SITT: Spectral Interferometric Thermal Testbed

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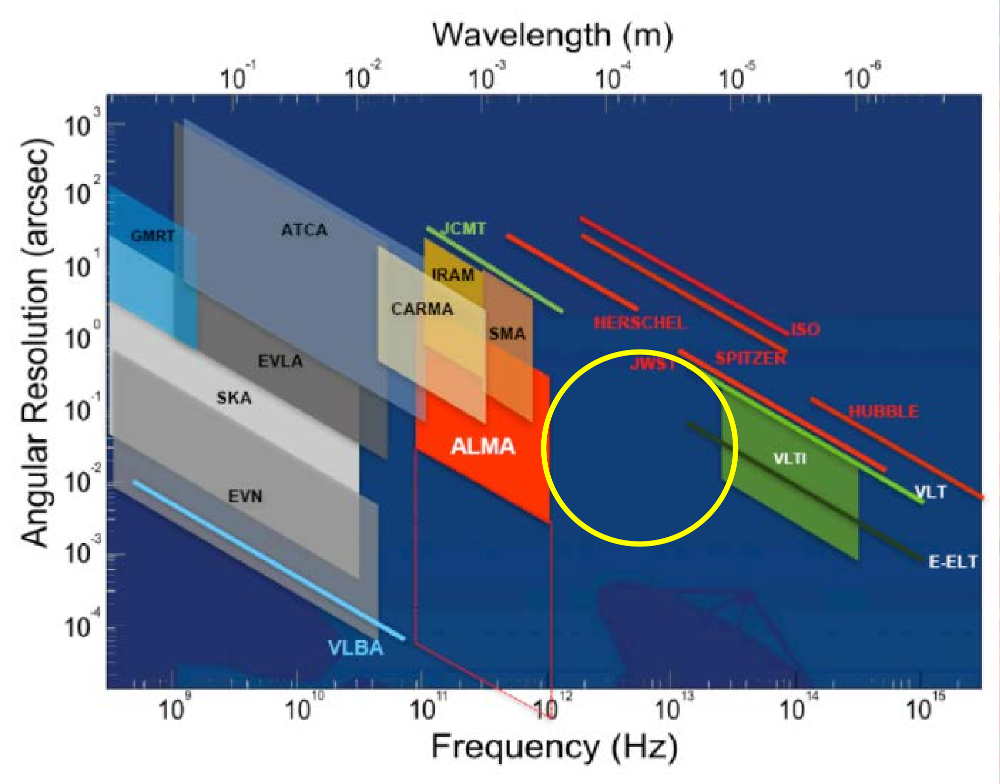
(University College London)

CEOI Workshop – Leicester – 30th April/1st May 2014

Faint background is the NASA MASTER airborne sensor picture of London (2003)

Context



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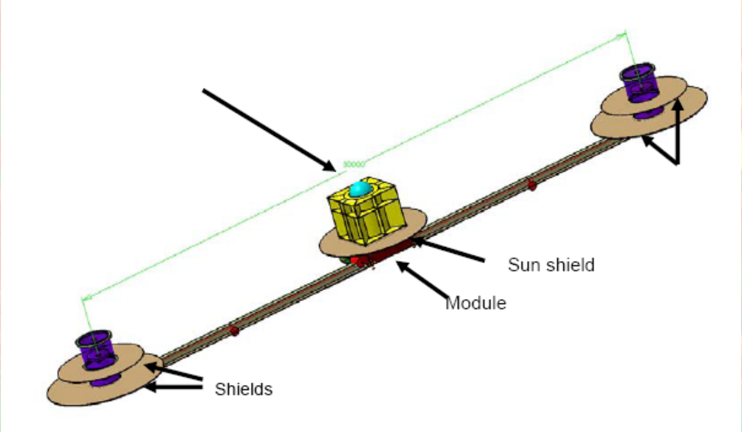
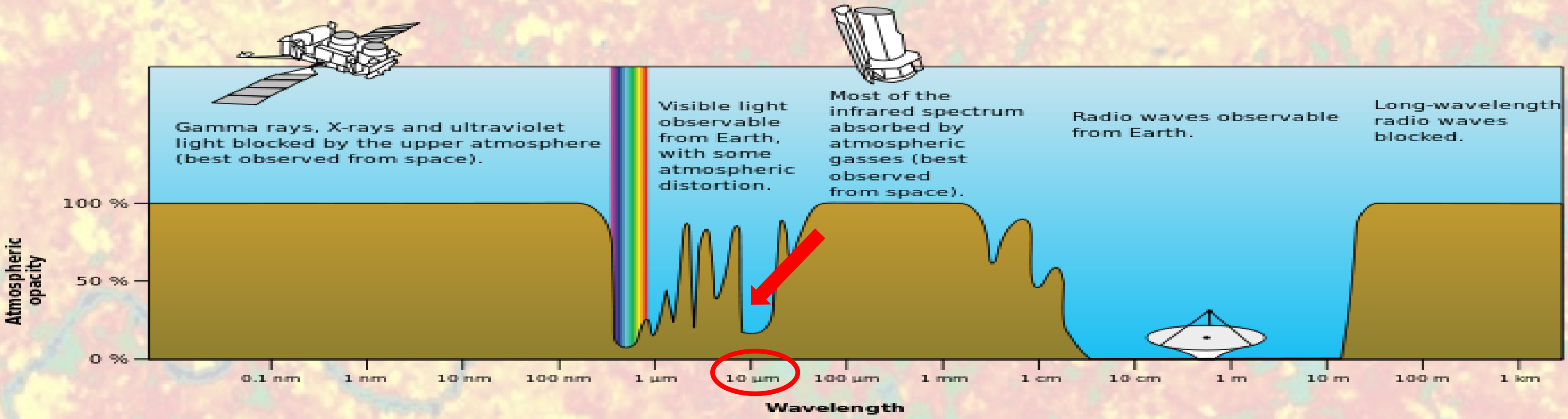


Recently re-discovered technique of **Double Fourier or Spectral-Spatial Interferometry** used in Astronomy observations.

Context

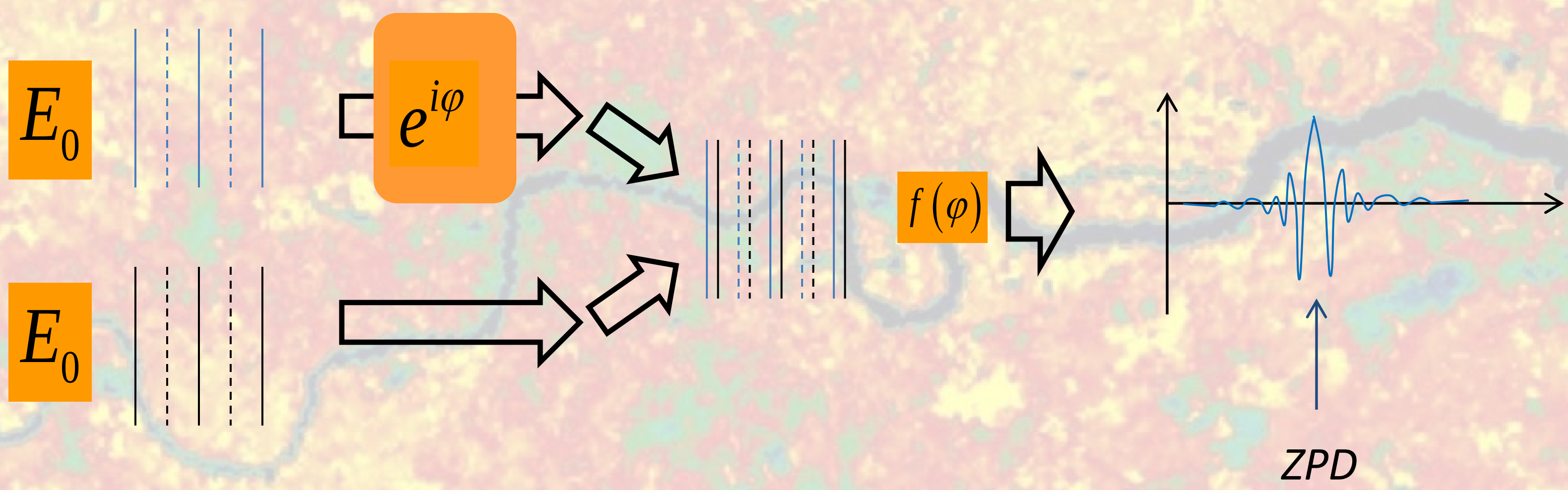
GOAL : Provide **high-angular resolution** with relatively small optics preserving spectral content information



Earth Observing and Remote Sensing well documented needs for High-Spatial resolution on the ground.

Fourier Modulation

Combination of two portions of the same plane wave after an appreciable phase delay.



Fourier Transform Spectroscopy

Variation of the optical delay allows (FT) separation of wavelengths.

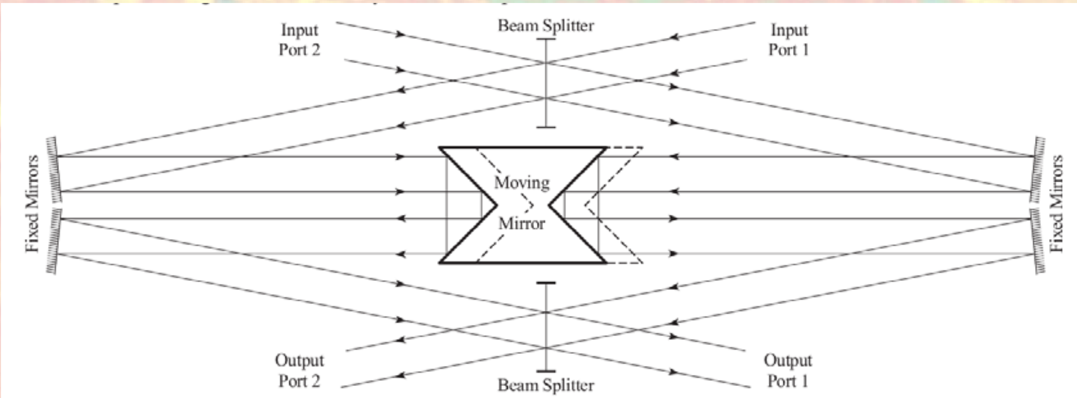
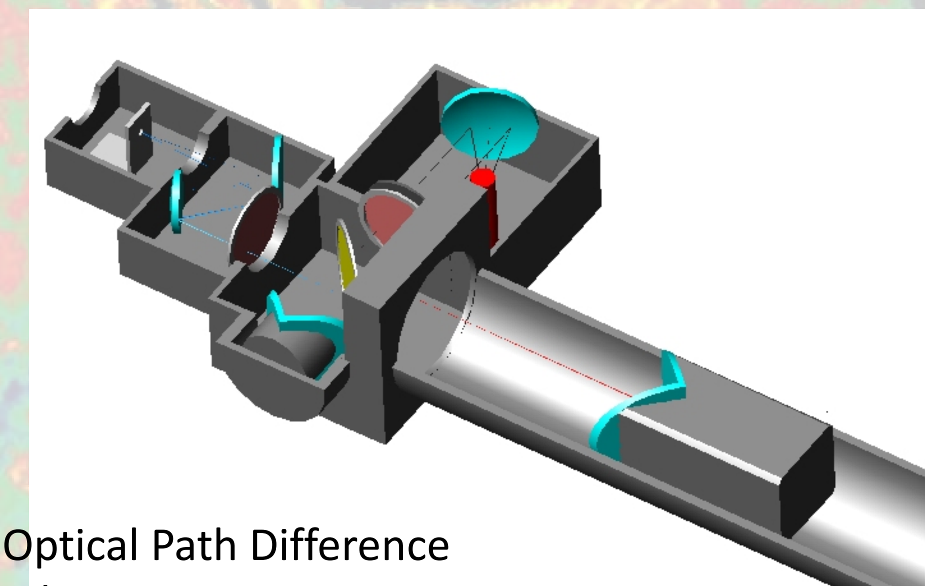


Figure 1: A schematic of the interferometer.

Ade, Hamilton, Naylor ('99).

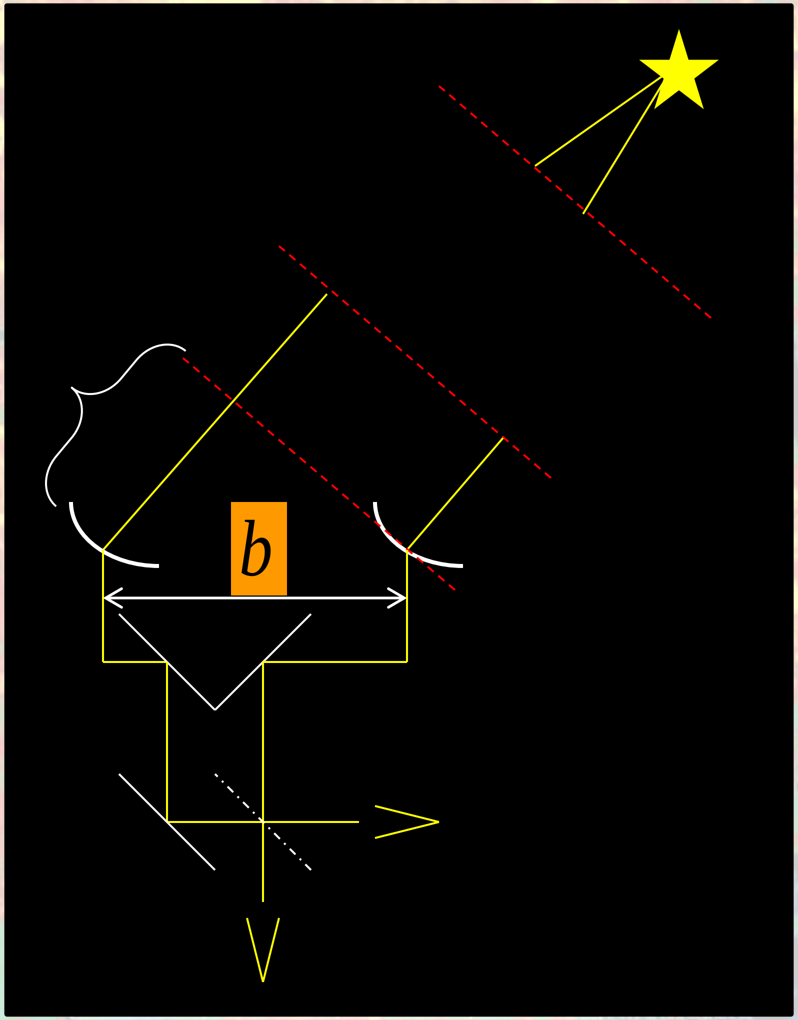


Defining parameter relations:

Spectral Resolution ←→ Maximum Optical Path Difference
Nyquist Frequency ←→ Spatial sampling

Interferometry

Optical delay tied to separate portions of the wavefront allowing (FT) sensitivity to different spatial scales.



Defining parameter relations:

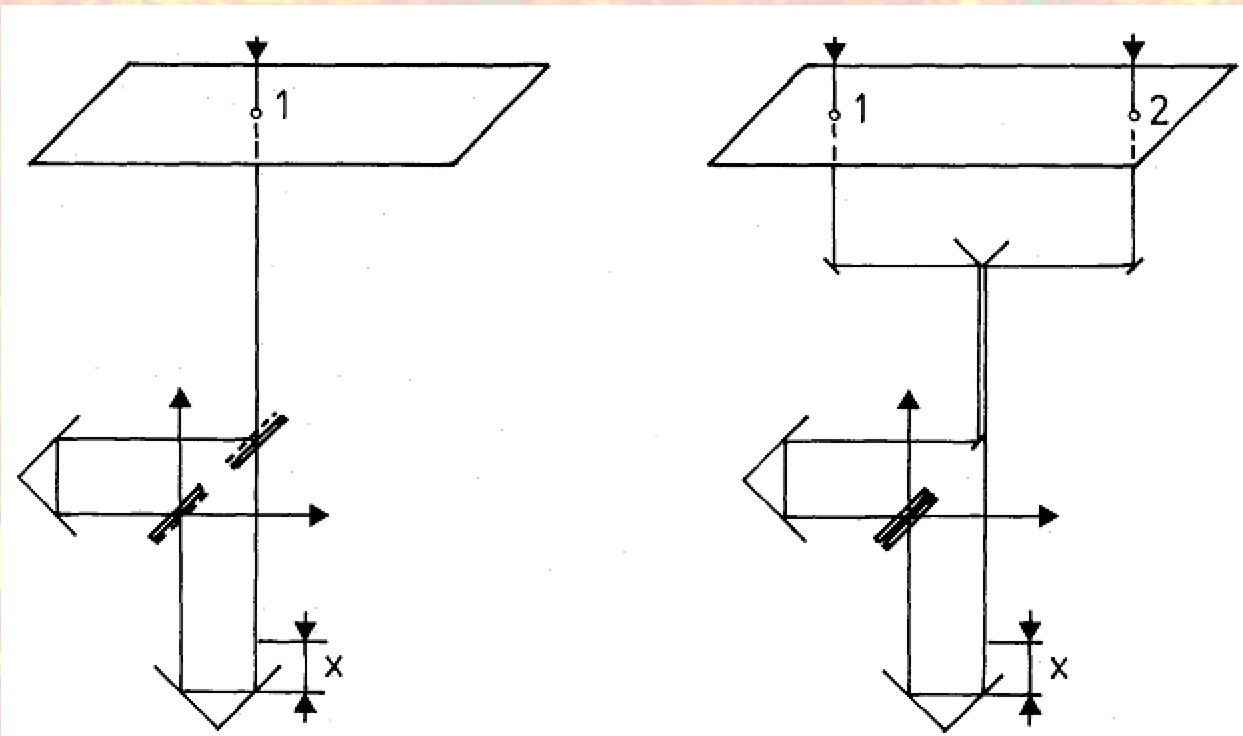
Spatial Resolution ←→ Maximum Baseline
+ Viewing Angle
Range of Scales ←→ Baseline Steps
Compensation stage.

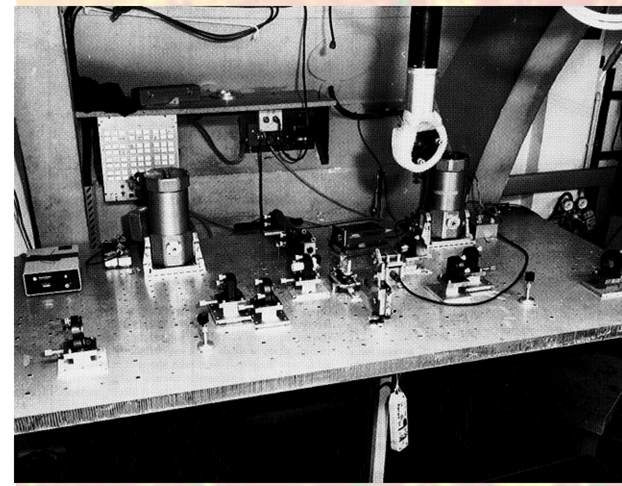
Double Fourier Interferometry

Astron. Astrophys. 195, 350–363 (1988)

Double Fourier spatio-spectral interferometry: combining high spectral and high spatial resolution in the near infrared *

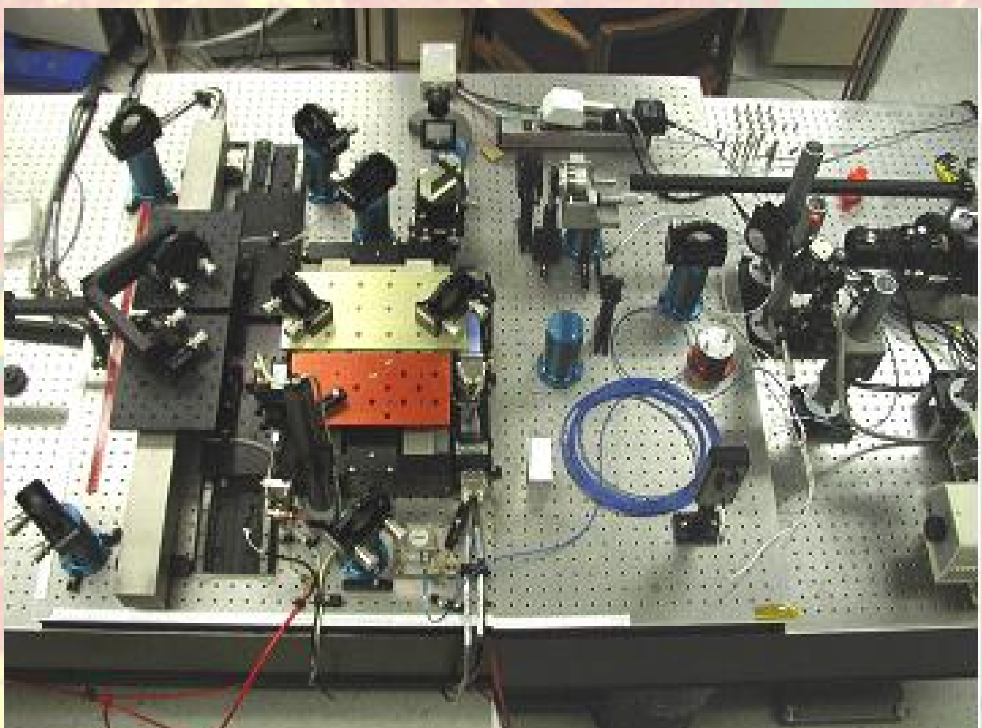
J.-M. Mariotti [1] and S.T. Ridgway [2]

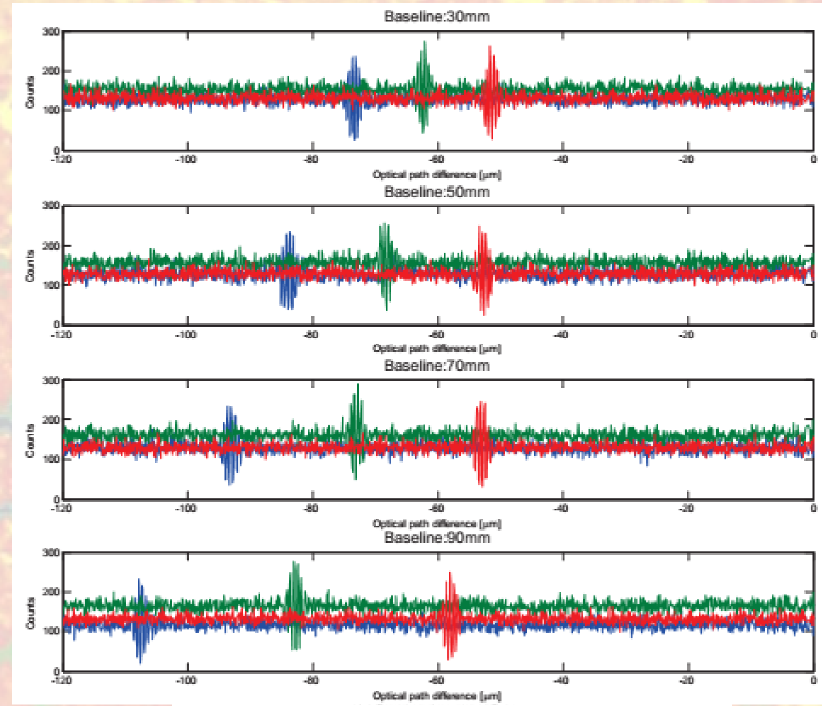


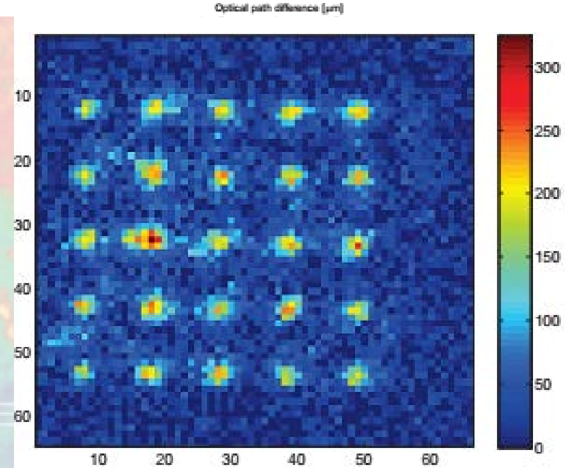


Double Fourier Interferometry in the Visible

WIIT : Wide field Interferometric Imaging Testbed

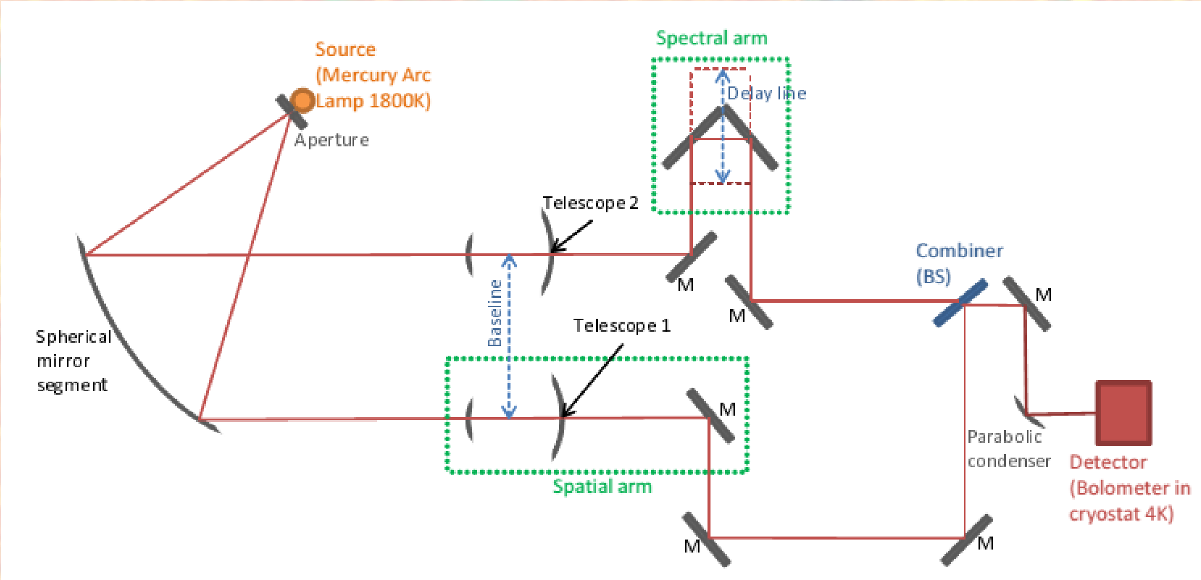


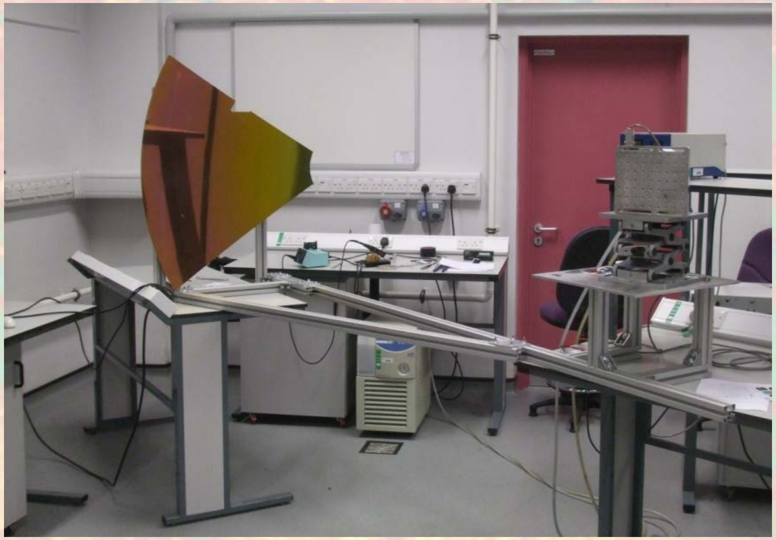


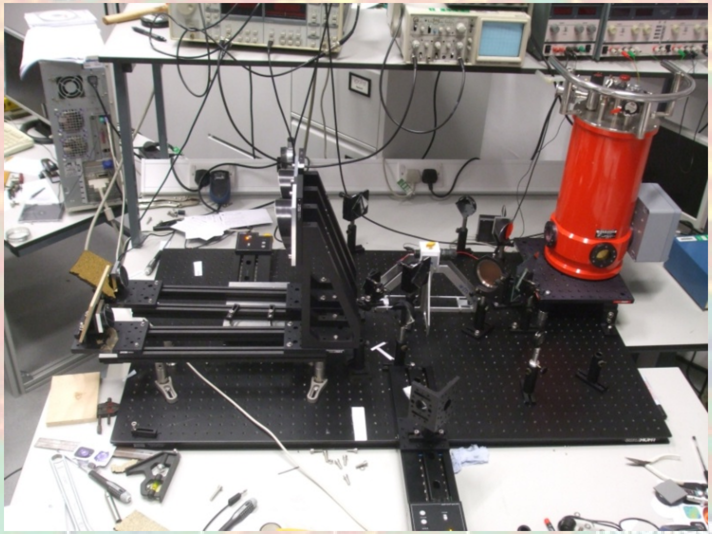


Double Fourier Interferometry in the sub-mm

The Cardiff University / RAL / UCL sub-mm test-bed.

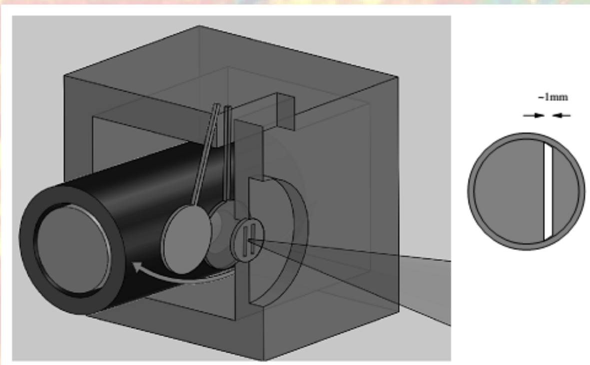


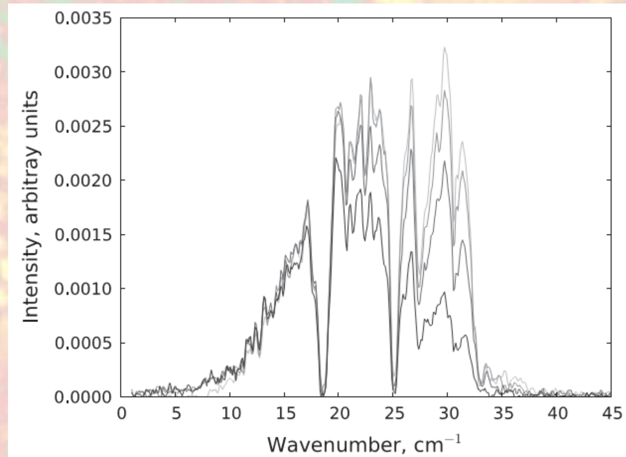


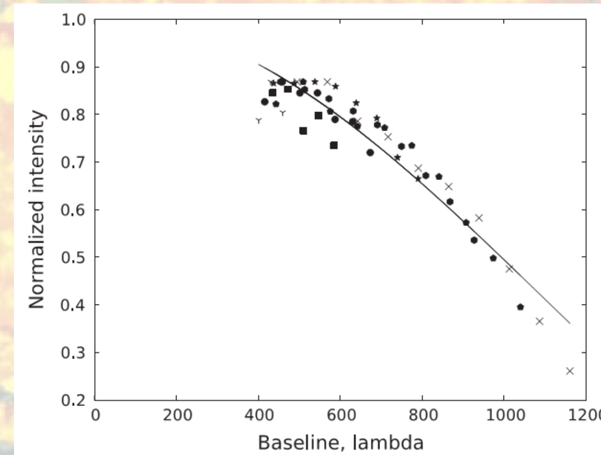


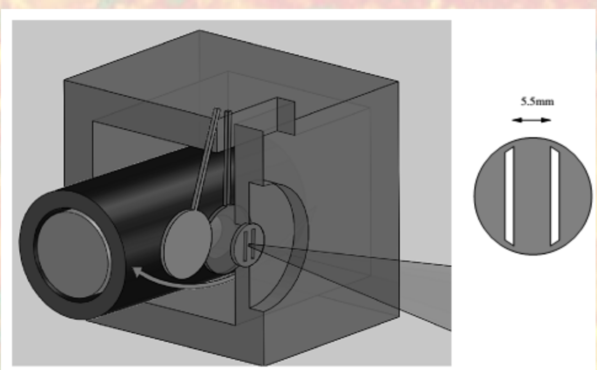
W.Grainger et al. App.Opt.(2012)

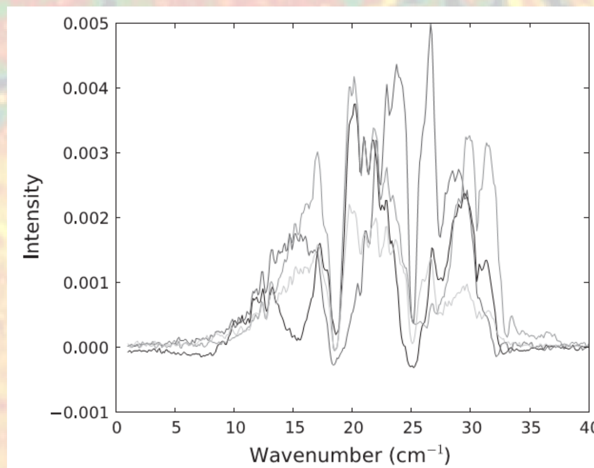
Double Fourier Interferometry in the sub-mm

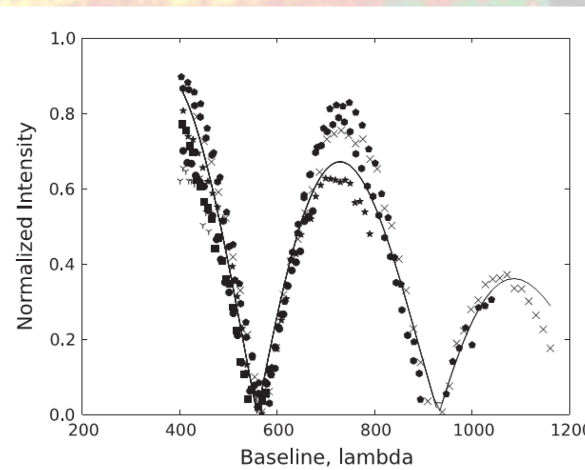








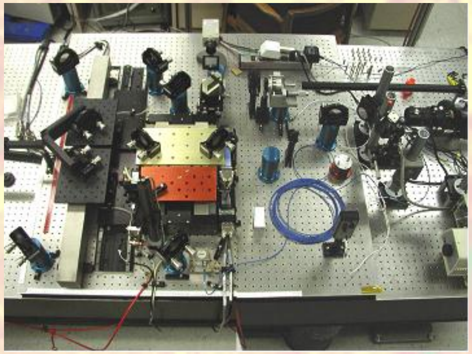




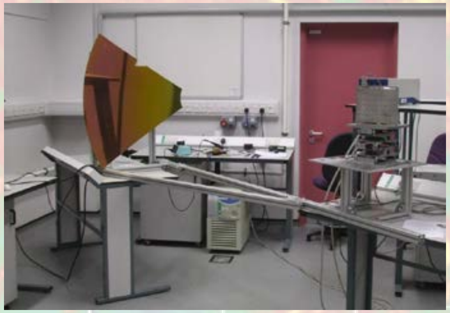
W.Grainger et al. App.Opt.(2012)

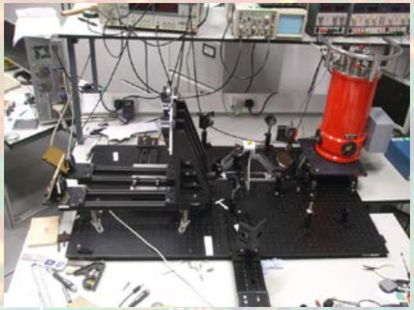
Testbed Family

An optical testbed exists at NASA to provide an exact scaled version of the instrument designed for the Far-Infrared (40-200um) in Space.



A sub-mm to mm-wave single-pixel testbed exists at Cardiff University to allow to study the performance of the relevant technology to be used in space.





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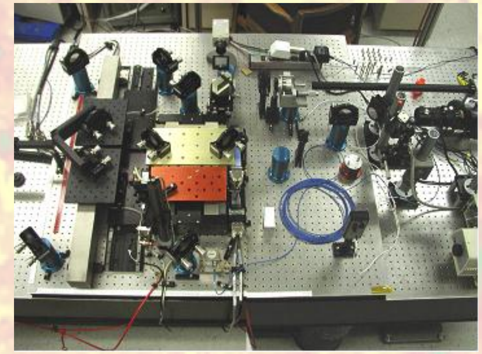

SITT
Spectral Interferometric Thermal Testbed

Provide an environement where all thermal aspects of the testbed and their impact on the data can be studied.

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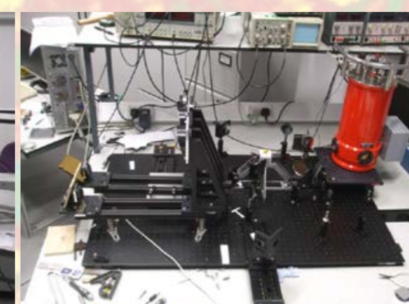

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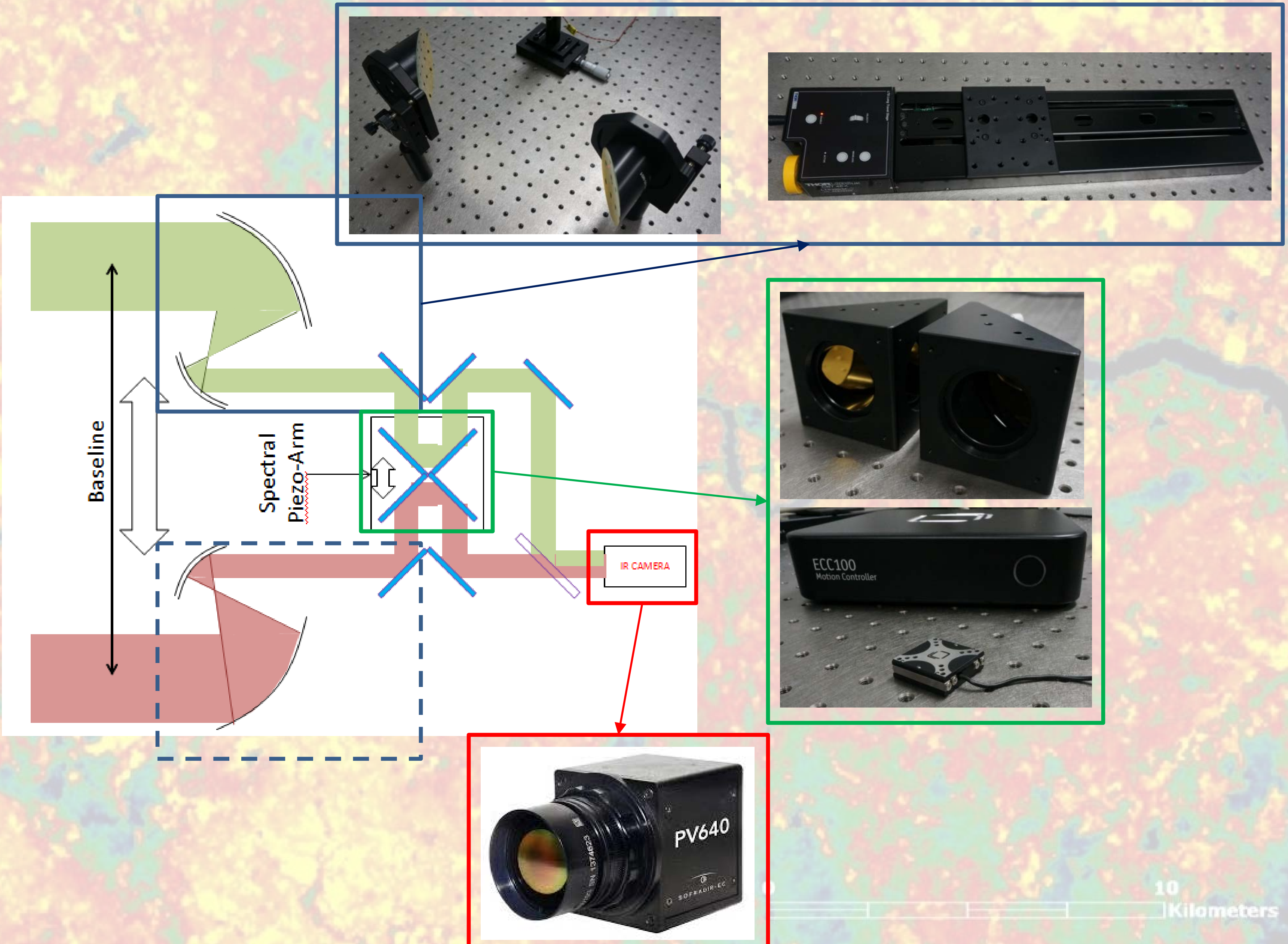
SITT : Spectral Interferometric Thermal Testbed

Rationale

-) Precision metrology is most challenging at visible wavelengths
-) Representative technology (detectors, beam combiners, ...) is required for the sub-mm and FIR
-) In both cases small temperature variation of the optical elements will not affect measurements

+) In space at FIR wavelengths a substantial part of the photons received will be from the optics
+) A thermal test-bed allows to test and model the effect that thermal fluctuations of elements affect the overall system

SITT : Spectral Interferometric Thermal Testbed



EO spatial resolution

Ground Sampling Distance

$$\text{GSD} = \frac{\text{Ground Velocity}}{\text{Frame Rate}}$$

Ground Sample Size

$$\text{GSS} = \frac{\text{Satellite Altitude}}{\text{Telescope Diam.}}$$

$\otimes$ Detector time constant

Current achieved EO thermal spatial resolution (GSD):

MTI	(US/DoE)		20m
LANDSAT	(US/NOAA)	[L7/ETM+]	60m
ASTER	(JP)		90m

SITT : Spectral Interferometric Thermal Testbed

Potential for Earth Observing :

-) The angular resolution is dictated by the baseline

In principle, two small telescopes can be co-aligned at opposite ends of a small satellite (5 → 50cm)

-) Ground speed a factor for LEO

Limitations on GSD from acquisition frequency do not drive mapping of point sources for large linear arrays (change of source position causes phase variation for the same baseline).
This makes such an instrument ideal to detect small features with a substantial dT.
There is scope to study the performance of such a system for extended areas with small dT variations (majority of applications)

-) Second stage (spectroscopy) possible with linear arrays

Unlikely double modulation with moving parts, delay architecture can be made static in order to create the IG on a line of detectors for a given pixel.

Conclusions

Double Fourier Interferometry could be a game changer in the thermal IR for:

- Step-up in higher ground resolution
- Adding spectral capabilities

SITT (Spectral Interferometric Thermal Testbed) will provide the ideal Technology Demonstration to assess the level of sensitivity achievable with “off the shelf” components and predict in-space capabilities

Broadband interferometric imaging - first step to assess the feasibility of wide-field imaging interferometry on the ground.

Thanks for your kind attention