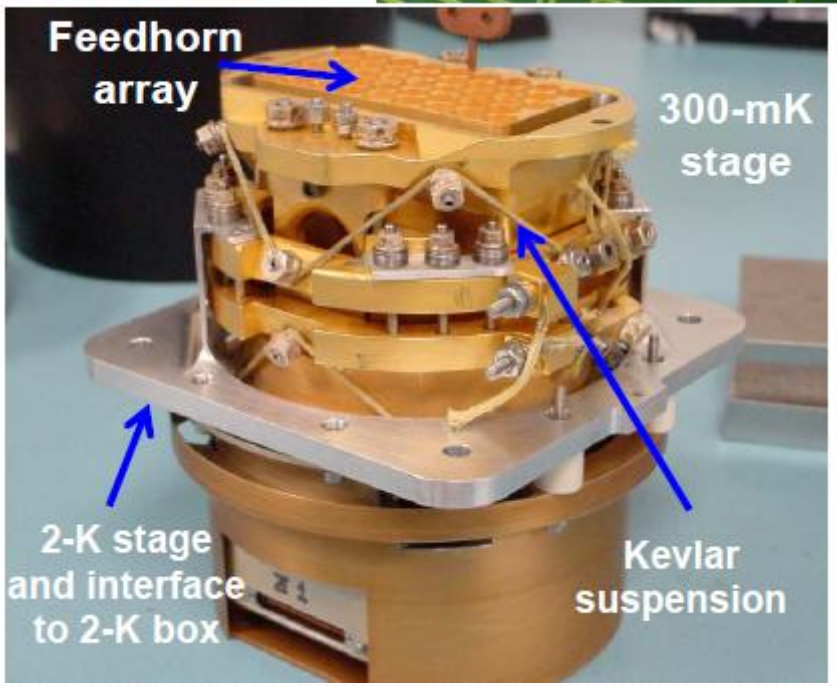
Bolometer arrays

- NEP ~ 3 x 10^{-17} W $Hz^{-1/2}$
- 100-K Si JFET readout
- 1/f noise knee < 100 mHz



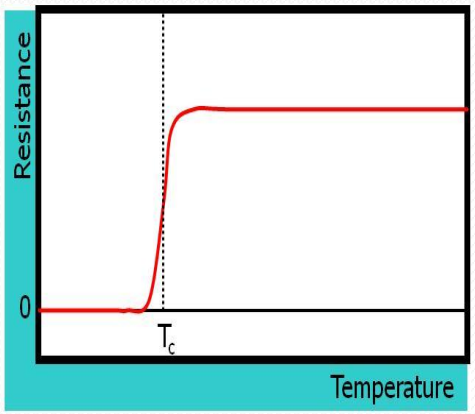


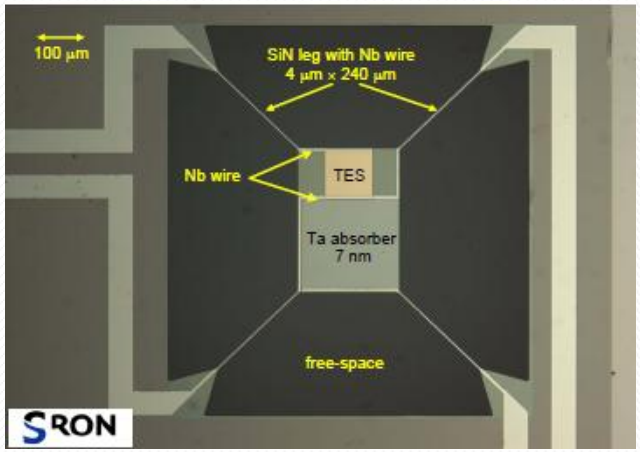


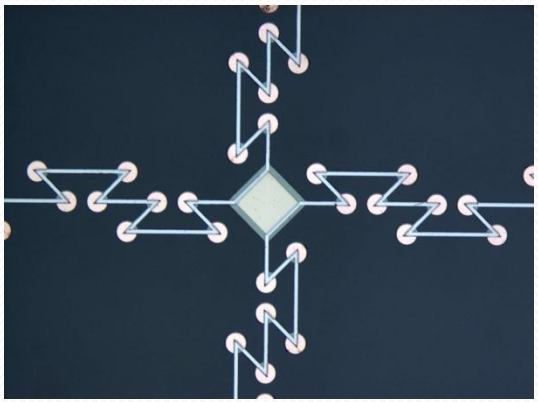


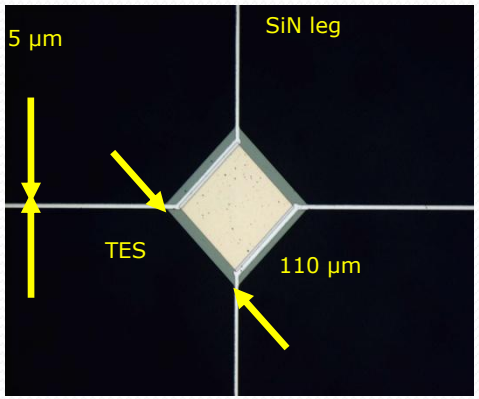
Transition-edge superconducting detectors

- Electrical NEPs
  - ~10^{-19}WHz$^{-1/2}$
  - (100mK bath)
- Current state-of-the-art
- Cardiff leading ESA study for SPICA-SAFARI









Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

Kinetic inductance detectors

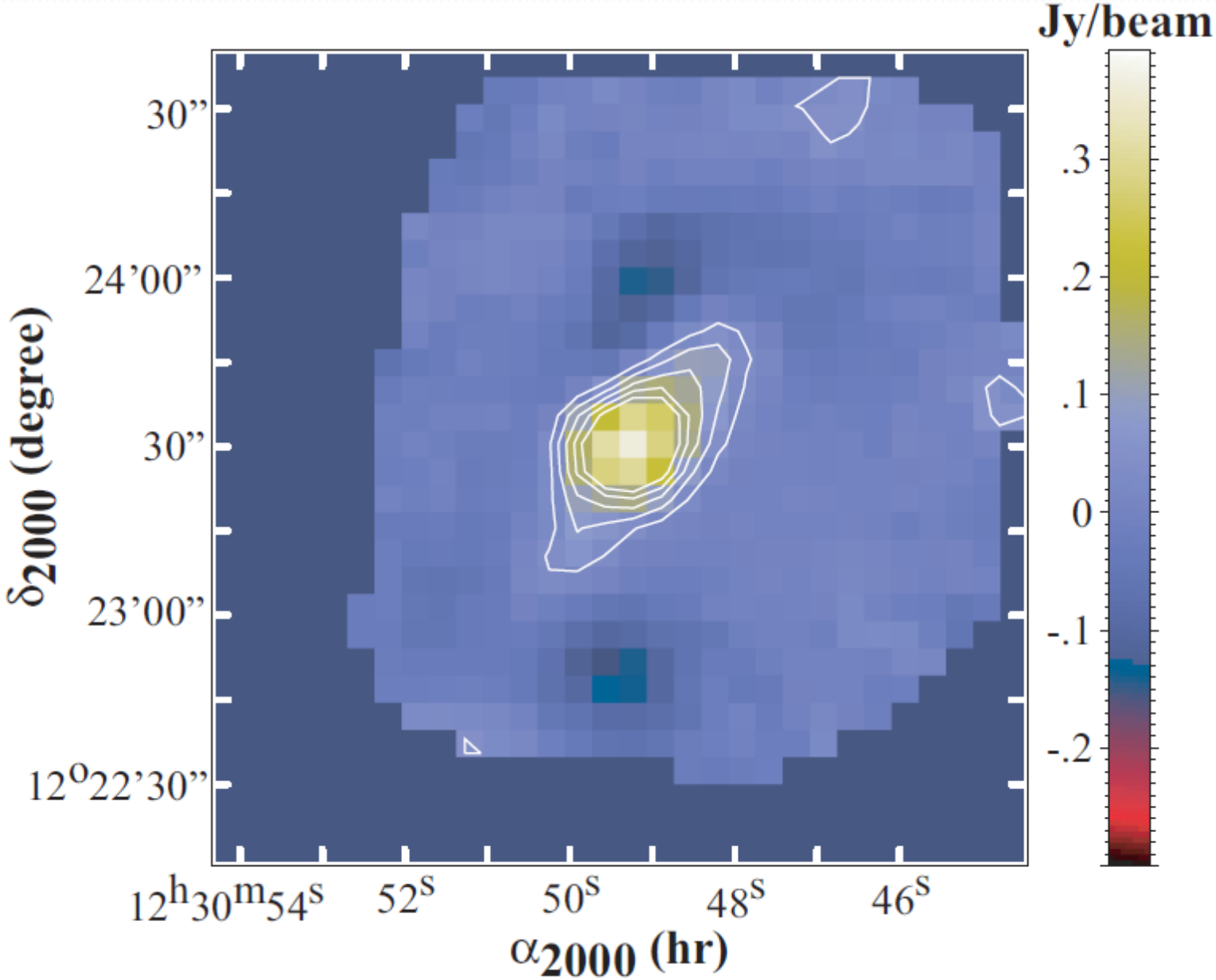
- Superconducting resonator
  - Resonant frequency sensitive to relative density of paired & unpaired electrons in the superconducting material
- Incident photons $hf > 2\Delta$ breaks Cooper pairs – change inductance of resonator
- Thousands of detectors can be read out on same signal line – vary resonant frequency of each detector

Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

LEKID – lumped element KID

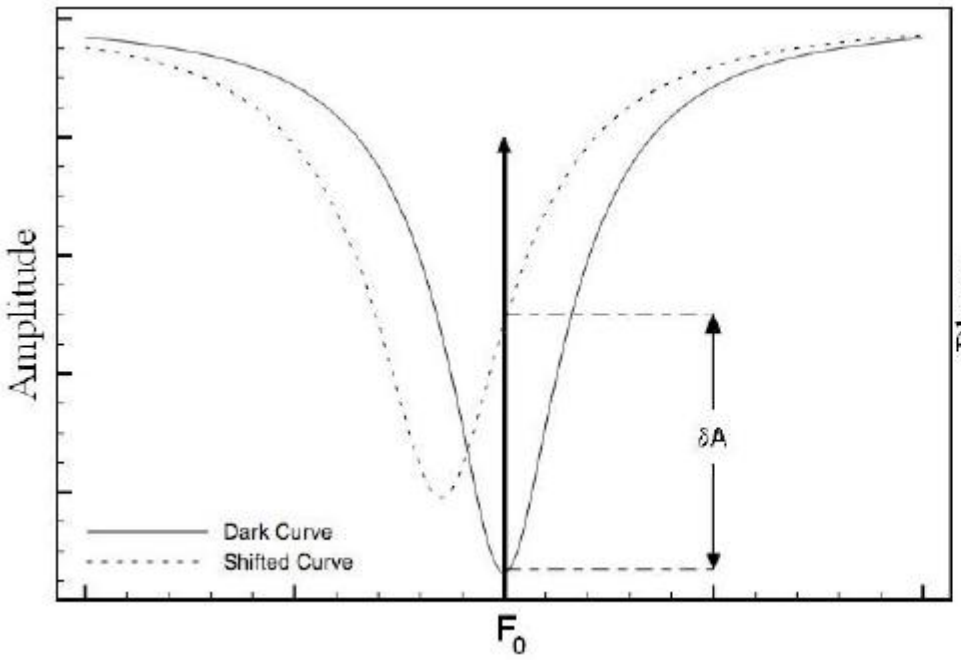
- Developed at Cardiff
- Does not require q-p traps or antennas
- VERY simple fabrication – single photolithographic step
- Can be used as a fast & sensitive direct detector
  - Operating from mm-wave to X-ray
  - Or as an energy-sensitive particle detector
- Only 2 years from concept to 30 pixel demo system on IRAM telescope (2mm)

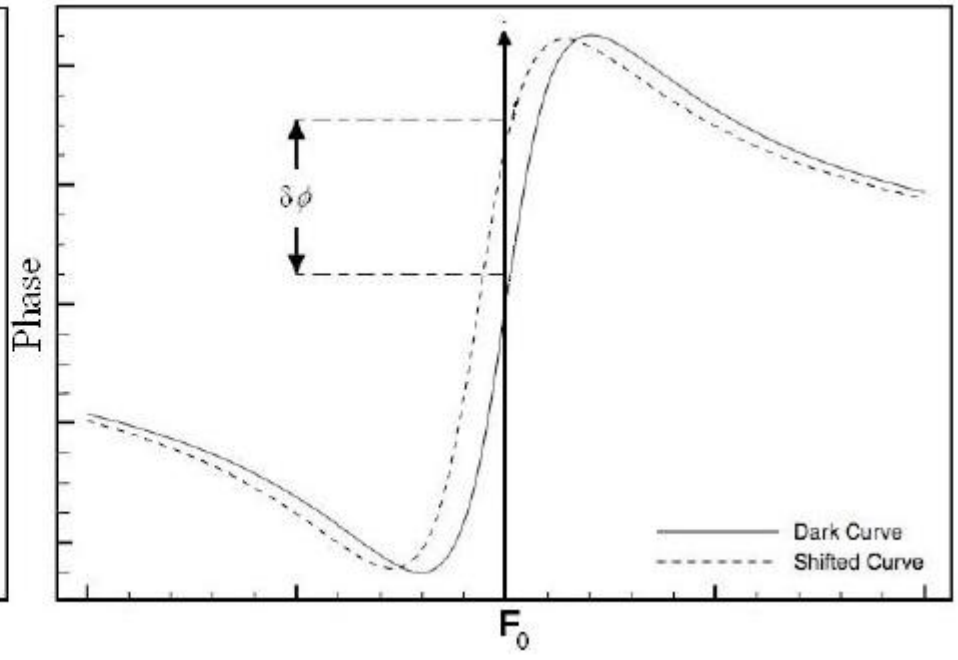
Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk


Jy/beam
.3
.2
.1
0
-.1
-.2
30”
24’00”
30”
23’00”
12°22’30”
δ2000 (degree)
12h30m54s
52s
50s
48s
46s
α2000 (hr)

LEKID – lumped element KID

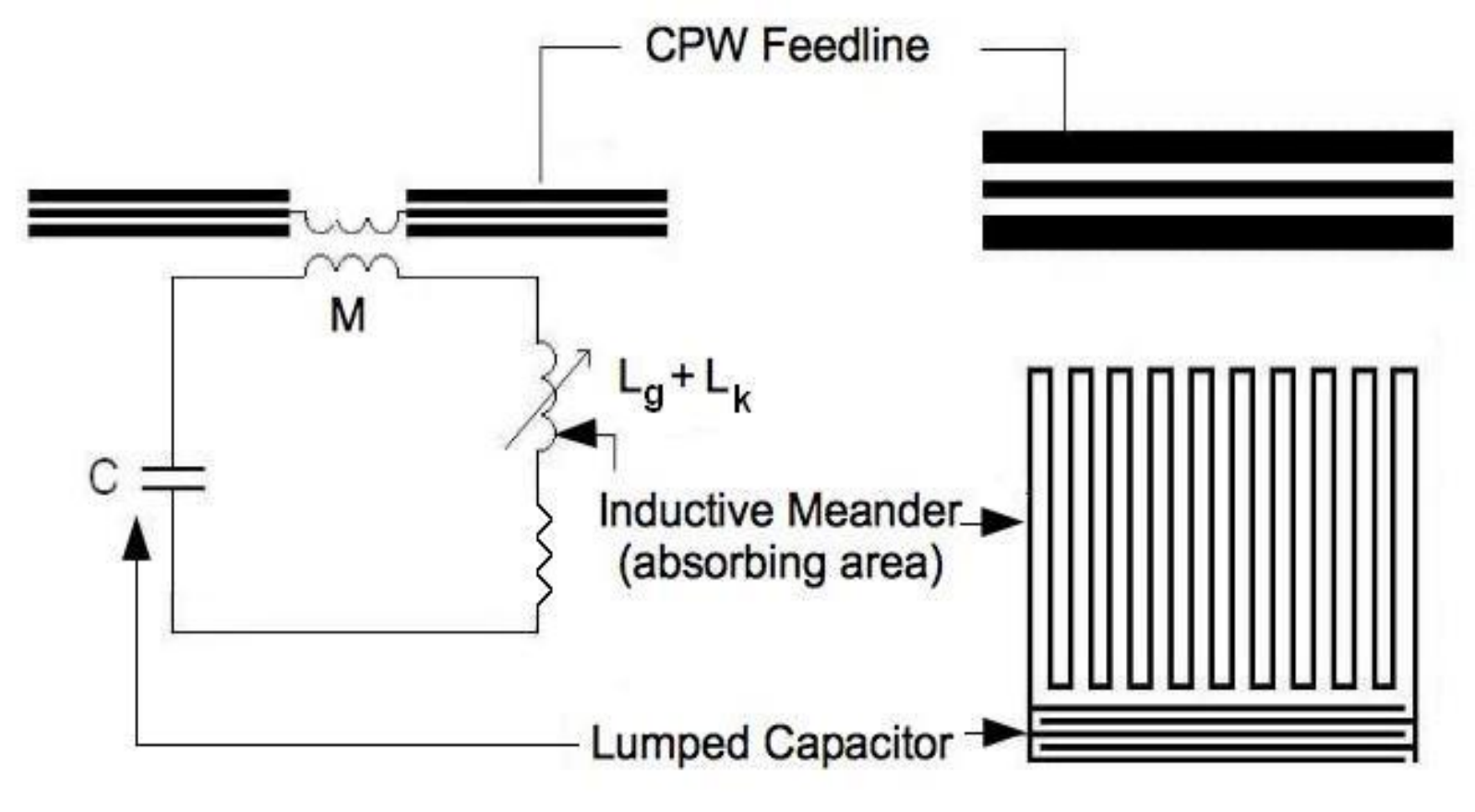
- Small change in inductance measured by high Q microwave resonant circuits





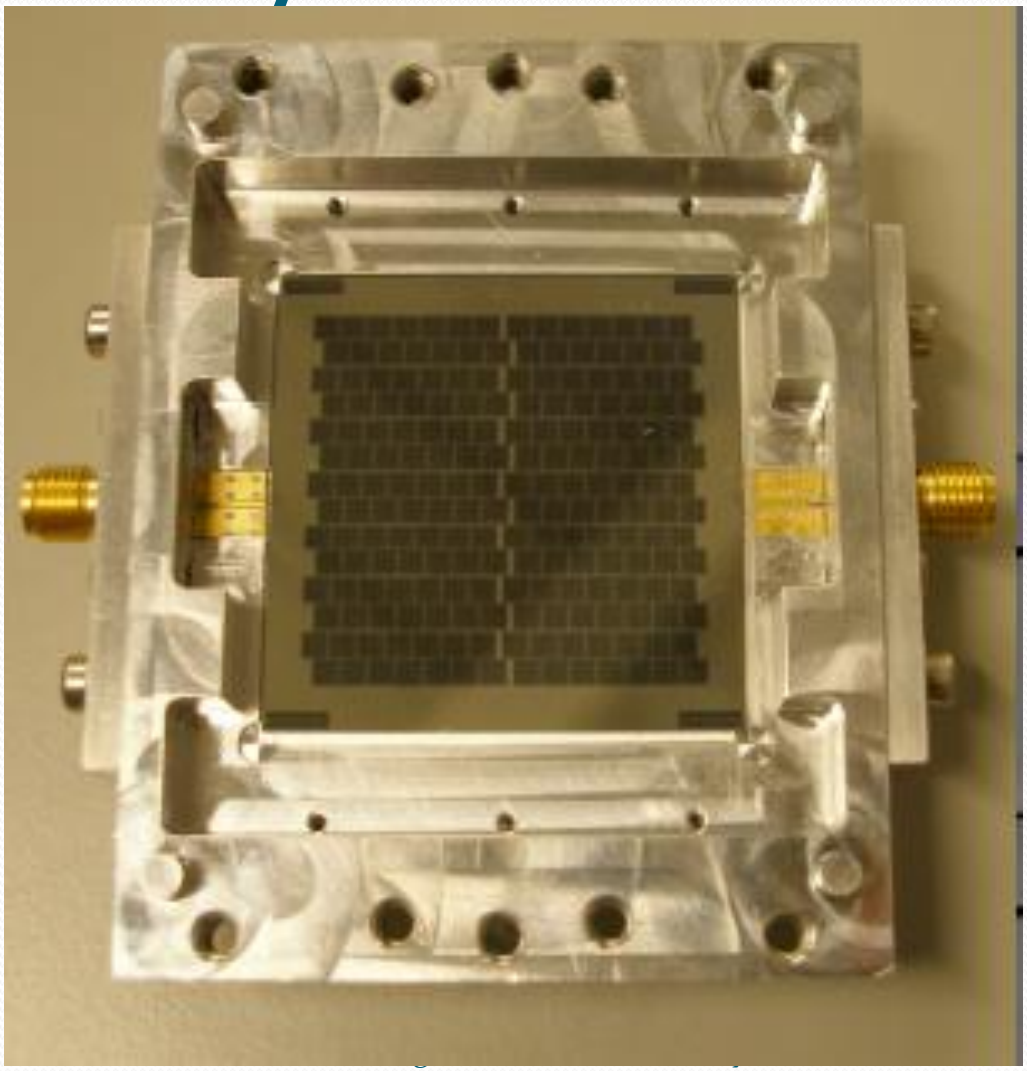
Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

LEKID



Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

LEKID array



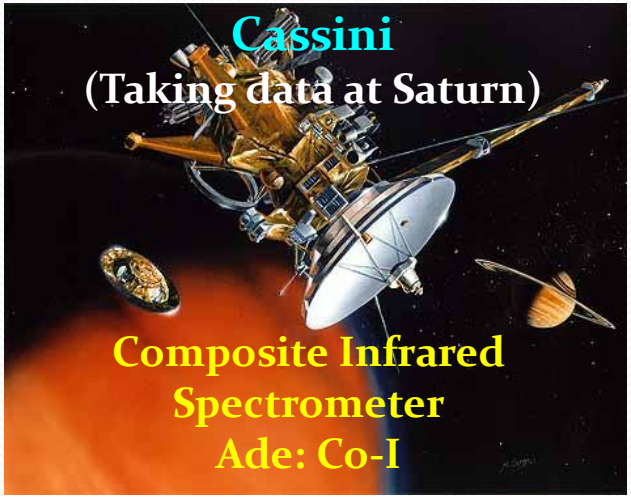
p.hargrave@astro.cf.ac.uk

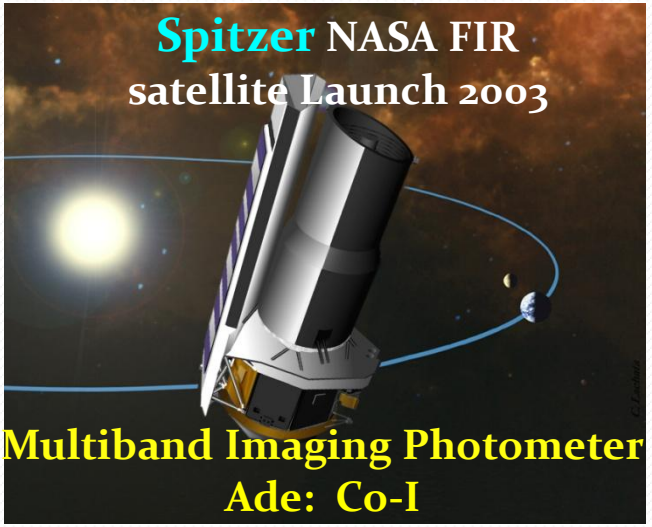
LEKID performance

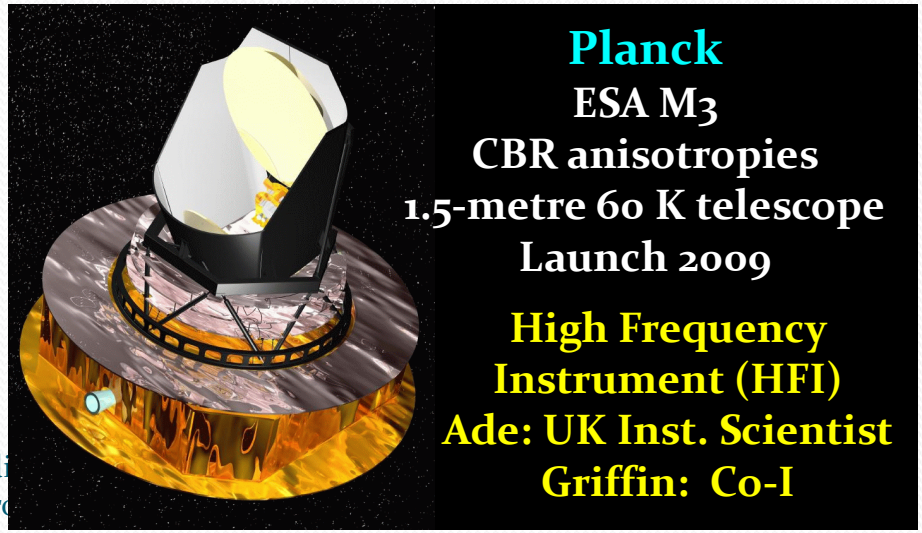
- Current performance details
  - Al films – NEP low x 10^{-18} W $Hz^{-1/2}$
    - Predicted ~ 10^{-20} $WHz^{-1/2}$ at 100 mK
  - TiN films – NEP ~ 4 x 10^{-19} W $Hz^{-1/2}$
  - Readout 1000 detectors with *single* coax line and HEMT amplifier
  - Time response ~10-20 μs (300 mK)
  - Speed & noise limit governed by G-R rate of quasiparticles – scales with temperature and film volume

Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

Space heritage







Current missions

- Herschel
  - Cardiff PI institute for SPIRE instrument
  - Instrument integrated at RAL
  - Significant Chinese contribution to SPIRE
- Planck
  - Cardiff Co-I institute for HFI instrument
  - Focal-plane integrated and tested in Cardiff
- Spitzer
  - Provided filters for MIPS instrument
- JWST-MIRI
  - Calibration sources – flight model delivered

Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

Future missions & studies

- EChO
- SPICA-SAFARI
- Feng-Yu 4
- Several ESA TRP contracts, including:
  - SPICA-SAFARI detector development
  - B-Pol CMB polarimetry antenna configuration study

Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

Collaboration with China

- Significant Chinese contribution to Herschel-SPIRE
  - NAOC Beijing – Dr Maohai Huang
    - Software development, instrument data pipeline
    - Chinese scientists involved in SPIRE guaranteed time science
      - Star formation
      - Interstellar medium
      - High-redshift galaxies
- Feasibility study for FY-4
  - With RAL and QMUL (Prof. Xiaodong Chen)
  - Antenna & scan system, quasi-optical network & detectors
- Royal society funding – UK-China THz technology partnership

Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk

RELD
Relativistic Electrons, Lasers and Discharges
Department of Physics
THE UNIVERSITY OF STRATHCLYDE IN GLASGOW

- Introduction
- Registration
- Paper Submission & Program
- Visas & Travel
- Accommodation
- People
- Sponsors
- Contact

4th UK/EU-China Workshop on Millimetre Wave and Terahertz Technology

The 4th UK/Europe-China workshop on Millimetre Waves and Terahertz Technologies will be held in Glasgow (Scotland) from September 1 to September 3, 2011. The conference will take place at the McCance building, University of Strathclyde, in the centre of Glasgow city.

The Conference is especially devoted to scientific and technological developments in the spectral range from the millimeter wave to terahertz. The conference topics include terahertz and millimeter wave sources, components including detectors and antennas, instrumentations and applications. The conference acts as a forum for presenting advances in Millimetre-wave and THz technologies as well as facilitating collaboration and exchange opportunities between the UK, mainland Europe and China.

The 4th UK/Europe-China Workshop on Millimetre Waves and Terahertz Technologies follows successful conference at UESTC, Chengdu, China in 2008, RAL, Oxford, UK 2009 and Beijing, China in 2010.

Important dates:

- **16 August, 2011:** Early registration deadline
- **08 August, 2011:** Final paper submission deadline
- **1-3 Sept., 2011:** Workshop

For an introduction to the conference, please download the conference Call-for-paper Flyer.

Pete Hargrave, Cardiff University
p.hargrave@astro.cf.ac.uk