



Spectral imagers for nanosatellites

Finnish Satellite Workshop 2018 Antti Näsilä VTT Microspectrometers

Fabry-Perot (FPI) technology for miniaturizing optical sensors

- ✓ FPI is a tunable optical filter electrical actuation changes the passband wavelength
- VTT develops miniaturized spectrometers based on tunable FPIs, for both imaging and nonimaging application
- ✓ FPI-based microspectrometers and hyperspectral imagers can be scaled to volume production







VTT's complementary FPI technologies

- 11010 MEMS FPIs for mass-producible microspectrometers in large-volume applications
 - Monolithic cleanroom fabrication processes
 - Hyperspectral imaging, gas sensing, IR sensors
 Automotive, mobile, IoT
 - Piezo-actuated FPI for small-to-medium volume applications
 - Separately assembled filter structure
 - Large optical apertures enable enhanced light throughput for high-performance applications
 - CubeSats, drones, medical, defense
 - Wavelengths available from UV to thermal IR



FPI platforms and examples of realized filters





FPI spectral imager characteristics





Compatible with

optics!

low-cost mobile

FPI tunable pass-band filter in spectroscopy



 Example: Visulization of gas distribution in standoff detection

FPI technology applications – examples and demonstrators



sensing

Mobile hyperspectra iPhone demo (2016)



Mobile and hand-held



Spectral Engines h NIR sensor (2016)

MEMS-based Me es hyperspectral imager demo (2012) (2012)

based Mobile CO2 ectral demo (2014)

Space and environmental



Hyperspectral imagers for space instruments

- Aalto-1
- PICASSO Vision
- Hello World
- 2018: Cubic-inch spectral camera

Drone hyperspectral imagers for forestry, precision agriculture, gas sensing and UV-Raman Visible-VNIR (2011), SWIR (2016), UV (2016)

SO₂/NO_x ship emissions imaging (2016)

Skin cancer hyperspectral imager (2014-2017)



Imaging of cells, micro well arrays & fluorescence imaging (2016)



Health and diagnostics



Fundus camera Detection of glaucoma and diabetes, oxygen saturation (hypoxia, apnea)

Brain surgery spectral imaging integrated to the Zeiss Pentero brain surgery microscope Stand-off - and and chemical detection



Thermal IR hyperspectral imager (2014) UV-FPI Raman stand-off trace detection (2014)





Chemical imager for 1-2.5 µm Distribution of active ingredients



Impact

- Customization of FPI technology to novel applications in research- and contract projects
- Several successfully commercialized sensing technologies
 - Space R&D activities have also generated first commercial CubeSat mission with Reaktor Space Lab





Aalto-1

- VNIR spectral camera (500-900 nm)
- Normal RGB camera
- Technical mission objectives have been almost fulfilled
- Camera system has been working well
- High speed downlink wanted ⊗





Ground based imaging tests



700 Wavelend





Picasso

- Picasso: Picosatellite for Atmospheric and Space Science Observations
- VISION: Visible Spectral Imager for Occultation and Nightglow
- 2 scientific experiments for Earth observation
- VISION: retrieving vertical profiles of ozone and temperature via Sun occultation (FM delivered in May 2017)
- SLP: studying the ionosphere (Langmuir probe)









VISION operation principle

- Observation of sunsets and sunrises through the Earth's atmosphere
- Occultation technique is self-calibrating (dividing by out-of-atmosphere signal)
- Vertical distribution retrieved by onion peeling method





Ground based measurements with the EM



Hello World

- 0.5 U SWIR-1 spectral imager
- Measuring from 900 to 1400 nm
- First IR spectral imager for a nanosatellite
 - To our knowledge...











Raw uncalibrated spectrum



ALTIUS





Asteroid Spectral Imager

- Instrument envelope: 1U
- 2 spectral imagers, VIS and NIR
- 1 SWIR spectrometer
- Includes the AOCS navigation





VIS channel

Based on Aalto-1 Spectral Imager Spectral range: 500 – 900 nm Image size: 1024 x 1024 Spectral bands: ca. 14

NIR channel

Spectral range: 900 – 1600 nm Image size: 640 x 512 Spectral bands: ca. 24

SWIR channel

Spectral range: 1600 – 2500 nm Image size: N/A (1 pixel) Spectral bands: ca. 30



Next: Cubic-inch spectral imager

- Goal is to combine mobile phone camera modules with new MFPI components
- From 5 x 10 x 10 cm³ to 2.5 x 2.5 x 2.5 cm³
- Easily fitted in very small UAVs, satellites or rovers
- First demonstrator will be presented in Photonics West 2018





Summary and conclusions

- Optical remote sensing is possible with nanosatellites
 - Just choose the application well
- VTT has develope spectral imaging solutions for UV, visible and infrared regions
- The technology is easily tailored for different mission needs



