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Wavelength Characterization of Brewer Spectrophotometer with a Tunable Laser at PTB Facilities

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Brewer wavelength calibration

The ozone retrieved for the brewer can be summarized: $X = \frac{F - ETC}{\alpha\mu}$

The calibration process can be divided in three steps:

The **Instrumental calibration** includes all the parameters that affect the measured counts (F). The **wavelength calibration** determines the ozone absorption coefficient, or differential absorption coefficient. This procedure called dispersion test obtain the particular wavelength for the instrument and the slit or instrumental function of the instrument. Finally the **ETC transfer** is performed by comparison with the reference.

With the wavelengths and the slit function determined during the dispersion the differential absorption coefficient is determined by

$$\tilde{\alpha}(X,\mu) = \sum w_i \frac{\int \alpha(\lambda) * S(\lambda,\lambda') * F(\lambda,\lambda',X,\mu) d\lambda'}{\int S(\lambda,\lambda') * F(\lambda,\lambda',X,\mu) d\lambda'}$$

Alpha = ozone cross section Wi= ozone weighting coefficients

S = Slit Function, (ILS) F = Sun Spectra , (X, and nu)

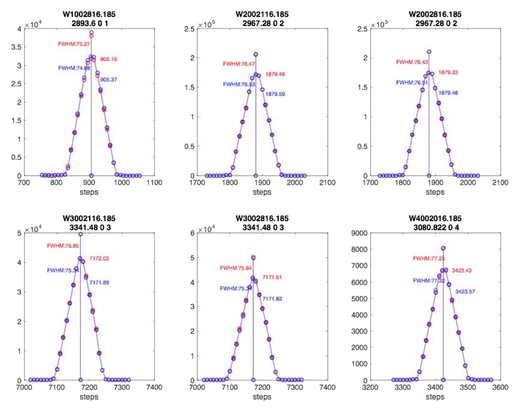
With the approximations:

- Use "ideal" or parametrized slits , (no wings, no stray light,)
- The FWHM of the triangle is dependent of the slit.
- This O_3 cross section is Bass & Paur absorption coefficient.
- Flat Spectra : Solar Spectra is not considered

Brewer dispersion procedure summary:

The brewer scans every 10 steps (~0.6 Å) the emission lines of Hg and Cd, using a particular slit

1. Central step and fwhm (step) are calculated for the six slits, assuming a isosceles triangle.
2. The dispersion relation (wavelength vs step) is determined
   a. Standard quadratic polynomial
   b. Cubic (Gröebner & Kerr 1998)
3. The central and fwhm steps are converted to wavelength.
4. Parametrized Slit are used for cross section calculation.



Lamp	Line (nm)	Slits
Mercury (Hg)	**289.36**	**0–1**
Indium (In)	293.263	0–3
Hg	**296.728**	**0–3**
Zinc (Zn)	301.836	0–5
Zn	303.578	0–5
Cd (multiplet)	**308.082**	**0-5**
Cd	**313.3167**	**0–5**
Cd	**326.1055**	**0–5**
Zn	328.233	0–5
Hg	**334.148**	**0–5**
Cd	**340.3652**	**0–5**
Cd	**349.995**	**4–5**
Cd (multiplet)	**361.163**	**5**

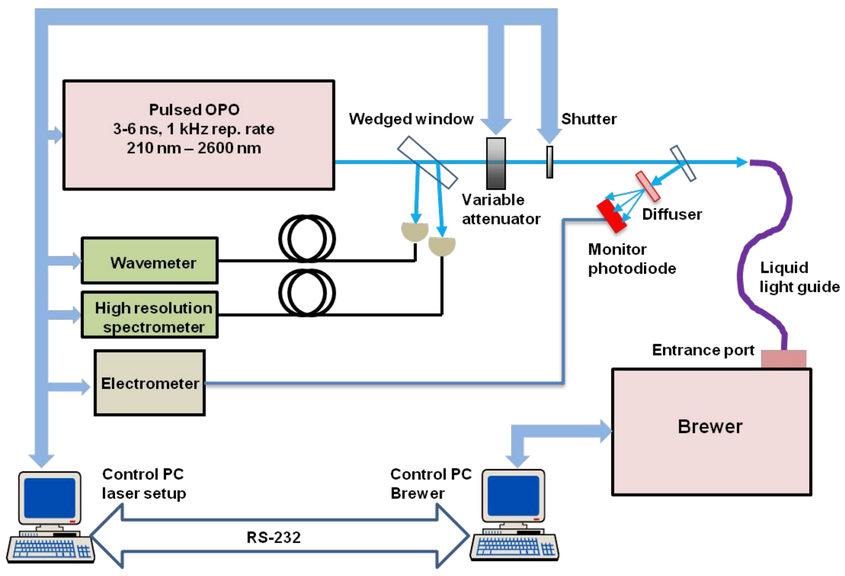
Example of the dispersion test and the lines discharge lamps used during the dispersion

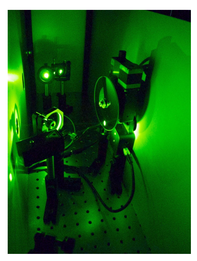
The experiment

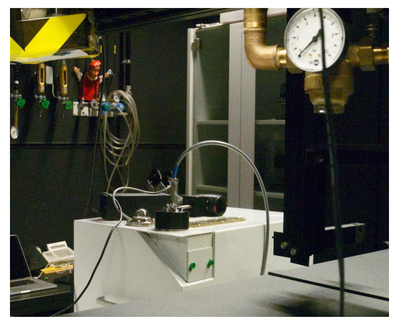
In this experiment we compare the operational wavelength calibration performed to Brewer instrument to the calibration results obtained using a tunable laser facility.The Brewer spectrophotometer has **two operating modes.** The **ozone** one, used for ozone measurement, is performed with the diffraction grating at a fixed position while the six operational wavelengths are measured by rotating slit mask. The **scanning mode**, used for the spectral UV measurements, is performed while the slits are fixed and the spectral scan is carried out by turning the diffraction grating.

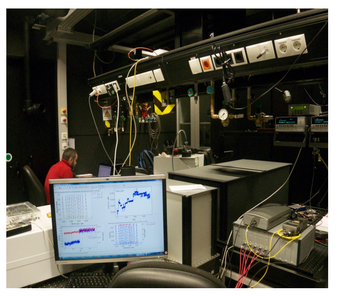
The use of the tunable source allow two studies:

1. Calculate the dispersion relation based on regularly spaced reference spectral lines provided by the tunable laser instead of the irregularly distributed emission lines of the Hg, Cd and Zn spectral lamps.
2. Calculate the ozone absorption coefficient directly. The ozone absorption coefficient determination normally uses the UV mode to scan the spectral lines so that dispersion relation is used to convert grating position in micrometer steps to wavelengths assuming a quadratic relation. Scanning with the laser around the ozone operational wavelengths we can determine the instrumental slit functions directly and weight them with the ozone cross sections without need for the assumptions of the slit functions and the dispersion relations used in the normal operational procedure.









During the experiment we perform three measurements:

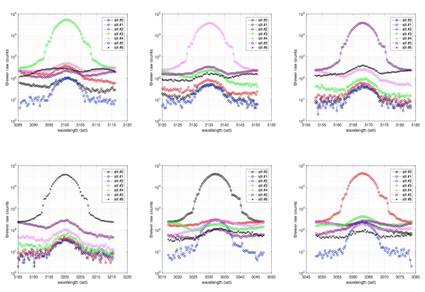
#1 - **Dispersion measurements** using spectral lamps (zinc, cadmium and mercury).

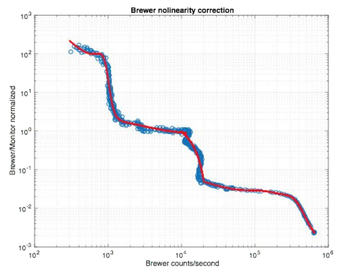
#2- Dispersion measurements using **tunable laser** (**Brewer scanning**): While Laser is emitting in a fixed wavelength, the Brewer will scan around this wavelength (±2nm) moving the grating and using the 6 slits. This process will be repeated 16 times, using wavelengths ranging from 290 nm to 365 nm with an increment of 5 nm. This allow us to estimate the error due to the lack of spectral lines in the usual dispersion determination procedure

#3 - Direct dispersion measurements (**Laser scanning**). While Brewer is measuring in ozone mode and in aerosol mode, the laser will scan around (±2nm) the six Brewer slits with a step of 0.05nm for different grating positions (ozone and aerosol).

The measurements: nonlinearity correction

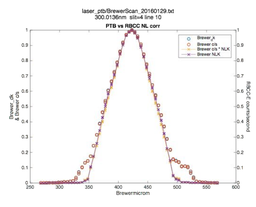
The PMT requires a different configuration to measure pulsed sources. With pulsed sources a nonlinearity correction is needed and there is an hysteresis area around 10^4 c/s. We can work on "linear regions" using the direct port for maximizing the laser output.



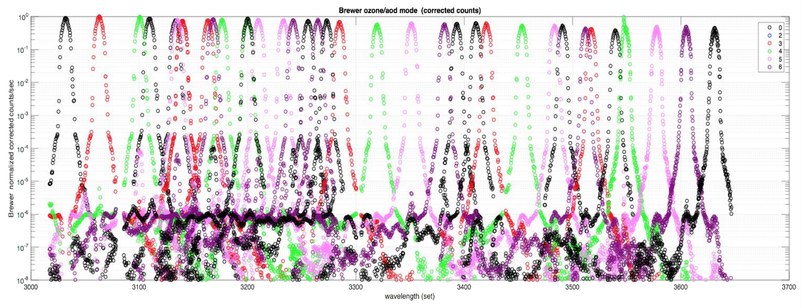


When the nonlinearity and dark correction is not applied the hysteresis of the nonlinearity is clear for the asymmetry of the peak. In some experiments the dark count is higher than the measurements.

Slit # 1 measurements correspond to the DARK (blocked) position



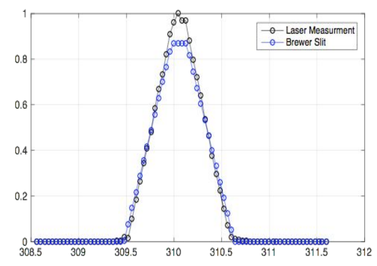
The nonlinearity do not affect to the center wavelength but the determination of the slit function.



Direct dispersion measurements for ozone and AOD the laser will scan around (±2nm) the six Brewer slits with a step of 0.05nm for different grating positions after dark and no linearity.

Brewer slit parameterization

The Brewer algorithms assume a trapezoidal slit, cut at 0.87, center and fwhm at the value calculated for every slit.



	Parametrized (B&P)	Measured (B&P)
Brw	**0.3381**	**0.3407**
B&P	**0.333**	**0.336**
DMB	**0.3483**	**0.3514**
SDK	**0.3392**	**0.3422**

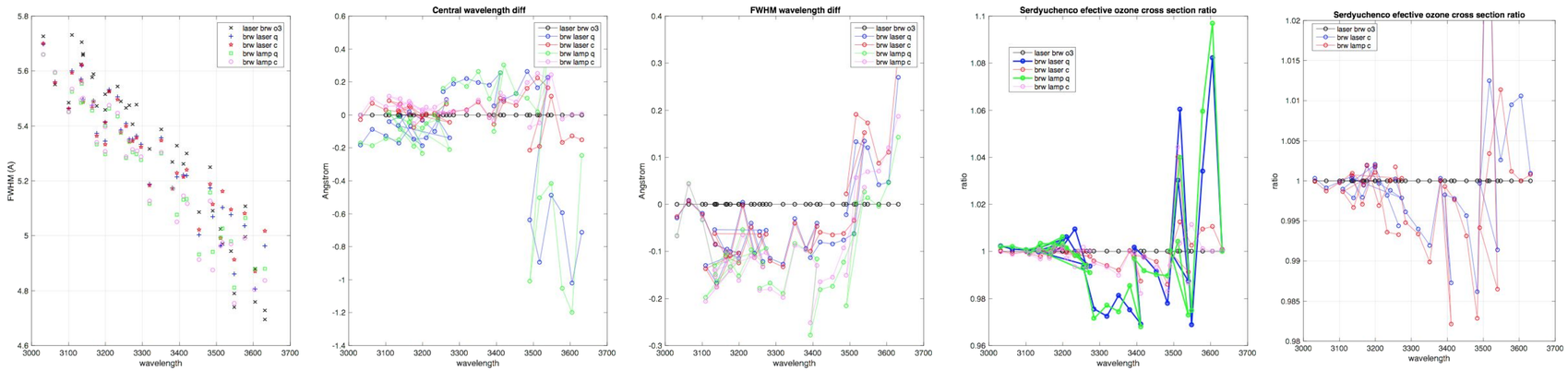
Using the measured slit, the effective ozone cross section calculated is ~0.4% higher respect the parametrized brewer slit used on the standard procedure with no variations if we use different cross-section.

Wavelength calibration methods comparison:

1. Laser wavelength scanned @ fixed Brewer position
2. Brewer grating pos. changed @ fixed laser wavelength, dispersion approx. by a quadratic function
3. Brewer grating pos. changed @ fixed laser wavelength, dispersion approx. by a cubic function
4. Brewer grating pos. changed @ fixed lamp emission wavelength, dispersion approx. by a quadratic function
5. Brewer grating pos. changed @ fixed lamp emission wavelength, dispersion approx. by a cubic function

The figures show the comparison of the dispersion results: central wavelength and FWHM and effective cross section using Serdyuchenko cross section using the direct measurement as reference. The effective ozone cross section is also shown on the table.

Method	1	2	3	4	5
SGW	**0.3409**	**0.3442**	**0.342**	**0.3446**	**0.3412**
ratio	**1**	**1.0096**	**1.0033**	**1.0108**	**1.001**



Conclusions

The quadratic fit originally used on the standard method is clearly not enough for this Brewer instrument. The underestimation is about 1% in total ozone content. Using the cubic fit the difference between the methods is 0.3% and 0.1%

Acknowledgments

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