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Bandpass and Wavelength Characterization of Dobson Reference Instruments at PTB

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Outline

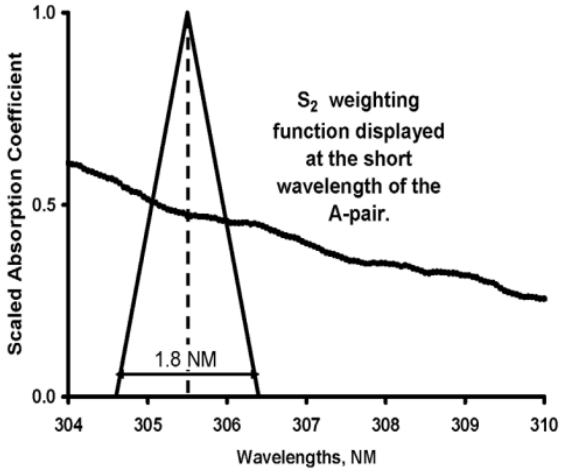
- Motivation: ATMOZ
- A short history of Dobson bandpass measurements
- Measurement setup and
- procedures implemented at PTB
- Results for D064 (DWD) and D083 (NOAA)
- Conclusions

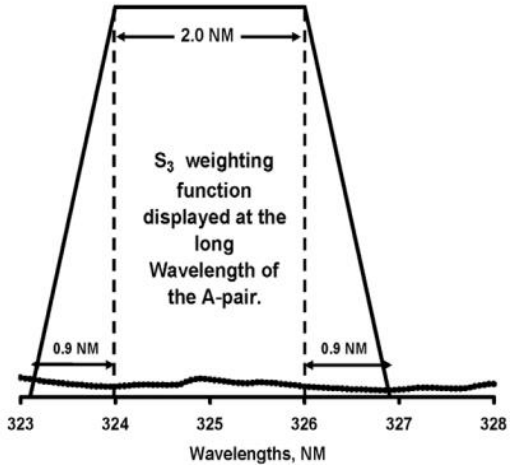
Motivation: ATMOZ

- TOC derivation from measurements by Dobson instruments since 1920s
- Bandpass and centre wavelengths needed for the algorithm
- These parameters are assumed to be equal to those of the world reference Dobson
- EMRP ATMOZ project: instrument characterisations in laboratories of PTB (laser based) and CMI (monochromator based) + a portable source suitable for field measurements (TuPS, CMI)
- Characterisations at PTB in May 2015:
  - Regional standard Dobson Nr. D064 (DWD)
  - World reference Dobson Nr. D083 (NOAA)

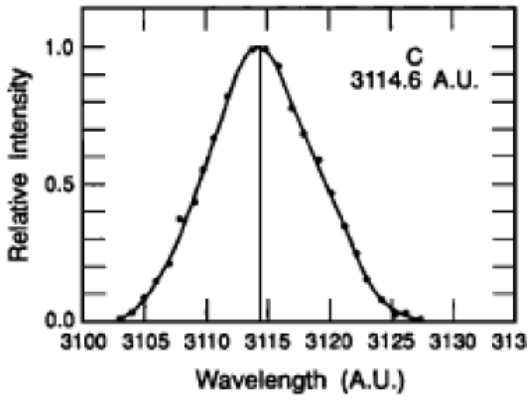
A short history of characterisations

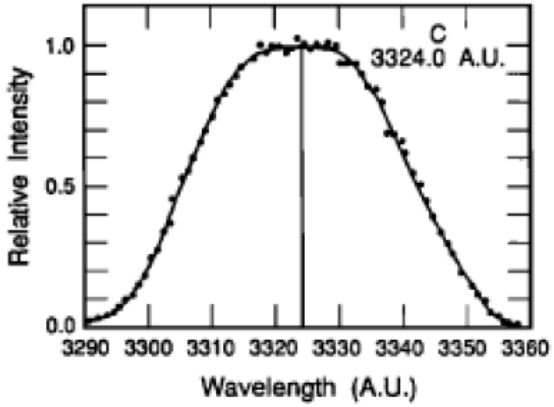
- Nominal slit functions

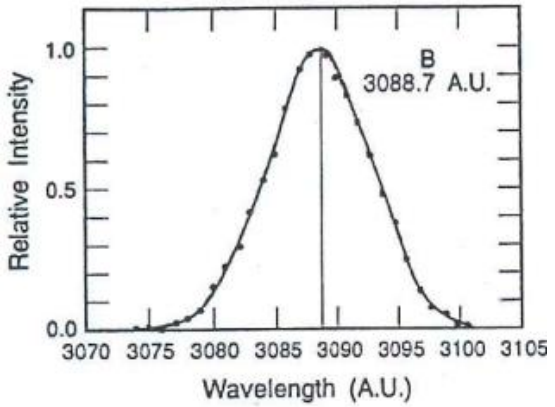




- Slit functions for the Dobson instrument Nr. 83 were determined using a model 783 McPherson spectrometer in 1992, published in 1993





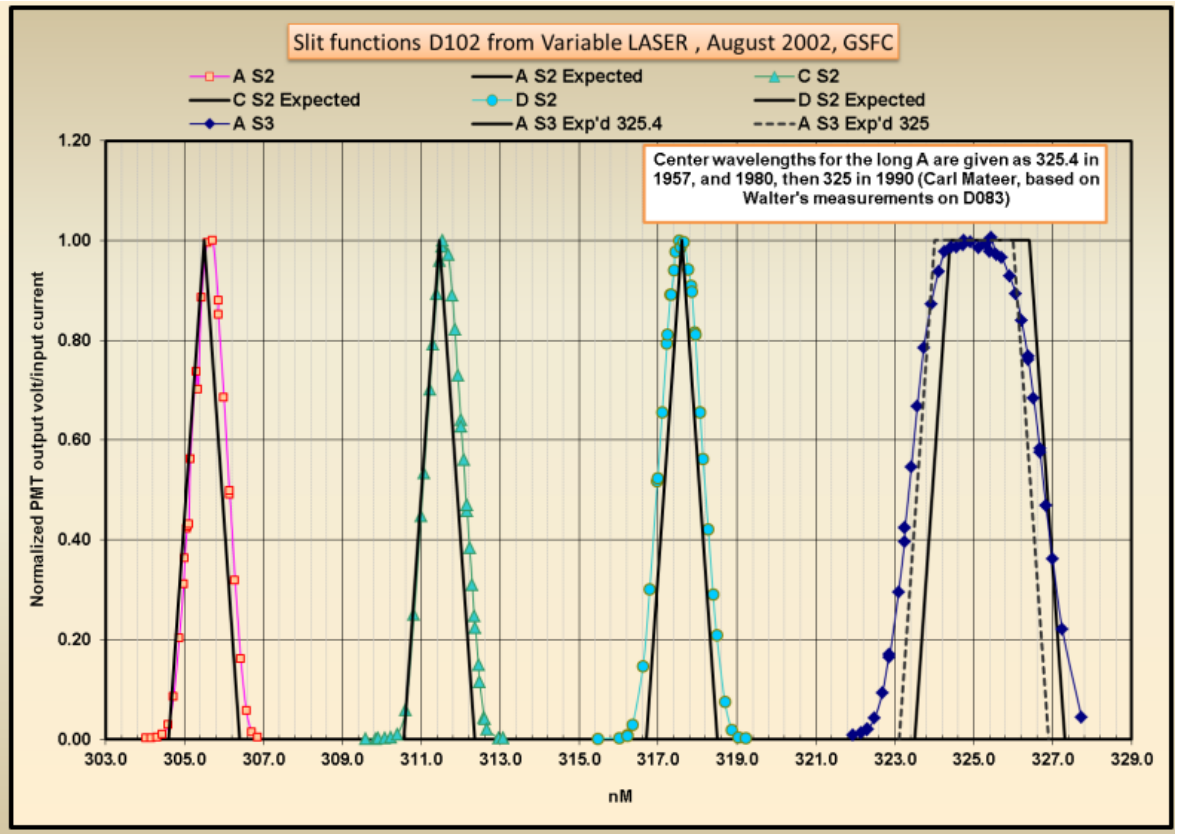


Effective Bass-Paur 1985 Ozone Absorption Coefficients for Use With Dobson Ozone Spectrophotometer
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 98, NO. Dll, PAGES 20,451-20,465, NOVEMBER 20, 1993 - Komhyr, Mateer and Hudson

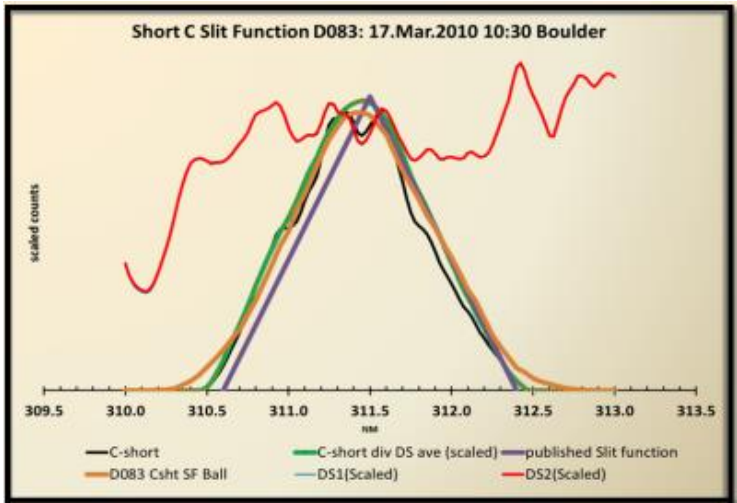
Courtesy Robert D. Evans, NOAA/ESRL

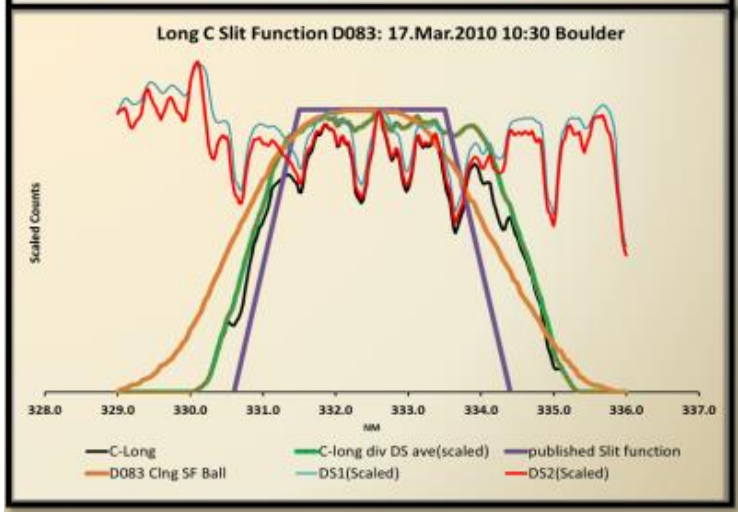
A short history of characterisations

- Slit functions of D102 measured by Robert D. Evans and Gordon Labow with a tunable laser at Goddard in August 2002



- Poster at 2012 QOS on Avantes-based measurements of D083

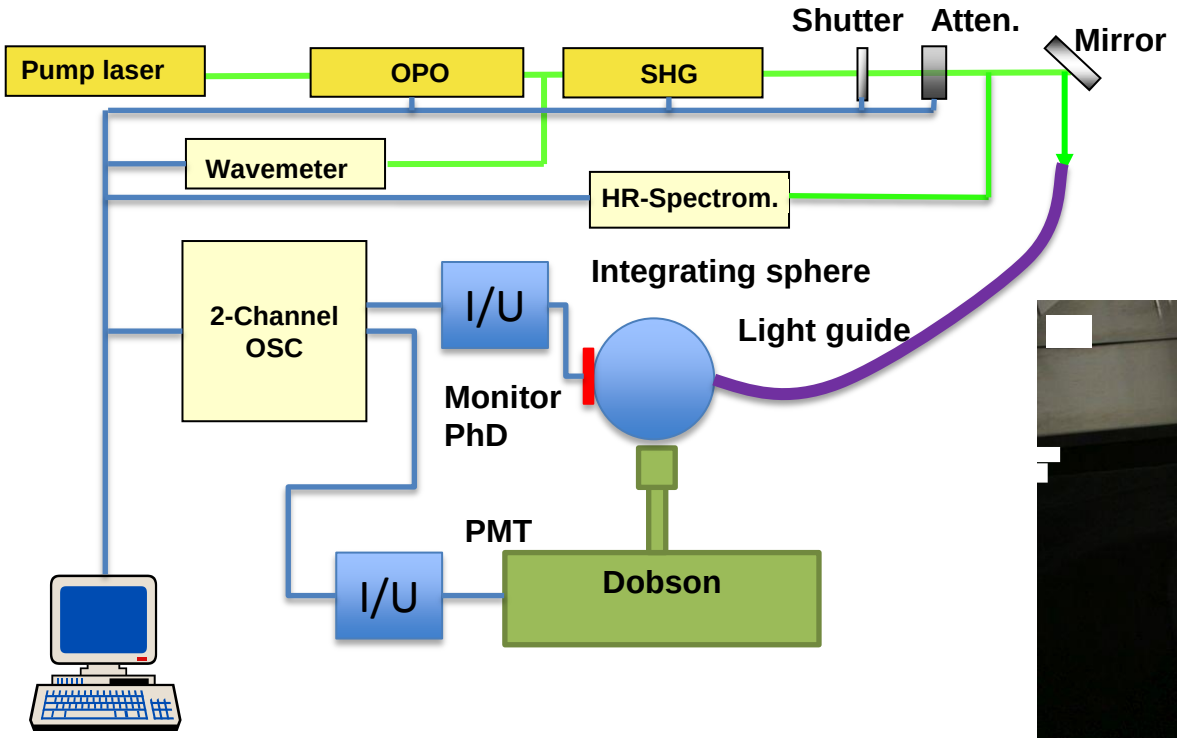


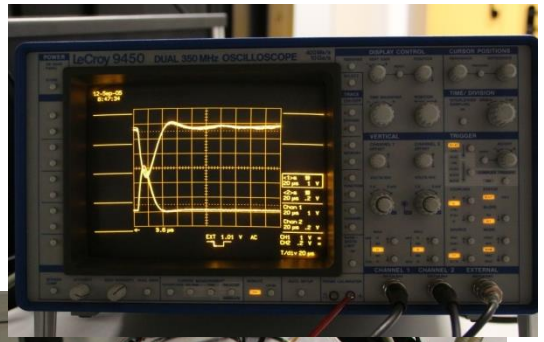


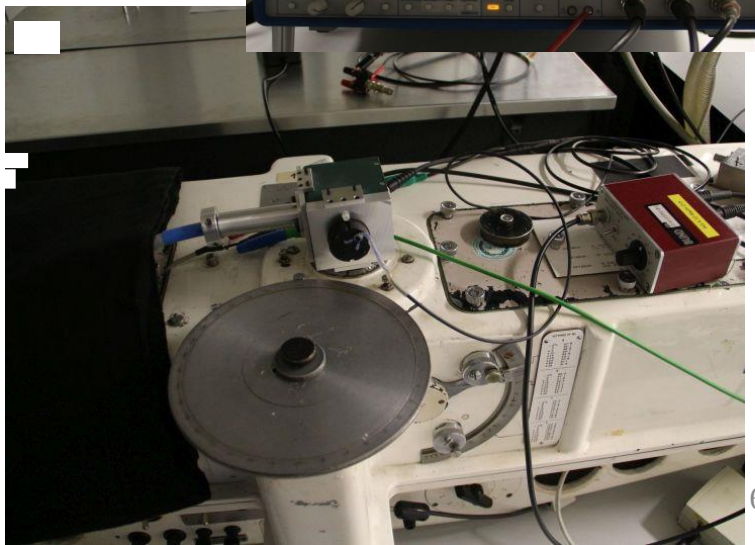
Courtesy Robert D. Evans, NOAA/ESRL

Measurement setup at PTB

- Measurements using a pulsed laser source:
  - anode current of the PTM and of a monitor Si photodiode
  - simultaneous recording of signal pulse waveforms from both detectors by a 2-channel osciloscope (LeCroy 9450)
  - post-processing of the captured waveforms

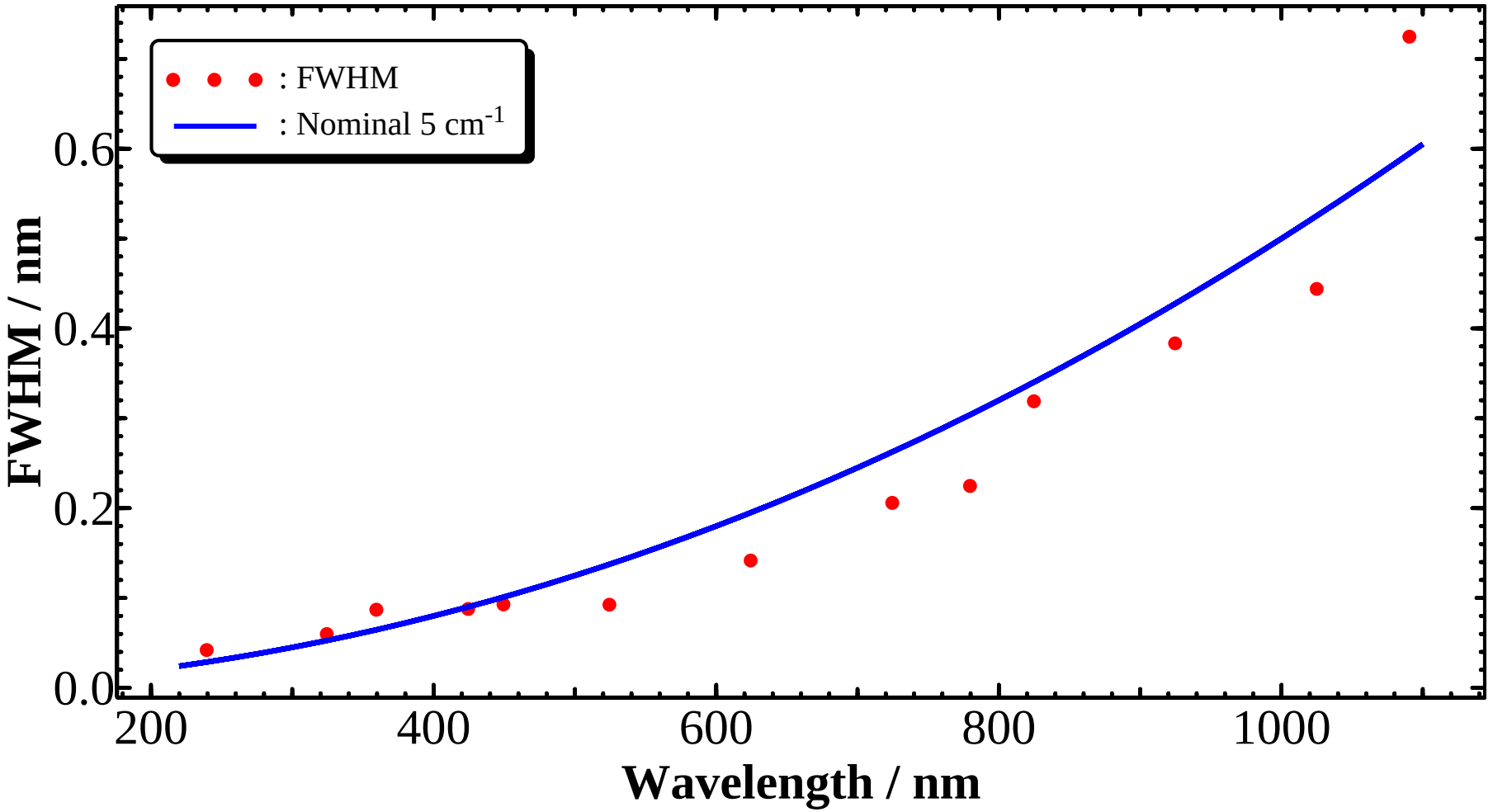






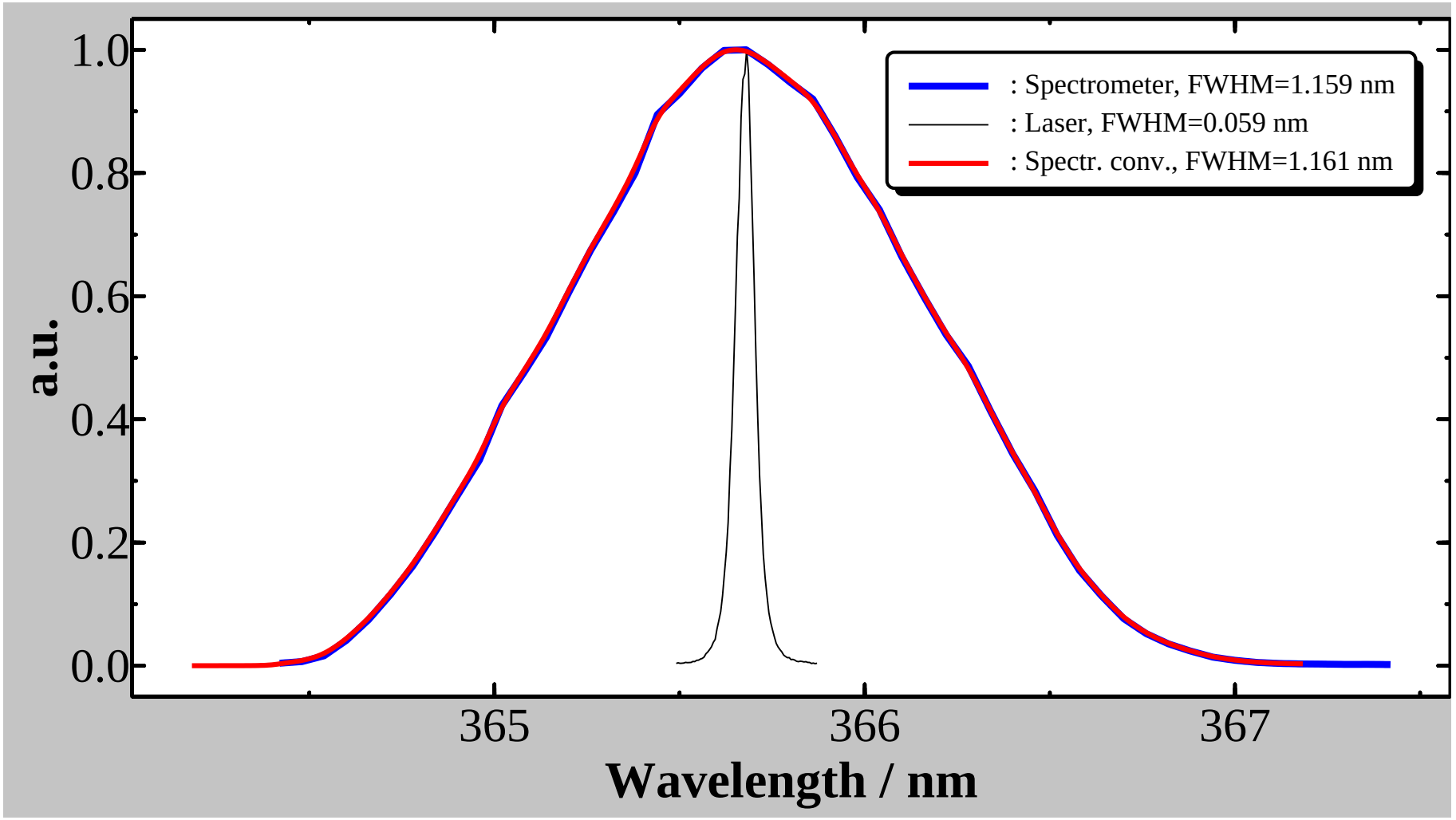
Measurement setup at PTB

Bandpass of the pulsed laser 5 cm^{-1} (20 Hz, 6-7 ns)



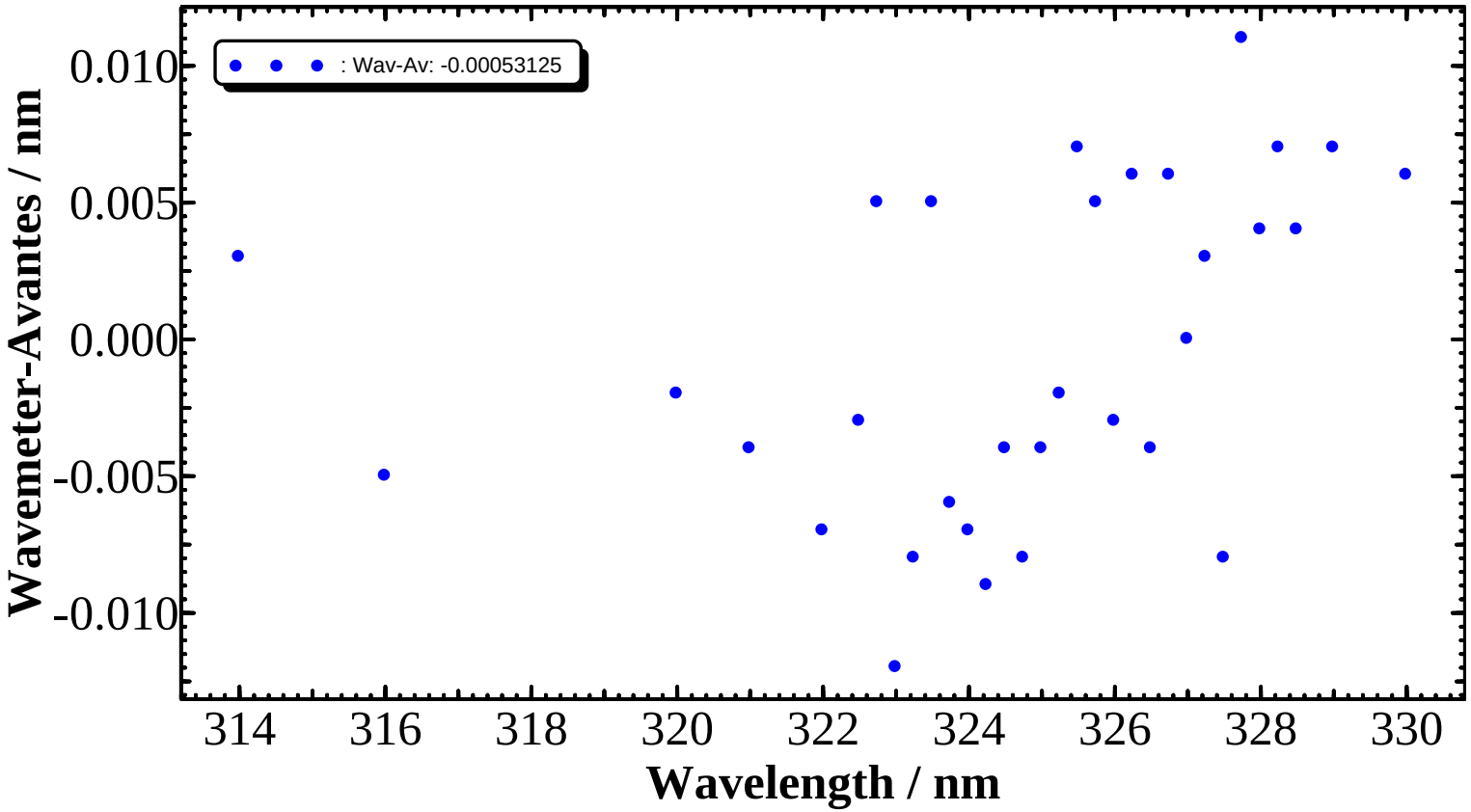
Measurement setup at PTB

- Simulated direct measurements of a spectrometer slit function (convolution)



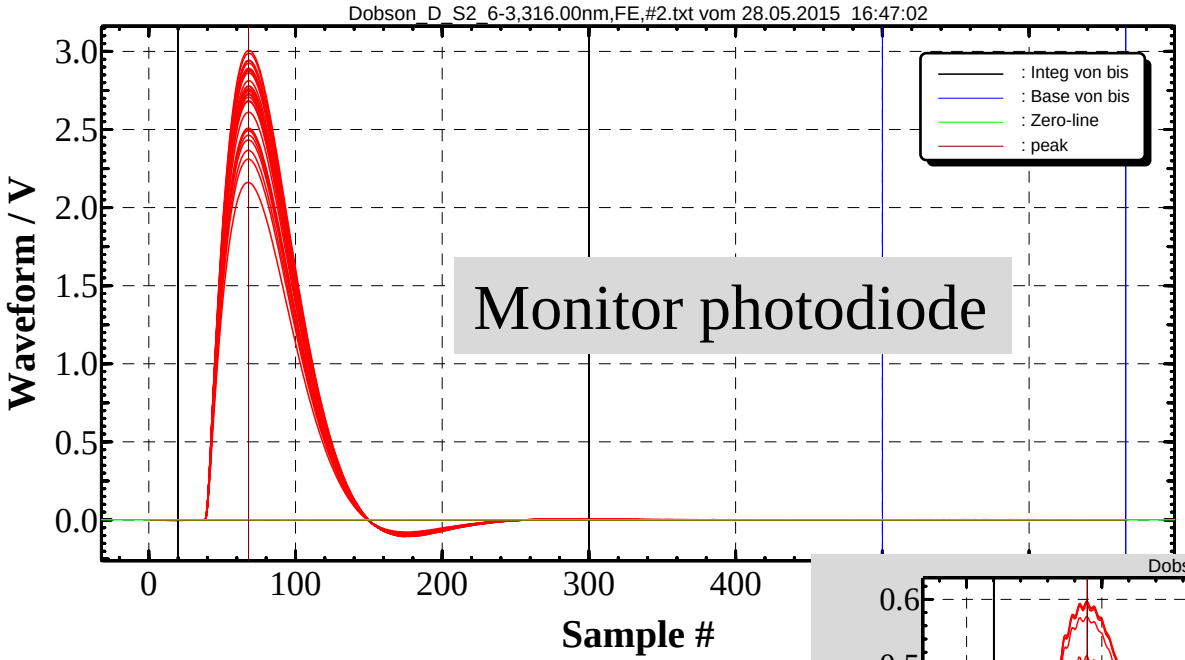
Measurement setup at PTB

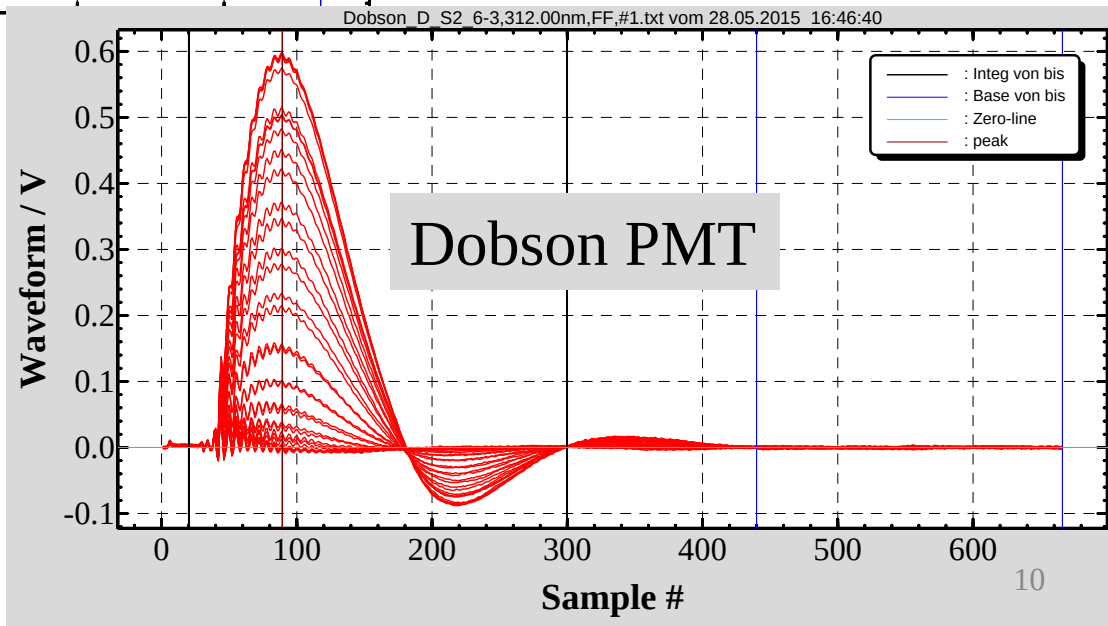
- The laser wavelength monitored both by a wavemeter and a calibrated high resolution (FWHM=0.1 nm) Avantes spectrometer
- Typical agreement between both instruments during one measurment:



Measurement procedure

- An example of waveform set recorded during a measurement of one slit





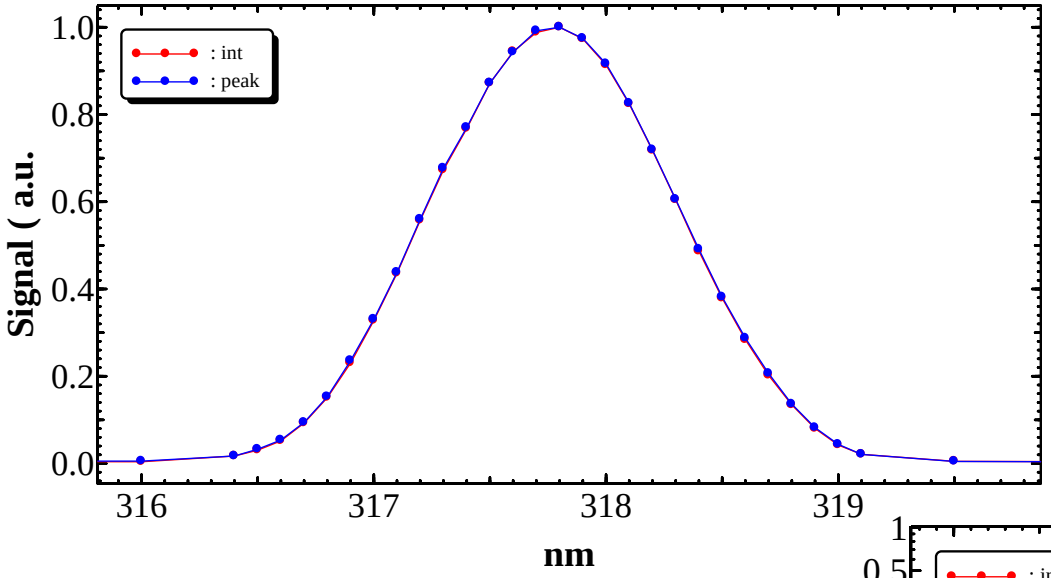
$$Sig^{\text{int}} = \int (Waveform(t) - Ground)dt, \text{ or}$$

$$Sig^{peak} = Waveform(t_m) - Ground$$

$$\frac{Sig(\lambda_0, \lambda)}{Mon(\lambda_0, \lambda)} = \frac{Sig^{\text{int}} - DarkSig^{\text{int}}}{Mon^{\text{int}} - DarkMon^{\text{int}}}$$

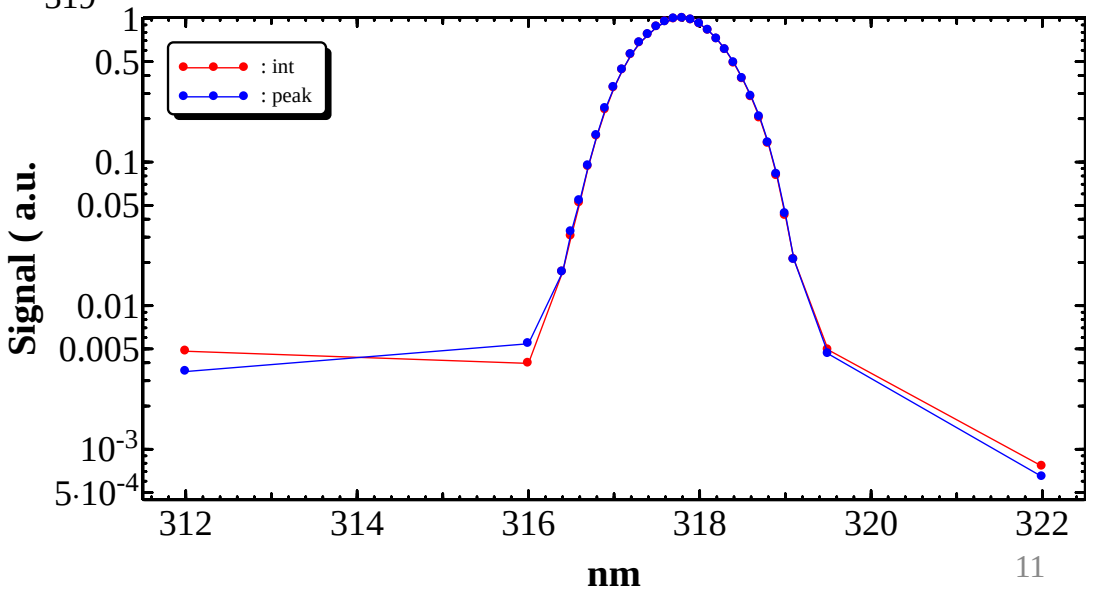
Measurement procedure

- Example of bandpassfunctions determined using the intergral or peak values of the waveforms



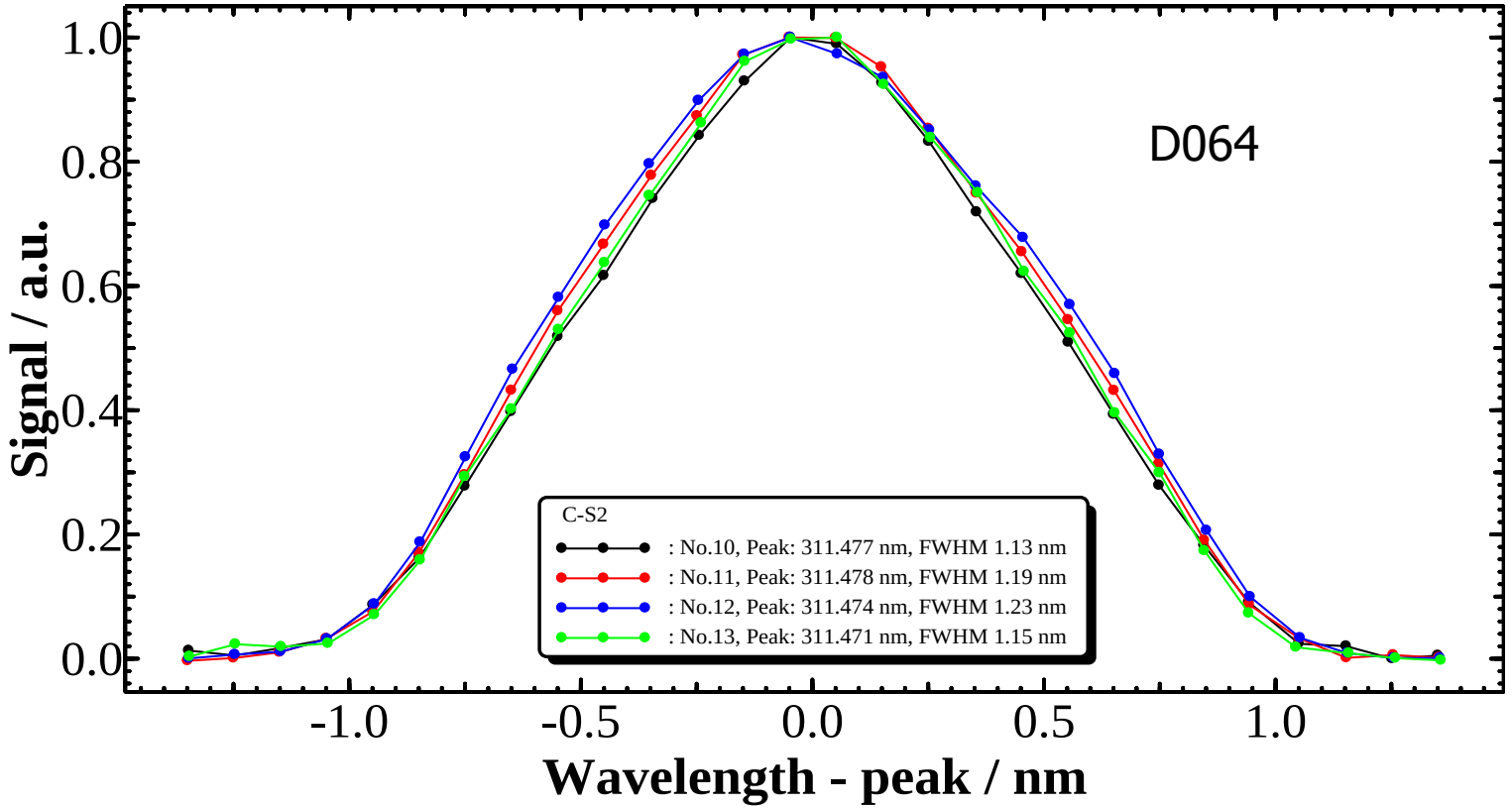
$$S(\lambda_0,\lambda)=\frac{\frac{Sig(\lambda_0,\lambda)}{Mon(\lambda_0,\lambda)}}{\max\left[\frac{Sig(\lambda_0,\lambda)}{Mon(\lambda_0,\lambda)}\right]}$$

- Peak wavelengths estimated using the centroid (center-of-gravity)



Results

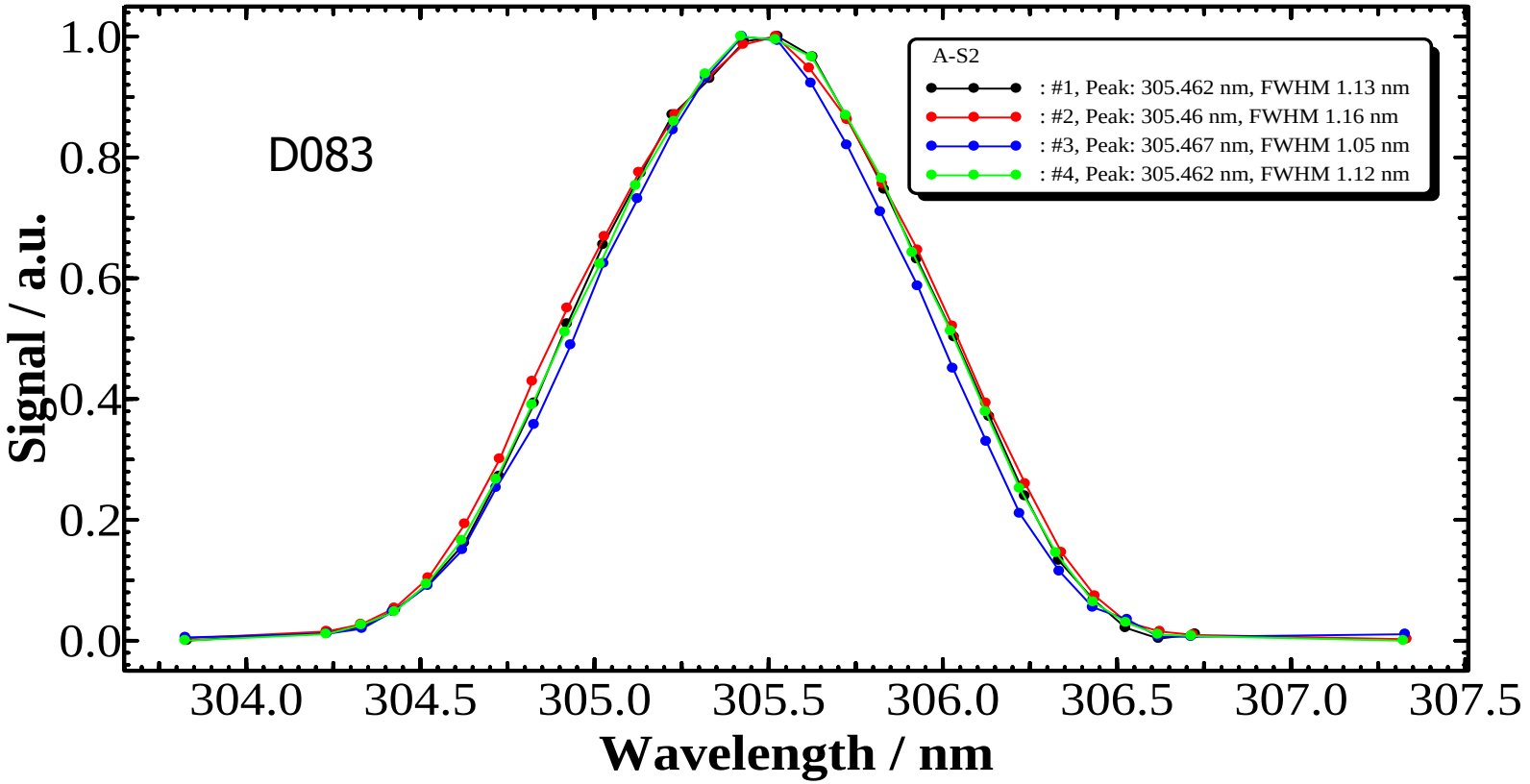
- Nonlinear behaviour of the PMTs under the pulsed laser irradiation observed for both Dobson instruments



Data set No.	Peak (nm)	FWHM (nm)	PMT (V)	Sig_{PP} (V)	Mon_{PP} (V)
10	311.477	1.13	280	0.43	1.70
11	311.478	1.19	300	0.74	1.66
12	311.474	1.23	300	1.09	2.63
13	311.471	1.15	300	0.44	0.88

Results

- Nonlinear behaviour of the PMTs under the pulsed laser irradiation observed for both Dobson instruments

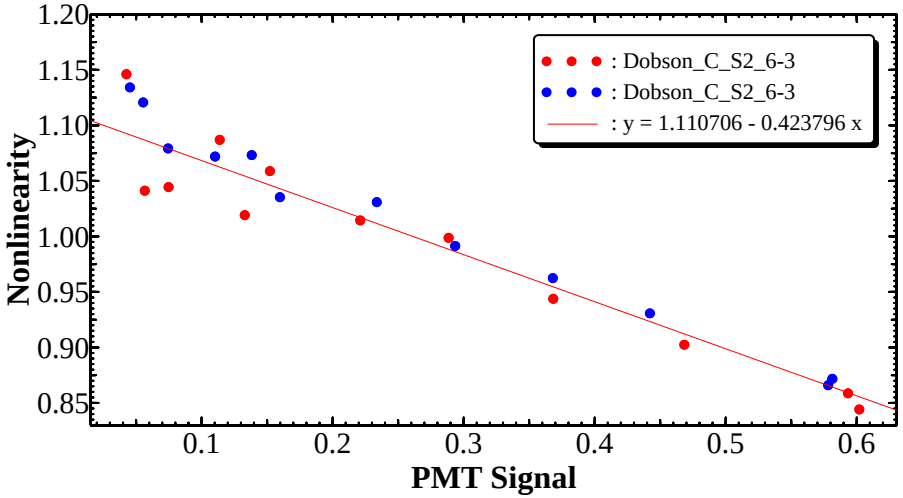


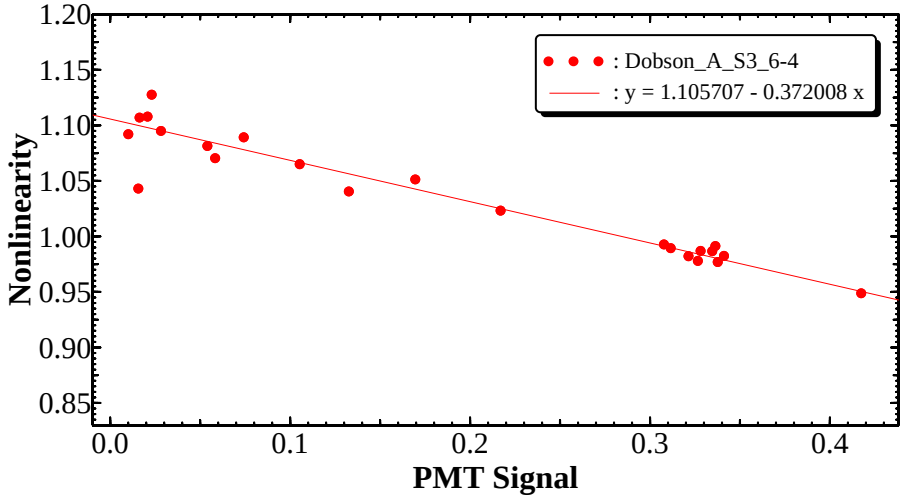
Measurement #	Peak (nm)	FWHM (nm)	PMT (V)	Sig (V)	Mon (V)
1	305.462	1.13	182	0.50	1.07
2	305.460	1.16	209	1.04	0.98
3	305.467	1.05	166	0.22	0.86
4	305.462	1.12	166	0.47	2.02

Results

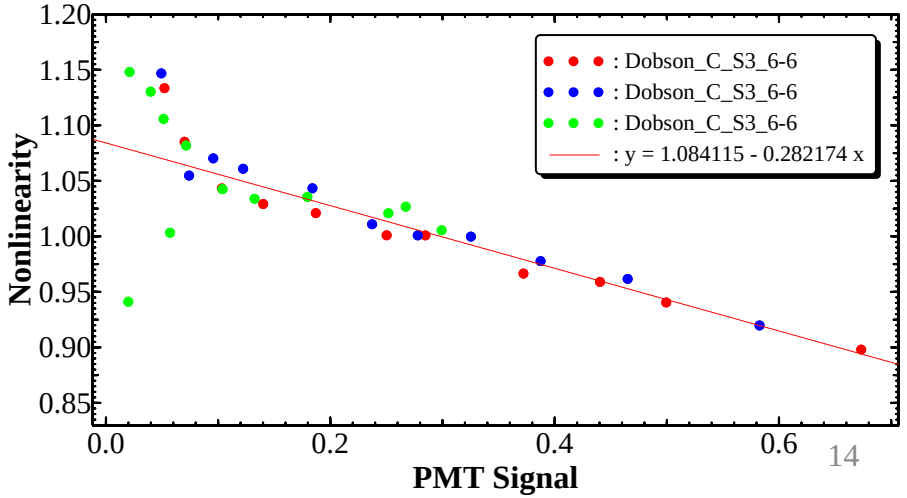
- The nonlinearity characterised for the D083 PMT: fix wavelength, tune the laser power, repeat for different PMT-HV settings

$$NL(Sig_{P-P}) = \frac{Sig / Mon}{(Sig / Mon)_{Sig_{P-P}=0.28V}} \qquad NL(Sig_{P-P}) = A + B \cdot Sig_{P-P} \qquad Sig_{NLcorr} = Sig / NL$$





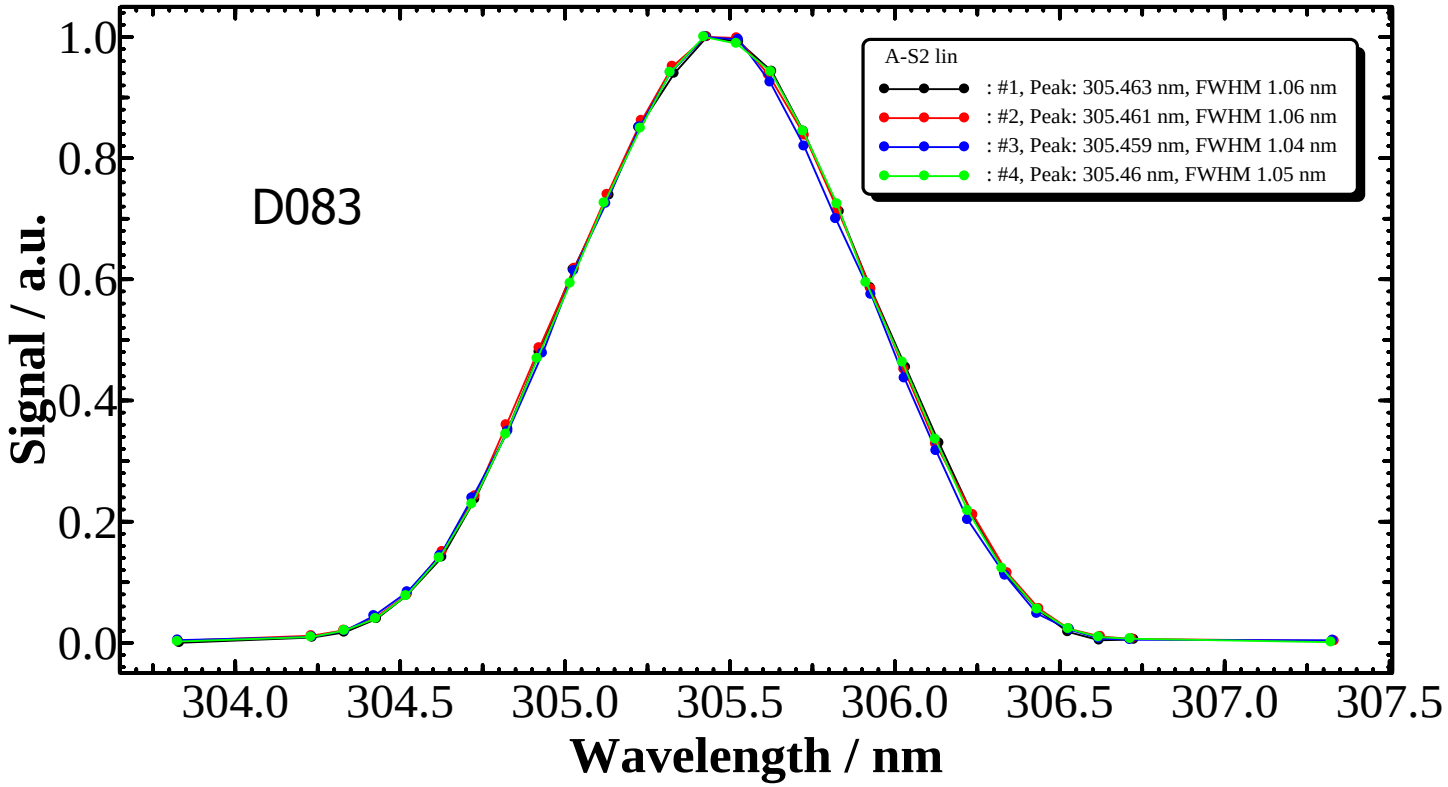
PMT voltage setting (V)	A	B
166	1.111	-0.424
182	1.106	-0.372
209	1.084	-0.282



- The lower the PMT-HV values, the higher was the observed nonlinearity

Results

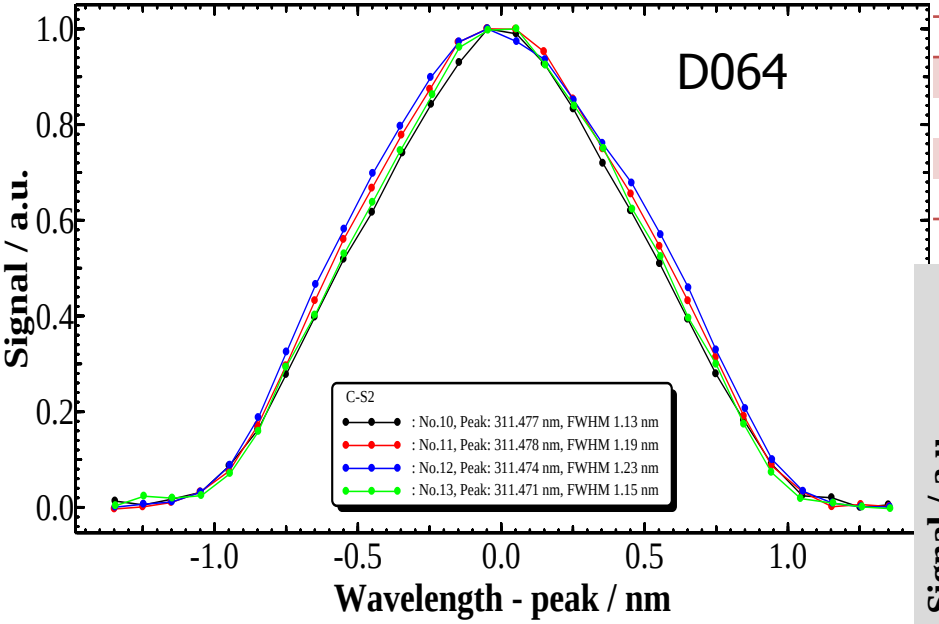
- Measured bandpass functions of A-S2 slit with the nonlinearity corrections applied



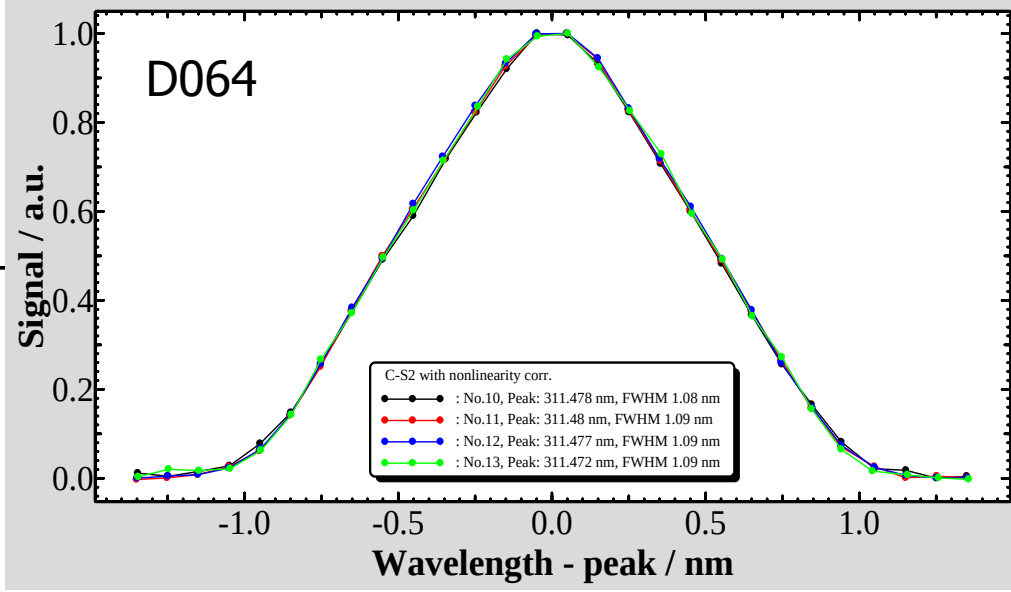
Measurement #	Peak (nm)	FWHM (nm)	PMT (V)	Sig (V)	Mon (V)
1	305.463	1.06	182	0.50	1.07
2	305.461	1.06	209	1.04	0.98
3	305.459	1.04	166	0.22	0.86
4	305.460	1.05	166	0.47	2.02

Results

- For D064 the parameters A and B of NL = A+B*Sig_{P-P} were obtained by fitting the whole data set of the bandpass function measurements to yield consistent results at the different laser power and PMT-HV values

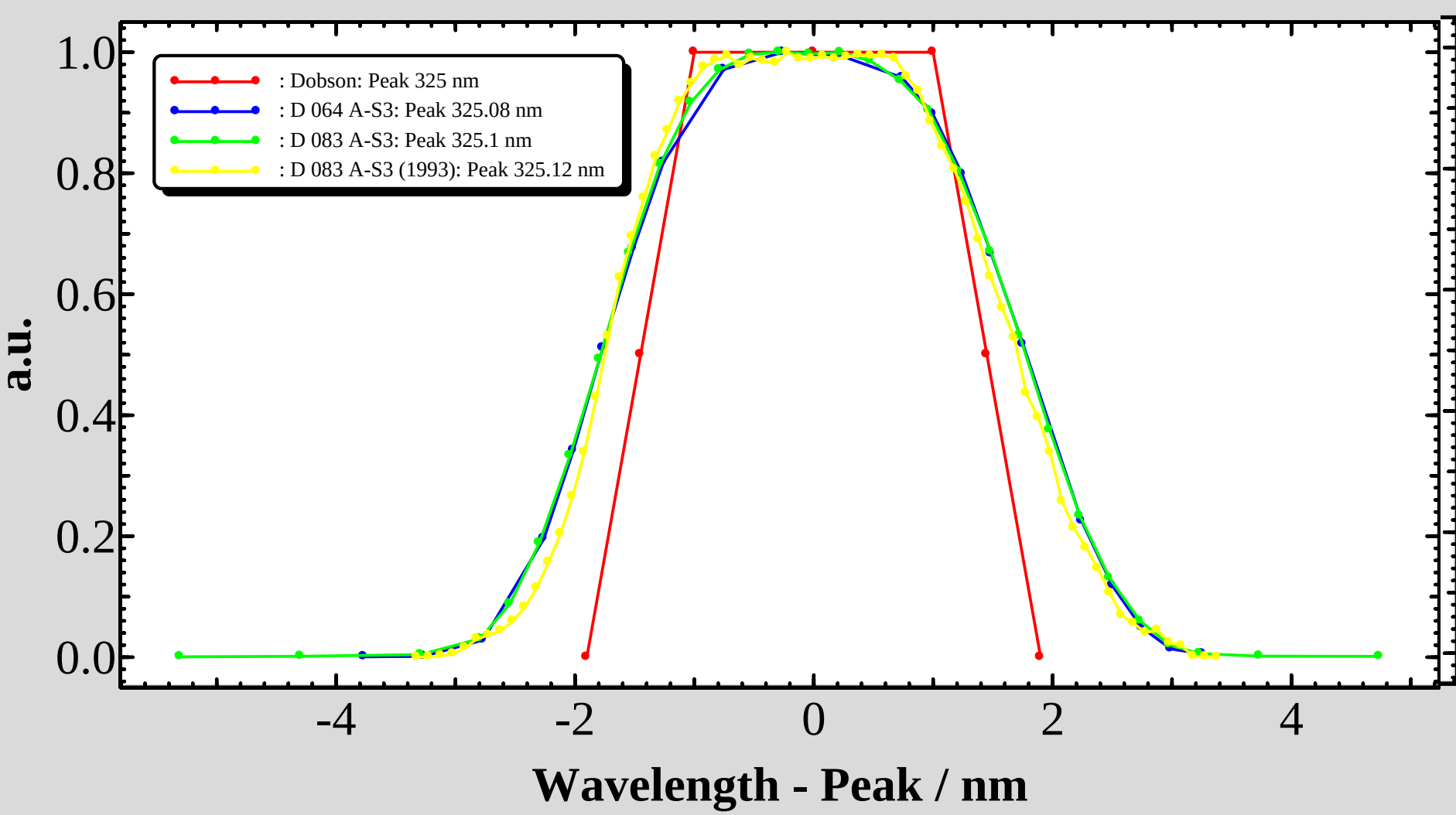


PMT voltage setting (V)	A	B
280	1.08	-0.30
300	1.08	-0.30
330	1.08	-0.23
350	1.08	-0.19



Results

- Measurement data for both reference instrument including the 1993 data



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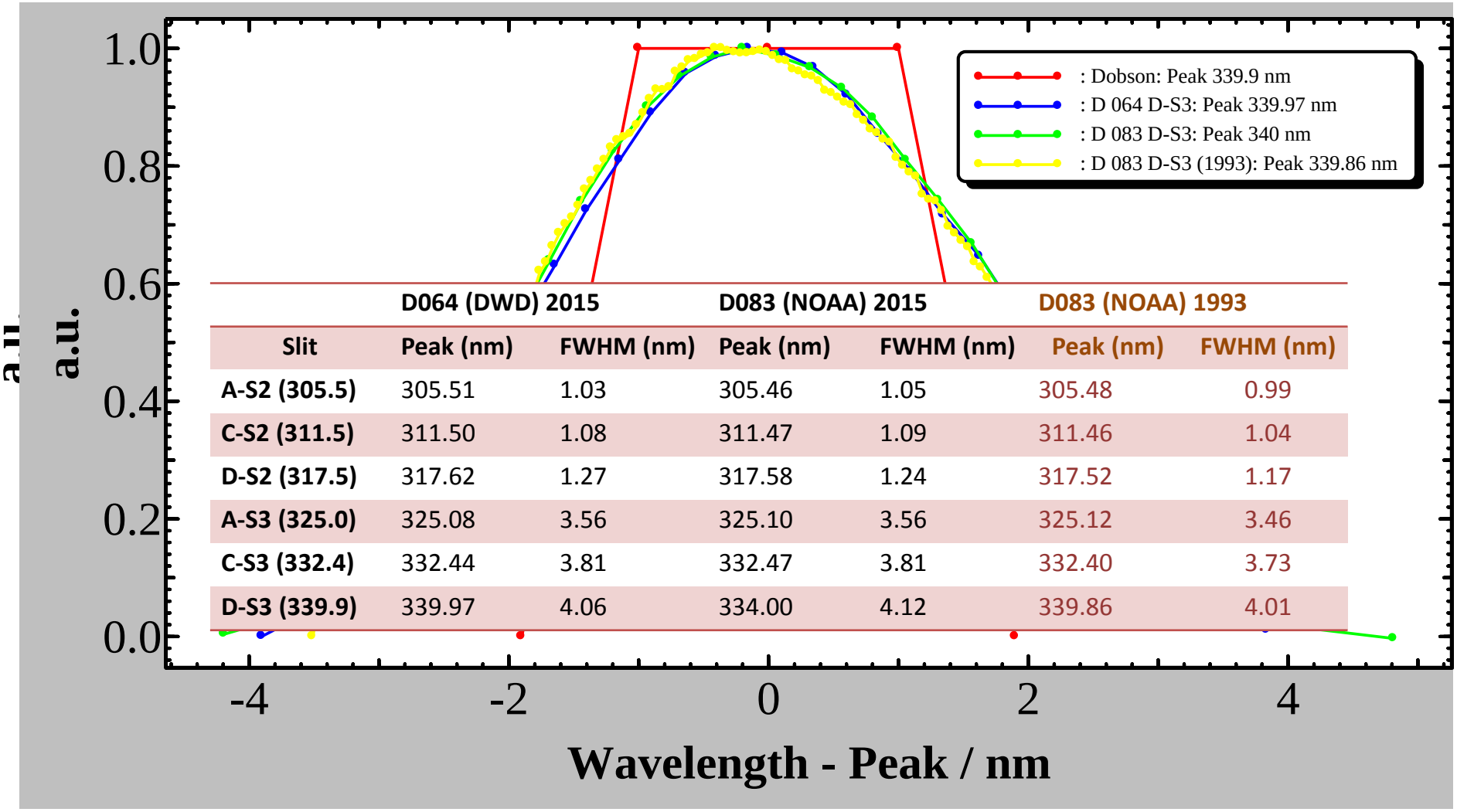

	D064 (DWD) 2015		D083 (NOAA) 2015		D083 (NOAA) 1993	
Slit	Peak (nm)	FWHM (nm)	Peak (nm)	FWHM (nm)	Peak (nm)	FWHM (nm)
A-S2 (305.5)	305.51	1.03	305.46	1.05	305.48	0.99
C-S2 (311.5)	311.50	1.08	311.47	1.09	311.46	1.04
D-S2 (317.5)	317.62	1.27	317.58	1.24	317.52	1.17
A-S3 (325.0)	325.08	3.56	325.10	3.56	325.12	3.46
C-S3 (332.4)	332.44	3.81	332.47	3.81	332.40	3.73
D-S3 (339.9)	339.97	4.06	334.00	4.12	339.86	4.01

Conclusions

- Wavelengths and bandpass characterisation of the reference instruments D083 and D064 carried out at PTB
- The two reference instruments showed very similar characteristics
- The results confirm also the good agreement and consistency observed between the two instruments in the regular TOC measurement comparisons
- The shape of measured bandpass functions deviate from the nominal tabulated ones
- The centre wavelengths match the nominal ones
- The results are comparable to the measurement data for D083 from 1993
- Characterisation of several other Dobson network instruments planed