Design and Development of a Tuneable Portable Radiation Source for In Situ Characterisation of Dobson Spectrometers

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A tuneable and portable radiation source (TuPS) has been developed for the in-field characterization of the wavelength scale (290 nm to 350 nm) and slit function of Dobson spectrometers. TuPS emits radiation with a bandwidth of 0.1 nm and an uncertainty less than 0.02 nm in the wavelength scale, while the radiant power of emitted beam exceeds 20 nW over the spectral range of interest. The past two years of operation have included two in-field calibration campaigns that have required shipping and in-field installations, and during which more than 14 Dobson spectrometers were calibrated. Over this period the long-term stability of both slit function and wavelength scale were determined to be as high as 0.02 nm.
TuPS was designed so that only minor modifications are necessary to extend/shift its spectral range towards visible and near-infrared spectral regions, thereby extending its application to the spectral characterisation of other spectrometers.

MOTIVATION AND OBJECTIVE

Dobson and Brewer spectrometers are key instruments used to monitor the ozone layer. Although networks using a specific instrument are self-consistent to better than ±0.5 % level, total column ozone retrieved from the two instrument types differ by up to 3 %. This large discrepancy currently prevents a merging of both datasets and an eventual replacement of one instrument with another type. Therefore, improved characterization and calibration of Dobson instruments I would be of great benefit.

The bandwidth and wavelength scale accuracy of Dobson spectrometers are not known for each instrument, but are assumed to be equal to the world reference Dobson. Currently, tuneable monochromatic sources which could be used for characterisation of Dobsons are complex and systems that are only found in a few laboratories world-wide and cannot be used for in-field calibrations as needed by the global spectrometer network.

Laboratory based characterisations have been performed at CMI and PTB [1] having requested typically two days time for each spectrometer plus additional time necessary for shipping of often heavy and large DUTs from their permanent in-filed installation down to the metrology laboratory.

Here we describe the design and development of a tuneable and portable radiation source (TuPS) for the in-field characterization of Dobson spectrometers. TuPS operates over wavelength range 290 nm to 350 nm. This light engine emits the radiation with the bandwidth of 0.1 nm with uncertainty lower than 0.02 nm in wavelength scale, while the radiant power of emitted beam exceeds the level of 20 nW over all spectral range of interest.

THE OPTICAL DESIGN

The TuPS is a combination of a broadband source and an optical tuneable dispersion system; the latter rejecting all but a narrow wavelength band. Optimal level of total radiant flux emitted from TuPS was found experimentally during the laboratory-based characterization of Dobson 074 [1] as a value that ranges from 10 nW to 100 nW. The optical layout was designed using Zemax, an important consideration in

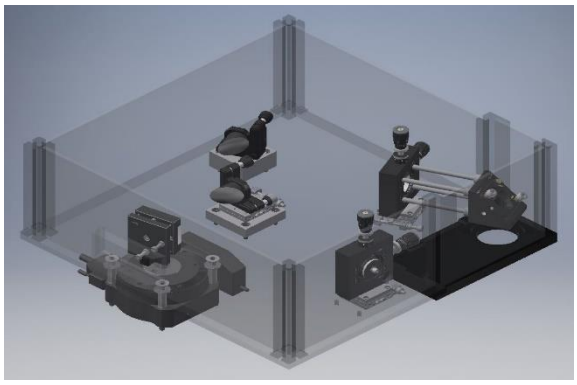

Figure 1. TuPSs' optical configuration of.

the design being that TuPS would be easily transportable thus enabling its use as an in-field source for Dobson spectrometers.

TuPS is contained within a 400 mm x 400 mm optical board, with the grating and the second parabolic mirror positions fixed; and the input pinhole, the first parabolic mirror and the output slit mounted on high precision micro-metric linear stages to provide the fine adjustment needed to compensate for the focal length tolerance of the parabolic mirrors. Both parabolic mirrors and the grating are mounted on adjustable stages to optimize the mirrors' optical alignment. A motorized rotation stage, which sets the grating angle, uses a high resolution encoder that has an accuracy of better than 0.001°. The optical configuration of the TuPS is shown in Figure 1.

TUPS OPTICAL CHARACETRISATION

The optical characterisation of TuPS light engine was performed using the fibre coupled CMI tuneable optical parametric oscillator laser facility (OPO). The OPO laser radiation wavelength and its stability is monitored by calibrated wavemeter with accuracy better than 0.01 nm [2]. Schematic diagram of the measurement setup is shown in Figure 2

For each wavelength the angular position of the peak ,A_{λ_n} relative to the laser line λ is calculated using the centroid formula, using this the relationship between the TuPS grating angle and the TuPS wavelength at the output slit can be determined. Using the same data set,, and the linear relationship between the grating angle and wavelength it is also possible to assess the bandwidth performance of the TuPS. With the same measurement setup used for the TuPS wavelength and bandwidth calibration the optical power output of TuPS over all spectral region of interestwas measured using a calibrated Si photodiode located at the TuPS output port.

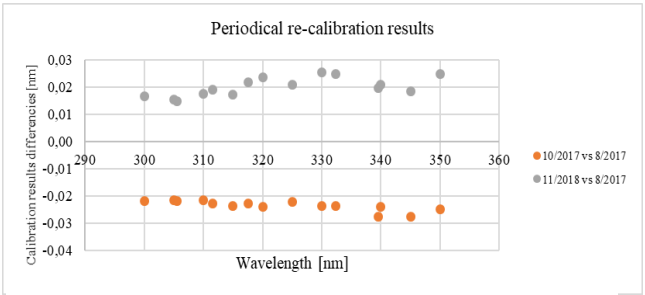

Figure 3. TuPS results of periodical recalibration of the wavelength scale after each in-field measurement.

The temporal stability of TuPS was investigated over a period of 2 years. During 2017 TuPS participated in five measurement campaigns, where it characterized 14 Dobson spectrometers. Before and after each measurement campaign the TuPS wavelength scale

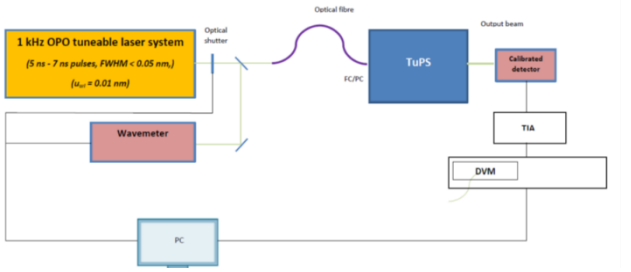

Figure 2. The schematic diagram of the TuPS characterisation measurement setup.

was recalibrated at CMI, using the OPO laser facility. The results for the calibrations before and after each campaign are shown in Figure 3. The largest difference in the wavelength scale of about 0.025 nm was recorded between the measurements in AEMET Izana (Spain) and the Deutscher Wetterdienst (Germany), a time interval of 45 days.

CONCLUSION

TuPS is an instrument for determining the slit function and centre wavelength of Dobsons. TuPS has been characterised for bandwidth and the central wavelength accuracy over the spectral range of interest. This characterisation was done using the fibre coupled CMI tuneable laser facility, this is a 1kHz ns pulsed OPO in combination with the CMI reference wavemeter being demonstrated better than 0.1 nm and 0.02 nm respectively. The stability of TuPS over two years has been shown to be 0.02 nm for both key parameters.

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