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Engineering

Aalto-1
The Finnish Student Satellite

# Miniature Imaging Spectrometer for Aalto-1 Nanosatellite

1st IAA Conference on University Satellite Missions and Cubesat Workshop

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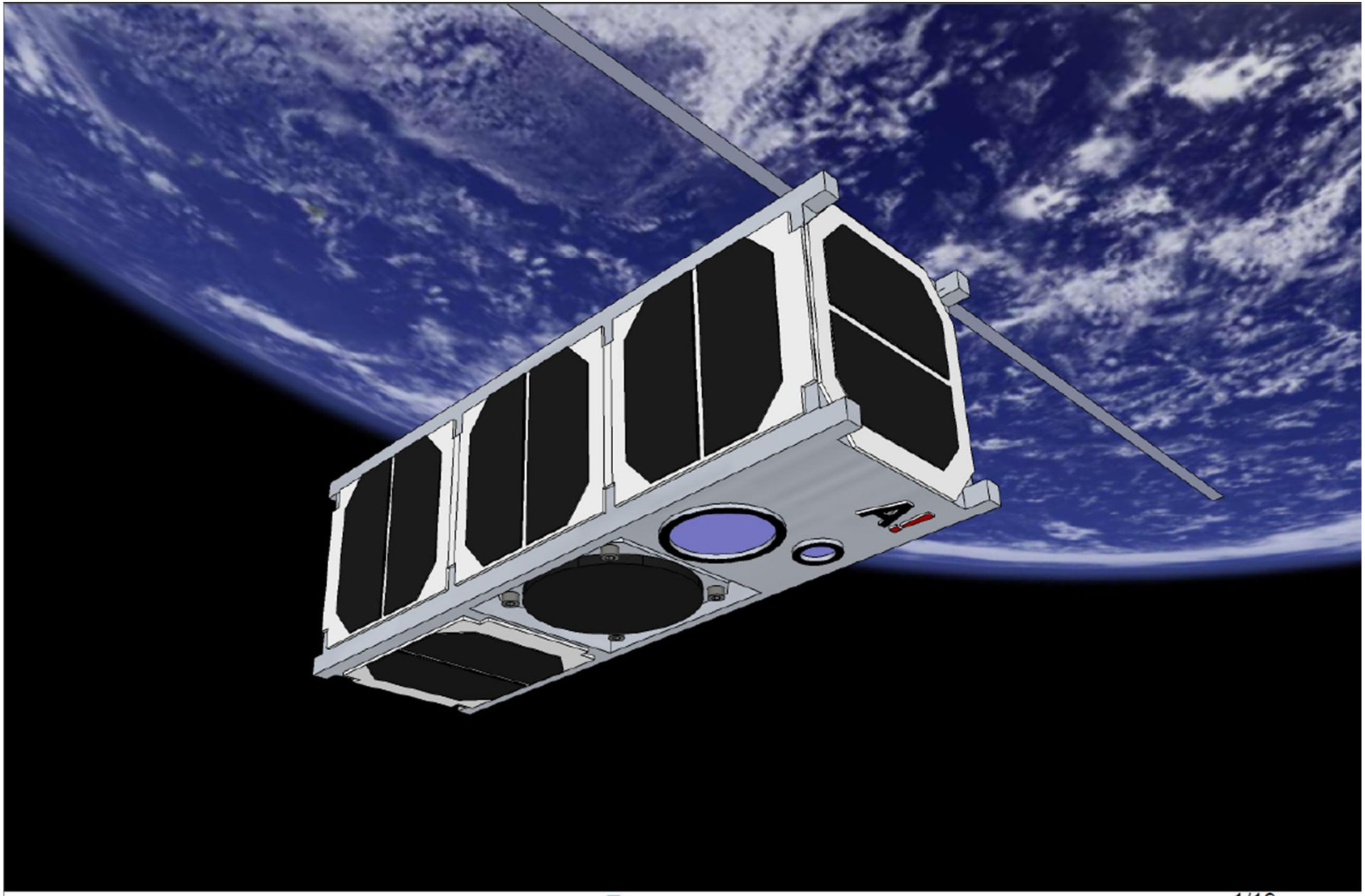



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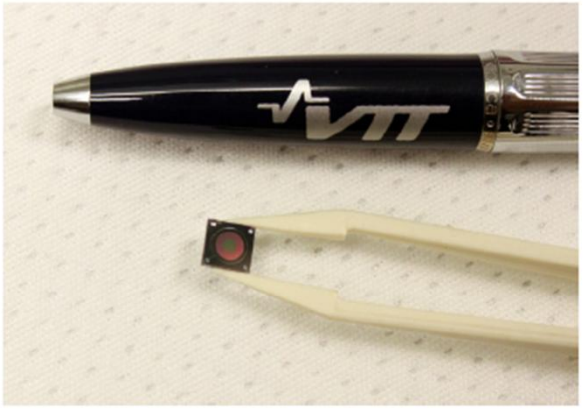
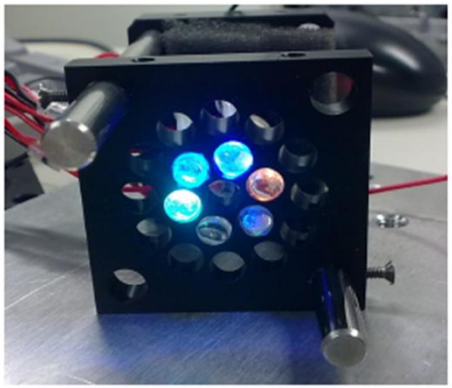
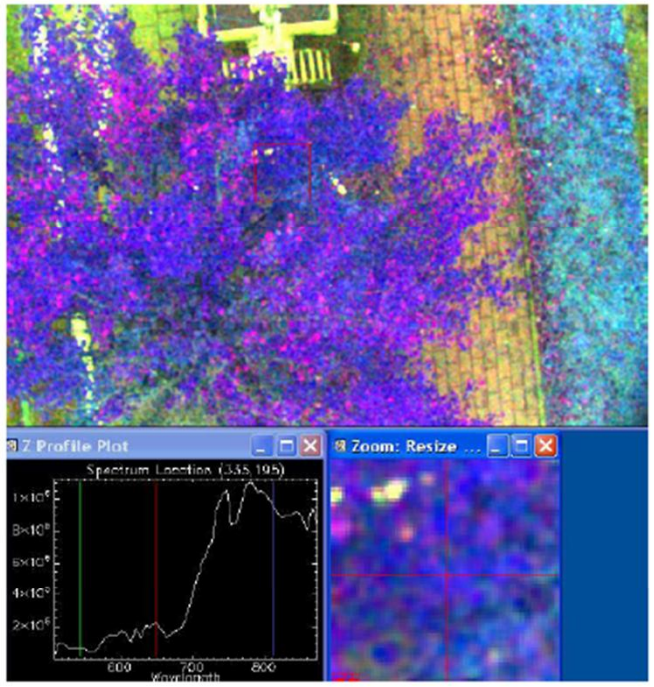
# Aalto-1: Demonstrating a novel imaging spectrometer concept

- Technology demonstration
- Space qualification for instruments
- Possible business opportunities
- Scientific results
- Education





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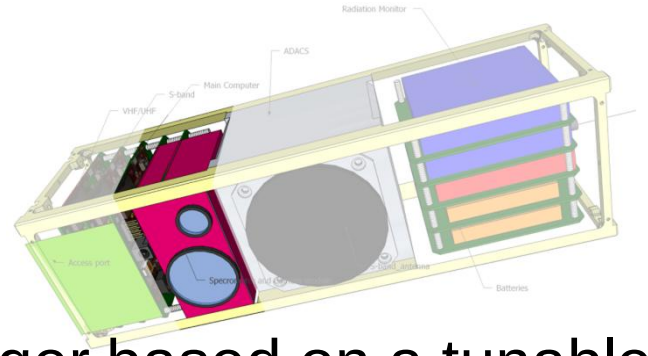
# Background

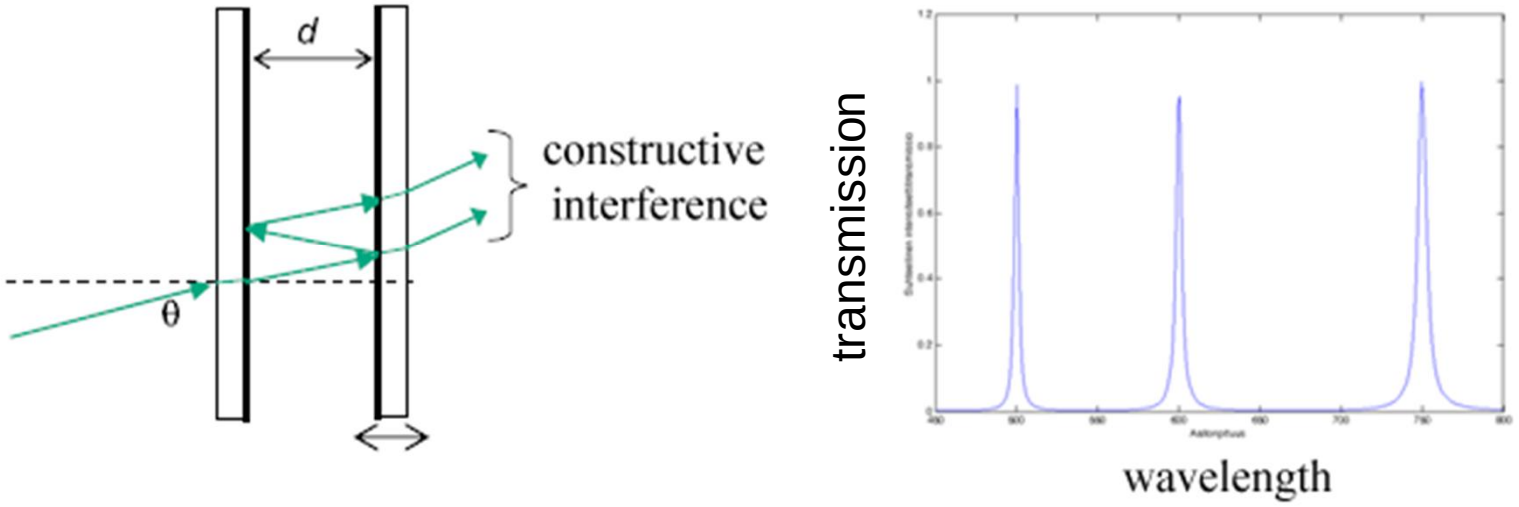
- VTT Technical Research Centre of Finland has developed MEMS (Micro-electro-mechanical system) FPI's since early 1990's
  - Similar technology has been used in Vaisala's CARBOCAP(R) sensor since 1997
- The theory behind the Fabry-Pérot interferometer (FPI) was introduced in 1897
- Fabry-Pérot filters have been used in space before (e.g. SOHO LASCO, launched 1995)

# Payload overview



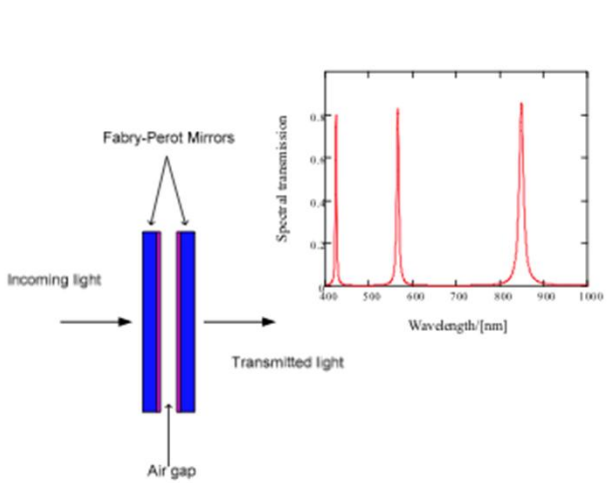

- A miniature Hyperspectral Imager based on a tunable Fabry-Pérot interferometer
- Joint project between Aalto-university and VTT Technical Research Centre of Finland
- The spectrometer module is built and developed by VTT Technical Research Centre of Finland
- The spectral imager is accompanied by a high resolution digital camera
- The smallest hyperspectral imager to be used in a satellite

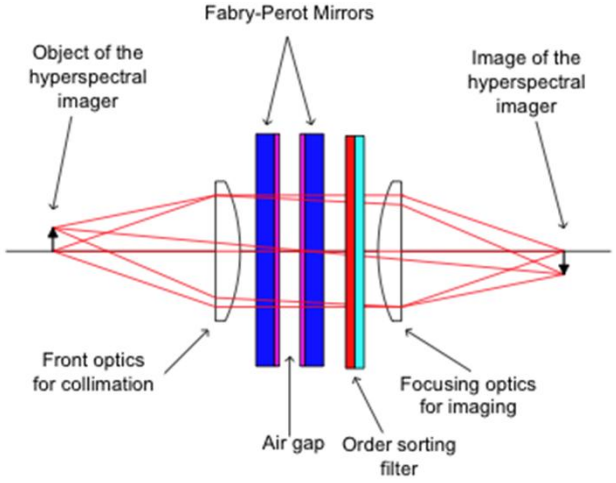
# Operating principle

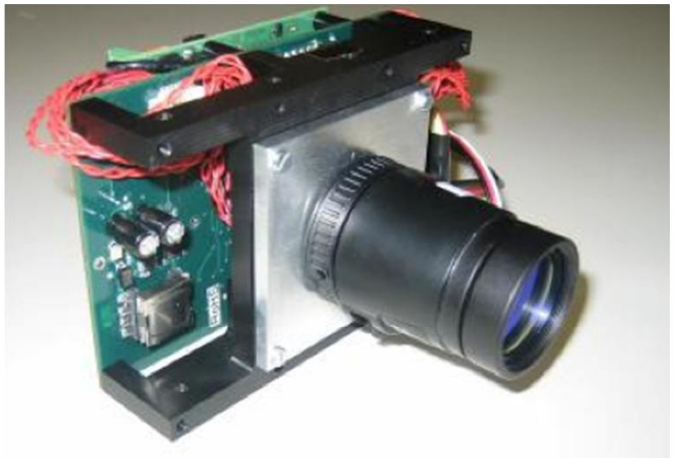


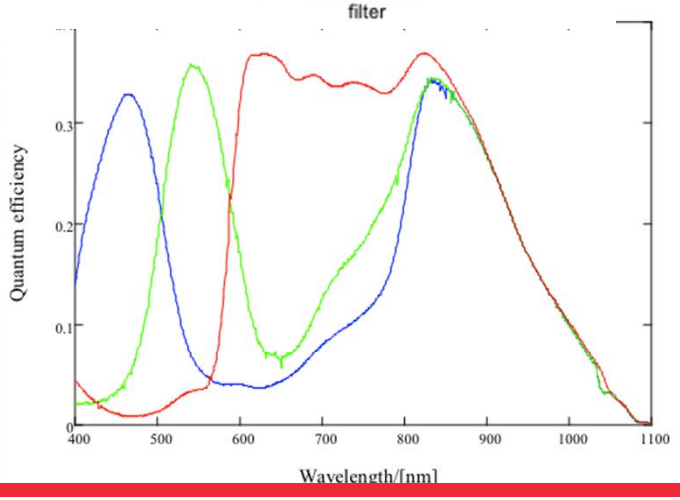

Fabry-Perot interferometer and it’s transmission

# Operating principle



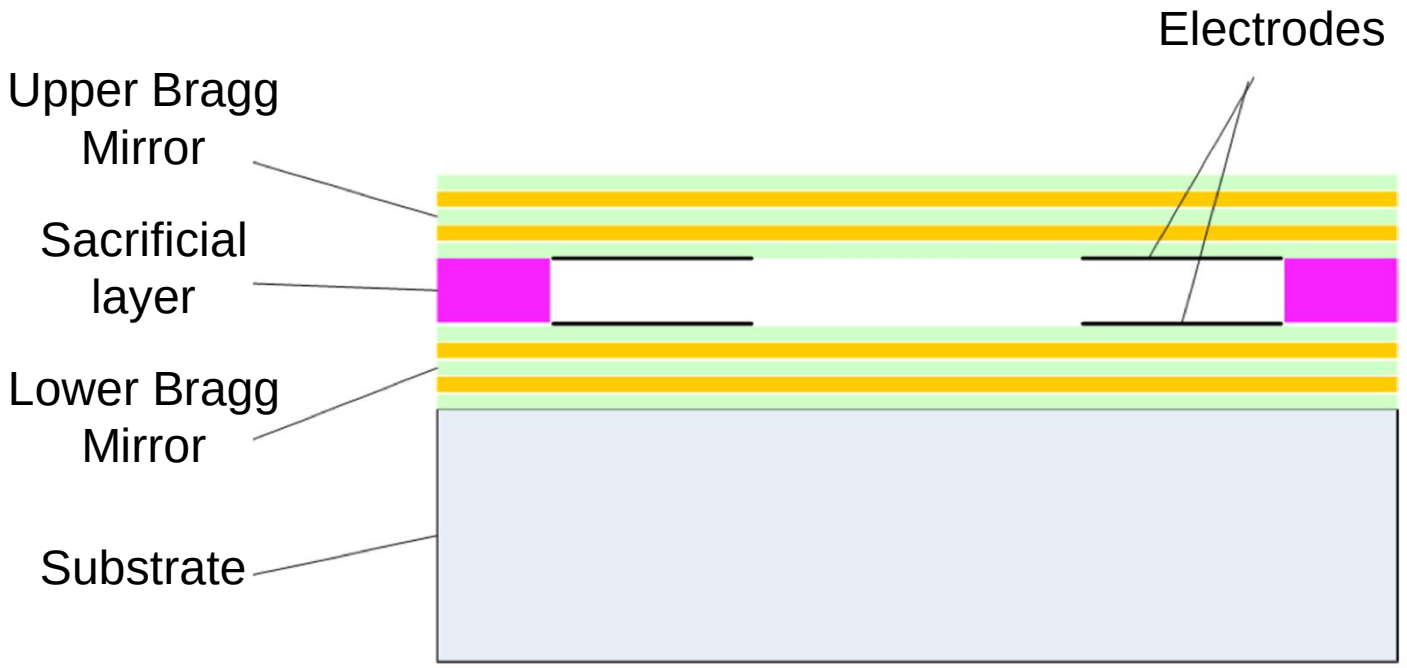





# Miniature Hyperspectral Imager

- Two possible concepts, MEMS and Piezo versions
- The design based on the piezo actuated FPI has already flown on UAVs
- Spectral resolution of 7-10 nanometers has been reached
- Operational spectral range depends on the configuration used (500-900 nm or 435-570 nm)
- Probably images at 6 to 20 spectral channels

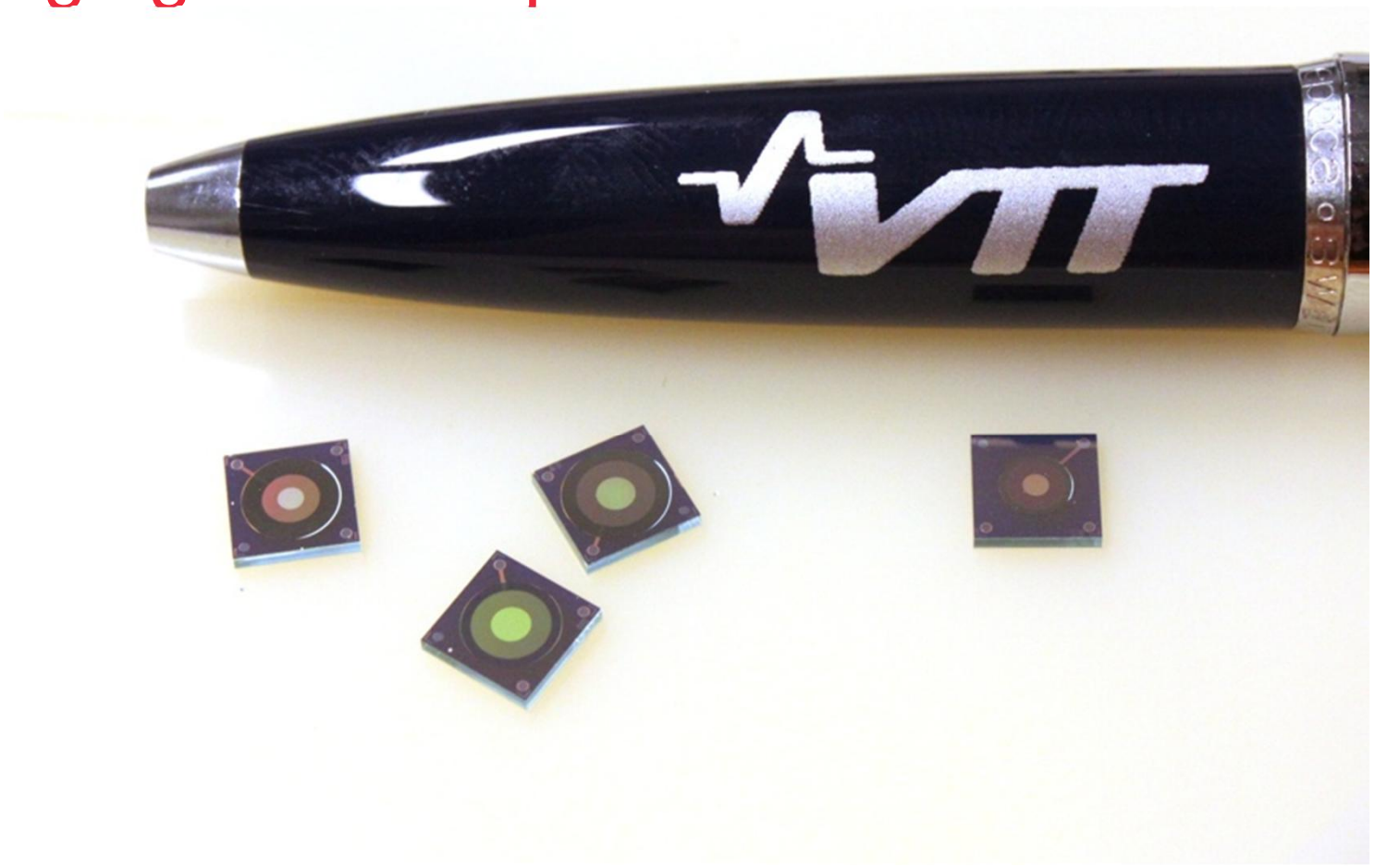
# Imaging MEMS Spectrometer



# Imaging MEMS Spectrometer

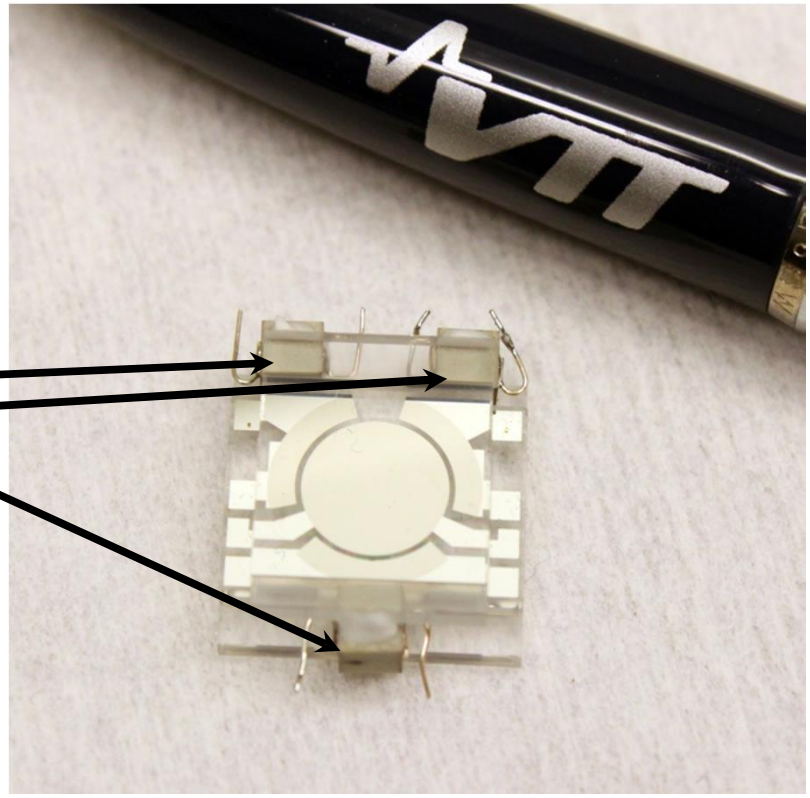
- VTT has built world's first MEMS based spectral imager device for demonstration to Photonics West 2011 fair
- The device consist of optics, a packaged MEMS Fabry-Perot interferometer (aperture diameter 2 mm), and a color imager, together with electronics and mechanics.
- Device can be used for surface inspection (it has built-in white LEDs as light source) or in remote sensing mode, focused to infinity
- The wavelength range is 460-585 nm and resolution ca. 5 nm

# Imaging MEMS Spectrometer



# Imaging Piezo-actuated Spectrometer

Commercial piezo-actuators



# Imaging Piezo-actuated Spectrometer

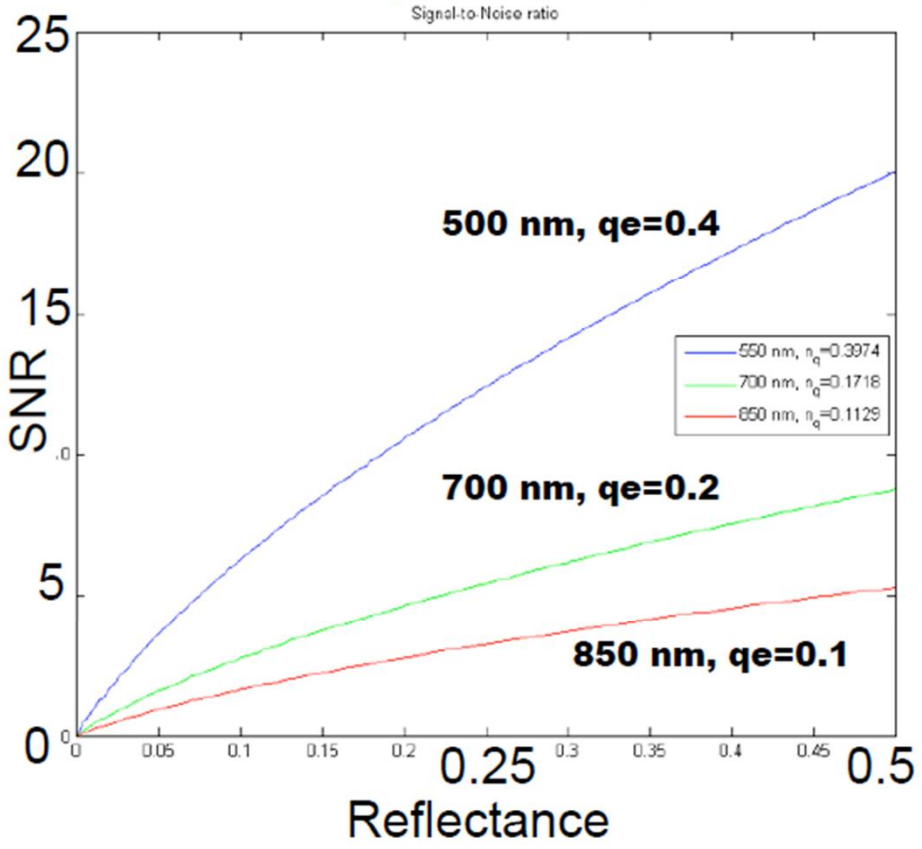
- Three devices have been built
  - A prototype was successfully flown in a UAV in 2009 (VIS)
  - Hyperspectral microscope (VIS)
  - Chemical imager (NIR)
- Apertures of 19 mm have been reached
- Easy to realize
- ca. three times the size of MEMS FPI

# Main payload of Aalto-1

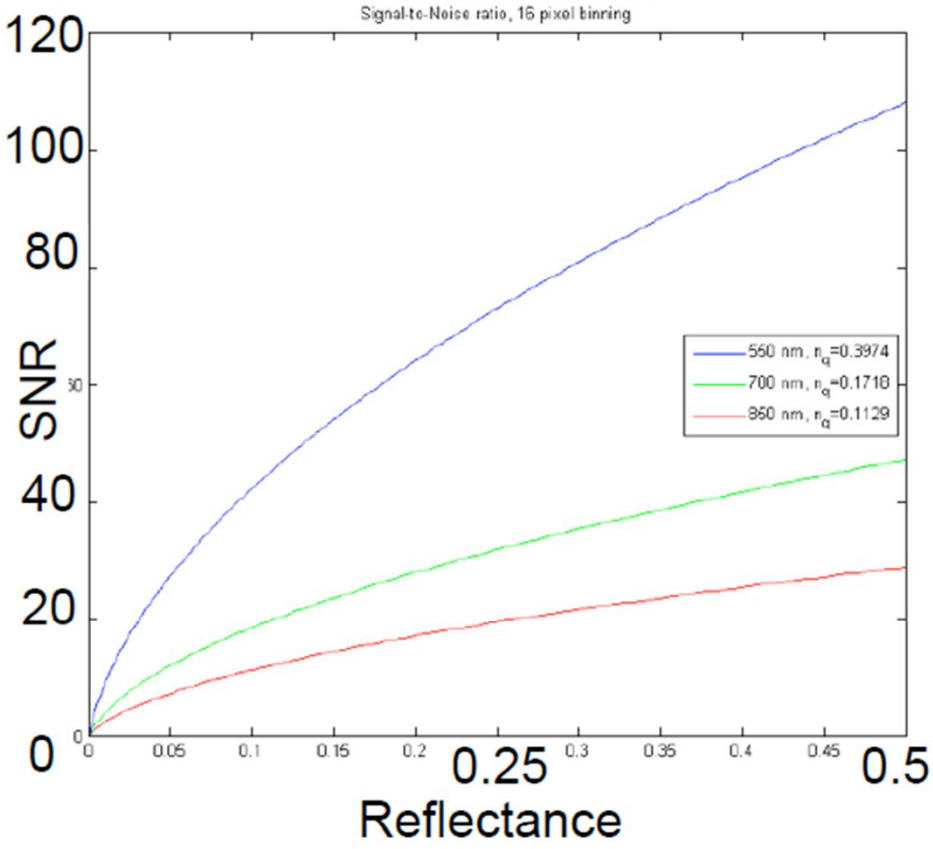
- The decision between different technologies has not yet been made
- Depends on the aperture requirements of the FPI
- Current apertures are around 1 mm (MEMS) and 5 – 19 mm (Piezo), but development is still ongoing
- The effective aperture for the final instrument is likely to be around 4 mm

# Current status

No pixel binning




16 pixel binning




Signal-to-noise ratio: signal electrons / noise electrons



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# Operational parameters

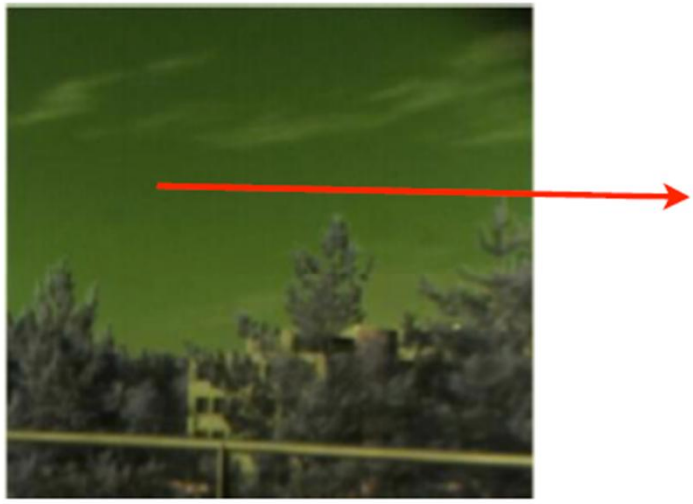
| Parameter | Values | notes |
|---|---|---|
| Spectral resolution | 7 - 10 nm | 3 nm possible |
| Spatial resolution | 50 - 100 m | Depends on SNR requirements |
| Spectral channels | 6 to 20 | 60 channels possible |
| Angle of View | 5° | |
| Spectral range | ca. 400 to 900 nm | Depends on technology and configuration |
| Optical transmission | ca. 35% to 80% | Depends on technology and configuration |
| Power usage | <2W | Peak power |
| Weight | ca. 350 g | |
| Sensor | 5 mpix RGB CMOS sensor | Aptina MT09P031 |

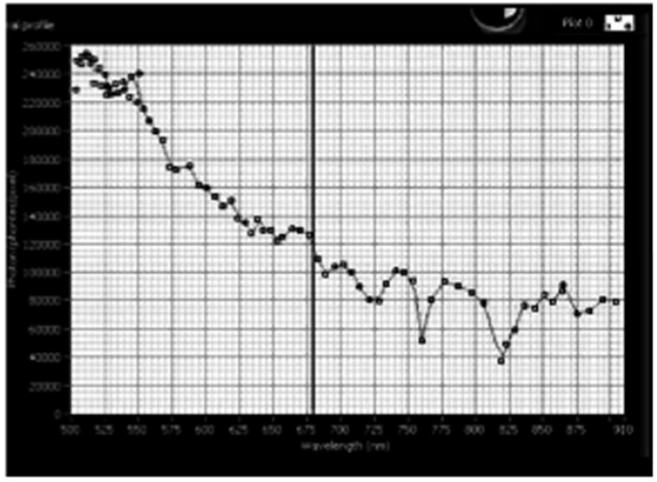
# Open issues

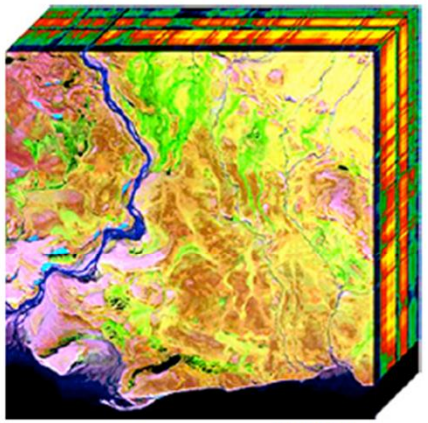
- Aperture of the MEMS FPI
- Thermal and vibration testing
- Optics performance
- Data rates

# … and beyond

- If the imager concept is proven spaceworthy, a true hyperspectral imager (100+ channels) could be built
- Spectral ranges of 400 to 3000 nm could be reached
  - Such instruments do not exist at the moment



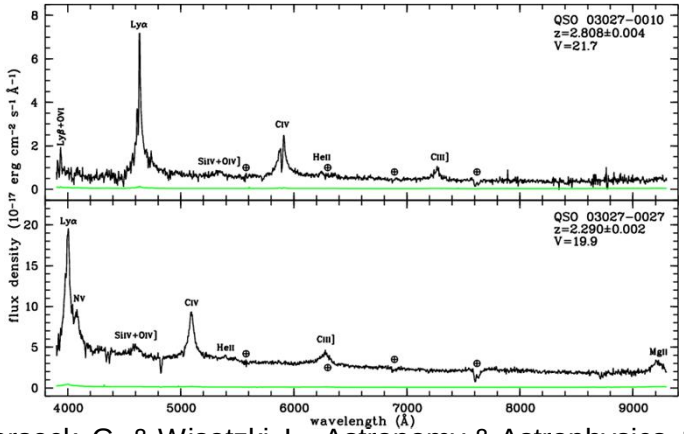




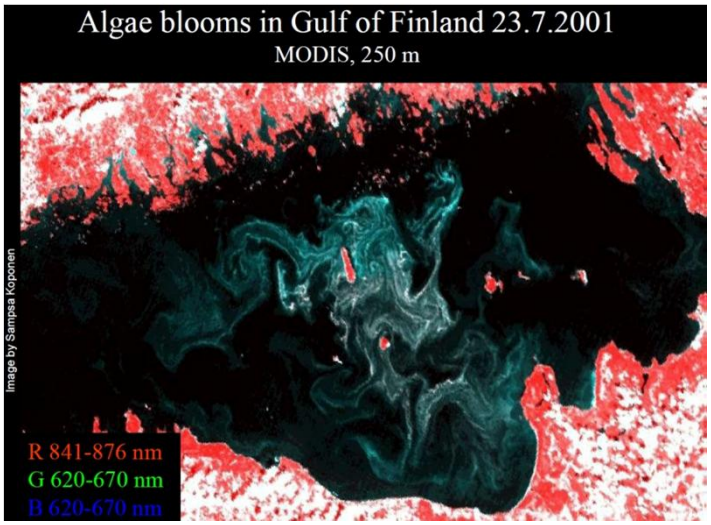
NASA

# Applications

- Cost effective hyperspectral imaging from space or UAVs (mass is money in space…)
- Agriculture, forestry, water monitoring, disaster management, climate research…
- Also in space research




Worseck, G. & Wisotzki, L., Astronomy & Astrophysics, 2006




Sampsa Koponen, TKK

# Summary

- Smallest hyperspectral imager ever to be used in a satellite
- Weighs less than 500 g
- Fits easily to a 1U cubesat

Thank you for your attention!

Questions?