Imaging SO_2 with a Fabry-Pérot interferometer: Combining advantages of DOAS and SO2 Cameras

Jonas Kuhn[1], Nicole Bobrowski[1], Peter Lübcke[1], Denis Pöhler[1], Jan-Lukas Tirpitz[1], Leif Vogel[1,2], and Ulrich Platt[1]

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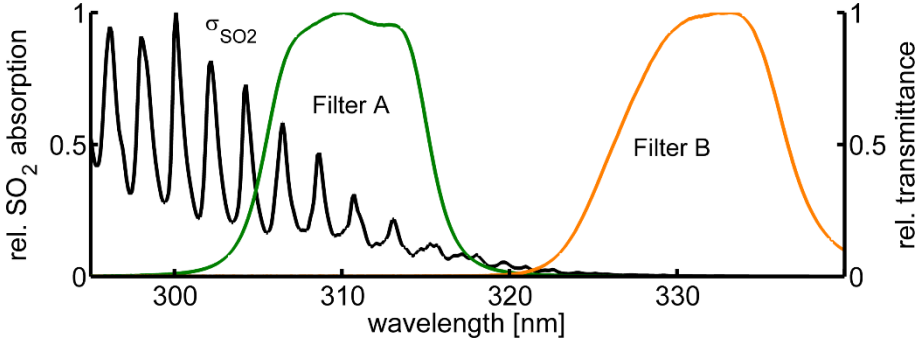
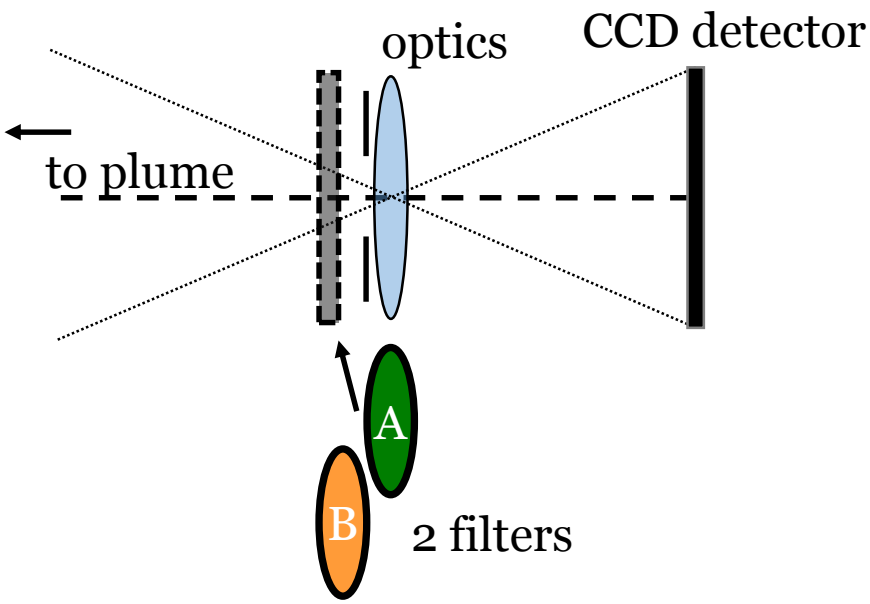
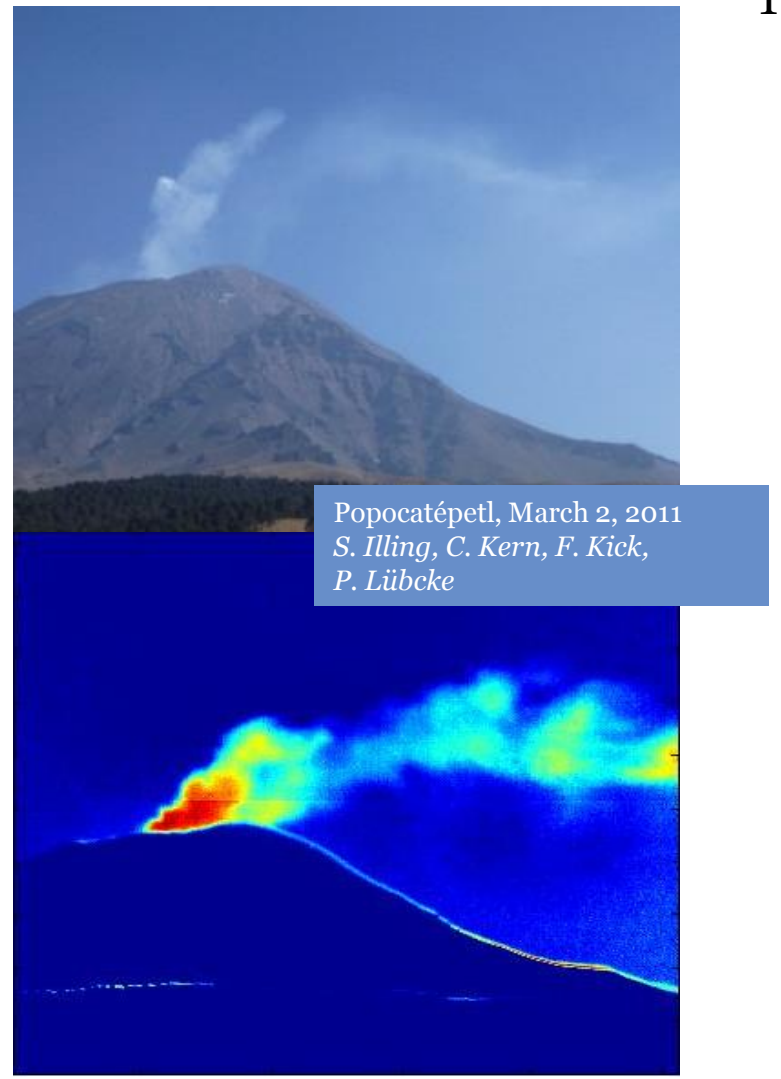
The SO_2 camera



$$\tau_A - \tau_B \propto S_{SO2}$$

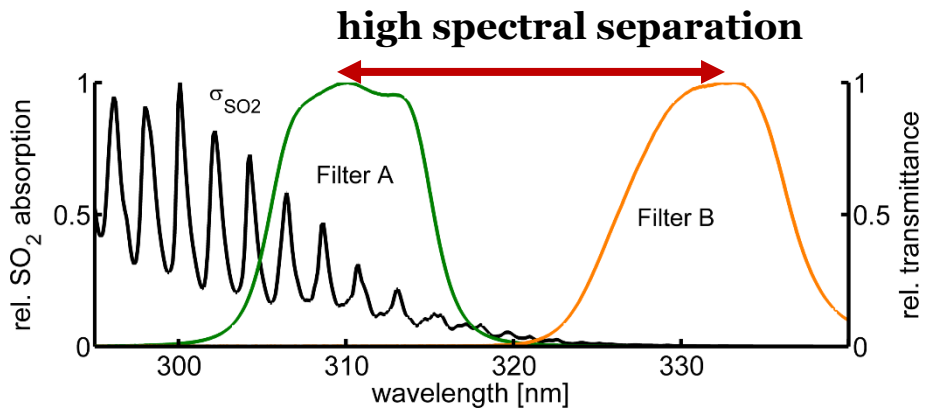


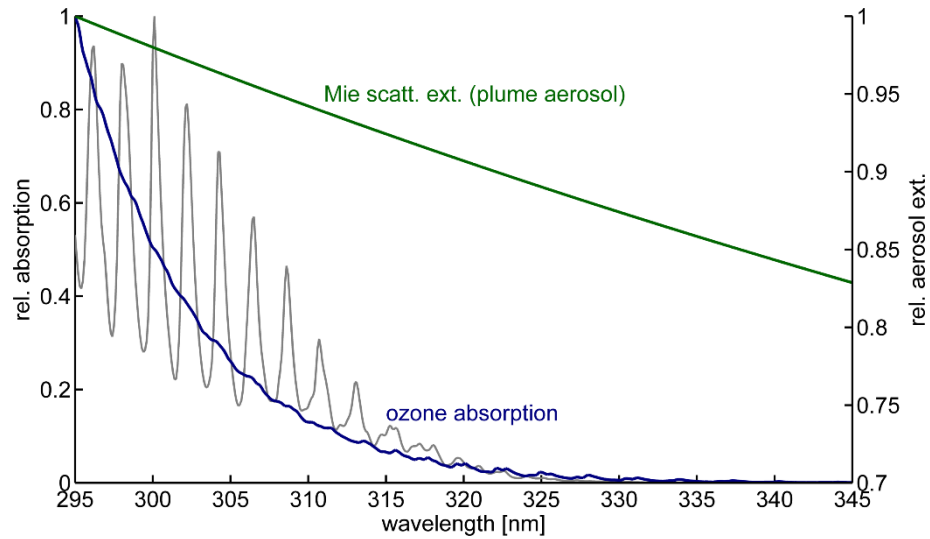


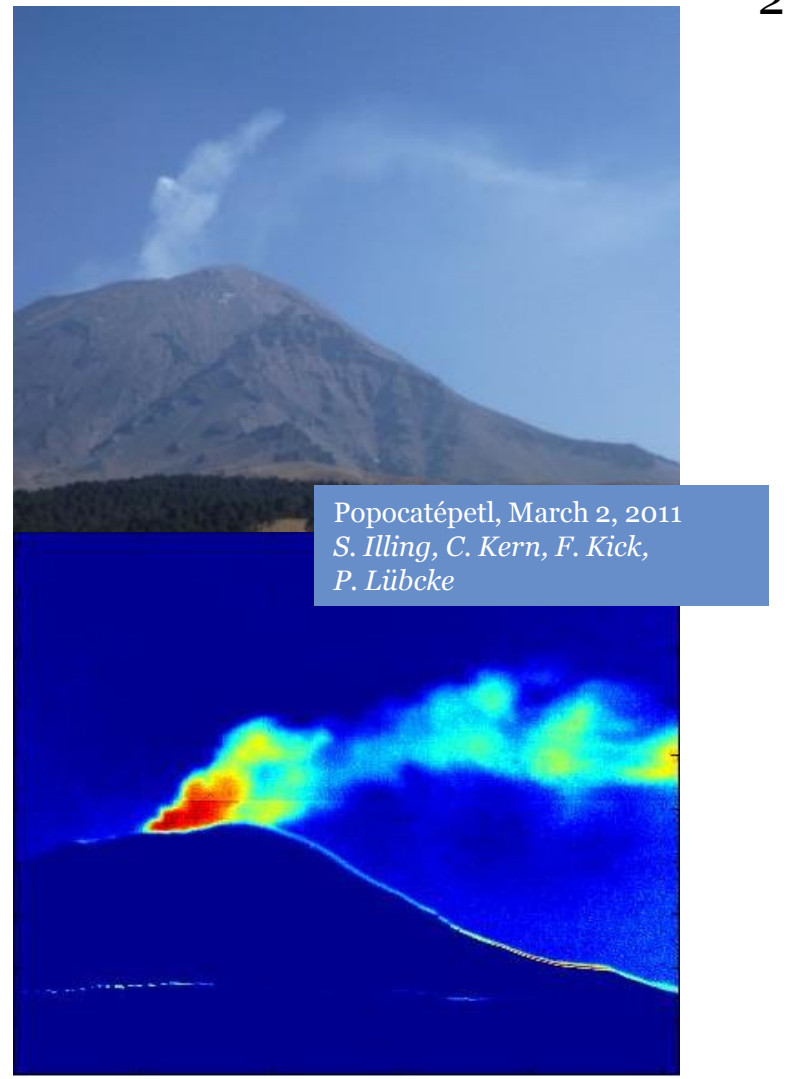
$\tau_i = -\ln(\frac{I_i}{I_{0i}})$, optical density for filter i

S_{SO2} : SO_2 column density

The SO_2 camera







Popocatépetl, March 2, 2011
S. Illing, C. Kern, F. Kick, P. Lübcke

cross interferences of
highly variable **plume aerosol**
and **ozone background**

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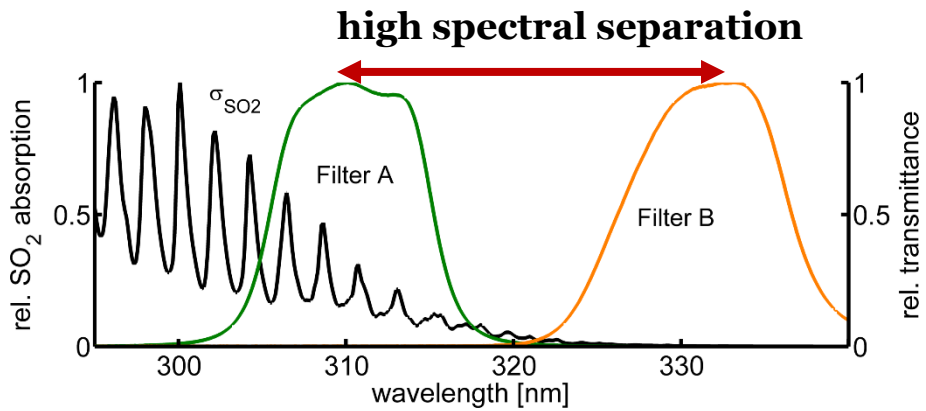

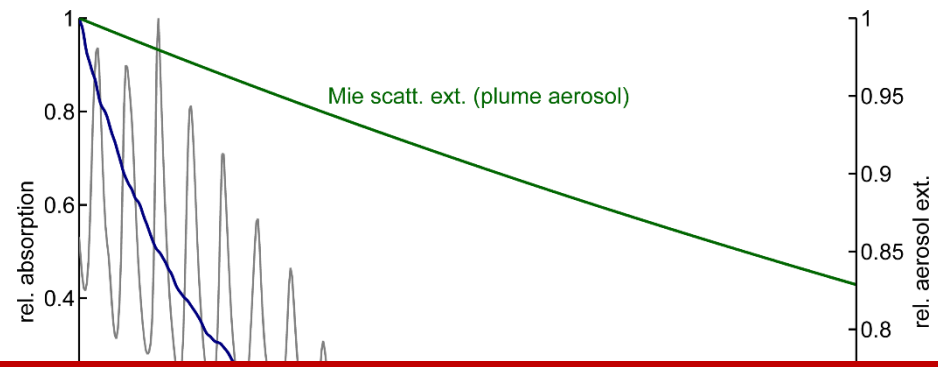

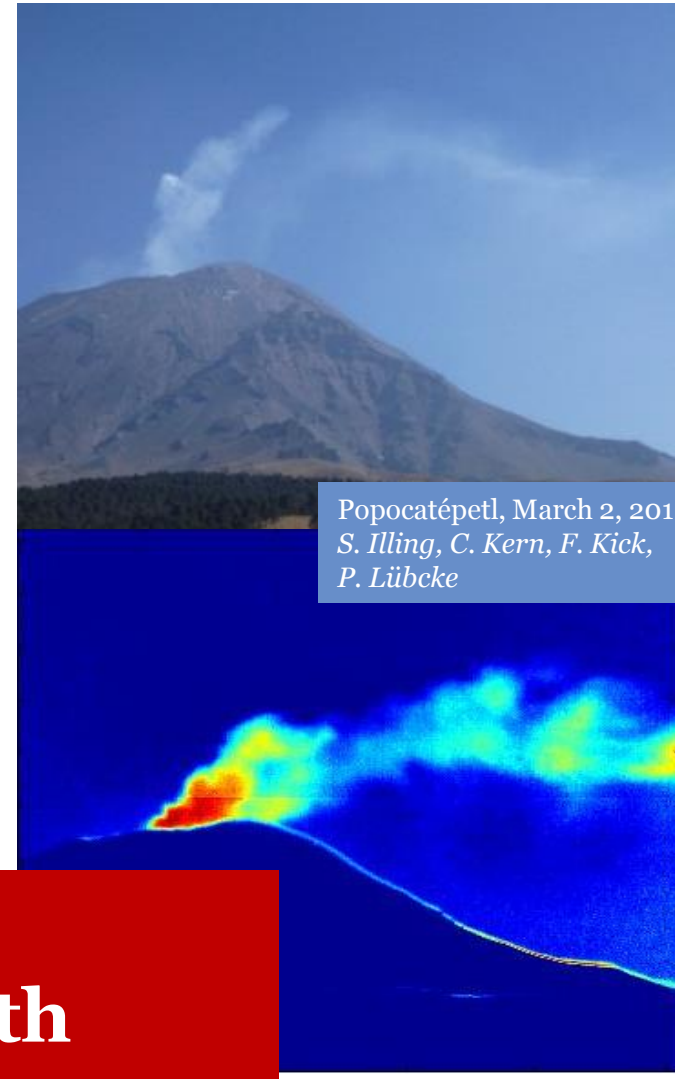

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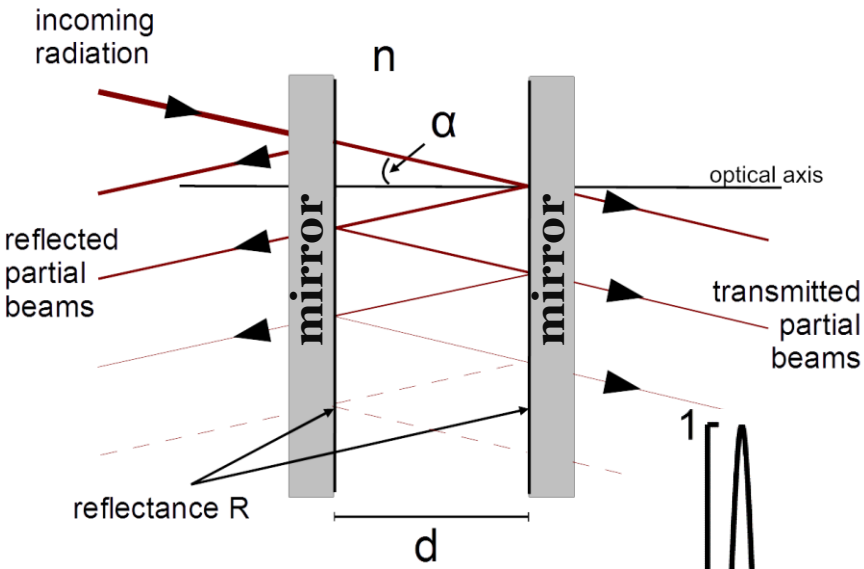
S. Illing, C. Kern, F. Kick, P. Lübcke

→ looking for :
fast imaging instrument with reduced cross interferences

cross interferences of
highly variable **plume aerosol**
and **ozone background**

Fabry-Perot interferometer (FPI)

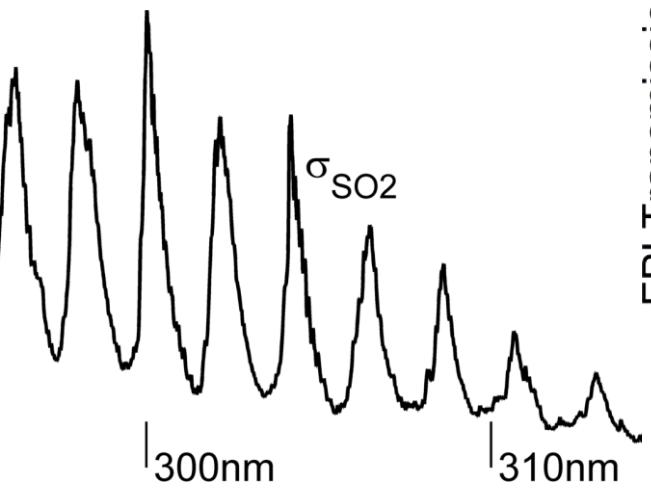


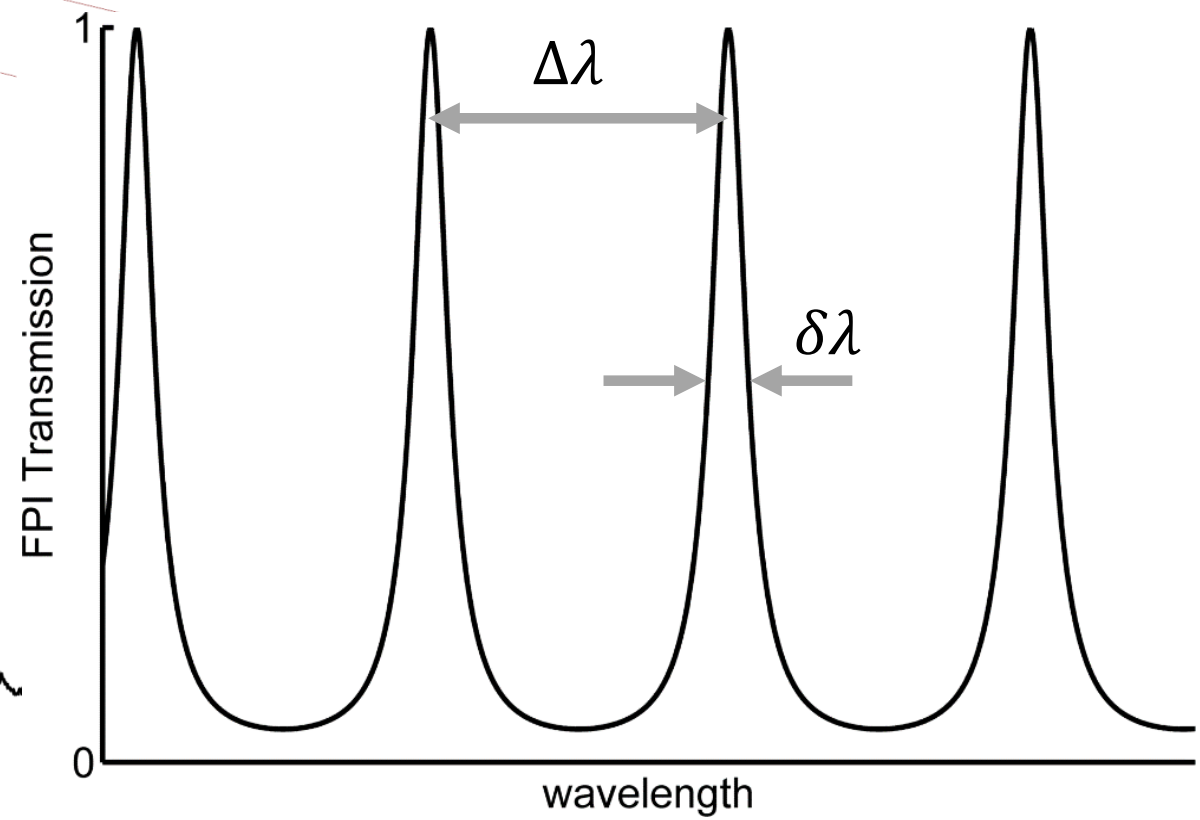
Free Spectral Range

$$\Delta\lambda \approx \frac{\lambda^2}{2 \cdot nd \cos(\alpha)}$$

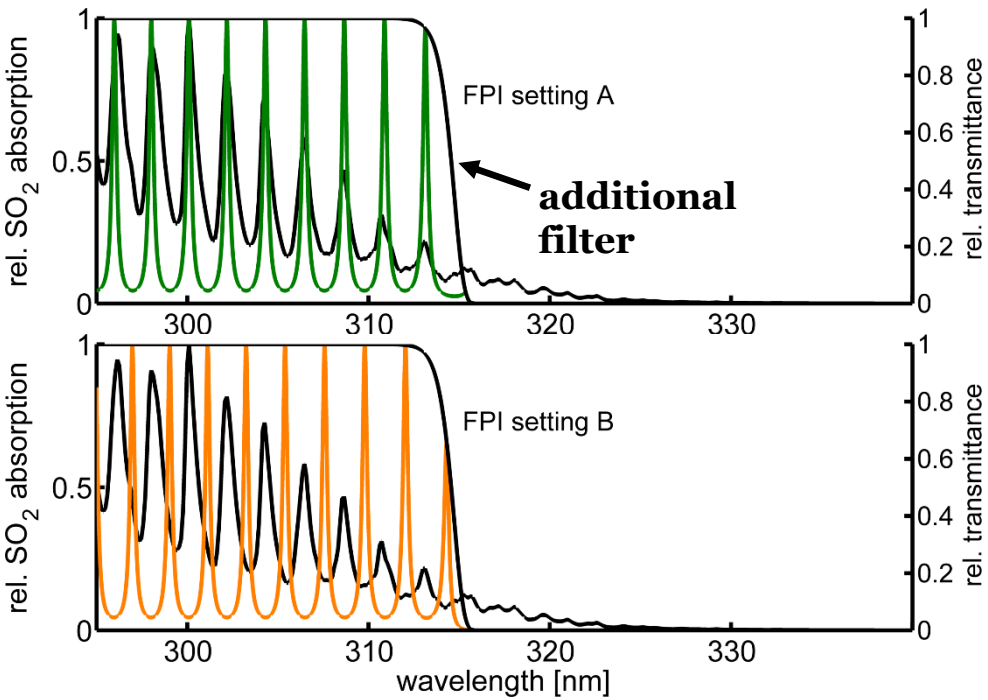
Finesse

$$F = \frac{\Delta\lambda}{\delta\lambda} \approx \frac{\pi\sqrt{R}}{1 - R}$$





SO_2 remote sensing with a Fabry-Perot interferometer

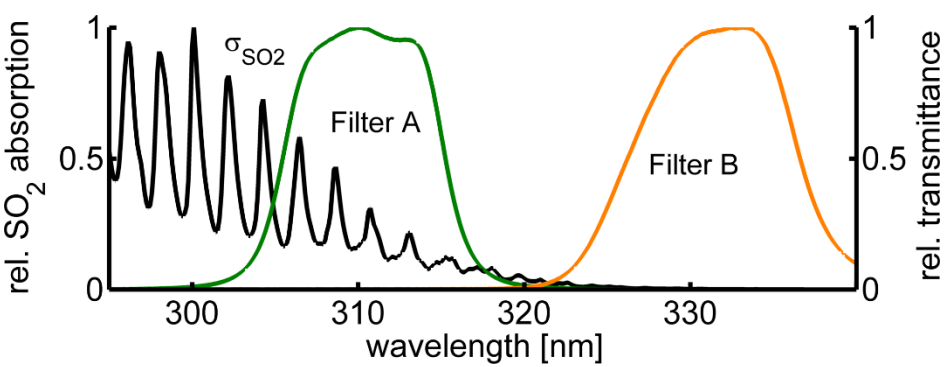


setting A: transmission at maximum SO_2 absorption

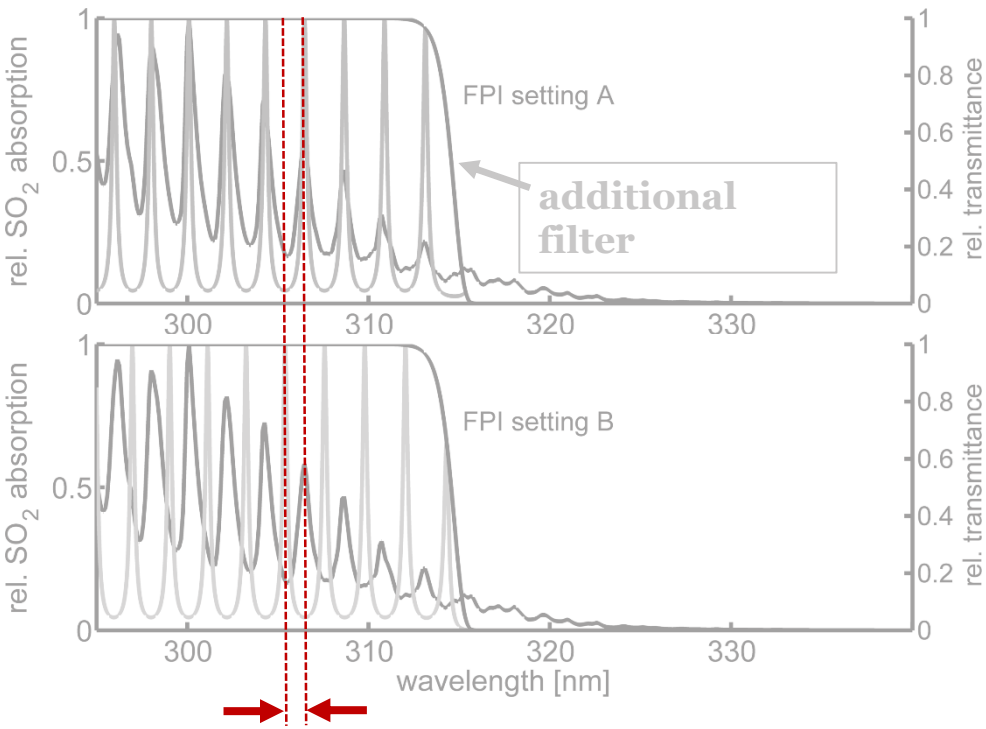
e.g. FPI tilt

setting B: transmission at minimum SO_2 absorption

$$\tau_{A\,FPI} - \tau_{B\,FPI} \propto S_{SO2}$$



SO_2 remote sensing with a Fabry-Perot interferometer



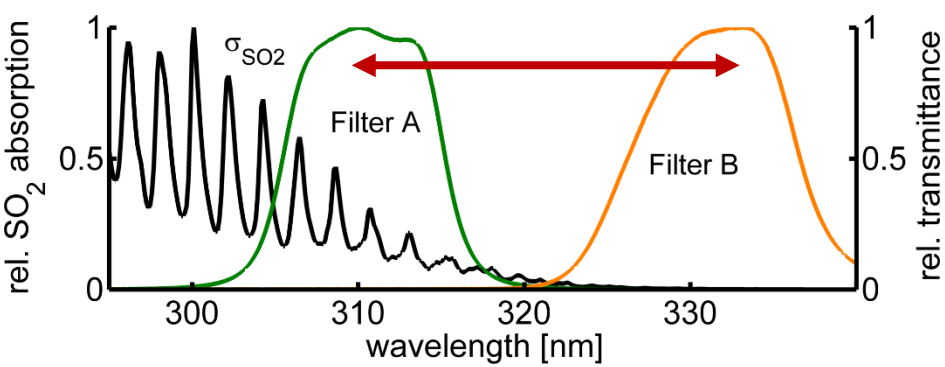
setting A: transmission at maximum SO_2 absorption

e.g. FPI tilt

setting B: transmission at minimum SO_2 absorption

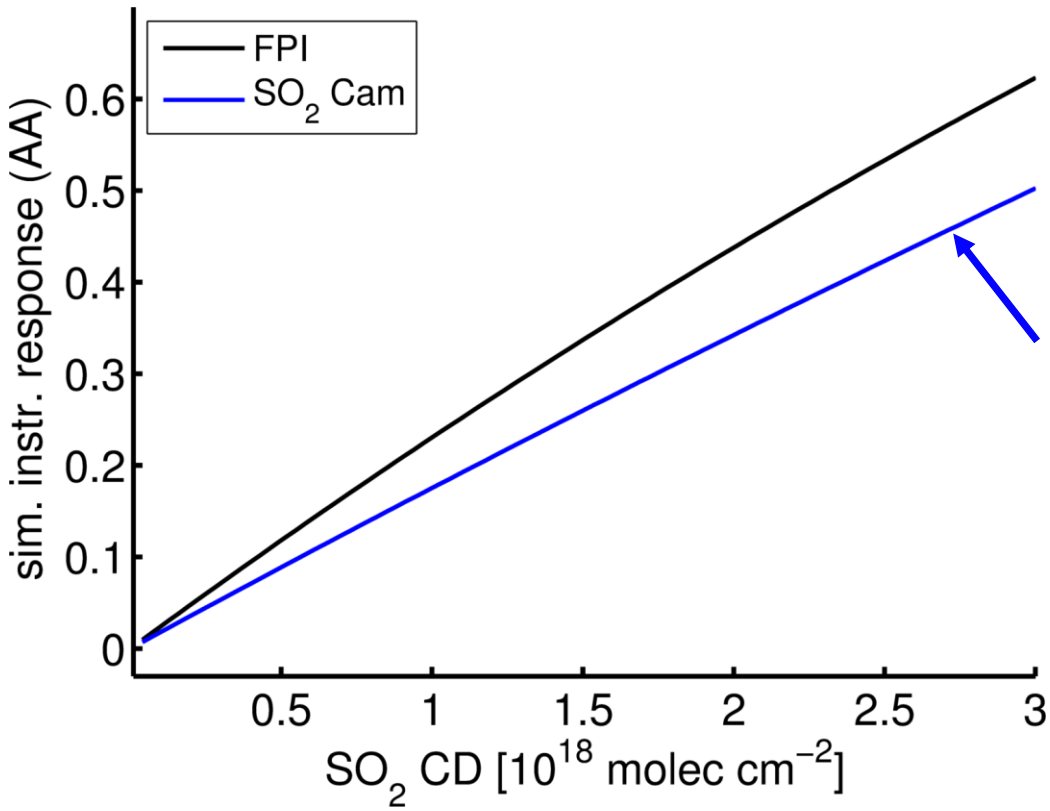
$$\tau_{A\,FPI} - \tau_{B\,FPI} \propto S_{SO2}$$

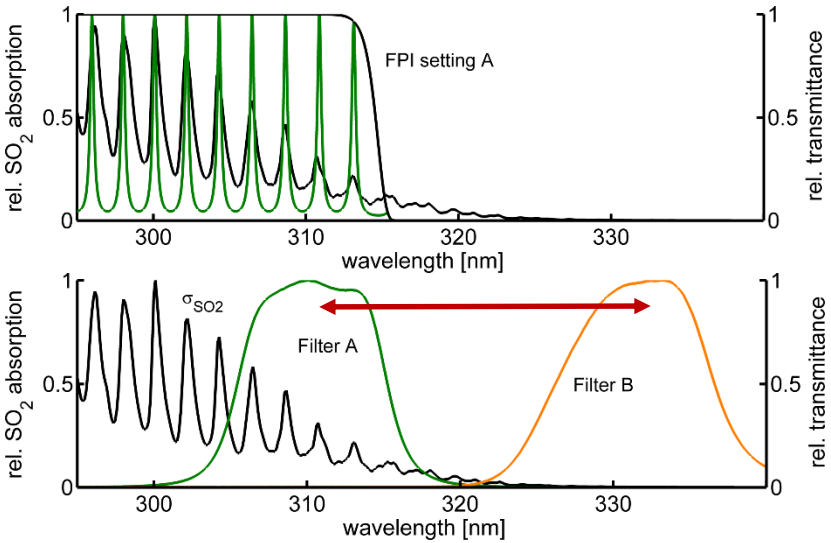
drastically reduced spectral separation



reduced cross interferences !

FPI vs. filter method – simulation





Kuhn J., Bobrowski N., Lübcke P., Vogel L., Platt U. (2014), A Fabry-Perot interferometer based camera for two-dimensional mapping of SO_2 distributions, Atmos. Meas. Tech., 7, 3705–3715

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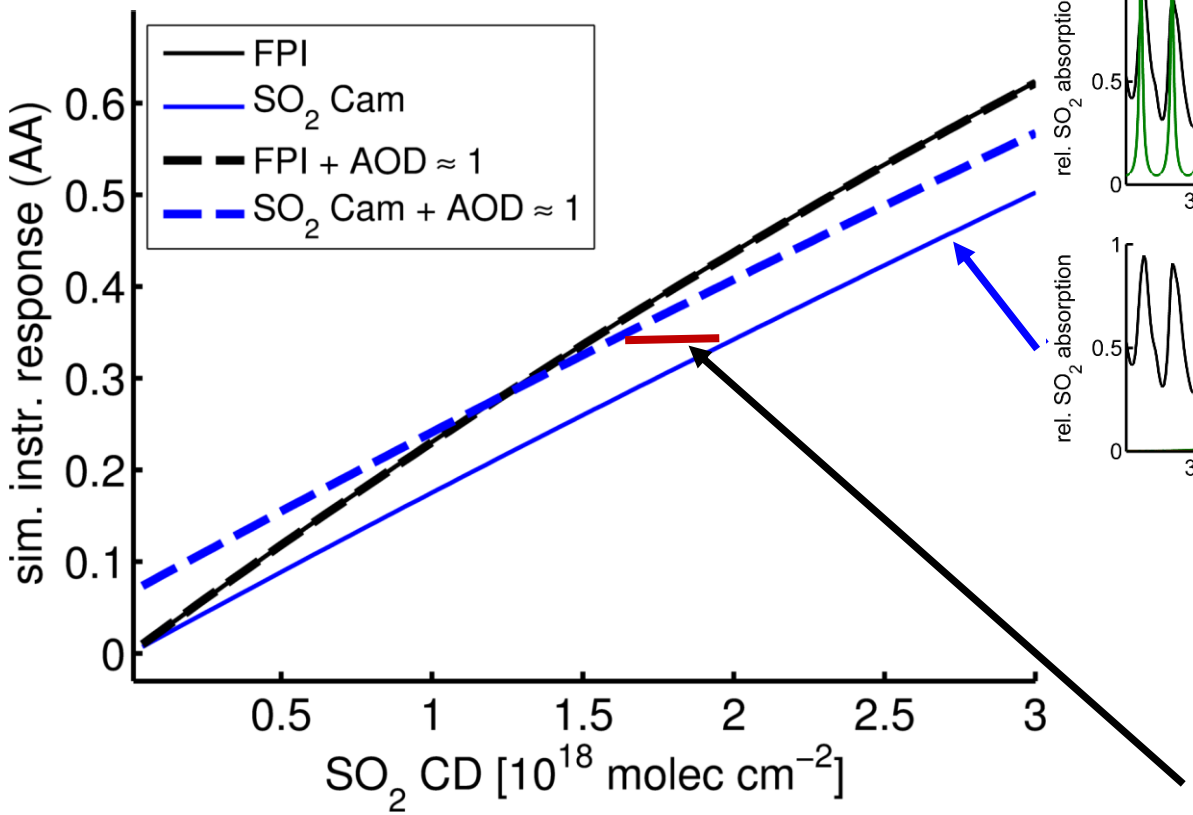

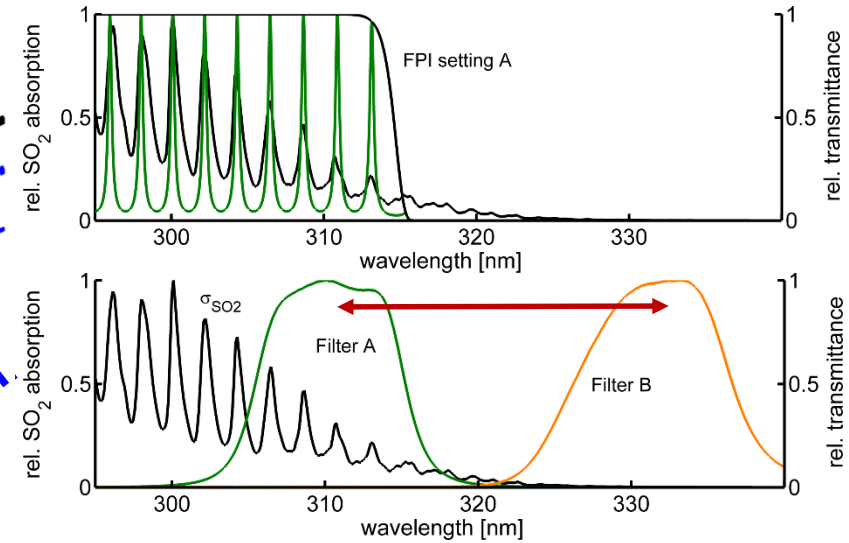

deviation due to plume aerosol
for SO_2 camera (~ $3 \cdot 10^{17}$ molec cm^{-2})

aerosol extinction

$$\epsilon(\lambda) = \epsilon_0 \cdot \left(\frac{\lambda}{\lambda_0}\right)^{-1.2}$$

$$\epsilon_0 = 1$$
$$\lambda_0 = 300\text{nm}$$

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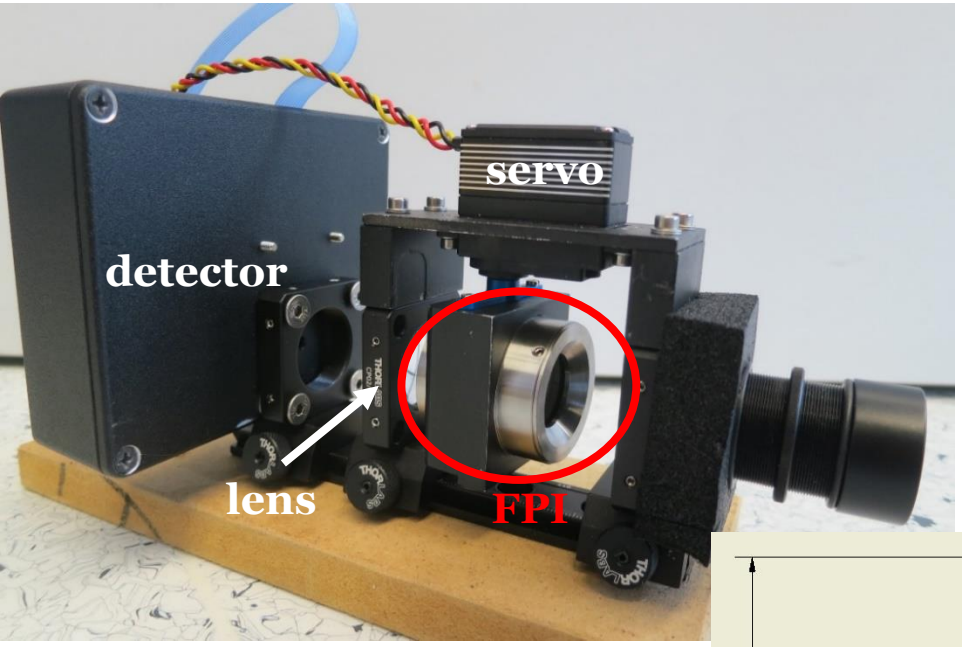
One pixel FPI SO_2 device



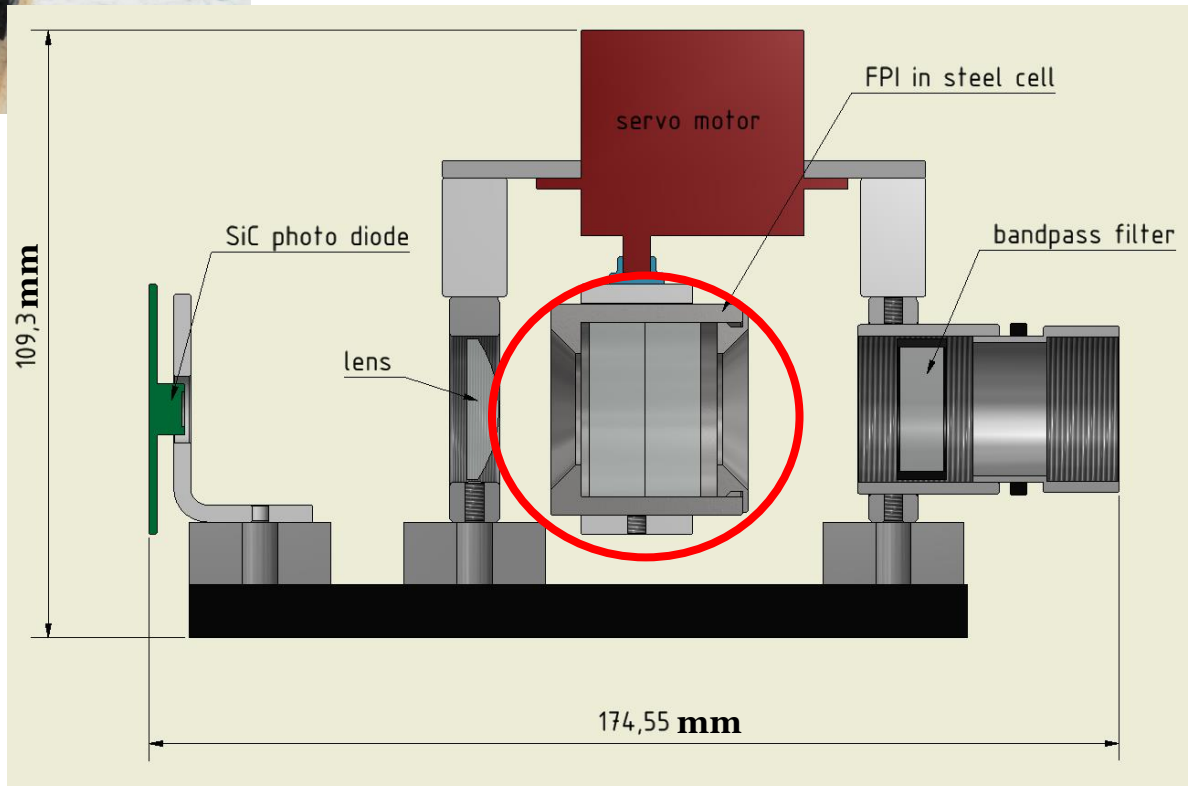
Proof of concept:

Fabry-Perot etalon

tilted by a servo motor

compact and robust

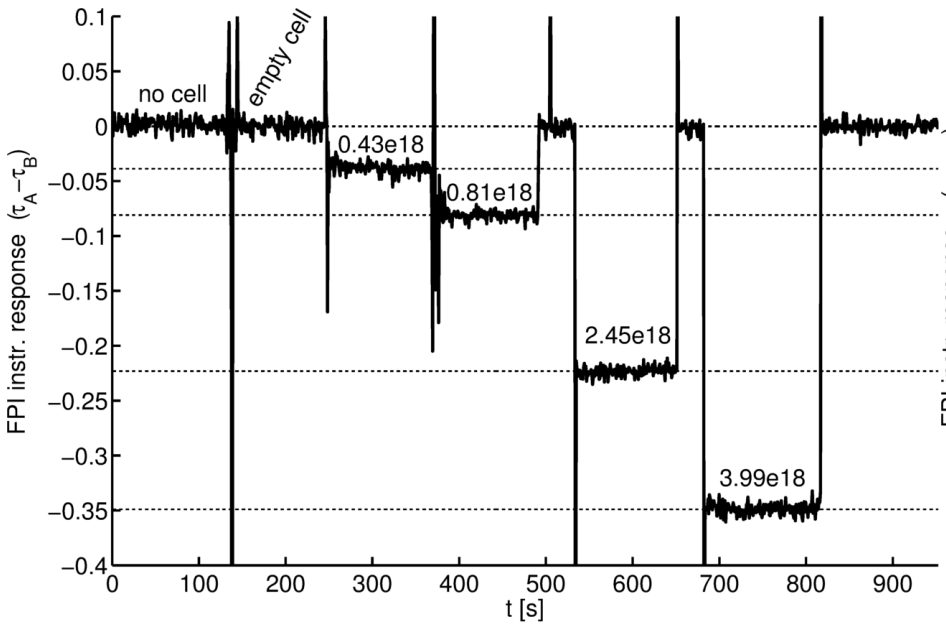
no temperature stabilization

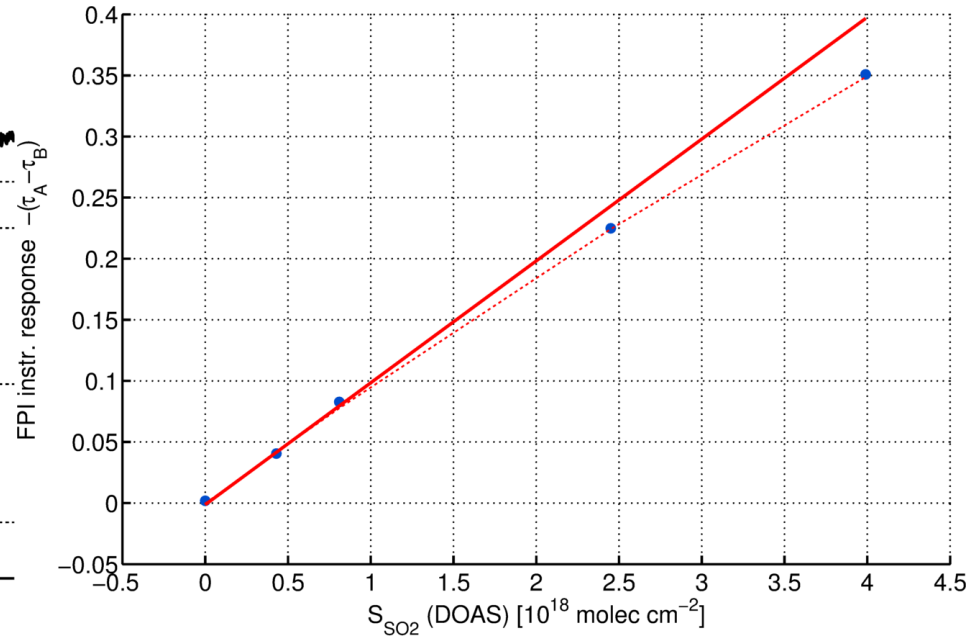


One pixel FPI SO_2 device - performance

measurement with calibration cells:

- clear correlation of instrument response to SO_2 column density
- noise mainly from servo imprecision





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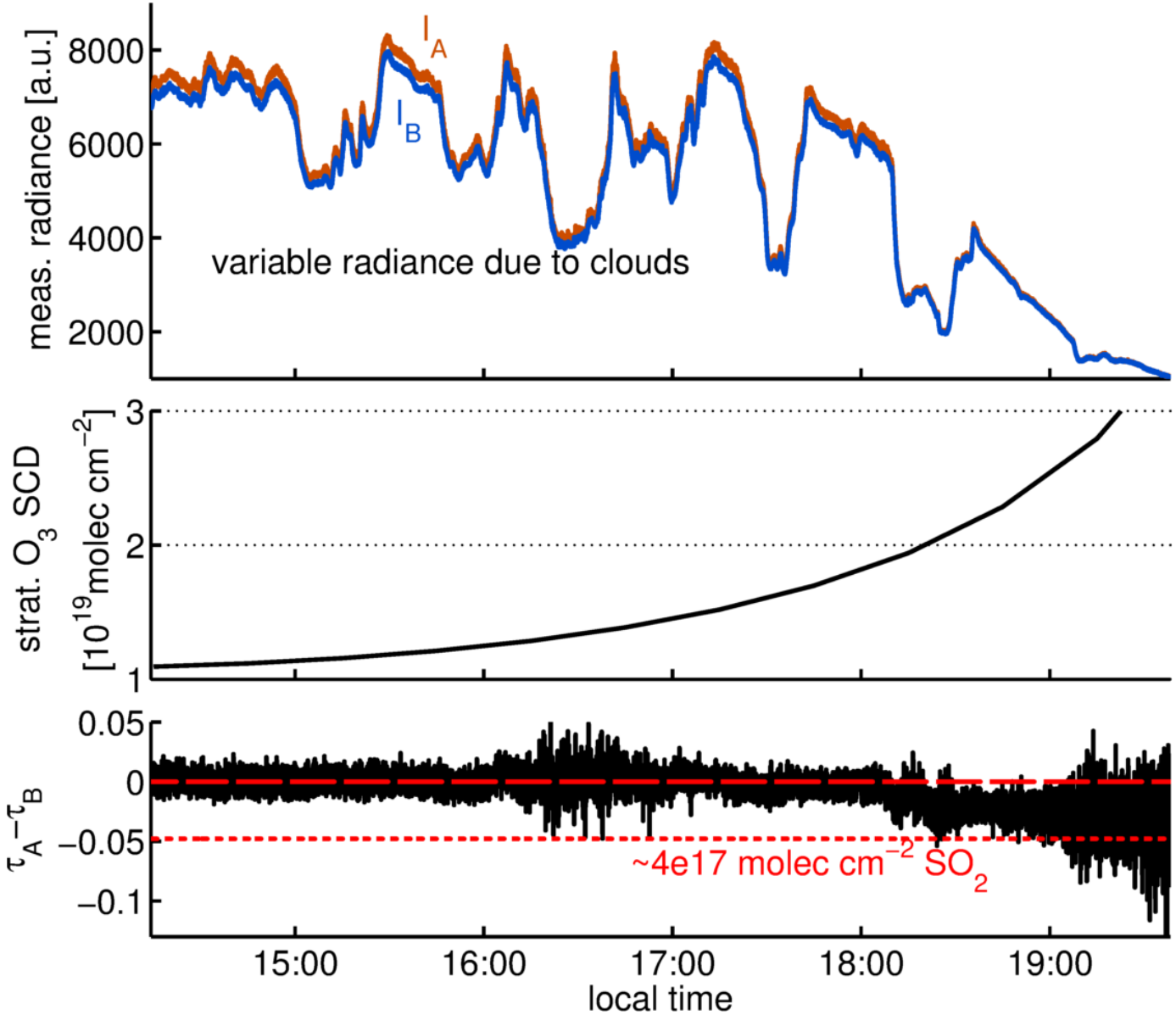
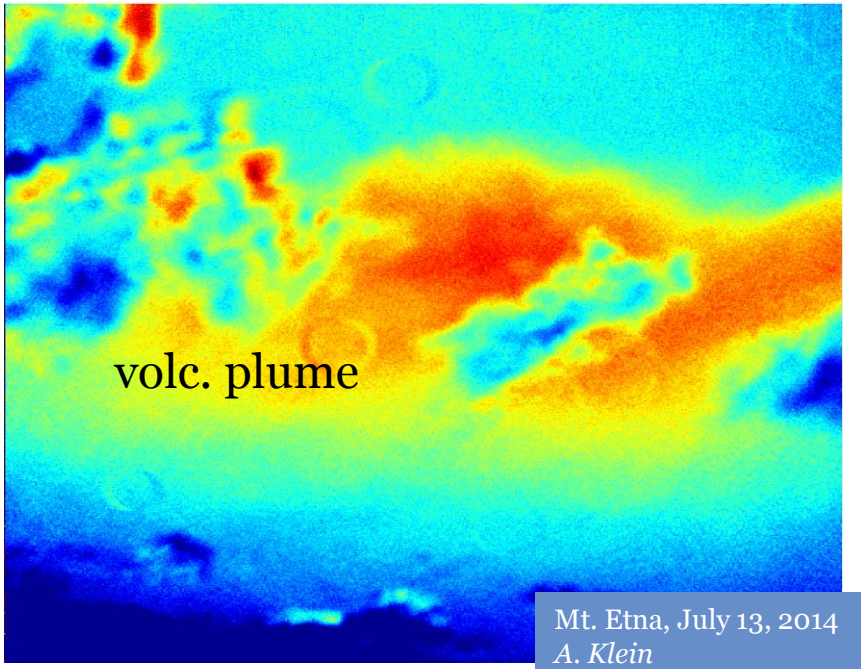


One pixel FPI SO_2 device - performance

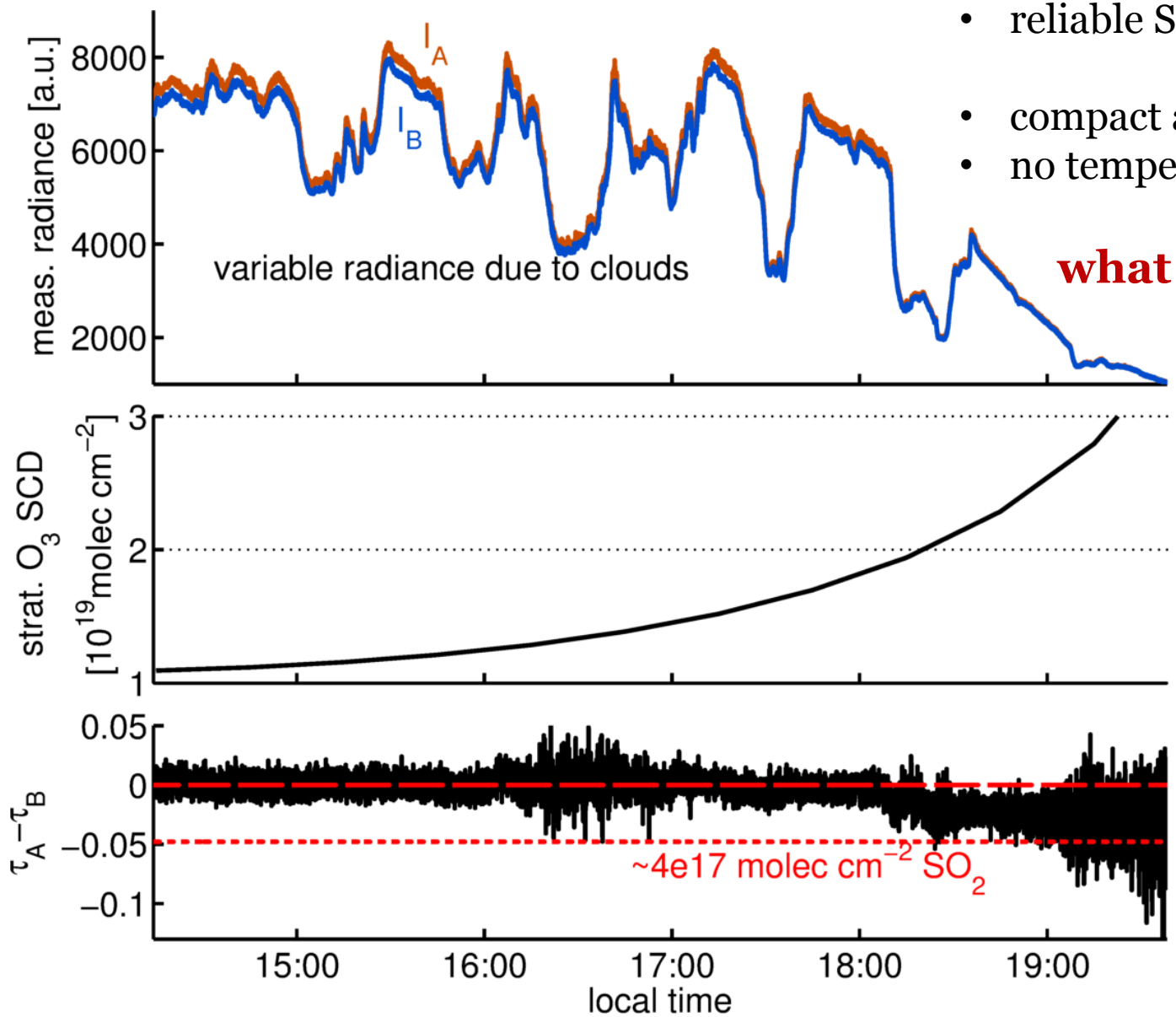
webcam

SO_2 Camera



Mt. Etna, July 13, 2014
A. Klein

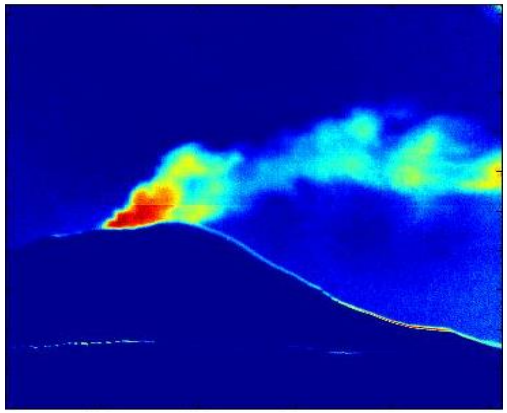
One pixel FPI SO_2 device - performance

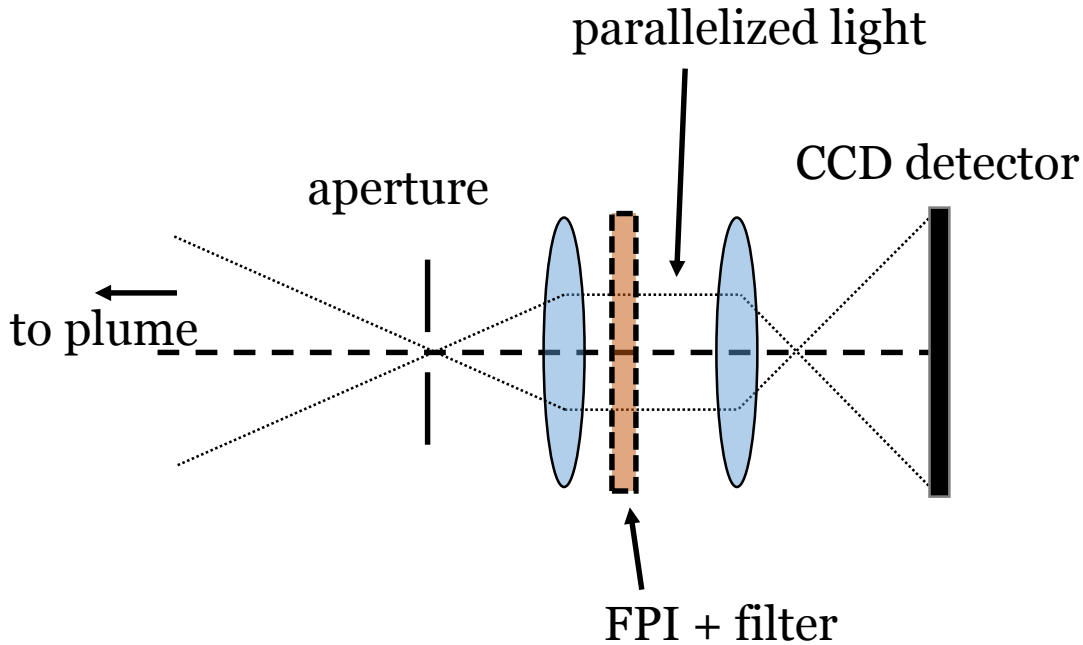


- reliable SO_2 information
- compact and robust setup
- no temperature stabilization

what about imaging ?

full frame FPI SO_2 Camera





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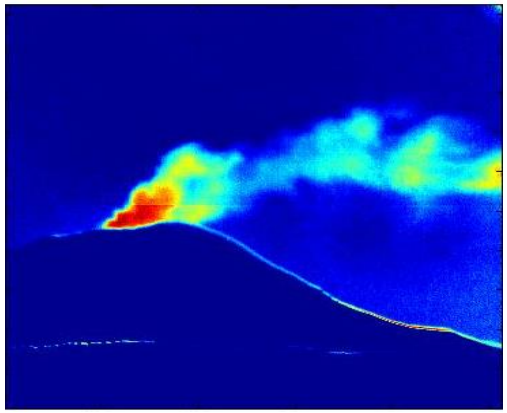
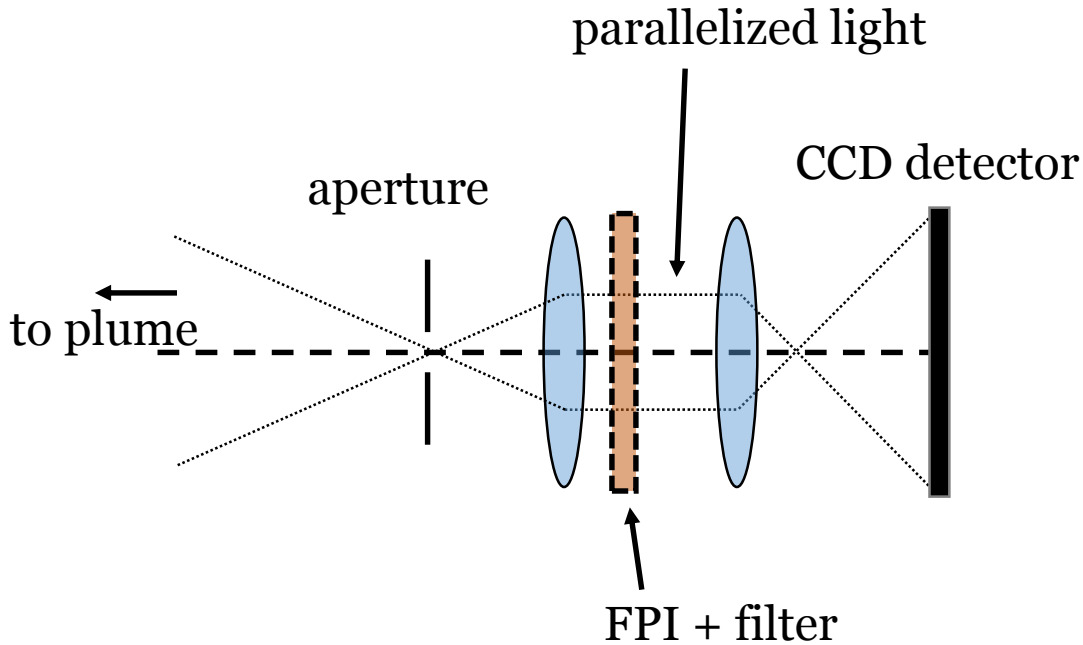
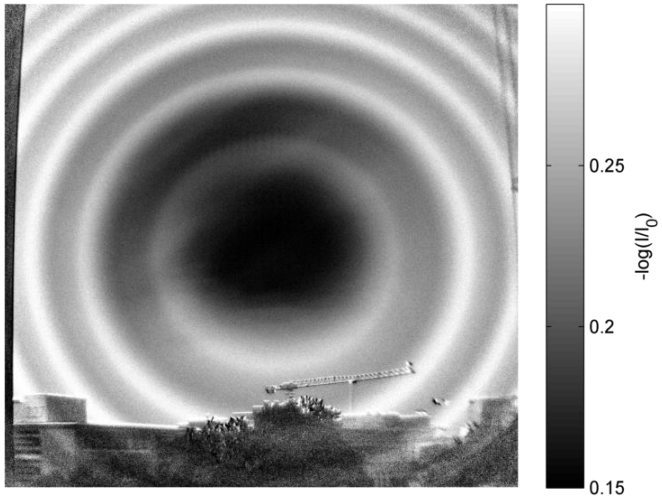
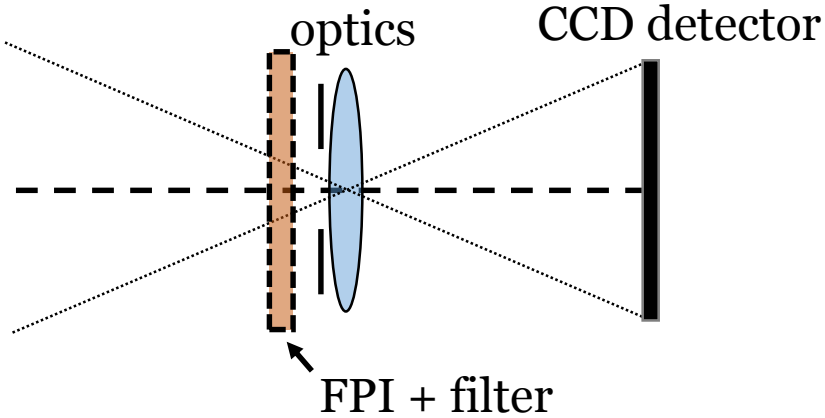








Conclusions and Outlook

imaging trace gases in the atmosphere
fast and
with low cross interferences

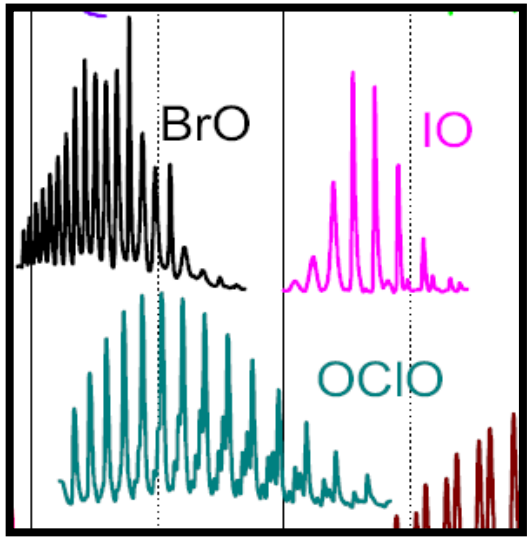
FPI technique

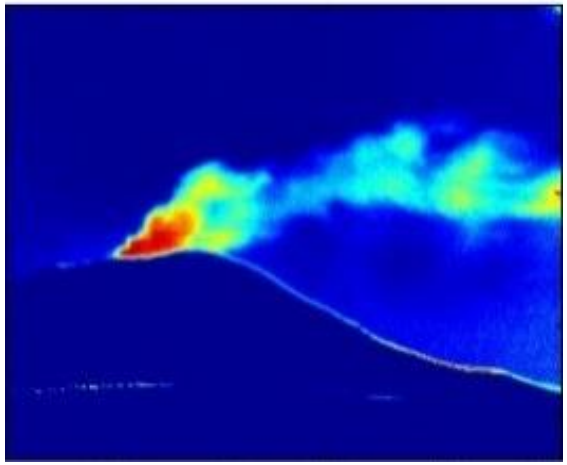
other gases ?

one pixel device

FPI camera

- compact and stable
- accurate SO_2 information
- no temperature stabilization





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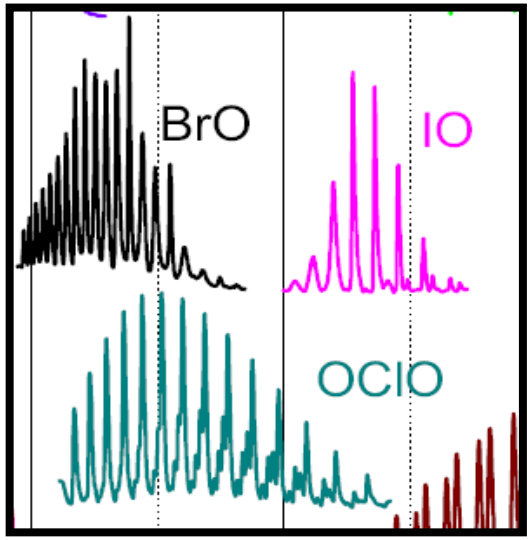

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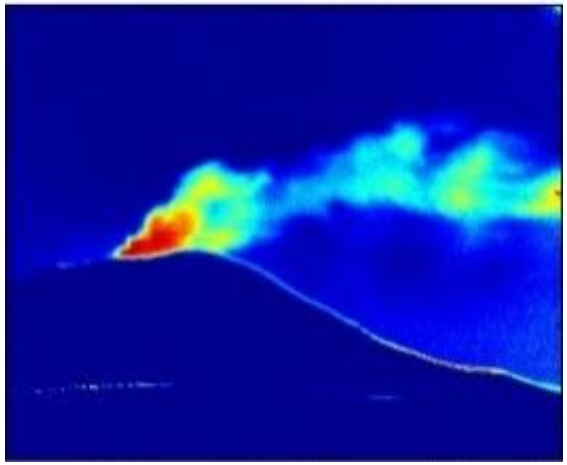

Thank you!

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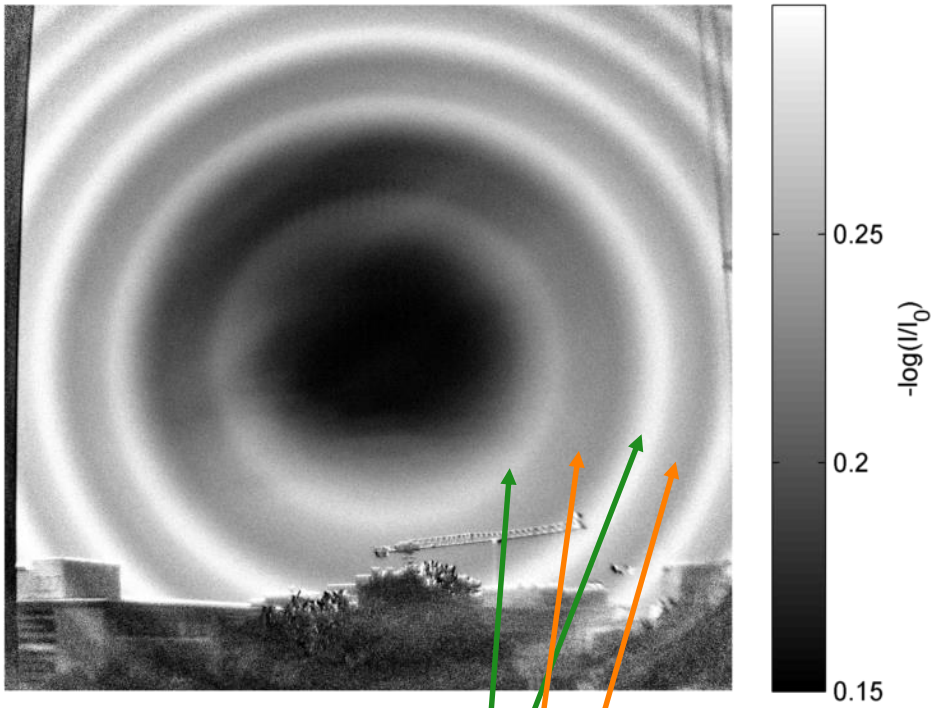
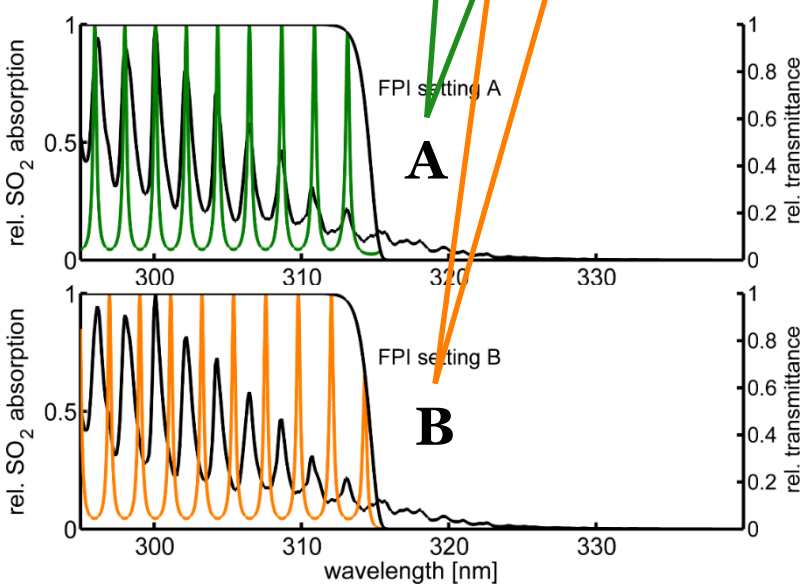
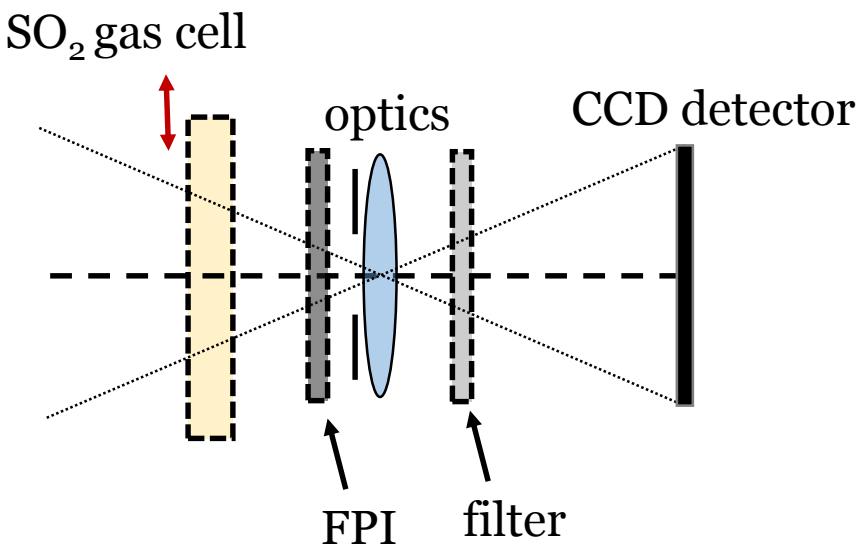
full frame FPI SO_2 Camera







full frame sensitivity by e.g.:

- tuning the FPI
- tilting the whole camera setup