Business from technology

Gap quality measurements of flat-mirror Fabry-Pérot interferometers

8th ESA ROUND TABLE ON MICRO AND NANO TECHNOLOGIES FOR SPACE APPLICATIONS

Akujärvi Altti, Antila Jarkko, Saari Heikki
VTT Technical Research Centre of Finland

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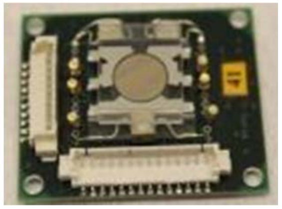
Introduction: The two VTT Fabry-Perot technologies

- **MEMS Fabry-Perot Interferometer**
  - For high volumes (>10’000/a)
  - Small, robust, inexpensive, batch-producible

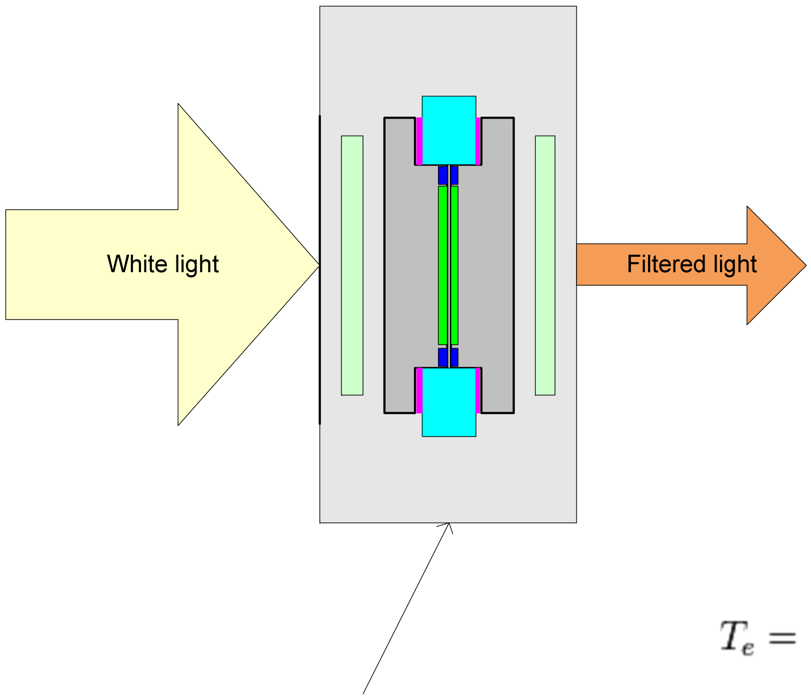



- **PIEZO-actuated Fabry Perot Interferometer**
  - Especially for imaging and multipoint applications
  - Assembled ’one-by-one’
  - For small to medium volumes (10 – 1’000 /a)

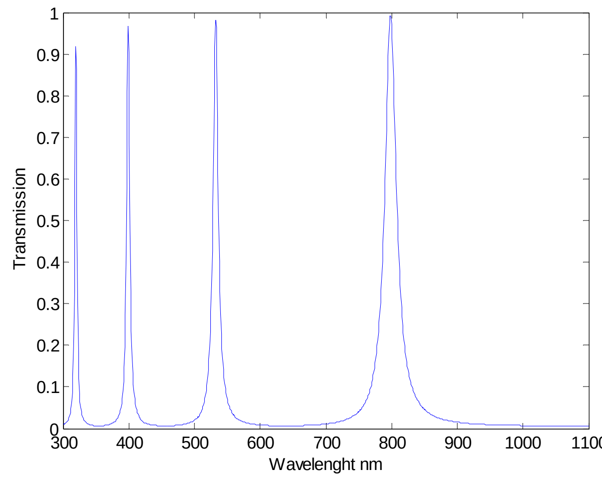




Theory: how the FPI works



Fabry-Perot Interferometer Module



$$T_e = \frac{(1-R)^2}{1+R^2-2R\cos\delta} = \frac{1}{1+F\sin^2(\delta/2)},$$

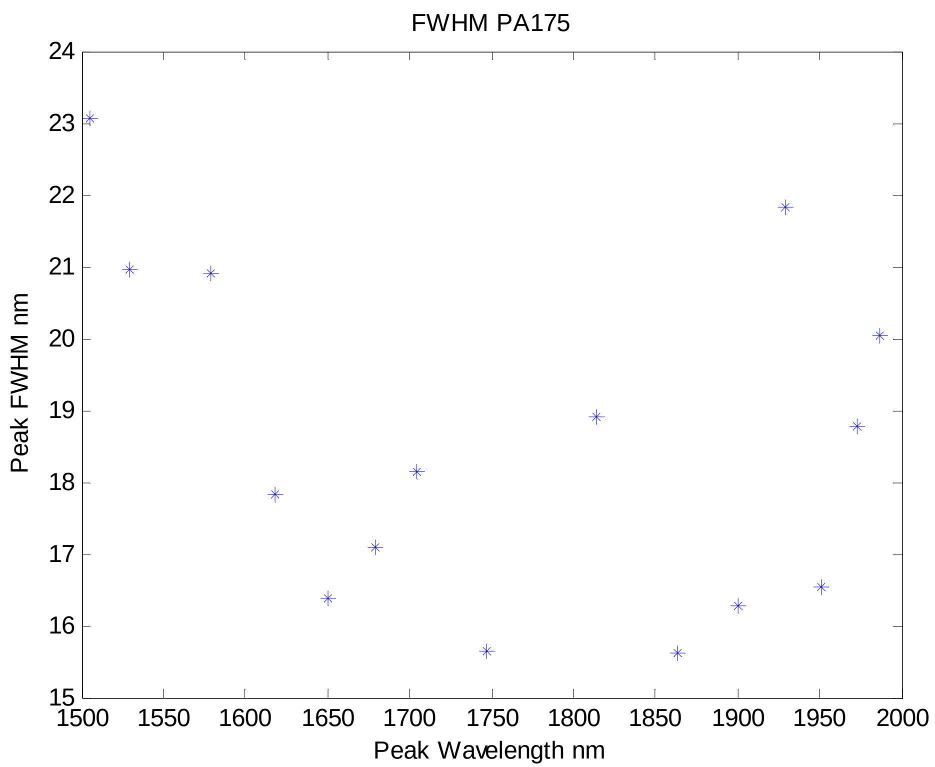
$$\delta = \left(\frac{2\pi}{\lambda}\right) 2n\ell\cos\theta.$$

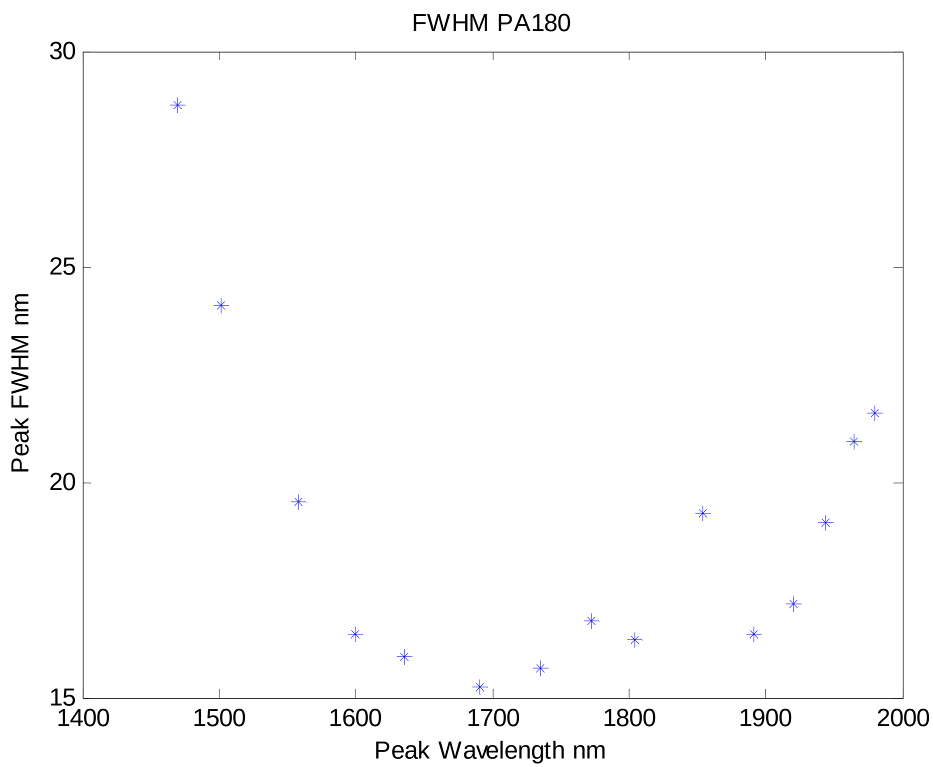
Theory: Transmission of the large aperture FPI

- The transmission of the FPI depends on the optical gap the light passes.
- The light is gathered on the sensor over a large area of the aperture, which is not complitely flat.
  - The surface of the mirrors hava a small scale variation of scratches and dig.
  - The substrate, on which the mirrors are manufactured can also suffer curvature, both natural and due to bending.
- The actual passband seen by the sensor is therefore the average transmission over the gathering area of the FPI.
  - The transmission is convoluted by the gap distribution of the gathering area.

Theory: How the MEMS FPI suffer the unequal gap

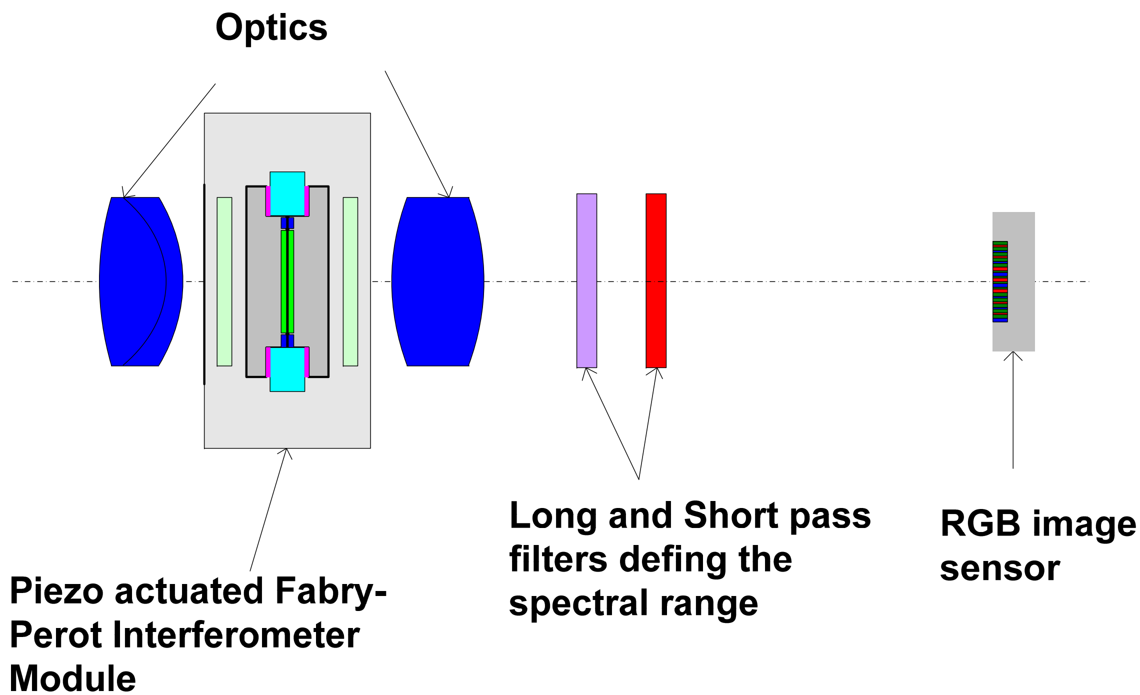
- In the MEMS FPI, the upper mirror may bend during the actuation, which will increase the FWHM with higher control voltages.
  - Indications on this phenomenon were observed in our MEMS studies.





Theory: How Piezo actuated FPI suffer unequal gap

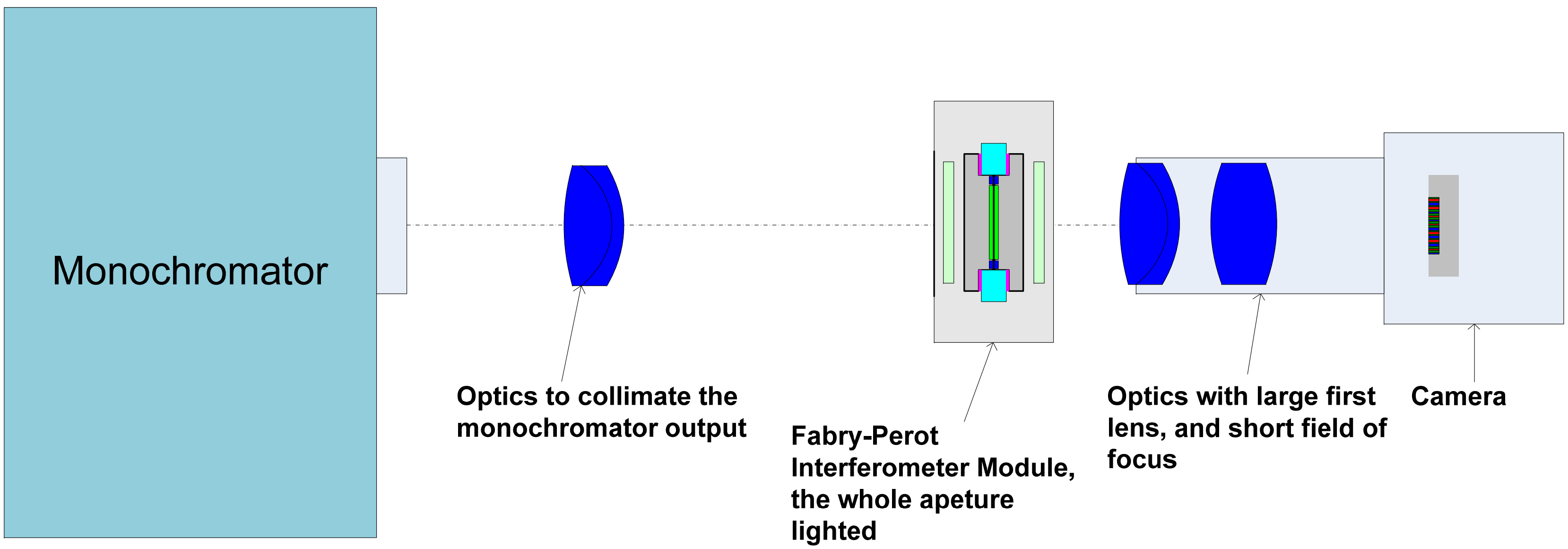
- The FPI is used as a tunable multi-band pass filter somewhere inside the imaging optics and the actual affect depends on the used configuration.
- In our current configuration for the AASI spectrometer, the light is gather on the imager over large areas of the FPI.
- This makes the gap distribution a crucial quality parameter for the FPI.



Method: Goal of our study

- We wish to measure the gap distribution of the FPI.
- The optical gap can be determined from the transmission spectrum of the FPI.
- If we can measure a 2D transmission data over the whole aperture of the FPI, we could use this to calculate the gap distribution.
- We need a system to make 2D transmission measurements, and the needed data-analysis.

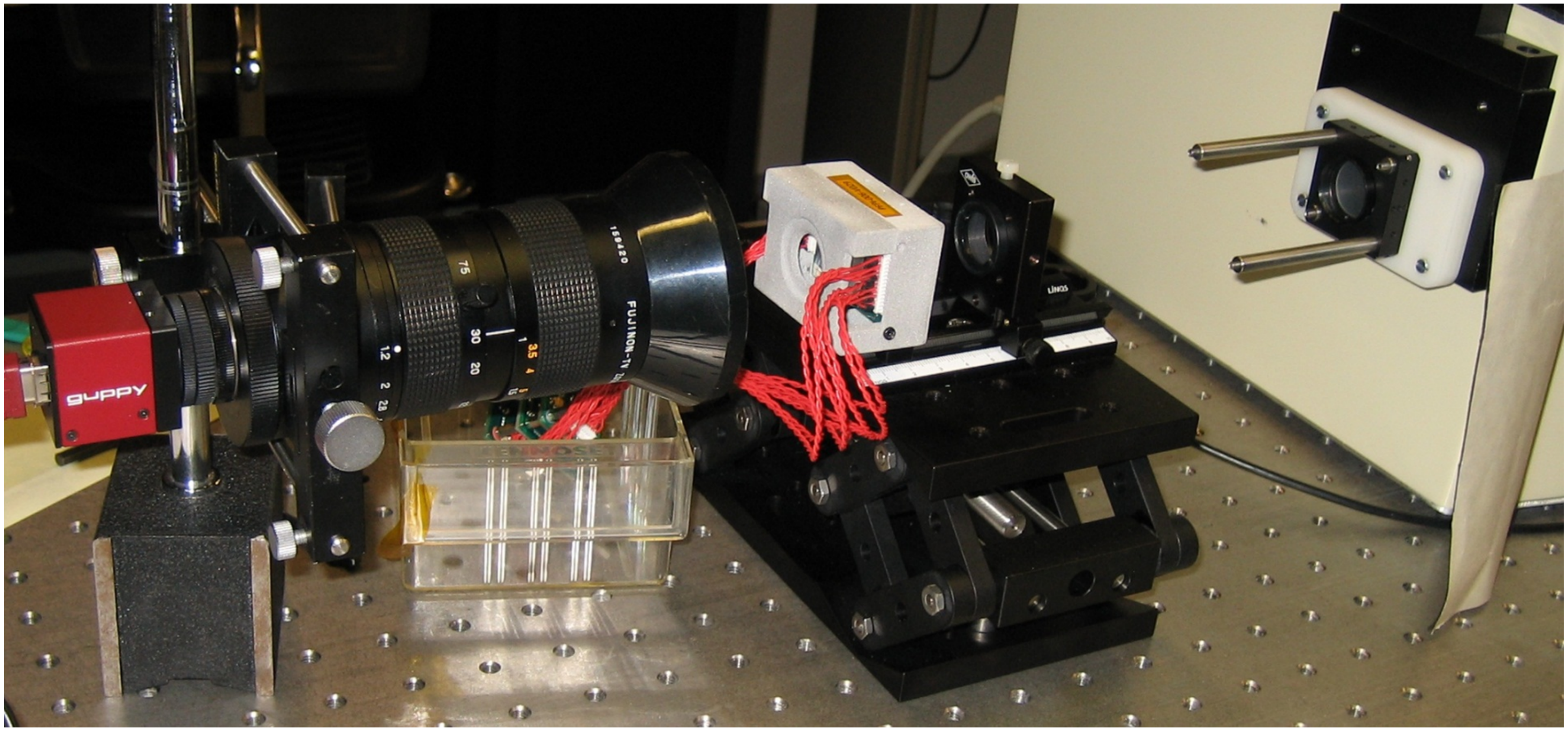
Method: The measurement concept.



Method: The measurement concept.

- To determine the gap distribution of the FPI, we measure its transmission with good spatial resolution.
- To do this, we use a monochromator as a source for narrow bandwidth light.
- We collimate the light beam to below 5° scattering angle, and use this to illuminate the whole FPI aperture.
- We then place a camera behind the FPI on the optical path to image the FPI.
    - The camera should have a large first lens to image the whole aperture.
    - Short depth of focus is used to blur the light source.
- We then take images of the FPI with different illuminating wavelengths.
- With proper reference measurement, we get the transmission of the FPI.

Results: Setup to measure the FPIs for AASI



Results: Performance of the setup

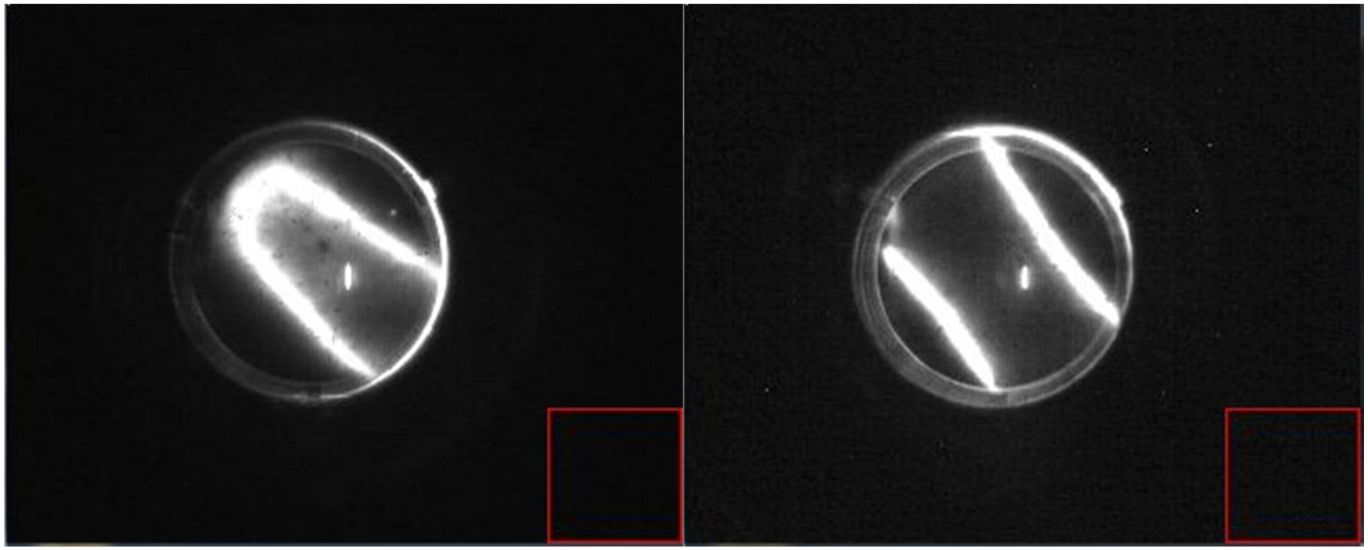
- The collimation is achieved using a diffuser from a distance.
- As a imaging optics, we use a Zoom-lens with an extension tube.
- The Allied Guppy camera we use as the image sensor has a resolving power of 10 line pairs per mm, measured with the 1951 USAF resolution test chart.
- In practice, we reduce the resolution to around ~150µm with binning.
- The light gathering power of the lens gives us a spectral resolution of 1nm on the range of 400nm to 1000nm.
- The integration times are in range of ms, and the main factor in the total scanning time is the time needed to move the monochromator.

Results: Setup variation for NIR range

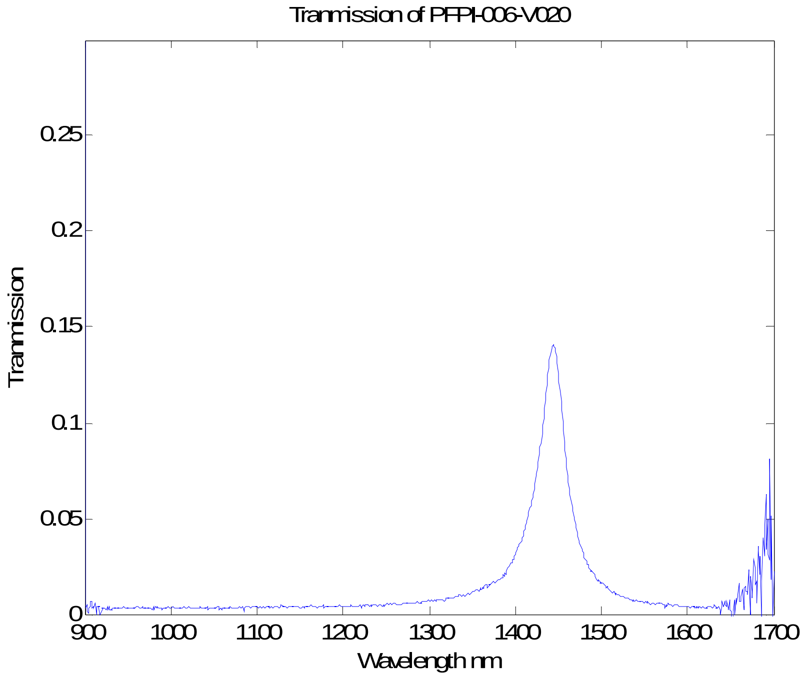
- We also have an alternative option for the image sensor.
- The Xenics XEVA 1.7 camera has an InGaAs sensor, and is able to give us a spectral resolution of 1nm from 920nm to 1680nm.
- The Xenics camera gives us a spatial resolving power of 2.8 linepairs per millimeter.
- The integration times are in the range of 100ms, wich still leaves the monochromator as the main source of scanning time.

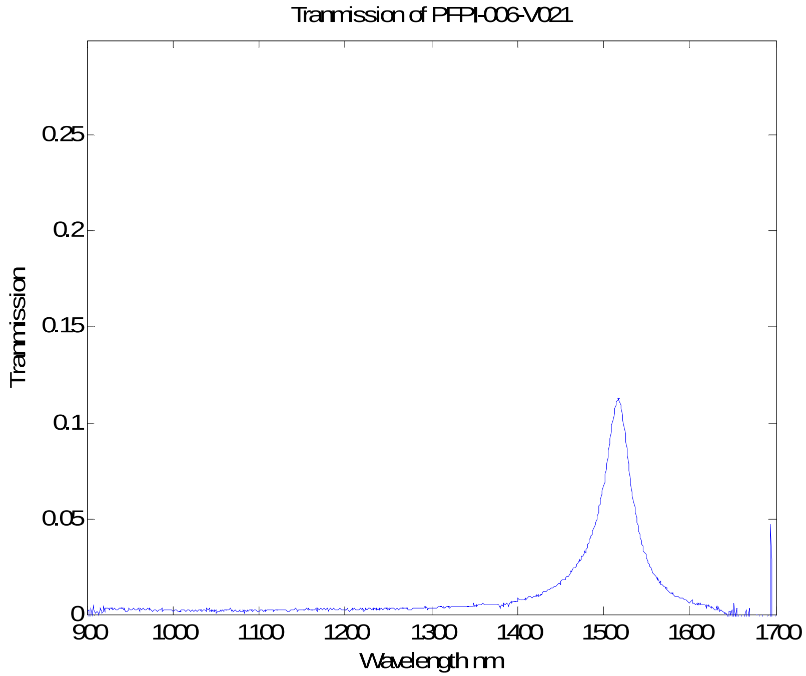
Results: Characterization of 2 FPIs for NIR range

- We made a test to evaluate the quality of two Piezo actuated Fabry-Pérot interferometers, similar to those found in AASI.
- From the raw data – images of the FPI with different wavelengths – one can only guess the quality.
- Below you can see images of the two measured FPIs taken with 1400nm illumination light wavelength.



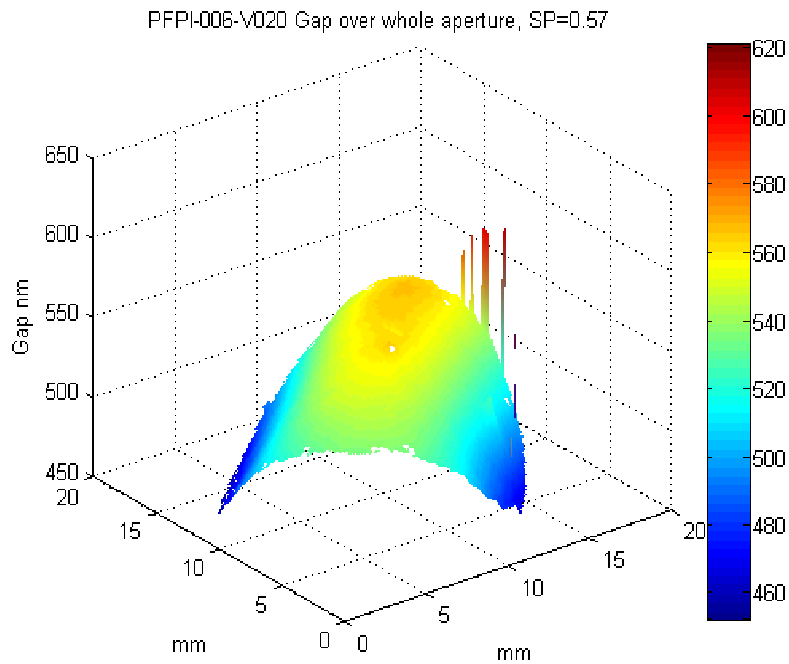
Results: Transmission from 1 pixel

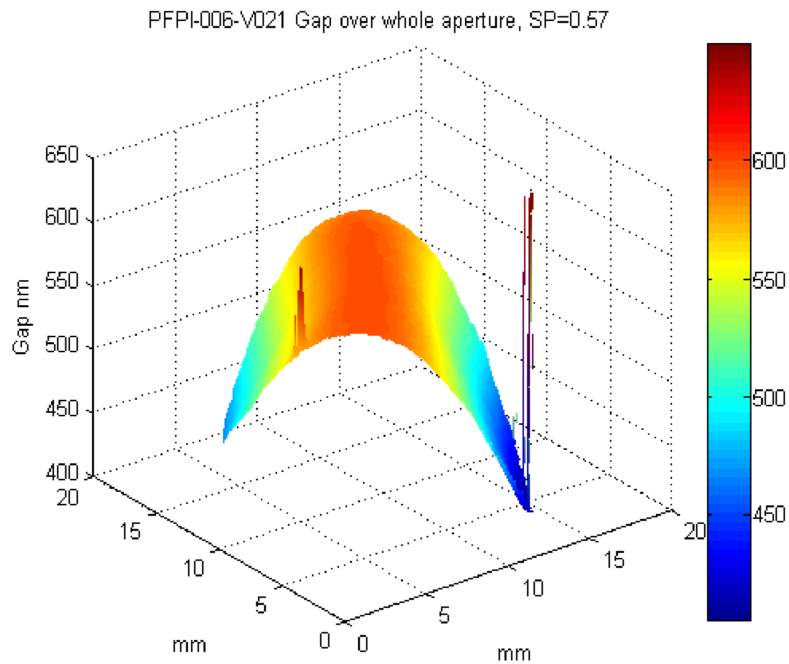




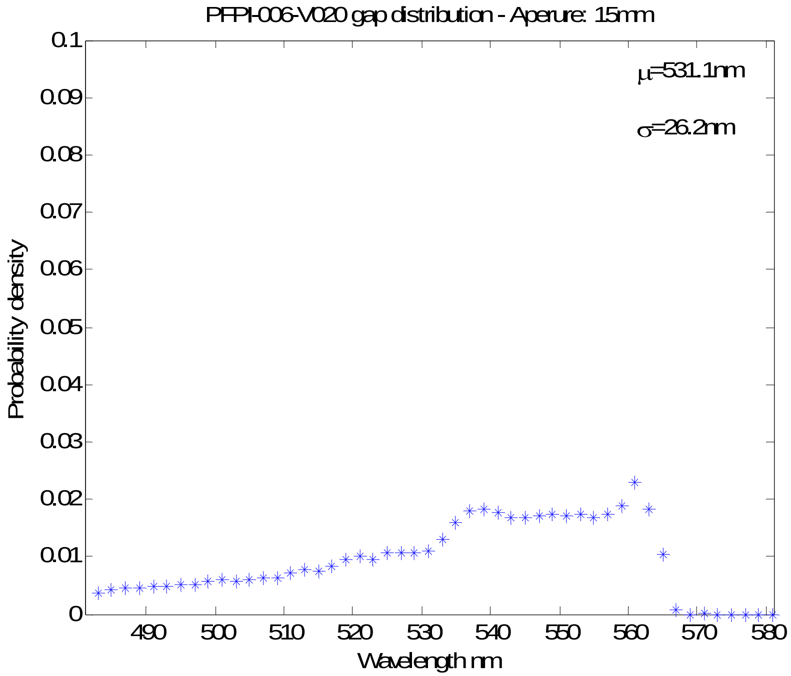
- The apeture diameter in the image is ~100 pixels => over 7500 transmissions.

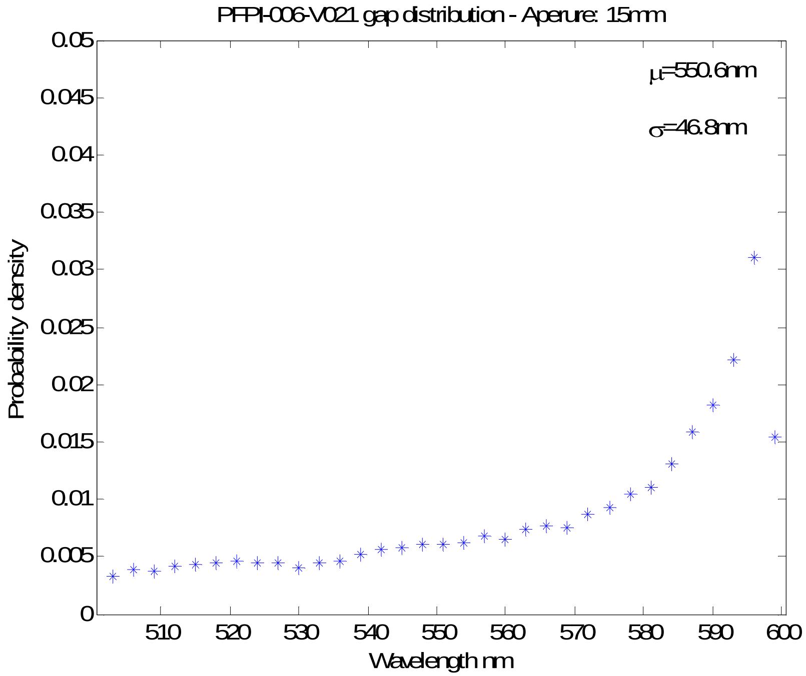
Results: Air gap shape



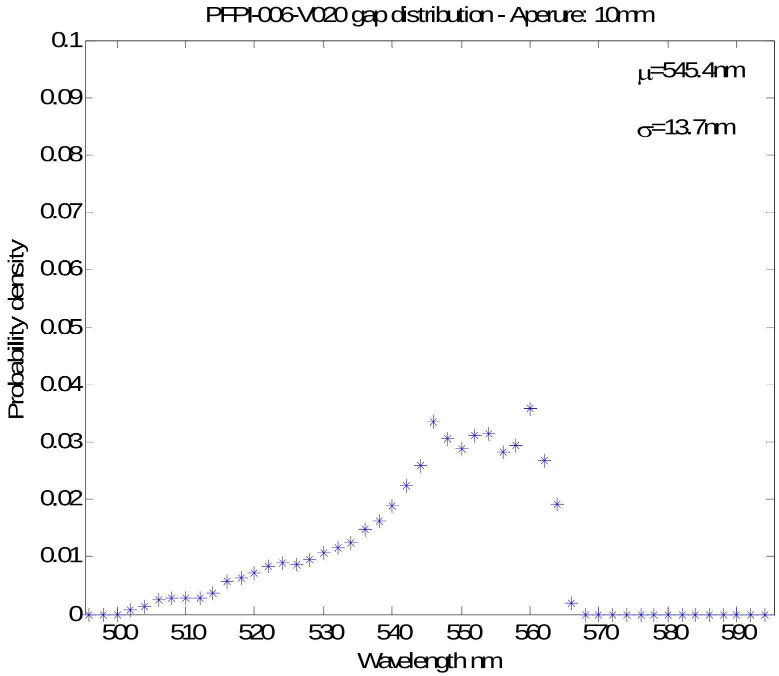


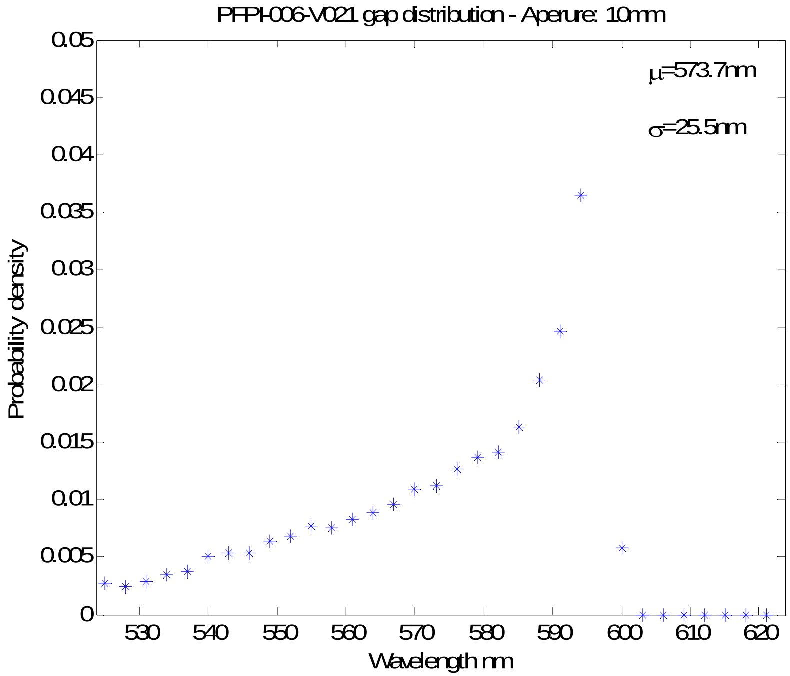
Results: Air gap distribution 15mm apeture



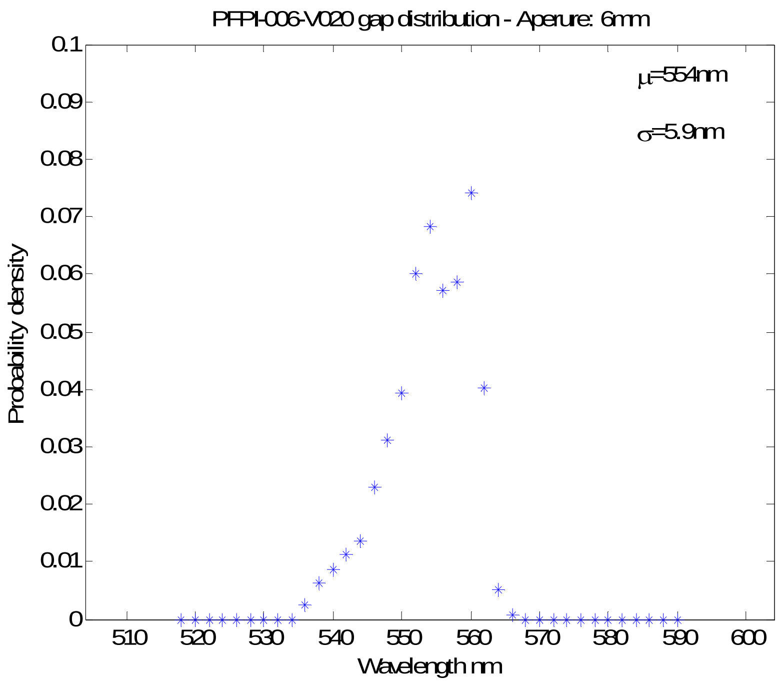


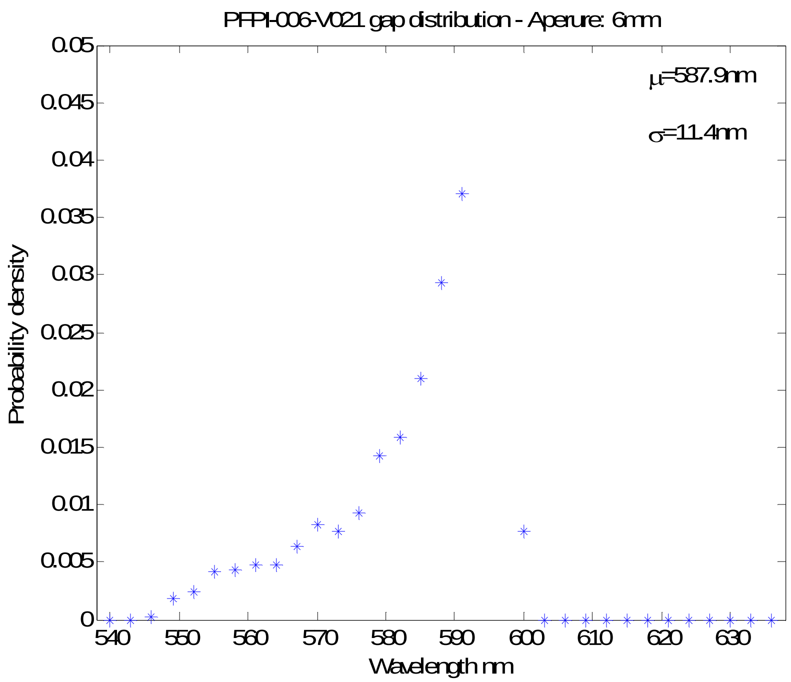
Results: Air gap distribution 10mm apeture





Results: Air gap distribution 6mm apeture





Discussion

- The presented measurement setup is capable of producing information on the gap quality, suitable for quality control.
  - The transmission is measured from over 7000 points.
- We also have made tests with microscope objectives to measure MEMS based FPI:s.
- Both the setup and the data processing operations are still quite unoptimized.
  - The optical layout of the measurement is not application optimized.
  - There is a geometrical distortion in the shape of the image.
  - The data processing takes a long time at the moment.
  - Much more information could be extracted from the data, if we include the final optical layout to determine the areas we measure the gap distributions.

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