Signal Dependent Non-Linearity Calibration of an Imaging Spectrometer

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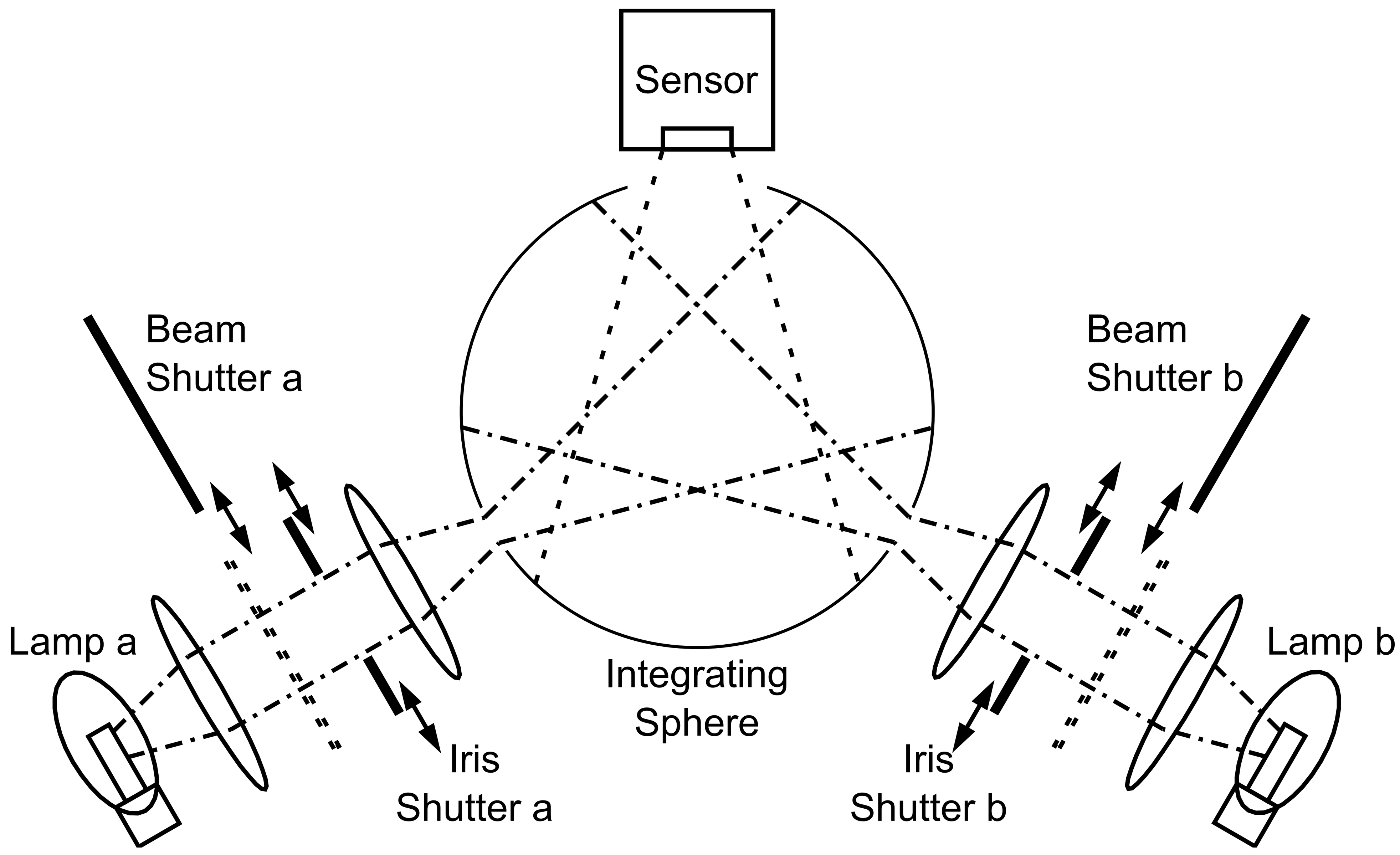
Motivation

- Use of light-addition method for non-linearity calibration as it does not depend on assumptions or reference detectors
- Convectional setups that use the light-addition method have one lamp with a single light path and fixed variable aperture pairs for light attenuation
- The achievable radiances are too low to cover the entire field of view (FOV) and apertures of typical imaging spectrometers while measuring with operational integration times of < 20 ms
- It is difficult to check whether covering one aperture changes the amount of light that falls through the other aperture



BAyLIS (Broadband Attenuable LIght Source)

In contrast to conventional setups

- Designed for imaging spectrometers
- Stepless and synchronous attenuation from 350 nm to 2500 nm using motorized iris shutters
- High intensity by using two light paths and 2 x 250 W lamps with F/1
- Covers entire HySpex VNIR-1600 aperture and FOV
- Beam shutter a/b influence on light level from light path b/a (< 0.02 %) is testable by turning lamp a/b off

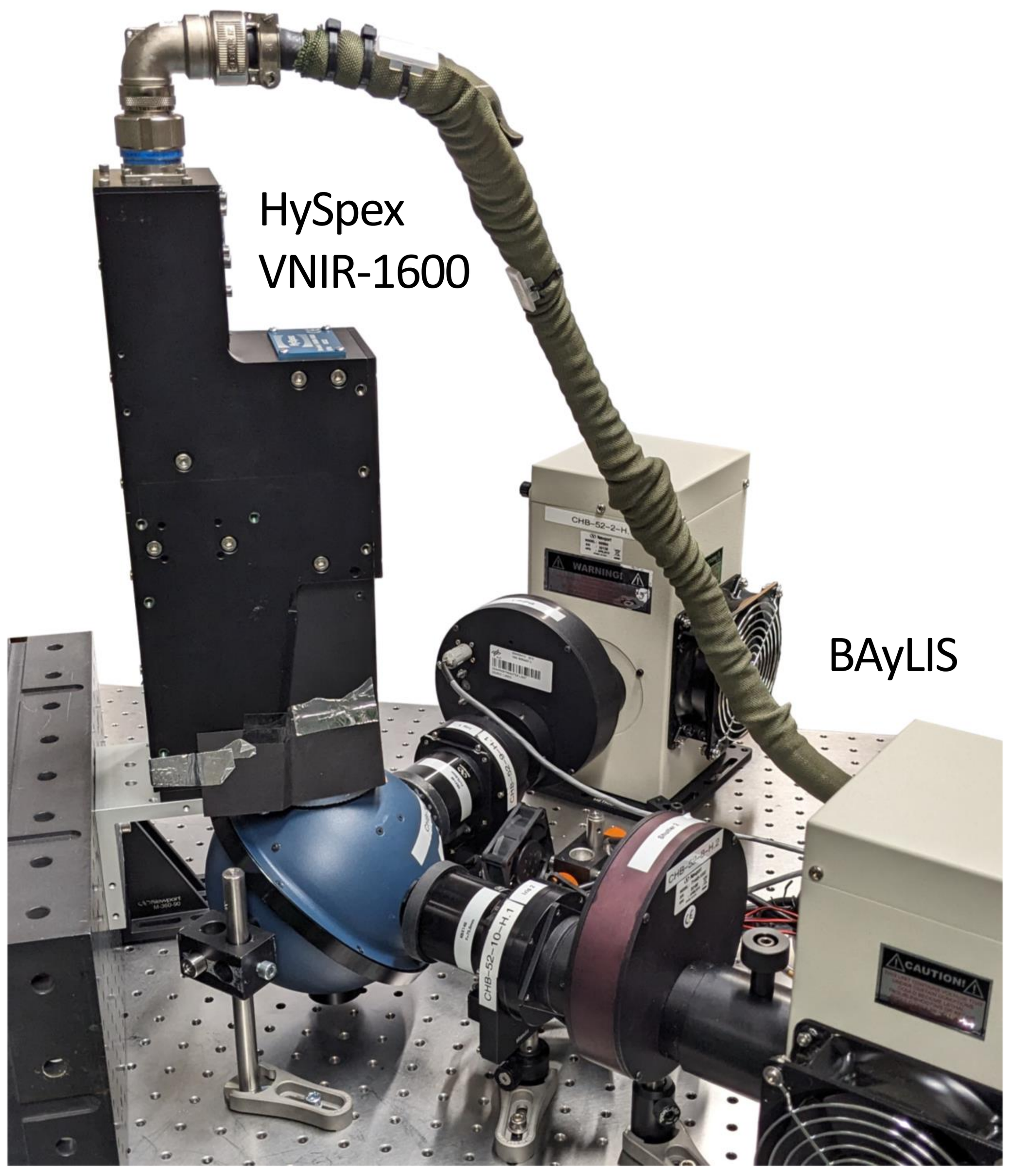
BAyLIS Calibration

Before sensor calibration → $L_a \approx L_b$

1. Relative lamp spectra matching: Change lamp a and b currents
2. Absolute intensity calibration: Adjust iris shutters

HySpex VNIR-1600

- Pushbroom imaging spectrometer
- 160 channels: 420 nm – 1000 nm
- 1600 spatial pixels: 17° field of view
- Two 12 bit ADCs: left + right detector half



Light-Addition Method

- For linear systems, the sum of individual signals $S(L_\mathrm{a})$ and $S(L_\mathrm{b})$ caused by the radiances L_a and L_b is equal to the signal of the sum of both radiances $S(L_\mathrm{a}+L_\mathrm{b})$:

$$\frac{S(L_\mathrm{a}+L_\mathrm{b})}{S(L_\mathrm{a})+S(L_\mathrm{b})}=\alpha$$

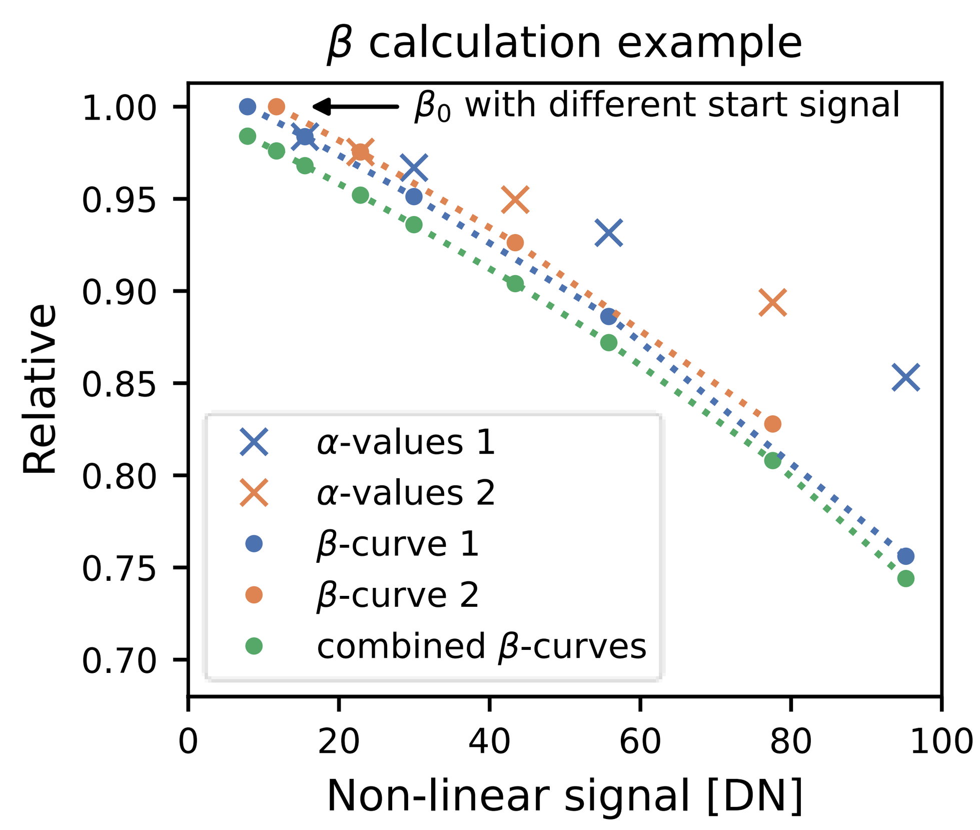
- $\alpha \neq 1$ → sensor response is non-linear
- α: relation between signal levels $S(L_\mathrm{a}) \approx S(L_\mathrm{b})$ and $S(L_\mathrm{a}+L_\mathrm{b})$
- Chained α-values → non-linearity β:

$$\beta_i = \prod_{k=1}^{i} \alpha_k, \quad \beta_0 = 1$$

- Signal axis of β-curve is exponentially spaced
- Additional β-curves by changing start signal
- Combining β-curves → contiguous β-curve
- β as function of the non-linear signal S^nl can be used for non-linearity correction:

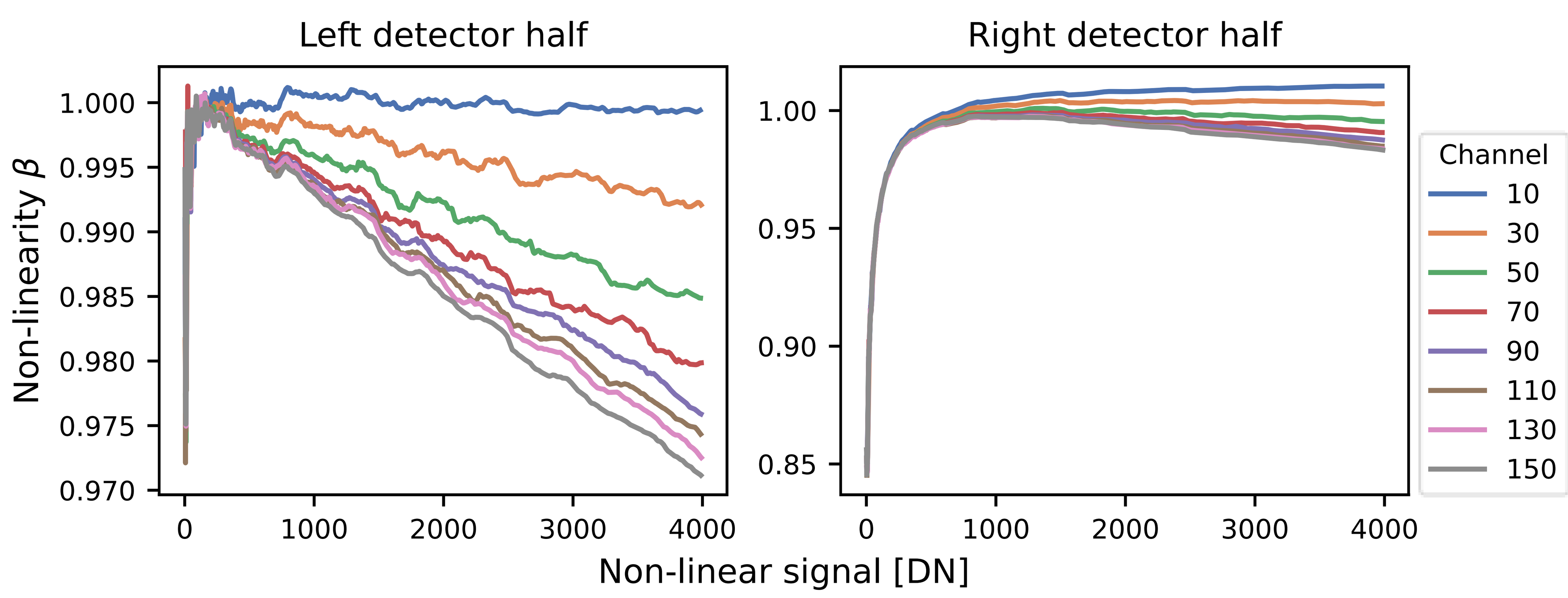
$$S^\mathrm{lin} = \frac{S^\mathrm{nl}}{\beta(S^\mathrm{nl})}$$

Meas. step	Beam shutter a	Beam shutter b	Signal
1	closed	closed	$S(0)$
2	open	closed	$S(L_\mathrm{a})$
3	closed	open	$S(L_\mathrm{b})$
4	open	open	$S(L_\mathrm{a}+L_\mathrm{b})$



Results for HySpex VNIR-1600

- Non-linearity depends on channel and detector half (ADC)
- Before correction: non-linearity < 3 % (left) and > 15 % (right)
- After correction: non-linearity < 0.1 % (not shown)



Detailed description of the setup and the calibration results: Andreas Baumgartner. 'Traceable Imaging Spectrometer Calibration and Transformation of Geometric and Spectral Pixel Properties'. October 2021. doi: 10.48693/38.

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