Centre for
EO Instrumentation

MEMS-based spectrometers for miniature remote remote sounders

PRM

RAL Space – 10th December 2018

Jérôme Bredin, Neil Macleod
and Damien Weidmann

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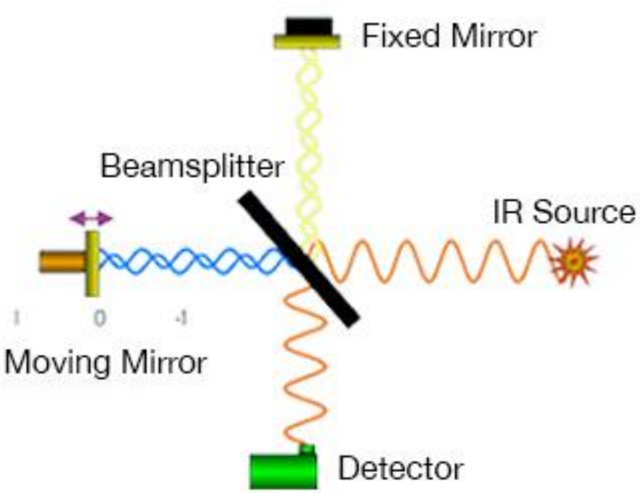
Motivations

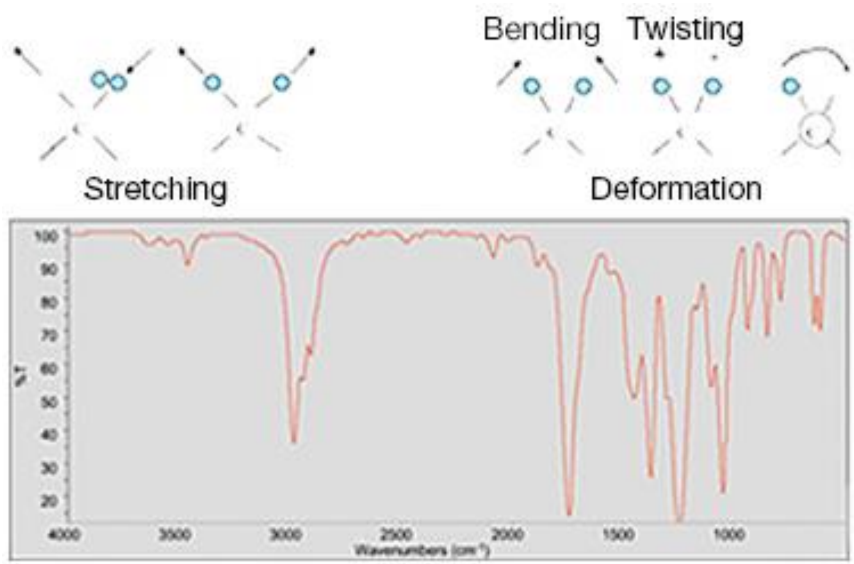
- Enabling greenhouse gases monitoring from ultra-miniature platforms
  - Space innovation and growth strategy 2014-2030
    - Low cost access to space – micro/nano satellites
    - Carbon monitoring and modelling
  - Miniaturized network of equipment complementary to high performance large platforms (OCO-2)

- Assessing a low cost, miniature, low consumption FTS

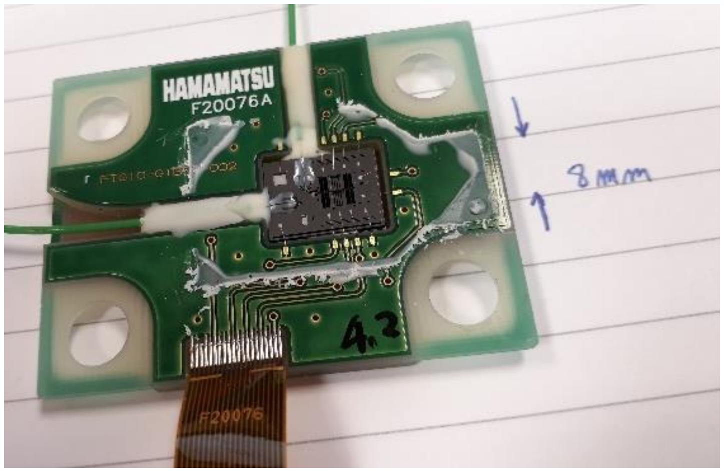
MEMs FTS

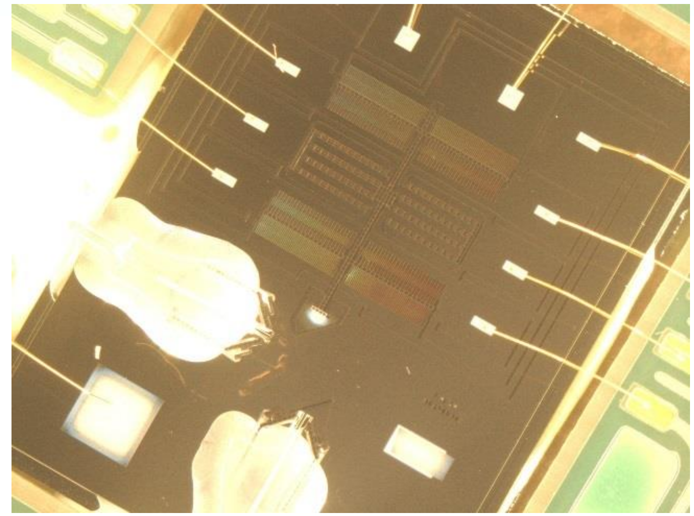
- Fourier Transform Spectroscopy (FTS) analyses incoming light to identify and quantify molecules;
- Micro-Electro-Mechanical systems (MEMs) enable to drastically reduce the size of moving mirror mechanism.
- Combine both to obtain an FTS that is relevant for miniaturised platform?

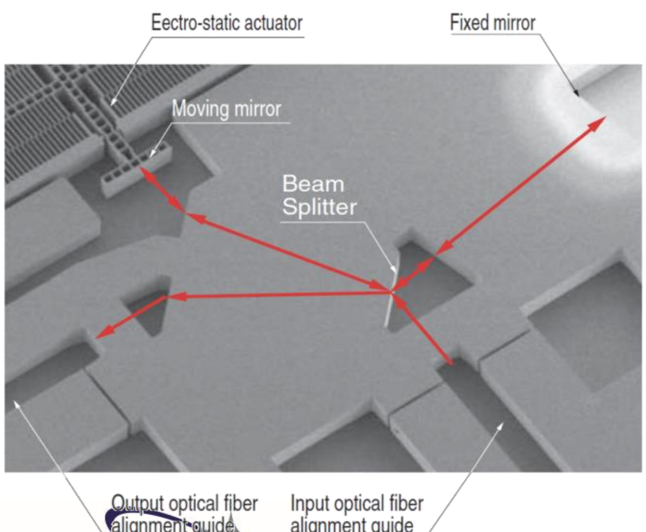


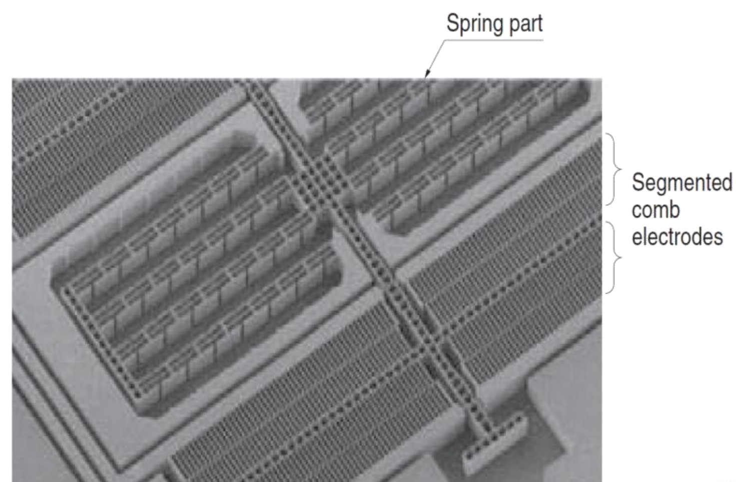


MEMs FTS

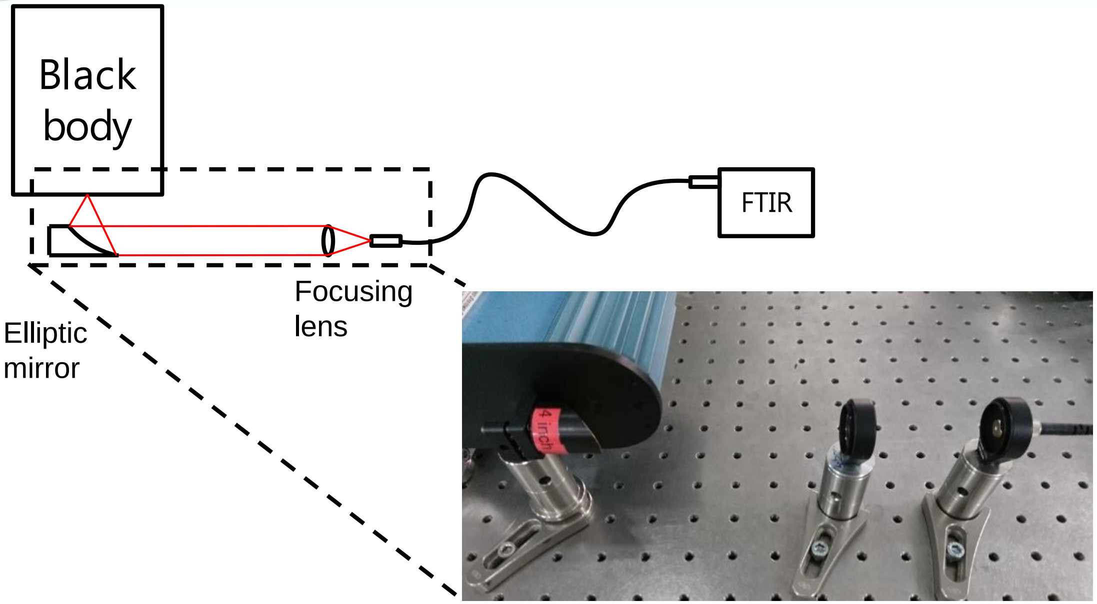

HAMAMATSU
F20076A
8 mm
4.2
F20076

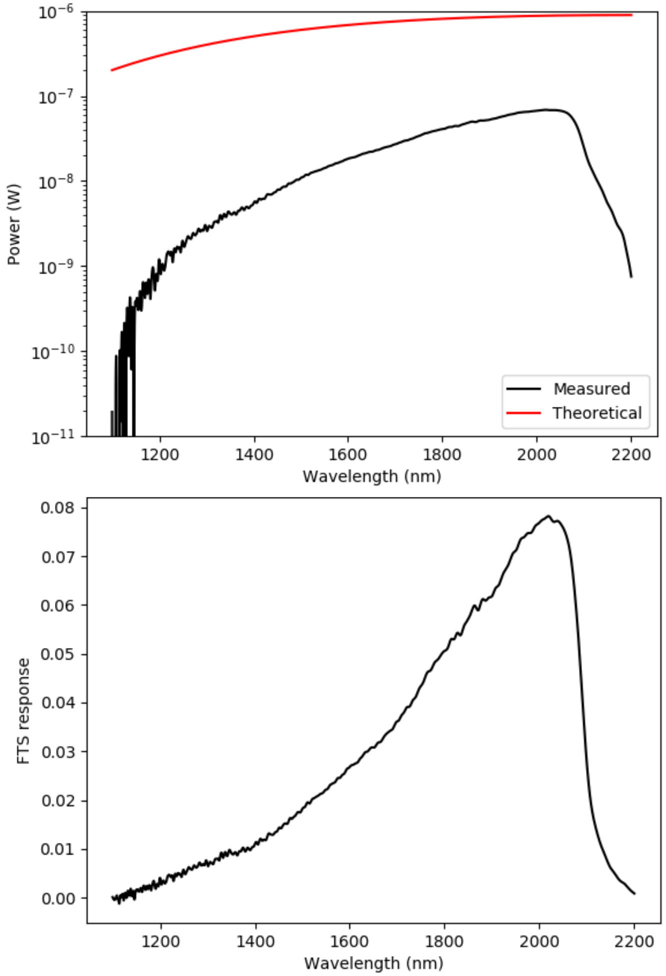



Eectro-static actuator
Fixed mirror
Moving mirror
Beam Splitter
Output optical fiber alignment guide
Input optical fiber alignment guide


Spring part
Segmented comb electrodes

Radiometric response study





- Measure black body radiation at 1050°C
- Compare with theoretical curve
- Get the response of the FTIR from ratio

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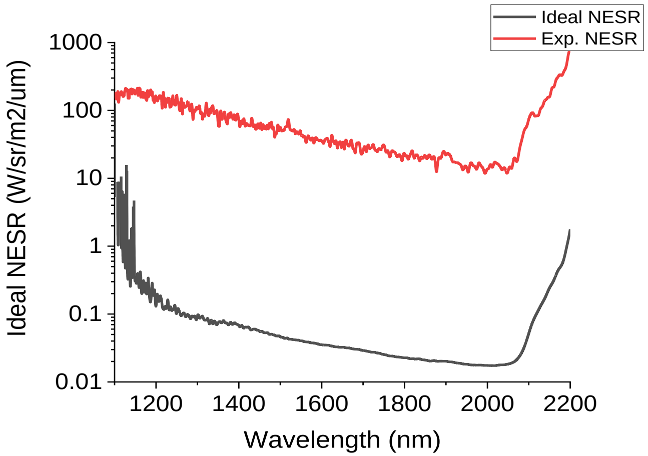
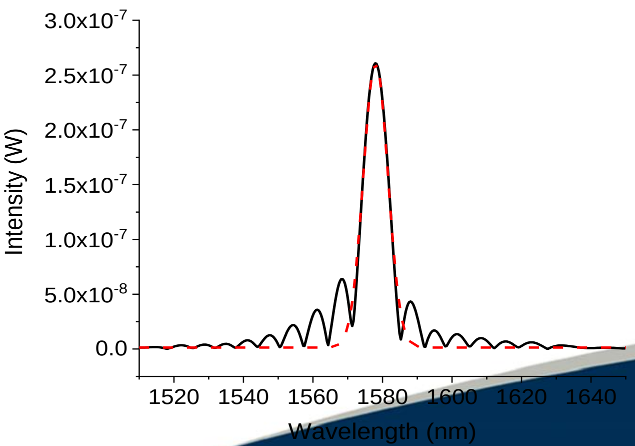
Characterisation of the MEMs-FTS

- Signal-to-noise ratio (SNR) measurements compared with ideal SNR
  - Determination of the noise equivalent spectral radiance (NESR)

$$\mathrm{NESR} = \frac{U_\nu(T)}{\mathrm{SNR}}$$



- Instrument line shape (ILS) determination with NIR Laser
  - ILS = 8 nm FWHM
  - Resolving power = 200



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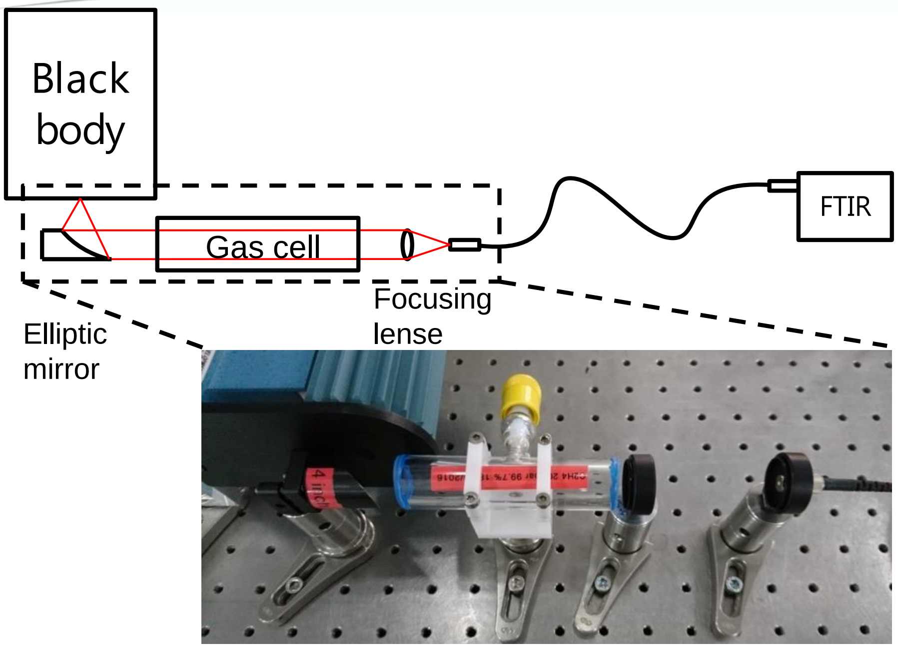
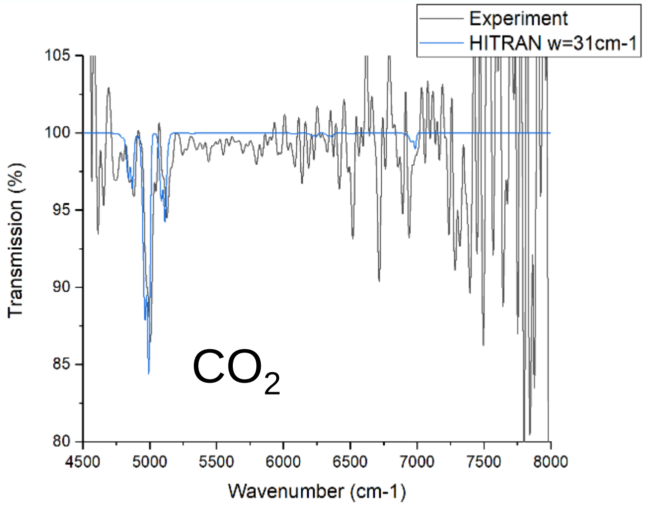
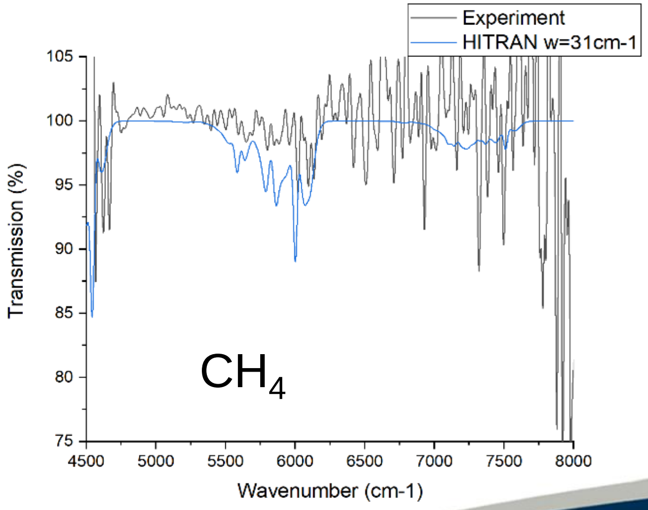
Gas analogue spectroscopy







- Absorption from 1050°C black body
- Cell filled with gas at 750 Torr CO_2/CH_4
- Simulation with HITRAN – 8 nm FWHM

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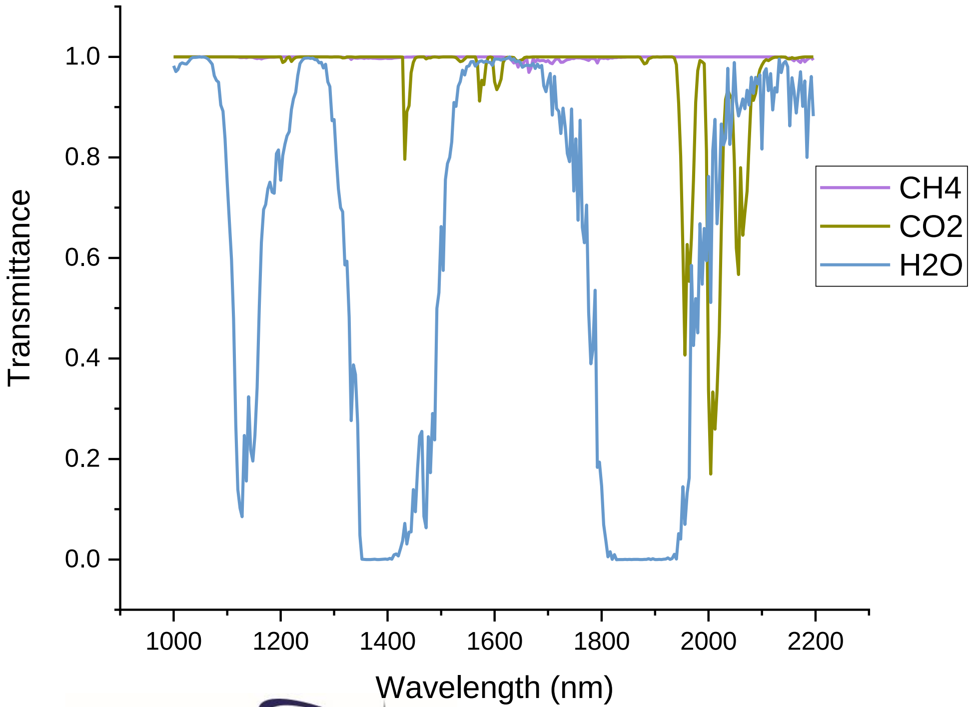
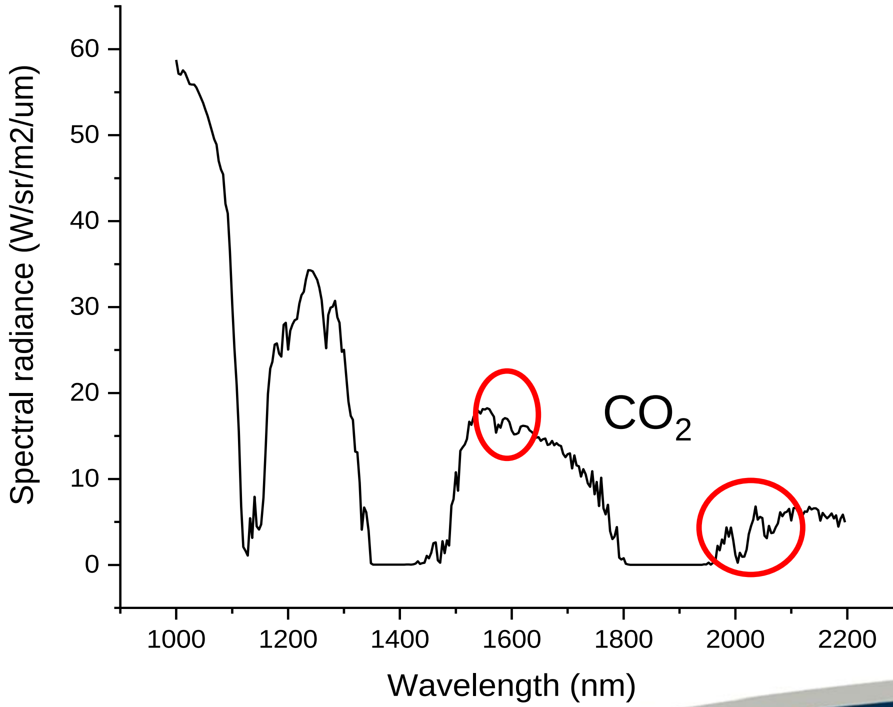
Early simulation of nadir sounding

- From online NASA Planetary Spectrum Generator
  - Conditions: Summer; Long. 0°; Lat. 50°; alt. 400 km; zen. 0°; res. 8 nm
  - Molecules: H2O, CO2, O3, N2O, CO, CH4, O2 and N2





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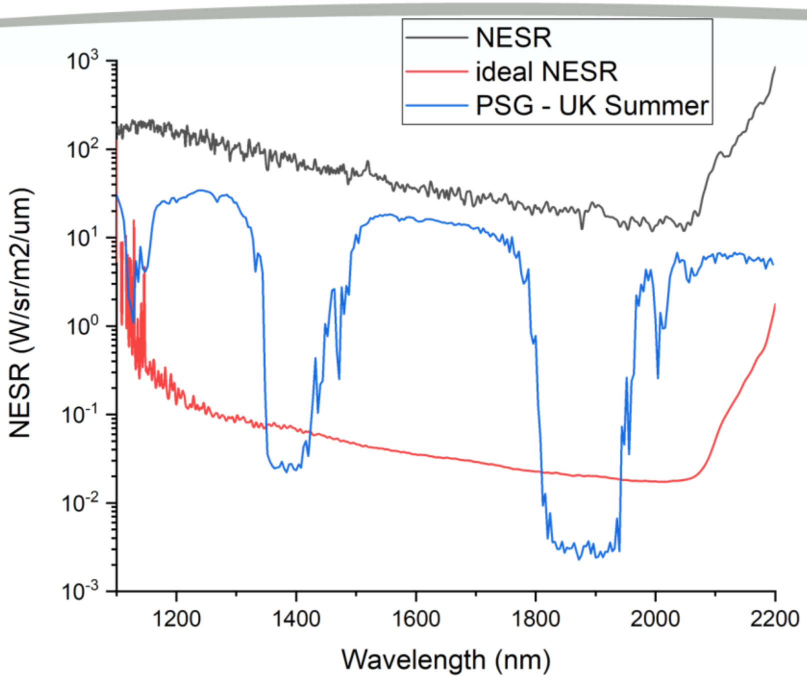
Extrapolated device performances



- Measured NESR > Spectral radiance from nadir looking simulation
  – With current device ➔ cannot do the measurement
- Ideal NESR < Spectral radiance from nadir looking simulation
  – With optimised device ➔ should be possible to measure

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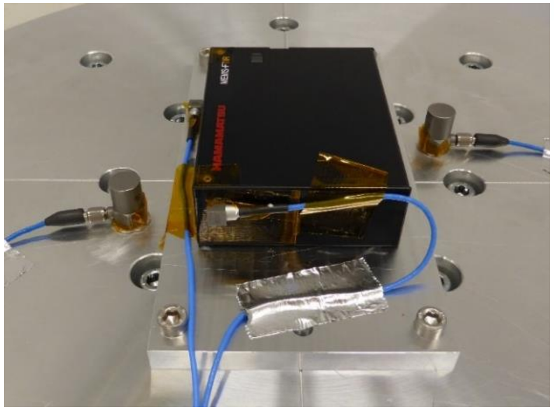
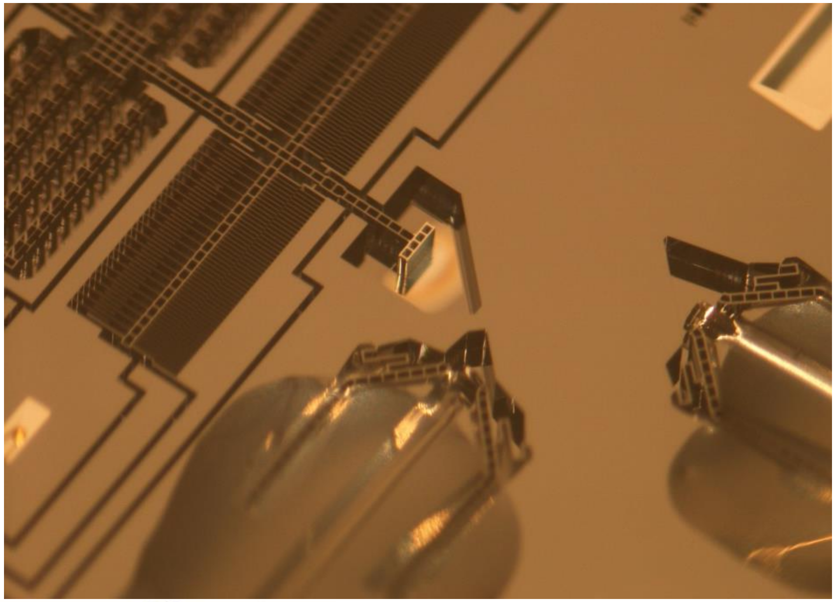
Vibration testing





Sinusoidal

Frequency (Hz)	Amplitude (g)
5-6	1.5
7-100	2.5
100-125	1.25
Sweep rate	4 oct/min

Random

Frequency (Hz)	ASD level (g2/Hz)
20	0.0113
50	0.0113
100	0.225
200	0.0563
500	0.0563
1000	0.0225
2000	0.0113 ➔ notched to: 0.00003
Grms	7.42 ➔ after notching: 6.48
Duration	2 min/axis

Conclusion

- Pros
  - FTS – range 1-2 µm – res. 8 nm – res. power 200 – within 1 cm^2
  - Low cost and scalable: could use tens for multi-pixel imaging
  - Enable hyperspectral sounding (150 channels)
  - From visual inspection MEMs structure survive vibration test
- Cons
  - SNR far from expectation ➔ off the shelf device, not design for that purpose
- Outlook
  - Work with MEMs designer: have a custom dedicated device for our specific application